DRAUGHTSMAN CIVIL

NSQF LEVEL - 4

2nd Year

TRADE THEORY

SECTOR : CONSTRUCTION

(As per revised syllabus July 2022 - 1200 Hrs)

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Media Development Committee members of various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Draughtsman Civil - Trade Theory** NSQF Level - 4 (Revised 2022) in **Construction Sector** under **Yearly Pattern.** The NSQF Level - 4 (Revised 2022) Trade Practical will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

Additional Secretary / Director General (Training),
Ministry of Skill Development & Entrepreneurship
Government of India.

New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of Federal Republic of Germany. The prime objective of this Institute is to develop and provide instructional materials for various trades as per the prescribed syllabus under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade practical book consists of series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

Chennai - 600 032 **EXECUTIVE DIRECTOR**

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisation to bring out this IMP **(Trade Theory)** for the trade of **Draughtsman Civil - NSQF Level - 4 (Revised 2022)** under the **Construction** Sector for ITIs.

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NIMI records its appreciation of the Data Entry, CAD, DTP Operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks, the invaluable efforts rendered by all other staff who have contributed for the development of this Instructional Material.

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

INTRODUCTION

TRADE PRACTICAL

The trade practical manual is intented to be used in practical workshop. It consists of a series of practical exercises to be completed by the trainees during the course of the **Draughtsman Civil** trade supplemented and supported by instructions/ informations to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF Level - 4 (Revised 2022) syllabus are covered.

This manual is divided into Fourteen modules. The Fourteen modules are given below.

Module 1	-	**Building Drawings**
Module 2	-	**Computer Practice**
Module 3	-	**3D Modeling in Cad**
Module 4	-	**Building Drawing (Public)**
Module 5	-	**Rein Forced Cement Concrete Structure**
Module 6	-	**Steel Structures**
Module 7	-	**Public Health and Sanitation**
Module 8	-	**Road engineering**
Module 9	-	**Bridge engineering**
Module 10	-	**Railway engineering**
Module 11	-	**Irrigation engineering**
Module 12	-	**Estimateing & costing**
Module 13	-	**Total station**
Module 14	-	**Global positioning systems**

The skill training in the shop floor is planned through a series of practical exercises centred around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI looks forward to the suggestions from the experienced training faculty for improving the manual.

TRADE THEORY

The manual of trade theory consists of theoretical information for the Course of the **Draughtsman Civil -** Trade Theory - NSQF Level - 4 (Revised 2022) in Construction. The contents are sequenced according to the practical exercise contained in NSQF Level - 4 (Revised 2022) syllabus on Trade Theory attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

The trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indications about the corresponding practical exercises are given in every sheet of this manual.

It will be preferable to teach/learn the trade theory connected to each exercise at least one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not for the purpose of self learning and should be considered as supplementary to class room instruction.

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LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

S.No	Learning Outcome	Lesson No
1	Draw single storied building site plan layout. **(NOS: CON/N1302)**	2.1.91-2.1.95
2	Create objects on CAD workspace using Toolbars, Commands, Menus, formatting layer and style. **(NOS: CON/N1302)**	2.2.96 - 2.2.101
3	Draw a sanction plan of double storied flat roof residential building by using CAD. **(NOS: CON/N1302)**	2.2.102-2.2.107
4	Create objects on 3D modeling concept in CAD. **(NOS: IES/N9424)**	2.3.108 - 2.3.114
5	Prepare a drawing of public building detailing with roof and coloumns by frame structures using CAD. **(NOS: CON/N1302)**	2.4.115 - 2.4.120
6	Prepare detailed drawing of RCC structures using CAD and prepare bar bending schedule. **(NOS: IES/N9425)**.	2.5.121 - 2.5.123
7	Prepare detailed drawing of RCC structures using CAD and prepare bar bending schedule. (NOS: IES/N9425).Draw the details of a framed structure and portal frame of a residential building Using CAD. **(NOS: IES/N9426)**	2.5.124 - 2.5.129
8	Draw the different types of steel sections, rivets and bolts using CAD. **(NOS: CON/N1302)**. Draw the details of girders, roof trusses and steel stanchions using CAD. **(NOS: CON/N1302)**.	2.6.130 - 2.6.133
9	Prepare the detailed drawing showing the different types of sanitary fittings, arrangements of manholes, details of septic tank using CAD. **(NOS: IES/N9427)**. Draw the details flow diagram of water treatment plant (WTP) and Swerage Treatment plant (STP). **(NOS: IES/N9428)**	2.7.134 - 2.7.141
10	Draw the cross sectional view of different types of roads showing component parts using CAD. **(NOS: IES/N9429)**	2.8.142 - 2.8.144
11	Draw the details of different types of culverts using CAD. **(NOS: IES/N9430)**. Prepare detailed drawing a bridge using CAD. **(NOS: IES/N9431)**	2.9.145 - 2.9.149
12	Draw the typical cross section of rail sections, railway tracks in cutting and embankment usingCAD. **(NOS: IES/N9432)**	2.10.150-2.10.153
13	Prepare detailed drawing of typical cross sections of Dam, barrages, weir and Cross drainageworks using CAD. **(NOS: IES/N9433)**.Draw the schematic diagram of different structures of Hydro electric project using CAD. **(NOS: IES/N9434)**	2.11.154-2.11.159
14	Prepare detailed estimate and cost analysis of different types of building and other structures using application software. **(NOS: IES/N9435)** Prepare rate analysis of different items of work. **(NOS: IES/N9436)** Problems on preparing preliminary/Approximate estimates for building project. **(NOS: IES/N9437)**	2.12.160-2.12.165
15	Prepare a map using Total station. **(NOS: IES/N9438)**	2.13.166-2.13.175
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SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 28Hrs; Professional Knowledge 08Hrs	Draw single storied Building site plan layout. (Mapped NOS: CON/ N1302)	Drawing details of:- 91. Single storied residential house with attached bath of both pitched and flat roof. (09hrs) 92. Making plan, elevation, and section with aid of line diagrams of the building. (10hrs) 93. Layout and detailing of residential building. (03hrs) 94. Create a drawing of building showing set backs. (03hrs) 95. Showing layout plan and key plan. (03hrs)	Building:- • Principle of planning • Objectives & importance. • Function& responsibility. • Orientation. • Local building Bye-Laws as per ISI code. • Lay out plan & key plan. • Submitted in composition of drawing. • Provisions for safety. • Requirement of green belt and land. (08 hrs.)
Professional Skill 28Hrs; Professional Knowledge 10 Hrs	Create objects on CAD workspace using Toolbars, Commands, Menus, formatting layer and style. (Mapped NOS: CON/N1302)	Computer practice:- 96. Function of keys and practice of basic commands. (03hrs) 97. Use of elementary commands by CAD toolbar. (03hrs) 98. Creation of objects in different layers on CAD workspace. (5 hrs) 99. Plotting of drawing from CAD. (01hr) 100. 2D drafting of flash door, panel door, window, hand railing, wash basin, sewerage pipe joints, etc. (10hrs) 101. Preparing Library folder by creating blocks of the above items. (6hrs)	Computer aided drafting:- • Operating system ,Hardware& software. • Introduction of CAD. • Its Graphical User Interface. • Method of Installation. • Basic commands of CAD. • Knowledge of Tool icons and set of Toolbars. • Knowledge of shortcut keyboard commands. (10hrs.)
Professional Skill 112 Hrs; Professional Knowledge 32 Hrs	Draw a sanction plan of double storied flat roof residential building by using CAD. (Mapped NOS: CON/N1302)	Building Drawing (Residential) Prepare:- 102. Plan, section and elevation of buildings with specifications for the given line drawing to suitable Scale. (32hrs) 103. A House single storeyed residential building with single bed room and attached bathroom with R.C.C. flat roof slab. (18hrs)	Building Planning:- • Economy & orientation. • Provision for lighting and ventilation. • Provision for drainage and sanitation. • Types of building. • Planning & designing of residential , public and commercial building. (16 hrs.)

		104. A residential building with double beded rooms with R.C.C. flat roof slab. (18 hrs.) 105. Two roomed house with RCC slope roof with gable ends. (12 hrs.) 106. A House with fully tiled roof with hips and valleys. (10 hrs.) 107. Design and create a double storied residential building (3BHK) with Positioning layout of Furniture, Electrical appliances and plumbing / sanitary fittings. (22 hrs.)	Prefabricated Structure:- • Preparation. • Method of construction, assembling. • Advantages & disadvantages.(16 hrs.)
Professional Skill 28Hrs; Professional Knowledge 08Hrs	Create objects on 3D modeling concept in CAD. (Mapped NOS: IES /N9424)	3D modeling in CAD :- (28hrs) 108. Create and use model space viewports. (04hrs) 109. Create a standard engineering layout. (04hrs) 110. Create and edit wireframe model. (04hrs) 111. Create and edit solid mesh and surface modeling. (04hrs) 112. Create and edit simple 2D regions and 3D solid models. (04hrs) 113. Generate 3D text and dimensions using a variety of 3D display techniques. (04hrs) 114. Render a 3D model with a variety of lights and materials. (04hrs)	3D modeling concept in CAD • 3D coordinate systems to aid in the construction of 3D objects • Knowledge of shortcut keyboard commands. (08 hrs.)
Professional Skill 56Hrs; Professional Knowledge 16Hrs	Prepare a drawing of public building detailing with roof and coloumns by frame structures using CAD. (Mapped NOS: CON/N1302)	Building Drawing (Public) Prepare:- 115. A Primary health center for rural area with R.C.C roof. (10 hrs.) 116. A Village Library building with R.C.C flat roof. (12 hrs.) 117. A small Restaurant building with R.C.C flat roof. (06 hrs.) 118. A Single storeyed School building with R.C.C flat roof. (10 hrs.) 119. A Small workshop with north light steel roof truss (6 to 10m Span) over R.C.C. Columns. (12 hrs.) 120. Service plans. (06hrs)	• Parks &play ground-Types of recreation, landscaping. etc • Concepts of design of earthquake resisting buildings- requirements resistance , safety, flexible building elements, special requirements, base isolation techniques. (16 hrs.)

Professional Skill 28Hrs; Professional Knowledge 08Hrs	Prepare detailed drawing of RCC structures using CAD and prepare bar bending schedule. (Mapped NOS: IES / N9425)	Drawing details of RCC members with reinforcement:- 121. Rectangular beams(Single reinforced &Double reinforced). (10hrs) 122. Lintel, chajjas&slabs.(10hrs) 123. Stair - details of step. (08hrs)	Reinforced cement concrete structure:- • Introduction to RCC uses. • Materials - proportions • Form work • Bar bending details as per IS Code. • Reinforced brick work. (8 hrs.)
Professional Skill 56Hrs; Professional Knowledge 18Hrs	Prepare detailed drawing of RCC structures using CAD and prepare bar bending schedule. (Mapped NOS: IES / N9425) Draw the details of a framed structure and portal frame of a residential building using CAD. (Mapped NOS: IES /N9426)	Draw Reinforced details of RCC members:- 124. Preparing bar-bending schedule. (08hrs) 125. Details of one-way slab & two-way slab. (18 hrs) 126. T-beam, Inverted beam, cantilever, retaining wall, Lift well. (08 hrs) 127. Column with footing. (07hrs) 128. Continuous columns showing disposition of reinforcement. (08hrs) 129. RCC framed structure, portal frame, B.I.S. Code 456-2000, SP - 34 and its application. (07hrs)	Materials used for RCC:- • Construction. • Selection of materials ¡V coarse aggregate, fine aggregate, cement water and reinforcement. • Characteristics. • Method of mixing concrete ¡V machine mixing and hand mixing. • Slump test. • Structure ¡V columns, beams, slabs - one-way slab & two-way slab. • Innovative construction. • Safety against earthquake. • Grade of cement, steel-behaviour and test. • Bar-bending schedule. • Retaining wall. • R.C.C. Framed structure. (18 hrs.)
Professional Skill 56Hrs; Professional Knowledge 16Hrs	Draw the different types of steel sections, rivets and bolts using CAD. (Mapped NOS: CON/ N1302) Draw the details of girders, roof trusses and steel stanchions using CAD. (Mapped NOS: CON/N1302)	Drawing of different types of:- 130. Steel sections, rivet,bolts,etc. (16 hrs) 131. Section and elevation of girders. (12hrs) 132. Structural Joints. (12hrs) 133. Plate girders roof trusses, stanchion etc. (16hrs)	Steel structures:- • Conmen forms of steel sections. • Structural fasteners , Joints. • Tension & compression member. • Classification, fabrication. • Construction details.(16 hrs.)
Professional Skill 56Hrs; Professional Knowledge 24Hrs	Prepare the detailed drawing showing the different types of sanitary fittings, arrangements of manholes, details of septic tank using CAD. (Mapped NOS: IES / N9427) Draw the details flow diagram of water treatment plant (WTP) and Swerage Treatment plant (STP). (Mapped NOS: IES /N9428)	Public Health & Sanitation. 134. Drawings of showing various pipe joints for underground drainage. (9hrs) 135. Types of sanitary fittings in multi-storeyed building. (9hrs) 136. Manholes and septic tank. (9hrs) 137. Water supply system. (6hrs) 138. R.C.C square overhead tank supported by four columns. (9hrs)	

		139.Preparation of service plan(drainage plan)for isolated building & in sewer system. (6 hrs) 140. Drawings of toilet fixtures. (04hrs) 141. Flow diagram of water treatment plant (WTP) and Swerage Treatment plant (STP). (04hrs)	House drainage of building:- • Introduction. • Terms used in PHE. • Systems of sanitation. • System of house drainage. • Plumbing, sanitary fittings, etc. • Types of sewer appurtenance. • Systems of plumbing. • Manholes & Septic tank. • Water treatment plant • Swerage treatment plant (24 hrs.)
Professional Skill 56Hrs; Professional Knowledge 16Hrs	Draw the cross sectional view of different types of roads showing component parts using CAD. (Mapped NOS: IES / N9429)	Roads:- 142. Draw showing road structure and component parts. (18hrs) 143. Prepare a drawing of Cross-sections showing the different types of roads-accordingto location materials. (20hrs) 144. Prepare a drawing of road curves & gradient. (18hrs)	Roads:- • Introduction. • History of highway development. • General principles of alignment. • Classification and construction of different types of roads, • Component parts. • Road curves, gradient. • Curves-types, designation of curves. • Setting out simple curve by successive bisection from long chords. • Simple curve by offsets from long chords. • Road drainage system.(16 hrs.)
Professional Skill 56Hrs; Professional Knowledge 16Hrs	Draw the details of different types of culverts using CAD. (Mapped NOS: IES /N9430) Prepare detailed drawing a bridge using CAD. (Mapped NOS: IES / N9431)	Bridge &Culvert :- Prepare drawing of - 145. Different types of culvert. (10hrs) 146. Preparing drawing of an arched bridge. (10 hrs) Draw plan and sectional views of the following:- 147. R.C.C Slab Culvert with splayed wing walls. (12hrs) 148. Steel Foot over bridge across a highway. (12hrs) 149. Two span Tee Beam Bridge with square returns. (12hrs)	Bridges &Culvert:- • Introduction to bridges. • Component parts of bridge. • Classification of culverts. • IRC loading. • Selection of type and location. • Factors governing the ideal site. • Alignment of bridge. • Foundation -selection-caisson. • Coffer dam- types. • Types of super structure. • Substructure-piers,abutments, wing walls. • Classification of bridge. • Tunnels- rules used for the sizes of different members.(16 hrs.)

Professional Skill 56Hrs; Professional Knowledge 16Hrs	Draw the typical cross section of rail sections, railway tracks in cutting and embankment using CAD. (Mapped NOS: IES /N9432)	Railway:- 150. Draw typical cross section of rail track. (06hrs) 151. Draw Railway tracks – embankment layout plans of railway platform. (22 hrs) 152. Draw typical cross-section of railway tracks cutting & embankment (single lane & double lane). (22hrs) 153. Draw layout of signalling points & croossing.(6hrs)	Railways :- • Permanent way • Rail gauges, Functions, Requirements, Types, Sections, Length of rail. • Welding of rail, wear of rail. • Coning of wheels, hogged rail, bending of rail, creep of rail. • Causes and prevention of creep. • Sleeper and ballast-function, types, requirement, materials, rail. • Fixtures, Fastenings and plate laying in rail. • Joints-types, fish plate, fish bolt-spikes, chairs and keys-bearing plate, block elastic, base plate. • Anchors and anti-creepers. • Construction of permanent ways. • Railway station and yard.(16 hrs.)
Professional Skill 56Hrs; Professional Knowledge 16Hrs	Prepare detailed drawing of typical cross sections of Dam, barrages, weir and Cross drainage works using CAD. (Mapped NOS: IES /N9433) Draw the schematic diagram of different structures of Hydro electric project using CAD. (Mapped NOS: IES /N9434)	154. Dams, barrages, weir etc. (9hrs) 155. Longitudinal section of distributaries with the help of given sketch & data. (9hrs) 156. Head regulators. (8hrs) 157. Types of cross drainage work. (9 hrs.) 158. Hydro electric project. (9hrs) Drawing of canal 159. Alignment including ongitudinal and cross sections of canals with the given data. (12 hrs)	Irrigation Engineering:- • Terms used in irrigation. • Hydrology like duty, delta, base period, intensity of irrigation. • Hydrograph, peak flow, run off, catchment area, CCA, corps like, rabi, kharifetc. • Storage, diversion head work - characteristics and types. • Reservoir ¡Vtypes of reservoirs, i.e., single purpose and multi-purpose, area, capacity and curves of reservoir. • Dams, weir & barrages- types purposes. • Hydro electric project like Forebay, Penstock, Turbines, Power house, etc. • Canals- classification and distribution system, canal structures. • Types of cross drainage works like Aquaduct, Super passage, Syphon, Level crossing, inlet and outlet, etc.(16 hrs.)
Professional Skill 84Hrs; Professional Knowledge 32Hrs	Prepare detailed estimate and cost analysis of different types of building and other structures using application software. (Mapped NOS: IES / N9435) Prepare rate analysis of different items of work. (Mapped NOS: IES /N9436) Problems on preparing preliminary/ Approximate estimates for building project. (Mapped NOS: IES / N9437)	Estimating and Costing:- (visualizing the plotted drawing) 160. Prepare detailed Estimate :- Calculate quantities of items of single storied and double storied building. (12 hrs.) 161. Prepare abstract of estimate by prevailing rates. (10 hrs.) 162. Prepare rate analysis of major items - RCC, PCC, Wood works, Stone & Brick masonry & Plastering. (16hrs)	

		163. Solve problems on preparation ofpreliminary / approximate estimates for building projects by Excel worksheet as per Govt. schedule. (16hrs) 164. Familiarisationwith and making estimation with software. (18 hrs) 165. Estimate earthwork of irregular boundaries. (12 hrs) Total Station:- 166. Application of survey using TS. (06hrs)	Estimating and Costing :- • Introduction. • Purpose and common techniques. • Drawing of construction. • Measurement techniques. • Estimate-necessity, importance, types-approximate and detailed estimate-main and sub estimates, revised, supplementary, maintenance / repair estimate-taking off quantities- method • Rate analysis of typical items and their specifications. • Labour and materials. • Govt. Schedule of rate. • Estimating of irregular boundaries by trapezoidal and Simpsons formula.(32 hrs.) Total Station:- ¡V
Professional Skill 56Hrs; Professional Knowledge 16Hrs	Prepare a map using Total station. (Mapped NOS: IES /N9438)	167. Field procedure for co-ordinate measurement. (06hrs) 168. Field procedure to run open traverse and closed traverse. (04hrs) 169. Transfer or establish Bench Mark. (03hrs) 170. Perform stakeout / demarcation of building layout /plot layout/ roads/ alignment. (08 hrs.) 171. Measure remote distance and elevation. (10 hrs) 172. Calculate surface area on field/ site. (03hrs) 173. Calculate volume of field/site. (03hrs) 174. Procedure for down load and up load data. (06 hrs) 175. Simple survey map using Auto CAD. (07hrs)	• Introduction. • Components parts, accessories used. • characteristics, features. • advantages and disadvantages. • principle of EMD. • Working and need. • Setting and measurement. • Electronic, display & Data reading. • Rectangular and polar co-ordinate system. • Terminology of open and closed traverse. (16 hrs.)
Professional Skill 28Hrs; Professional Knowledge 08Hrs	Locate the station point using GPS and obtain a set of co-ordinates. (Mapped NOS: IES / N9439)	GPS Awareness:- 176. Practical application of GPSComponents of GPS data processing.GPS signal. 9hrs 177. Code and biasesTechniques of GPS observing. 4hrs 178. Set up and use GPS equipment. – (9 hrs) 179. Compare with GPS, GIS,GNSS& CAD. (06hrs)	GPS (Global Positioning System):- • Introduction of GPS system. • Co- ordinate and time system. • Satellite and conversional geodetic system. • GPS. Signal, code, and biases • Role of TRANSIT in GPS development. • GPS segment organisation. • GPS survey methods. Basic geodetic co-ordinate. • Ground support equipment, signals. • Tracking devises& system. • Time measurement and GPS timing. 8hrs

Planning of building and orientation

Objectives: At the end of this lesson you shall be able to
- **introduction objectives and importance of building**
- **state principles of planning**
- **explain orientation of building**
- **state the functions and responsibility while planning.**

Introduction

Food, shelter and clothing are the basic requirements of human being. By considering the sheltering aspects, the Civil Engineering play an inevitable role. Convenient branches of tree, suitable caves and huts of bamboo are a few examples of early means of sheltering.

Even in the modern era, adequate housing is a social impacting problem so planning of building is an intellectual task of modern civil engineering.

Building planning

Planning is the process of providing a safe, healthy, economic and hygienic atmosphere in and around of a building for the human habitation.

Plan of a building is the assembling or grouping and arranging of its component parts in a systematic manner and proper order so as to form a meaningful wholesome and homogeneous body with a comprehensive look out of meet its day to day functional purpose.

Object use and importance kept in mind while planning

- Planning should be according to the functional objects and requirements
- General scope and purpose of the building.
- Legality of ownership right, local rules and financial status etc. Considered.
- A double storied building providing same floor area that of a single story is cheaper by about 15% to 20%
- Local bye laws and rules should be considered.
- Climatic conditions of the area should take under consideration.
- A square and circular plan is cheaper & compact
- Plan should be according to the shape of plot.
- Relationship between different rooms and their sizes should be considered.
- Availability of materials and methods.
- Topography of the plot.
- A square plan to cheaper than oblong. The area occupied by walls of a square building may be 15% to 25% less than a rectangular plan.
- A square plan makes a house compact. It makes the house cooler in summer season and warmer in window season. Since fewer walls are exposed. Hence a sequence plan is always preferred.

According to the planning acts the main objects of planning may be summarised in three words

1 Health.

2 Convenience.

3 Beauty.

1 Health: To create and promote healthy conditions and environment for all people.

2 Convenience: The object of convenience is meant in the form of various needs of the community such as social, economic, cultural and recreational amenities etc.

3 Beauty: To preserve the asthetics in the design of all elements of town and city plan, which included preservation of trees, ancient architectural buildings of cultural and historical importance and buildings of worship etc.

Principles of planning

The factors or principles which govern the theory of planning are detail as shown below.

1 Aspect.	2 Prospect.
3 Privacy.	4 Furniture requirement.
5 Roominess.	6 Grouping.
7 Circulation.	8 Sanitation.
9 Flexibility.	10 Elegance.
11 Economy.	12 Practical considerations.

1 Aspect: The arrangement of doors and windows in external walls of a buildings which the occupants to receive and enjoy nature's gifts as sunshine, breeze and the beauty of landscape and at the same time protecting the inmates from the effects. The manner of arrangement of rooms or peculiarity of arrangement of doors and windows in the external walls of the building to draw maximum effect from sun and wind is termed as aspect. A room which receives light and air a particular direction is said to have aspect of that direction.

A building must be designed to suit the site with all its varying aspects. As not only provide comfort, but are a requisite from the hygienic point of view as well.

Each room of a residential building should have a particular aspect been certain rooms need morning sun and other rooms need less light.

Aspect is a very important consideration in the planning of a building. It influence the appearance of a building.

Aspects of different rooms of a residential building are as shown below.

Room	Recommended aspect	Influencing factor
Bed	NW-W-SW	To receive plentiful of breeze in summer,
Kitchen	E and rarely NE	To receive morning sun which is germicides. It purifies the air. It should be well illuminates and cool in afternoon.
Dinning	SE-S-SW	Proximity of kitchen. It should be cool.
Drawing	SE-S-SW-W N-NW	Adequate natural lighting during winter and obviate the sun during summer.
Store	NW-N-NE	Light from north being diffused and events distributed and cool. Dark and cool.

2 Prospect

Prospect is to enrich the outside view i.e., elevation or end-view created by prominent exposing the better constructed and better looking portions and at the same time concealing from the view any undesirable ones.

Prospect must not only make outer appearance attractive, but also maintain qualities such as comfort, cheerfulness, security, labour-saving and up-to -date ness, must also prove a good investment.

The outside appearance can be improved by attractive planning, providing by a windows and utilization of good landscape.

3 Privacy

Privacy is the screening provided for the individuals from the others different from seclusion. It is one of the important principles in the planning buildings of all types in general and residential buildings in particular. If there in respect of privacy, it is a deplorable fault which cannot be compensated on a host of other merits.

Privacy can be a privacy of sight as needed in bath rooms, water closet, urinals etc. or privacy of sound as needed in confidential discussions and in a room, or both privacy of sight and sound as required in a bed room.

Privacy is broadly classified as.

1 Internal privacy.

2 External privacy.

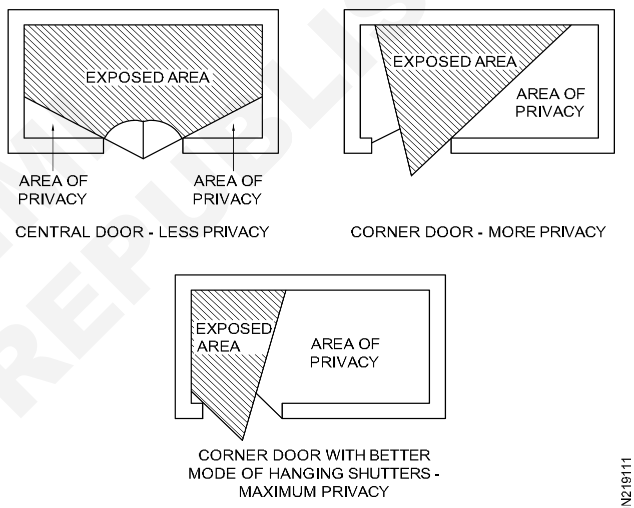
1 Internal Privacy. Internal privacy is the privacy within the building. It can be easily achieved by proper grouping of rooms as bed, dressing and toilet, kitchen and dining.

Useful planning of entrance and circulation space.

Better disposition of doors and windows and mode of their hangings.

locate the doors at one corner rather at the middle. The desirable ways of disposing and hanging shutters are illustrated in Fig 1.

Fig 1



DISPOSITION OF DOORS AND MODE OF HANGING SHUTTER

Doors with single shutter offer more privacy only when they are kept closed.

Doors with two shutters offer better privacy as one shutter can be closed leaving the other open.

Internal privacy can be obtained by proper grouping of rooms and careful planning of circulation space.

2 External privacy

Privacy of the whole building with reference to the surrounding buildings and roads.

External privacy can be achieved by

i Having a compound wall to a height of 1.35m to1.5m.

ii Planting trees along the compound walls which acts as sound barriers and sight barriers as well.

iii Providing ground glass windows and ventilators. Venetians have the advantage of offering privacy as well as air circulation. Ground glass venetians offer light as well.

iv Providing screen walls, certain walls and dwarf wall on verandah.

v Planting creepers along the boundary fencing or growing shrubs.

4 Furniture requirement

One of the most important requirements of a building planner, is to know how is space is needed by each function in a particular building. The room sizes for particular function can be completed on the basis of permanent furniture to be and in that room as the furniture dimensions are standardized.

How much space is required for performing a particular activity is known through anthropometric studies science Dimensions of furniture to be used in that room is also known The arranging furniture in that particular room keeping clearance for circulation, dimension can be finalized. Hence, while planning a building, furniture arrangement must be shown to justify the size of a room.

Rooms areas are not related only to furniture sizes, but also to their arrangement. A difference layout if arranged in the same space may not be equally efficient. Hence, planning of a room depends on the number of users and on its furniture and its alignment.

5 Roominess

It is the general feeling created after a room is well-furnished with all the furniture (as the beds inside a bed room)as a spacious and well-planned.

The room dimension should be such that the maximum use of a room having possible dimensions can be made. It means the accomplishment of economy at the same time avoiding cramping of the plan.

Some rooms may create the impression of being cramped with furniture, whereas may create a tunnel like feeling as we enter.

As square room has no advantage and a rectangular room of the same floor area gives a better outlook.

A breadth to length ratio of 1:1.2 to 1:1.5 is desirable. When the length exceeds two times its breadth it creates a tunnel-like effect i.e., a feeling as when one is inside a long tunnel or a railway compartment. Similarly height also plays an important role. A large room with less headroom will give very bad impression, and a small room with large ceiling height will produce a cavernous effect. Hence a room should have all proportional dimensions.

The utility of space in a room can be increased by providing left and built in cupboards to accommodate furniture, especially furniture of an easy-folding nature.

6 Grouping

Grouping is the planning of two or more related rooms in proximity of each minimises the length of circulation and at the same time improved the comfort, privacy and convenience of the inmates of the house.

Grouping varies according to the type of a building. All public buildings should be designed taking into consideration the movement of persons from one unit to another without causing disturbance to the other units.

The shape of a building depends upon grouping of various individual units.

The following points are to be considered while planning residential buildings.

The dining room close to the kitchen permits an easy serving of dishes in the desirable state i.e., hot or cold. Further the odors and smoke of kitchen are kept off from other rooms, bed and drawing rooms in particular.

The bed room, toilet and dressing room may be grouped together for better privacy.

The bath room and water closet should be nearer to each other. This saves the length of the water supply pipe. Besides, these two rooms require water and storage vessels, when the supply is intermittent. They also collect waste water blended with the body wastes whose disposal is to be done in an hygienic manner. They are to be provided with doors of 650 mm to 750 mm in size and of single shutter. The lower half of the shutter is to be protected against spillage of water which causes severe damage to the shutter. Wooden shutters are decayed and steel shutters are corroded due to alternate wetting and drying. Bath water-closet and bathroom should be provided with a ventilator at a height of 1.8 m above the floor level to an outer wall. When the number of inmates is less than 5, it is desirable to its have a bath-cum-water-closet, but when the number exceeds 5, it is better to have two separate units provided side by side.

Kitchen should be nearer to the backyard and the doors and windows are so located that the housewife can have a free unobstructed sight of the children playing in the open space or in the drawing room.

If more than one bedroom is provided, they should have an easy access to the drawing and dining-rooms.

Staircase should be centrally located and easily accessible from all the rooms.

The water-closet should be away from dining-room and this is mainly to get privacy of sound and the psychological feeling of being away from the insanitary place.

7 Circulation

Circulation is the access into or out of a room. It is the internal movement inside a building and the area earmarked for it. It is the space used for getting comfortable communication from one room to another or from one floor to another.

The position of doors indicates the area of circulation which in turn controls privacy, comfort and convenience.

Circulation inside a house should be simple, systematic and short.

The sequential operations like the movements from kitchen to dining and the toilet control the provisions for circulation.

Circulation area should be straight, short, bright, lighted both day and night and well ventilated.

Circulation should neither affect the privacy of a room nor interfere with utility space.

Circulation in a building is of two types

1 **Horizontal circulation.**

2 **Vertical circulation.**

When the circulation is within the same floor, it is called horizontal circulation and when it is between different floors it is called vertical circulation.

1 **Horizontal circulation:** Horizontal circulation within a building is facilitated by verandahs, corridors, halls and lobbies.

Passages should never be narrow, dark, zigzag or winding. They should be tree from obstructions.

Window-shutters should never flung open into the passages particularly when people are passing over.

No stationary object is to be situated on a corridor or verandah.

Area of the horizontal circulation may constitute about 20% to 25% of the total plan area of a residential building.

i.e.. Circulation area/utility area =1/5 to 1/4

It may be more for public buildings where a room can be divided into two spaces, one a useful space and the other circulation space.

2 **Vertical circulation:** It is the movement from one floor to another in multi-storied building.

It is possible because of stairs, ramps (sloping slabs), elevators (lifts) and escalator (mobile stairs).

Stairs are quite common in small residential buildings. Lifts are a must when.

i Number of stories are more than three.

ii Number of users are many as in a public building.

iii Old people, children and sick people frequently move in and out as in the case of a hospital.

Lift is to be provided nearer to the stairs.

Stairs are to be provided with smooth hand-rail for easy ascent and descent.

Stairs are to be well ventilated both day and night. They should have a free and independent access from all rooms.

Ramps are common for the movement of heavy objects like cars going to upper floors in a multi-storied building.

Escalators have the virtues of both saris and lifts, but they are a little slow as compared to lifts.

Sanitation: It is the provision and upkeep of the various components of a house to keep the inmates cheerful and free from disease.

The factors influencing sanitation are

1 Lighting. 2 Ventilation. 3 Cleanliness.

1 Lighting

It can be natural light as that obtained from the sun during the day or artificial one as that from a filamentous bulb or fluorescent light. Fluorescent light. Produces more illumination per unit of power consumed hence is cooler and produces a softer shadow.

Adequate illumination is essential in day to day activities to execute the tasks safely, comfortably and efficiently.

Good visibility is a must for accident prevention, comfortable watching and reading decoration, to reduce fatigue, avert confusion, present true colour and for efficient security.

Day lighting

Sun is the source of light.

Day light is preferred to artificial illumination.

Morning sun is pleasant and has vitamin D. It is the best tonic for rickets. Sun rays even diffused kill pathogenic bacteria and keep the vision clear. Natural light stimulates the blood. This simulation controls tuberculosis.

The intensity of illumination depends on

Latitude-Maximum on equator and reduces with increase in latitude (towards N)

Solar altitude-Increases with solar altitude (0° at sunrise or sunset and 90° at noon)

Sky factors Maximum when clear, least when cloudy.

Season-very bright in summer and less bright in winter.

Orientation of windows

Transmission factor (inversely proportional to shielding of light because of the trees, dark coloured glasses of Doors, Windows and Ventilators).

Reflection factor of walls, ceiling and flooring in White colour offers 100 reflection and black colour 0% reflection.

Day light factor = Incidental light + Reflected light, 1% day light factor =80 Lux.

Focused or concentrated light may be required for some jobs like reading writing, whereas the light spread uniformly is needed for various other avocations.

Diffused light is preferred to direct light. Light from more than one source preferred to that from a single source.

Uniform lighting may not reveal good contrast. Hence, predominant light to direction and less intense light in other direction or directions will present better contrast.

Twinkling or glistering light can be appreciated, but not glare and dazzling light.

Glare harms the eye and may cause fatigue. One cannot see the details in glare.

All the rooms of a residential house except store room need a reasonable amount of illumination both day and night.

Stairs or for that matter any other flight of steps must be well-illuminated day and night to avoid confusion and accidents.

Drawing room and kitchen should be very well-illuminated. A relatively less amount of light may be sufficient in dining room, bed room and toilet. However in the dressing room light focusing arrangement should be provided about mirror to have a clear image revealing the true details.

A standard candle emits 4 lumens.

1 Lux = 1 lumen/m2.

Ventilation is replacement of state warm and odourous air within the room with fresh coal and odour free air.

i Supplies fresh cool air rich in oxygen,

ii drives out CO_2 and odourous gases,

iii Reduces humidity,

iv Expels smoke and other gases of combustion and

v Preserves heat balance of human body.

Extent of ventilation required depends on

1 **Climate:** Chill cold climate does not require any air exchanges. Hence windows are kept closed during chill winter nights.

In very hot climate outside hot air (greater than 37°C) the human body temperature of the day is never welcome to get into the room. Hence, windows are kept close during the daytime in summer.

Dry hot climate requires air exchanges only at night (when outdoor temperature is less than human body temperature).

Warm humid climate requires frequent air exchanges.

2 **Purpose of the room**

Residential house: Residential odourous rooms as toilet require a minimum 6 air changes per hour.

Kitchen which gives out steam, fumes, heat and odour requires a minimum of 6 air changes per hour when designed for 5 or less number of users.

All other habitable rooms including bedroom and drawing room need a minimum of 3 air changes per hour.

Public buildings: Less than 1 air change per hour is no ventilation at all.

In a place where neither heat nor any offensive odours are given out as a small class room or a small office room a minimum of 5 air changes per hour is required.

A kitchen of a restaurant needs a minimum of 12 air changes per hour. The ward of a hospital requires more than 12 air changes per hour.

It is a maximum of 60 air changes per hour in case of places which products odourous gases or excessive quantities of heat.

More than 60 air changes per hour need high velocities of wind greater than 1.5m which causes discomfort to the occupants of the room and hence is undesirable.

3 **Number of occupants and the nature of occupancy:** More is the number of occupants of the room, more ventilation is required.

Place	Characteristics of occupancy	Ventilation air m^3/h/person
Cinema theatre	Still watching with no activity	8.5
Office	Little physical action	17
Restaurant	Hot and odourous products	25
Bar	Quite odourous products	35
Gymnasium	Body strained, heat, sweat and body odours, exuded	85

Types of ventilation

1 Natural ventilation.

2 Mechanical Ventilation.

1 Natural Ventilation

It is the controlling of the movement of air within a room by providing openings as windows, ventilators and louvers, in the walls.

A single window (irrespective of its size) in a wall rarely serves the purpose of ventilation unless the door of the room is also kept open. Therefore for effective ventilation a minimum two windows to different walls is a must.

Width of window: In general more is the window area more is the ventilation. But when the total width of windows exceeds 66.67% of the total length of the wall any further increase has little influence on ventilation.

Window area should be a minimum of 10% of floor area for any habitable room while 15% to 20% is preferred for Bed and Drawing rooms. A value greater than 25% does not increase ventilation much.

A minimum sill level of 0.9 m is preferred for privacy as well as effective ventilation. Window top level at more than 2 m may not serve any useful purpose except where the headroom is more than 3.5 m.

Number of windows: A wider window is preferred to 2 or more narrower windows on the same wall.

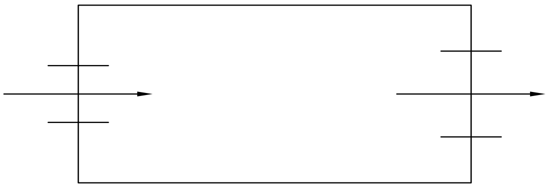
At least two windows on the opposite walls serve effective ventilation and windows on adjacent walls is the next preference.

A small window (ventilator or opening) is provided just below the roof slab of walls to expel hot air accumulated.

Operating forces in natural ventilation

1 **Wind effect:** Fig 2 Wind flows from a higher pressure to a lower pressure. It exerts positive pressure on the windward face and suction on the leeward face.

Fig 2



WIND EFFECT

DC20N219112

Narrow window openings on the windward side and broader ones on the leeward side cause good air flows into the room and keeps it cool.

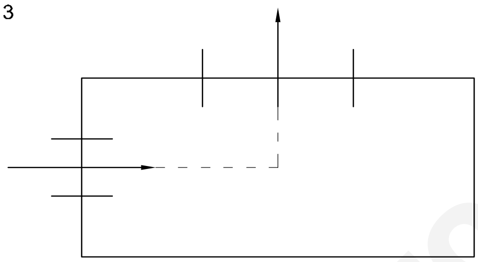
Change of direction reduces the velocity of flow of air.

2 **Stack effect:** Fresh air shall be cool and heavy. As it becomes stale it gets warmed and becomes lighter. Hence, it is collected over cool air. Thus, coolest air shall be the densest and collected at the bottom while warm and light air shall be collected at the top.

If we provide an outlet (an opening, louver or ventilator) at a higher level i.e., just below the roof level, the warm air flows out sucking in cool free air at the floor level. This is known as stack effect which works because difference in temperature between inside and outside the room.

Stack effect increases with Fig 3

Fig 3



STACK EFFECT

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a Difference in temperature between outside and inside of the room. More is the difference more is ventilation;

b Difference in elevation between inlets and outlet. More is the different vigorous is the ventilation.

c Sizes of inlets and outlets. Bigger inlets and outlets cause greater stack effect Natural ventilation may not be adequate even in a small residential building.

a Variation of wind. The wind changes both velocity and direction from time to time and hence windward and leeward directions change accordingly.

b Less window area.

c Less head room and hence less stack effect.

d Hot climate as summer which requires frequent air changes.

In public places where the number of occupants of a room is more than 50 (fifty) and is designed at less than 10 cubic metres per person, forced air circulation may be necessary.

2 **Mechanical ventilation:** Besides providing circulatory fan to create air current different other methods are available.

i **Exhaust system:** It is sucking out of the warm, vitiated air collected nearest to the roof by means of propeller type of fans provided to the outer warm which in turn such fresh air into the room. It is better suited in kitchen Toilets and Laboratories giving out heat, odours and smoke.

ii **Plenum (supply) system:** It is the injection of pure air into the room through ducts forcing the vitiated air to leave through ventilators or other openings.

It is adopted in crowded gatherings as assembly halls, factories and templates of heavy rush.

Cleanliness: Dust harbours bacteria. Besides rendering the surface dull, it creates health problem Hence, the floor which receives most of the dust should be smooth, impervious non-absorbing and uniformly sloping so that it collects less dust and is easily cleanliness non-absorbing and uniformly sloping so that it collects less dust and is easily clean.

Dampness is the root cause of infection. Hence, walls and floors should be damp-proof.

Sanitary conveniences such as bath and water-closet should be so designed that the waste water drains off as quickly as possible. Their flooring should be smooth, impervious, non-absorbent, non-slippery and given proper slope for the quick drainage. Also their walls are to be finished with glazed tiles to a height of one metre above the floor level. The corners are preferably rounded off and this is for the quick drainage. Similarly wastewater generated in the kitchen must find a way out in hygienic manner.

Flexibility: Flexibility means that a room which is planned for one function be used for other so required.

In the case with which a room designated for a particular activity can accommodate the load temporarily or sometimes may have to supplement the activity of another room as the drawing room being used as a bed room for guests, kitchen as an additional dining room etc.

If the rooms are big enough (more than 15 sq. m) and have a minimum width of 3m, then they are more flexible and even the activities of various rooms can be exchanged.

A bigger drawing room, a number of rooms and verandas, offer better flexibility.

Independent access to bath and toilet offer maximum flexibility.

Flexibility planning is very important for public and commercial buildings.

Elegance: Elegance is the grand architectural appearance of a building attained mainly owing to the elevation which in turn depends on the plan.

Selection of site for the building greatly affects the elegance. A building located a depression will always give depressed elegance, whereas that located on an elevated spot gives impressive appearance, and catch the attention of everyone.

Without elegance even a best-planned building may not have beauty whilst a poorly and building, if given a slight consideration on front portion may produce good elegance.

Also elegance depends on architecture, neighbourhood, conformity with nature, activity, adjoining buildings and their relative placement which governs the contrast.

A type of architecture which created a sensational feeling at one place may be miserable failure at another place because of lack of conformity with neighbourhood, environment and natural background.

A better elegance can be obtained by

1 Selecting superior building materials for facing such as polished stone-granite, marble or mosaic.

  Glass - either transparent or opaque , coloured or plain.

  Timber - polished teak or sun-glass.

  Paints and varnishes with proper contrast.

2 Providing projections like sunshades, balconies, canopies, porch with or without openings.

3 Providing bay windows, corner windows etc.

Aesthetics, utility and easy maintenance are to be considered while planning elevation. Dark pockets, dusty areas and elements depriving or privacy are to be avoided.

11 Economy: The building should have minimum floor area with maximum utility. It will reduce cost of construction and hence will be economical. Economy should not be achieved at the cost of strength, otherwise the useful life of a building will reduce only with proper planning and utility of space being maximized (passage being minimized), it should be achieved. Hence, economy may not be a principle planning but it is definitely a factor which affects planning.

Economy restricts the liberties of an architect on aesthetic development upon certain extent.

Economy can be achieved by implementing the following measures without affect the utility and strength of the structures.

1 Providing simple elevation.

2 Dispensing of porches, lobbies and balconies.

3 Reducing the storey height.

4 Reducing the number of steps of stairs by giving more rise to the steps.

5 By standardization of sizes of various components and materials.

The present trend of construction is towards simplicity. Simplicity and effect strength lend a lasting beauty and stability to a building.

12 Practical considerations

Besides all the principles of planning discussed, the following practical and should be kept in mind in the planning of a residential building.

1 Strength and stability coupled with convenience and comfort of the occupation should be the first consideration in planning.

2 In the years to come, a man perhaps has to add a wing or extend some part of the house. Provision for this should be made in the planning in the first instance so that some part already built may not be required to dismantle in future.

3 The elements of the building should be strong and capable of withstand the adverse effects of environmental factors that are likely to arise.

4 As far as possible, sizes of rooms should be kept large. Larger rooms can be shortened by providing movable partitions, but smaller rooms cannot be enlarge.

5 Life period of a building should be at least 50 years.

6 Money should not be spent unnecessarily for elaborate architectural pure like balconies, arches etc.

7 Use prefabricated elements for lintels, chajas, steps etc. This measurement useful in effecting economy.

8 If all bedrooms are in the first floor, lifts should be provided for sick and old, at least one bedroom should be provided in the ground floor for the aged person

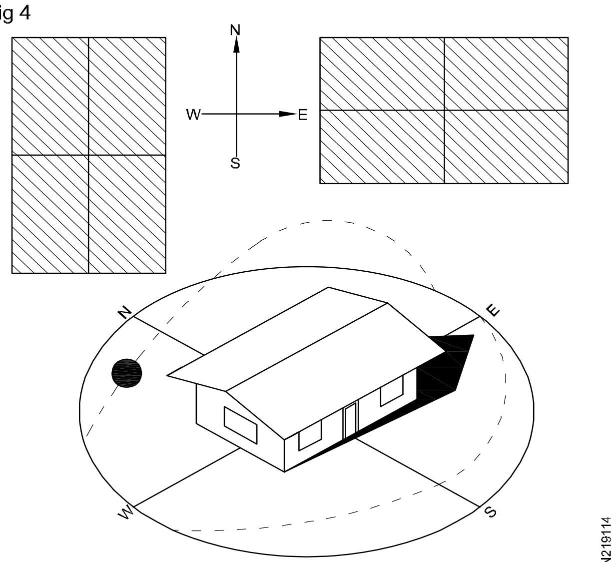
9 The number of doors and windows should be a minimum from the area and strength point of view.

Orientation of building (Figs 4, 5, 6 & 7)

Placing of different units of building with respect to the sun prevailing wind direction, rain, and topography of the locality is called orientation. Orientation means fixing the direction of the building in such a way that it derives maximum benefit from the sun, air and nature. Faulty housing condition cause poor health and spread of various types of diseases. Resistance to disease may be increased by living in fresh air and exposing the body to sun shine. Proper orientation of a house increases fresh air and sun shine in the house and decrease possibility of direct infection.

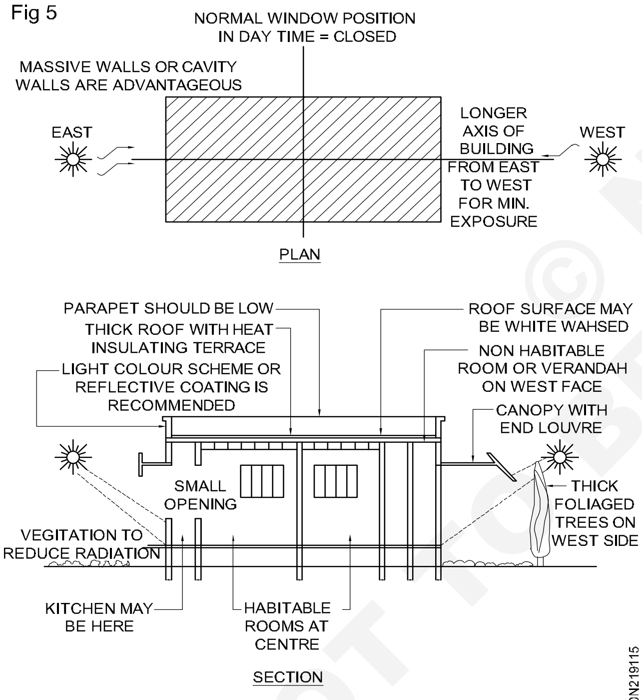
Building orientation is the practice of facing a building so as to maximize certain aspects of its surroundings, such as street appeal, to capture a scenic view, for drainage considerations, etc. With rising energy costs, it's becoming increasingly important for builders to orient buildings to capitalize on the Sun's free energy. For developers and builders, orienting a new home to take advantage of the warmth of the sun will increase the home's appeal and marketability. For homeowners, it will increase their indoor comfort and reduce their energy bills.

Fig 4



ORIENTATION OF BUILDING

Fig 5



ORIENTATION OF BUILDING

Hot dry climate

Describe conditions

1 Close layout and compact planning

2 Radiation barriers on east & west

3 Smooth and reflective surface

4 Roofs with heat insulation

5 Adoption of evaporative cooling system

6 Avoding stone slab pavings around the buildings

7 Developing vegetation around the building

8 Providing ventilated false ceilings

9 Internal courtyard

Suggestions for good orientation of the building

1 **Cross ventilation:** Sufficient number of window, doors and ventilation.

2 **Damp proof course:** To keep away walls from damp, it is desirable to provide DPC at suitable level.

3 **Placing of walls:** Exposing less area of walls to the sun rays will assist in maintaining comfortable temperature.

4 **Projection:** In the form of balconies, verandas, etc are provided on East and west sides.

5 **Roof:** R.C.C flat roofs should be provided with weathering and pitched roofs should contain valley gutters, overhang eaves etc. For drawing rain-water.

6 **Treatment of ground:** Plantation of grass, trees vegetation etc. To reduce the temperature inside the building.

7 **Wind direction:** For enjoying the natural breeze.

Planning of rooms: It is a unit design for the residence of human beings on a permanent basis.

Every unit will have its own identify depending on the site conditions, kinds of occupants, standards of accommodation required, size of family, financial condition etc.

Usual requirement

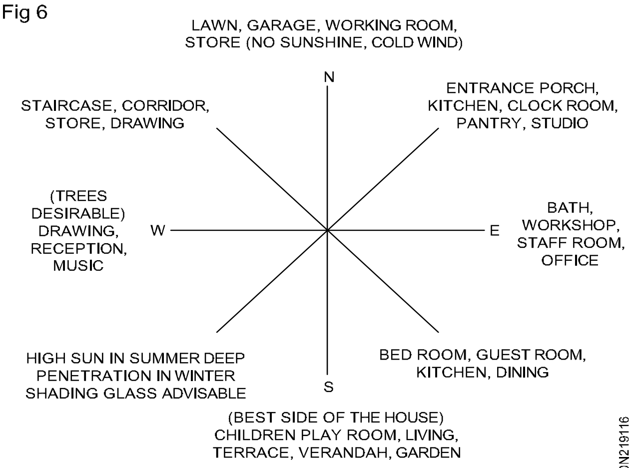
Living room

Bed room

Kitchen

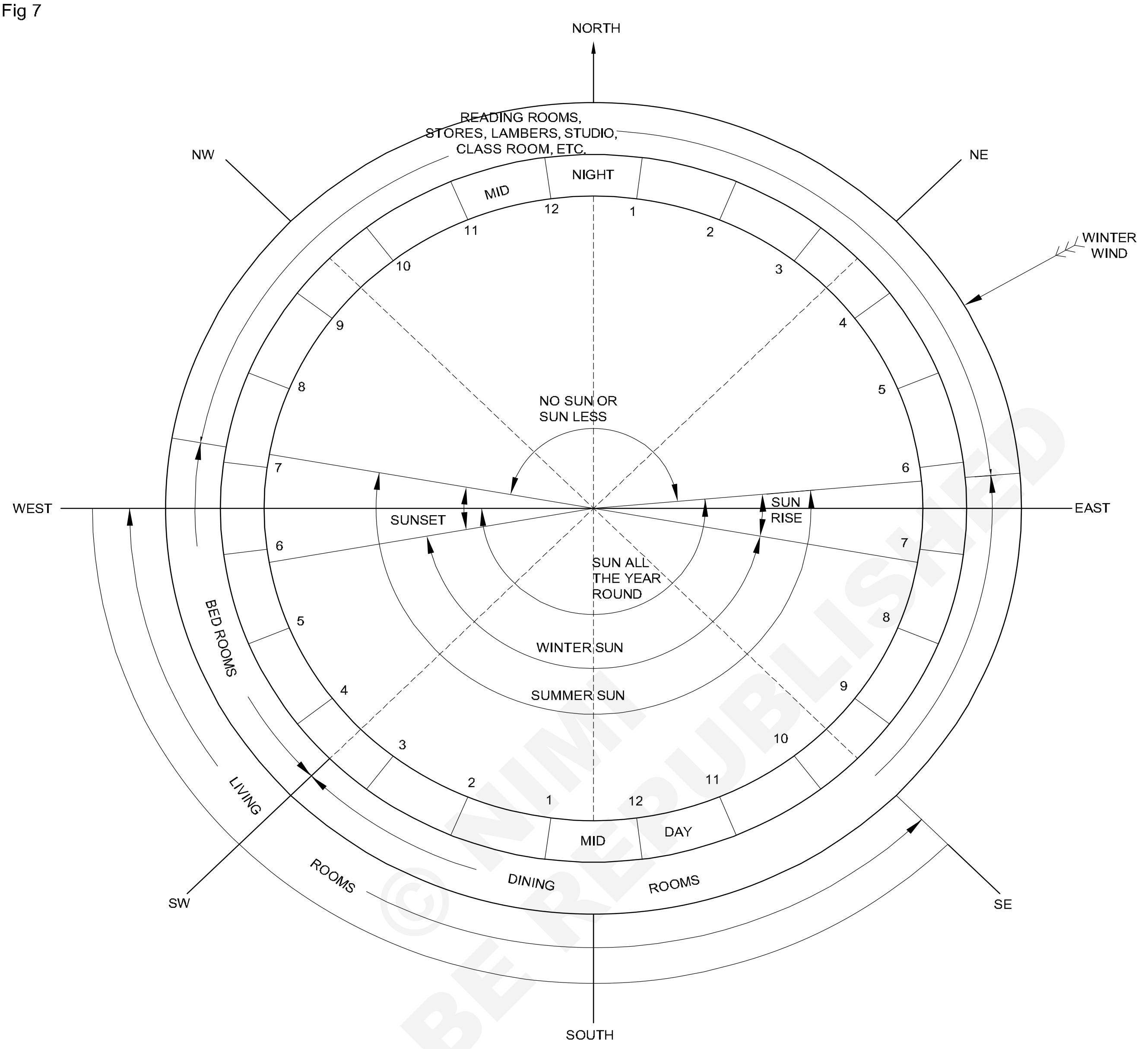
Bath & W.C.

Fig 6



ORIENTATION OF A BUILDING

Fig 7



ASPECTS AND SUN DIAGRAM

Bed room: Should be of adequate size to accommodate the furniture including space for movement and other requirements (dressing, cupboard, w.c.etc) and should be adequately ventilated.

Main factors, privacy, location requires careful and better planning.

Bath and water closet: The practice for modern building is to provide bathing space and W.C., wash basin, mirror etc. In a single unit of toilet only.

It should be so arranged that an economical layout of water supply, drainage and electric connection developers.

Dining room: Its main function will be taken meals and refreshments, therefore, should be easily serviceable from the kitchen and immediately approachable from the drawing room.

Drawing room: It is meant for receiving guest also used for various purpose,

- Occasions in the family.
- Office discussions.
- Occupational work.
- Library reading, etc

Therefore, it should be located very near to the entrance with adequate size and easily approachable to the common toilet, dining room, front verandah and staircase.

Garage: It is for the vehicle to be parked in enclosed space.

Kitchen: one of the important unit of the building it is the preparation of food for family.

A nicely designed and well-equipped kitchen afford great comfort and convenience to the family life, social status, etc of the persons occupying the building.

The location should be such that an overall view of the whole building is obtained,

Easily approachable to the entrance, drawing room, dining room, and washing place.

Suitably combined with stone.

It should allow private working.

Should be on the opposite side of breeze or wind direction to avoid smell spreading into other rooms.

Living room: Similar to drawing room.

Open spaces: To grant air, light and ventilation to the rooms also serves for storage, washing, clothes cleaning utensil etc. Open spaces becomes necessary.

Passages: It is to avoid undue attack on the privacy or utility of any rooms.

Stairs: The purpose of giving access to different floor of a building the location, required good and careful consideration for adequately lighted and properly ventilated.

Store: If necessary it may accommodated.

Verandah: Essential in the entrance to avoid direct entry of unknown person and back/rear side to protect the rooms directly from the sun sets.

Function and responsibility while planning

1 Selection of proper size.

- Plot-shape size and natural slope.
- Width and type of road in frontage.
- Position of plot with respect to sun and wind.

2 No. of occupants and their profession.

3 Financial capability of owner

4 Requirements of room

5 Provision of garage, porch etc

6 Feasibility of basement/first floor

7 Provision of internal/external staircase

8 Feasibility of future expansion

9 Soil and sub soil particular

10 Sub soil water level.

Residential building an overview

1 Portico (Fig 8)

It is a space provided for packing vehicles. The location of portico may be provided near the entrance or easy accessible space from the road. The size of the portico is sufficient to park the new generation vehicles, without any discomfort to usage.

Fig 8

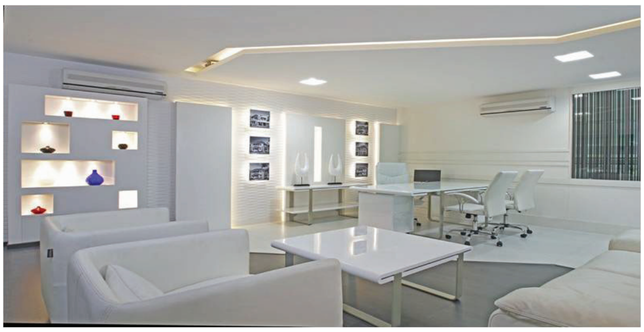
2 Sit out (Fig 9)

It is the welcome space for the inmates and it can also treated as a waiting space for visions. It is used for recreation in the morning and evening times.

Fig 9

3 Living (Fig 10)

Fig 10



As far as a residential building is considered living room is the most important room because three fourth of the day of inmates is consumed by this room. So it should be sized and furnished accordingly.

4 Pooja room

It is the space for worship and it should be located at an area free from all sorts of disturbance.

5 Dining (Fig 11)

Dining room is situated near by kitchen and drawing room with maximum ventilation. It should be furnished with photos with delicious food. Rooms like bed room toilet etc. Can have direct access from dining room.

Fig 11

6 Bed room (Fig 12)

Bed room is the most important room in a residential building and it is located with sufficient privacy and space of a habitable.

Fig 12

7 Kitchen (Fig 13)

It is a hygienic space provided for preparing food. It is normally placed at the rear side of the building. It should be placed accordingly fumes from kitchen should not enter the other parts of the building and falling of sunlight in the morning where foods are prepared.

Fig 13

8 Work area (Fig 14)

It is the utility area provided adjacent to the kitchen.

Fig 14

9 Store (Fig 15)

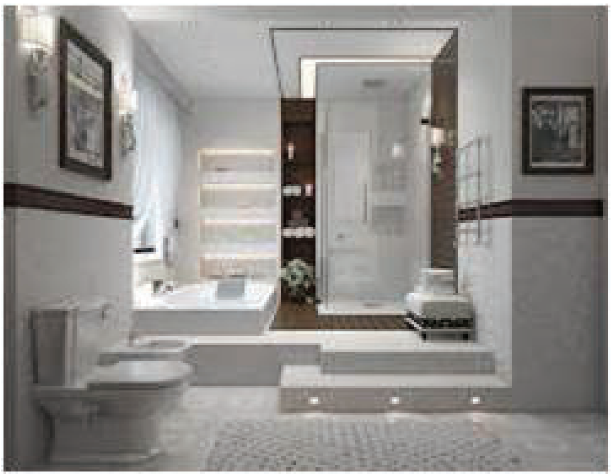
This room should be located close to the kitchen with sufficient storing facilities.

Fig 15

10 Bath room (Fig 16)

It is the room provided for bathing. Bath room may be separated as dry and wet areas and water closet and wash basin may be provided at dry areas. Flooring materials may have anti skip properties.

Fig 16



11 Study Room (Fig 17)

It is an area provided for learning and reading. Space should be provided for keeping books in a systematic manner and it is located in an area with fewer disturbances.

Fig 17

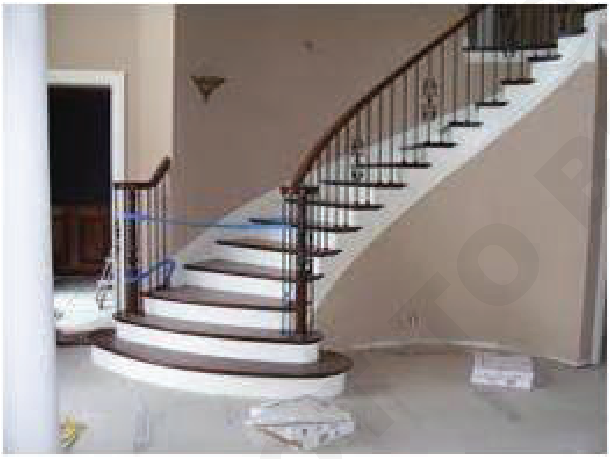
12 Entertainment Room

Area provided for placing home theatre and music systems for entertainment.

13 Stair case (Fig 18)

It is located such that easy accessible from all parts of the building with standard size and with good ventilation.

Fig 18



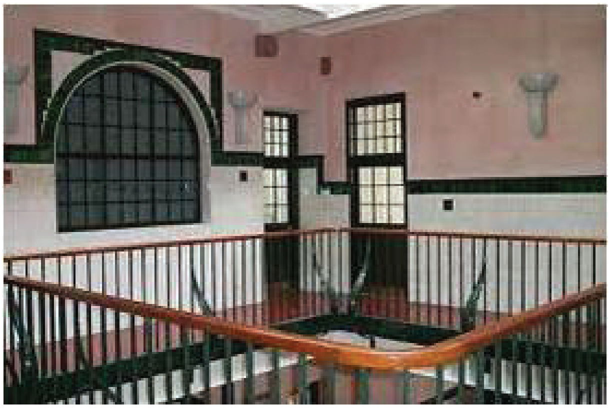
14 Balcony (Fig 19)

It is an open space provided in the upper floor seen from below for gathering.

1 In general for different type of plots for residential houses the minimum covered

Area i.e. area on which the building can be constructed is given below.

Fig 19



Type of plot	Area of plot	Permissible covered area
A Type	More than 1000 sq.m	33% of site area
B Type	501 sq.m to 1000 sq.m	40% of site area
C Type	201 sq.m to 1000 sq.m	50% of site area
D Type	Upto 200 sq.m	60% of site area

2 A standard residential houses should have drawing or living room, dining room, bed room, guest room, kitchen, store, Bathroom, water closet, front and rear verandah and a staircase if the building in double storeyed. (Figs 20 to 23)

3 If considerable formality is not observed in a family, the drawing room, dining room, may be combined and the two may be isolated by a sliding curtain and the whole room can be utilized on some special occasions.

If the house belongs to a professor or an Advocate a study room should also be provided.

Design steps: The following step by step procedure is suggested for the beginner in order to evolve a reasonably acceptable building design.

Step 1. If the owner gives his needs in clear terms that is ideal. But often the designer has to ask leading questions and extract his needs.

Step 2. Analyze the space needs as listed and estimate the floor area of a building. An increase of 20-25 percent of this area may be assumed for wall space and lobbies and the gross built-up area of the floor may be certain spaces all together and/or by reducing the area under each space.

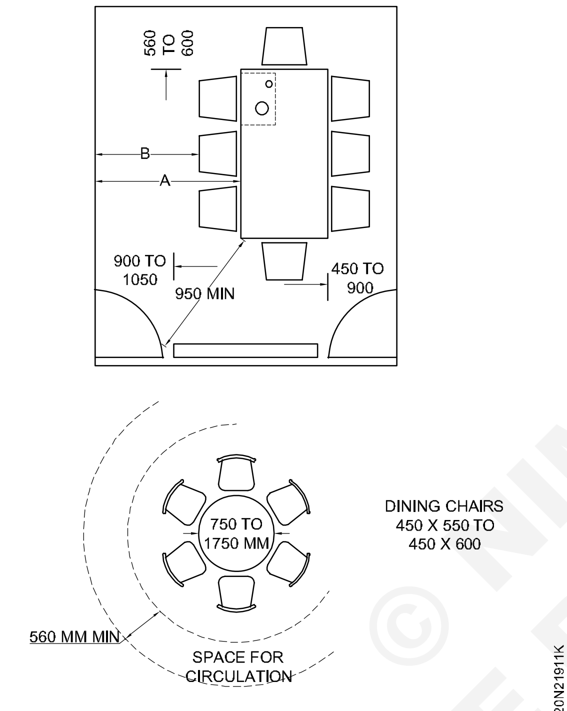
Step 3. Analyze the site in detail with respect to its dimensions, existing trees, and restrictions for building by ground slopes, adjoining development access north direction, wind direction, and view. A map showing the possible area for the building.

Step 4. Organize the plan of the building considering the pattern suggested the site structure plan and relative position of different rooms. This is done by a flexible bubble diagram in which each room is represented by a bubble close to that having good proximity requirement.

Step 5. The line plan can now be developed into a fully dimension floor plans, section to explain the constructions and elevation to show the overall front views of the finished building.

The site plan is now finalized by incorporating the final plan in the site and showing other detail to suitable scale.

Fig 20

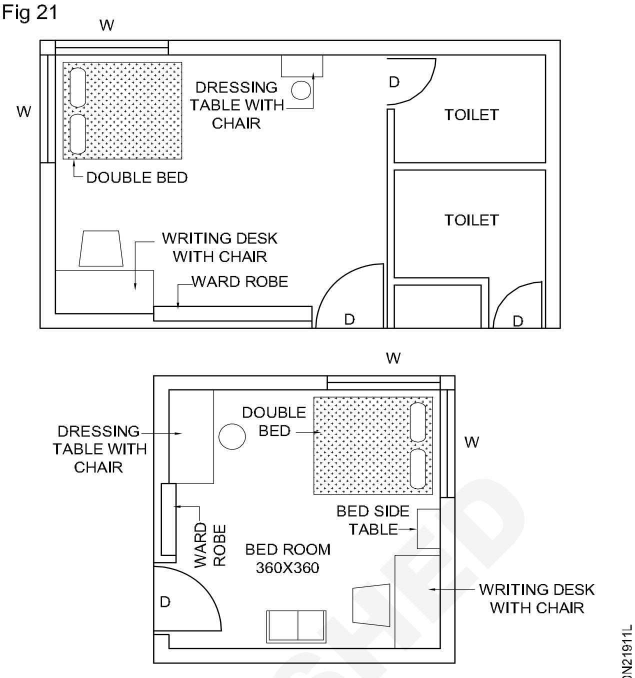


DINING ROOM

Vastu shatra (Fig 24)

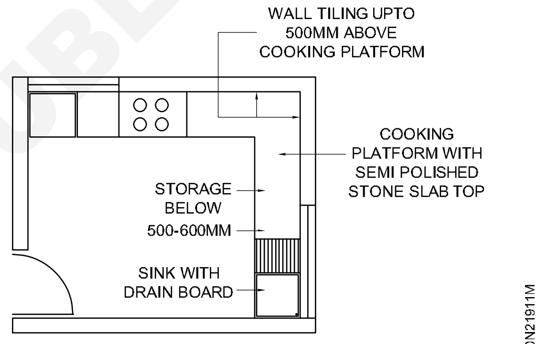
Vastu is an attempt towards finding aesthetic design solutions. Most of the clients wished to incorporate vastu principles in the construction and decorations of their houses. Therefore, vastu principles have today become the house rather than an exception. Instead of being considered as constraints, these principles are taken as underlying guide lines for aesthetic solutions to design problems.

Fig 21



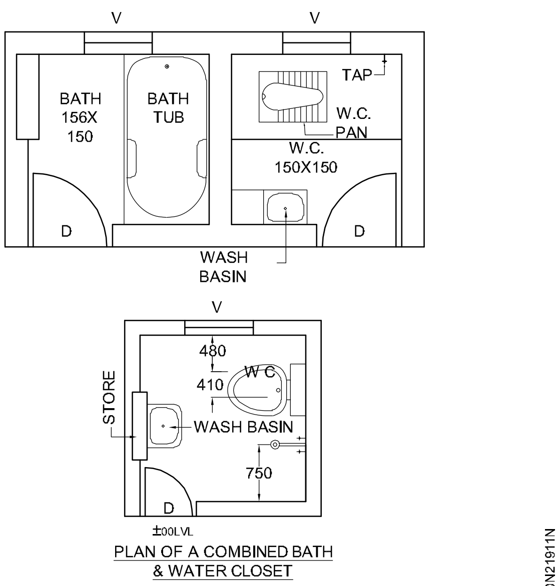
BED ROOM

Fig 22



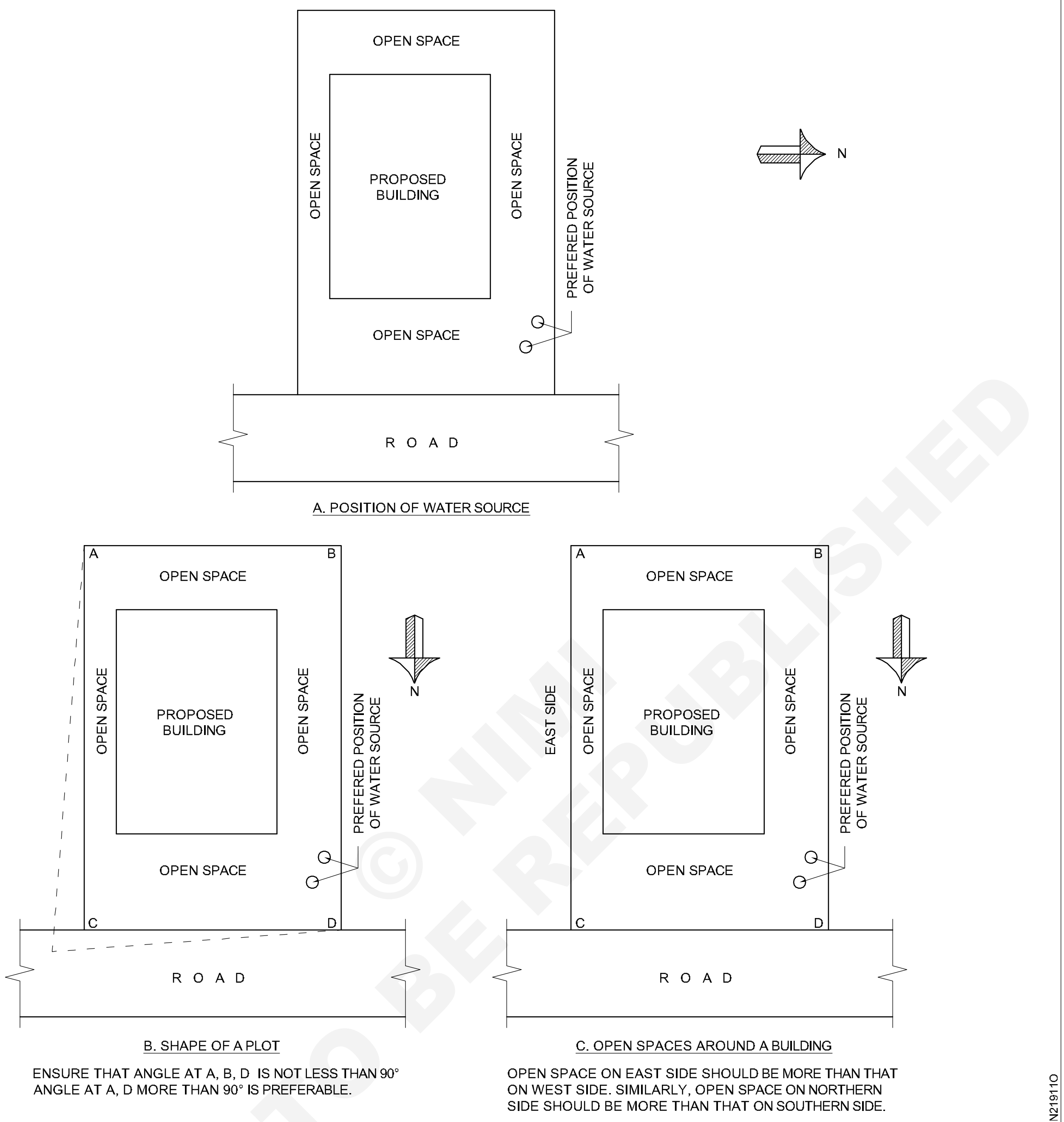
KITCHEN

Fig 23



BATH ROOM

Fig 24



VASTHU SHASTRA

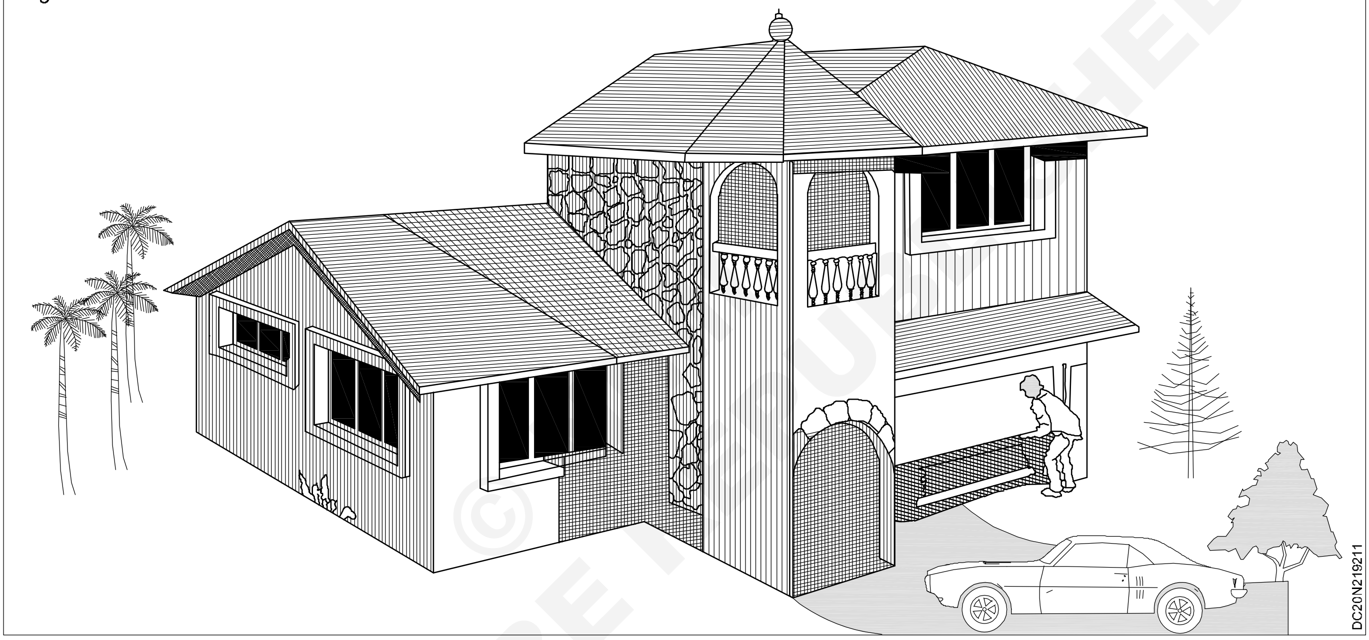
Local building bye-laws as per I.S code

Objectives: At the end of this lesson, you shall be able to
- **describe the different types of building**
- **define the term related to bye-laws**
- **explain requirements of building as per NBC.**

Introduction

Building is a structure that is built with three parts, foundation, superstructure and roof. Building means any structure whatever be the purpose and whatever materials used for construction includes foundation, plinth, walls, floors, chimney, plumbing and building services, verandas, balconies etc. (Fig 1)

Fig 1



Types of building

Occupancy classification

All buildings can be classified in one of the following groups:

Group A: Residential

Group B: Educational

Group C: Institutional

Group D: Assembly

Group E: Business

Group F: Mercantile (Includes both retail and wholesale stores)

Group G: Industrial (Includes low, moderate and high fire hazard)

Group H: Storage

Group I: Hazardous

A Brief description of the various classes of buildings is as follows:

Group A: Residential buildings

These include any building in which sleeping accommodation is provided for normal residential purposes, with or without cooking or dining or both facilities, except any building classified under group C.

a Subdivision A-1. Lodging or rooming houses. These include any building or group of buildings under the same management, in which separate sleeping accommodation for a total of not more than 40 persons (beds) on transient or permanent basis, with or without dining facilities, but without cooking facilities for individuals, is provided. This includes inns, clubs, motels and guest houses.

A lodging or rooming house shall be classified as a dwelling in subdivision A-2 if no room in any of its private dwelling units is rented to more than three persons.

b Subdivision A-2. One-or two - family private dwellings. These include any private dwelling which is occupied by members of one or two families and has a total sleeping accommodation for not more than 20 persons.

If rooms in a private dwelling are rented to outsiders, these shall be for accommodating not more than three persons per room.

If sleeping accommodation for more than 20 persons is provided in any one residential building, it shall be classified as a building in subdivision A-1, A-3 or A-4 as the case may be.

c Subdivision A-3. Dormitories. These include any building in which group sleeping accommodation is provided, with or without dining facilities, for persons who are not members of the same family, in one room or a series of closely associated rooms under joint occupancy and single management, For example, school and college dormitories, student's hostels and military barracks.

d Subdivision A-4. Apartment houses (flats). These include any building or structure in which living quarters are provided for three or more families, living independently of each other and with independent cooking facilities, for example, apartment houses, and mansions.

e Subdivision A-5. Hotels. These include any building or group of buildings under single management, in which sleeping accommodation is provided with or without dining facilities, for hotels classified up to 4 star category.

f Subdivision A-6. Hotels star. These include the hotels duly approved by the concerned authorities as Five star and above hotels.

Group B: Educational Buildings

These include any building used for school, college other training institutions for day-care purposes involving assembly for instruction, education or recreation for not less than 20 students.

a Subdivision B-1. (schools upto senior secondary level). This includes any building or group of buildings under single management for students not less than 20 in number.

b Subdivision B-2. (all others/training institutions). This includes any building or group of buildings under single management used for students not less than 100 in number.

Group C: Institutional buildings

This includes any building or part thereof, which is used for purposes, such as medical or other treatment or care of persons suffering from physical or mental illness, disease or infirmity; care of infants, convalescents or aged persons and for penal or correctional detention in which the liberty of the inmates is restricted. Institutional buildings ordinarily provide sleeping accommodation for the occupants.

a Subdivision C-1: (hospitals and sanatoria). This subdivision includes any building or a group of buildings under single management, which is used for housing persons suffering from physical limitation because of health or age, for example, hospitals, infirmaries, sanatoria and nursing homes.

b Subdivision C-2: (custodial institutions). This subdivision includes any building or a group of buildings under single management, which is used for custody and care of persons, such as children, convalescents and the aged, for example, homes for the aged and infirm, convalescent homes and orphanages.

c Subdivision C-3: (penal and metal institutions).This subdivision includes any building or a group of buildings under single managements, which is used for housing persons under restraint, or who are detained for penal or corrective purpose, in which the liberty of the inmates is restricted, for example, jails, prisons, mental hospitals, mental sanatoria and reformatories.

Group D: Assembly building

These include any building or part of a building, Where groups of people congregate or gather for amusement, recreation, social, religious, patriotic, civil, travel and similar purposes, for example, theatres, motion picture houses, assembly halls, auditoria, exhibition halls, museums, skating rinks, gymnasiums, restaurants, places of worship, dance halls, club rooms, passenger stations and terminals of air, surface and marine public transportation services, recreation piers and stadia, etc.

a Subdivision D-1: This subdivision includes any building primarily meant by theatrical or operatic performances and exhibitions and which has a raised stage, proscenium curtain, fixed or portable scenery or scenery loft, lights, motion picture booth, Mechanical appliances or other theatrical accessories and equipment and which is provided with fixed seats for over 1000 persons.

b Subdivision D-2: This subdivision includes any building primarily meant for use as described for subdivision D-1, but with fixed seats up to 1000 persons.

c Subdivision D-3: This subdivision includes any building, its lobbies, rooms and other spaces connected thereto, primarily intended for assembly of people, but which has no theatrical stage or theatrical and/or cinematographic accessories and has accommodation for 300 persons or more. For example, dance halls, night clubs, halls for incidental picture shows, dramatic, theatrical or educational presentation, lectures or other similar purposes, having no theatrical stage except a raised platform and used without permanent seating arrangement; art galleries, exhibition halls, community halls, marriage halls, places of worship, museums, lecture halls, passenger terminals; and heritage and archaeological monuments.

d Subdivision D-4: This subdivision includes any building, primarily intended for use as described in subdivision D-3, but with accommodation for less than 300 persons with no permanent seating arrangement.

e Subdivision D-5: This subdivision includes any building or structure permanent or temporary meant for assembly of people not covered by subdivisions D-1 to D-4,for example, grandstands, stadia amusement park structures, reviewing stands and circus tents.

f Subdivision D-6: This includes any building for assembly of people provided with multiple services/ facilities like shopping, cinema theatres and restaurants, for example, multiplexes.

d Subdivision D-7: Any building or structure permanent or temporary meant for assembly of people not covered by D-1 to D-6. For example, underground or elevated railways.

Group E: Business Buildings

These include any building or part of a building which is used for transaction or business more than covered by Group F) for keeping of accounts and records and similar purposes, professional establishments, service facilities, etc. City halls, town halls, court houses and libraries classified in this group so far as the principal function of these is transaction of people business and keeping of books and record.

Business building are further subdivided as follows

a Subdivision E-1: Offices, banks, professional establishments, like offices of architecture engineers, doctors, lawyers and police stations.

b Subdivision E-2: Laboratories, research establishments, libraries and test houses.

c Subdivision E-3: Computer installations.

d Subdivision E-4: Telephone exchanges.

e Subdivision E-5: Broadcasting stations and T.V. Stations.

Group F: Mercantile buildings

These include any building or part of a building, which is used as shops, stores, market, for display and sale of merchandise, either wholesale or retail.

Mercantile buildings shall be further sub classified as follows

Subdivision F-1: Shops, stores, departmental stores, markets with area up to 500 m^2.

Subdivision F-2: Shops, centres, departmental stores, markets with are more than 500 m^2 .

Subdivision F-3: Underground shopping centres.

Storage and service facilities incidental to the sale of merchandise and located in the same building shall be included under this group.

Group G: Industrial buildings

These include any building or part of a building or structure, in which products or materials of all kinds and properties are fabricated, assembled, manufactured or processed. For example, assembly plants, laboratories, dry cleaning plants, power plants, pumping stations, smoke houses, laundries, gas plants, refineries, dairies and saw - mills, etc.

The hazard of occupancy shall be the relative danger of the start and spread of fire, the danger of smoke or gases generated the danger of explosion or other occurrence potentially endangering the lives and safety of the occupants of the buildings.

a Subdivision G-1: (Buildings used for low hazard industries): This subdivision includes any building in which the contents are of such low combustibility and the industrial processes or operations conducted therein are of such a nature that there are no possibilities for any self- propagating fire to occur and the only consequent danger to life and property may arise from panic, fumes or smoke, or fire from some external source.

b Subdivision G-2: (Buildings used for moderate hazard industries): This subdivision includes any building in which the contents or industrial processes of operations conducted therein are liable to give rise to a fire which will burn with moderate rapidity and give off a considerable volume of smoke, but from which neither toxic fumes nor explosions are to be feared in the event of a fire.

c Subdivision G-3: (Buildings used for high hazard industries): This subdivision includes any building in which the contents or industrial processes or operations conducted therein are liable to give rise to a fire which will burn with extreme rapidly or from which poisonous fumes or explosions are to be feared in the event or a fire.

Group H: Storage buildings

These include any building or part of a building used primarily for the storage or sheltering (including servicing, Processing or repairs incidental to storage) of goods, wares or merchandise (except those that involve highly combustible or explosive products or materials) vehicles or animals. For example, warehouses, cold storages, freight depots, transit sheds, storehouses, truck and marine terminals, garages, hangars (other than aircraft repair hangars), grain elevators, barns and stables.

Storage properties are characterized by the presence of relatively small number of persons in preposition to the area. Any new use which increases the number of occupants to a figure of the new use. For example, hangars used for assembly purposes, warehouses used for office purposes, garage buildings used for manufacturing.

Group 1: Hazardous buildings

These include any building or part of a building which is used for the storage, handling, manufacture of processing of highly combustible or explosive materials or products which are liable to burn with extreme rapidity and /or which may produce poisonous fumes or explosions; for storage, handling, manufacturing or processing which involve highly corrosive, toxic or noxious alkalies, acids or other liquids or chemicals producing flame, fumes and explosive, poisonous, irritant or corrosive gases; and for storage, handling or processing of any material producing explosive mixtures of dust which result in the division of matter into fine particles subject to spontaneous ignition. Examples of buildings of this class are those buildings which are used for:

a Storage, under pressure of more than 0.1 N/mm^2 and in quantities exceeding 70 m^3 ,of acetylene, hydrogen, illuminating and natural gases, ammonia, chlorine, phosgene, sulphur dioxide, carbon dioxide, methyl oxide and all gases subject to explosion, fume or toxic hazard, cryogenic gases, etc.

b Storage and handling of hazardous and highly flammable liquids, liquefiable gases like LPG, rocket propellants, etc

c Storage and handling of hazardous and highly flammable of explosive materials, (other than liquids) and

d Manufacture of artificial flowers, synthetic leather, ammunition, explosives and fireworks.

Introduction to building bye-laws

For a planned development of towns and cities, planning authorities of the area lay down certain norms for construction of buildings which are known as "BUILDING BYE - LAWS"

For provisions and requirement for safe and stable design, methods of construction and sufficiency of materials in structures and regulations for maintenance of equipments, use and occupancy of all structures and premises, these rules may be helpful.

Term related to bye-laws

Abut: A building is said to be abut on the street, when the outer face of any of its (external) walls is on the street boundary.

Alley: Alley means a secondary public thoroughfare which affords a mean of access to the abutting properly.

Alteration: A change from one occupancy to another or a structural change such as an addition to the area or height or removal of the part of the building or any change to the structure.

Balcony: Balcony shall mean a cantilevered horizontal projection from the wall of building without any vertical support and having a balustrade or railing not exceeding one metre in height and intended for human use.

Barsati: It means a habitable space on the roof of the building with/without toilet facilities.

Basement/cellar: It means the lower storey of the building below or partly below the ground level.

Building line: Building line is also known as set back or front building line. It is a line parallel to the plot boundaries beyond which no construction work is permitted. The distance is taken from the centre line of the road and building line.

Type of road	Building line
Village road	9.0 m.
Other district road	9.0 m.
Major district road	15.0 m.
National & state highway	30.0 m.

Cabin: A non residential enclosure constructed of non load bearing partitions.

Canopy: Cantilever projection known as canopy of size limit 4.5 m long and 2.4m width will not be considered as covered area.

Carpet area: Carpet area means usable floor area excluding staircase, lift and walls.

Carpet area = total floor area - circulation area

Carpet area of an office building is 60% to 70% of plinth area

Carpet area of residential building is 50% to 65 % of plinth area

For framed multi storied building the area occupied by wall is 5% to 10% of plinth area.

For ordinary building without frame the area occupied by walls may be 10% to 15% of plinth area.

Circulation area: It is floor area of veranda, passage, corridor, balconies, entrance hall, staircase etc, which are used for movement of persons using the building. It may be divided into two parts.

a **Horizontal circulation area:** Horizontal circulation area is area of veranda, passages, corridor, porch, etc which are required for horizontal movement of the users, it may be 10% - 15% of plinth area of building.

b **Vertical circulation area:** It is the area or space occupied by stair cases, lift and the entrance hall adjacent to them which are required for vertical movement of the users, it may be 4% - 5% of plinth area.

Cooking alcove: A cooking space having direct access from main room without any intermediate.

Court yard: Court yard shall mean an area open to sky within the boundary of a plot, which is enclosed of partially enclosed by building. parapet of railing may be provided all around the court yard. It provided access to light air and rain water inside the building It may be at ground floor level.

Covered area: Covered area means ground area covered by the building at the ground level.

The maximum covered area of the building of different classes shall be governed by the following.

1 In a bazaar or market area the covered area shall not exceed 75% of the area of the site. Provided that sufficient off street parking facilities for loading and unloading of vehicles are available.

2 In an industrial area, the covered area shall not exceed 60% of the site area.

3 In residential area, the covered area shall be as given in table.

4 In the case of building of mixed class, the covered area shall be determined by the rules pertaining to the particular class for which the particular floor is used or intended to be used.

Table - Covered area

Sl.No.	Area of plot	Maximum permissible covered area
1	Less than 200 sq.m	60% of the site area on the ground and first floor and nothing on the (or 240 sq.yd) second floor except a " barsati" not exceeding 25% of the ground floor.
2	200sqm. To 500 sq.m. (or 240 sq.yd. to 600 sq.yd)	50% of the site area or 150 sqm (180 sq.yd.) whichever is more.
3	501 sqm. To 1000 sqm. (or 601 sq.yd.to 1200 sq.yd.)	40% of the site area or 250 sqm. (or 300 sq.yd.) whichever is more.
4	More than 1000 sq.m. (1200 sq.yd)	33 1/2 % of the site area or 400 sqm.(480 sq.yd) whichever is more.

Cross wall: An internal wall built into an external wall.

Damp proof course: Damp proof course means a course consisting of some appropriate water proofing material provided to prevent penetration of dampness.

Dead load: Dead load means the weight of all permanent stationary construction, becoming a part of structure.

Drainage: Drainage means the removal of any liquid by a system constructed for the purpose.

Detached building: A building whose roofs and walls are independent of any other building with open spaces on all sides as specified.

Development of land: Development of land means any material change on the use of land intended for sale or construction of any structure.

Development plan: Development plan means a general planning scheme for the local area as a whole or any detailed planning scheme for any specified area.

Floor area: Floor area means the built up area of a building at any floor level. To get floor area, the area of wall shall be deducted from the plinth area. It includes all room veranda, corridor, entrance hall, dining hall, kitchen, store, bath, latrine, etc.

Floor area = Plinth area- area occupied by walls.

Floor area ratio: It means the quotient obtained by dividing the floor area of all floors by the area of the plot and multiplied by hundred.

$$\text{F.A.R.} = \frac{\text{Total floor area of all floors}}{\text{Total plot area}} \times 100$$

Assume :- Total plot area = 100 sq.m.

Total floor area at ground floor = 60.00 sq.m.

Floor area at first floor = 60.00 sq.m.

Floor area at second floor = 30.00 sq.m.

Total floor area = 150.00 sq.m.

(Ground floor + first floor + second floor)

$$\text{F.A.R.} = \frac{150}{100} \times 100 = 150$$

Floor space index :- It is the ratio of built up area allowed to the plot area available.

$$\text{F.S.I} = \frac{\text{Builtup area allowed}}{\text{Plot area available}}$$

Built up area = floor area at ground level + 20% of floor area for walls = 60 sq.m + 12 sq.m = 72 sq.m.

$$\text{F.S.I.} = \frac{72}{100} 0.72$$

Footing: The offset portions of a foundation to provide a greater bearing area.

Foundation: "Foundation" means the part of a structure which is below the lower most floor and which provides support for the super- structure and transmits the loads to the ground below.

Frontage: It means side or part of a side of a plot which abuts on a street.

Front yard: Means an open space extending laterally along the front side (entrance side) of a building and formatting part of the plot.

Gallery: Means an intermediate floor or platform projecting from a wall or an auditorium or a hall providing extra floor area, additional seating accommodation, etc.

Garage: A building or outhouse used for the storage of vehicles.

Ground floor: The storey of a building to which there is an entrance from the outside of the adjacent ground or street.

Habitable room: It means a room having windows and doors of size not less than one tenth of the floor area of the room and bath room.

Head room: Head room means the clear vertical distance measured from the finished floor surface to the finished ceiling surface.

Height of building: Height of building means vertical distance measured in the case of flat roofs from the average level of the ground around and contiguous to the building to the terrace of the last livable floor of the building.

Height of the room: It means the vertical distance between the floor and the lowest point on the ceiling.

Jhamp: A downward, vertical or sloping projection hanging below any horizontal projection like balcony, canopy, verandas, passage etc, to provide protection from direct sun and rain.

Jhot: A strip of land permanently left open for drainage purposes not to be used as an access way and is not a street or to be included as a part of setbacks.

Katra or chawl: A Building so constructed as to be suitable for letting in separate tenements each consisting of a single room, or two rooms, but not more than two rooms, and with common sanitary arrangements.

Key plan: It is a plan to a scale of not less than one in 10,000 (1:10,000) It shell be submitted along with the application for a development/building permit It gives the boundary location of the site w.r.t. neighborhood.

Ledge: A shelf like projection supported in any manner what so ever, except by means of vertical support, within a room itself but not having, projection wider than 0.75m.

Lift well: It means the unobstructed enclosure provided for the vertical movement of the lift car(s) and any counterweight (s) including the lift pit and the space for top clearance.

Live load: It means all loads except dead load that may be imposed on structure.

Loft: A residual space in a pitched roof or any similar residual space, above normal floor level, which may be constructed for storage purpose.

Mezzanine floor: An intermediate floor in any story over-hanging and overlooking a floor beneath.

Open space: Means an area forming integral part of the plot left open to the sky.

Open space around building: The national building code of our country has recommended following open space around building of varying heights.

Parking space: Means an area enclosed or un closed, sufficient in size to park vehicles, together with a driveway connecting the parking space with a street or alley.

Party wall: Shall mean a common wall partly constructed on the plot of land and partly on an adjoining plot and serving both structurally.

Parapet: Means a wall not more than 1.2m in height built along the edge of a room or a floor.

Pathway: An approach constructed with materials, such as bricks, Murrum, concrete, stone, asphalt or the like.

Pilaster: A pier forming part of a wall partially projecting there and bonded there to.

Plinth: The portion of a structure between the surface of the surrounding ground and the surface of the floor first above the ground.

Plinth area: Plinth area means the area of the building at plinth level, it is the built up covered area measured at the floor level of basement or any storey. This is calculated by taking external dimension of the building at floor level excluding plinth offset.

Plinth height: Shall mean the height of the ground floor above the street level of the centre of the adjoin street.

Plinth level: Plinth level shall mean the level of the ground floor of a building.

Depth of plot: Depth of plot means the mean horizontal distance between the front and rear plot boundaries.

Porch: A covered surface supported on pillars or otherwise for the purpose of pedestrian or vehicles to approach a building.

Rain water pipe: A pipe or drain situated wholly above the ground and used for carrying water directly from roof surface of elevated court yard or other open surface.

Road: Road means any highway, street, lane, pathway, alley., stairway, passageway, carriage way, footway, or bridge, whether a through fare or not, over which the public have a right of passage or access uninterruptedly, for a specified period.

Road line: The line defining the side limits of a road.

Row housing: A row of houses with only front, rear and interior open spaces.

S.No.	Description of building	Front space (width in m.)	Side space (width in m.)	Back space (width in m.)	Remarks
1	Building having height less than 10.0m	3.0 In no case less than 1.8	3.0	3.0 In no case less than 1.8	Minimum building line 7.5m.
2	Building having height more than 10.0m and less than	3.0+A	3.0+A	3.0+A	The value of a is 1 m. for every 3m. 10m. height of
3	Building having height more than 25.0m and less than 30.0m	10.0	10.0	10.0	
4	Building having height more	10.0+B	10.0+B	10.0+B	The value of B is 1m. for every 5m. yond 30m height of building.

Sanctioned plan: It means the set of drawing and statements submitted under these rules in connection with a building and duly approved and sanctioned by the authority.

Semi detached building: A building detached on three sides with open space.

Sewage drain: A drain used or constructed to be used for conveying solid or liquid waste matter, excremental or otherwise to a sewer.

Site: Site means a parcel (piece) of land enclosed by definite boundaries.

Site double frontage : A site having a frontage on two streets other than corner plot.

Site plan: The site plan shall be drawn to a scale of not less than 1:400 provided that when circumstances are such as to make a smaller scale necessary or sufficient, the plan may with the constant of the authority be drawn to a scale of 1:800. It shall be fully dimensioned and shall show.

1 The boundaries of the plot and of any continuous land belonging to the owner thereof including the revenue survey particulars in full.

2 The position of the site in relation to the neighbouring street (s) and its main access.

3 The name of such street(s), if any.

4 All existing structure standing on, over or under the plot.

5 All existing streets of footpaths within the plot.

6 The layout of street or foot paths within, adjoining or terminating at the site, existing or proposed to be widened or newly aligned.

7 The purposed plot subdivision, if any, and the area and uses of each subdivision thereof

8 The access to each plot sub division, if any.

9 The layout of any service road or foot paths and public parking space proposed or existing, if any.

10 The area and location of any land within the plot that is not proposed to be developed or redeveloped.

11 The area and location of any land that is proposed to be reclaimed.

12 North direction is related to the site.

Stair covered: Stair covered means cabin like structure with a covering roof over a staircase and its landing built to enclose only the stairs for the purpose of providing protection from weather/and not used for human habitation.

Sunshade: It means a sloppy or horizontal structural overhang usually provided over opening an external walls to provide protection from sun and rain.

Stall: Stall means any temporary structure other than a hut used solely for the display and side sale of goods.

Storage: A space where goods of any kind or nature are stored.

Storey: Storey means any portion of a building included between the surface of any floor and the surface of the floor next above it, or if there be no floor above it, then the space between any floor and the ceiling next above it.

Street line: Street line means the line defining the side limits of a street.

Street level: Street level means the level at the centre line of the street.

Verandah: Veranda means a covered area with at least one side open to the outside with the exception of a parapet, trellis, jolly or grill work on the open side.

Vertical exit: A vertical exit is a means of exit used for ascension or descension between two or more levels including stairways, smoke- proof towers, ramps, and fire escapes.

Yard: An open space at ground level between a building and the adjoining boundary lines of the plot un occupied and unobstructed except by encroachments or structures specifically permitted by these by laws on the same plot with a building.

Yard front: Yard front means an open space extending laterally along the front side (main entrance side) of a building and forming part of the plot.

Yard rear: Yard rear means the utility open space extending laterally along the rear side of the plot and forming part of the plot.

Yard side: Yard side means an open space extending laterally between any side of a building of the plot facing that side other than front and rear/utility yard and forming part of the plot.

Building plan: The plan, elevation and sections of buildings accompanying the application shall be accurately drawn to a scale of not less than 1:100.

1 Include floor plan of all floors together with the covered area, accessory buildings and basement floor. It indicates clearly size of rooms, position of stair cases, ramps and lift well.
2 Show the use or occupancy of all parts of the building.
3 Show the exact position of services like water closet, sink, bath etc.
4 Include sectional drawing, showing clearly the size of footings, thickness of basement, wall construction, size and spacing of framing members, etc.
5 Show street elevations.
6 Include terrace plan indicating the drainage, and slope of the roof.
7 Specify total floor area of building.

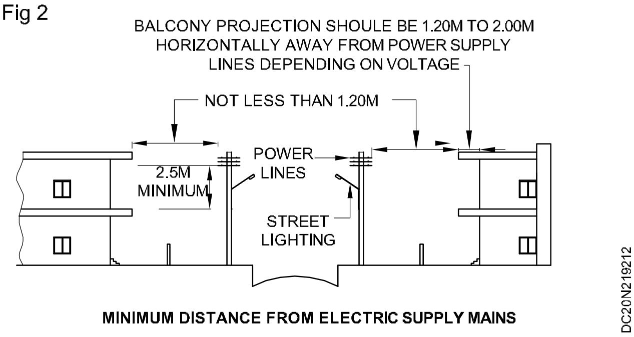
Service plan: Service plan shall be drawn to the same scale as the building plan. It shall include plans and sections of private water supply and sewage disposal systems.

General site & building requirements

1 No land development/redevelopment shall be made and / or no building shall be constructed on any plot, on any part of which there is deposited before, excrete or other offensive matter.
2 No land development /redevelopment shall be made and /or no building shall be constructed on a plot which comprises or includes pit, quarry, and other similar excavation.
3 No development/redevelopment shall be made and /or no building shall be erected on a plot liable to flood or on a slope forming an angle of more than 45° with horizontal, or on soil un suitable for percolation, or in sandy beds.
4 Any land development/redevelopment or building construction or reconstruction in any area modified by the government of India. As a regulation zone under the environment (protection)act. 1986 (29 of 1986).

Distance from power supply mains (Fig 2)

Fig 2



MINIMUM DISTANCE FROM ELECTRIC SUPPLY MAINS

The distance between any accessible part of the building and the electric supply mains should be between 1.2 m. to 2.0 m horizontally and 2.50 m to 3.70 m. vertically depending upon the voltage of power supply lines. This is necessary to avoid mishaps like electrocuting of children playing in the balcony adjacent to the electric supply mains. House wife or servants drying wet clothes on the open terraces, loss of property and lives due to fall of supply mains of building etc.

Voltage of electric lines	Minimum distances	
	Vertical	Horizontal
1 Low medium	2.5m	1.2m
2 High voltage lines	3.7m	1.2m
Up to 11000 v(11kv)		
11000-33000 v(11kv-33kv)	3.7m.	2.0 m.
Above 33000 v(33kv)	3.7m.+	2.0 m.+
	o.s.m for for every addl 33000 volt	0.3 m for every addl 33000 volt

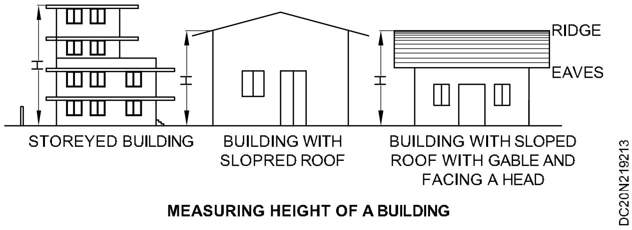
For voltage lines beyond 33 kv add 0.3 m to the above horizontal and vertical distance for every additional 33 kv and part there of.

Minimum distance between central line of a street and building: The minimum distance between the central line of street an building other than compound wall or fence or outdoor display structure shall be 5.0 m and that between plot boundary abutting the street and building shall be 3.0 m.

Prohibition for constructing abutting public roads: No person shall construct any building other than compound wall within 3.0 m from plot boundary abutting national highway, state highway or other road provided that open ramps or bridges or step with or without parapet or railing permitted as access from the street to the building within that 3.0 m and cornice or roof with protection had not exceeding 75.0cm shall be permitted with in that 3.0m.

Area and height limitations: The limitations of area and height of different occupancy classes are achieved by specifying the floor area ratio (FAR) (Fig 3)

Fig 3



MEASURING HEIGHT OF A BUILDING

ACCESS: 1 The clear width of access to a building from the street shall be the following:

Building	Individual occupancy	Multiple occupancy
Single storey building	1.2 m	3.6 m
Two storey building	2.0 m	5.0 m

Height of building

a The maximum height of the building shall not exceed 1.5 times width of the street abutting the plot plus 1.5 times the width of the yard.

b If the building abuts two or more streets of different width, then the building shall be deemed to face upon the street that has greeter width and the height of the building shall be regulated by the width of that street.

Sl.No	Building use of occupancy	Maximum permissible coverage percentage of plot area	Maximum permissible F.A.R.
1	Residential	50	1.5
2	Special residential	50	1.5
3	Educational (medical)	30	1.2
4	Institutional(medical)	25	1.0
5	Assembly	40	0.7
6	Governmental or semi public business	30	1.5
7	Mercantile(commercial)	60	2.0
8	Industrial	40	1.2
9	Storage	70	2.0
10	Hazardous	25	0.7

Occupancy: All buildings whether existing or proposed shall be classified as: GROUP A1: Residential [Normal residential purpose] GROUP A2:- Special residential [Lodging or rooming, hotels exceeding 150 sq. m floor area]

GROUP B : Educational

GROUP C : Medical/Hospital

GROUP D : Assembly

GROUP E : Office/ Business [Governmental or semi public business]

GROUP F : Mercantile

GROUP G1 : Industrial

GROUP G2 : Small Industrial

GROUP H : Storage

GROUP I : Hazardous

Parts of building

Foundation: Minimum depth of 60cm

Plinth :- Every plinth shall have a minimum height of

- 30 cm above the level of abutting street.
- 45 cm above the surrounding ground.

Habitable room: The carpet area of habitable room shall not be less than 9.5 sq.m. and a width not less than 2.4m. The average height shall not be less than 2.75m from the surface of floor to the lowest point of the ceiling or false ceiling.

Kitchen: The carpet area of a kitchen or any other room used as kitchen shall not be less than 5.0 sq m and its width shall not be less than 1.8m. The average height of kitchen measured from floor to the ceiling shall not be less than 2.75m there is a separate store area of kitchen reduced to 4.5m^2.

Bath room and latrines: The area of a bath room shall not be less than 1.8 sq m. with either side not less than 1.2m. The carpet area of latrine shall not be less than 1.1 sq.m. with one side not less than 0.9m. provided that the area of combined bathroom latrine shall not be less than 2.8 sqm with one side not less than 1.2m.

Height of bathroom and for latrine measured from floor to the ceiling shall not be less than 2.1 m.

Mezzanine floor: The floor area of mezzanine floor shall not exceed area of the main floor or room accommodating the mezzanine floor. The head room measured from the surface of the floor to any point underside of the mezzanine floor shall not be less than 2.2m.

Roof: The rise of Mangalore tile roof shall neither be more than half the span nor be less than one third the span.

Corrugated galvanized iron sheet, asbestos cement sheet roof: Rise shall be less than one fifth of the span.

Trussed roof: The rise of trussed roof shall not be less than either 1/5 th of the span or 11-20 degree whichever is greater.

Floors: Every kitchen, bathroom / latrine shall be provided with impermeable floor with a suitable slope towards the drain.

Stair case: In any building exceeding four storeys (including basement or sunken floor) every floor area above and below plinth shall have at least two staircases, one of which may be external stairway.

1 The minimum width of stair shall not be less than 0.75m. for single family residential occupancy and 1.20m. for buildings of other occupancies. (As per NBC 1.00M for dwelling and 0.75m for row house)

2 Width of tread without nosing shall not be less than 25 centimetre for internal stair in the case of residential buildings and 30cm in the case of other buildings.

3 Height of riser shall not exceed 19 cm. In case of residential buildings & 15cm, in case of other buildings.

4 Height of hand rail shall not be less than 80 cm.

Industrial occupancies open space: All building with built up area exceeding 75 square meter or the power used exceeds 30 H.P and/or the number of workers exceed 20 shall have open space not less than those prescribed below.

Open space	Value
Front yard	7.50 Mt.
Side yard on either side	3.00 Mt.
Rear yard	7.50 Mt.

Size of work room: All work rooms in buildings under this occupancy shall be provided with in a carpet area, not less than 3.4 sqm.

Height of work room: The minimum height of work room shall depend up on the type of industry. The height of any work rooms shall not be less than 2.6m, measured from the floor level to the lowest point in the ceiling.

Height of other ancillary rooms: Height of office laboratory, entrance hall, canteen, cloak room, etc. shall not be less than 3.0m.

In the case of store room and toilet, the height shall not be less than 2.4m.

Disposal of trade wastes and effluents

1 In a case of a factory where the internal drainage system is proposed to be connect to the public sewerage system, prior approval of the arrangements shall be obtained from the pollution board and water and drainage authority.

2 The industrial sewage effluents if proposed to be discharged into nearby water bodies such as river, lakes, canals or sea, the dilution of such waste shall be such that the water bodies, area not polluted.

Rat-proofing of building: Every building or part thereof designed or intended for the handling or storage of foodstuffs shall conform to the requirements specified below.

1 Every such building unless supported on posts shall have continuous foundation from at least 60 cm. below ground level to at least 15 cm above ground level.

2 All opening is such foundation or floors, windows and drains and all junctions between foundation and walls of the building shall be effectively rat-proofed. They are securely covered with rat-proof screening or grillage.

Sanitation requirement: Sanitation facilities shall be provided as stipulated below

a One water closet for the first 50 males or part thereof and two water closets for the first 50 females.

b One urinal for every 100 males.

c Drinking water foundation shall be provided at the rate of one for every 100 persons or part thereof.

d Washing facilities shall be provided at the rate of one for 50 persons or part thereof.

Hazardous occupancy

Open space: There shall be minimum open space of 10 m all round for the hazardous occupancy.

Petrol filling station: The location of petrol filling stations and its layout shall be approved by the authority in consultation.

Traffic terminal stations: The location of traffic terminal stations like municipal bus stand, inter-stand, bus, terminals railway station and air ports shall be decided by the authority of consultation.

Sanitation requirements: The sanitation requirements for bus or train station and airports shall be as stated in table, below. Two non service type latrine one each for males and females and one non service type urinal for males.

1 Wash basin: At the following rates:

a Domestic airports: minimum of 2 each for males and females.

b International airport : 10 for 200 persons

2 Shower stall: With wash basin

a 4 stall each in the females and males toilets in the transit/departure lounge.

b 4 stall each in the females and males toilets in the main concourse.

Tele communication towers.

1 The base of the tower or poles shall have minimum 3 meters distance from the plot boundary abutting the road whether it is proposed on land or over a building, even if the building is having less than 3 meters distance.

2 Distance from other boundaries of the plot to the base of the telecommunication tower or pole structure or accessory rooms shall be minimum 1.20 meters.

Assessary rooms.

1 The cabin may be made with any material but the area of such cabin shall not exceed 15 sq.m.

2 Installation of electricity generator may be allowed if the generator is covered with insulated sound- proof cabin.

Protective wall.

1 Every tower erected on the ground and through which electric power is transmitted or passed shall be provided with protective wall or grill at a distance of one mater from any point of the base.

2 The wall or grill shall have a minimum of 1.20m, height and shall be kept under lock and key, if provided with door.

Warning light and specifications

1 Every telecommunication tower shall have one light (ANL) each at 40 meters and 70 metres height from the ground level.

2 Every telecommunication tower shall be painted with international orange and international white colours alternatively starting with international orange at the top.

Educational institutional (Medical) government or semi public business occupancies

In the case of educational institutional (medical) Government or semi public business occupancies, provision of Rule 14 to 31 shall apply, subject to the modifications specified below.

1 Plot requirements: All plot sub Division and building and layout shall be approved by the chief town planner.

2 Usage of plot: The usage of plots proposed for development/redevelopment or for construction of any building shall be governed by provisions contained in the detailed town planning scheme prepared for the locality.

3 Open space: All buildings with floor area exceeding 75sq.mt, shall have open space not less than those prescribed below:

Open space	Value
Front Yard	7.50 Mt.
Side yard on either side	8.00 Mt.
Rear yard	7.50 Mt.

4 Habitable Rrooms: The carpet area of any habitable room shall not be less than 9.50 m^2 with width not less than 3 meters.

5 Kitchen, store, record room, laundry etc: The width of kitchen, store, record room, and laundry etc, shall not be less than 2.4 meters. The head room shall not be less than 2.4 meters at any point from the floor.

6 Corridor, veranda, and passage way: The clear width of any corridor, veranda, and passage way shall not be less than 1.5 meters.

7 Circulation area: Horizontal circulation shall not be less than 12% of the floor area. The area occupied by vertical circulation space such as lift, ramp and stair cases shall not be less than 4% of the floor area.

8 Assembly occupancies: In the case of assembly occupancies open spaces shall be as given below.

Requirements of assembly spaces

a Any room in a building under assembly occupancy shall have clear height of not less than 4m for the assembly area. Provided that the clear head room beneath or above the mezzanine or balcony shall not be less than 3 m.

Provided also that the head room shall not be less than 2.4 m in air conditioned rooms, the height of store room, toilets and cellar rooms shall not be less than 2.4 m

b Balconies or galleries or mezzanines shall be restricted to 25% of the total accommodation of assembly hall area and the maximum slope of the balcony or gallery or mezzanine shall not exceed 35°.

Ventilation: The standard of ventilation shall be 28 m^3 fresh air per seat per hour.

Fire protection

a Every such building shall be constructed of the fire resistant material throughout.

b Every place of assembly with a capacity of up to 600 persons shall have minimum of two separate exits as remote from each other as practicable.

Provided that where the capacity ranges from 601 to 1001 persons, such place of assembly shall have minimum of two separate exits as remote from each other as practicable, with each exit of not less than 2 unit width.

Provided further that where the capacity range over 1001 person, such place of assembly shall have minimum of four separate exits as remote from each other as practicable.

c When more than one auditorium or assembly hall is housed in the same building the exit requirements and fire escape provisions for each of the 2 units shall be mutually exclusive but shall be complimentary.

Mercantile (commercial) occupancies

Size of a shop: Every shop unit shall have a carpet area not less than 15 m^2 with a width not less than 3 meter. Provided that in case of stalls in markets the carpet area of such stall shall not be less than 5.0 m^2 with a width not less than 2.0 meter.

S.No.	Extent of built up area	Nature of open space	Dimension
1	Built up area exceeding 100 sq.m but below 400 sq.m	Front yard side yard (each) Rear yard	7.5m 3.0m 3.0m
2	Built up area exceeding 400sq.m but below 800 sq.m	Front yard side yard(each) Rear yard	10.5m 4.5m 3.0m
3	Built up area exceeding 800 sq.m	Front yard side yard(each) Rear yard	12.0m 6.0m 3.0m

Submitted in composition of drawing

Objectives: At the end of this lesson you shall be able to
- **describe sanitary requirement and area of building**
- **describe plan, section and elevation**
- **explain site plan, layout plan, and building plan detail**
- **explain first stage planning clearance**
- **describe second stage for building permit clearance .**

Introduction

1 **Side yard:** Every building of two or more stories in area zoned for commercial purpose in the development plan for the town or city or detailed town planning scheme for the locality and abutting on public street not less than 7 m width, may not provide any side yard.

Provided that in case any window/ventilator or such other opening envisaged on any side of the building, the building shall have a clear side space of 1.5 m on that side.

2 **Rear yard:** The rear yard shall not be less than 1.5 meter.

3 **Covered path ways:** All stalls in public market shall be provided with a covered access passage of not less than 1.8 m width.

4 **Fish and meat stalls:** Fish and meat stalls in a public market shall invariably be provided with flies proof enclosure. The access passage in these stalls shall have minimum width of 2 meter.

5 **Sanitation requirements:** Sanitation facilities to be provided for occupants in the group shall be as stipulated in table below.

Sanitation requirements for shops/commercial buildings

Sl. No	Fitments	For personal
1.	Water closet	One for every 25 persons or part thereof exceeding 15 (including employees and customers). For female 1 per every 15 persons of or part thereof exceeding 10.
2.	Drinking water	One for every 100 persons with a minimum of one for each floor.
3.	Wash basin	One for every 100 persons or part thereof.
4.	Urinals	Nil up to 6 persons 1 for 7-20 persons 2 for 21-45 persons 3 for 46-70 persons 4 for 71-100 persons For 101-200 persons @ of 3% For over 200 persons @ 2.5%
5.	Cleaner's sink	One for floor minimum preferably in or adjacent to toilets.

Building in small plot: Building under residential or commercial occupancy can be constructed in small plot not exceeding 125sqm of area.

i **No of floors to be limited** - The number of floors allowed shall be three

ii **Conditions regarding set back**

1 The minimum distance between the plot boundary abutting any street other than National highway, state highway, district road, and other roads and the building shall be 2m.

2 Any one side shall have minimum of 90 cm and other side shall have minimum of 60cm.

3 The rear side shall have an average of 1m set back with minimum 0.50m.

Row buildings

The number of dwelling units in a row building shall not exceed ten.

Plot area: The area of plot for one unit shall not exceed 85sq.mt.

Distance from street: The minimum distance between the plot boundary abutting any street other than NH,SH,DR,OR, shall be 1.5m

Maximum floors: The maximum number of floors permitted shall be 2 with a staircase room.

Wells: The site plan should show the position and dimension of well and all existing and proposed buildings and structures in the land within 7.5m radius from that well.

Set back

1 The set back from any street shall be as that required for a building

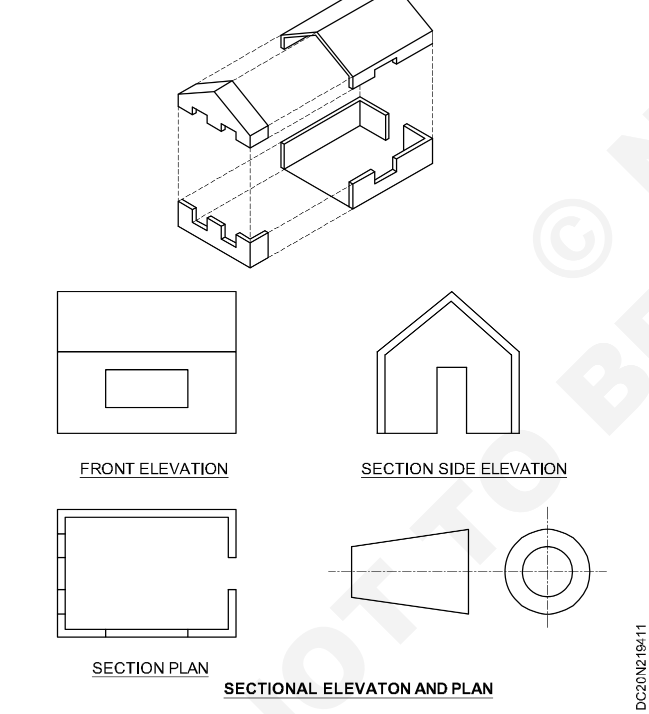
2 There shall be 1.5m set back from other boundaries

3 No leach pit, sock pit, refuse fit, earth closet or septic tank shall be allowed or made within a distance of 7.5m radius from any existing well and 1.2m distance from plot boundaries.

4 Well and surrounding:- The well shall be protected with brick wall with minimum 1m height.

Plans, Sections and Elevations of building (Fig 1)

Fig 1



Three kinds of drawings are commonly used to illustrate buildings. They are plans, sections and elevations. All of these are drawn directly from measurements of the building, so they are more straightforward to do than perspective drawings. Always the buildings are drawn in first angle projections as shown.

Plan: A plan drawing shows what you would see if you sliced through the building horizontaly, lifted off the top part and looked down. The “cut” is usually made just above the level of the window sills. A separate plan is usually made for each storey of the buildings. Any solid part of the building which is cut through can be coloured with shading or hatching. This is shown on the walls in the drawing.

Sub divisional / layout plan: In the case of development work, the notice shall be accompanied by the sub-division/ layout plan which shall be drawn on a scale of not less than 1:500 containing the following”.

a Scale used and north point.

b The location of all proposed and existing roads with their existing/proposed/prescribed widths within the land.

c Dimensions of plot along with buildings lines showing the setbacks with dimensions within each plot.

d The location of drains, sewers, public facilities and service and electrical lines etc.

e Table indicating size, area and use of all the plots in the sub-divisional /layout plan.

f A statement indicating the total area of all the site, area utilized under roads, open spaces for parks, playgrounds, recreation spaces for parks, playgrounds recreation spaces and development plan reservations, schools, shopping and other public places along with their percentage with reference to the total area of the site propped to be subdivided and

g In case of plots which are subdivided in built up area in addition to the above, the means of access to the sub-division from existing streets.

h the width of the street (if any) in front and of the street (if any) at the side or near the buildings

i the direction of north point relative to the plan of the buildings

j any physical features, such as wells, drains, etc and

k such other particulars as may be prescribed by the Authority.

Building plan and details

The plan of the buildings and elevations and sections accompanying the notice shall be drawn to a scale of 1:100. The plans and details shall

a include floor plans of all floors together with the covered area clearly indicating the size and spacings of all framing members and sizes of rooms and the position of staircases, ramps and lift wells.

b show the use or occupancy of all parts of the buildings.

c show exact location of essential services, for example, WC, sink, bath and the like.

d include at least one section through the staircase.

e include the structural arrangements with appropriate sections showing type/arrangements of footings, foundations, basement walls, structural load bearings walls, columns and beams, walls and arrangements/ spacing of framing members, floor slabs and roof slabs with the material used for the same.

f show all street elevations.

g give dimensions of the projected portions beyond the permissible building line.

h include terrace plan indicating the drainage and the slope of the roof and

i give indications of the north point relative to the plan.

The requirement of 1:100 is permitted to be flexible for specific details needed for further illustration and also for drawings for these in electronic form.

Building plan for multi-storeyed/special buildings.

For all multi-storeyed buildings which are 15 m or more in height and for special buildings like educational, assembly institutional, industrial, storage and hazards and mixed occupancies with any of the aforesaid occupancies having covered area more than $500m^2$, the building sanction shall be done in two stages.

Stage 1. First stage for planning clearance

The following additional information shall be furnished/ indicated in the building plan.

a Access fire appliances/ vehicles with details of vehicular turning circle and clear motorable access way around the building.

b Size (width) of main and alternative staircases along with balcony approach, corridor, ventilated lobby approach.

c location and details of lift encloures.

d location and size of fire lift.

e smoke stop lobby/door, where provided

f refuse chutes, refuse, chamber, service duct, etc.

g vehicular parking spaces.

h refuse area, if any.

i details of buildings services - Air-conditioning system with position of fire dampers, mechanical ventilation system, electrical services, boilers, gas pipes etc.

j details of exits including provision of ramps, etc, for hospitals and special risks.

k location of generator, transformer and switchgear room.

l smoke exhauster system if any.

m details of fire alarm system network.

n location of centralized control, connecting all fire alarm systems, built-in-fire protection arrangements and public address system, etc.

o location and dimension of static water storage tank and pump room along with fire service inlets for mobile pump and water storage tank.

p location and details of fixed fire protection installations such as sprinklers, wet risers, hose-reels, trenchers, etc and.

q location and details of first-aid fire fighting equipment/ installations.

Second stage for building permit clearance

After obtaining the sanction for planning (Stage 1) from the Authority a complete set of structural plans, sections, details and design calculation duly signed by engineer/ structural engineer along with the complete set of details duly approved in stage 1 shall be submitted. The building plans/details shall be deemed sanctioned for the commencement of construction only after obtaining the permit for stage 2 from the authority.

Lighting and ventilation.

Aggregate area of opening for lighting and ventilation excluding doors shall not be less than

1/10 of the floor area for dry hot climates.

1/6 of the floor area for wet hot climates.

1/8 of the area for intermediate climates.

1/12 of the floor area for cold climates.

No portion of the room shall be assumed to be lighted if it is more than 7.5m from the opening. The windows shall open in to external air or to an open verandah of width not more than 3m. The openings in kitchen shall be increased by the 25% of the above value.

Provision of safety

Objectives: At the end of this lesson you shall be able to
- **introduction to fire protection**
- **general fire safety requirements for buildings**
- **fire resistant construction**
- **fire alarms.**

Introduction to fire protection engineering: Fire engineering is the application of science and engineering principles to protect people, property, and their environments from the harmful and destructive effects of fire and smoke. It encompasses fire protection engineering which focuses on fire detection, suppression and mitigation and fire safety engineering which focuses on human behaviour and maintaining a tenable environment for evacuation from a fire. In the United States fire protection engineering is often used to include fire safety engineering.

The discipline of the engineering includes, but is not exclusive to: Fire detection - fire alarm systems and brigade call systems.

Active fire protection - fire suppression systems.

Passive fire protection - fire and smoke barriers, space separation.

Smoke control and management.

Escape facilities - Emergency exits, Fire lifts etc.

Building design, layout, and space planning.

Fire prevention programs.

Fire dynamics and fire modelling.

Human behaviour during fire events.

Risk analysis, including economic factors.

Wildfire management: Fire protection engineers identify risks and design safeguards that aid in preventing, controlling, and mitigating the effects of fires. Fire engineers assist architects, building owners and developers in evaluating buildings'life safety and property protection goals. Fire engineers are also employed as fire investigators, including such very large scale cases as the analysis of the collapse of the Word Trade Centers. NASA uses fire engineers in its space program to help improve safety. Fire engineers are also employed to provide 3rd party review for performance based fire engineering solutions submitted in support of local building regulation submitted in support of local building regulation applications.

Categories of active fire protection: Fire suppression: Fire can be controlled or extinguished, either manually (fire fighting) or automatically. Manual includes the use of a fire extinguisher or a Standpipe system. Automatic means can include a fire sprinkler system, a gaseous clean agent, or fire fighting foam system. Automatic suppression systems would usually be found in large commercial kitchens or other high -risk areas.

Sprinkler systems: Fire sprinkler systems are installed in all types of buildings, commercial and residential. They are usually located at ceiling level and are connected to a reliable water source, most commonly city water. A typical sprinkler system operates when heat at the site of a fire causes a glass component in the sprinkler head to fail, thereby releasing the water from the sprinkler head. This means that only the sprinkler head at the fire location operates - not all the sprinklers on a floor or in a building. Sprinkler systems help to reduce the growth of a fire, thereby increasing life safety and limiting structural damage.

Fire detection: Fire is detected either by locating the smoke, flame or heat, and an alarm is sounded to enable emergence evacuation as well as to dispatch the local fire department. An introduction to fire detection and suppression can be found here. Where a detection system is activated, it can be programmed to carry out other actions. These include de-energising magnetic hold open devices on fire doors and opening servo- actuated vents in stairways.

Hypoxic air fire prevention: Fire can be prevented by hypoxic air. Hypoxic air fire prevention systems, also known as oxygen reduction systems are new automatic fire prevention systems that reduce permanently the oxygen concentration inside the protected volumes so that ignition or fire spreading cannot occur. Unlike traditional fire suppression systems that usually extinguish fire after it is detected, hypoxic air is able to prevent fires. At lower attitudes hypoxic air is safe to breathe for healthy individuals.

Construction and maintenance All AFP systems are required to be installed and maintained in accordance with strict guidelines in order to maintain compliance with the local building code and the fire code.

AFP works alongside modern architectural designs and construction materials and fire safety education to prevent, retard, and suppress structural fires.

General fire safety requirements for buildings: In order that the fire hazards (i.e. personal hazard, internal hazard and exposure hazards) are minimised, IS: 1641-1960 recommends that the buildings shall conform to the following general requirements:

1 All buildings and particularly buildings having more than one storey shall be provided with liberally designed and safe fire-proof exits or escapes.

2 The exits shall be so placed that they are always immediately accessible and each is capable of taking all the persons on that floor as alternative escape routes may be rendered unusable and/or unsafe due to fire.

3 Escape routes shall be well-ventilated as persons using the escapes are likely to be overcome by smoke and/ or fumes which may enter from the fire.

4 Fire - proof doors shall conform rigidly to the fire safety requirements.

5 Where fire-resisting doors are employed as cut - off or fire breaks, they shall be maintained in good working order so that they may be readily opened to allow quick escape of persons trapped in that section of the building, and also, when necessary, prompt rescue work can be expeditiously carried out.

6 Electrical and/or mechanical lifts, while reliable under normal conditions may not always be relied on for escape purposes in the event of a fire, as the electrical supply to the building itself may be cut- off or otherwise interrupted, or those relying on mechanical drive may not have the driving power available.

7 Lift shafts and stairways invariably serve as flues or tunnels thus increasing the fire by increased drought and their design shall be such as to reduce or avoid this possibility and consequent spread of fire.

8 False ceiling, either for sound effects or air-conditioning or other similar purpose shall be so constructed as to prevent either total or early collapse in the event of fire so that persons underneath are not fatally trapped before they have the time to reach the exits; this shall apply to cinemas, and other public or private buildings where many people congregate.

9 To a lesser extent, the provisions of clause (8) above shall apply to single - storey buildings which may be used for residence or an equivalent occupancy. Whatever be the class or purpose of the building, the design and construction shall embody the fire retardant features for ceilings and/or roofs.

10 Floors. Floors are required to withstand the effects of fire for the full period stated for the particular grading. The design and construction of floors shall be of such a standard that shall obviate any replacement, partial or otherwise, because experience shows that certain types of construction stand up satisfactorily against collapse and suffer when may first be considered as negligible damage, but in practice later involves complete stripping down and either total or major replacement. This consideration shall also be applied to other elements of structure where necessary.

11 Roofs. Roof for the various fire-grades of the buildings shall be designed and constructed to withstand the effect of fire for the maximum period for the particular grading, and this requires concrete or equivalent construction. It is, however, important that maximum endurance is provided for as stated in para 9.

12 Basements. Where basements are necessary for a building and where such basements are used for storage, provision shall be made for the escape of any heat arising due to fire and for liberating and smoke which may be caused. It is essential that fire resistance of the basement shall conform to the highest order and all columns for supporting the upper structures shall have a grading not less than laid down in types 1 to 3.

13 Smoke extraction from basements. The following requirements shall be provided for smoke extraction

a Unobstructed smoke extracts having direct communication with the open air shall be provided in or adjoining the external walls and in positions easily accessible for firemen in an emergency.

b The area of smoke extracts shall be distributed, as far as possible, around the perimeter to encourage flow of smoke and gases where it is impracticable to provide a few large extracts, for example, not less than 3 m^2 in area, a number of small extracts having the same gross area shall be provided.

c Converse to the smoke extracts shall, where practicable, be provided in the stall board and/or pavement lights at pavement level, and be constructed of light cast iron frame or other construction which may be readily broken by fire-men in emergency. The covers shall be suitably marked.

d Where they pass through fire resisting separations, smoke extracts shall in all cases be completely separated from other compartments in the building by enclosures of the appropriate grade of fire resistance. In other cases, steel metal ducts may be provided.

e Where these are sub-basements, the position of the smoke extracts from subbasements and basements shall be suitably indicated and distinguished on the external faces of the building.

Fire resistant construction: In a fire resistant construction, the design should be such that the components can withstand fire as an integral member of structure, for the desired period. We shall Consider the construction of the following components:

1 Walls and columns.

2 Floors and roofs.

3 Wall openings.

4 Escape elements.

5 Strong room construction.

1 Walls and columns

The following points should be observed for making walls and columns fire-resistant:

i Masonry walls and columns should be made of thicker section so that these can resist fire for a longer time, and can also act as barrier against spread of fore to the adjoining areas.

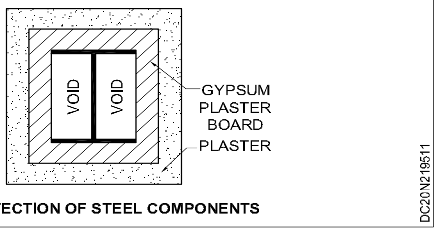
ii In the case of solid load-bearing walls, bricks should be preferred to stones.

iii If walls are to be made of stones, granite and lime stone should be avoided.

iv In the case of building with framed structure, R.C.C should be preferred to steel.

v If steel is used for the framed structure, the steel structural components should be properly enclosed or embedded into concrete, terracotta, brick, gypsum plaster board, or any other suitable material, as illustrated in Fig 1.

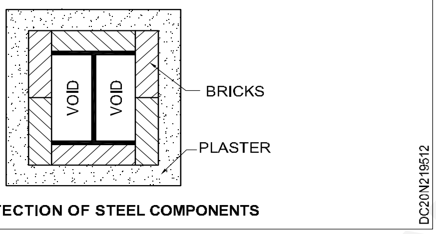
Fig 1



PROTECTION OF STEEL COMPONENTS

vi If the frame work is of R.C.C., thicker cover should be used so that the members can resist fire for a longer time. It is recommended to use 40 to 50 mm cover for columns, 35 to 40 mm cover for beams and long span slabs and 25 mm for short span slabs (Fig 2).

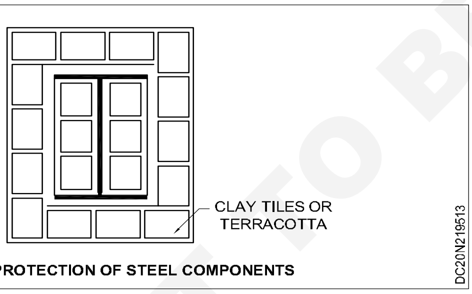
Fig 2



PROTECTION OF STEEL COMPONENTS

vii Partition walls should be of fire-resistant materials such as R.C.C., reinforced brick work, hollow concrete blocks, burnt clay tiles, reinforced glass, and asbestos cement boards (Fig 3).

Fig 3



PROTECTION OF STEEL COMPONENTS

viii Cavity wall construction has better fire resistance.

ix All walls, whether load bearing or non-load bearing, should be plastered with fire-resistive mortar (Fig 4)

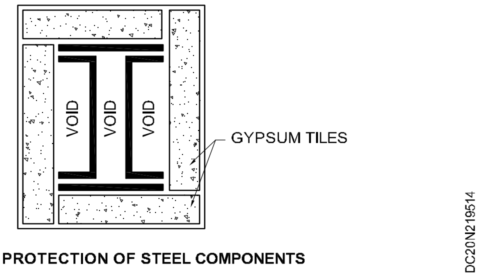
2 Floors and roofs

The following points are note-worthy for fire-resistant floors and roofs:

i For better fire resistance, slab roof is preferred to sloping or pitched roofs.

ii If it is essential to provide sloping roof, trusses should either be of R.C.C. or of protected rigid steel with fire proof covering.

Fig 4



PROTECTION OF STEEL COMPONENTS

iii For better fire resistance, the floor should be either of R.C.C. or of hollow tiled ribbed floor or of concrete jack arch floor with steel joists embedded in concrete.

iv If floor is made of timber, thicker joists at a greater spacing should be used, and fire stops or barriers should be provided at suitable interval.

v The flooring materials like concrete tiles, ceramic tiles, bricks etc. Are more suitable for fire resistance.

vi If cast iron, wrought iron, cork carpet, rubber tiles etc. Are to be used, these should be protected by a covering of insulating materials like ceramic tiles, plaster, terracotta, bricks etc.

vii Ceiling, directly suspended from floor joists should be of fire resistant materials like asbestos cement boards, fibre boards, metal lath with plaster etc.

3 Wall openings

i From the point of view of fire spread, openings in the walls should be a bare minimum.

ii Openings serve means of escape. Hence these should be properly protected by suitable arrangements, in case of fire.

iii Doors and windows should be made of steel. Fire resistant doors can be obtained by fixing steel plates to both the sides of the door.

iv Wire-glass panels are preferred for windows.

v Rolling shutter doors should be used for garages, go downs, shops etc.

vi In case of timber doors, minimum thickness of door leaf should be 4 cm. And that of door frame as 8 to 10 cm.

vii All escape doors should be such as to provide free circulation to the persons in passages, lobbies, corridors, stairs etc., and should be made of fire proofing material.

4 Escape elements

i All escape elements, such as stair cases, corridors, lobbies, entrances etc. Should be constructed of fire resistant materials.

ii These escape elements should be well separated from the rest of the building.

iii Doors to these escapes should be fire proof.

iv Staircases should be located next to the outer wall and should be accessible from any floor in the direction of flow towards the exits from the building.

v Five proof doors to the emergency stair cases should be fixed in such a way as to make them close from inside only.

vi The lift shafts connecting various floors should be surrounded with the enclosure walls of fire-resisting materials.

vii Lift shafts should be vented from top to permit escape of smoke and hot gases.

viii An emergency ladder should be provided in the fire resisting building. This ladder should be at least 90 cm wide, constructed of fire-resistant materials.

ix All escape routes over roofs should be protected with railings, balustrades or parapets not less than one metre in height.

5 Strong room construction

A strong room construction is found to be useful in case of safe deposit vaults in banks. Following are the important features of construction:

i The walls, floors and ceilings of a strong room are made of at least 30cm thick cement concrete. If thin R.C.C. walls are used, they should be have covering of bricks or terra-cotta and then suitably plastered with fire-resistant plaster.

ii Doors and windows are well anchored to concrete walls by large number of steel hold fasteners longer in length.

iii Doors and windows should be fire-proof. It is preferable to have double fire-proof door.

iv Windows and ventilators should be covered by special grills made of 20 mm steel square bars. These grills should be well fixed to concrete walls by means of long steel hold fasteners.

Fire alarms: Fire alarms are installed to give an alarm and to call for assistance in event of fire. The fire alarms give enough time to the occupants to reach to a safe place.

Fire alarms can be either manual or automatic

1 Manual alarms

These are of a hand-bell type or similar other sounding device, which can emit distinctive sound when struck. These are sounded by watchmen and the occupants are there by warned to have safe exit in shortest possible time. Manually operated alarms shall be provided near all main exits and in the natural path of escape from fire, at readily accessible points which are not likely to be obstructed.

2 Automatic alarms

These alarms start sounding automatically in the event of fire. It is used in large industrial buildings which may remain unoccupied during night. The automatic fire alarm sends alarm to the nearest control point. The system can also perform the function of sending message to the nearest fire brigade station.

Fire extinguishing equipments: Each building should have suitable fire extinguishing arrangements, depending upon the importance of the building and the associated fire hazards. Following are usual equipments required for fire extinction.

Manual fire extinguishing equipment: These devices are useful for extinguishing fire as soon as it starts. They are not so useful when once the fire has spread. Under this category comes the portable extinguishers of carbon - dioxide type or foam generation type etc. The discharge from a portable fire extinguisher lasts only for a short duration of 20 to 120 seconds. In some cases, especially in small buildings buckets of water, sand and asbestos blanket may be kept ready at all times to extinguish fire. These buckets are installed at convenient locations for taking care of fire of minor size.

Fire hydrants: These fire hydrants are provided on a ring main of 150 mm dia. In the ground around the building periphery. The ring main gets water from underground tank with pressure, so that available pressure at each hydrant is of the order of about 3.5 to 4 kg/cm2.

Wet riser system: The system consists of providing 100 to 150 mm dia. Vertical G.I pipes (risers) at suitable locations in the building. A fire pump is used to feed water from underground tank to these pipes, to ensure a pressure of 3 kg/cm2 at uppermost out let.

Automatic Sprinkler system: This arrangement is adopted for important structures like textile mills, paper mills etc. The system consists of a network of pipes 20 mm dia. Fixed to the ceiling of the room. These pipes are spaced at 3m centre to centre. Heat actuated sprinkler heads are fixed to these pipes at regular interval. The pipes get supply from a header. Each sprinkler head is provided with fusible plug. In the event of fire, the fusible plug in the sprinkler nearest to the wire melts due to rise of temperature, and water gushes out of the sprinkler head. The fire is thus brought under control in a short period.

Requirement of green belt and land

Objectives: At the end of this lesson you shall be able to
- **describe green belt land and its purposes**
- **explain environmental law for green belts developments.**

What is Green Belt Land and its purpose: Green belt land refers to an area that is kept in reserve for an open space, most often around larger cities. The main purpose of the green belt policy is to protect the land around larger urban centers from urban sprawl, and maintain the designated area for forestry and agriculture as well as to provide habitat to wildlife.

Green belt offers a number of benefits for both urban and rural population. By preventing the urban sprawl, it helps protect agricultural activities and the unique character of rural communities, urban population, on the other hand, is provided an access to an open space which offers opportunities for outdoor activities and an access to clean air.

Areas that are designated as green belt must not be built upon because green belt is defined as an open space, however, that does not mean that no buildings can be erected in green belt. Buildings for agricultural uses and sanitation facilities, for instance, are usually allowed. In some cases, it is also possible to change the use of land in green belt and even gain permission for structures that are officially not allowed in green belt. However, such cases are very rare and the local authorities grant permission only if no suitable site for the building can be found in the urban centre or outside the green belt and there is an accessible business electricity source.

Are there any regulations or environmental law for green belts development in India?: Environmental protection has been considered as an important domain for industrial and other developmental activities in India. Ministry of Environment & Forests (MOEF) has taken several policy initiatives and promoted integration of environmental concerns in developmental projects. One such promoted integration of environmental impact Assessment (EIA) of developmental projects issued in 1994 and further revised notification in year 2006 under the provisions of Environment (protection) Act., 1986. EIA notifications from here. EIA guidance manual for building. Construction, townships and area development projects proactively talks about the importance of green belts in such projects. Environmental guidelines for Industries developed by MOEF, suggest that the industries must care about the surrounding environment and minimize the adverse impacts of industrial operations in the immediate neighborhood as well as distant places. Therefore, these guidelines mandate project owners to maintain the certain distances by the industries from the areas like ecologically sensitive areas, costal areas, flood plain of the Riverside systems, transport/communication system and major settlements,

In addition, these guidelines also mandate that economic and social factors have to be recognized and assessed while cutting industry. Following are the key points that all industries need to follow while moving ahead with the establishment of manufacturing/processing unit in certain areas. These are.

1 No forest land shall be converted into non-forest activity for the sustenance of the industry (reference, forest conservation act, 1980)

2 No prime agricultural and shall be converted into industrial site.

3 Within the acquired site the industry must locate itself at the lowest location to remain obscured from general sight.

4 Land acquired shall be sufficiently large to provide space for appropriate treatment of waste water still left for treatment after maximum possible reuse and recycle. Reclaimed (treated) wastewater shall be used to raise green belt and to create waster body for aesthetics, recreation and if possible for aquaculture. The green belt shall be ½ km Wide around the battery limit of the industry. For industry having odour problem it shall be a kilometer wide.

5 The green belt between two adjoining large scale industries shall be one kilometer.

6 Enough space should be provided for storage of solid wastes so that these could be available for possible reuse.

7 Lay out and form of the industry that may come up in the area must conform to the landscape of the area without affecting to scenic features of that place.

8 Associated township of the industry must be created at a space having physiographic barrier between the industry and the township.

9 Each industry is required to maintain three ambient air quality measuring stations within 120 degree angle between stations.

Environment Management plan (EMP) prepared by MOEF mandates that community buildings and townships should build 1-1.5 kilometer of green belt. This is suggested to restrict air and noise pollution in the vicinity.

As per the National forest policy, 1988 (NFP), It is necessary to encourage the planting of trees alongside of roads railway lines, rivers and streams and canals, and on other unutilized lands under state/corporate, institutional or private ownership. NFP give emphasis on the green belt development. It says - green belts should be raised in urban/industrial areas as well as in arid tracts. Such a programmed will help to check erosion and desertification as well as improve the microclimate (reference).

As per the stipulations of MOEF, green belt is to be provided all around the power station boundary by planting trees and the total green area including landscaping area will be 1/3 (about 33%) of the plant area. This will include Lay down area which will be later on converted into green area. (Report on the land requirement of thermal power stations by CEA)

In India, there is no exclusive green belt regulation/policy. However, under the purview of other regulations such as Environmental Guidelines for Industries, Environment Management plan, National Forest policy, Forest Conservation Act, etc, certain percentage of land designated for green belts is recommended for deferent categories of industrial projects. Expansion of agricultural, urban and industrial activities are causing additional burden on natural resources. Industrial development is causing severe health hazards due the exceeded level of pollution. Green belt not restrict environmental pollution but it helps to maintain the ecological balance of the region.

Introduction of CAD

Objectives: At the end of this lesson you shall be able to
- **define the computer and CAD**
- **describe history of computer.**

Introduction: Computer are increase singly of a becoming a part of everyday life computers calculates our electricity and telephone bill find its useful applications in the field up medicine and medication assists various business organization system to keep their accounts and other basic jobs up to date its also provides the facility of plying games and surfing over the internet so as to gain to information on different filed into days time.

Definition: Computer are an electronic devices which are used to perform arithmetic and logic operation at a very high speed. The application of computers in different fields and areas is successful and economically justified.

A brief history of computers and software: The first computers were developed in the 1950s, shortly after the transistor was invented. In the mid 1960 s general Motors, Boeing and IBM began developing CAD programs, but the development was slowed by the high cost of computer hardware and programming.

In 1971, Ted Hoff developed the first microprocessor. All circuitry of the central processing unit (CPU) was now on one chip. This started the era of the personal computer (PC). In the 1980s, additional improvements to the microprocessor changed the mainframe computers to powerful desktop models.

Of course, computer software was advancing along with the computer hardware. CAD started as a simple drafting tool and has now evolved into a powerful design tool. CAD has progressed from two-dimensional (2-D) to three dimensional (3-D), to surface modelling and to solid modelling with animation. Each generation has become more powerful and more user friendly.

AutoCAD: AutoCAD is the leading computer-aided design and drafting (CAD) program in the world. Since its original introduction in November, 1982, AutoCAD has grown in sales and functionality to become the standard PC-based CAD program against which all other similar programs complete and against which they are judged. Over the years, AutoCAD has kept pace with developments in the computer industry. The program has grown from its original command line driven DOS-based roots to become a fully compatible windows application.

Enlarging or reducing diagrams: CADD allows you to enlarge or reduce diagrams in a convenient manner. To enlarge or reduce diagrams, you need to select the objects and enter a scale factor. The scale factor determines by how much the diagrams are to be reduced or enlarged. (illustrated with fig. In CAD PRIMER)

Mainframe computers have a lot of data processing power and their size is quite big. A single mainframe computer performs all the data processing and is accessed via terminals connected to it. Minicomputers are smaller versions of mainframe computers. Microcomputers (PCs0 are the desktop or laptop computers of today and are used for individual computing needs.

There are two main categories of computer software:

- **System software**
- **Application program**

The system software manages the internal operations of the computer. The application programs are tools that help you accomplish your work, such as CADD. (This topic is further described in CADD PRIMER)

CAD hardware: The following are the main hardware components of CAD

- System unit
  - Central processing unit.
  - Memory.
  - Hard disk, CD-ROM pen drive.
- External storage devices.
- Monitor.
- Printers and plotters.
- Keyboard.
- Digitizer, puck and mouse.

System unit: The system unit is the computer that is used for all data processing. The main components of the system units are the central processing unit (CPU) and memory. In mainframe and minicomputers CPU and memory are usefully separate compartments that house thousands of devices. In today's PCs, however, they all fit in a small box commonly known as a desktop computer. Most desktop computers today come equipped with a hard disk, and CD-ROM. Let us have a look at the components of a system unit:

- Central processing unit.
- Memory.
- Hard disk, CD-ROM.

External storage devices: There are a number of external storage devices available such as magnetic tapes, zip drives and removable hard disks. They are commonly used to keep backup copies of electronic files for safekeeping.

Magnetic tapes are quite common for storing large volumes of data. A magnetic tape that looks like a small videocassette can store thousands of megabytes of data. However, they are quite slow and require a lot of time to store or retrieve data.

The new option for data storage is the removable hard disk. You can remove the entire hard disk from your computer and use it on another computer. This approach is commonly used when you need to work on different computers and you want the same information to be available instantly.

Computer Aided Design (CAD): Is simply, design and drafting with the aid of a computer. Design is creating a real product from an idea. Drafting is the production of the drawings that are used to document a design. CAD can be used to create 2D or 3D computer models. A CAD drawing is a file that consists of numeric data in binary form that will be saved onto a disk.

Why should you use CAD?: Traditional drafting is repetitious and can be inaccurate. It may be faster to create a simple "rough" sketch by hand but larger more complex drawings with repetitive operations are drawn more efficiently using CAD.

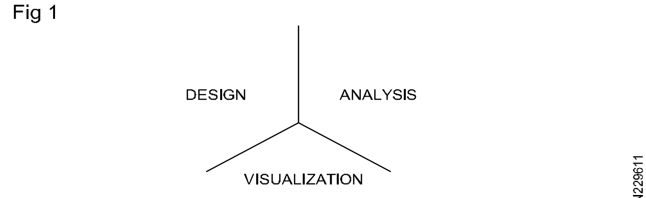
Why use AutoCAD?: AutoCAD is a computer aided design software developed by Autodesk Inc. AutoCAD was first introduced in 1982. By the year 2000,it is estimated that there were over 4 million AutoCAD users worldwide.

What this means to you is that many employers are in need of AutoCAD operators. In addition, learning AutoCAD will give you the basics for learning other CAD packages because many commands, terms and concepts are used universally.

Learning to use a CAD system is similar to learning a new language. It is necessary to begin with the basic alphabet and learn how to use it correctly and effectively through practice. This will require learning some new concepts and skills as well as learning a different vocabulary. Today, the majority of the Mechanical CAD systems are capable of creating three-dimensional solid models. Nonetheless, all CAD systems create designs using basic geometric entities and many of the constructions used in technical designs are based upon two-dimensional planar geometry. The method and number of operations that are required to accomplish the basic planar constructions are different from one system to another.

In general, a Computer Aided Design (CAD) package has three components: a) Design, b) Analysis, and c) Visualization, as shown in the sketch. A brief description of these components are follows as Fig 1

Fig 1



COMPONENTS OF COMPUTER AIDED DESIGN

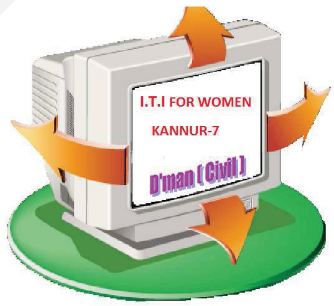
Hardware and Software overview: There are two parts of a computer system, hardware and software, and a CADD system in no exception. Computer hardware is the physical components of the computer such as system unit, monitor and plotter. Computer software is the program that determines the application of a system.

There are three main categories of computers with respect to hardware:

- Mainframe.
- Minicomputer.
- Microcomputers, for example personal computers (PCs).

The monitor (Fig 2): The monitor sis the computer screen and is used to display information. A good monitor is very important for CADD in order to display fine graphics. A colour monitor is essential because many CADD drawing techniques are based on colours. Monitors are available in various sizes ranging from 13" to 30" or more. Today, average monitors have the ability to display millions of colours.

Fig 2



The main factor that determines the quality of a monitor is the resolution. The term resolution refers to sharpness of an image displayed on the screen. Resolution is measured by the number of picture elements (pixels) that a screen can display. The more pixels and the closer they are the sharper the image. The distance between pixels is called the "dot-pitch". The smaller the dot-pitch, the sharper the image. A 26 or smaller dot-pitch monitor is recommended for CADD applications.

Printers and plotters (Fig 3): CADD drawings are printed using fine-quality printers and plotters. Drawings are neat and clean and as accurate as the naked eye can see. You can print drawings at as much as 1200-dpi (dots per inch) accuracy. This means 1200 dots are printed in a non-inch-long line! All the text dimensions and other graphics are printed highly accurate, neat and crisp. You can print drawings with a lot of variations; for example, drawings can be printed with different sizes, line types, text fonts and colours.

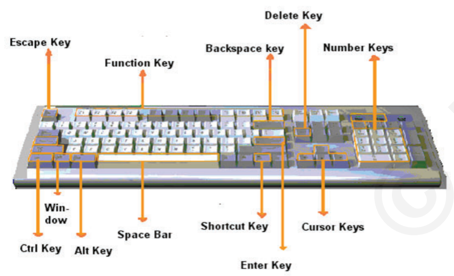
There are a variety of printers and plotters available in the computer industry. They work on different principles and their prices very significantly. There are many types of pen plotters, ink-jet printers, laser printers and plotters, electrostatic printers, etc.

Fig 3

Printer

Key board (Fig 4): Key board: This is an input devices. Which contains keys to feed information in to the computer.

Fig 4



Key Board

Type writer key: Used for letters, numbers and punctuation symbol.

Function Keys: F1 to F12 performs depend on the software use.

Cursor control keys: To move the cursor to the left, right, up, or down.

Page up and down key: To move the preceding page and to move the text page.

Home key: To the top of the Document.

End key: To end of the Document.

Num lock key: Numeric 0-9, pressing any of them, a number gets displayed on the screen.

Caps lock key: By pressing, type letters will appear in the small or capital.

Shift key: To appear the upper symbol, if hold down this key.

Ctrl & Alt key: Often used in combination with other keys to carry out special actions. By pressing Ctrl, Alt 7 delete keys simultaneously, the machine automatically restart.

Enter key: In alert PC that finish given instruction to execute the Instructions.

Tab key: Move the cursor along the line to a preset point and also to move from one option to another in a menu.

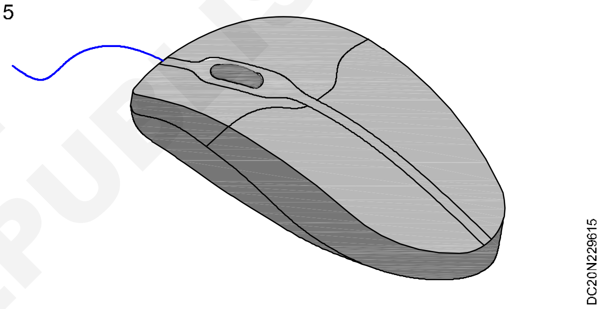
ESC key: To cancel or to ignore the entry or command that just Entered.

Delete key: Erase the character to the place to the right side of the Blinking cursor.

Back space key: Erase the character to the left side of the blinking curser, also it moves the cursor back.

Digitizer, puck and mouse (Fig 5): The digitizer (also known as a graphic tablet) and the puck are the data input devices most commonly used in CADD systems. These devices allow you to enter point locations on the screen and to make selections from the menus. As the puck is moved over the surface of the digitizer, it moves the indicator (cursor) on the screen relatively. To enter a point, you need to position the cursor at the appropriate position on the screen and then press the "Enter" button on the puck.

Fig 5



Digitizers are available in many sizes and styles. A number of commands are printed on the digitizer surface. To enter a command, place the puck over the desired command and press the "Enter" button. The selected command is instantly entered. The puck buttons are configured to perform many other tasks. For example, one button is used to make selections, another to enter the data, another to return to the previous menu and another to cancel the last command.

A mouse is another pointing device that can be used with CADD. Like the puck, the mouse allows you to control the position of the cursor on the screen by rolling it across a flat surface, but it does not require a digitizer. Some programs support working with a mouse only, while others support both the mouse and the digitizer. A mouse is much cheaper than a digitizer or puck, but provides only limited data entry options.

CADD software: A CADD program contains hundreds of functions that enable you to accomplish specific drawing tasks. A task may involve drawing an object, editing and existing drawing, displaying a view of the drawing, printing or saving it, or controlling any other operation of the computer. The functions contain a number of commands that enable you to specify exactly what you want to do and how you want to do it.

The functions are organized into modules that provide easy access to all the commands. The program is divided into modules such as draw, edit, data output, function control, data storage and management. A program may also have a number of specialized functions such as layers, database and 3D. Let s have a look at the CADD modules.

- Draw.
- Edit.
- Data output.
- System control.
- Data storage and management.
- Special features.

Draw: The draw module provides access to all the drawing functions of CADD. Whenever you need to draw something this group of functions is used. The draw module enables you to draw lines, arcs, circles, ellipses, text, dimensions, symbols, borders and many other drawing components.

Draw is CADD s most frequently used module because all drawing work is accomplished using it.

Edit: The edit module lets you change existing drawing elements and manipulate them in a number of ways. You can move, copy or erase drawing components. You can enlarge or reduce the sizes of diagrams or change the colour and line type of drawing components. You can also change the size and style of text and dimensions, as well as edit a dimension to show different units of measurement. A good CADD program is designed to change the appearance of all drawing elements created with CADD.

The edit functions also act as convenient drawing-aid tools. They enable you to join missing corners of lines, trim drawing components along a line, stretch them to fit a new shape, etc. The list of editing capabilities goes on and on. The edit functions make CADD a dynamic drawing tool.

Data output: The data output module enables you to display drawings on the screen and then print them on paper. There are two separate sets of functions that help accomplish this:

- **View-display functions.**
- **Print/plot functions.**

The view-display functions allow you to display different views of a drawing on the screen. These functions are used quite often, because every time you need to draw something or edit something, you need to focus on that portion of the drawing. With the help of view-display functions, you can zoom in on a specific portion of the drawing.

The print and plot functions allow you to print drawings using a printer or a plotter. You can control many aspects of printing and plotting. You can print the same drawing in different sizes by applying the appropriate scale factor. You can plot the drawings with specific colours, pen thickness, and line types.

Data storage and management: The data storage and management module allows you to store and manage drawing data. Through the use of the functions in this module, you can store drawings as files on the hard disk. You can manage the files in directories and sub-directories, and move, copy or delete them as needed.

CADD data management functions also let you translate drawings created by other CADD programs. These functions convert drawing data to a generic format that can be read by any CADD program. Data exchange format (DXF) is one of the common data translation formats used by CADD program. There are a number of data exchange formats available.

System control: The system control module (also known as system defaults) allows you to control how CADD works. CADD programs are designed for a broad range of professionals, including architects, designers, engineers and surveyors. With the help of system control functions, you can set the working environment of CADD to suit your needs.

Example: You can set the type of units that you will be using, the accuracy of the units, a style for dimensions and text, colours, layers, line type in a drawing, etc. Additionally, you can customize screen menus, the display of colours on the screen, resolution of the screen, size, the speed of the cursor, etc.

You can also specify whether the selected defaults should apply to a single drawing, to a specific project, or to all the projects in a specific category. The defaults can be set on a temporary or permanent basis.

Special features: CADD programs usually offer a number of special features that make working with CADD easier and allow you to automate many drawing tasks. For example, you can create layers in a drawing that allow you to segregate drawing components. You can develop spreadsheets and databases that can be used to create many types of project reports. You can create three-dimensional (3D) drawings, such as isometrics and perspectives, with the help of 3D functions. You can also accomplish many other automated tasks with the help of macros.

The number of special features a CADD program has or how elaborate they are various from one program to another. Some vendors sell specialized features as separate packages, while others include them in a single package. It all depends how a program is written, how big or small it is, and how it is sold.

CADD user interface: CADD user interface provides the environment and the tools that allow you and the computer to communicate. Each CADD program establishes an environment that best suits its purpose. The goal is to make working with CADD efficient. Most programs use a Graphic User Interface (GUI) to communicate with the user. The GUI provides visual aids for quick data entry. You are given tools to select functions, enter textual or mathematical data, locate points in the drawing window, select objects in the drawing window, etc.

Graphical user interface (GUI)

Objectives: At the end of this lesson you shall be able to
- **describe graphical interface of auto cad**
- **explain key board function keys.**

Introduction

Note that AutoCAD automatically assigns generic name, Drawing X, as new drawings are created. In our example, Auto CAD opened the graphics window using the default system units and assigned the drawing name Drawing1.

Graphical user interface (GUI) OF Auto CAD (Figs 1,2, 3)

Fig 1

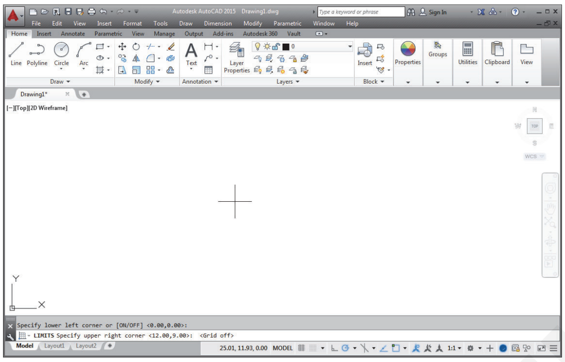


Fig 2

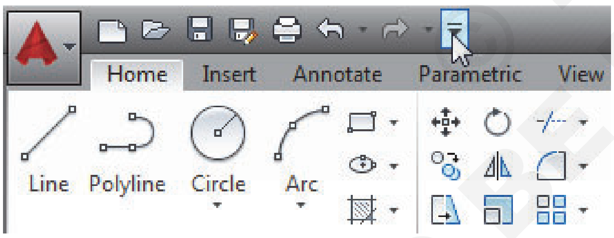


Fig 3

Quick access toolbar (Fig 4)

1 Click on one of the following icons for quick access to commands QNEW, OPEN, SAVE, PLOT, and UNDO/ REDO.

Fig 4

Right-click the quick toolbar and click customize quick access toolbar. The customize user interface dialog opens and displays the list of commands available.

Drag commands you want to add from the command list pane in the customize user interface dialog box to the quick access toolbar.

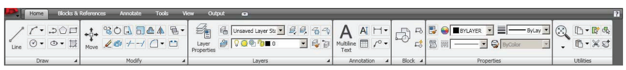
Info center

Quickly search for a variety of information sources, access product updates and announcements, and save topics with info center.

Ribbon (Fig 5)

The ribbon provides a single, compact placement for operations that are relevant to the current workspace. It eliminates the need to display multiple toolbars, reducing clutter in the application window. The ribbon maximizes the area available for work using a single compact interface.

Fig 5



The ribbon can be displayed horizontally, vertically, or as a floating palette. The horizontal ribbon is displayed at the top of the drawing window by default when you create or open a drawing.

You can create your own panels to display on the ribbon; you can also modify the commands and controls on existing ribbon panels.

1.5 Menus and colours.

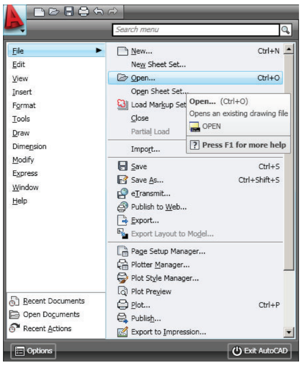
Menu browser (Fig 6)

1 Click on the a icon in the upper left corner of the drawing area.

2 Click the desired pull down menu.

3 Click on the command to be executed from the pulldown.

Fig 6



Workspaces (Fig 7)

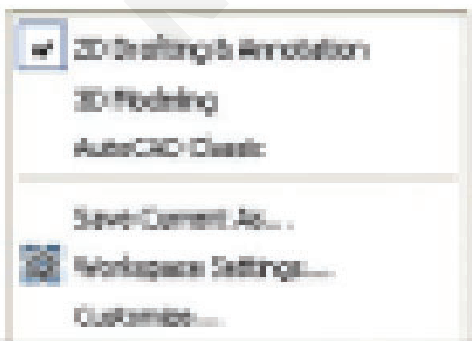
You can switch between the workspaces from the menu browser.

1 Click the workspace switching icon in the lower left corner of the screen.

Fig 7

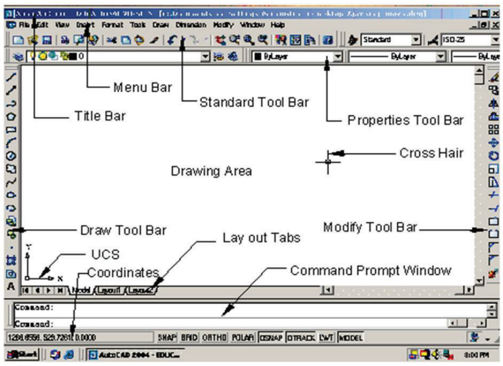
2 Click on one of the following workspace options. (Fig 8)

Fig 8



Auto CAD classic workspace (Fig 9)

Fig 9



Title bar: This shows the name of drawing which is currently used.

Menu bar: This menu bar help us quicker way to access the general controls and setting for AutoCAD. The main commands and functions are available in this menu bar it has the following facilities.

1 It gives a command that requires key board or drawing input.

2 It displays additional menus choice with > symbol, in this menu called cascading menus.

3 It displays a dialogue box that contains settings which have changing options.

Standard tool bar: This tool bar contains the standard functions of commands which is used for getting information's and modifications.

Properties tool bar: This tool bar have the properties of the entity such as thickness of line, colour, layer type of line etc. We can change the properties of the entity by using this tool bar.

Draw tool bar: This tool bar contains the group of drawing commands such as line, arc, circle etc.

Modify tool bar: This tool bars are used to do the modifications in the entities such as erase, trim etc.

Draw area: This is a black space to draw the drawings. This area has formed as grids, we can increase or decrease the area by using boundary limit command.

UCS: UCS (user coordinate system is an indication to the use of for which plane the drawing is drawn. We can change any plane according to our wish to draw the drawing in views.

Command prompt window: This window is used to give commands by typing in key board.

Cross hair: This is the pointer used to draw, select and to locate.

Layout tabs: These tabs are used to select the particular lay out of the drawing.

Function tabs: Below the command prompt window drawing function tabs are available. These tabs show us the position of grid, other, o snap etc. The functional keys are used for effective function of the drawing.

Key board function keys

There are some function keys in the keyboard for quick access to certain commands. These keys are pressed for the following purposes.

Key	Function defined
F1	Online help.
F2	Toggles between command window on and off.
F3	Toggles between OSNAP on and off.
F4	Toggles between Tablet on and off.
F5	Switches among isoplanes top, right and left.
F6	Toggles between coordinates on and off.
F7	Toggles between grid on and off.
F8	Toggles between ortho mode on and off.
F9	Toggles between snap mode on and off.
F10	Toggles between polar tracking on and off.
F11	Toggles between objects snap tracking on and off.
F12	Save as.

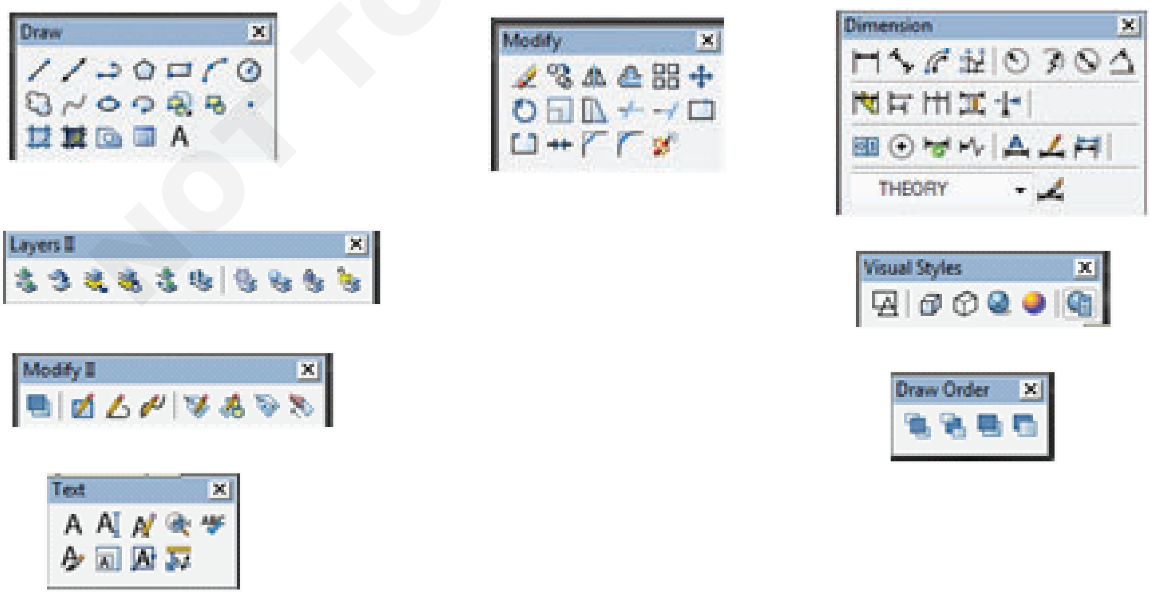
You can disable the group selection quickly by pressing FUNCTION KEYS (Ctrl + Key) combination to quickly toggle some of the modes and invoke some of the commands.

Function keys used in Auto CAD

Key strokes	Function defined
Ctrl+Z	Undo
Ctrl+C	Copy clip
Ctrl+E	Osoplane top/right /left
Ctrl+G	Grid on/off
Ctrl+L	Ortho on/off
Ctrl+O	OPEN command
Ctrl+S	QSAVE command
Ctrl+U	Polar tracking on/off
Ctrl+W	Object snap tracking on/off
Ctrl+Y	Redo
Ctrl+2	ADCENTER command
Ctrl+F6	Switch between open drawings
Ctrl+B	Snap on/off
Ctrl+D	Coordinate display on/off
Ctrl+F	Osnap setting dialog box
Ctrl+K	HYPERLINK command
Ctrl+N	NEW command
Ctrl+P	PRINT command
Ctrl+T	Tablet on/off
Ctrl+V	Paste
Ctrl+X	Delete
Ctrl+1	Object properties window on/off
Ctrl+6	DBCONNECT command
Ctrl + Tab	Switch between open Drawings.

The functionality of these Ctrl + Key combination depends on the settings done on the User Preferences tab on the option dialog box. (Fig 10)

Fig 10



Example:

That is to say Ctrl+ C works for COPYCLIP command, if the check box is cleared, Ctrl + C works for the CANCEL command.

Text edit keys

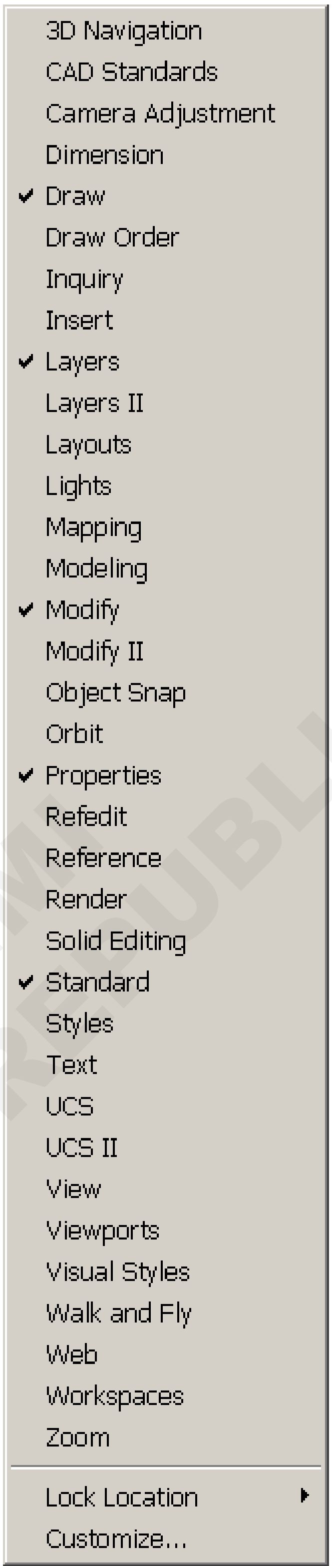
The following accelerator keys, which are effective within the Multilane Text Editor, dialog box.

Key strokes	Function defined
Ctrl+A	Select all text in the multiline text editor.
Ctrl+B	Applies or removes bold format for selected text.
Ctrl+C	Copies selected text to the clip board.
Ctrl+1	Applies or removes italic format for selected text.
Ctrl+Shift+L	Converts selected text to lower case.
Ctrl+Shift+U	Converts selected text to upper case.
Ctrl+U	Applies or removes underline format for selected text
Ctrl+V	Pastes Clipboard contents to cursor location
Ctrl+X	Cuts selected text to the clipboard
Ctrl+SPACE	Removes character formatting in selected text.

Loading toolbars.

Right- clicking on an icon in any toolbar.

This will show a list of all available toolbars.



Method of installation

Objectives: At the end of this lesson you shall be able to
- **introduction of CAD installation**
- **system requirements serial number and production.**

Introduction of CAD Installation

Auto CAD installation provides information, have to prepare and then how to install. If the product is never installed before, one should familiarize with the installation process. It should be done before installing and in beginning. Before installing one should aware of the minimum requirements to install and run the product.

System requirements: To should be reviewed about the system requirements administration permission locating serial number and product key closing all numbering applications completing the dead tasks and now it is ready for installing auto cad. Before installing auto cad that make sure the computer needs the minimum hardware and software.

Serial number and product key.

Whatever auto cad install, which is prompter for the per sons serial number and the product key in the product. And the user information page. This can be done by installing the product in trial mode. The serial number and the product key are located on the outside of the product packing or in the auto desk. The serial is consists of in three digit pre fix followed by the product key consists of fine characters.

The information entered is permanently retained with the product. This information cannot changed later without uninstalling . To review this product information later and the mars menu bar click auto cad about auto cad. In the about dialog box, click product, information.

The Auto CAD installation wizard contains all installation related material in one place from the installation wizard one can select installation register product and customize the install.

Basic Commands - I

Objectives: At the end of this lesson you shall be able to
- **circle arch**
- **ellipse polygon.**

Introduction

AutoCAD allows you to have across to a large number of commands, a general rule is that you use 20% of the commands 80% of the time. I will start by introducing you to the most common drawing commands. When you combine these with the basic modify commands, you will be able to make elaborate drawings quite quickly. In other words, most of the commands you will use while using Auto cad are taught in level1.

The important thing to remember is that AutoCAD will expect you give it information in a very particular order. The most frustrating thing when you begin using this program is that you will try to do something, but auto cad will not work. In most cases, it means that you are trying to input information at the wrong time. This is why it is very important to be in the habit of looking at the command line.

Circles

Circle command (Fig 1,2, & 3)

1	Choose	Draw, circle.
		(or)
2	Click	The Circle icon.
		(or)
3	Type	Circle at the command prompt.
4	Type	One of the following options:
		3P/2P/TTR/<<center point>>:
		(or)
5	Pick	A center point
6	Type	A radius or diameter.
		(or)
7	Pick	A radius or diameter
		Diameter/<<radius>>:

TIPS

- To create circles that are the same size, press ENTER when asked for the circle radius.
- When selecting a circle with a pick box, be sure to select the circumference of the circle.

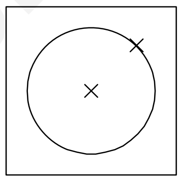
The command line tells you what information AutoCAD requires to continue.

Your first drawing alignment will be to use the drawing commands in conjunction with the co-ordinate system it is very important to understand how to give the program accurate information. You will use the following commands.

Drawing arcs and circles.

CADD provides many ways to draw arcs and circles. There are a number of advanced techniques available for drawing arcs and circles, which can simplify many geometrical drawing problems. You can draw an arc by specifying circumference and radius, radius and rotation angle, chord length and radius, etc.

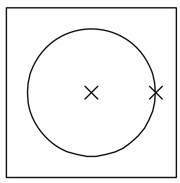
Fig 1



CIRCLE COMMAND

DC20N2210011

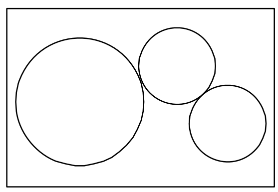
Fig 2



CIRCLE COMMAND

DC20N2210012

Fig 3



CIRCLE COMMAND

DC20N2210013

Arc command (Fig 4)

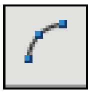
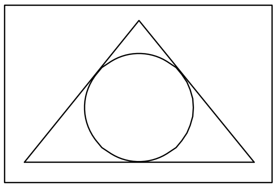
1	Choose	Draw, arc.
		(or)
2	Click	The Arc icon. 
		(or)
3	Type	Arc at the command prompt command: ARC
4	Draw	One of the arcs.

Fig 4



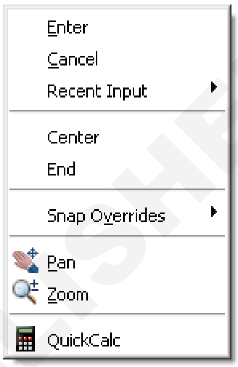
CIRCLE COMMAND

DC20N2210014

TIPS (Fig 5)

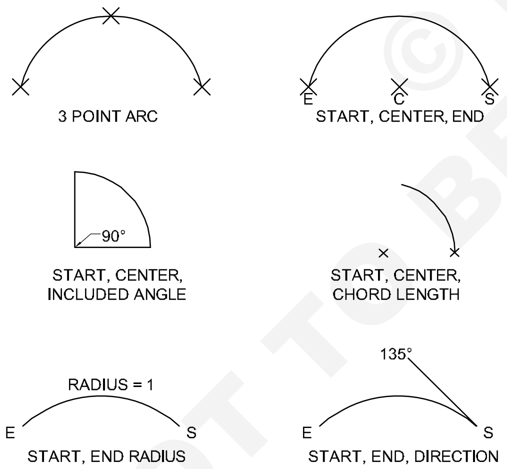
- Except for 3 point arcs, arcs are drawn in a counter clock wise direction.
- While in the arc command, press the right mouse button to select the following options for arcs:

Fig 5



Arc examples (Fig 6)

Fig 6



ARC COMMAND

DC20N2210016

3 point arc

Start, centre, chord length

Start, centre, end

Start, end, radius

Start, centre, included angle

Start, end direction

Drawing ellipses and elliptical arcs

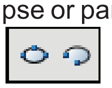
Ellipses are much easier to draw with CADD than on a drawing board. On a drawing board, you need to find the right size template or draw a series of arcs individually to draw an ellipse. With CADD, all you need to do is specify the size of the ellipse.

The following are two basic methods for drawing ellipses:

- Length and width.
- Axis and rotation angle.

Ellipse.

Creates an ellipse or an elliptical arc:

1	**Choose**	Draw, Ellipse.
		(or)
2	**Choose**	The ellipse or partial ellipse icon
		(or) 
3	**Type**	Ellipse at the command prompt Command: ellipse
4	**Type**	One of the following options:

Arc/Center/Isocircle/<Axis endpoint1>:

Ellipse options

Axis endpoint 1: Defines the first axis by two specified endpoints. The angle of the first axis determines the angle of the ellipse. The first axis can define either the major or the minor axis of the ellipse.

Ellipses options

Axis end point 2: <Other axis distance>/Rotation: Specify a point or enter a distance

Arc: Creates an elliptical arc. The angle of the first axis determines the angle of the elliptical arc. The first axis can define either the major or the minor axis of the elliptical arc.

Center : Creates the ellipse by a specified center point.

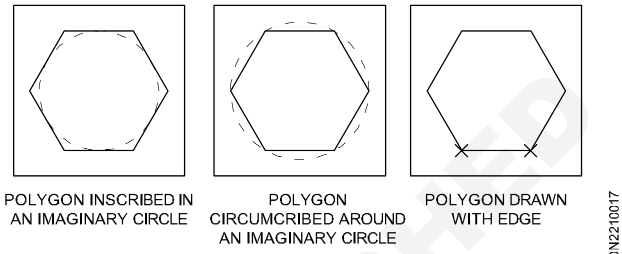
Isocircle : Creates an isometric circle in the current isometric drawing plane.

Rotation : The major axis is now treated as the diameter of a circle that will be rotated a specified amount around the axis. You enter an angle between 0 and 89.4 degrees.

Polygon (Fig 7)

1	Choose	Draw, polygon.
		(or)
2	Click	The polygon icon.
		(or)
3	Type	Polygon at the command prompt.
4	Type	The number of sides for the polygon (3-1024).
5	Pick	The center of the polygon. Edge/ <Center of polygon>: pick.
		(or)
6	Type	E to define the polygon by two edges.
		(or)
7	Type	I or C to place the polygon in side or outside of an imaginary circle. Inscribed in circle/ circum scribed about circle (I/C)

Fig 7



POLYGON COMMAND

Basic commands - II

Objective: At the end of this lesson you shall be able to
- **express move, copy, offset, rotate, trim, on, fillet, array, straiten, lengthen.**

The previous lesson dealt with drawing commands. This lesson will introduce some common modifying commands. In AutoCAD, you may actually use modifying commands more often than drawing commands. Now that you know the basics, here's some more commands to add to your collection. Three commands, Trim, Extend and Offset are used often in 2D AutoCAD work.

Command	Keystroke	Location	Result
Rectangle	RECTANGLE/REC	Home>Draw>Rectangle	Draws a rectangle after you enter one corner and then the second.
Trim	TRIM/TR	Home>Modify>Trim	Trims objects to a selected cutting edge.
Exlend	EXTEND/EX	Home>Modify>Extend	Extends objects to a selected boundary edge.
Offset	OFFSET/O	Home>Modify>Offset	Offsets an object (parallel) by a set distance.
Object snaps	OSNAP/OS/F3	Tools>Object Snap Settings	Brings up the OSNAP dialog box.
Move	Move/M	Home>Modify>Move	Moves an object or objects.

Command	Keystroke	Location	Result
Copy	Copy/CP	Home>Modify>Copy	Copies object(s) once or multiple times.
Stretch	Stretch/S	Home>Modify>Stretch	Stretches an object after you have selected a portion of it.
Mirror	Mirror/MI	Home>Modify>Mirror	Creates a mirror image of an object or se lection set.
Rotate	Rotate/RO	Home>Modify>Rotate	Rotates objects to a certain angle.
Fillet	Fillet/F	Home>Modify>Fillet	Creates a round corner between two lines.
Chamfer	Chamfer/CHA	Home>Modify>Chamfer	Creates an angled corner between two lines.
Array	Array/AR	Home>Modify>Array	Creates a repeating pattern of the selected objects.

Move command (Fig 1 & 2)

1	Choose	Modify, Move. Or
2	Click	The Move icon or
3	Type	Move at the command prompt command: MOVE or M
4	Pick	Objects to move select objects (select)
5	Pick	A point to move from base point of displacement: (Pick point)
6	Pick	A point to move to second point of displacement: (pick point)

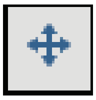


Fig 1

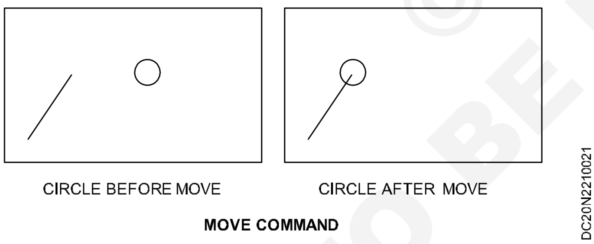
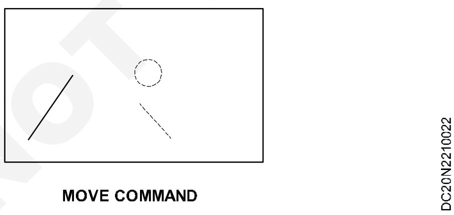


Fig 2



TIP

To move an object a specified distance, type a distance at the second point of displacement prompt:@1<0

Moving drawing objects

CADD allows you to move drawing objects within a drawing in a convenient manner. Unlike on a drawing board, you don't need to first erase and then redraw in a new place. You can simply rearrange the existing drawing objects, as you like. This is a very useful tool for analyzing design alternatives and making quick adjustments to drawings.

Previous selection

Places selected objects in the previous selection set

1	Choose	Modify, move.
		(or)
2	Click	The move icon.
		(or
3	Type	Move at the command prompt. Command: Move or M
4	Pick	Objects to move. Select objects : (P)

Previous selection set highlighted

TIP

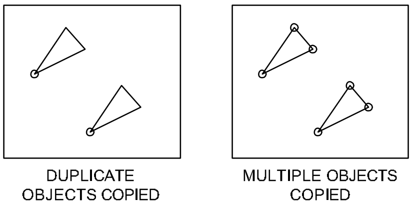
AutoCAD requires that objects be selected in order to be processed. The Select Objects prompt occurs after many commands, including the SELECT command itself.

Copying drawing objects (Fig 3)

CADD allows you to make quick and easy copies of existing drawing objects. You can copy individual drawing objects or the entire drawing all at once. You can even make multiple copies of drawing objects within seconds.

Using the copy function is quite similar to the way the move function is used. First, you need to select objects using any of the methods described earlier. Then you need to indicate a base point and a relocation (or destination) point. The copied objects are placed according to the relocation point.

Fig 3



COPY COMMAND

DC20N2210023

Making multiple copies in a rectangular fashion

There are separate functions available in CADD that allow you to make multiple copies in a linear or rectangular fashion (commonly known as a rectangular array). You can make hundreds of copies within seconds. You don't need to enter a base point and a destination point. You just need to select the objects, specify how many rows and columns you need and the distance between them.

Copy command

1 Choose Modify, copy.

(or)

2 Click The copy icon 

(or)

3 Type Copy at the command prompt.

4 Pick Objects to copy.

Select objects: (select)

5 Pick A point to move from.

Base point or displacement /multiple: (pick point).

6 Pick A point to copy to.

Second point of displacement: (Pick point)

(or)

7 Type A point to copy to.

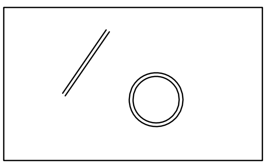
Second point of displacement: @1<0

TIP

To copy many objects in the same copy command, type M for Multiple at the "Base point or displacement/Multiple" option.

Offset command (Fig 4)

Fig 4

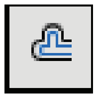


OFFSET COMMAND

DC20N2210024

Offset distance

To offset a specified distance:

1 Choose Modify, Offset. 

(or)

2 Choose The offset icon.

(or)

3 Type OFFSET at the command prompt. Command: OFFSET or O

4 Type The distance to offset. Offset distance or <Through point>: (number)

5 Pick The object to offset. Select object to offset: (select object)

6 Pick A side to offset object to. Side to off set: (pick side)

7 Pick Another object to offset

Select object to offset: (Pick side)

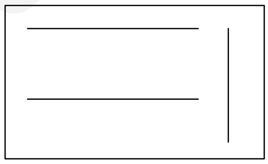
(or)

8 Press Enter to end the command.

Offsetting objects by specifying a distance

Offset through point (Fig 5)

Fig 5



OFFSET COMMAND

DC20N2210025

To offset through point

1 Type Offset at the command prompt

Command: Offset

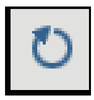
2 Type T to specify a through point

Offset distance or <Through point>: (T)

3 Pick A point to offset through (HINT: use ob ject snaps) Select object to offset: (pick) through point: (select object)

Offset through a point

Rotate (Fig 6)

1 Choose Modify, rotate 

(or)

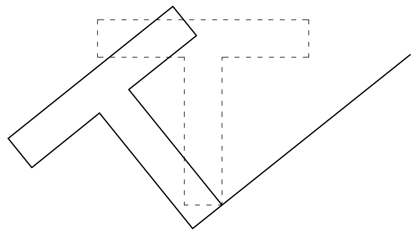
2 Click The modify icon.

(or)

3 Type Rotate at the command prompt Command: Rotate

4	Pick	Objects to rotate: Select objects: (select)
5	Pick	A pivot point to rotate around Base point: (point)
6	Type	A rotation angle<Rotation angle>/Reference: (number) (or)
7	Pick	A rotation angle<Rotation angle>/Reference: (point)

Fig 6



ROTATE COMMAND

DC20N2210026

Rotating the drawings

CADD drawing allows you to rotate selected drawing objects to a specified angle. To rotate, you need to select the drawing objects, enter a reference point (or base point) and the rotation angle. The base point acts as a pivot point around which the objects are rotated. The rotation angle determines by how much the objects will be rotated and in which direction.

Reference angle rotation

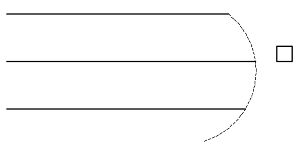
A positive angle causes counterclockwise rotation, and a negative angle produces clockwise rotation. If you respond to the last prompt with r, you can specify the current rotation and the new rotation you want. AutoCAD prompts

1	Type	R for a rotation angle<Rotation angle>/Reference: (R)
2	Choose	An existing rotation angle Rotation angle: (number or points)
3	Choose	A new rotation angle New angle: (number or points)

TIP (Fig 7)

You can show AutoCAD the reference angle (by pointing to the two endpoints of a line to be rotated), and then specify the new angle. You can specify the new angle by pointing or by dragging the object.

Fig 7

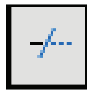


TRIM COMMAND

DC20N2210027

Trim

The trim command allows you to trim objects in a drawing so they end precisely at a cutting edge defined by one or more other objects in the drawing.



1	Choose	Modify, trim (or)
2	Click	The trim icon. (or)
3	Type	Trim at the command prompt Command: trim Select cutting edge(s)
4	Pick	The cutting edge to extend to Select objects: (select)
5	Press	Enter to accept the cutting edge Select objects: (press enter)
6	Pick	Objects to trim <Select object to trim>/Project/Edge/Undo: Select an object, enter an option, press enter
7	Press	ENTER when you are done choosing objects Select object to trim/Undo: (press enter)

TIP: Hold the shift key to interactively extend instead of trim.

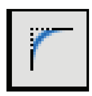
Cutting drawing objects along an edge

CADD allows you to erase drawing objects along a selected edge (this technique is often called trimming).When you use this function, you are prompted to select the drawing object that is to be used as the cutting edge and then select the objects that are to be erased along that edge.

Making sharp and rounded corners

CADD allows you to make fine corners of any two lines or arcs. This technique, often called filleting, is the quickest way to join the missing corners of lines and arcs. With this function active, to make a corner all you need to do is select the lines or arcs that have missing corners. CAD automatically extends or shortens the selected objects to form a corner. You can also specify whether you want a sharp corner or a rounded corner.

Fillet (Fig 8)



1	Choose	Modify, fillet. (or)
2	Click	The fillet icon. (or)

3 Type FILLET at the command prompt. Command: FILLET

4 Pick First object to fillet. Polyline/radius/ trim<Select two objects>: Select first object.

5 Pick Second object to fillet.

Select second object: select second object.

(or)

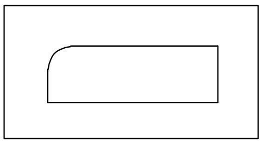
6 Type One of the following options:

P Fillets a nentire Polyline

R Sets the filletradius.

T Sets the trimmode (trim cuts the fil let corner and no trim keeps the fillet corner).

Fig 8



FILLET COMMAND

DC20N2210028

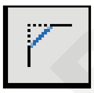
TIP

You can also fillet PARALLEL lines as well as PLINES with LINES

Type a radius of Zero (0) to create a clean 90 degree corner.

Chamfer

1 Choose Modify, chamfer.



(or)

2 Click The chamfer icon.

(or)

3 Type CHAMFER at the command prompt.

Command: Chamfer

4 Pick First object to chamfer. Polyline/ distance/angle/trim/ method<Select first line>: select first object.

5 Pick Second object to chamfer.

Select second object: select second object.

(or)

6 Type One of the following options:

P Chamfers entire Polyline.

D Sets chamfer distances.

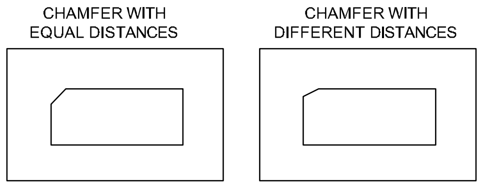
A Uses a distance and angle method in stead of two distances.

T Sets the trim mode

M Sets the method to distance or angle.

Chamfer with equal distances (Fig 9)

Fig 9



CHAMFER COMMAND

DC20N2210029

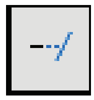
Chamfer with different distances

Making chamfered corners

CADD allows you to make a chamfered corner between two lines. It works quite like the fillet command. When you enter the chamfer command, you are prompted to select the lines that are to be chamfered and enter a chamfer distance. The chamfer distance determines the size of the chamfer.

EXTEND (Fig 10)

1 Choose Modify, extend,



(or)

2 Click The extend icon.

(or)

3 Type EXTEND at the command prompt command: EXTEND Select boundary edge (s)...

4 Pick The BOUNDARY edge to extend to select objects: (select)

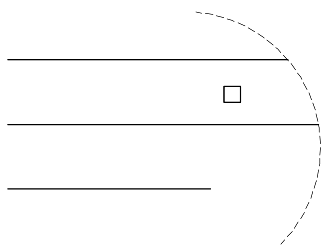
5 Press ENTR to accept the boundary edge select objects: (press enter)

6 Pick The object to extend <Select object to extend> / Project/ edge/ undo: Select an object, enter an option, or press enter: (select)

7 Press ENTER when you are done choosing objects.

Lines extended to an arc (Arc is boundary edge) (Fig 10)

Fig 10



EXTEND COMMAND

DC20N221002A

TIP

- Use the object selection option FENCE to choose mul tiple objects.

Extending drawing objects to an edge

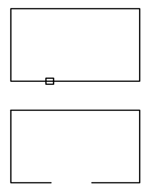
CADD allows you to extend lines to a selected drawing object. Often you need to extend lines to construct a drawing and to fix any graphical errors. To extend lines, you need to select an edge to which the lines should extend and then select the lines to be extended.

Dividing an object into equal parts

CADD allows you place dividing marks on a drawing object such as a line, arc, ellipse or spline. To use this command, you need to select an object and specify how many divisions are required. This function places markers at equal distances on the drawing object.

Break (Figs 11 & 12)

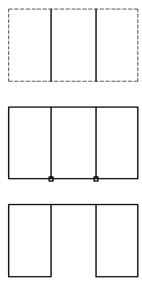
Fig 11



BREAK COMMAND

DC20N221002B

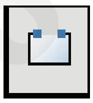
Fig 12



BREAK COMMAND

DC20N221002C

1 Choose Modify, break.



(or)

2 Click The break icon.

(or)

3 Type BREAK at the command prompt.
Command: BREAK

4 Pick Object to break.
Select object: (select one object)

5 Pick A second break point. Enter second point: (point)

6 Type F to choose a different break point Enter second point (or F for first point): (F)

7 Pick The first break point on the object

Enter first point: (point)

8 Pick A second break point

TIP

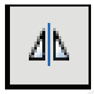
You can also type coordinates instead of picking a break point. Enter second point (or F for first point): @3'<0

If you break a circle, it changes to an arc by deleting the portion from the first point to the second, going counterclockwise.

Breaking a polyline with nonzero width will cause the ends to be cut square.

Mirror command (Fig 13)

1 Choose Modify, mirror.



(or)

2 Click The mirror icon

(or)

3 Type MIRROR at the command prompt.
Command: MIRROR

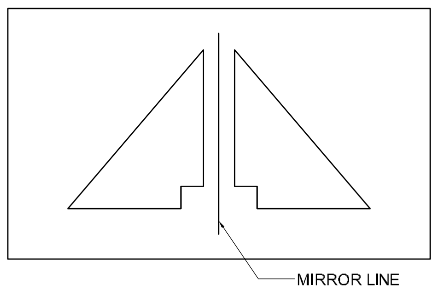
4 Pick Objects to mirror. Select objects: (Select)

5 Pick First point of mirror line: (point)

6 Pick Second point: (Point)

7 Type Yes to delete the original objects and No to keep them.
Delete old objects? Y or N

Fig 13



MIRROR COMMAND

DC20N221002D

Mirroring drawings

CADD allows you to create mirror images of drawings. This capability is very useful when you want to draw something that is symmetrical on both sides. You need to draw only one half of the drawing; the rest of the drawing can be completed using the mirror function. To make a mirror image, you need to select the objects to be mirrored and indicate a mirror axis. The mirror axis is an imaginary line along which the diagram is mirrored.

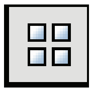
Array

Rectangular array (Fig 14)

To draw rectangular array

1 Choose Modify, array.

(or)

2 Click The array icon. 

Or

3 Type ARRAY at the command prompt. Command: ARRAY objects to array. Select

4 Pick Objects to array. Select Objects: (select)

5 Type The number of rows top to bottom. Number of rows (----) <1>: (number)

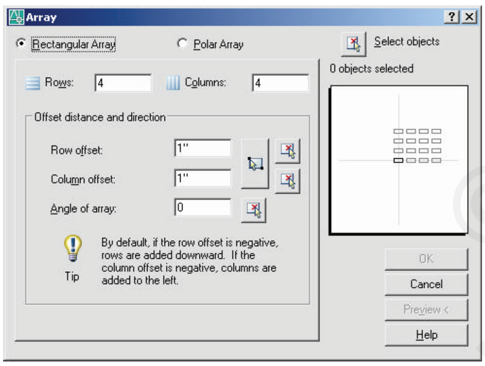
6 Type The number of columns left to right. Number of columns (III) <1>: (number)

7 Type The unit cell distance between items in each row. Distance between rows: (+number=up, number = down)

8 Type The unit cell distance between items in each column.

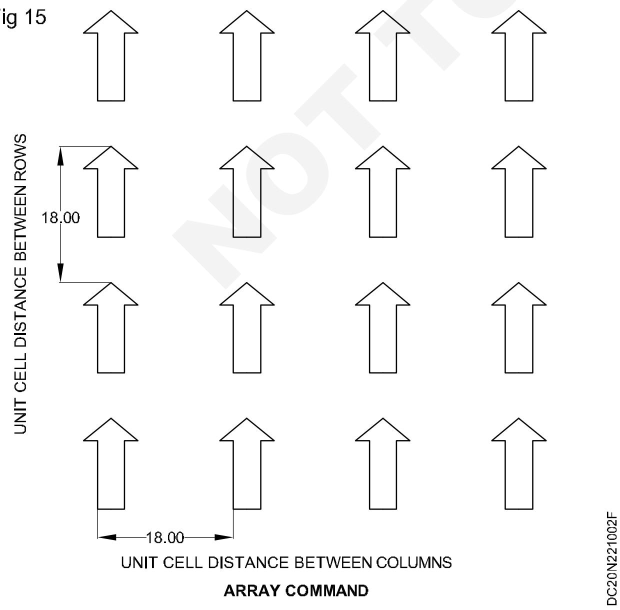
Distance between columns: (+ number = right, - number = left)

Fig 14



Creating an array of objects (Fig 15)

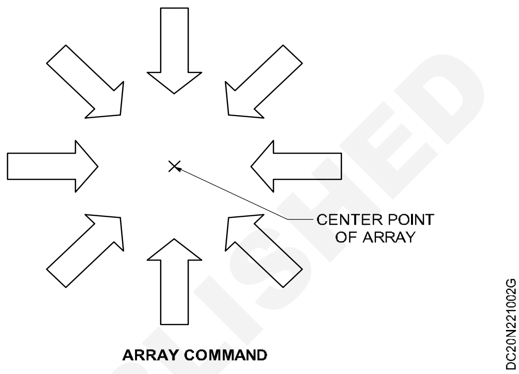
Fig 15



The array command in AutoCAD is used to make multiple copies of objects. Although you can use the copy command to duplicate objects, the array command is more flexible and precise. One advantage of using the array command is that it allows you to copy objects in a defined angle and exact number of copies. Therefore, you can create array in various pattern. For example, you can show multiple objects in a row, column, or irregular pattern such as a spiral. Let's look at a few examples below:

Polar array (Fig 16)

Fig 16



To draw a polar array:

1 Choose Modify, array.

(or)

2 Click The array icon.

(or)

3 Type Array at the command prompt. Com mand: Array

4 Pick Objects to array. Select Objects: (select)

5 Type P to draw a polar array. Rectangular or Polar array (R/P):P

6 Pick A center point for the array. Center point of array. Pick point

7 Type The total number of items in the array. Number of items: number

8 Type The number of degrees to rotate the objects. Degrees to fill (+=CCW, -+CW) <360>: Number

9 Type Yes No to rotate objects. Rotate objects as they are copied? <y> Y or N

Stretch (Fig 17)

1 Choose Modify, stretch

(or)

2 Click The stretch icon.

3 Type STRETCH at the command prompt. Command: STRETCH select objects to stretch by window.

4 Type C to choose CROSSING window Select objects: C

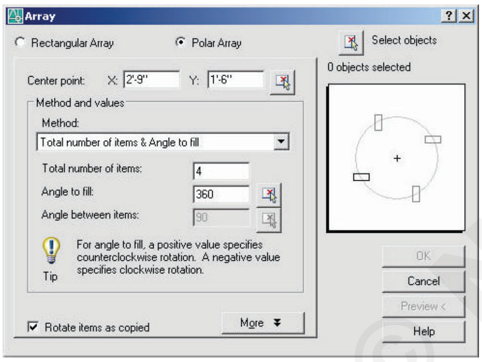
5 Pick A first corner to stretch. First corner: (point)

6 Pick The opposite corner to window the objects to stretch.
Other corner: (point)

7 Press ENTER to accept objects to stretch

8 Pick A base point to stretch from Base point: (point)

Fig 17



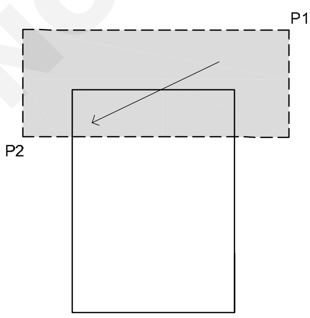
Stretching diagrams (Fig 18)

CADD allows you to quickly change the size of diagrams by stretching lines, arcs, splines, etc. This function is very helpful to make quick alterations to drawings. To use the stretch function, you need to select the drawing objects to be stretched and specify the distance and direction of stretching.

9 Pick A point to stretch to New point: (point)

10 Type A distance to stretch. New point: @ 1<0

Fig 18



STRETCH COMMAND

DC20N221002I

TIP

The Stretch command must use a CROSSING window or a CROSSING POLYGON window.

Lengthen (Fig 19)

1 Choose Modify, lengthen.

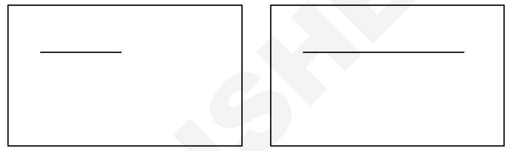
(or)

2 Type Lemgthen at the command prompt. Command:_ lengthen (Fig 19)

Select an object or [Delta/Percent/Total/ Enter delta length or [Angle]<0.0000>:2 Select an object to change or [Undo]: pick object

Object before lengthen
Object after lengthen

Fig 19



OBJECT BEFORE LENGTHEN OBJECT AFTER LENGTHEN

LENGTHEN COMMAND

DC20N221002J

Explode command (Fig 20)

1 Choose Modify, explode.

(or)

2 Pick The explode icon.

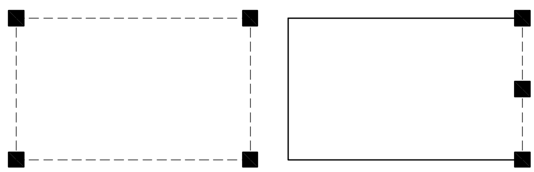
3 Type EXPLODE at the command prompt.

Command: EXPLODE (Fig 20)

(or)

4 Pick The object to explode. Select objects: (pick)

Fig 20



POLYLINE BEFORE EXPLODE POLYLINE (LINE) AFTER EXPLODE

EXPLODE COMMAND

DC20N221002K

4.3 OOPS commands

Reinserts the last erased set of objects or block even if it was not the last command issued. Otherwise oops acts like UNDO.

1 Type OOPS at the command prompt to reinsert erased objects
Command: OOPS

Other CAD commands

Objectives: At the end of this lesson you shall be able to
- **points, rectangle, polyline, spline, multilines, construction line**
- **adding patterns to drawings.**

Introduction

Drawing multiple parallel lines

CADD allows you draw parallel lines simultaneously just by indicating a starting point and an end point. These lines can be used to draw something with heavy lines or double lines. For example, they can be used to draw the walls of a building plan, roads of a site map, or for any other presentation that requires parallel lines.

Most programs allow you to define a style for multiple parallel lines. You can specify how many parallel lines you need, at what distance and if they are to be filled with a pattern or solid fill.

A number of add-on programs use multiple lines to represent specific drawing features. For example, an architectural program has a special function called "wall". When you use this option, it automatically draws parallel lines representing walls or specified style and thickness.

Drawing flexible curves

CADD allows you to draw flexible curves (often called splines) that can be used to draw almost any shape. They can be used to create the smooth curves of a sculpture, contours of a landscape plan or roads and boundaries of a map.

To draw a flexible curve, you need to indicate the points through which the curve will pass. A uniform curve is drawn passing through the indicated points. The sharpness of the curves, the roughness of the lines and the thickness can be controlled through the use of related commands.

Adding hatch patterns to drawings

The look of CAD drawings can be enhanced with the hatch patterns available in CAD. The patterns can be used to emphasize portions of the drawing and to represent various materials, finishes, and spaces. Several ready-made patterns are available in CAD that can be instantly added to drawings.

Hatch patterns are quite easy to draw. You don't need to draw each element of a pattern one by one. You just need to specify an area where the pattern is to be drawn by selecting all the drawing objects that surround the area. The selected objects must enclose the area completely, like a closed polygon. When the area is enclosed, a list of available patterns is displayed. Select a pattern, and the specified area is filled.

Point command (Fig 1)

1 Choose Draw, point, single or multiple point

(or)

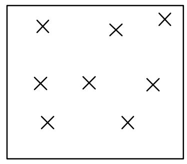
2 Click The point icon

(or)

3 Type Point at the command prompt
Command: Point

4 Pick A point on the drawing

Fig 1



POINT COMMAND

DC20N2210031

Point (point)

Point styles (Fig 2)

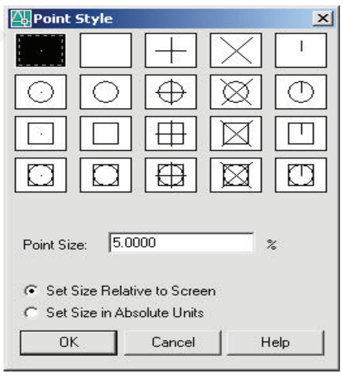
Changes the appearance of points and point sizes.

1 Choose Format, Point Style...

(or)

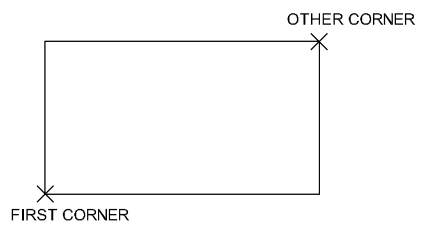
2 Type DDP type at the command prompt.
Command: DDP type

Fig 2



Rectangle Fig 3

Fig 3



RECTANGLE COMMAND

DC20N2210033

1 Choose Draw, rectangle.

(or)

2 Click The rectangle icon

(or)

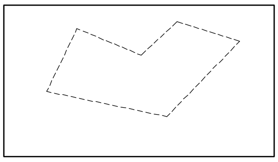
3 Type Rectangle at the command prompt Command: RECTANG chamfer/ Elevation/Fillet/Thickness/Width/<First corner>

4 Pick first corner

5 Pick other corner or type coordinates (i.e. @ 4,2)

Plane command (Fig 4)

Fig 4



PLINE

A polyline is a connected sequence of line segments created as a single object. You can create straight line segments, arc segments, or a combination of the two.

1 Choose Draw, polyline.

(or)

2 Pick The pline icon.

3 Type PLINE at the command prompt Com mand: PLINE or PL

4 Pick A point on the drawing to start the polyline
Form point: (select)

5 Type One of the following options Arc/Close/ Halfwidth/Length/Undo/Width/<endpoint of line>:

(or)

6 Pick A point to continue drawing Arc/Close/ Halfwidth/Length/Undo/Width/<endpoint of line>: (pick point)

PLINE options (Fig 5)

Arc : Toggles to arc mode and you receive the following: Angle/Center/CLose/Direction/Halfwidth/Line/Radius/ Second Pt/Undo/Width/<enter of arc>:

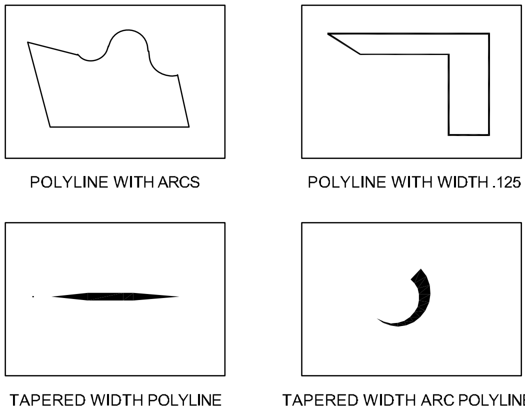
Close : Closes a polyline as it does in the line command.

Halfwidth : Specifies the halfwidth of the next polyline segments. Can be tapered.

Length : Specifies the length to be added to the polyline in the current direction.

Undo : Undoes the previous plane segment as with the line command.

Fig 5



PLINE

Width : Specifies the width of the next polyline segments. Can be tapered.

Polyline with arcs

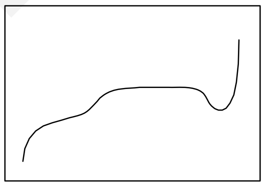
Polyline with width 125

Tapered width polyline

Tapered width arc polyline

Convert pline to pline (Fig 6)

Fig 6



PLINE TO SPLINE

1 Draw A Pline

2 Type PEDIT to edit the polyline as a spline.

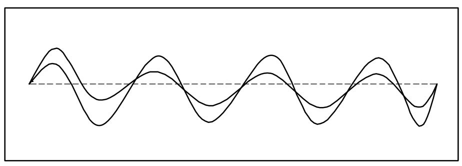
3 Choose Draw, Spline

4 Type Object at the command prompt.

5 Click Once on the polyline to turn it into a spline.

Spline (Fig 7)

Fig 7



SPLINE

The spline command creates a particular type of spline known as a non-uniform rational B-spline (NURBS) curve. A NURBS curve produces a smooth curve between control points.

1	Choose	Draws, spline.
		(or)
2	Click	The spline icon
		(or)
3	Type	Spline at the command prompt Command: Spline
4	Pick	A start point for the spline Object / <Enter first point> (pick point)
5	Pick	Points until you are done drawing splines Enter point: (pick points)
6	Press	Enter or close to complete the spline
7	Pick	Starting tangent point for the spline Enter start tangent (pick point)
8	Pick	Ending tangent point for the spline Enter end tangent (pick point)

Spline options (Fig 8 & 9)

Fig 8

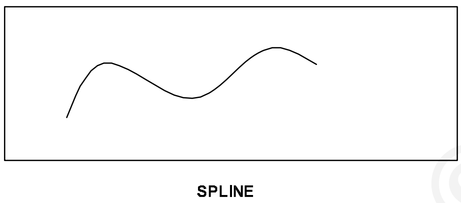
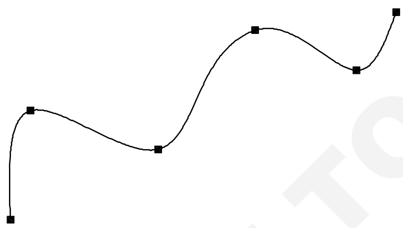


Fig 9



Object: Convers 2D or 3D spline-fit polylines to equivalent splines

Points: Points that defines the spline

Close: Closes a spline

Fit Tolerance: Allows you to set a tolerance value that creates a smooth spline.

TIP: Refer to AutoCAD online help topic for more i nformation on spline options.

Editing splines

1. Choose Modify, Object, Spline.

TIP

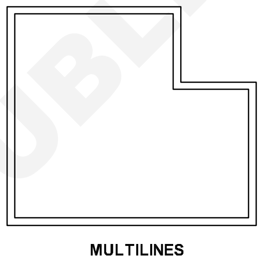
Drawings containing splines use less memory and disk space than those containing spline-fit polylines of similar shape.

Multilines (Fig 10)

MLINE Command

1	Choode	Draw, multiline.
		(or)
2	Type	MLINE at the command prompt Command: MLINE
3	Pick	A point to start the multiline.
		Justification/Scale/Style/<From point>: pick point
4	Pick	A second point to continue the multiline. <To point>: Pick point
5	Pick	The next point to continue drawing Multilines. Undo/<To point>: pick point

Fig 10



6	Press	ENTER to end the multiline
		Close/Undo/<To point>: press enter
		(or)
7	Type	C to close the multiline back to the first point. Close/Undo/<To point:C

Multiline styles (Figs 11 & 12)

1	Choose	Format, multiline style.
2	Type	Mlstyle at the command prompt.
		Command: Mlstyle
3	Rename	The existing style called STANDARD to your new style.
4	Choose	Element properties to change the appearance of the Multilines.
5	Choose	ADD to create the new multiline.

Fig 11

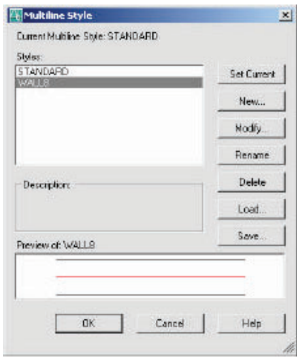
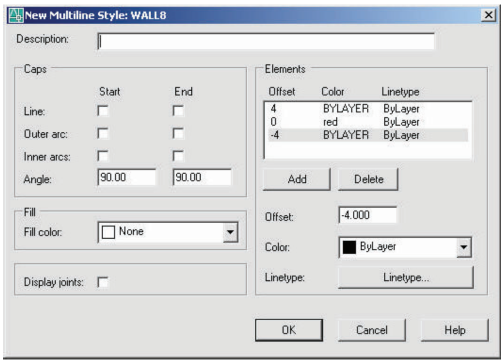


Fig 12



Editing multilines (Fig 13 & 14)

Fig 13

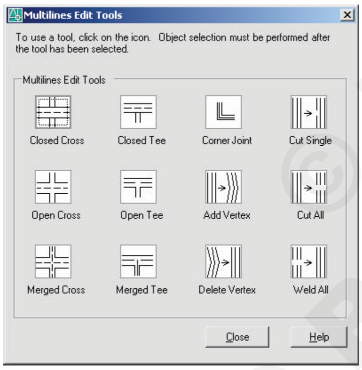
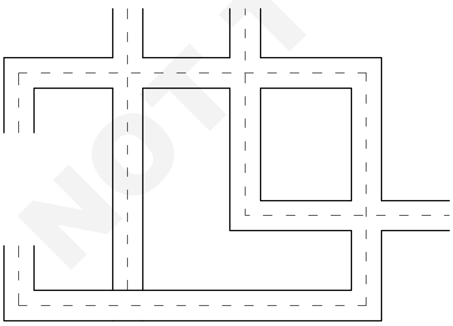


Fig 14



MULTILINES

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1 Choose Modify, Multiline

(or)

2 Type MLEDIT at the command prompt

Command: MLEDIT

3 Choose from one of the mledit options

Construction line

Creates an infinite line.

1 Choose Draw, Construction Line

(or)

2 Choose the XLINE icon.

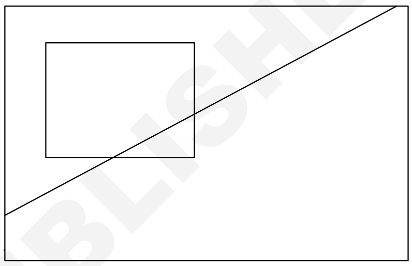
(or)

3 Type XLINE at the command prompt.
Command: XLINE

Specify a point or [Hor/Ver/Ang/Bisect/Offset]

XLINE options (Figs 15 & 16)

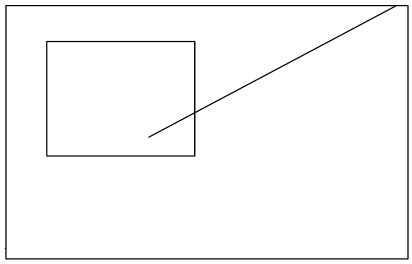
Fig 15



XLINE

DC20N221003F

Fig 16



XLINE

DC20N221003G

HOR: Creates a horizontal xline passing through a specified point

VER: Creates a vertical xline passing through a specified point

ANG: Creates an xline at a specified angle.

BISECT: Creates an xline that passes through the selected angle vertex and bisects the angle between the first and second line

OFFSET: Creates an xline parallel to another object.

Ray command

Creates an infinite line in one direction

1 Choose Draw, ray

(or)

2 Type Ray at the command prompt. Command: Ray specify a point: (pick through point)

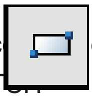
Bhatch command

1 Choose Draw, hatch...

(or)

2 Click The hatch icon.

(or)

3 Type BHATCH at the c  d prompt

Command: BHATCH

Bhatch options (Figs 17 & 18)

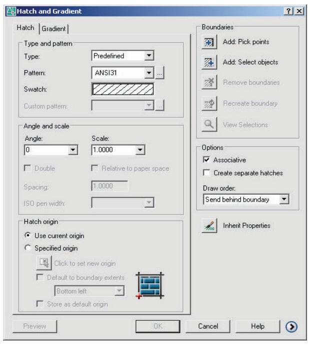
Pattern type: Sets the current pattern type by using AutoCAD's Predefined patterns or user defined patterns.

Pattern properties: Sets the current pattern, scale, angle, and spacing, Controls if hatch is double spaced or exploded.

Pick points: Constructs a boundary from existing objects that form an enclosed area.

Select objects: Selects specific objects for hatching. The boundary hatch dialog box disappears and AutoCAD prompts for object selection.

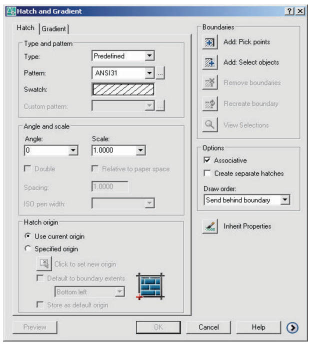
Fig 17



Inherit properties: Applies the properties of an existing associative hatch to the current pattern type and pattern properties options.

Preview hatch: Displays the hatching before applying it. AutoCAD removes the dialog box and hatches the selected areas.

Fig 18



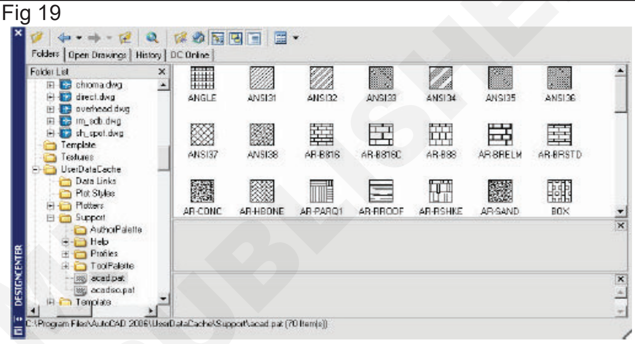
Associative: Controls associative hatching.

Apply: Crates the crosshatching in the boundary.

Annotative hatch

Hatching from the design center (Fig 19)

Fig 19



1 Choose: A cross hatch pattern from the following AutoCAD directly\AutoCADxxxx\Support\acad.pat or \AutoCADxxxx\Backup

2 Drag: and drop a pattern into a drawing.

TIP

Be sure the HPSCALE is set before dropping a hatch pattern into a drawing.

CAD basics

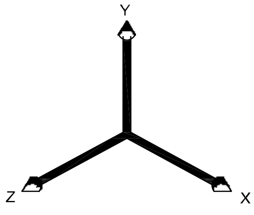
Objectives: At the end of this lesson you shall be able to
- **explain user co-ordinate system**
- **enumerate Auto CAD commands**
- **express line & erase commands.**

The CAD Database and the user coordinate system

Designs and drawings created in a CAD system are usually defined and stored using sets of points in what is called world space. In most CAD systems, the world space is defined using a three-dimensional Cartesian coordinate system. Three mutually perpendicular axes, usually referred to as the X-, Y-, and Z-axes, define this system. The intersection of the three coordinate axes forms a point called the origin. Any point in world space can then be defined as the distance from the origin in the X-, Y- and Z- directions. In most CAD systems, the directions of the arrows shown on the axes identify the positive sides of the coordinates.(Fig 1)

A CAD file, which is the electric version of the design, contains data that describes the entities created in the CAD system. Information such as the coordinate values in world space for all endpoints, center points, etc., along with the descriptions of the types of entities are all stored in the file. Knowing that AutoCAD stores designs by keeping coordinate data helps us understand the inputs required to create entities.

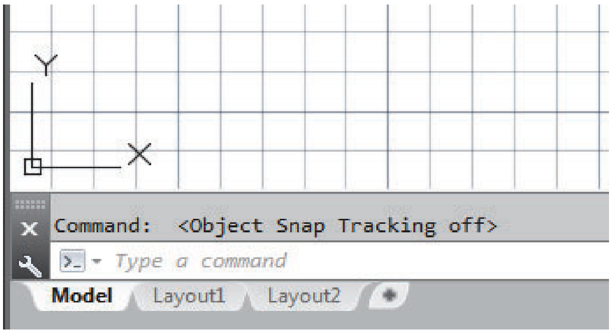
Fig 1



USER COORDINATE SYSTEM

DC20N2210041

Fig 2

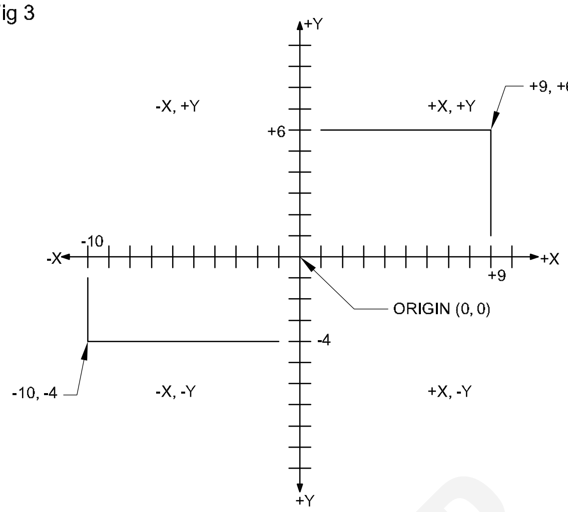


The icon near the bottom left corner of the default AutoCAD graphics window shows the positive X-direction and positive Y-direction of the coordinate system that is active. In AutoCAD, the coordinate system that is used to create entities is called the user coordinate system (UCS). By default, the user coordinate system is aligned to the world coordinate system (WCS). The world coordinate system is a coordinate system used by AutoCAD as the basis for defining all objects and other coordinate systems defined by the users. We can think of the origin of the world coordinate system as a fixed point being used as a reference for all measurements. The default orientation of the Z-axis can be considered as positive values in front of the monitor and negative values inside the monitor.

AutoCAD uses points to determine where an object is located. There is an origin where it begins counting from. This point is (0,0). Every object is located in relation to the origin. If you were to draw a line straight out to the right from the origin, this would be considered the positive X-axis. If you were to draw a line straight up, this would be the positive Y-axis. The picture above shows a point located at (9,6). This means that the point is 9 units over in the X-axis and 6 units up in the Y-axis. When you are working with points, X always comes first. The other point shown is (-10-4). This means that the point is 10 units in the negative X-axis (left) and 4 units in the negative Yaxis(down) (Fig 2)

A line has two points, a start point and an end point. AutoCAD works with the points to display the line on the screen. Move your cursor over the picture above and you will see line drawn from the absolute points of (-10-4) to (9,6).

Fig 3



USER COORDINATE SYSTEM

DC20N2210043

Most of the time you will not have an indication of where the origin is. You may need to draw a line from the endpoint of an existing line. To do this you use relative points. These work the same way, but you have to add the @ symbol (shift+2) to tell AutoCAD that this next point is relative from the last point entered.

To review

Absolute points are exact points on the drawing space.

Relative points are relative to an object on the drawing space.

its simple system, but mastering it is the key to working with AutoCAD and is explained in more detail further below. In order to work effectively with AutoCAD, you have to work with this system. Until you are comfortable and familiar with it, learning AutoCAD will be more of a chore. My experience in teaching is that the better a student is with coordinates, the faster they will learn.

Entering points in AutoCAD

You can enter points directly on the command line using three different systems. The one you use will depend on which is more applicable for the situation. The first assignment will get you used to this. The three systems are as follows.

Absolute co-ordinates: Using this method, you enter the points as they relate to the origin of the WCS. To enter a point just enter in the exact point as X,Y.

Relative co-ordinates : This allows you to enter points in relation to the first point you have entered. After you've entered one point, the next would be entered as @ X,Y. This means that AutoCAD will draw a line from the first point to another point X units over and Y units up relative to the previous point.

Polar co-ordinates: You would use this system if you know that you want to draw a line a certain distance at a particular angle. You would enter this as @ D<A. In this case, D is the distance and A is the angle. Example: @10<90 will draw a line 10 units straight up from the first point.

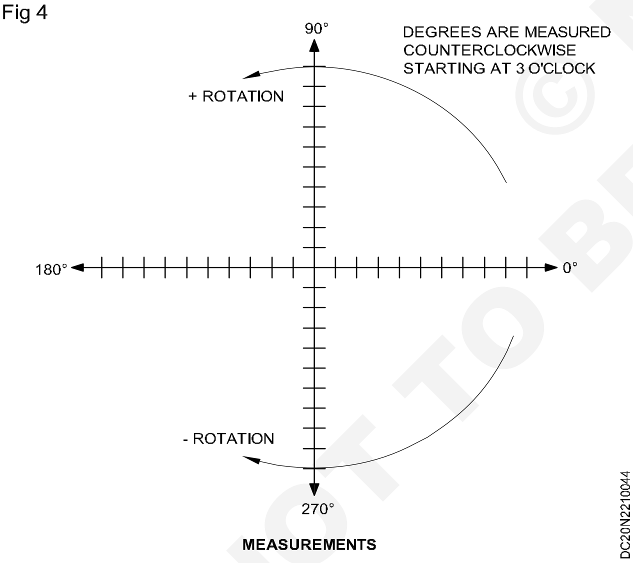
The three ways of entering coordinates shown above are the ONIY way AutoCAD accepts keyboard input. First decide which style you need to use, and then enter as shown. Remember that X is always before Y (alphabetical). Don't forget the '@' symbol when you are entering relative points. Any typing error or omission will give you results you don't want. If you make a mistake and need to see what you typed, Press F2 to bring up the text screen and check your typing. (press F2 to get back to your drawing.)

Key terms

Term	Description
Absolute coordinates	Distance measured from a fixed reference point.
Aperture	Effective diameter of the cursor on the screen.
Cartesian coordinates	A rectangular system of measurement to locate points in the drawing area.
Object snaps	A method for indicating point locations using existing drawing objects as a reference.
Origin point	The 0,0 location of the coordinate system.
Polar coordinates	A system to locate of the coordinate system.
Prototype drawing	A template drawing that has a last location of the cursor.
Relative coordinates	Distance measured from the last location of the cursor
User-defined co-ordinates System	A mode of measurement that allows the user to set up a customized coordinate system.

Angular measurement (Fig 4)

Fig 4



AutoCAD measures angles in a particular way also. Look at the diagram below and then place your mouse on it to see how this is

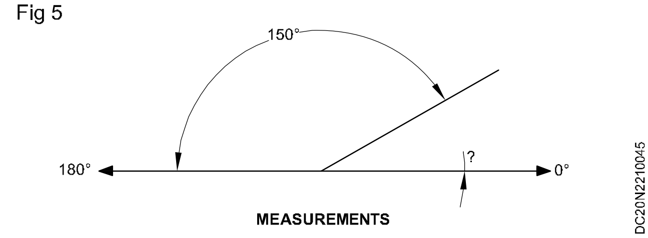
Degrees are measured counterclockwise starting at 3 O'CLOCK

When drawing lines at an angle, you have to begin measuring the angle from 0 degrees, Which is at the 3 O'clock position. If you drew a line at 90 degrees, it would go straight up. The example above (When you move your mouse over it) shows a line drawn at+300 degrees (270+30), or-60 degrees.

Your might not always have an obvious reference point for 0 degrees. Look at the example below and place your mouse on the image to find out the angle in question.

In this example, you are given information about the lines, but not the angle AutoCAD needs to draw the line from the start point. What you are given though, is (a) the knowledge that 0°is at the 3 o'clock position (b) the knowledge that180° is at the 9 o'clock position and (c) the angle between 180° and the line you want to draw is 150°. With this information, you can figure out what angle you need. Here is a fool-proof way of getting the angle you need (Fig 5)

Fig 5



1 Start at the 0° position and measure counter-clockwise (+) to 180°

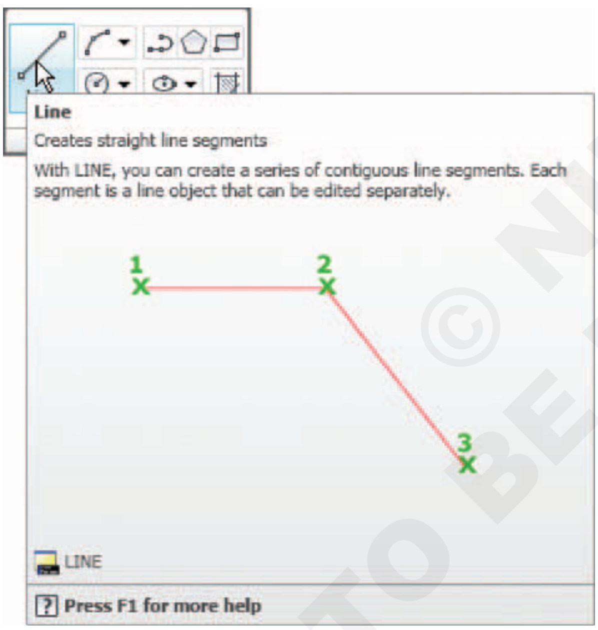
2 From 180°, measure clockwise 150°(-)

3 Consider that you just went+180-150 and use that as an equation:+180-150=30

4 Now you can draw your line using polar coordinates (discussed below)

There are many ways to do things in most windows programs. AutoCAD is no exception. Everyone will develop a way that works best for him or her. In this course, we will primarily be working with the keystroke commands. The reason for this is because they will work in most AutoCAD versions (including DOS versions), and in some other CAD programs. The icons work well, but as you will see, icons can be placed anywhere on the screen and can be difficult to find quickly. You may be working on another employee's computer that is set up differently than what you're used to. The pulldown menus will access almost all commands, but are a slower way of doing things. Icons in AutoCAD 2010 are found on the ribbon, divided into panels-just click on the appropriate tab to open the panel you need. (Fig 6)

Fig 6



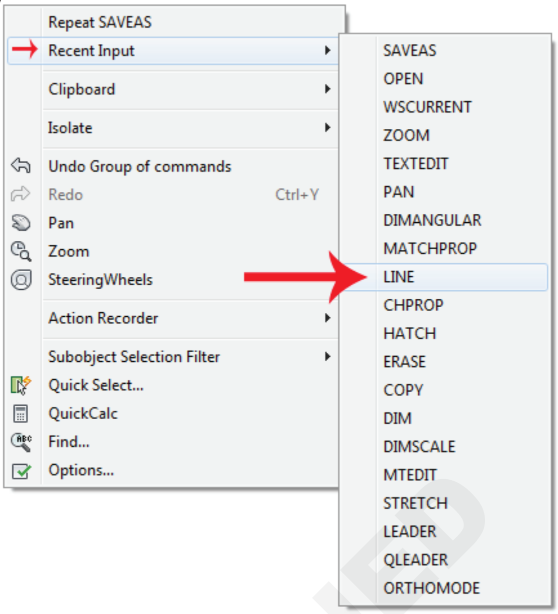
Example: If you want to draw a line, you can do it a few ways:

At the command line type: LINE (or) L and press the ENTER key.

Select the line icon from the DRAW Panel.

Another way is to Right-Click on the drawing space and choose "Recent Input" from the menu. This will give a list of the most recent command that you have used. (Fig 7)

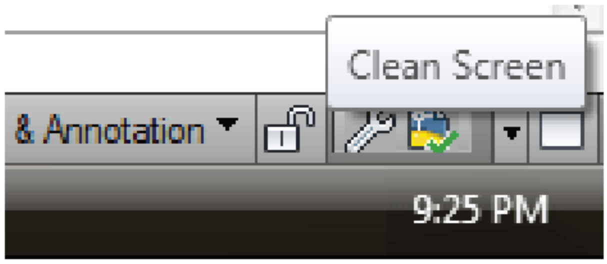
Fig 7



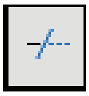
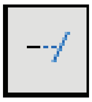
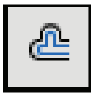
All three approaches will do the same thing: prepare AutoCAD to draw a line where you tell it.

AutoCAD is a popular program because it can be customized to suit an individual's needs. The toolbars are a good example of this. You can have the toolbars you use most often on the screen all the time. You can easily make them go away so that you have more drawing space. You can also customize them so you have the most common commands on one toolbar. For example, the dimensioning toolbar is one that you will not want taking up space on your screen while drawing, but is very handy when you're dimensioning your drawing. (Fig 8)

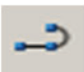
Fig 8

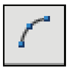


To remove the ribbon and have the most drawing space available, click on the "Clean Screen" icon in the bottom right corner of the screen (or press CTRL+O[letter O]. To go back the to the standard display, click again on the same icon.

Symbol	Command	Purpose
	Erase	Delete object
	Move	Move object one place to other place
	Copy	Create one or more copies of object
	Stretch	Stretch, shorte, or move object
	Trim	Shorten object using other object
	Extend	Lengthen object using object
	Mirror	Creates a mirror image of objects.
	Rotate	Rotate objects around a specified point.
	Offset	Create a new object at a specified distance from an existing object or through a specified point.
	Array	Each object in an array can be manipulated independently.

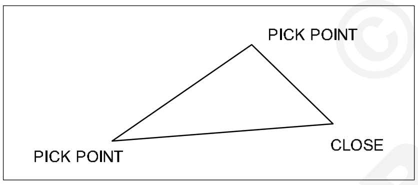
Auto CAD Drawing Commands

Symbol	Command	Major option	Toolbar button	Draw men
	Line	Start, End Point	Line	Line
	Mline	Justification, Scale Style	None	Multiline
	Pline	Vertices	Polyline	Polyline
	Polygon	Number of sides, Inscribed / Circumscribed	Polygon	Polygon

Symbol	Command	Major option	Toolbar button	Draw men
	Rectangle	Two Corner	Rectangle	Rectangle
	Arc	Various methods of definition	Arc	Arc, submenu for definition methods
	Circle	Three point, two point, Tangent	Circle	Circle submenu for definition methods
	Donut	Inside, Outside Diameters	None	Donut
	Spline	Convert polyline or Create new	Spline	Spline
	Ellipse	Arc, center, axis	Ellipse	Ellipse, submenu fo definition methods
	Revcloud	Arc Length	Revcloud	Revision cloud

Line command (Fig 9)

Fig 9



LINE COMMAND

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Create single straight line segments

1 Choose draw, line

(or)

2 Click the line icon

(or)

3 Type line from the command prompt command: line or L

4 Press enter

5 Pick from point: (point)

6 Pick specify next point or [Close/Undo]: (point)

7 Pick specify next point or [Close/Undo]: (point)

8 Press ENTER to end line sequence

(or)

9 Type U to undo the last segment to point: U (undo)

(or)

10 Type C to create a closed polygon to point: C (close)

Erase and selection sets

Erasing Objects (Fig 10)

1 Choose Modify, erase

(or)

2 Click The Erase icon

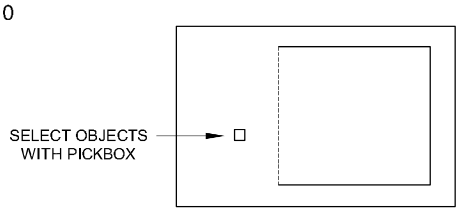
(or)

3 Type Erase at the comm ompt. Command: Erase or E

4 Pick Object at the select object prompt.

5 Press ENTER when you are done choosing objects.Select objects: ENTER

Fig 10



ERASE COMMAND

DC20N221004A

Knowledge of short cut key board commands

Objective: At the end of this lesson you shall be able to
- **describe the features of key board commands in detail.**

Toggle general features

Ctrl + d	Toole coordinate display
Ctrl + g	Toggle grid
Ctrl + e	Cycle isometric planes
Ctrl + f	Toggle running object snaps
Ctrl +h	Toggle pick style
Ctrl + Shift + h	Toggle hide pallets
Ctrl + l	Toggle cords
Ctrl + Shift + l	Toggle infer Constraints

Toggle drawing modes

F1	Display Help
F2	Toggle text screen
F3	Toggle object snap mode
F4	Toggle 3DO snap
F5	Toggle Iso plane
F6	Toggle Dynamic UCS
F7	Toggle grid mode
F8	Toggle ortho mode
F9	Toggle snap mode
F10	Toggle polar mode
F11	Toggle object snap tracking
F12	Toggle dynamic input mode

Manage screen

Ctrl + o(zero)	Clean screen
Ctrl + 1	Property palette
Ctrl + 2	Design center palette
Ctrl + 3	Tool palette
Ctrl + 4	Sheet set palette
Ctrl + 6	DB connect manager
Ctrl + 7	Markup set manager palette
Ctrl + 8	Quick calc
Ctrl + 9	Command line

Manage workflow

Ctrl + c	Copy object
Ctrl + x	Cut object
Ctrl + v	Paste object
Ctrl + Shift + C	Copy to clipboard with base point
Ctrl + Shift + V	Paste data as block
Ctrl + Z	Undo last action
Ctrl + Y	Redo last action
Ctrl + [	_Cancel current Command(or+ Ctrl +\)
ESC	Cancel current command

Fig 1

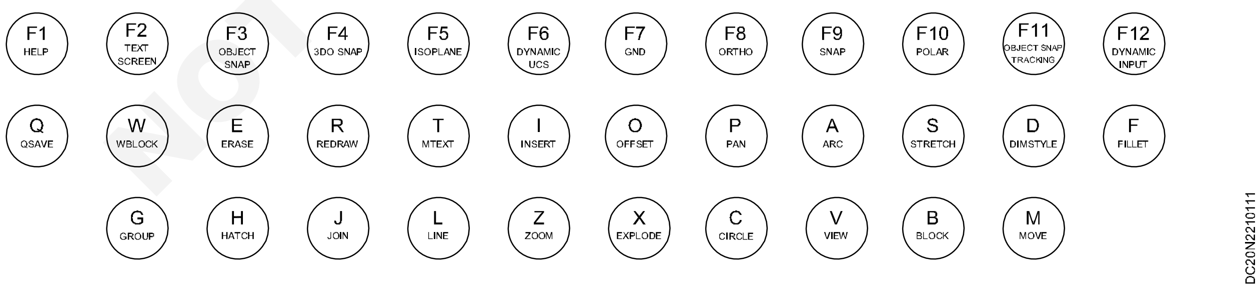
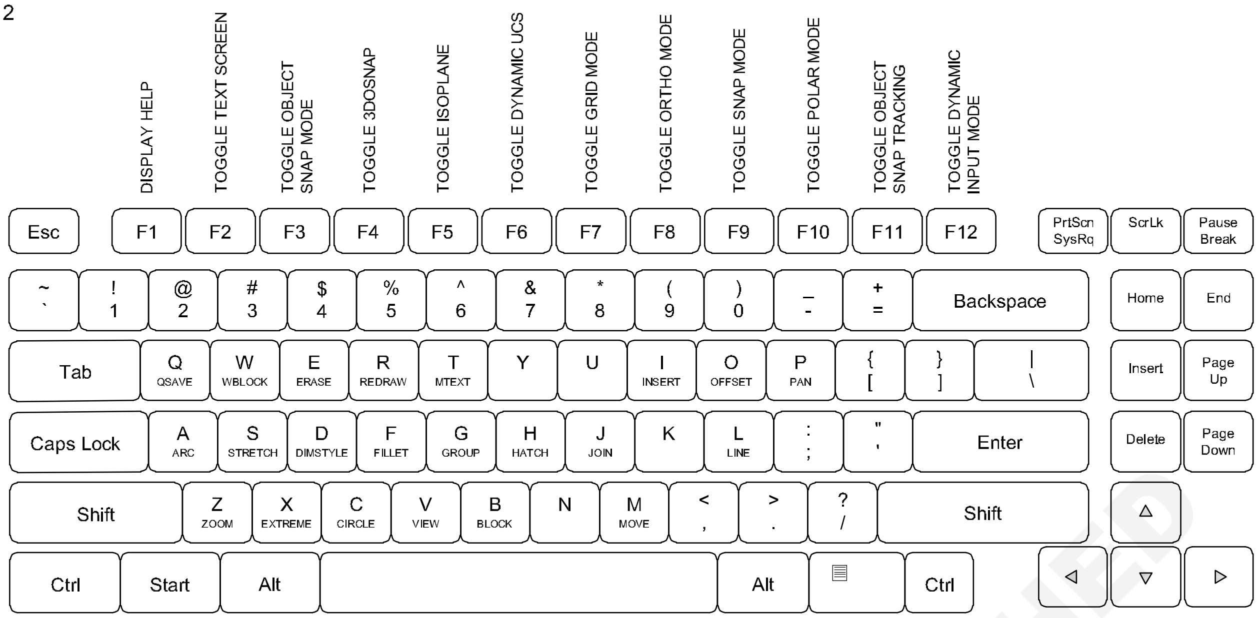


Fig 2



Q QSAVE / SAVES THE CURRENT DRAWING

A ARC / CREATES AN ARC

Z ZOOM / INCREASES OR DECREASES THE MAGNIFICATION OF THE VIEW THE CURRENT VIEWPORT

W WBLOCK / WRITES OBJECTS OR A BLOCK TO A NEW DRAWING FILE

S STRETCH / STRETCHES OBJECTS CROSSED BY A SELECTION WINDOW OR POLYGON

X EXPLODE / BREAKS A COMPOUND OBJECT INTO ITS COMPONENT OBJECTS

E ERASE / REMOVES OBJECTS FROM A DRAWING

D DIMSTYLE / CREATES AND MODIFIES DIMENSION STYLES

C CIRCLE / CREATES A CIRCLE

R REDRAW / REFRESHES THE DISPLAY IN THE CURRENT VIEWPORT

F FILLET / ROUNDS AND FILLETS THE EDGES OF OBJECTS

V VIEW / SAVES AND RESTORE NAMED VIEWS, CAMERA VIEWS, LAYOUT VIEWS, AND PRESET VIEWS.

T MTEXT / CREATES A MULTILINE TEXT OBJECTS

G GROUP / CREATES AND MANAGES SAVED SETS OF OBJECTS CALLED GROUPS

B BLOCK / CREATES A BLOCK DEFINITION FROM SELECTED OBJECTS

H HATCH / FILLS AN ENCLOSED AREA SELECTED OBJECTS WITH A HATCH PATTERN, SOILD FILL OR GRADIENT FILL

J JOIN / JOINS SIMILAR OBJECTS TO FORM A SINGLE, UNBROKEN OBJECT

M MOVE / MOVES OBJECTS A SPECIFIED DISTANCE IN A SPECIFIED DIRECTION

I INSERT / INSERTS A BLOCK DRAWING INTO THE CURRENT DRAWING

O OFFSET / CREATES CONCENTRIC CIRCLES, PARALLEL LINES AND PARALLEL CURVES

L LINE / CREATES STRAIGHT LINE SEGMENTS

P PAN / ADDS A PARAMETER WITH GRIPS TO A DYNAMIC BLOCK DEFINITION

DC20N2210112

Manage Drawings

Ctrl + n	New drawing
Ctrl + s	Save drawing
Ctrl +o	Open drawing
Ctrl + p	Plot dialog box
Ctrl + Tab	Switch to next
Ctrl+shift+Tab	Switch to previous drawing
Ctrl +page up	_Switch to next Tab in current drawing
Ctrl + Q	Exit
Ctrl + a	Select all objects

A

A	Arc/Creates an arc.
AA	_AREA / Calculates the area and Perimeter of objects or of defined areas.
ADC	ADCENTER / Manages and inserts Content such as blocks, xrefs, and hatch patterns.
AL	ALIGN/Aligns objects with other objects in 2D and 3D
AP	_APPLOAD / Load Application.
AR	_ARRAY / Creates multiple copies of objects in a pattern.
ARR	_ACTRECORD / Starts the Action Recorder.
ARM	_ACTUSERMESSAGE / Insert a user message into an action macro.
ARU	_ACTUSERINPUR / Pauses for user input In an action macro.
ARS	_ACTSTOP / Stops the Action Recorder and provides the option of saving the recorded actions to an action macro file.
ATI	_ATTIPEDIT / Change the textual content of am attribute within a block.
ATT	_ATTDEF / Redefines a block and updates associated attributes.
ATE	_ATTEDIR / changes attribute information in a block

B

B _BLOCK / Creates a block definition from selected objects.

BC _BCLOSE / Closes the Block Editor.

BE _BEDLT / Opens the block definition In the Block Editor.

BH _HATCH / Fills an enclosed area or selected objects with a hatch pattern, solid fill, or gradient fill.

BO _BOUNDARY / Creates a region or a poly line from an enclosed area.

BR _BREAK / Breaks the selected object between two points.

BS _BSAVE / Saves the current block definition.

BVS _BVSTATE / Creates , sets, or deletes a visibility state in a dynamic block.

C

C _CIRCLE /Creates a circle.

CAM _CAMERA /Sets a camera and target location to create and save a 3D perspective view of objects.

CBAR _CONSTRAINTBAR / A toolbar-like UI element that displays the available geometric constraints on an object.

CH _PROPERTIES / Control Properties of existing objects.

CHA _CHAMFER / Bevels the edges of objects.

CHK _CHECKSTANDARDS / Checks the current drawing for standards violations.

CLI _COLOR / Sets the color for new objects.

CO _ COPY / Copies objects a specified Distance in a specified direction

CT _CTABLESTYLE / Sets the name of the current table style.

CUBE _NAVVCUBE / Controls the visibility and display properties of the View Cube tool.

CYL _CYLINDER / Creates a 3D solid cylinder.

D

D _DIMSTYLE / Creates and modifies dimension styles.

DAN _DIMANGULAR / Creates an angular dimension

DAR _DIMARC / Creates an arc length dimension.

DBA -DIMBASELINE / Creates a linear, angular, or ordinate dimension from the baseline of the previous or selected dimension.

DBC _DBCONNECT / Provides an interface to external database tables.

DCE _DIMCENTER / Creates the center mark or the center lines of circles and arcs.

DCO _DIMCONTINUE / Creates a dimension that starts from an extension line of a previously created dimension

DCON _DIMCONSTRAINT / Applies dimension that starts from an extension line of a previously created dimension.

DCON _DIMCONSTRAIN / Applies dimensional constraints to selected objects or points on objects.

DDA -DIMDISASSOCIATE / Removes associatively from selected dimensions.

DDI _DIMDIAMETER / Creates a diameter dimension for a circle or an arc.

DED _DIMEDIT / Edits dimension text and extension lines.

DI _DIST / Measures the distance and angle between two points.

DIV _DIVIDE / Creates evenly spaced point objects or blocks along the length or perimeter of an object.

DJL _DIMJOGLINE / Adds or removes a jog line on a linear or aligned dimension.

DJO _DIMJOGGED / Creates jogged dimensions for circles and arcs.

DL _DATALINK / The Data link dialog box is displayed.

DLU _DATALINK /Updates data to or from an established external data link.

DO _DONUT /Creates a filled circle or a wide ring.

DOR _DIMORDINATE / Creates ordinate dimensions.

DOV _DIMOVERRIDE /Controls overrides of system variables used in selected dimensions.

DR _DRAWORDER / Changes the draw order of images and other objects.

DRA _DIMRASSOCIATE / Associates or re -associates selected dimensions to objects or points on objects,

DRM -DRAWINGRECOVERY / Displays a list of drawing files that can be recovered after a program or system failure.

DS _DSETTINGS / Sets grid and snap, polar and object snap tracking, object snap modes, Dynamic input, and Quick properties.

DT _TEXT/Creates a single-line text object.

DV _DVIEW / Defines parallel projection or perspective views by using a camera and target.

DX _DATAEXTRACTION / Extracts drawing data and merges data from an external source to a data extraction table or external file.

E-F

E _ERASE / Removes objects from a drawing.

ED _DDEDIT / Edits single-line text, dimension text, attribute definitions, and feature control frames.

EL _ELLIPSE / Creates an ellipse or an elliptical arc.

EPDF _EXPORTPDF / Exports drawing to PDF

ER _EXTERNALREFERENCES / Opens the External References palette

EX _EXTEND / Extends objects to meet the edges of other objects.

EXIT _QUIT / Exits the program.

EXP -EXPORT / Saves the objects in a drawing o a different file format.

EXT _EXTRUDE / extends the dimensions of a 2D object or 3D face into 3D space.

F fillet / Rounds and fillets the edges of objects.

FI _FILTER / Creates a list of requirements that an object must meet to be included in a selection set.

FS _FSMODE / Creates a selection set of all objects that touch the selected object.

FSHOT _FLATSHOT / Creates a 2 D representation of all 3D objects based on the current view.

G-H

G _GROUP / Creates and manages saved sets of objects called groups.

GCON _GEOCONSTRAINT / Applies of persists geometric relationships between objects or points on objects.

GD _GRADIENT / Fills an enclosed area or selected objects with a gradient fill.

GEO _GEOGRAPHICLOCATION / Specifies the geographic location information for a drawing file.

H _HATCH / Fills an enclosed area or selected objects with a hatch pattern, solid fill, or gradient fill.

HE _HATCHEDIT / Modifies an existing hatch or fill.

HI _HIDE/Regenerates a 3D wireframe model with hidden lines suppressed.

I-K

I _INSERT / Inserts a block or drawing into the current drawing.

IAD _IMAGEADJUST / Controls the image display of the brightness, contrast, and fade values of images.

IAT -IMAGEATTACH / Inserts a reference to an image file.

ICL _IMAGECLIP / Crops the display of a selected image to a specified boundary.

ID _ID / Displays the UCS coordinate values of a specified location.

IM _IMAGE / Displays the External References palette.

IMP _IMPORT / Imports files of different formats into the current drawing

IN _INTERSECT / Creates a 3D solid, surface, or 2D region from overlapping solids surfaces, or regions.

NF _INTERFERE / Creates a temporary 3D solid from the interferences between two sets of selected 3D solids.

IO _INSERTOBJ / Inserts a linked or embedded object.

J _JOIN / Joins similar objects to form a single, unbroken object,

JOG _DIMJOGGED / Creates jogged dimensions for circles and arcs.

L-M

L _LINE / Creates straight line segments.

LA _LAYER / Manages layers and layer properties.

LAS _LAYERSTATE / Saves, restores, and manages named layer states.

LE _QLEADER / Creates a leader and leader annotation.

LEN _LENGTHEN / Changes the length of objects and the included angle of arcs.

LESS _MESHSMOOTH;ESS /Decreases the level of smoothness for mesh objects by one level.

LI _LIST / Displays property data for selected objects.

LO -LAYOUT / Creates and modifies drawing layout tabs.

LT _LINETYPE / Loads, sets, and modifies line types.

LTS _LTSCALE / Changes the scale factor of line types for all objects in a drawing.

LW _LWELGHT / Sets the current line weight, display options, and line weight units.

M _MOVE / Moves objects a specified distance in a specified direction.

MA -MATCHPROP / Applies the properties of a selected object to other objects.

MAI _MATERIALS / Shows or hides the Materials window.

ME _MEASURE / Creates point objects or blocks at measured intervals along the length or perimeter of an object.

MEA _MEASUREGEOM / Measures the distance, radius, angle, area, and volume of selected objects or sequence of points.

MI -MIRROR / Creates a mirrored copy of selected objects.

ML -MLINE / Creates multiple parallel lines.

MLA _MLEADERALIGN / Aligns and spaces selected multilayer objects.

MLC _MLEADERCOLLECT / organizes selected multileaders that contain blocks into rows or columns, and displays the result with a single leader.

MLD _MLEADER / Creates a multileader object.

MLE _MLEADEREDIT / Adds leader lines to, or removes leader lines from, a multileader object.

MLS _MLEADERSTYLE / Creates and modifies multileader styles.

MO _PROPERTIES / Controls properties of existing objects.

MORE _MESHSMOOTHMORE / Increases the level of smoothness for mesh objects by one level.

MS _MSPACE/ Switches from paper space to a model space viewport.

MSM _MARKUP / Opens the markup set manager.

MT _MTEXT / Creates a multiline text object.

MV _MVIEW / Creates and controls layout view ports

N-O

NORTH _GEOGRAPHICLOCATION / Specifies the geographic location information for a drawing file.

NSHOT _NEWSHOT / Creates a named view with motion that is played back when viewed with Show motion.

NVIEW _NEW VIEW / Creates a named view with no motion.

O _OFFSET / Creates concentric circles, parallel lines, and parallel curves.

OP _OPTIONS / Customizes the program settings.

ORBIT _3DORBIT / Rotates the view in 3D space, but constrained to horizontal and vertical orbit only.

OS _OSNAP / Sets running object snap modes.

P

P _PAN / Adds a parameter with grips to a dynamic block definition.

PA _PASTESPEC/Pastes objects from the Clipboard into the current drawing and controls the format of the data.

PAR _PARAMETERS / Controls the associative parameters used in the drawing.

PARAM _PARAMETER / Adds a parameter with grips to a dynamic block definition.

PATCH _SURFPATCH / Creates a new surface by fitting a cap over a surface edge that forms a closed loop

PC _POINTCLOUD / Provides options to create and attach point cloud files.

PCATTACH _POINTCLOUDATTACH / Inserts an indexed point cloud file into the current drawing.

PCINDEX _POINTCLOUDINDEX / Creates an indexed point cloud (PCG or ISD)file from a scan file.

PE _PEDIT/ Edits poly lines and 3D polygon meshes.

PL _PLINE/Creates a 2D poly line.

PO _POINT / Creates a point object.

POFF -HIDEPALETTES /Hides currently displayed palettes (including the command line)

POL _POLYGON / Creates an equilateral closed poly line.

PON _SHOWPALETTES / Restores the display of hidden palettes

PR _PROPERTIES / Displays properties palette.

PRE _PREVIEW / Displays the drawing as it will be plotted.

PRINT _PLOT/Plots a drawing to a plotter, printer, or file.

PS _PSPACE/Switches from a model space viewport to paper space.

PSOLID _POLYSOLID / Creates a 3D wall -like poly solid.

PTW _PUBLISHTOWEB / Creates HTML pages that include images or selected drawings

PU _PURGE / Removes unused items, such as block definitions and layers, from the drawing

PYR _PYRAMID / Creates a 3D solid solid pyramid.

Q

QC _QUICKCALC / Opens the Quick calc calculator.

QCUI _OUICKCUI / Displays the customize User Interface editor in a collapsed state.

QP _QUICKPROPERTIES / Displays open drawing and layouts in drawing in preview images.

QSAVE _QSAVE / Saves the current drawing.

QVD _QVDRAWING / Displays open drawings and layouts in drawing using preview images.

QVDC _QVDRAWINGCLOSE / Closes preview images of open drawings and lay outs in a drawing.

QVL _QVLAYOUT / Displays preview images of model spaces and layouts in a drawing.

QVLC _QVLAYOUTCLOSE / Closes preview images of model space and layouts in the current drawing.

R

R _REDRAW /Refreshes the display in the current viewport.

RA _REDRAWALL / Refreshes the display in all viewports.

RC _RENDERCROP / Renders a specified rectangular area, called a crop window, within a viewport.

RE _REGEN / Regenerates the entire drawing from the current viewport.

REA _REGENALL / Regenerates the drawing and refreshes all viewports.

REC _RECTANG / Creates a rectangular poly line.

REG _REGION / Converts an object that encloses an area into a region object.

REN _RENAME / Changes the names assigned to items such as layers and dimension styles.

REV _REVOLVE / Creates a 3D solid or surface by sweeping a 2D object around an axis

RO _ROTATE / Rotates objects around a base point.

RP _RENDERPRESETS / Specifies render presets, reusable rendering parameters, for rendering an image.

RPR _RPREF / Displays or hides the Advanced render settings palette for access to advance rendering settings.

RP _RENDER/ Creates a photorealistic or realistically shaded image of a 3D solid or surface model.

RW _REDERWIN / Displays the Render window without starting a rendering operation.

S

S _STRETCH / Stretches objects crossed by a selection window or polygon.

SC _SCALE / Enlarges or reduces selected objects, keeping the proportions of the object the same after scaling.

SCR _SCRIPT /Executes a sequence of commands from a script file

SEC _SECTION / Uses the intersection of a plane and solids, surfaces, or mesh to create a region.

SET _SETVAR / Lists or changes the values of system Variables.

SHA _SHADEMODE / Starts the VSCURRENT command.

SL _SLICE / Creates new 3D solids and surfaces by slicing, or dividing, existing objects.

SN _SNAP / Restricts cursor movement to specified intervals.

SO _SOLID / Creates solid-filled triangles and quadrilaterals.

SP _SPELL / Checks spelling in a drawing

SPE _SPLINEDIT / Edits a spine or spline-fit poly line.

SPL _SPLINE / Creates a smooth curve that passes through or near specified points.

SPLANE _SECTIONPLANE / Creates a section object that acts as a cutting plane through 3D objects.

SPLAY _SEQUENCEPLAY / Play s named views in one category

SPLIT _MESHSPLIT / Splits a mesh face into two faces.

SPE _SPLINEDIT / Edits a spline or spline-fit poly line.

SSM _SHEETSET / Opens the sheet set Manager.

ST _STYLE / Creates. Modifies. Or specifies text styles.

STA _STANDARDS / Manages the association of standards files with drawings.

SU _SUBTRACT / Combines selected 3D solids, surfaces, or 2D regions by subtraction.

T

T _MTEXT / Creates a multiline text object.

TA _TABLET / Calibrates, configures, and turns on and off an attached digitizing tablet.

TB _TABLE / Creates an empty table object.

TEDIT _TEXTEDIT / Edits a dimensional constraint, dimension, or text object.

TH _THICKNESS / Sets the default 3D thickness property when creating 2D geometric objects.

TI _TILEMODE / Controls whether paper space can be accessed.

TO _TOOLBAR / Displays, hides , and customizes toolbars.

TOL _TOLERANCE / Creates geometric tolerances contained in a feature control frame.

TOR _TORUS / Creates a donut-shaped 3D solid

TP _TOOLPALETTES / Opens the Tool palettes window.

TR _TRIM / Trims objects to meet the edges of other objects.

TS _TABLESTYLE / Creates modifies, or specifies table styles.

U-W

UC _UCSMAN / Manages defined user coordinate systems.

UN _UNITS / Controls coordinate and angle display formats and precision.

UNHIDE _UNISOLATEOBJECTS / Displays UNIOLATE objects previously hidden with the ISOLATEOBJECTS or HIDEOBJECTS command.

UNI _UNION / Unions two solid or two region objects.

V _VIEW / Saves and restores named views, camera views , layout views, and preset views.

VGO _VIEWGO / Restores a named view.

VP _DVPOINT / Sets the 3D viewing direction.

VPLAY _VIEWPLAY / Plays the animation associated to a named view.

VS _VSCURRENT / Sets the visual style in the current viewport.

VSM _VISUALSTYLES / Creates and modifies visual styles and applies a visual style to a viewport.

W _WEDGE / Creates a 3D solid wedge.

WHEEL _NAVSWHEEL / Displays a wheel that contains a collection of view navigation tools.

X- Z

X _EXPLODE / Breaks a compound object into its component objects.

XA _XATTAC H / Inserts a DWG file as an external reference (xref).

XB _XBIND / Binds one or more definitions of named objects in an xref to the current drawing.

XC _XCLIP / Crops the display of a selected external reference or block reference to a specified boundary.

XL _XLINE/Creates a line of infinite length

XR _XREF / Starts the EXTERNALREFERENCES command.

Z _ZOOM / Increases or decreases the magnification of the view in the current viewport.

ZEBRA _ANLYSISZEBRA / Projects stripes onto a 3D model to analyze surface continuity.

ZIP _ETRANSMIT / Creates a self -extracting or Zipped Transmittal package.

3D Coordinate systems to aid in the construction of 3D objects and knowledge short cut key board commands

Objectives : At the end of this lesson you shall be able to
- **describe solid modeling**
- **describe surface modeling**
- **describe mesh modeling**
- **describe construction plane commands.**

Introduction

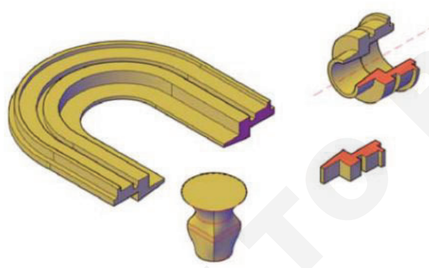
Auto CAD 3D modeling allows you to create drawings using solid, surface, and mesh objects.

Solid, surface, and mesh objects offer different functionality, that, when used together, offer a powerful suite of 3D modeling tools. For example, you can convert a primitive solid to a mesh to take advantage of mesh creasing and smoothing. You can then convert the model to a surface to take advantage of associatively and NURBS modeling.

Solid modeling (Fig 1)

A solid model is a volume that represents a 3D object, and has properties such as mass, center of gravity, and moments of inertia. You can create 3D solids from primitive solids such as cones boxes, cylinders, and pyramids, or by extruding, revolving, sweeping, or lofting closed 2D objects as shown.

Fig 1



You can also combine 3D solids using Boolean operations such as union, subtract, and intersect, The illustration below shows two solids that were extruded from closed poly lines, and then combined by intersecting them. **(Fig 2)**

Surface modeling (Fig 3)

A surface model is a thin shell that does not have mass or volume. Auto CAD offers two types of surfaces: procedural and NURBS, Use procedural surfaces to take advantage of associative modeling, and use NURBS surfaces to take advantage of sculpting with control vertices.

Fig 2

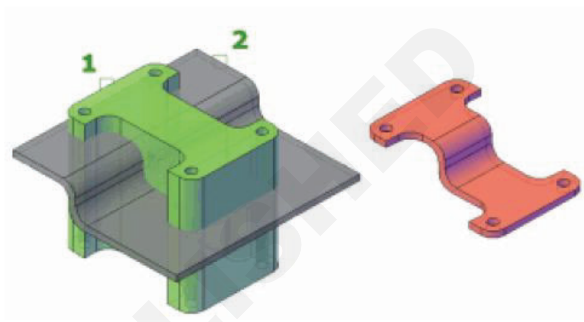
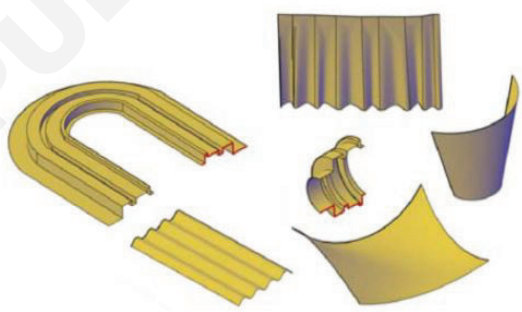


Fig 3



A typical modeling workflow is to create basic models using mesh, solids, and procedural surfaces, and then convert them to nur7bs surfaces. This allows you to utilize not only the unique tools and primitive shapes offered by solids and meshes, but also the shaping capabilities provided by surface - associative modeling and nurbs modeling.

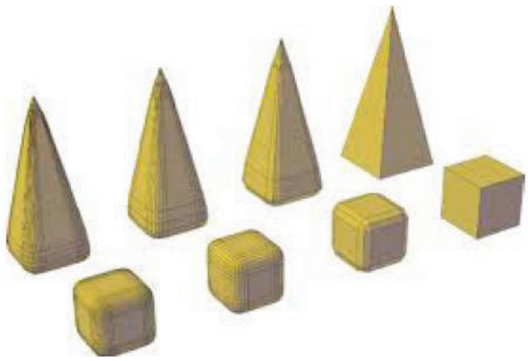
You create surface models using some of the same tools that you use for solid models: sweeping, lofting, extruding, and revolving. You can also create surfaces by blending, patching, offsetting, filleting , and extending other surfaces.

Mesh modeling (Fig 4)

A mesh model consists of vertices, edges, and faces that use polygonal representation (including triangles and quads) to define a 3D shape.

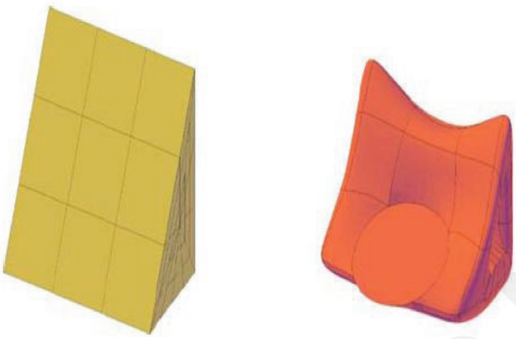
Unlike solid models, mesh has no mass properties. However, as with 3D solids, you can create primitive mesh forms such as boxes, cones and pyramids, starting with

Fig 4



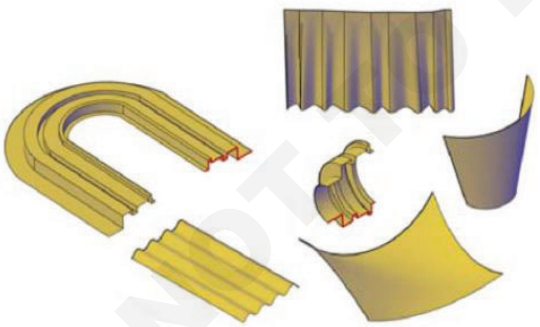
Auto Cad-based products 2010 or later. You can modify mesh models in ways that are not available for 3D solids or surfaces. For example you can apply creases, splits, and increasing levels of smoothness . You can drag mesh sub objects (faces, edges, and vertices) to shape the object. To achieve more granular results, you can refine the mesh in specific areas before modifying it. **(Fig 5)**

Fig 5



Use mesh models to provide the hiding, shading, and rendering capabilities of a solid model without the physical properties such as mass, moments of inertia, and so on. **(Fig 6)**

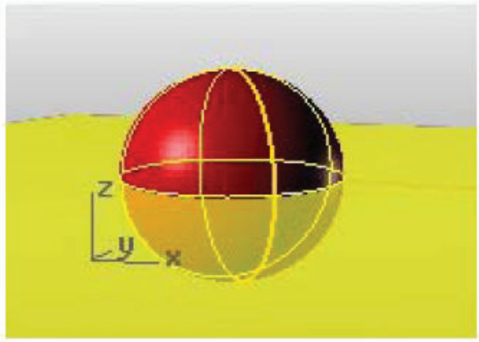
Fig 6



A construction plane is like a tabletop that the cursor normally moves on. The construction plane has an origin, X-and y-axes, and a grid. The construction plane can be set to any orientation, and each viewport's construction plane is independent of those in other viewports. **(Fig 7)**

The construction plane represents the local coordinate system for the viewport and can be different from the world coordinate system.

Fig 7



Rhino's standard viewports come with construction planes that correspond to the viewport. The default perspective viewport, however, uses the world Top construction plane. Which is the same construction plane that Is used in the top viewport.

The construction plane grid lies on the construction plane. The dark red line represents the construction plane Y axis. The red and green lines meet at the construction plane origin. The color of these lines can be changed.

To change the direction and origin of a construction plane, from the menu, use the C plane command. Preset construction planes: world Top, right, and Front give you quick access to common.

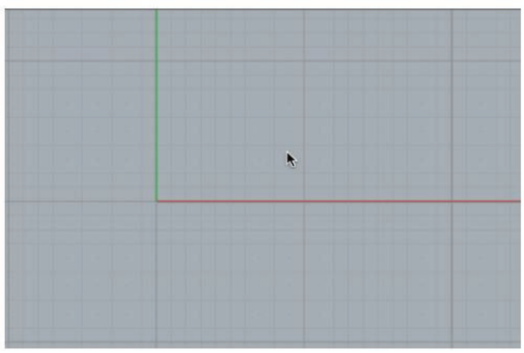
Construction planes: In addition, you can save and restore named construction planes and import named construction planes from another rhino file.

Coordinate input, elevator mode, object snaps, and other cursor constraints allow the cursor to move away from the construction plane.

Notes

- Construction plane behavior in the viewports is controlled by the standard and universal options. With the standard option, the construction plane of each viewport is independent from all of the other constructions planes. With the Universal option, the behavior of the construction planes in the viewports is linked. Set these in Modeling Aids Options. **(Fig 8)**

Fig 8



- The construction plane is infinite. The array of lines lying on a specified portion of the construction plane in the viewport is the grid. The grid is a visual reference only. The size, spacing, and color of the grid lines can be changed.

- The x- and Y-axes of the construction plane are shown on the grid in color by default. The visibility and color of the grid axes can be changed.

- Custom construction planes can be named and saved in the 3dm document, They can be restored in any viewport using the Named C Plane command.

Construction plane commands (Fig 9)

C Plane

Set the construction plane in the active viewport.

Copy C plane settings to all

Match all viewports' grid and snap settings to the specified viewport.

Copy C plane to all

Match all viewports, construction planes to the specified viewport.

M Plane

Set up a relationship between a construction plane and an object.

Shortcut	PC	Mac
Bold	Ctrl +B	Command + B
Italic	Ctrl + I	Command + I
Underline	Ctrl +U	Command +U
Select All	Ctrl + A	Command + A
Redo	Ctrl + Y	Command + Y
	Ctrl+Shift+Z	(Command+ Shift+Z)
Undo	Ctrl + Z	Command + Z
Header 1	Alt+shift+1	Ctrl + Alt + 1
Header 2	Alt+shift+2	Ctrl + Alt + 2
Header 3	Alt+shift+3	Ctrl + Alt + 3
Header 4	Alt+shift+4	Ctrl + Alt + 4
Header 5	Alt+shift+5	Ctrl + Alt + 5
Header 6	Alt+shift+6	Ctrl + Alt + 6
Paragraph	Alt+shift+7	Ctrl + Alt + 7
Div	Alt+shift+8	Ctrl + Alt + 8
Address	Alt+shift+9	Ctrl + Alt + 9
Focus to menu bar	Alt+F9	Alt+F9
Focus to toolbar	Alt+F10	Alt+F10
Focus to (element path)	Alt+F11	Alt+F11

Named C plane.

Manage the named construction planes list.

Universal construction plane.

Link the viewport origin and position.

Fig 9

Shortcut keys ABCs

Shortcut keys help provide an easier and usually quicker method of navigating and executing commands in computer software programs. Shortcut keys are commonly accessed by using the alt key (On IBM compatible computers), command key (on Apple computers), Ctrl key, or shift key in conjunction with another key. The de facto standard for listing a shortcut is listing the modifier key, a plus symbol, and another key. In other words, "Ctrl +S" is telling you to press and hole the Ctrl key, and then press the S key too.

You can also find the shortcut keys to their most popular program by looking for underlined letters in their menus. For example, the image to the right has an underline on the "F' in file, which menus. You can press the Alt key and then the "F" key to access the File menu. Some programs require the user to press and hold Alt to see the underlined

Characters. In the same image above, you can see that some of the common features, such as open (Ctrl+ O) and save (Ctrl + S), have shortcut keys assigned to them. As you begin to memorize shortcut keys, you'll notice that many applications share the same shortcut keys. We have a list of the most commonly shared ones in the basic PC shortcut keys section.

Tip: Users outside the United states or who have a foreign copy of Microsoft Windows or a Microsoft application may not be able to use all of the below shortcut keys.

Basic PC shortcut keys

Below is a list of some of the most commonly used basic shortcut keys that work with almost all IBM compatible computers and software programs. It is highly recommended that all users keep a good reference of these shortcut keys or try to memorize them. Doing so will dramatically increase your productivity.

Tip: Besides the special character shortcuts listed here, some special characters are also located on the number keys (below the F1-F12 Keys). You can enter these special characters by pressing the Shift key and the number key that has the special. Character listed on it.

Shortcut keys	Description
Alt + F	File menu options in current program
Alt + E	Edit options in current program
Alt + Tab	Switch between open programs
F1	Universal help in almost every Windows program
F2	Rename a selected file
F5	Refresh the current program window
Ctrl + N	Create a new, blank document in some software programs
Ctrl + O	Open a file in current software program
Ctrl + A	Select all text.
Ctrl + B	Change selected text to be bold
Ctrl +I	Change selected text to be in Italics
Ctrl + U	Change selected text to be underlined
Ctrl + F	Open find window for current document or window.
Ctrl + S	Save current document file.
Ctrl + X	Cut selected item
Shift + Del	Cut selected item.
Ctrl + C	Copy selected item.
Ctrl + Ins	Copy selected item
Ctrl + Y	Redo last action
Ctrl + K	Insert hyperlink for selected text
Ctrl + P	Print the current page or document
Home	Goes to beginning of current line
Ctrl + Home	Goes to beginning of document
End	Goes to end of current line
Ctrl + End	Goes to end of document.
Shift + Home	Highlights from current position to beginning of line.
Shift + End	Highlights from current position to end of line
Ctrl + Left Arrow	Moves one word to the left at a time
Ctrl + Right Arrow	Moves one word to the right at time
Ctrl + Esc	Opens the START menu
Ctrl + Shift + Esc	Opens windows task manager
Alt + F4	Close the currently active program
Alt + Enter	Open the properties for the selected item (file, folder, shortcut, etc,)

PC shortcut keys for special characters

Many special characters can be created using keyboard shortcuts, Below are some of the more common and popular special characters and the keyboard shortcuts to create them.

Shortcut keys	Description
Alt + 0224	à
Alt + 0232	è
Alt + 0236	ì
Alt + 0242	ò
Alt + 0241	ñ
Alt + 0228	ä
Alt + 0246	ö
Alt + 0252	ü
Alt + 0248	ø
Alt + 0223	ß
Alt + 0198	Æ
Alt + 0231	ç
Alt + 0191	¿
Alt + 0176	° (degree symbol)
Alt + 0177	± (plus/minus symbol)
Alt + 0153	™
Alt + 0169	©
Alt + 0174	®
Alt + 0128	• (Euro currency)
Alt + 0162	¢ (Cent symbol)
Alt+0163	£ (British pound currency)
Alt+ 0165	¥ (Japanese yen currency)
Focus to contextual toolbar	Ctrl + Shift + E Ctrl + Shift + E
	Ctrl + Shift + P Ctrl + Shift + P
Insert Link	Ctrl + K Command + K
Toggle Full screen	Ctrl + Shift + F Ctrl + Shift + F
Save	Ctrl + S Command + S
Find	Ctrl + F+ Query Command + F+ Query

Type of recreation land scaping etc

Objectives : At the end of these lesson you shall be able to
- **describe the types of recreation**
- **define park**
- **classification of parks.**

Introduction: Now a days man moved to towns and cities and there came to the urban civilization. As a by-product of this civilization, the town in and around became polluted in all respects even at this state he has got the deep rooted desire to remain in contact with soil and it is for this reason that open spaces in the form of parks and playgrounds should invariably be provided in all town planning.

Types of recreations

On the basis of services rendered by open spaces in the form of recreation, they can be divided into the following two types.

Passive type recreation or parks

Active type recreation or play grounds.

Definition: The park is a place which is provided to meet with the needs of fresh air and peaceful enjoyment of the unspoiled nature.

Location of urban parks: The urban green space should be located in the town plan very carefully as they serve as a kind of filter or protection against noise, dust, hot sun and harrmful winds.

Classification parks: The parks can be classified into the following three ways.

According to character: These are prepared artificially with greats lone by experts in the parks layout. They are planted with grass, shrubs, flower and trees. The water may be introduced in the form of fountains and pools. The seats of suitable design may be provided.

Amusement park or theme park: It is group of entertainment attraction rides, and other events in a location for the enjoyment of loss human of peoples.

Natural parks: In these parks, all efforts are made to maintain the original features of parks and only the necessary minimum adjustment are made to put them for public use.

According to purpose: Botanical parks: These parks are primarily meant for the study of plant specimens. But their atmosphere can be made more pleasant and appealing by the presence of beautiful trees, flowers and lawns.

Zoological parks: These parks contain zoo and it is absolutely necessary for the zoo be given an atrractive parklike setting. A zoological park contains houses and other facilities for animals to be maintained in the zoo.

According to size

Small size parks: The area of these parks varies from one hectare to 4 hectare.

Medium size parks: The size of the parks should not be less than 12 hectares. In this parks, both types of recreation passive as well as active, may be provided.

Large size parks: The minimum size required for this type of parks is about 40 hectares. This park as a summation of all types of active recreations like cricket, boating, riding, swimming etc and different types of passive recreations. It also accommodate zoological gardens.

Reservations: The minimum area required for this type of park is 400 hectares. These parks are situated outside the city limits and they include extensive areas of natural sceneries.

National parks: The area of these types of parks may run into thousands to lakhs of hectares. These may includes within their limits Rivers, forests, waterfalls, mountains, wild life places of historical importance, coastal belts. etc,

Play grounds

Objectives : At the end of this exercise, you shall be able to
- **define play grounds**
- **classifications as per age group**
- **describe the size of playgrounds for organized games.**

Introduction: From the days of mankind itself, human beings had more interest to keep themselves physically fit. They also had a deep passion to keep themselves engaged in various active recreations, and there by they managed to maintain sound health, both physically and mentally.

Definition: Play ground is a place with a specific design to allow man to play there. The playgrounds furnish opportunities for the physical growth of body by actively engaging muscels in various games.

Play grounds: The size and location of playgrounds will depend upon the age group of people for whom they are required. The provision for various age groups are as follows

Children upto the age of 6 years: It is quite obvious that playground must be near their homes, say within a radius of 400m as they cannot be expected to travel safely more than this distance. The playground must have fencing all round and for further safety, the children play must be supervised, the usual provision is 0.13 hectare per 1000 children,

Children at school: Each school should have its own playground. The land required for primary schools is aboul 0.40 hectare for 1000 pupils and for secondary school, it is about 1.20 hectares per 1000 pupils.

Youth and adults: The provision should be within a range of 3 kms or so. The land required is about 1 hectare per 1000 population.

Private clubs: The provision should be made at the rate of 1.20 hectares per 100 members.

If all the above requirements are grouped together, the aggregate area of land required works out to about 2.40 hectares per 1000 population and hence, the open space, for playgrounds should accordingly be reserved in the town planning scheme.

Size and layout of organized games

Athletic field - 400 meters

Volley ball court

Foot ball

shuttle badminton

Landscape

Objectives : At the end of this lesson you shall be able to
- **define landscape**
- **state the elements of soft and hard land scape**
- **state the basic landscape principles.**

Introduction: Landscape architecture helps in bringing man closer to nature by allowing him to think about the scenic visual quality of outdoor space. Hence it is rightly considered as a part of environmental design. Cheerful, colourful and refreshing landscape creates a stimulating environment

Mass tree plantation on hills and on the slopes of hills, in green belts, on river banks, around industries and in open spaces is found useful to control pollution, noise and dust. It also controls temperature and humidity. Towns with well planned landscapes, with mass tree plantation act as environmental filter number one.

The relationship of human being with the surrounding physical environment is long and instinctive. It is developed gradually right from childhood through paintings, poetry, literature films television and while observing flowers and plants. A garden is considered as an extension of the house while parks in towns are considered as lungs with clean air for citizens.

Towns with open spaces for parks and gardens, residential and other types of building with their open space around the building and their terraces, industries with their specific problems of controlling pollution, amusement parks, hotels, aerodromes, roadways, riverbanks, etc. are some areas that require the service of a landscape architect. A landscape architect works with ecologists, horticulturists. Architects and services engineers, besides clients.

Definition: Landscape ecology is the science of studying and improving relationship between ecological processes in the environment and particular ecosystems.

Soft and hard landscape: The total landscape design consists of two parts soft landscape and hard landscape. The details mentioned in the following lines will throw light on various consideration in soft and hard landscaping which will help achieving unity in design with low cost maintenance.

Soft landscape deals with plantations, their unitary selection, types of trees, shrubs and hedges vines and climbers. It also deals with ground cover, planning of gardens, terrace gardens and their maintenance.

Hard landscape deals with design of space for people and their pedestriain movements. It includes footpaths and cycle ways and also deals with areas around view points, space between buildings, paved surfaces from road to the entrance of a buildings or around buildins. Human scale, their to and fro movements, visual quality of the surrounding and relation to the building and its finishing material are the major considerations in this design.

A harmony between soft and hard landscapes results in pleasing patterns and scenic in small or large available plot areas. It also gives a picturesque identity to the town Imaginative utilization of the total available space finally adds to the visual quality of natural and man-made features in the town and around the buildings.

Basic landscaping principles: The extent of landscaping varies from small areas around buildings to gardens and parks. Housing complexes, industrial complexes, amusement parks, water scopes in the garden, terraces on buildings, hotel complexes in and around cities and numerous other areas. The demands of the client. budget, nature of land and climate are some variable factors involved.

Some common basic principles to remembered and implemented in landscaping are as follows:

Unity: Plants, gradients and structures all work harmoniously together.

Balance: To use mass of vegetation, colour or form to create equal visual weight on either side of the centre of interest.

proportion: To take into consideration the scale of the buildings, ultimate size of trees and shrubs.

Variety: Breaking of monotonous effect by selecting suitable of trees and plants with variety in texture and colour. To create elements of surprise in landscaping.

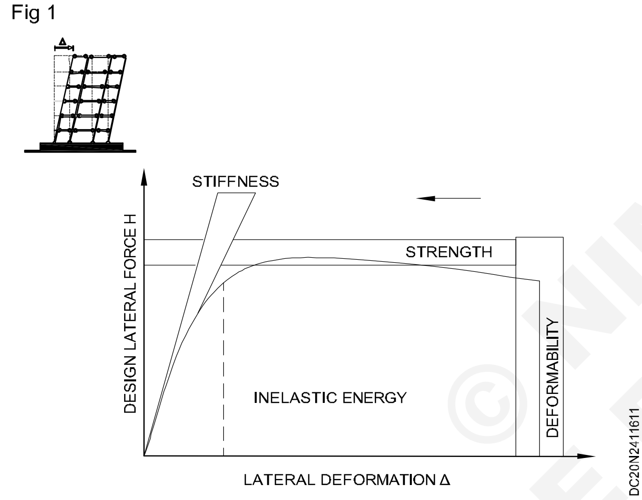
Earthquake resisting building

Objectives : At the end of this lesson you shall be able to
- **define earthquakes**
- **state types earthquakes**
- **explain magnitude and intensity of earth quake**
- **explain terminology and seismograph.**

Introduction

Investigations of past and recent earthquake damage have illustrated that the building structure are vulnerable to severe damage and/or collapse during moderate to strong ground motion. Among the possible structural damages, seismic induced pounding has been commonly observed in several earthquakes. (Fig 1)

Fig 1



Ground shaking from earthquakes can collapse buildings and bridges, disrupt gas, electric, and phone services and sometimes trigger landslides, avalanches, flash floods, fires, and huge, destructive ocean waves (tsunamis). Every year, earthquakes take the lives of thousands of people, and destroy property worth billions of dollars. Hence, the study of earthquakes and their seismic effects induced on structures are necessary.

The natural disasters like earthquake cannot be prevented, but measures are required to be taken to reduce the extent of damage. Therefore, designing earthquake resistant structures is indispensable.

This loss of life and property can be prevented by using latest techniques and developments in the field of earth quake engineering. It is imperative that structures are designed to resist earthquake forces, in order to reduce the loss of life.

The paper discusses the impact of earthquakes on building structures, seismic effects on the structure, hazardous effects of earthquakes, necessity of construction of earthquake resistant structures by using latest techniques such as base isolation and energy dissipation devices. What are earthquake resistant structures? How do we design them? are enrolled.

Definition

Earthquakes are natural phenomena, while cause the ground to shake. The earth's interior is hot and in a molten state. As the lava comes to the surface, it cools and new land is formed. The lands so formed have to continuously keep drifting to allow new material to surface. According to the theory of plate tectonics, the entire surface of the earth can be considered to be like several plates, constantly on the move. These plates brush against each other or collide at their boundaries giving rise to earthquakes. Therefore regions close to the plate boundaries exhibit less seismicity. Earthquakes may also be caused by other actions such as underground explosions.

Types of earthquakes

Depending upon the possible cause, the earthquakes may be classified as:

Natural earthquake.

Earthquakes due to induced activities.

Natural earthquakes.

Natural earthquakes may be due to active faults.

Movement of tectonic plates or due to volcanic eruptions.

In earth's crust there are some faults which are not yet settled. The displacement of rocks along faults cause earthquake.

Tectonic means large scale process affecting the structure of the earth curst. This process causes gradual movement of material within the crust of earth. Sometimes it shakes the earth crust.

Volcano is a mountain or hill having a crater through which lava, rock fragments, hot vapour and gas are or have been erupted from the earths crust. Occasionally the volcanoes become active and create earthquake near the mountain crater.

Earthquakes due to induced activities

These are caused by vibrations induced by atomic explosions and collapse of ground due to faulty mining.

Magnitude and intensity of earthquake

The richter magnitude scale

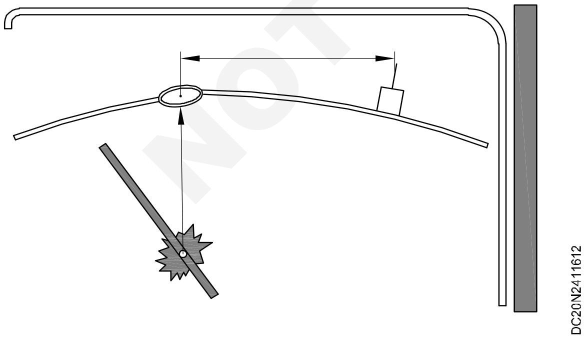
Seismic waves are the vibrations from earthquakes that travel through the earth. They are recorded on instruments called seismographs, Seismographs record a zigzag trace that shows the changing in amplitude of ground oscillations beneath the instrument. Sensitive seismographs, which greatly magnify these ground motions, can detect strong earthquakes from sources anywhere in the world. The time , location, and magnitude of an earthquake can be determined from the data recorded by seismograph stations. The richter scale was developed as a mathematical device to compare the size of earthquakes.

The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. On the Richter scale, magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude of 5.0 might be computed for a moderate earth quake, and a strong earthquake might be rated as magnitude 6.0. Each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

The richter scale is not used to express damage. An earthquake in a densely populated area which results in many deaths and considerable damage may have the same magnitude as a shock in a remote area that does nothing more than frightens the wildlife. Large - magnitude earthquakes that occur beneath the oceans may not even be felt by humans. Earthquakes with magnitude of about 2.0 or less are usually called micro earth quakes; they are not commonly felt by people and are generally recorded only on local seismographs. Events with Magnitudes of about 4.5 or greater. There are several thousand such shocks annually are strong enough to be recorded by sensitive seismographs all over the world. Great earthquakes, such as the 1964 good Friday earthquake in Alaska, have magnitudes of 8.0 or higher. On the average, one earthquake of such size occurs somewhere in the world each year.

The modified meracal intensity scale (Fig 2)

Fig 2



The effect of an earthquake on the Earth's surface is called the intensity. The intensity scale consists of a series of certain key response such as people awakening, movement of furniture, damage to chimneys, and finally total destruction. The current intensity scale being used in the U.S. is the modified Mercalli (MM) intensity scale. The scale is composed of 12 increasing levels if intensity that range from imperceptible shaking to catastrophic destruction. This scale does not have a mathematical basis, instead it is an arbitrary ranking system based on observed effects.

To following is an abbreviated description of the 12 levels of modified mercalli intensity (MMI)

Not fell except by a very few under especially favorable conditions

Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing

Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Durable estimated.

Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed: wall shake cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

Felt by nearly everyone, many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

Felt by all, many frightened . Some heavy furniture moved, a few instances of fallen plaster.

Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary structures, considerable damage in poorly built of badly designed structures' some chimneys broken.

Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

Damage considerable in specially designed structures well-designed frame structures throw out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

Some well-built wooden structure destroyed, most masonry and frame structures destroyed with foundations. Rails bent.

Few, if any (masonry) structures remain standing. Bridges destroyed. Rail bent greatly.

Damage total lines of sight and

Terminology

Focus: The point on the fault where slip starts is the focus. It is also known as hypocenter.

Epicenter: The point vertically above the focus on he surface of the earth is the epicenter.

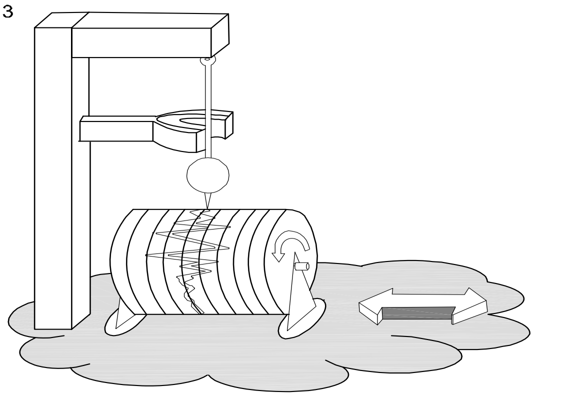
Focal depth: The depth of focus from the epicenter is called the focal depth.

Epicentral distance: Distance from epicenter to any point of interest on the surface of earth is called epicentral distance.

Seismograph (Fig 3)

Seismograph is an instrument for measuring oscillation of earth during earthquakes. It has three major components the sensor, the recorder and the timer. Figure shows a typical seismograph. The pendulum mass, string, magnet and support together constitute the sensor. The drum, pen and chart paper constitute the recording.

Fig 3

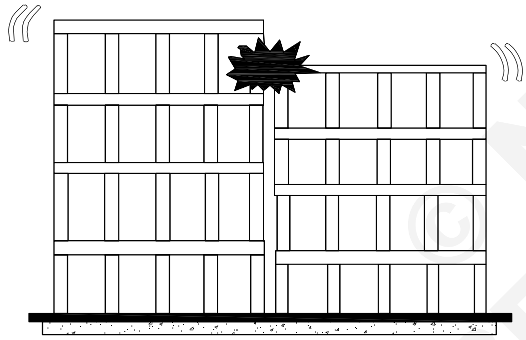


Earthquake hazards & seismic effect

Objectives : At the end of this lesson you shall be able to
- **describe types of earthquake hazards**
- **explain how to building respond to earthquakes**
- **explain seismic effects on structure.**

Earthquake hazards (Fig 1): Pounding of adjoining structures. Pounding occurs between the two adjoining and structures and is dangerous.

Fig 1



Ground sliding (Fig 2): Strong ground motion is also the primary cause of damages to the ground and soil upon which, or in which people must build. These damages to the soil and ground can take a variety of forms, cracking and fissuring and weakening, sinking. Settlement and surface fault displacement.

Fig 2

Sometimes, due to earthquake, there is tilting action in the ground. This causes plain land to tilt, causing excessive stresses on building, resulting in damage to buildings. (Fig 3)

Fig 3

Differential settlement: A structure built upon soil which is not homogeneous, there is differential settlement, with some part of the structure sinking more than other inducing excessive stresses and causes cracking. (Fig 4)

How to buildings respond to earthquakes: The dynamic response of building to earthquake ground motion is the most important cause of earthquake-induced damage to buildings. The damage that a building suffers primarily depends not upon its displacement, but upon acceleration. Whereas displacement is the actual distance the and building may move during an earthquake,

Fig 4

acceleration is a measure of how quickly they change speed as they move. During an earthquake, the speed at which both the ground and building are moving will reach some maximum. The more quickly they reach this maximum, the greater their acceleration.

Liquefaction (Fig 5): During an earthquake significant damage can result due to instability of the soil may result in the development of excess hydrostatic pour water pressure of sufficient magnitude to cause liquefaction of the soil, resulting in settlement, tilting and rupture of structures

Fig 5

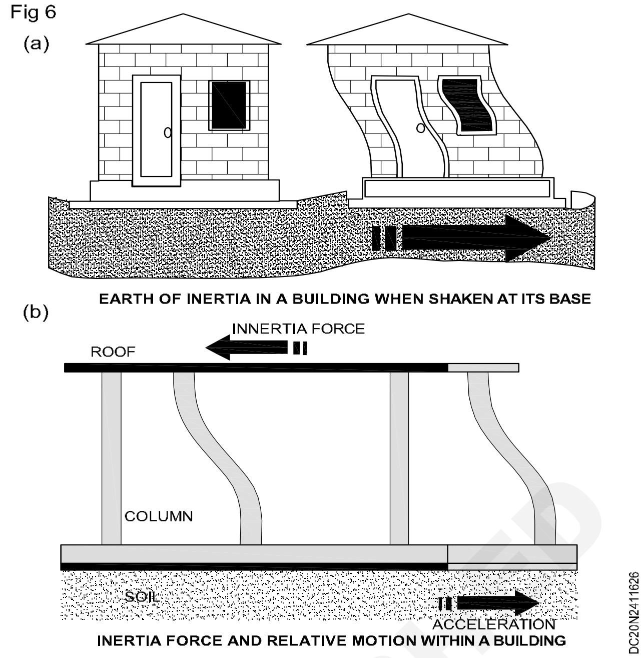
Seismic effects on structures: Earthquake ground motion: The seismic waves travel for great distances before finally losing most of their energy. At some time after their generation, these seismic waves will reach the earth' surface, and set it in motion. Which we surprisingly refer to as earthquake ground motion. When this earthquake ground motion occurs beneath a building and when it is strong enough, it sets the buildings in motion, starting with the buildings foundation, and transfers the motion throughout the rest of building in very complex way. These motions in turn induce forces which can produce damage.

Real earthquake ground motion at a particular building site is vastly more complicated than the simple wave from. Here it's useful to compare the surface of ground under an earthquake to the surface of a small body of water like a pond. You can set the surface of a pond in motion by throwing stones into it. The first few stones create a series of circular waves. Which soon being to collide with one another. After while, the collisions, which term interference patterns, are being to predominate over the pattern of circular waves. Soon the entire surface of water is covered by ripples and you can no longer make out the original wave forms. During an earthquake, the ground vibrates in a similar manner, as waves of different frequencies and amplitude interact with one another.

Ground motion an building frequencies: (Fig 6a & 6b): Response of the building to ground motion is a complicated as the ground motion itself. Yet typically quite different. It also begins to vibrate in a complex manner, and because it is now a vibratory system , it also possesses a frequency content. However, the building's cob rations tend to center around one particular frequency. Which is known as its natural or fundamental frequency. So the shorter a building is the higher its natural frequency. The taller the building is, the lower its natural frequency.

Seismic zones: In most countries, the macro level seismic zones are defined on the basis of seismic intensity scales. In this guide, we shall refer to seismic zones as defined with reference to MSK intensity scale as described in appendix I for buildings.

Fig 6



Zone A: Risk of widespread collapse and destruction (MSK IX or greater),

Zone B: Risk of collapse and heavy and heavy damage (MSK vIII likely),

Zone C: Risk of damage (MSK VII likely),

Zone D: Risk of minor damage (MSK VI maximum),

The extent of special earthquake strengthening should be greatest in Zone A and, for reasons of economy , can be decreased in zone C, with relatively little special strengthening in zone D. However, since the principles state in 3.1 are good principle for building in general (Not just for earthquake), they should always be followed.

Building frequency and period: Another way to understand this to think of the building's response in terms of its natural period. The building period is simply the inverse of the frequency: Whereas, the frequency is the number of times per second that the building will vibrate back and forth, the period is time it takes for the building to make one complete vibration. The relationship between frequency f and the period T is: $T= 1/f$. This means that a short building with a high natural frequency also has short natural period. A very tall building with a low frequency has a long period. For example, It takes the empire state building a comparatively long time to away back and forth during a strong gust of wind.

Building stiffness: The taller a building, the longer its natural period tends to be. But the height of a building is also related to another important structural characteristic: The building's flexibility. Taller buildings tend to be more flexible than short buildings. (consider a thin metal rod. If the rod is somewhat longer, and of the same diameter it becomes much easier to bend. Buildings behave similarly.) So, a short building is a stiff. While a taller building is flexible.

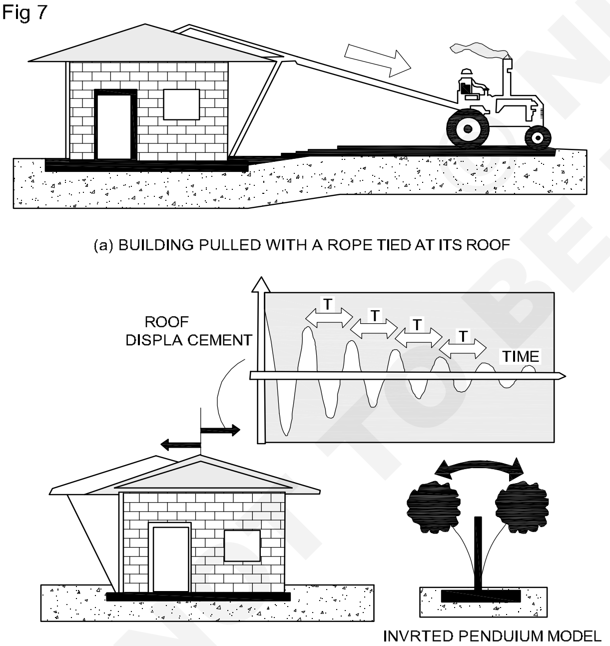
Stiffness greatly affects the building's uptake of earthquake generated force. Reconsider the example above, of the rigid stone block deeply founded in the soil. The rigid block of stone is very stiff; as result responds in a simple., dramatic manner. Real buildings, of course are more inherently flexible. Being composed of many different parts.

Furthermore, not only is the block stiff, it is brittle: and because of this, it cracks during the earthquake. This leads us to the next important structural character sting affecting a building's earthquake response and performance: ductility.

Ductility: Ductility is the ability to undergo distortion or deformation bending, for example without resulting in complete breakage of failure. The ductility or flexibility of structure is one of the most important factors affecting its earth quake performance. One of the primary tasks of an engineer designing a building to be earthquake resistant is to ensure that the building will possess enough ductility to withstand the size and types of earthquakes it is likely to experience during its lifetime.

Damping (Fig 7): All vibrating objects, including, will eventually stop vibrating as time goes on. More precisely, the amplitude of vibration decays with time. Without damping, a vibrating object would never stop vibrating. Once it had been set in motion. In a building during an earthquake, damping the decay of the amplitude of building's vibrations is due to internal friction and the absorption of energy by the building's structural and nonstructural elements.

Fig 7



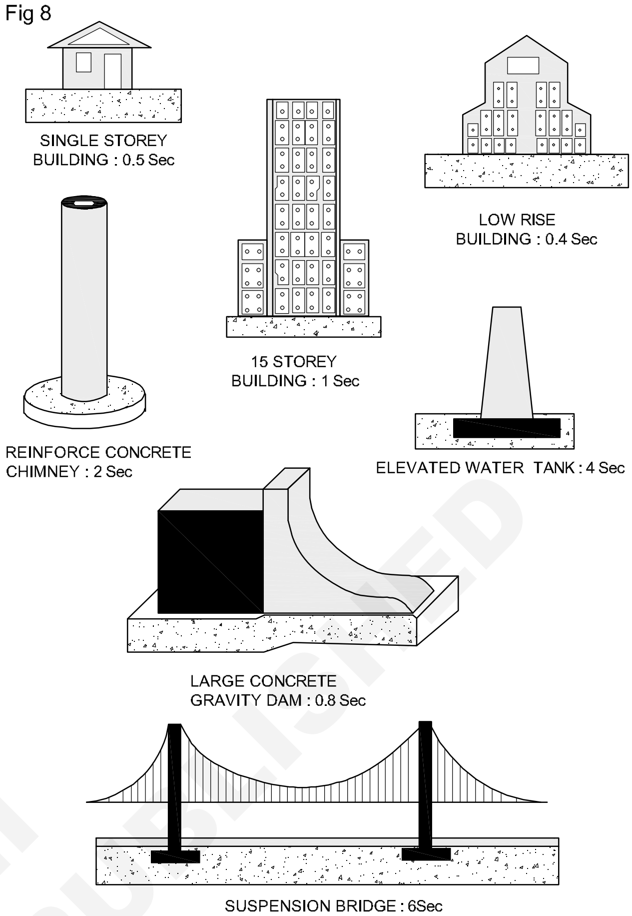
(a) BUILDING PULLED WITH A ROPE TIED AT ITS ROOF

(b) OSCILATION OF BUILDING ON CUTTING THE ROPE

FREE VIBRATION OF RESPONSE OF A BUILDING :
THE BLACK AND FORTH MOTION IS PERIODIC.

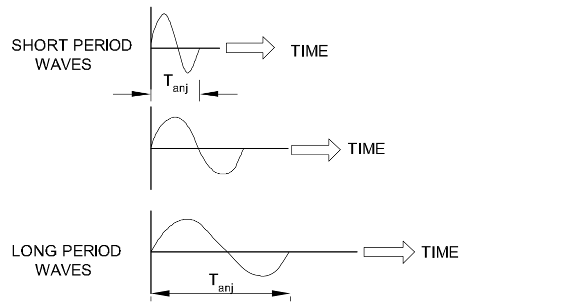
All buildings have some intrinsic damping. The more damping a building possesses, the sooner it will stop vibrating which of course is better. Today, some of the more advanced techniques of earthquake resistant design and construction employ added damping devices like shock absorbers to increase artificially the intrinsic damping of a building and so improve its earthquake performance. (Figs 8 & 9)

Fig 8



FANTAMENTAL NATURAL PERIODS OF STRUCTURES DIFFER OVER A LARGE RANGE.THE NATURAL PERIOD VALUES ARE ONLY INDICATIVE ; DEPENDING ACTUAL PROPERTIES OF THRE STRUCTURE , NATURAL PERIOD MAY VARY CONSIDERABLY

Fig 9



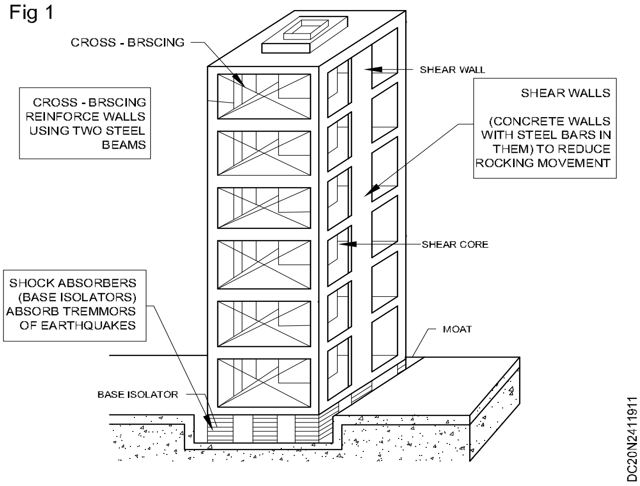
STRONG EARTH QUAKE GROUND MOTION IS TRANSMITTED BY WAVES OF DIFFERENT PERIODS

Earthquake resistant structure

Objectives : At the end of this lesson, you shall be able to
- **state the concept of earthquake**
- **explain the structural safety.**

Concept of earthquake resisting buildings (Fig 1)

Fig 1



Experience in past earthquakes has demonstrated that many common buildings and typical methods of construction lack basic resistance to earthquake forces. In most cases this resistance can be achieved by following simple, inexpensive principles of good building construction practice. Adherence to these simple rules will not prevent all damage in moderate or large earthquakes, but life threatening collapses should be prevented, and damage limited to repairable proportions. These principles fall into several broad categories.

Planning and layout of the building involving consideration of the location of rooms and walls, openings such as doors and windows, the number of storey's, etc. At this stage, site and foundation aspects should also be considered.

Layout and general design of the structural framing system with special attention to furnishing lateral resistance, and Consideration of highly loaded and critical sections with provision of reinforcement as required.

Earthquake - proof: An earthquake proof building is a building that has been built to survive an earthquake. The building is built with special technology that has materials made in earthquake areas. No building, however, can be made 100% safe and building earthquake proof structures to be more effective is just trial and error.

Why earthquake resistant structural design?

Buildings or structures are usually designed to bear only vertical loads. However, in the event of an earthquake. The ground shakes to & fro. This motion of the ground, imposes an additional horizontal load on the building which it is unable to withstand unless specifically so designed: hence the damage.

Surprisingly, the additional cost to make a building/ structure earthquake resistant is very low, usually about 5% of the structural cost of the building which comes out to be not more than.

How to build?

A number of methods have been developed to build earthquake - resistant structures. These techniques range from extremely simple to fairly complex. For small to medium - sized buildings, the simpler reinforcement techniques include making the structure ductile when subjected to earthquake. This ductility is achieved using properly placed reinforcement and providing support walls called shear walls. Shear walls, made of reinforced concrete (concrete with steel rods or bars embedded (in it). help

Strengthen the structure and help resist rocking forces

Sometimes, the buildings are protected using medium sized devices that act like shock absorbers between the building and its foundation. These devices called base isolators, are usually bearings made of alternate layers of steel and an elastic material such as synthetic rubber. Also base isolators absorbs some of the sideways motion that would otherwise damage a building.

Reducing earthquake damage

An earthquake - resistant building has a number of special structural features. Interior support walls called shear walls, made of reinforced concrete. Strengthen the structure and help resist rocking forces. Shear walls in the center of a building form a shear core. Cross - bracing reinforces walls with diagonal steel beams. Base isolators act as shock absorbers, and a most allows a building to sway.

Seismic retrofitting

Seismic retrofitting means providing earthquake resistance to an old building. Retrofitting also allows a building to withstand much greater earthquake forces then those for which it was originally designed with much less structural damage. Retrofitting also means making a building re - serviceable and reusable after it has suffered moderate to major structural damages during an earthquake. A seismic retrofitting generally costs between 1% and 3% of a home's value.

Structural safety

As a result of the discussion of structural action and mechanism of failure of chapter 2, the following main requirements of structural safety of buildings can be arrived

A free standing wall must be designed to be safe as a vertical cantilever.

This requirements will be difficult to achieve in un-reinforced masonry in zone A. Therefore all partitions inside the buildings must be held on the sides as well as top. Parapets of category I and II buildings must be reinforced and held to the main structural slabs or frames.

Horizontal reinforcement in walls is required for transferring their own out-of-plane inertia load horizontally to the shear walls.

The walls must be effectively tied together to avoid separation at vertical joints due to ground shaking.

Shear walls must be present along both axes of the building.

A shear wall must be capable of resisting all horizontal forces due to its own mass and those transmitted to it.

Roof or floor elements must be tied together and be capable of exhibiting diaphragm action.

Trusses must be anchored to the supporting walls and have an arrangement for transferring their inertia force to the end walls.

To meet these safety requirements are presented in the following chapters for various building types. In view of the low seismicity of Zone D, no strengthening measures from seismic consideration are considered necessary except and emphasis on good quality of construction. The following recommendations are therefore intended for Zones A, B and C. For this purpose certain categories of construction in a number of situations were defined in table.

Table : Categories of buildings for stregthening puposes

Category	**Combination of contionuous for the catergory**
I	Important building on soft soil in zone A
II	Important building on firm soil in zone A
	Important building on soft soil in zone B
	Important building on soft soil in zone A
III	Important building on firm soil in zone B
	Important building on soft soil in zone C
	Important building on firm soil in zone A
	Important building on soft soil in zone B
IV	Important building on firm soil in zone C
	Important building on firm soil in zone B
	Important building on firm soil in zone C

I.S: Codes on earthquake resistant buildings

After observing Indian earthquakes for several years bureau of Indian standard has divided the country into five zones depending upon the severity of earthquake. IS 1893 -1984 shows the various zones.

The following IS codes will be of great importance for the design engineers:

IS 1893 - 2002: Criteria for earthquake resistant design of structures (5th revision)

IS 4928 - 1993: Code of practice for earthquake resistant design and construction of buildings. (2nd revision)

IS 13827- 1992: Guidelines for improving earthquake resistance of low strength masonry building.

IS 13920 -1997: Code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces.

IS 13935 - 1993: Guidelines for repair and seismic strengthening of buildings.

Improving earthquake resistant for structure

Objective : At the end of this lesson you shall be able to
- **explain special requirement for earth quake in small and tall building.**

Special requirements for earth quake resisting buildings

For small building (Fig 1)

The earthquake resistance of small buildings may be increased by taking some precautions and measures in site selections, building planning and constructions as explained below:

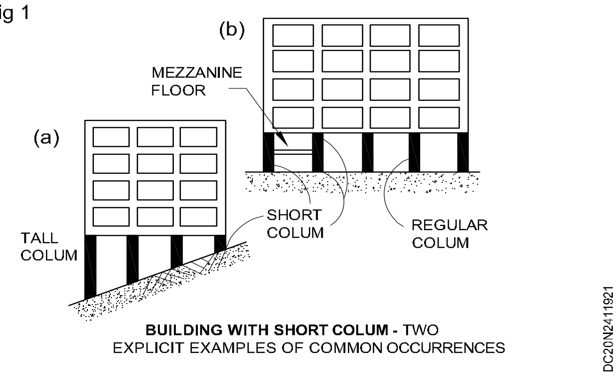
Site selection: The building constructions should be avoided on

Near unstable embankments

On sloping ground with columns of different heights

Flood affected areas

Fig 1

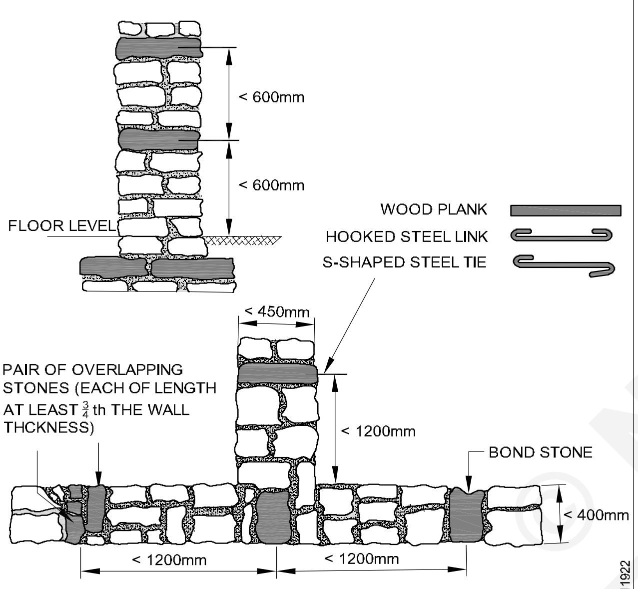


On subsoil with marked discontinuity like rock in some portion and soil in some portion.

Building planning: Symmetric plans are safer compared to unsymmetrical. Hence go for square or rectangular plans rather than L, E, H, T shaped. Rectangular plans should not have length more than twice the width.

Foundations: Width of foundation should not be less than 750 mm for single storey building and not less than 900 mm for storeyed buildings. Depth of foundation should not be less than 1.0 m for soft soil and 0.45 m for rocky ground. Before foundation is laid remove all loose materials including water from the trench and compact the bottom. After foundation is laid back-fill the foundation properly and compact. (Fig 2)

Fig 2



USE OF THROUGH STONES OR BOND STONES IN STONE MASONRY WALLS-VITAL IN PREVENTING THE WALL FROM SEPARATING INTO WYTHES

Masonry. In case of stone masonry

Place each stone flat on its broadest face.

Place length of stones into the thickness of wall to ensure interlocking inside and outside faces of the wall.

Fill the voids using small chips of the stones with minimum possible mortar.

Break the stone to make it angular so that it has no rounded face.

At every 600 to 750 mm distance use through stones.

In case of brick masonry.

Use properly burnt bricks only.

good bond.

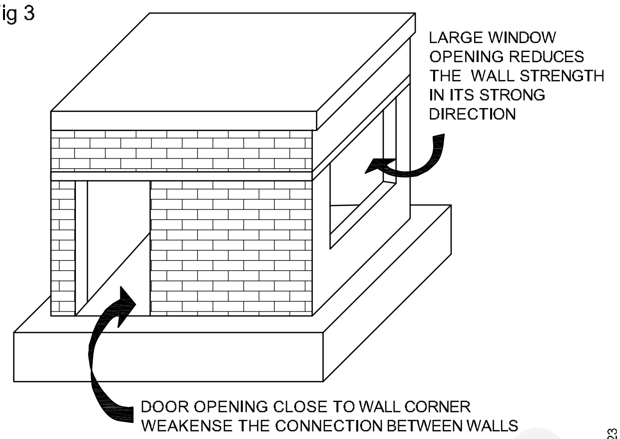
Blocks should be strong.

Brush the top and bottom faces before laying.

In general walls of more than 450 mm should be avoided. Length of wall should be restricted to 6 m. Cross walls make the masonry stronger. It is better to build partition.

Doors and window openings (Fig 3)

Fig 3



OPENINGS WEAKEN WALLS IN A MASONRY - BUILDING - A SINGLE CLOSED HORIZONTAL BAND MUST BE PROVIDED ABOVE ALL THEM.

Walls with too many doors and windows close to each other collapse early.

Windows should be kept as same level.

The total width of all openings in wall should not exceeded the length of wall.

Doors should not be placed at the end of the wall. They should be at least at 500 mm from the cross wall.

Clear width between two openings should not be less than 600 mm.

Roof

In sloping roofs with span greater than 6 m use trusses instead of rafters.

Buildings with 4 sided sloping roof is stronger than the one with two sided sloping, since gable walls collapse early.

Chajas

Restrict chaja or balcony projections to 0.9 m. For larger projections use beams and columns.

Parapet

Masonry parapet wall can collapse easily. It is better to build parapet with bricks up to 300 mm followed by iron railings.

Concrete and mortar: Use river sand for making mortar and concrete. It should be sieved to remove pebbles. Silt should be removed by holding it against wind. Coarse aggregates of size more than 30 mm should not be used. Aggregates should be well graded and angular. Before adding water cement and aggregates should be dry mixed thoroughly.

Bands

The following R.C. bands should be provided (Fig 4)

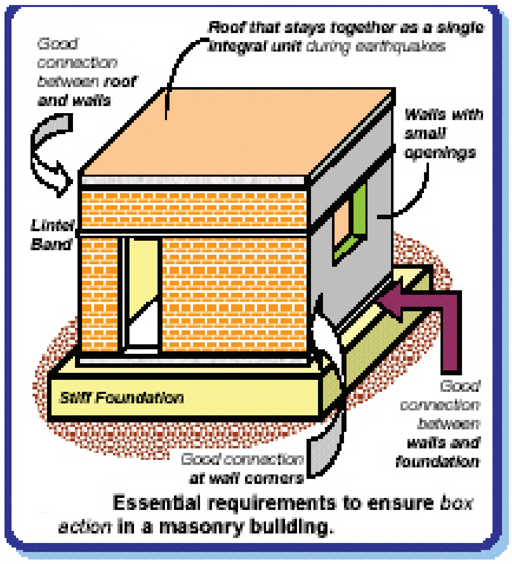
Plinth band

Lintel band

Roof band

Gable band

Fig 4



For making R.C. bands minimum thickness is 75mm and at least two bars of 8 mm diameters are required. They should be tied with steel limbs of 6 mm diameter at 150 mm spacing.

If wall size is large, diagonal and vertical bands also may be provided.

Retrofitting: Retrofitting means preparing a structure in a scientific manner so that all elements of a building act as an integral unit.

It is generally the most economical and fastest way to achieve safety of the building. The following are some of the methods in retrofitting:

Anchor roof truss to walls with brackets.

Provide bracings at the level of purlins and bottom chord members of trusses.

Strengthen gable wall by inserting sloping belt on gable wall.

Strengthen corners with seismic belts.

Anchor floor joists to walls with brackets.

Improve storey connections by providing vertical reinforcement.

Induce tensile strength against vertical bending of walls by providing vertical reinforcement at all inside and outside corners.

Encase wall openings with reinforcements.

Earthquake resistance of tall buildings

Tall buildings are subjected to heavy horizontal forces due to inertia during earthquake. Hence they need shear walls. A shear wall is a R.C.C. enclosure within the building built to take shear forces. It is usually built around lift room. These shear walls must be provided evenly throughout the buildings in both directions as well as from bottom to top. Apart from providing shear walls, the following techniques are also used for making tall buildings earthquake resistant.

The conventional approach to earthquake resistant design of buildings depends on providing the building with strength, stiffness and inelastic deformation capacity which are strong enough to withstand a given level of earthquake - generated force. This is generally accomplished through the selection of an appropriate structural configuration and the careful detailing of structural members, such as beams and columns, and the connections approach to earthquake resistance is not to strengthen the building, but to reduce the earthquake - generated forces that is put on the building. By de - coupling the structure from seismic ground motion it is possible to reduce the earthquake - induced forces in it.

The most important advanced techniques of earthquake resistant design and construction are:

Increase natural period of structure by "Base isolation".

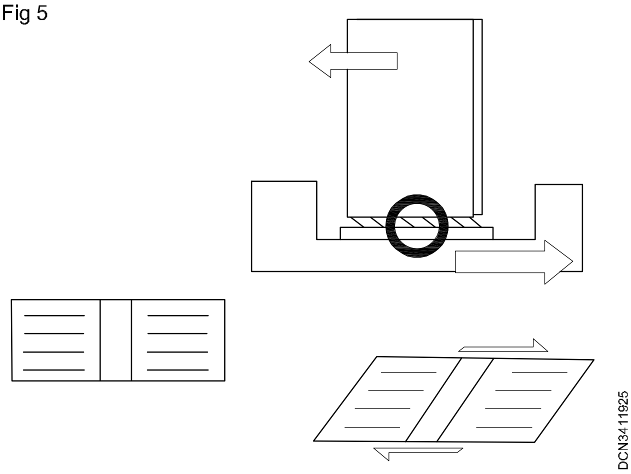
Increase damping of the system by "Energy dissipating devices".

By using active control devices.

Base isolation

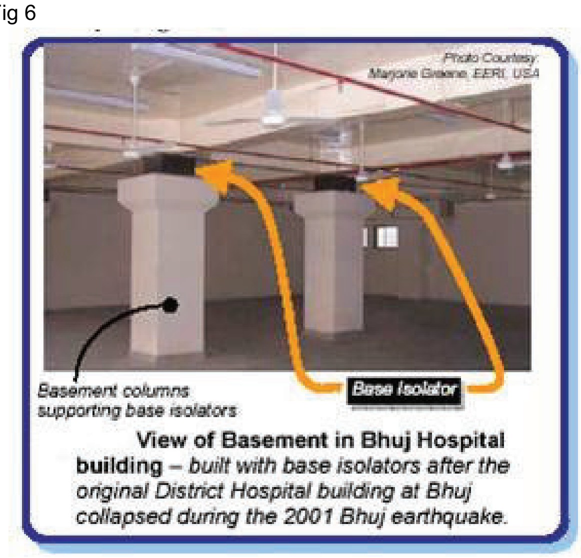
This is the most widely used method against earthquake damage. A base isolated structure is supported by a series of bearing pads which are placed between the building and the building's foundation. A variety of different types of base isolation bearing pads have now been developed, including ones called lead rubber bearings. (Fig 5)

Fig 5



The concept of base isolation is explained through an example building resting on frictionless rollers. When the ground shakes, the rollers freely roll, but the building above does not move. Thus, no force is transferred to the building due to the shaking of the ground; simply, the building does not experience the earthquake. Now, if the same building is rested on the flexible pads that offer resistance against lateral movements, then some effect of the ground shaking will be transferred to the building above. If the flexible pads are properly chosen, the forces induced by ground shaking can be a few times smaller than that experienced by the building built directly on ground, namely a fixed base building. The flexible pads are called base-isolators, whereas the structures protected by means of these devices are called base-isolated buildings. The main feature of the base isolation technology is that it introduces flexibility in the structure. (Fig 6)

Fig 6



Due to the flexibility in the structure, a robust medium rise masonry or reinforced concrete building becomes extremely flexible. The isolators are often designed, to absorb energy and thus add damping to the system. This helps in further reducing the seismic response of the building. (Fig 7)

Many of the base isolators look like large rubber pads, although there are other types that are based on sliding of one part of the building relative to other. Also, base isolation is not suitable for all buildings. Mostly low medium rise buildings rested on hard soil underneath: high - rise buildings or buildings rested on soft soil are not suitable for base isolation. A leader-rubber bearing is made from layers of rubbers sandwiched together with layers of steel. In the middle of the bearing is a solid lead "plug." On top and bottom, the bearing is fitted with steel plates which are used to attach the bearing to the building and foundation. The bearing is very stiff and strong in the vertical direction, but flexible in the horizontal direction.

Working principle: Fig 8 shows how this isolation system works. As a result of an earthquake, the ground beneath each building begins to move. In figure 8, it is shown moving to the left. Each building is undergoing displacement towards the right, which is due to inertia. In addition to displacing to the right, the un-isolated building is also changing shape into more of a parallelogram from a rectangular. This is the process if deforming. And of course, the primary cause of earthquake damage is deformation which the building goes through as a result of inertial force acting on it.

Fig 7

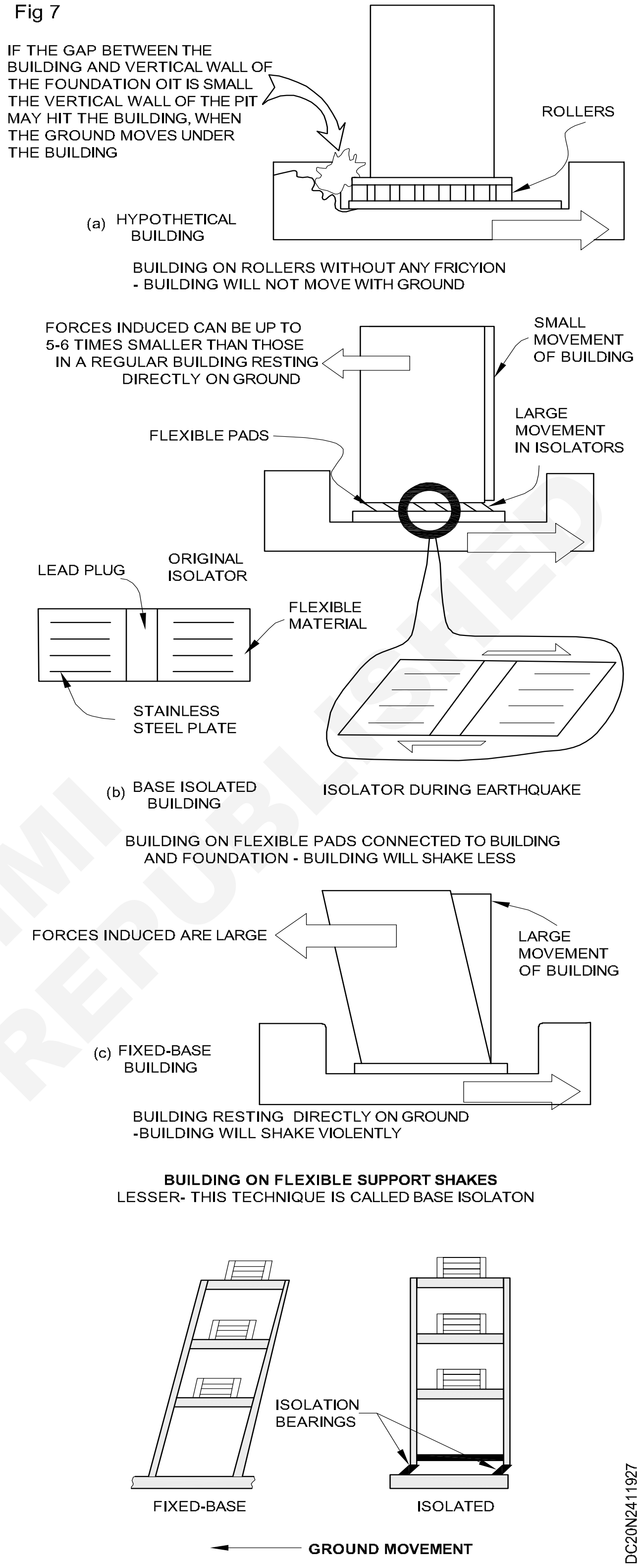
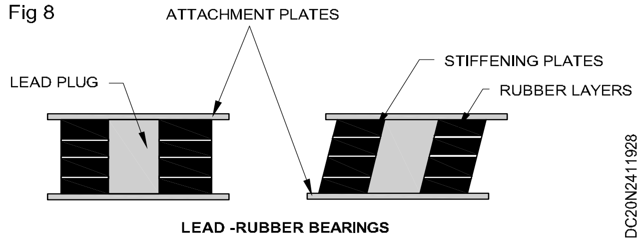


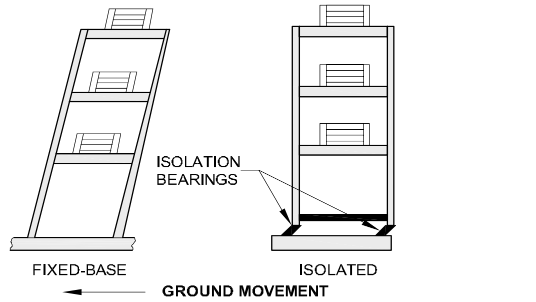
Fig 8



Response of base isolated buildings

The base-isolated building, though is still displacing, retained it's original rectangular shape. Only the lead rubber bearing supporting the building are deformed. The base isolated building escaped the deformation and damage-which shows that the inertial forces acting on the base-isolated building have been reduced. Experiments and observations of base-isolated buildings in earthquakes have been shown to reduce building accelerations to as little as ¼ of the acceleration of fixed base buildings. (Fig 9)

Fig 9



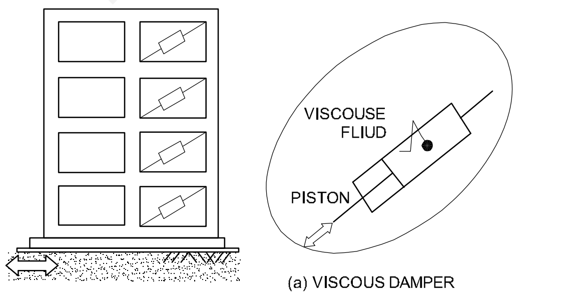
Since the rubber isolation bearings are highly elastic, they don't suffer any damage. The lead plug in the middle of the example bearing experience the same deformation as the rubber. However, it also generates heat as it does so. In other words, the lead plug reduces, or dissipates, the energy of motion i.e. kinetic energy-by converting that energy into heat. And by reducing the energy entering the building, it helps to slow and eventually stop the building's vibrations sooner- in other words; it damps the building's vibrations.

Energy dissipation devices

Another approach for controlling seismic damage in buildings and improving their seismic performance is by installing seismic dampers in place of structural elements, such as diagonal braces. These dampers act like the hydraulic shock absorbers in cars-much of the sudden jerks are absorbed in the hydraulic fluids and only little is transmitted above to the chassis of the car. When seismic energy is transmitted through them, dampers absorb part of it, and thus damp the motion of the building. Commonly used types of seismic dampers includes:

Viscous dampers (energy is absorbed by silicon-based fluid passing between piston cylinder arrangement) (Fig 10)

Fig 10

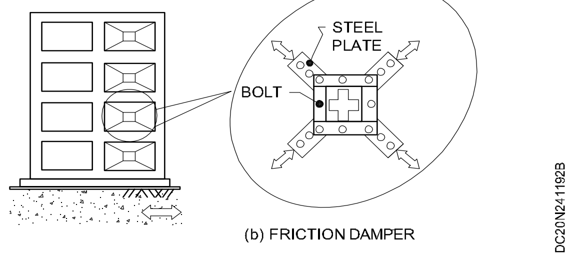


(a) VISCOUS DAMPER

Friction dampers (energy is absorbed by surfaces with friction between them rubbing against each other)

Each of these are suitable for a certain building and are isolated accordingly. (Fig 11)

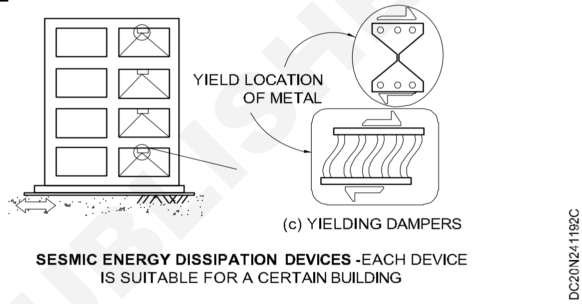
Fig 11



(b) FRICTION DAMPER

Yielding dampers (energy is absorbed by metallic components that yield) (Fig 12)

Fig 12



(c) YIELDING DAMPERS

SESMIC ENERGY DISSIPATION DEVICES -EACH DEVICE IS SUITABLE FOR A CERTAIN BUILDING

Thus by equipping a building with additional devices which have high damping capacity, we can greatly decrease the seismic energy entering the building.

Visco elastic dampers(energy is absorbed by utilizing the controlled shearing of solids)

Working principle

The fluid damper consists of a stainless steel piston with bronze orifice head. It is filled with silicon oil. The piston head utilizes specially shaped passages which alter the flow of the damper fluid and thus alter the resistance characteristics of the damper. Fluid dampers may be designed to behave as a pure energy dissipater or a spring or as a combination of the two.

A fluid viscous damper resembles the common shock absorber such as those found in automobiles. The piston transmits energy entering the system to the fluid in the damper, causing it to move within the damper. The movement of the fluid within the damper fluid absorbs this kinetic energy by converting it into heat.

In automobiles, this means that a shock received at the wheel is damped before it reaches the passengers compartment. In buildings this can mean that the building columns protected by dampers will undergo considerably less horizontal movement and damage during an earthquake.

Active control devices

After development of passive devices such as base isolation and TMD. The next logical steps is to control the action of these devices in an optimal manner by an external energy source the resulting system is known as active control device system. Active control has been very widely used in aerospace structures. In recent years significant progress has been made on the analytical side of active control for civil engineering structures. Also a few models explains as shown that there is great promise in the technology and that one may expect to see in the foreseeable future several dynamic "Dynamic intelligent buildings" the term itself seems to have been joined by the Kajima corporation in Japan. In one of their pamphlet the concept of active control had been explained in every simple manner and it is worth quoting here.

People standing in swaying train or bus try to maintain balance by unintentionally bracing their legs or by relaying on the mussels of their spine and stomach. By providing a similar function to a building it can dampen immensely the vibrations when confronted with an earthquake. This is the concept of Dynamic Intelligent Building (DIB).

The philosophy of the past conventional a seismic structure is to respond passively to an earthquake. In contrast in the DIB which we propose the building itself functions actively against earthquakes and attempts to control the vibrations. The sensor distributed inside and outside of the building transmits information to the computer installed in the building which can make analyses and judgment, and as if the buildings possess intelligence pertaining to the earthquake amends its own structural characteristics minutes by minute.

Active control system: The basic configuration of an active control system consists of three basic elements:

Sensors to measure external excitation and/or structural response.

Computer hardware and software to compute control forces on the basis of observed excitation and/or structural response.

Actuators to provide the necessary control forces.

Thus in active system has to necessarily have an external energy input to drive the actuators. On the other hand passive systems do not required external energy and their efficiency depends on turnings of system to expected excitation and structural behaviors.

The advantage of an active system lies in its much wider range of applicability since the control forces are worked out on the basis of actual excitation and structural behavior.

Conclusion

Earthquakes occur without any prior warning and are, therefore, unpredictable. But, they lead to severe damage to civil engineering structures, bridges, and living things.

Hence, the natural disasters like earthquake cannot be prevented, but measures are required to be taken to reduce the extent of damage.

As a civil engineer, the precautions to be taken such that there is no destruction to structures which are responsible for severe deaths of living things.

The design and construction of structures that are resistant to earthquakes have to be planned very effectively since they affect the building structures and cause severe damage/destruction to living things.

The two recent technologies are base isolation and energy dissipation devices which absorbs the seismic waves during an earthquake are using in the construction of earthquake resistant structures.

The recent technologies have been introduced for safeguarding the life. These improvements of structures however, reduce the damage to the structure but, to some extent only.

Innovative construction and safety against earthquake

Objectives : At the end of this lesson you shall be able to
- **define innovative construction**
- **explain modern method of construction and perceived benefit**
- **explain earthquake safety tips.**

Introduction

To protect and improve the built and natural environment, the government promotes the construction of green and innovative buildings. The objective is to encourage the design and construction of buildings that encompass the following features. Fig 1

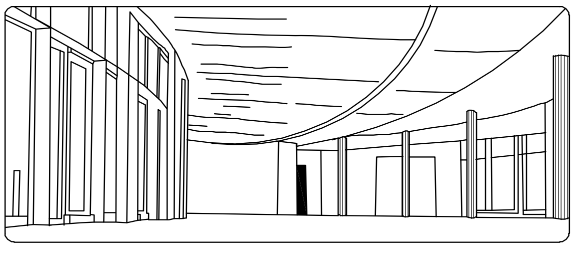
a Adopting a holistic life cycle approach to planning, design, construction and maintenance.

b Maximizing the use of natural renewable resource and recycled/green building material.

c Minimizing the consumption of energy, in particular those non - renewable types, and

d Reducing construction and demolition waste.

Fig 1



Definition

Innovation is a complex and multidimensional process that has received the attention of researches in all fields due to its contribution to economic growth, competitiveness and quality of life. Innovation in general terms is the creation and adoption of new knowledge to improve the value of products, processes, and services. Innovation in construction services has been recognized as a source of competitive advantage by the policy makers as well as industry practitioners.

The construction industry has always been among the driving forces of the economy, however it has also long been criticised for its lack of efficiency in comparison to other industries and its unwillingness to innovate. The performance of the UK construction industry was analysed in the "Rethinking construction" report (Egan, 1998). In addition to creating a 'movement for innovation' the report described how the construction industry, at its best, displayed excellence and delivered the most difficult and innovative projects.

Innovative construction is defined as

"A construction process that can encompass the use of composite new and traditional materials and components often with extensive factory produced sub-assembly sections and components. This may be in combination with accelerated on - site assembly methods and often to the exclusion of many of the construction industry traditional trades. The process includes new buildings and retrofitting, repair and extension of existing buildings."

Modern methods of construction (MMC)

In the real estate business with companies activity competing for tenants to occupy their buildings to sustain their income flow and maximise profits the development of new attractive modern buildings using innovative construction materials and techniques can provide a real market advantage. Consequently designers of buildings are under tremendous pressure to reduce erection and manufacturing costs and to consider sustainable materials that offer sufficient thermal insulation properties, whilst still producing aesthetically pleasing buildings.

To achieve this many new and innovative methods of construction are being adopted and the use of modern methods of construction (MMC) is becoming increasingly prevalent. However, from a risk engineering and insurance perspective the introduction of new materials and innovative construction techniques can create uncertainly about the risk posed and the performance of these buildings in the longer - term.

Perceived benefits of MMC

Some of the perceived benefits of MMC are:

- Improved quality control of components produced under factory controlled conditions.
- Services (eg. electrics, plumbing) can be pre - planned and either fully or partly pre - installed for final connection on site.
- Faster construction times on site.
- Fewer workers required on site and for shorter periods.
- Less wastage of materials.

Current and emerging methods of construction

This section highlights some of the new and innovative building products and methods of construction being encountered now and which are becoming increasingly common. These new methods tend to involve extensive factory production of sub- assembly sections and components in combination with accelerated on - site assembly methods. The methods can broadly be separated into two distinct areas.

1 Superstructure components

- Volumetric or modular construction
- Pods
- Panellized
- Hybrid
- Timber framed
- On - site manufacture

2 Lightweight cladding systems

- Brick slip
- Rain screen
- Render systems
- Timber
- Concrete
- Tile hanging
- Steel

The preceding is by no means an exhaustive list with new materials and construction techniques continually being developed and evolving. However, the following sections will provide a little more insight into each of the preceding.

Superstructure components

Volumetric

Factory produced three - dimensional units that are then transported to site and bolted together. The frames will normally be steel, timber or concrete and can be supplied with all external and internal finishes (including services such as electrics and plumbing), or solely the basic structure. Unlike pod construction, volumetric does not require a superstructure. Examples include: hotels, students accommodation, fast food restaurants.

Pods

Factory produced three - dimensional elements that are incorporated into the superstructure of a building. These are ready made rooms which can be pieced together to make complete premises when set within a light steel framework. All the building services will typically be pre installed with just the final connection made on site. Examples include: hotel bathrooms, kitchen units for accommodation blocks.

Panellized: Factory produced flat panel units transported to site for assembly. Typically these would form the exterior walls of the building - they can be load - bearing (ie. providing structural support) or non - load- bearing. They can be made of timber, light gauge steel, structurally insulated panels (SIPs), concrete or non - structural in-fill walling used to create the whole building. They can be used for virtually any type of building.

Hybrid: These structures combine both volumetric and panellised approaches within the same building and are also known as semi - volumetric.

Timber framed: Timber framed buildings have been around for hundreds of years, however, the concept is now being used to create some much larger and more innovative structures that have been previously. Examples include: apartment blocks and retail shed type buildings where it is sometimes used to support the roof in combination with steelwork. There have been some very large fires involving timber framed buildings while under construction leading to their total destruction.

On - site manufacture: Site based assembly methods include the use of traditional components but in innovative designs including the establishment of manufacturing facilities at construction sites. An example of this is aircrete planks that have the strength of concrete but whose micro cellular structure is low in unit weight.

Lightweight cladding systems: These are external finishes that link well with off-site manufacturing systems due to their low structural loadings and speed of installation.

Brick slips: Individual brick slices that are fixed vertically by adhesive. Normally brick slips will be glued to plastic wall facing sheet though they are also available in larger panels that are hung onto the superstructure.

Rain screen: These are weatherproof external coverings that are easily fixed to factory produced framework attached to the building and can be made from metals, ceramics, granite, terracotta, vitreous enamel, laminates and timber. Insulation material may be present behind the cladding.

Render systems: Render is an external covering applied to the outside of a building, usually directly on to bricks, blockwork, boards, or insulation. It is normally made from limestone, cement and polymers and can be produced in a wide variety of colours and finishes. The actual render is non combustible, but the covered material to which it is applied can often be combustible (eg. foam plastic insulation).

Timber cladding: Although a traditional building material the use of timber cladding has become increasingly common in recent years alongside the desire for increased use of sustainable building materials. For new commercial buildings it is commonly used in combination with other cladding systems, although it can form the majority of the external area of the building.

External insulated finish systems (EIFS): These systems involve attaching insulation material directly to an external wall that is then covered with a render or other type of finish such as tiles, metal or brick. There are ventilated and non - ventilated systems, the former having an air gap between the insulation and the exterior covering. The insulation used is very often a foam plastic material (eg. expanded polystyrene) which is highly combustible when exposed to fire.

Risk and insurance considerations: As many of these method and forms of construction are new there is a level of uncertainly how they will perform over time and the impact that might arise on the frequency and size of loss. Issues which need to be considered in relation to MMC buildings include.

- The use of lightweight and combustible materials may allow a greater degree of fire spread leading to increased claims costs. Similarly the use of combustible materials externally may increase potential for damage from external fires whether deliberate (arson) or accidental.
- Where component parts are fixed together (notably modules and pods), there may well be hidden voids through which smoke and water can permeate throughout the building, leading to even a small incident causing a disproportionately high loss.
- Because many MMC systems are new and innovative, the contractors may have no previous experience of the materials and assembly techniques required. This may actually lead to a poorer quality finish than if more traditional methods had been used.
- Repairs may be more or less straightforward. For example if a building is constructed of pods and one of these is damaged the pod may not be able to be repaired in situ but may need to be removed and replaced causing disruption to and removal of the surrounding pods and external finishes thus increasing the replacement costs and times.
- There may be increased risks of water damage and storm losses due to the materials used and the effects of wear and tear over time. Also, the ability of many MMC materials to withstand the effects of flooding is unknown in many cases.
- There may be problems in obtaining replacement components in future, especially in the event that manufactures go out of business.

Safety against earthquake

Earthquake safety tips to follow: Emergency kit and disaster plan are important

Earthquakes are not a frequent occurrence. However, they can be very disruptive because they occur suddenly and tend to affect large areas. Earthquakes can be a one time event of a few seconds shaking or a series of events of varying duration.

Because earthquakes happen without warning, being prepared in advance is critical to minimize damages and loss. Consider these earthquake safety tips

Before an earthquake

- Know your risk. Research the area and find out if you live near an active fault line and whether or not the ground around you is more susceptible to the effects of an earthquake.
- Retrofit and reinforce your house. If you're in a high risk area, take steps to reinforce your house. Bolt your house to the foundation and reinforce support beams as needed. Secure any furniture such as bookshelves and cabinets to the walls to minimize risk of falling over during a quake. Secure cabinet doors to help keep dishes and other contents from falling out.
- Create a disaster plan to protect yourself and your family. Earthquake preparedness can help reduce anxiety and minimize injury. Know where to take cover in your house and how to communicate with other family members after the earthquake if you're not together. Designate a safe place to meet outside of the house after the shaking stops.
- Put together an emergency kit. Your kit should include non- perishable food, water, first aid supplies, flashlights, camping supplies (stove, battery - powered lantern, etc). extra batteries, blankets and any personal items you may need (medications, toiletries, clothing). If you have pets, make sure they also have adequate supplies. Plan for a week's worth of supplies for each person. You'll need at least four gallons of drinking water per person for a week.
- Be prepared to act. Know how to act so your response is automatic. Identity safe places in your work area to 'Drop, cover and hold on'. Know at least two ways to exit the building safely after an earthquake.
- Stock up on emergency supplies. Keep the basics: Flashlight, first - aid kit, whistle, gloves, goggles, blankets and sturdy shoes. Coordinate supplies with your work group or department. Plan as if food and water may not be available for about 24 hours and other supplies for up to 3 days.
- Arrange your work area for safety. Make sure that bookcases, large file cabinets and artwork are anchored. Store heavy objects on low shelves. Store breakable objects in cabinets with latches. Use normal work order process to get furniture anchored.

During an earthquake

- Stay away from windows and furniture that could potentially fall over. One of the biggest hazards during an earthquake is falling debris and furniture. Avoid areas in your house where you might be exposed to these hazards.
- Take cover in a safe place in your house. Get under a sturdy table or desk to avoid being hit by anything. If you can't take safe cover, protect your head and neck with your arms.
- Do not try and go outside until after the shaking stops. If you are already indoors, you are safer taking cover inside than attempting to leave your house during an earthquake you could be hit by falling debris as you're trying to get out.
- Remain calm as the quake occurs - others will respond to your actions. A cool head can prevent panic. If you are indoors when the shaking occurs, stay there. Move away from windows and unsecured tall tall furniture. Drop, cover and hold on under a desk, a table or along an interior wall. Protect your head, neck and face. Stay under cover until the shaking stops and debris settles.
- If you are outdoors, move to an open area away from falling hazards such as trees, power lines, and buildings. Drop to the ground and cover your head and neck.

After an earthquake

- Be prepared for aftershocks. Earthquakes are often followed by aftershocks additional quakes that follow the main event. These can last for days or even weeks after a major earthquake.
- Check your gas lines and make sure there are no leaks. If you smell gas leaking, turn off the gas if possible and call the gas company. Do not use an open flame in your house until you are sure it is safe. Wait for the gas company to turn the gas back on.
- Check for damaged electrical wiring. Shut off the power if you see damaged wiring in your house.
- Keep your shoes on. You may have broken glass or spilled chemicals on the floor of your house as a result of the earthquake. Don't walk around barefoot until you're sure the floor is clean and safe.
- Document the damage. If your insurance policy covers earthquake damage, make sure you take photos or video of the damage to use in the claim process.
- Remain calm and reassuring. Check yourself and other for injuries. Do not move injured people unless they are in danger. Use your training to provide first aid, use fire extinguishers, and clean up spills. In laboratories, safely shut down processes when possible.
- Expect aftershocks. After large earthquakes, tremors and aftershocks can continue for days.
- Be ready to act without electricity or lights. Know how to move around your work area and how to exit in the dark. Know how to access and use your emergency supplies. Be aware of objects that have shifted during the quake.
- If you must leave a building, use extreme caution. Continually assess your surroundings and be on the lookout for falling debris and other hazards. Take your keys, personal items and emergency supplies with you if safe to do so. Do not re - enter damaged buildings until an all - clear is given.
- Use telephones only to report a life-threatening emergency. Cell and hard - line phone systems will be jammed. Text messages take less band width and may go through when voice calls can't be made.

Introduction to R.C.C uses materials and proportion

Objectives : At the end of this lesson you shall be able to
- **define R.C.C**
- **state advantages of R.C.C**
- **list out materials used in R.C.C**
- **explain reinforcement materials**
- **explain bending of bars**
- **state the testing of steel reinforcement.**

Introduction

Concrete may be defined as a building material obtained by mixing cement, aggregates and water in a suitable proportion which when allowed to cure, becomes hard like a stone. The proportion of ingredients varies with the nature of work for which the concrete is to be used. It can be readily moulded into durable structural items of various size and shapes. This mixed concrete is strong in compression but weak in tension.

Reinforced cement concrete (R.C.C) is the above said mixture of cement concrete with addition of reinforcement in it. The plain concrete is weak in tension, so steel reinforcement is added to make it strong both in compression and tension. The resulting product of cement, aggregates, water and steel reinforcement is called reinforced cement concrete.

Definition

Concrete is a brittle material and is strong in compression. It is weak in tension, so steel is used inside concrete for strengthening and reinforcing the tensile strength of concrete. The steel must have appropriate deformations to provide strong bonds and interlocking of both materials. When completely surrounded by the hardened concrete mass in forms an integral part of the two materials, known as “reinforced concrete”.

Reinforced concrete is a structural material widely used in many types of structures. It is competitive with steel if economically designed and executed.

Advantages of reinforced concrete

- Reinforced concrete also has greater compressive strength as compared to most other materials used for construction besides good in tension.
- It has better resistance to fire than steel and capable of resisting fire for a longer time.
- It has long service life with low maintenance cost.
- In some types of structures, such as dams, piers and footings, it is the most economical structural material.
- It can be cast to take the shape required, making it widely used in pre - cast structural components.
- It yields rigid members with minimum apparent deflection.
- Yield strength of steel is about 15 times the compressive strength of structural concrete and well over 100 times its tensile strength.
- By using steel, cross sectional dimensions of structural members can be reduced e.g in lower floor columns.
- Less skilled labour is required for erection of structures as compared to other materials such as structural steel.

Disadvantages of reinforced concrete

- It needs mixing, casting and curing, all of which affect the final strength of concrete.
- The cost of the forms used to cast concrete is relatively high.
- It has low compressive strength as compared to steel (the ratio is about 1:10 depending on material) which leads to large sections in columns/beams of multistory buildings cracks develop in concrete due to shrinkage and the application of live loads.

Materials used in R.C.C

1 Cement

Generally any of the following cements is used for R.C.C

a Ordinary or low heat portland cement conforming to IS: 269.

b Rapid hardening portland cements conforming to IS: 8041.

c Portland slag cement conforming to IS: 455.

d Portland pozzolona cement conforming to IS: 1489.

e High strength ordinary portland cement conforming to IS: 8112.

f Hydrophobic cements conforming to IS: 8043.

g High alumina cements conforming to IS: 6452.

h Super sulphated cement conforming to IS: 6909.

2 Fine aggregate

The aggregate which passes through IS sieve no.480 is called fine aggregate. The particle size of this aggregate does not exceed 4.75 mm. Fine particles passing though the sieve no. IS: 15 should not exceed 8%. Sand and sieved quarry dust are usually using as fine aggregate. It should be free from silt clay, salts and other organic matter and it should be conforming to IS: 383.

3 Coarse aggregate

The aggregate, which is retained over, sieve no. IS: 480 are called coarse aggregate. The size of this aggregate depends upon the type and nature of work. It should be free from clay, clots and other organic matter. It should not have glossy surface. It should not be soft, porous or flaky. It should not absorb more than 5% of water by weight when immersed in 24 hours and in all aspects it should be conforming to IS: 383.

4 Water

Water used for making concrete should be free from dirt, organic impurities, sulphur contamination and chlorides which cause efflorescence. The clear water used for drinking purpose (IS: 14543) should be used. The pH value of water should be between 6 and 8. Mixing or using of concrete with seawater is not recommended because of presence of harmful salts in seawater.

5 Reinforcement

Reinforcement shall be any of the following

- Mild steel and medium tensile steel bars conforming to IS: 432.
- Hot rolled deformed bars conforming to IS: 1139.
- Cold twisted bars conforming to IS: 1786.
- Hard - drawn steel wire fabric conforming to IS: 1566.
- Rolled steel made from structural steel conforming to IS: 226.
- All reinforcement shall be free from mill scales, loose rust and coats of paints, oil, mud or other coatings, which destroy or reduce bond.

Grades of concrete

The concrete shall be in grades M5, M7.5, M10, M15, M20,M25,M30,M35 and M40. In the designation of concrete grade, letter M refers to the mix and the number to the specified characteristic compressive strength of 15 cm cube after 28 days, expressed in N/mm2. Grades of concrete lower than M15 shall not be used in R.C.C.

Nominal Proportion for different Grades

Grade	Proportion			Quantity of water in litres per 50 kg of cement
	Cement	Fine aggregate	Coarse aggregate	
M5	1	5	10	60
M7.5	1	4	8	45
M10	1	3	6	34
M15	1	2	4	32
M20	1	1.5	3	30
M25	1	1	2	28

Caution in the use of 53 grade cement in construction

The strength of 53 grade cement does not increase much after 28th day because of early gain while 33 grade cement continues to gain strength after 28th day.

In addition, due to faster hydration process, the concrete releases heat of hydration at much faster rate initially and release of heat is the highest in case of 53 grades. The heat of hydration being higher, the chances of micro cracking of concrete is much greater. Thus during initial setting period of concrete, the higher heat of hydration can lead to the damage of micro-cracking within the concrete which may not be visible at surface.

This cracking is different from shrinkage or cracks which occur due to faster dryness of concrete in windy conditions. The situation can be worse when we tend to increase the quantity of the cement in concrete with a belief that such increments are better for both strength and durability of concrete.

Thus it is very essential to be very careful in advance that higher grade cement specially grade 53 should be used only where such use is warranted for making the concrete of higher strength and also where precautions are taken to relieve the higher heat of hydration through chilling of aggregates. (Grade refers to the strength of cement at 28 days, when tested as per IS: 4031 - 1988). If the 28 days strength is less than 33N/mm2, it is called 33 grade cement. If the 28 days strength lies between 33 to 43 N/mm2, it is called 43 grade cement. If the 28 days strength is lies between 43 to 53 N/mm2, it is called 53 grade cement.

Reinforcement: The material which can be used as reinforcement in R.C.C. work should have the following characteristics:

1 It should be able to develop perfect bond with concrete.

2 Its co-efficient of thermal expansion should be nearly same as that of concrete.

3 It should have high tensile strength.

4 Concrete should not produce any harmful effect on the embedded material.

5 It should be easy to cut, bend, bind or weld.

6 It should be easily available.

It is seen that steel meets all the above requirements and as such it is the only material which is used on large scale in R.C.C works.

The various types of steel that are commonly used for making different forms of reinforcement are mild steel, medium tensile steel, high tensile steel and hard drawn steel. These differ from each other in their chemical composition and other properties like, ultimate tensile strength, yield points etc.

The various forms in which steel is used as reinforcement in R.C.C work are: round bars, deformed bars, twisted bars, square bars and flats. Sometimes expanded metal fabric or fabric made by welding or weaving steel wire in the form of oblong or square mesh are also used as reinforcement in slabs, shells and concrete roads. For works of large dimensions like massive foundations, etc., sections like rolled steel beams, channels or angle iron are also used as reinforcement.

Mild and medium tensile steel bars of round section are most commonly used in R.C.C work. The diameter of round bars (in mm.) used in normal building work are:

6,8,10,12,16,18,20,22,25,28,32,36 and 40

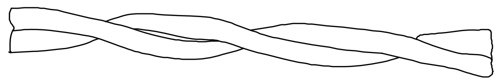
Bars of greater diameter, i.e., 45 mm. and 50 mm., are only used in exceptionally heavy foundations, large girders, or counterforts etc.

With the introduction of deformed bars and twisted bars, the use of plain round bars is gradually declining. Deformed bars or high yield strength deformed bars (HYSD) are furnished with lugs, ribs or other form of surface deformations for the purpose of increasing their bond strength with concrete. (Fig 1)

It is seen that the process of twisting a plain or a deformed bar results in the following improvements in its properties:

- Considerable increase in yield stress.
- Increase in tensile strength.
- Increase in bond strength.

Fig 1



TWIN TWISTED BARS

DC20N2512111

Twisted plain or deformed bars not only have high yield stress but also have bond strength which is 40% more than that of plain round bars. On account of increased bond strength such bars do not need end hooks, and require reduced length for overlaps etc. thereby effecting reduction in the cost of reinforcement and labour.

Permissible stresses in reinforcement: The permissible stresses in steel reinforcement as per IS: 456 - 1978 are given in table 1.

Table 1 - Permissible stresses in steel reinforcement

Types of stress in steel reinforcement	**Permissible stresses**		
	Mild steel bars conformating to grade I of IS:432 (Part I) - 1966 or deformed mild steel bars conforming to IS:1139 - 1966	**Medium tensile steel conforming to IS: 432 (part I) 1966 or deformed medium tensile steel bars conforming to IS: 1139 - 1966**	**High yield strength deformed bars conforming to IS: 1139 - 1966 or IS: 1786 - 1979 (Grade Fe 415)**
1	**2**	**3**	**4**
1 Tension (σ_{st} or σ_{sc}) a Upto and including 20 mm b Over 20 mm	140N/mm² 130N/mm²	Half the guaranteed yield stress subject to a maximum of 190 N/mm²	230 N/mm² 230 N/mm²
2 Compression in column bars (σ_{sc})	130 N/mm²	130 N/mm²	190 N/mm²
3 Compression in bars in a beam or slab when compressive resistance of concrete is taken into account.	The calculated compressive stress on the surrounding concrete multiplied by 1.5 times the modular ratio or σ_{sc} which ever is lower.		
4 Compression in bars in a beam or slab where the compressive resistance of concrete is not taken into account. a Upto and including 20 mm. b Over 20 mm.	140N/mm² 130N/mm²	Half the guaranteed yield stress subject to a maximum of 190 N/mm²	190 N/mm² 190 N/mm²

HYSD bars having yield stress (0.2% proof stress) equal to 415 N/mm^2 and permissible tensile stress equal to 230 N/mm^2 are exceedingly being used in R.C.C. work. These bars are also commonly known as Fe 415 HYSD bars.

In case of structures requiring use of still higher tensile strength of reinforcing bars, another form of HYSD bars known as Fe 500 HYSD are used. These bars have a yield stress equal to 500 N/mm^2 and have permissible tensile stress equal to 275 N/mm^2.

It is observed that HYSD bars when used in combination with high strength concrete i.e. M20 and above prove to be more economical.

Characteristic strength of steel reinforcement

The term characteristic strength of steel reinforcement means that value of the strength of steel below which not more than 5% of the test results are expected to fall. The characteristic strength of different type of steel reinforcement or (fy) is taken as the value of the minimum yield stress (or 0.2% proof stress) for the type or grade of steel used in the manufacture of the reinforcement. The value of (fy) or the characteristic strength for three commonly used type of reinforcing bars are given in table 2.

Table 2 - Characteristic strength of steel reinforcement

S.N.	Types of reinforcement	Yield stress or 0.2% proof stress	Characteristic strength (F_y)	Permissible tensile strength σ_{st}
1	Mild steel bars conforming to grade 1 of IS:432 (Part 1) or deformed m.s. bars conforming to IS: 1139.	250 N/mm^2 (average)	250 N/mm^2	140 N/mm^2 (for bars upto 20 mm ϕ) 130 N/mm^2 (for bars over 20 mm ϕ)
2	High yield strength deformed bars (HYSD bars) conforming to IS: 1109 or grade Fe 415 of IS: 1786.	415 N/mm^2	415 N/mm^2	230 N/mm^2
3	High yield strength deformed bars conforming to grade Fe 500 of IS:1786.	500 N/mm^2	500 N/mm^2	275 N/mm^2

Note 1: For high yield strength deformed bars of grade Fe 500, the permissible stress in direct tension and flexural tension shall be 0.55 fy. The permissible stresses for shear and compression reinforcement shall be as for grade Fe 415.

Note 2: For welded wire fabric conforming to IS: 1566 - 1967 the permissible value in tension is 230 N/mm2.

Note 3. The yield stress of steels for which there is no clearly defined yield point should be taken to be 0.2 percent proof stress.

Note 4: When mild steel conforming to grade II of IS: 432 (part I) - 1966 is used, the permissible stresses shall be 90 percent of the permissible stresses in column 2 above or if the design details have already been worked out on the basis of mild steel conforming to grade I of IS 432 (part I) - 1966, the area of reinforcement shall be increased by 10 percent of that required for grade I steel.

Handling of reinforcement at site: Whatever be the magnitude of R.C.C. work, it is necessary to prepare a bar bending schedule based on the structural drawing prior to start of handling reinforcement at site. Bar bending schedule is a descriptive list containing details regarding the exact bending shape, dimension and diameter of each and every bar together with the number of bars of each shape.

Bars are cut to the desired lengths and then bent cold in accordance with the details given in bar bending schedule. Before placing the bars in position in the formwork it is necessary to ensure that the reinforcement is clean and free from, loose mill scale, loose rust, oil or other coating. This precaution is necessary to meet the requirement of good bond between concrete and steel for monolithic behaviour.

The reinforcement should be placed accurately in position and maintained in position by tying bars at junction with binding wire or by welding. To ensure proper cover to reinforcement, small precast cover blocks made out of cement mortar are used. The cover blocks are inserted below the reinforcement mesh and tied to it with the help of binding wire, prior to concreting. In addition, precaution should be taken to prevent the displacement or distortion of reinforcement during concreting.

Reinforcement shall be any of the following:

a Mild steel and medium tensile steel bars conforming to IS: 432.

b Hot rolled deformed bars conforming to IS: 1139.

c Cold twisted bars conforming to IS:1786.

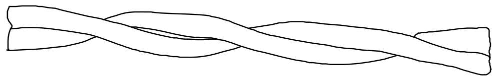
d Hard - drawn steel wire fabric conforming to IS: 1566.

e Rolled steel made from structural steel conforming to IS: 226.

f All reinforcement shall be free from mill scales, loose rust and coats of paints, oil, mud or other coatings, which destroy or reduce bond.

Types of reinforcement steel (Figs 2-16)

Fig 2



TWIN TWISTED BARS

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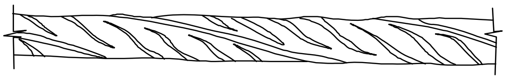
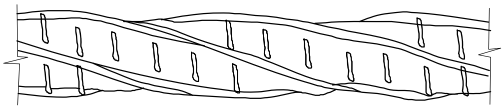
Fig 3



RIBBED TORSTEEL

DC20N2512113

Fig 4



GRIP BAR

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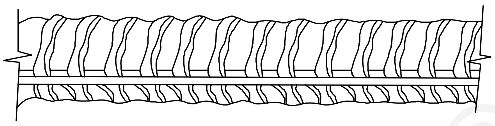
Fig 5



TRSTRONG BAR 1 & 2

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Fig 6

TISCON 42 , 12 MM , 2 RIBS

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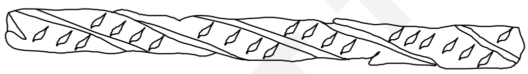
Fig 7



TISCON 42 , 12 MM , 4 RIBS

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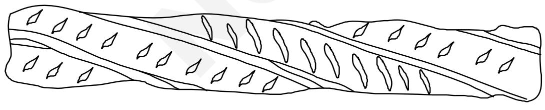
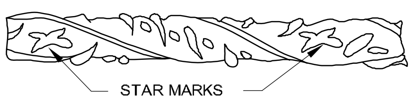
Fig 8



TISCON 42 , 20 MM , 4 RIBS

DC20N2512118

Fig 9



TISCON 50 , 12 MM , 2 RIBS

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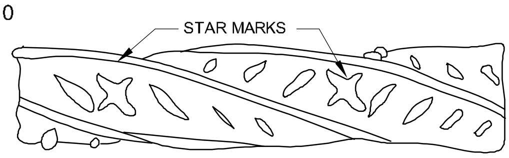
Fig 10



TISCON 50 , 20 MM , 4 RIBS

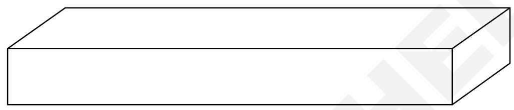
DC20N251211A

Fig 11

CIRCULAR BAR

DC20N251211B

Fig 12



SQUARE BAR

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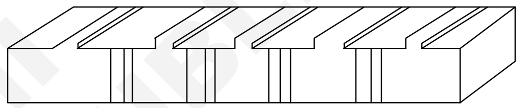
Fig 13



SQUARE BAR WITH INDENTATIONS

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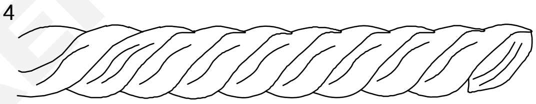
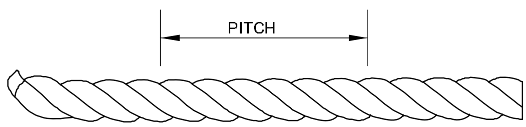
Fig 14



TWISTED BAR

DC20N251211E

Fig 15



SINGLE - SQUARE TWISTED BAR

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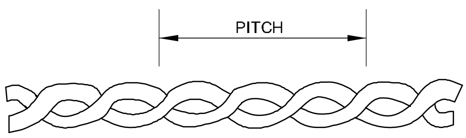
Fig 16



TWIN TWISTED BAR

TWISTED BARS

DC20N251211G

In R.C.C works steel reinforcement may be used in the form of plain round bars deformed bars, twisted bars, and square bars or flats. According to chemical composition and other properties like yield point, ultimate strength etc. steel is divided into.

1 Mild steel (Fe 250)

Grade -I (IS:432)

Grade -II (IS:432)

2 Medium tensile steel (IS:432)

3 High yield strength deformed bars (Fe 415) (IS: 1139).

Twisted bars are nothing but mild steel bars whose quality has been improved by various processes of cold working and have improved its yield stress is about 50% more than that for ordinary mild steel bars. The ribs, legs and deformations on their surface increase the bond strength.

Reinforced materials

1 **Deformed bars:** There are bars whose surface is roughened to increase the resistance to slipping between the bar and the concrete. These have same types of corrugation or projections on their surface which check the slipping.

2 **Twisted bars:** The quality of steel bars can be improved by the use of various processes or working. One of these methods is if twisting of bars. Twisting of bars may be singly or doubly is shown in figure. During the double as twin twisting the length of combined bar will be shortened. The effects of twisting are as follows"

i A considerable increase in the yield strength of bar.

ii A slight increase in ultimate tensile stress.

iii Considerable decrease in the ultimate elongation.

Do the yield stress is increased by 50% or more and thus the working stresses are also increased proportionality and it results by 33% or so. The steel used as reinforcement shall conform with IS:456.

I.S. Codes

Indian standard codes have been prepared to be used for the construction of various structures. On such code IS: 456 which deals with construction of reinforced cement concrete structures. Various specification to be adopted for steel and concrete are laid down in the code for guidance. While designing the R.C.C structures these codes are followed.

Bending of bars

In case round bars are used as reinforcement in concrete, hooks at the ends are provided. Provision of hooks, bends and laps etc. are shown in figs 17 to 20.

Cover in reinforcement

The reinforcement in shape of bars is embeded in concrete so that it is fully covered. Minimum cover required for various structures as per IS: 456 - 1962 is as given below:

Clear cover at the ends of bars = Not less than twice the dia of bars but minimum 25 mm.

Clear cover of slabs = 15 mm or dia of bar whichever is more

Clear cover of beams = 25 mm or dia of bar whichever is more

Clear cover for columns = 40 mm or dia of longitudinal bar whichever is more

Clear cover for foundation slabs and beams = 50 mm.

When surfaces of concrete members are exposed to the action of harmful chemicals, acids, vapours, sulphurous smoke etc. the cover thickness may be increased.

Fig 17

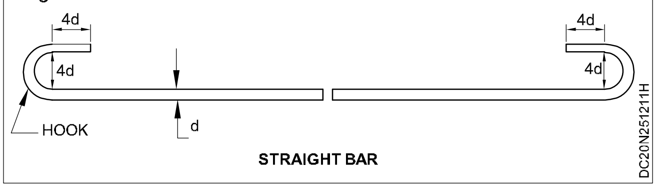


Fig 18

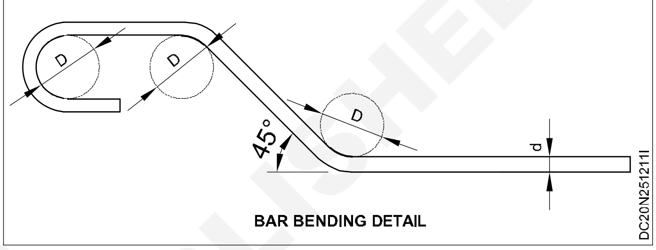


Fig 19

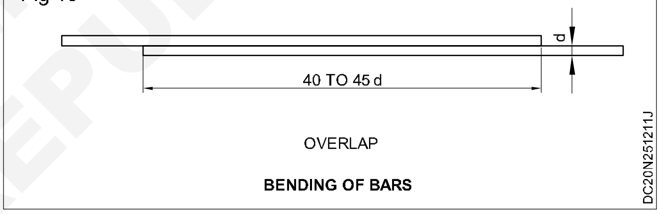
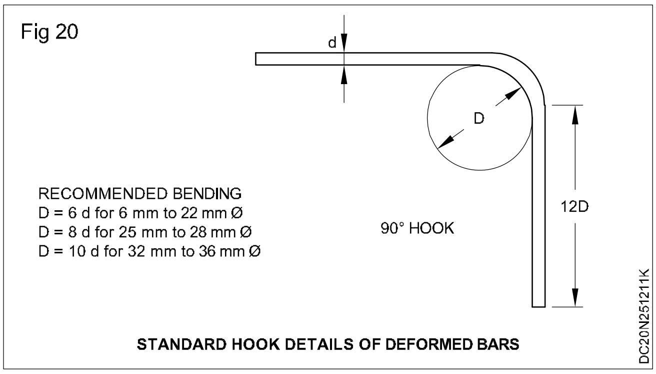


Fig 20



Symbols and conventions

a **Abbreviations relating to shape of bars:** These are to indicate the general shape of reinforcing bars.

Alt Alternate bar

Bt Bent bar

B Bottom bar

T Top bar

St Straight bar

Stp Stirrup

Sp Spiral

Ct Column tie

Min Minimum

Max Maximum

b Abbreviations relating to structural members: These are used in the key plan for easy identification of members.

Bm or B Beam (S)

Col Column (S)

FG Footing (S)

GR Girder (S)

JT Joint (S)

LL Lintel (S)

LB Lintel beam (S)

Sb or S Slab (S)

WL Longitudinal wall

Wx Cross wall

£ Centre line

c Symbols for type and size of reinforcement: These are used distinguishing between plain, square or deformed bars used in a structure.

Plain round bar or diameter of plain round bar

ø Plain square bar or side of plain square bar

Deformed bar, or square twisted bar or its nominal size

d Symbols relating to position and direction of reinforcement: These indicate the limits and direction of particular bars used in structural elements.

EW Each way.

@ Spacing centre to centre.

Limit of area covered by bars.

Direction in witch bars extend.

e Examples denoting reinforcement: These form the most important symbols used against each type of reinforcement indicated in a drawing.

16 @ 150

(16 mm DIA PLAIN BARS SPACED AT

150mm CENTRE TO CENTRE)

20@ 250

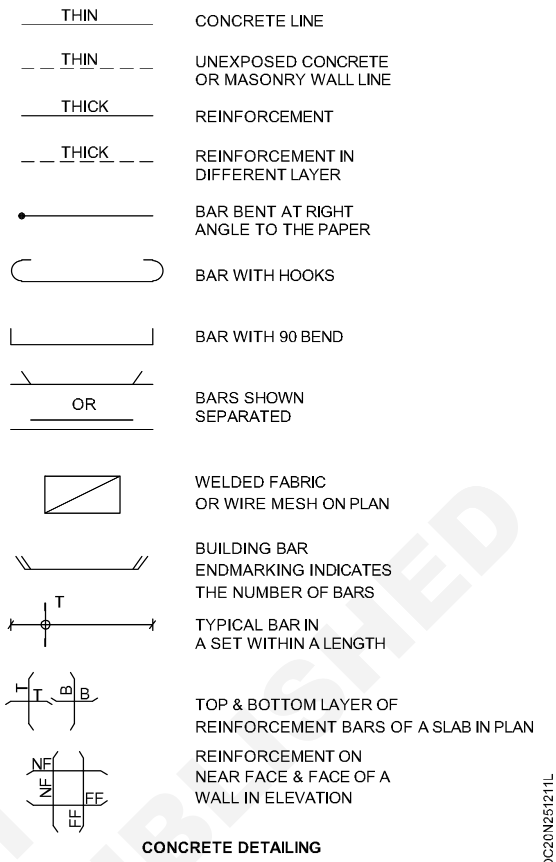
(20mm DIA DEFORMED BARS SPACED AT

250mm C.C)

f Some drawing conventions in R.C.C detailing (Fig 21)

Each symbol is to be pointed by an arrow and the details of bars denoted as given in (e).

Fig 21



CONCRETE DETAILING

Testing of steel reinforcement

Steel reinforcement shall be produced under a permanent system of routine inspection and testing.

The testing is done to determine the yield point, ultimate strength, percent elongation, bend and weight per meter.

The universal tensile test is to determine the strength of materials. During the test, the specimen, elongation reduction and applied load are measured, tensile stresses and strain are calculated from the result. After the material break, the final length and cross sectional area of specimen is used to calculate the percentage of elongation and percentage of reduction.

The rate of testing shall be as follows:

- For chemical composition, one analysis per test unit. The chemical composition (cast analysis) of the steel reinforcing bar shall have been determined by the QA manufacturer. (Quality assessment manufactures)
- For rebend tests and nominal mass per metre, one test specimen per test unit and nominal diameter.
- For surface geometry, one test specimen per test unit and nominal diameter. Alternatively, beam test with the same rate of testing may be used.
- For tensile tests, one test specimen per 30 tones with at least three test specimens per test unit and nominal diameter.

Bending moments and shearing forces

Introduction: When any structure is loaded, stresses are induced in the various parts of the structure, and in order to calculate the stresses, where the structure is supported at a number of points, the bending moments and shearing forces acting must also be calculated. In general, a structure may be considered to consist of a series of beams, linked together in some way, and further, the complete structure may be treated as a beam with an elaborate cross-section. Calculations can be made progressively first on the structure as a whole and then on the individual parts.

Some basic definitions

Beam: Beam is a structural member which is acted upon by a system of external loads at right angles to the axis.

Bending: Bending implies deformation of a bar produced by loads perpendicular to its axis as well as force - couples acting in a plane passing through the axis of the bar.

Plane bending: If the plane of loading passes through one of the principal centroid axes of the cross-section of the beam, the bending is said to be oblique.

Point load: A point load or concentrated load is one which is considered to act at a point. In actual practice, the load has to be distributed over a small area because such small knife-edge contacts are generally neither possible nor desirable.

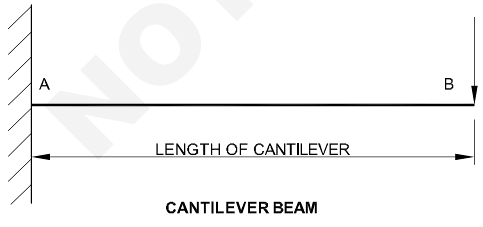
Distributed load: A distributed load is one which is distributed or spread in some manner over the length of the beam. If the spread is uniform (i.e. at the uniform rate, say w kN/metre run) it is said to be uniformly distributed load and is abbreviated as U.D.L. If the spread is not at uniform rate, it is said to be non-uniformly distributed load, triangular and trapezium distributed loads takes under this category.

Classification of beams

Depending upon the type of supports beams are classified as follows:

1 **Cantilever:** A cantilever is a beam whose one end is fixed and the other end free. Fig 22 shows a cantilever with end A rigidly fixed into its support and the other end B free. The length between A and B is known as the length of cantilever.

Fig 22

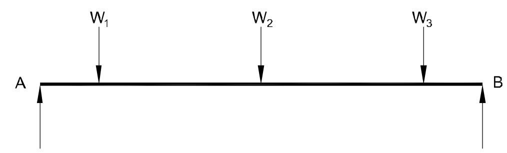


CANTILEVER BEAM

2 **Simply (or freely) supported beam:** A simply supported beam is one whose ends freely rest on walls or columns or knife edges (Fig 23). In all such cases the reactions are always upwards.

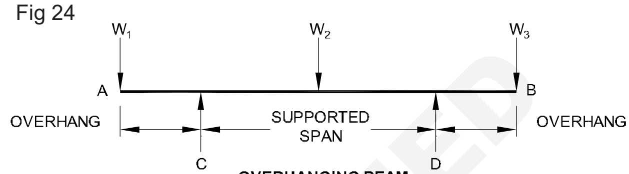
3 **Overhanging beam:** An over-hanging beam is one in which the supports are not situated at the ends i.e. one or both the ends project beyond the supports. In Fig 24 and D are two supports and both the ends A and B of the beam are overhanging beyond the supports C and D the respectively.

Fig 23



SIMPLY SUPPORTED BEAM

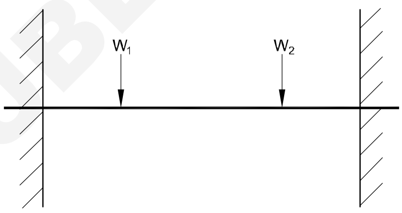
Fig 24



OVERHANGING BEAM

4 **Fixed beam:** A fixed beam is one whose both ends are rigidly fixed or built in into its supporting walls or columns. (Fig 25)

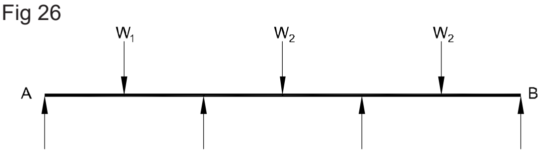
Fig 25



FIXED BEAM

5 **Continuous beam:** A continuous beam is one which has more than two supports (Fig 26) The supports at the extreme left and right are called the end supports and all the other supports, except the extreme, are called intermediate supports.

Fig 26



CONTINUOUS BEAM

It may be noted that the first three types of beams (i.e. cantilevers, simply supported beams and overhanging beams) are known as statically determinate beams as the reactions of these beams at their supports can be determined by the use of equations of static equilibrium and the reaction are independent of the deformation of beam. The last two types of beams (i.e. fixed beams and continuous beams) are known as statically indeterminate beams as their reactions of support cannot be determined by the use of equations of static equilibrium.

Reinforcement details concrete mixes and ratios

Objectives: At the end of this lesson you shall be able to
- **state steel reinforcement and assembly reinforcement**
- **state bar bend, hook**
- **state cross sectional area of bar and weight**
- **state the grade of concrete.**

- Plain cement concrete is too strong in taking compression. but on the other hand it also too weak in taking tension.
- By taking tension by the concrete members, steel is used in it.
- The concreting which has steel in it for taking tension is known as "Reinforced cement concrete".

Reinforced cement concrete work shall comprise of the following.

- Form work. (Centering and shuttering)
- Reinforcement
- Concreting cast -in situ and pre- cast

Materials

- The raw materials for concrete are water, cement, fine and coarse aggregate.

Steel reinforcement

- The steel used for reinforcement shall be
- Miled steel and medium tensile bars conforming to IS 432 part - I
- High strength deformed steel bars conforming to IS:1786
- High drawn steel wire fabric conforming to IS 1566
- Structural steel conforming to grade A of IS: 2062
- Thermo mechanically treated bars TMT bars

  (high strength deformed steel bars)

Steel reinforcement shall be stored in such a way as to prevent distorting and corrosion. Care shall be taken to protect the reinforcement from exposure atmosphere during storage .

It may be achieved by treating the surface of reinforcement with cement wash.

Assembly reinforcement

Bar shall be bent correctly and accurately to the size and shape as shown in the detailed drawing.

Preferably bars of full length shall be used.

The overlaping bars shall not touch each other and these shall be kept apart with concrete between them by 25mm. or 11/4 times the maximum size to the course aggregate whichever greater but where this not possible the overlapping bars shall be bound together at internals not exceeding twice the dia.

Bonds and hooks forming end anchored

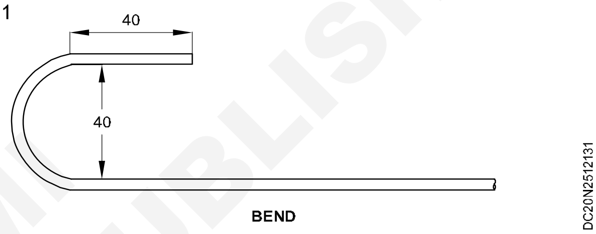
Reinforcement shall be bent fixed in accordance with procedure specified in IS 2502 code of practice for bending and fixing of bars for concrete reinforcement.

The details of bend and hooks

'U' type hook

In case of mild steel plain bars standard 'U' type hook shall provided by bending ends of rod into semicircular hooks having clear diameter equal to four times of diameter of the bars, as shown in (Fig 1).

Fig 1



Bends

Bends forming anchorage to a m.s plain bar shall be bent with an internal radius equal to two times the diameter of the bar with a minimum length beyond the bend equal to four times of the diameter of the bar.(Fig 2)

Fig 2

Anchoring bars in tension:

Deformed bars may be used without end anchorage provided development length requirement is satisfied. Hooks should normally be provided for plain bars in the tension development length of bars will be determined as per IS 456 - 2000.

Anchoring bars in compression

- The anchorage length of straight bar in compression shall be equal to the "development length" of bars in compression as specified in IS 456 - 2000.
- The projected length of hooks bends and straight lengths beyond bend, if provided for a bar in expression, shall be considered for development length.

Cross sectional area and mass of steel bar.

Nominal size mm	Cross sectional area Sqmm	Mass per meter run kg
6mm	28.3	0.222
7mm	38.5	0.302
8mm	50.3	0.395
10mm	78.6	0.617
12mm	113.1	0.888
16mm	201.2	1.58
18mm	254.6	2.00
20mm	314.3	2.47
22mm	380.3	2.98
25mm	491.1	3.85
28mm	616.0	4.83
32mm	804.6	6.31
36mm	1018.3	7.99
40mm	1257.2	9.85
45mm	1591.1	12.50
50mm	1964.3	15.42

Grades of concrete

Group	Grade Designation	Compressive strength of 150mm cube at 28 days in N/mm2
	M - 5	5
Lean concrete	M - 7.5	7.5
	M - 10	10
Ordinary	M - 15	15
Concrete	M - 20	20
Standard	M - 25	25
Concrete	M - 30	30
	M - 35	35
	M - 40	40
	M - 45	45
	M - 50	50
	M - 55	55
High	M - 60	60
Strength	M - 65	65
concrete	M - 70	70
	M - 75	75
	M - 80	80

Concrete mix “M” refers to the mix and specified compressive strength of 150mm size cube at 28 days expressed in N/mm^2

The volumetric mix proportions are to the grades of concrete as specified in the IS 456 . 1964

Concrete mix proportions.	Grades of Concrete
1:4:8	M - 7.5
1:3:6	M - 10
1:2:4	M - 15
1:11/2 :3	M - 20
1:1:2	M - 25

In the designation of concrete mix M - refers to mix and the number to the specified compressive strength of 150mm size cube at 28 days expressed in N/mm^2

Proportion of total quantity of coarse and fine aggregate to 50kg of cement

No.	Grade of concrete	Total quantity of sum of the masses of fine and coarse aggregate per 50kg of cement
1	M- 5	800 kg
2	M - 7.5	625 kg
3	M - 10	480 kg
4	M - 15	330 kg
5	M - 20	250 kg

Reduction of strength of cement with passage of time

No.	Storage period of cement	Strength of reduction
1	Fresh	Nil
2	3 months old	20%
3	6 months old	30%
4	12 months old	40%
5	24 months old	50%

Table showing mix proportions by weight under normal mix for different grades of concrete

No.	Grade of concrete	Maximum size of coarse aggregate	Nominal mix proportion by weight			Usage
			Cement Kg	Sand Kg	Coarse aggregate Kg	
1	M - 5	40mm	50	230	570	Lean concrete Levelling course
2	M - 7.5	40mm	50	180	445	------ do ---------
3	M - 10	40mm		140	340	Plain concrete
		20mm	50	160	320	-------- do -------
4	M - 15	40mm		95	235	Plain concrete
		20mm	50	110	220	--------- do ------
		10/12.5 mm		130	200	---------- do --------
5	M - 20	20mm	50	85	165	Reinforced concrete work.

Converting concrete mix proportions by weight to mix proportions by volume for concrete and grades can be easily calculated by using the given tables above and it is more useful for calculation.

Form work for columns

Objectives : At the end of this lesson you shall be able to
- **describe form work**
- **describe the requirements of form work**
- **state two materials used in the form work**
- **describe the removal of form work.**

Form work or shuttering

When concrete is placed in a plastic state. It is required a temporary supports and casings of the desired, shape The temporary supports sufficiently strong. This temporary casing is called as form work or shuttering

Moulds:

If the form work is in small units such as lintel, cornices etc is called as moulds.

Centering:

For circular work such as arch, domes etc. is called as centering.

Requirements of form work

Easy removal:

Form work can be removed easily, without damage of concrete. The operation of removing the form work is known as stripping. It can be reused.

Economy:

Form work materials is easily available at low cost. Form work materials can be reused for several times.

Less leakage:

There is minimum leakage through joints.

Quality:

It should be designed and built accurately

Rigidity:

The form work should be rigid enough so as to retain the shape without any deformation.

Smooth surface

Form work should be smooth so as to get good concrete surface. The inside surface should be applied crude oil. This makes easy to remove of form work.

Strength:

It should be strong enough to bear the load of wet concrete, weight of equipments and workman etc.

Supports:

It should be rest on sound and hard and non-yielding supports.

Materials used for form work

1 Timber for work

For small works, required less repetition timber form work is used.

This is cheap in initial cost.

The timber form work can be used for 10 to 12 times

The ply-wood form work can be used for 20 to 25 times

2 Steel form work

Steel form work is used several times.

The intial cost is high

Erection and removal are simple

It presents a smooth surface on removal

The Cost of form work may be upto 20 to 25% of the cost of the structure

Removable of form work in

1. Walls, columns, and vertical side of beam 1 to 2 days
2. Slabs ----------------------------- 3 days
3. Beam soffit ------------------------ 7 days

Removable of probs to slab

Spanning upto 4.5m ----------------- 7 days

Spanning over 4.5m ------------------ 14 days

Removable of probs to beam and Arches

spanning upto 6m --- 14 days

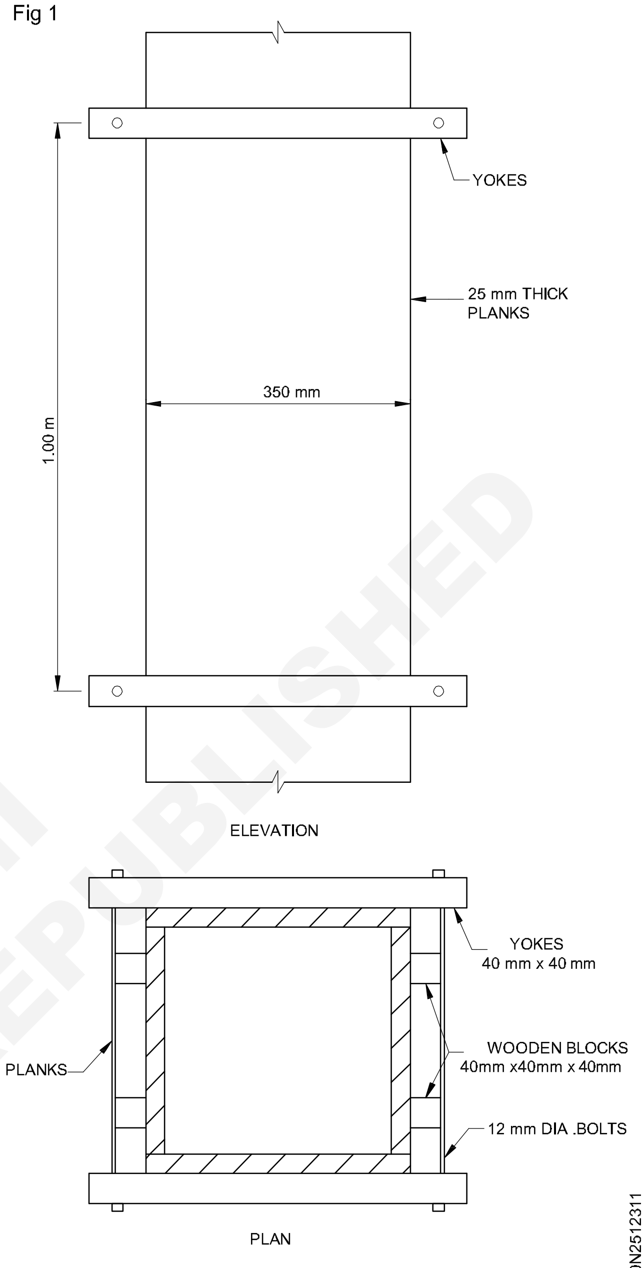
Spanning over 6m ----- 21 days

Column:

- The column form work consists of a box prepared four separate sides.(Fig 1)
- The four sides of box are held in position by wooden block, bolts and yokes.
- The spacing of yokes is about 1m
- Depending upon the shape of the column, the box can be prepared.

- A hole is provided at the bottom of the form work of column to remove the waste which might have fallen before concrete is placed. This is called as cleanout (or) washout hole
- The hole is filled up before placing of the concrete starts.
- Easy to remove the form work, the nails are kept projecting instead of being firmly driven.
- For circular column is made of narrow vertical bounds are called staves.
- Staves are correctly shaped to the required curvature.

Fig 1



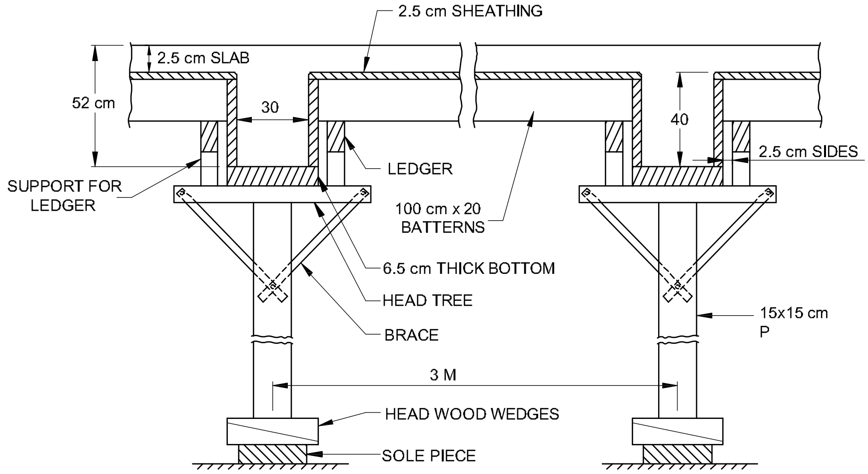
FORM WORK FOR COLUMN

Form work for beams and slabs

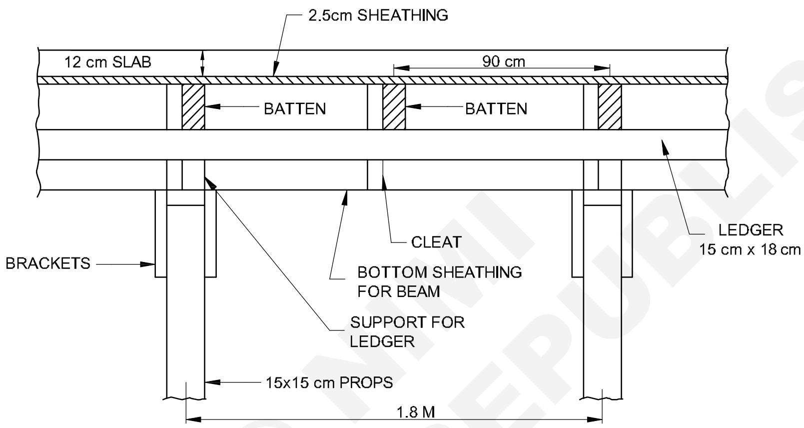
Objective: At the end of this lesson you shall be able to
- **describe form work of Floors and beams.**

- The form work for an R.C.C floor consists of a skeleton to receive the concrete. (Fig 2)
- It consists new vertical posts.
- The vertical post carry small wooden beams at their tops.
- The planks are provided for slabs on these beams
- The boxes for beams are provided from two sides and one bottom.
- The laterals, blocks, beams and struts are provided to make the form work.

Fig 2



(a) SECTION ACROSS BEAMS



(b) SECTION ALONG BEAMS

DC20N2512312

Reinforced brick work

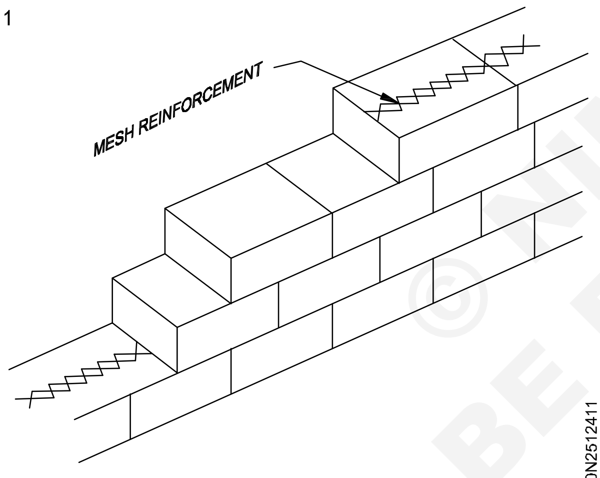
Objectives : At the end of this lesson you shall be able to
- **state reinforced masonry**
- **state reinforced masonry wall**
- **state reinforced masonry column**
- **state reinforced masonry lintel**
- **state reinforced masonry slab.**

Reinforced masonry

- Reinforced masonry is essentially well materials
- Beams, Slabs, lintel, column, have been built in reinforced masonry
- Reinforced masonry is a cheap, durable, fire proof, easy to construct and increase of floor space due to adoption of brick work of lesser thinkers

Reinforced masonry walls (Fig 1)

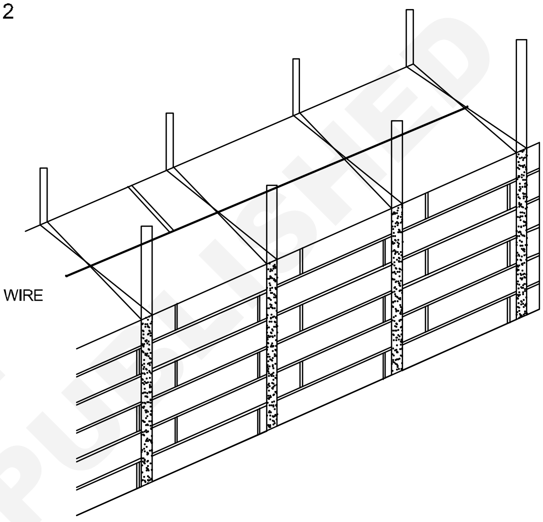
Fig 1



MESH REIN FORCEMENT MASONRY WALLS

- Iron bars or expanded metal much is provided at every third or fourth course
- Before starting the next course steel fabric is spread flat on the cement mortar
- Flat bar section about 25mm x 2 mm be used as hoop iron reinforcement for walls
- Flat bars are hooked at corners and junctions.
- Flat bars are dipped in tar and sanded, so as to resist against rusting.
- Vertical reinforcement provided by using special bricks (Fig 2)
- 6mm diameter mild steel bars can be used as longitudinal reinforcement in walls.

Fig 2



VERTICAL REINFORCEMENT IN WALLS

Masonry reinforced columns (Fig 3)

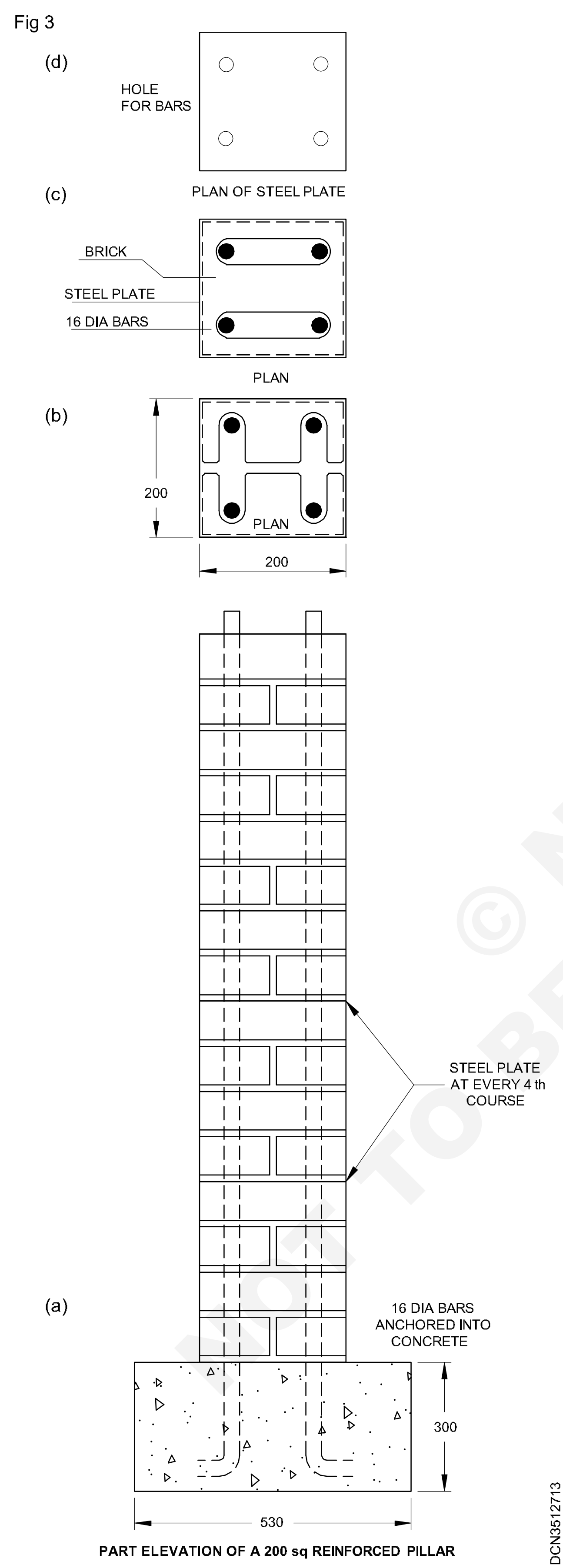
- In steel reinforced columns are provided with steel plate of about 6mm thickness at every fourth course
- Vertically reinforced bars are placed between special type of blocks used
- The steel bars are fixed in the foundation concrete block

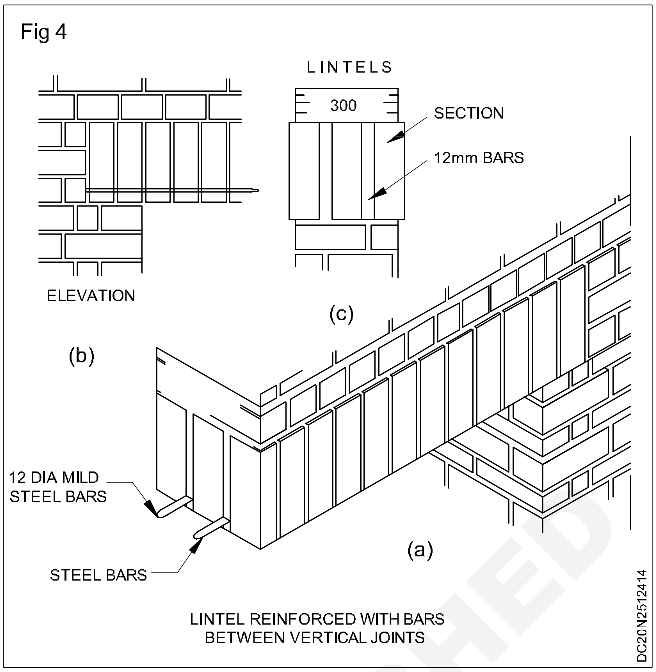
Reinforced masonry lintels (Fig 4)

- 6 to 12 mm diameter bars are provided longitudinally in between the vertical joint
- 6mm diameter stirrups are provided at every third vertical joint to take up the vertical shear

Reinforced masonry slab

- For construction of reinforced masonry slap, centering should be provided.
- The centering is covered with beaten earth and fine sand.
- The centering is covered with well-beaten earth and fine sand is sprinkled over it.





- Reinforced placed in position.
- Bricks are laid in one or two courses.
- Joints should be properly filled with mortar.
- The slab is kept wet for two to four weeks.
- Centering should be removed after 28 days.
- Top and bottom surfaces of slab are finished with cement mortar.

Method of mixing concrete-machine mixing & hand mixing

Objectives : At the end of this lesson you shall be able to
- **state method of mixing cement**
- **state hand mixing and machine mixing.**

Mixing: All concrete should be mixed thoroughly until it is uniform in appearance and all ingredients are uniformly distributed.

- Mixing will be done either.
- Hand mixing.
- Machine mixing.

Hand mixing

- Hand mixing of concrete is done on hard platform.
- This method is mainly employed at such places where the quantities of concrete to be mixed in small.
- Cement and sand are first mixed together in dry condition.
- The coarse aggregate is spread on the platform in uniform thickness varying from 20 to 30 cm.
- The mixed cement and sand are spreaded in a uniform thick layer over the stack of coarse aggregate.
- These are mixed together first in dry state.
- Then measured quantity of water is sprinkled over it and the mass is continuously mixed till uniform workable concrete is obtained.

Machine mixing

- Machine employed for mixing concrete are known as "Concrete mixers"
- These mixers may be of continuous mixing type or batch mixing type. For big projects where large quantity of concrete is required continuous mixing type mixers are used.
- The ingredients of concrete may be fed in the mixture by means of continuous moving conveyor belts or by other suitable methods.
- For small works of building mostly tilting drum type mixtures are used.
- While mixing concrete with mixtures first the coarse aggregates are fed in the mixture, then sand and then cement.
- After dry mixing the measured quantity of water is poured in the mixture and the concrete is mixed for 2 to 3 minutes to obtain the desired workable concrete.
- Before placing concrete in position care should be taken that proper mould is prepared around where the concrete is to be laid
- All the faces of moulds coming in contact with concrete properly coat with crude oil. So that it may not absorb water from concrete and it is difficulty while removing batterns.

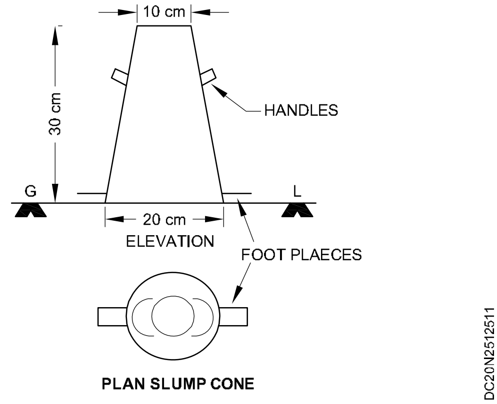
Slump test

Objectives : At the end of this lesson you shall be able to
- **state slump test**
- **state the advantages of slump test**
- **state the limitation of slump test.**

Slump Test:

- The standard slump concrete as shown in Fig 1. And placed firmly the ground.
- The concrete is filled with about one-fourth portion.
- Rammed with a rod which is provided with ballet nos at the lower end.
- The dia of rod 16 mm and length is 60cm.
- The strokes to be given for ramming vary from 20 to 30.
- The remaining portion of the cone is filled in with similar layers

Fig 1



- The top of concrete surface is stuck off, so that the cone is completely full of concrete.
- The cone is gradually raised vertically removed.
- Concrete is allowed to sub side
- Measure the height of the concrete
- Slump of concrete is obtained by deducting height of concrete after subsidence form 30 cm.

Table 1

Commended slumps of concrete

Sl No.	Types of concrete slump	Slump
1.	Concrete for road construction	20 to 40 mm
2.	Concrete for parapet, slab, walls and piers	40 to 50 mm
3.	Mass concrete	25 to 50 mm
4.	R.C.C work	80 to 150 mm
5.	Concrete for arch work	90 to 100 mm

Advantage of slump test

1 It general the facility to easily detect the difference in water content of successive batches of concrete of the same identical mix

2 The apparatus is portable and convenient to be used at site .

Imitating of slump test

1 There is no direct relationship between the workability and the value of slump

2 The maximum size of the aggregate should not excel 40 mm.

3 The stump occurs only in case of plastic mixes. It does not occur in case of dry mixer.

R.C.C lintel & sunshade

Objectives: At the end of this lesson you shall be able to
- **define R.C.C lintel**
- **express type of R.C.C lintel**
- **describe structural concept and structural detailing of lintels and sunshades.**

Introduction

It becomes necessary to provide openings in walls for doors, windows, cupboards, etc. Such opening must be bridged over so as to support the load of the wall above them. This is accomplished by providing a lintel.

Definition

RCC lintel is small beam provided over the door, window or openings to support the masonry wall built above it.

Types of R.C.C lintel (Fig 1)

1 Break lintel

2 Continuous lintel

Break lintel

Break lintel is the lintel which provides only over the opening with minimum bearing on jambs.

Continuous lintel

The lintel running continuous over all openings and supporting wall is called continuous lintel. This will provide more stability to the wall as well as fulfills the function of a lintel.

Design data's

The lintel has to be designed for a triangular load if the wall above lintel is greater than 1 ¼ h, where 'h' is the height of the triangle, if the height is less than 1 ¼ h, then the lintel has to be designed for complete load of full length of masonry.

Loading for which a lintel must be designed are

1 When the length of wall on each side of opening is at least equal to half the effective span.

2 When one end of the lintel is close to the end of the wall.

3 When both ends are close to the ends of the walls.

4 When the wall carries a slab.

5 When there are opening above the lintel.

Reinforcement arrangement

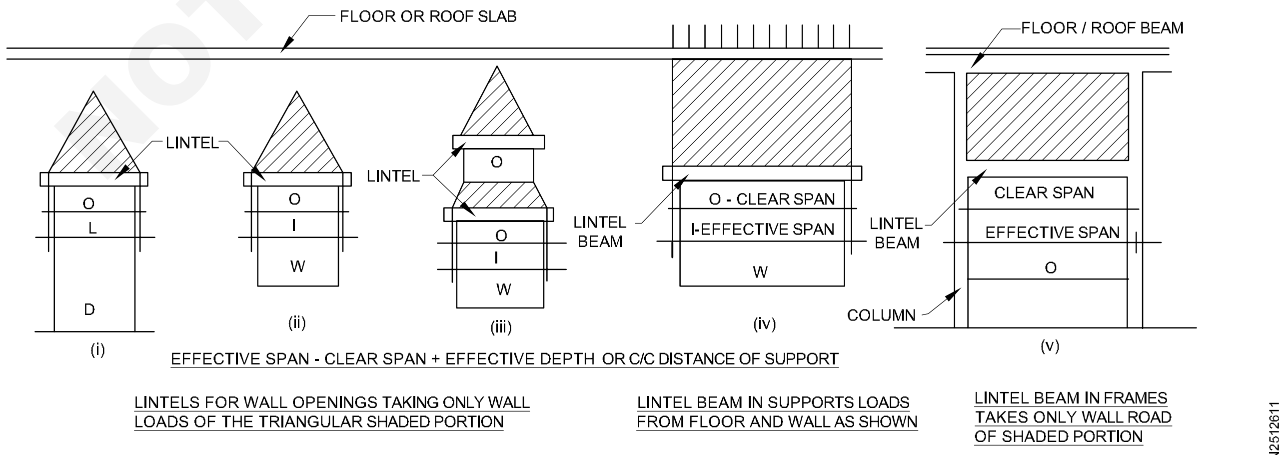
In break lintel main bars are provided just like in simply supported beam while in a continuous lintel, it will be same as that of continuous beam. In both case usual forms of stirrups are provided.

Structural concepts and detailing of lintels

a Load acting on lintels: Lintels span between the openings for doors, windows, ventilators etc. They carry the loads of the triangular portion of masonry above them. When this triangle intercepts the floor slab the loads over the entire length of the lintel come over it. Lintel beams in framed construction carry the weight of the masonry infill between the lintel and floor beam above. (Fig 2)

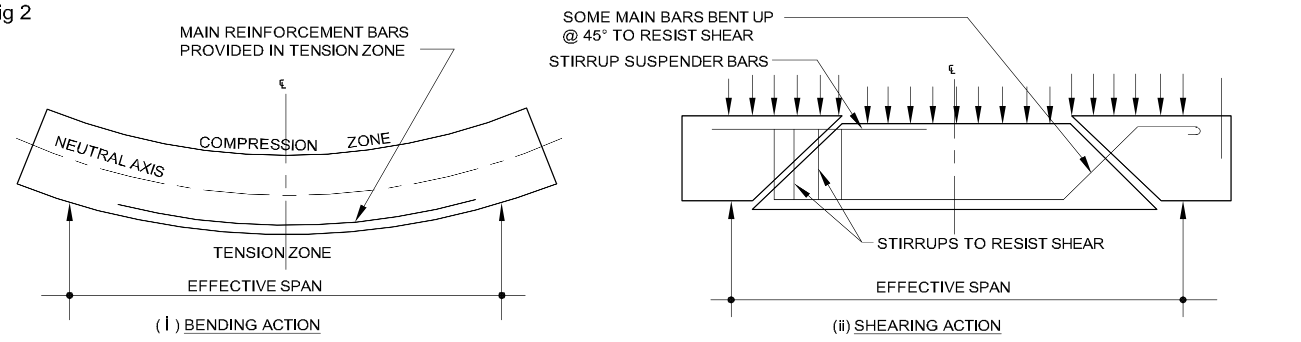
b The structural behavior: A lintel is subjected to bending and shearing action. In the tension zone reinforcement is provided in concrete, to resist the tensile stresses. The shearing action is taken care of by vertical stirrups or cranked bars as indicated.

Fig 1



(a) LOAD ACTING ON LINTELS

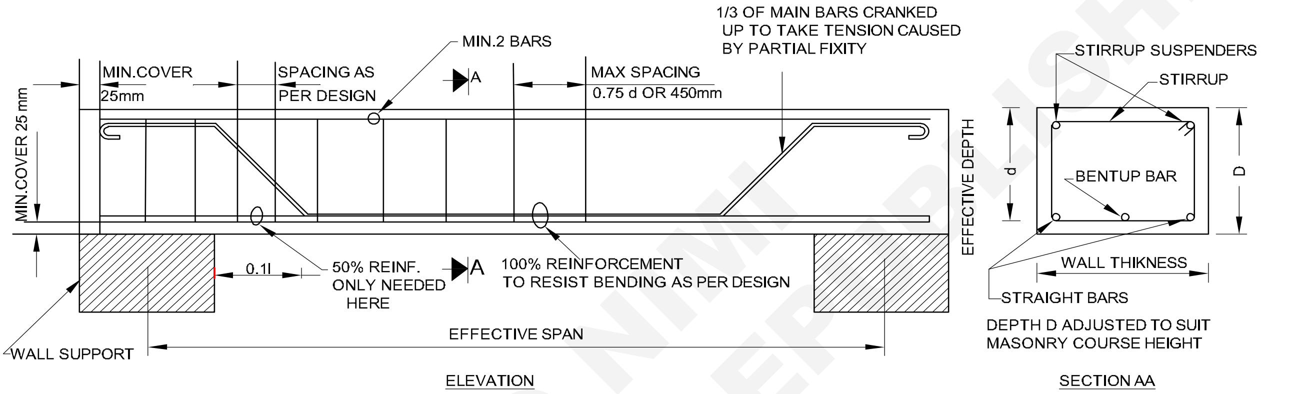
Fig 2



STRUCTURAL BEHAVIOUR OF A SIMPLY SUPPORTED LINTEL (BEAM)

Method of detailing: All information regarding the size of the lintel, type, number and position or reinforcements, the cover for reinforcement bars etc. are presented in a longitudinal elevation and one or more cross sections. Note the two types of main reinforcement (straight and cranked bars), stirrup suspenders, stirrups at varying spacings (closer near the end), position of cranks etc. in the drawing. (Fig 3)

Fig 3



SIMPLIFIED STRUCTURAL DETAILING FOR A LINTEL

Work specification for lintels and sunshades

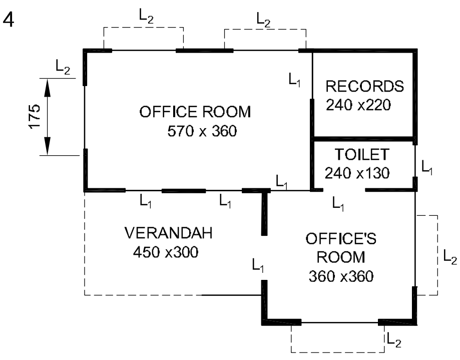
1 lintel thickness shall be of 2 brick thickness (20 cm)
2 sunshade projection shall be 70 cm
3 concrete of M15 grade of nominal mix with 350 kg. of aggregate to 50 kg. of cement and 32 liters of water is assumed.
4 Proportion of fine aggregate to coarse aggregate shall be 1:2 by weight.
5 Aggregate shall be well graded with a max size of 20 mm.
6 MS bars of σst 230N/mm^2 is assumed.
7 Wall thickness or width of lintels 250.
8 Clear spans L1 - 100 cm, L2 - 135 cm.

Drawings of lintels and sunshades

The key plan indicates two types of lintels (L1 and L2) and positions of sunshades.

Details of lintel type I (LI): This has a clear span of 100 cm. Three different types of bars marked 1,2 and 3 within circles are used for this member. (Figs 4 & 5)

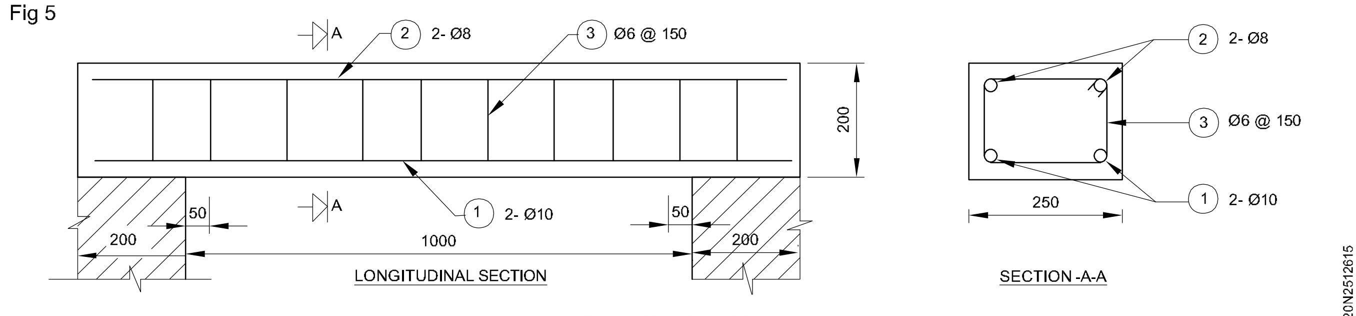
Fig 4



KEY PLAN

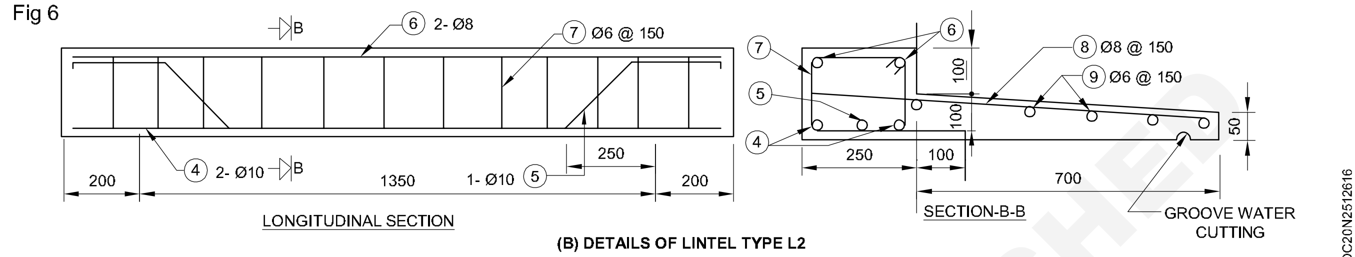
Details of lintel type II (L2): This lintel has a clear span of 135 cm, and is attached to sunshade. The longitudinal section shows only reinforcement in the lintel. The cross section gives bar details of lintel as well as sunshade. (Fig 6)

Fig 5



(a) DETAILS OF LINTEL TYPE L1

Fig 6



(B) DETAILS OF LINTEL TYPE L2

R.C.C Columns with footings

Objectives: At the end of this lesson you shall be able to
- **define R.C.C column and footings**
- **explain general and reinforcement detailing of R.C.C columns with footings**
- **explain type of columns and footings.**

Columns introduction

Columns support primarily axial load but usually also some bending moments. The combination of axial load and bending moment defines the characteristic of column and calculation method. A column subjected to large axial force and minor moment is design mainly for axial load and the moment has little effect. A column subjected to significant bending moment is designed for the combined effect. The column is subjected to compression only compression force may cause lateral bursting because of the low - tension stress resistance. To resist shear, ties or spirals are used as column reinforcement to confine vertical bars.

Definition

Columns are vertical supports which take the loads of floors, beams, walls, lintels and transmit to ground. The failure of a column can thus endanger a whole structure. These are carefully designed, planned and constructed. These can be made into any of the following shapes. Reinforcing of a concrete column helps in restricting the size of a column and thus helps in designing a most economical section.

a Square or rectangular

b Round circular

c L - shape

d Hexagonal

e Octagonal

General

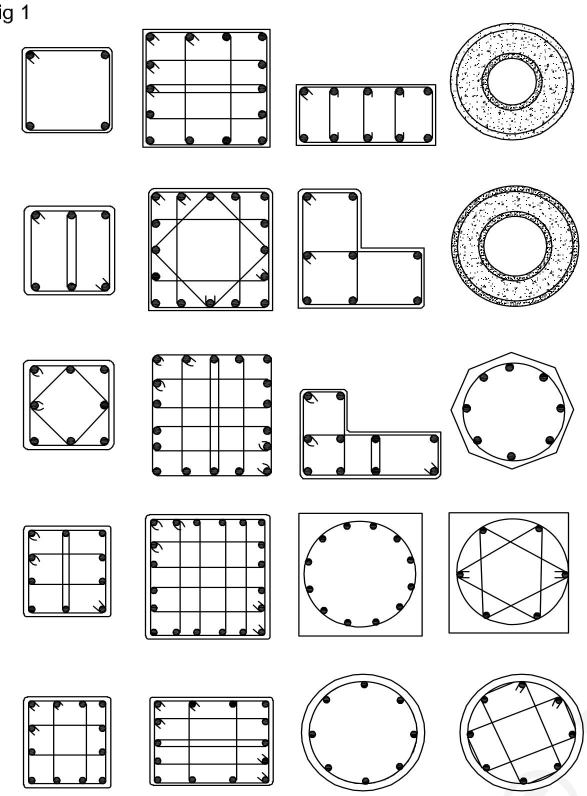
A reinforcement concrete column is said to be subjected to axial load when the line of the resultant thrust of loads supported by the column is coincident with the line of CG. of the column in the longitudinal direction. Depending upon the architectural requirements and the loads to be supported, R.C.C columns may be cast in various shapes i.e. square, rectangular, hexagonal, octagonal or circular. Columns of L- shape or T - shape are also sometimes used in multistoreyed buildings. The longitudinal bars in columns help to bear the load in combination with the concrete. These bars are uniformly spaced along the perimeter of the column as near the surface as permissible. The longitudinal bars are held in position by transverse reinforcement, or lateral binders. The binders prevent displacement of the longitudinal bars during concreating operation and also check the tendency of their buckling outwards under loads. The transverse reinforcement, or binders are of two types. Type (1) consists of separate small diameter steel binders bent around the longitudinal bars. The diameter, centre to centre spacing and the arrangement of the separate binders, depend upon the number and diameter of longitudinal bars and the size of the column. In the second type, reinforcing bar forming the tie, is wound round the longitudinal bars in the form of a closely spaced continuous helix and is termed as spiral or helical reinforcement. The helical reinforcement in addition to rendering support to longitudinal bars against buckling and displacement also act to confine the concrete within it in the form of a core thereby increasing the load carring capacity of the column.

Different arrangements of separate binders and helical reinforcement are shown in figure 1.

The following points should be kept in view while designing a column to effect saving in cost.

1 Column with separate lateral ties work out cheaper than columns with spiral reinforcement.

Fig 1



ARRANGEMENT OF TIES FOR DIFFERENT NUMBERS OF COLUMN BARS

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2 Axially loaded columns with a low percentage of steel work out more economical per tonne of load supported than columns with a higher percentage of steel.

3 The richer the concrete the more economical in the design.

Types of columns (Fig 2)

Depending upon the slenderness ratio or length to diameter ratio, columns can be divided into three classes.

1 Short columns:

Columns which have lengths less than 8 times their respective diameters or slenderness ratio less than 32 are called short columns. When short columns are subjected to compressive loads, their buckling is generally negligible and as such the buckling stresses are very small as compared with direct compressive stress. Therefore it is assumed that short columns are always subjected to direct compressive stresses only.

2 Medium size columns

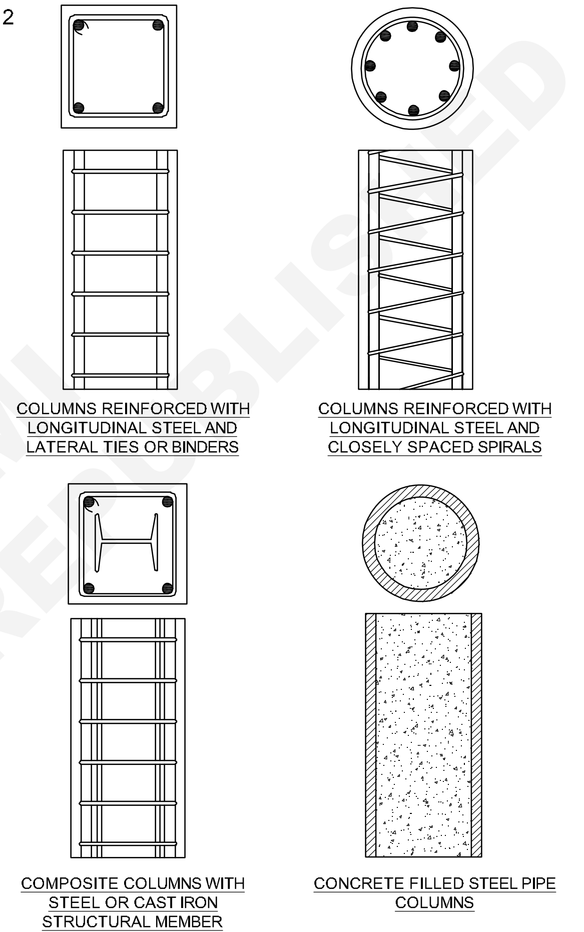
The columns which have their lengths from 8 times their diameter to 30 times their respective diameters or their slenderness ratio lying between 32 and 120 are called medium size columns or intermediate columns, both the buckling as well as direct stresses are of significant values. Therefore, in the design of intermediate columns both these stresses are taken into account.

3 Long columns

The columns having their lengths more than 30 times their respective diamters or slenderness ratio more than 120 are called long columns. They are usually subjected to bucking stress only. Direct compressive stress is very small as compared with buckling stress and hence it is neglected.

Reinforcement

Fig 2



TYPES OF COLUMNS

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a Longitudinal

i Area of main vertical bars to be not less than 0.8% of the area of concrete section and not more than 8% of the gross, cross - sectional area of concrete. From practical point of view it should not be more than 4% of the gross - cross sectional area of concrete.

ii Diameter of bar to be not less than = 12 mm.

iii A circular column having spiral or helical reinforcement will have at least 6 number vertical bars.

2 Transverse reinforcement: It is of two types.(Figs 3 & 4)

i Lateral ties or polygonal links

ii Spiral, or helical or hoop reinforcement.

Lateral ties

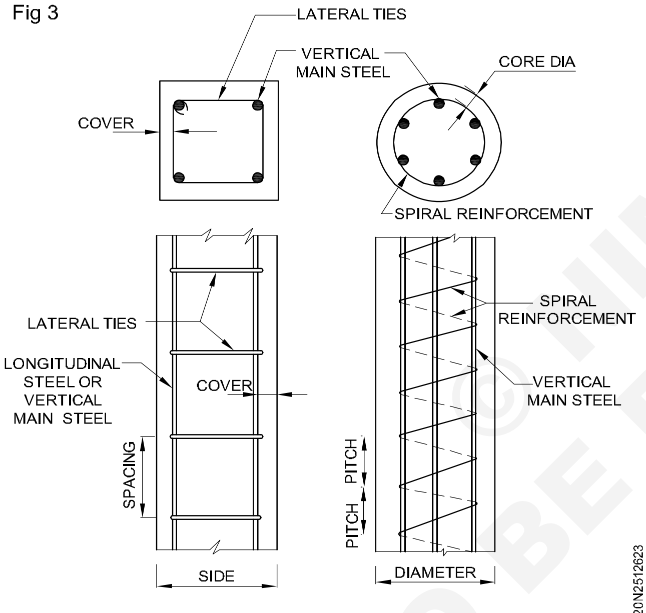
Spacing	= 16 times the dia of longitudinal reinforcement.
	= the least lateral dimension of column.
	= 300 mm
Diameter	= Minimum 5 mm.
OR	= ¼ th of vertical bars diameter.

Spiral

Pitch	= not less than 75 mm.
OR	= 1/6 th of core diameter of column.
Diameter	= Minimum 6 mm.
OR	= ¼ th of vertical bars diameter.

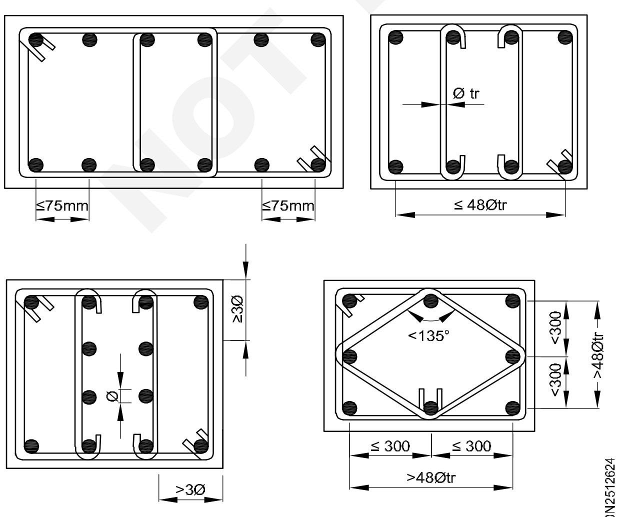
Cover

Fig 3



COLUMN WITH VERTICAL BARS HOOP IRON TIES AND SPIRAL REINFORCEMENT

Fig 4



ARRANGEMENT OF TRANSVERSE REINFORCEMENT

For longitudinal bars = min.40 mm. or diameter of bar whichever is greater.

For columns of 20 cms. dia. or under, where the diameter of vertical steel is not more than 13 mm. cover is to be taken as 25 mm.

Lap in vertical bars

Splice or lap = 24 x dia. of longitudinal bar.

Drawing of a column

i **Plan** in it foundation - raft is shown. Vertical bars, size of column and lateral reinforcement are shown by thick lines.

ii **Vertical section** Vertical section shows the height of column, longitudinal bars, spacing of ties, foundation concrete, foundation steel, plinth, depth below ground level and splicing of longitudinal bars, if any.

Footing

Introduction

The foundation of a building is the part of a structure that transmits the load to ground to support the superstructure and it is usually the last element of a building to pass the load into soil, rock or piles. The primary purpose of the footing is to spread the loads into supporting materials so the footing has to be designed not to be exceeded the load capacity of the soil or foundation bed. The footing compresses the soil and causes settlement. The amount of settlement depends on many factors. Excessive and differential settlement can damage structural and nonstructural elements. Therefore, it is important to avoid or reduce differential settlement. To reduce differential settlement, it is necessary to transmit load of the structure uniformly. Usually footings support vertical loads that should be applied concentrically for avoid unequal settlement. Also the depth of footings is an important factor to decide the capacity of footings. Footings must be deep enough to reach the required soil capacity.

Definition

The complete sub - structure with reinforcing cement concrete transmitting load of super structure to the bearing soil at shallow depth is called RCC footing.

Types of footings

The most common types of footings are strip footings under walls and single footings under columns.

Common footings can be categorized as follow

1 **Individual column footing (Fig 5a)**

This footing is also called isolated or single footing. It can be square, rectangular or circular of uniform thickness, stepped, or sloped top. This is one of the most economical types of footing. The most common type of individual column footing is square of rectangular with uniform thickness.

2 **Wall footing (Fig 5b)**

Wall footings support structural or nonstructural walls. This footing has limited width and a continuous length under the wall.

3 Combined footing (Fig 5c,d &e)

They usually support two or three columns not in a row and may be either rectangular or trapezoidal is shape depending on column. If a strap joins two isolated footings, the footing is called a cantilever footing.

4 Mat foundation (Fig 5f)

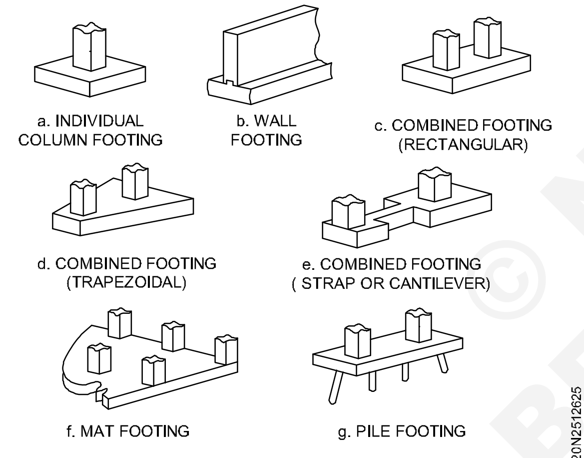
Mats are large continuous footings, usually placed under the entire building area to support all columns and walls. Mats are used when the soil bearing capacity is low, column loads are heavy, single footings cannot be used, piles are not used, or differential settlement must be reduced through the entire footing system.

5 Pile footing (Fig 5g)

Pile footings are thick pads used to tie a group of piles together and to support and transmit column loads to the piles.

Is code provisions

Fig 5



FOOTING TYPES

1 Footing shall be designed to sustain applied loads, moments and forces and induced reaction and to ensure that any settlement which may occur shall be as nearly uniform as possible, and the safe bearing capacity of the soil is not exceeded.

2 Thickness at the edge of footing shall not be less than 15 cm for footings on soil, nor less than 30 cm above the tops of piles for footing on piles.

i Thickness at the edge to be ≮15cm

ii Min. cover to main reinforcement to be 50mm for surfaces in contact with earth face and ≮40mm for other exposed surfaces

iii Max. cover to reinforcement 75mm.

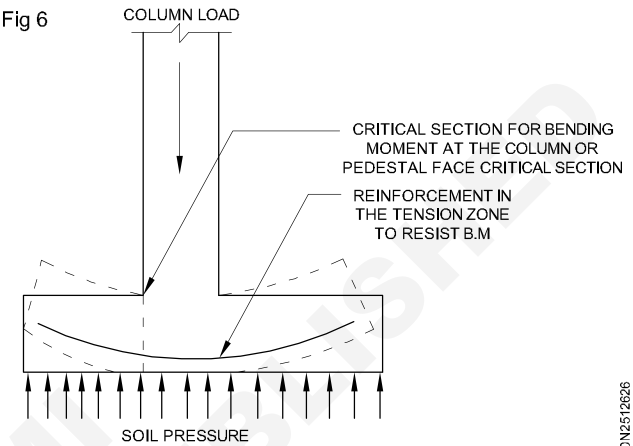
iv Min. diameter of main bars 10mm.

v Min. reinforcement in either direction 0.15 percent (plain bars) or 0.12 percent (deformed bars) of gross sectional area of concrete.

Code provisions for designing and detailing (Figs 6 & 7)

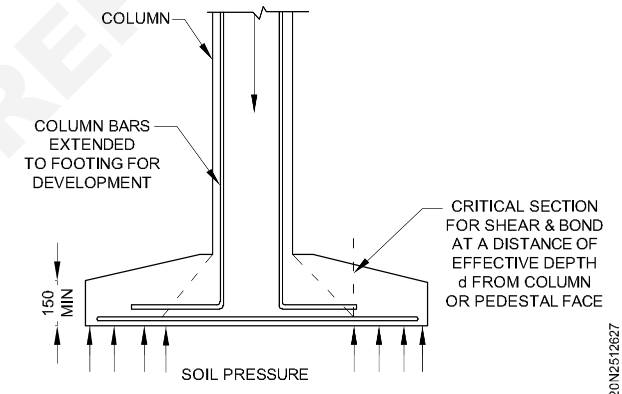
Simple isolated column footings transfer the column load to soil by bearing. The soil pressure generates bending and shearing actions on the footing slab. The concrete section and reinforcements resist the resulting stresses. Important code provisions for designing and detailing of the footing are listed.

Fig 6



BENDING ACTION

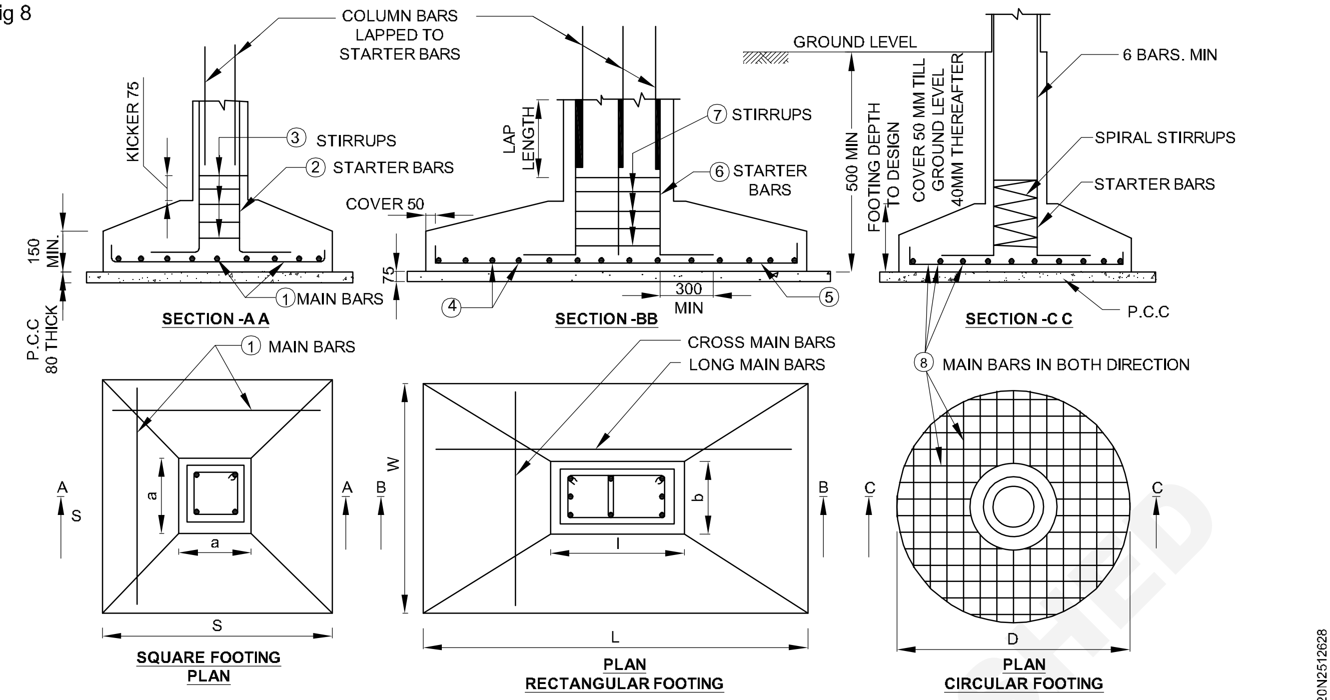
Fig 7



SHEARING ACTION

Method of detailing: The footing for square, rectangular and circular columns are shown in Fig.8. A circular column may also be provided with a square footing. For each type of footing a plan and sectional view are given to clearly detail the bars. The plan gives the dimensions of the footing slab and column section. The section gives the dimensions of the footing in relation to the ground level. The spacing and direction of bars are marked in the plan. The section gives full details regarding the cover, positions, arrangement and splicing of the bars. Each of the bars is identified by a specific bar mark, for relating its position in two views and for preparing the bar bending schedule.

Fig 8



MAIN TYPES OF ISOLATED COLUMN FOOTINGS

R.C.C beam

Objectives: At the end of this lesson you shall be able to
- **define R.C.C beams**
- **explain classification of R.C.C beam**
- **explain detailing of reinforcement of R.C.C beam.**

Introduction

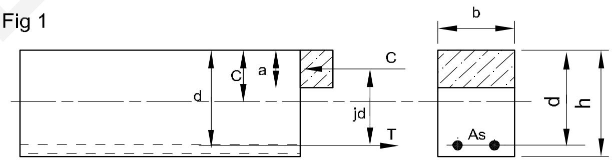
Beams can be described as members that are mainly subjected to flexure and it is essential to focus on the analysis of bending moment, shear, and deflection. When the bending moment acts on the beam, bending strain is produced. The resisting moment is developed by internal stresses. Under positive moment, compressive strains are produced in the top of beam and tensile strains in the bottom. Concrete is a poor material for tensile strength and it is not suitable for flexure member by itself. The tension side of the beam would fail before compression side failure when beam is subjected a bending moment without the reinforcement. For this reason, steel reinforcement is placed on the tension side. The steel reinforcement resists all tensile bending stress because tensile strength of concrete is zero when cracks develop. In the ultimate strength design (USD), a rectangular stress block is assumed.

As shown Fig.1 the dimensions of the compression force is the product of beam width, depth and length of compressive stress block. The design of beam is initiated by the calculation of moment strengths controlled by concrete and steel.

Definition

It is an R.C.C member, which bridges two, or more walls or columns and supports the structural member coming over it.

Fig 1



REINFORCED RECTANGULAR BEAM

Classification of R.C.C beams

1 Simply supported

In this type of beam there is no fixity at supports. The value of BM at supports will be zero and the beam is designed with maximum BM on the span. As per IS: 456 the minimum depth required to this type are span/20. Arrangement of reinforcement is given in the figure (2).

2 Fixed beams

Beam having some kind of fixity at ends with the supporting column or wall is called fixed beams. The beams coming in a framed structure are best example for this type. BM value in the span as well as in supports also should be considered for design of this. Main reinforcement is provided at bottom in span and at top on supports. For this 50% of main reinforcement is cranked and taken to top. The crank distance may be 1/5 of span from the face of the support. Minimum depth of beam should be span/26.

The beams coming over masonry walls are called partially fixed. The hogging movement at support will be less than the totally fixed beams. In this case the cranking may be done at a distance of 1/7 span from support face. Detail of reinforcement arrangement is given in the following Fig 3

Fig 2

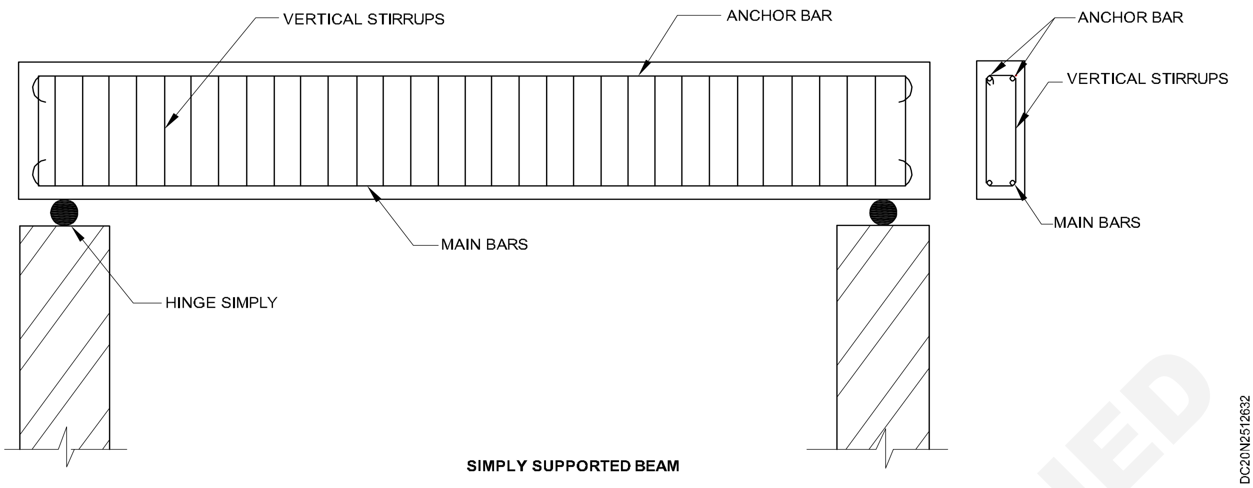
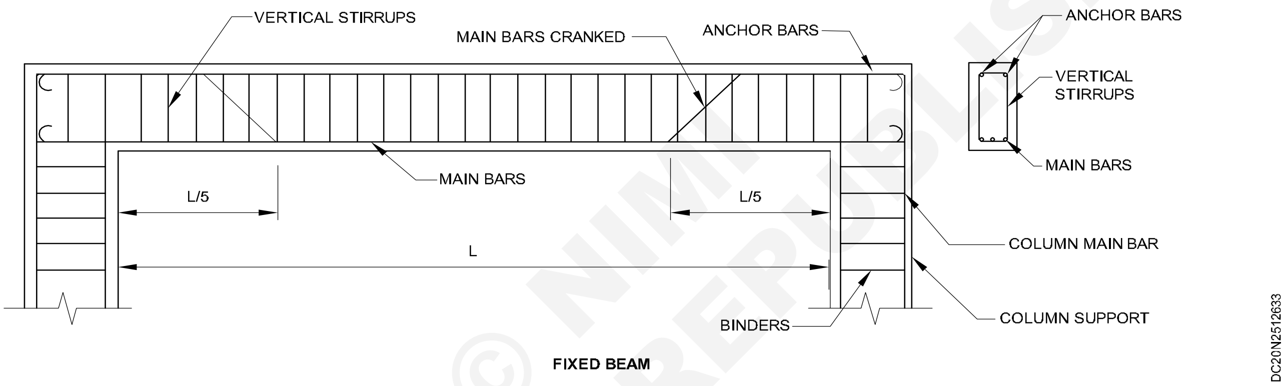


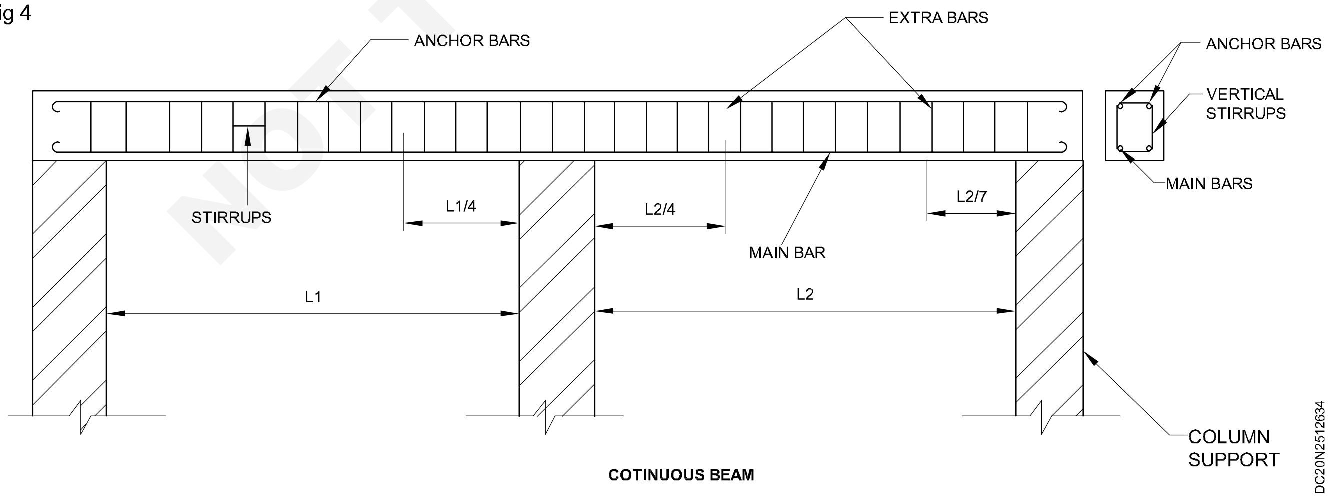
Fig 3



3 Continuous beams (Fig 4)

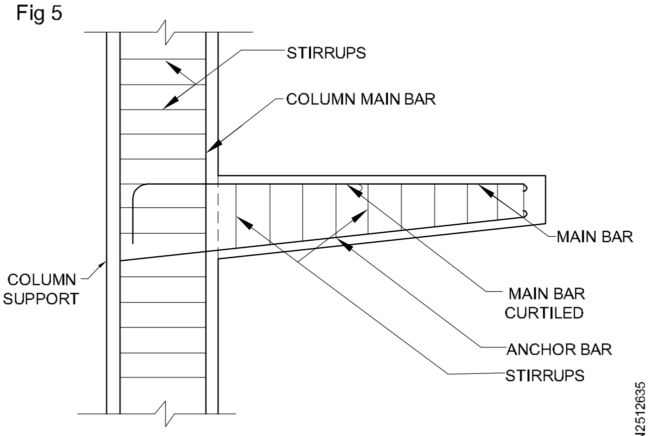
Beams, which rest more than two supports, are called continuous beams. In this case the intermediate support are treated just like totally fixed support and the end support may be either totally fixed or partially fixed or simply supported. The simplicity of execution cranking is obsolete and extra bars of length, span/4 to each span from support face are provided at where ever the hogging moment occurs.

Fig 4



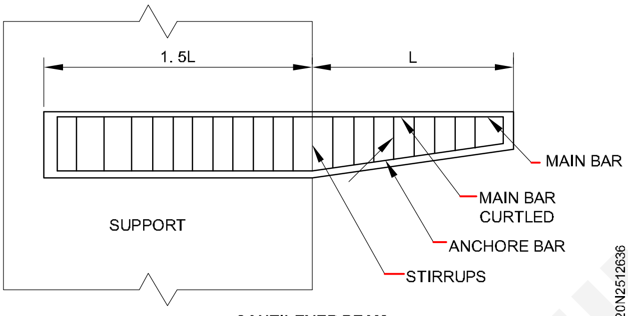
4 Cantilever beams (Figs 5 & 6)

Fig 5



CANTILEVER BEAM ON COLUMN

Fig 6



CANTILEVER BEAM

Beams in which one end is fixed and other end is free is called cantilever beam. Beams provided to support projection slabs of verandah, balcony etc are some example for this. In a cantilever beam the moment will be hogging and maximum amount of it occurs at fixed end. So the main reinforcement should be provide in top at fixed end of the beam. If the span is more no need to provide same quantity of reinforcement throughout, according to the moment variation bars can be curtailed.

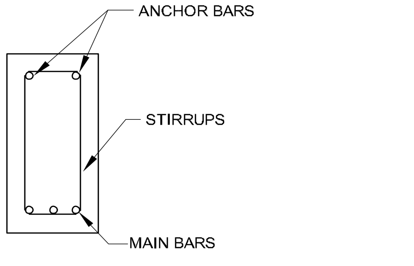
If the fixed end is over a masonry wall necessary anchor weight should be provided at support. Also the length of beams behind the support should not less than 1.5 times the span. Thickness at support should not less than span/ shear force and bending moment are zero at free and, reinforcement as well as size of beam also can be reduced to a minimum. Reinforcement arrangements for typical cantilever beams are given in the figures 5 & 6. Stirrups should provide with a closer spacing at support face and can increase the spacing towards the free end.

Classification according to shape

1 Rectangular beams (Fig 7)

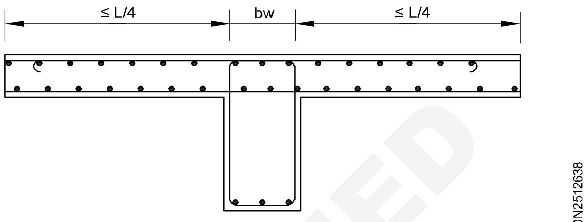
These are the beams having cross section in the shape of a rectangle. This can be adopting for any type of beam in the first category and it is the popular shape of R.C.C beam. Main reinforcements are provided at its corners. Near the periphery shear reinforcement in the form of stirrups are also provided.

Fig 7



2 T - beam (Fig 8)

Fig 8



T-BEAM

In beam and slab construction if beam and slab are cast at one time, the construction becomes monolithic. The slab above beam takes compression and thus the rib derives strength from the slab, which acts as a compression flange called T beam. The slab portion is called 'flange' and the beam 'web'.

The width of a flange effective for taking compression may be taken as follows, but in no case it should be greater than the c/c spacing of beams.

$B_f = L_o/6 + bw + 6df$

B_f = Width of flange.
L = the distance between point of zero moments (For continues beams L may be assumed as 0.7 length)

bw = Breadth of web
df = thickness or flange.

Minimum effective depth should be as follows:

1 D ≥ L/20.

2 For light load D ≥ L/15 to L/20.

3 For medium load D ≥ L/12 to L/15.

4 For head load D ≥ L/12.

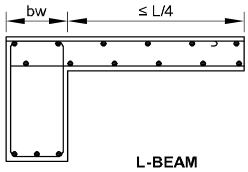
Minimum tensile reinforcement shall not be less than 0.3% of the area equal to overall depth multiplied by the width of the web.

If the main reinforcement of the slab is parallel to the beam, traverse reinforcement shall be provided as in fig.8, such reinforcement shall not be less than 60% of the main reinforcement at mid span of the slab.

3 L- Beam (Fig 9)

Beam cast monolithic with slab, to use the slab as the compression flange on one side of the rib only is called L beam.

Fig 9



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Effective depth condition are same as to T- beam flange width should be as follows.

B_f=L/12+bw+3df

For rotated beam, the effective flange width shall be obtained as below but in no case grater the actual width.

B_f=[0.5l/(l/b)+4]+bw

Singly reinforcement beam: Beam designed such a way that, main reinforcement provide only in tension zone is called a singly reinforced beam. Any of the above beams can be designed in this way. So the minimum requirement of depth is same as that of each given earlier.

Doubly reinforcement beam: When the dimensions of a beam are restricted by architectural or structural consideration the section will have insufficient area of compressive stresses. Steel is placed in the compression part of the section to supplement, beam having tensile and compressive reinforcement are known as doubly reinforced beam.

Circumstances under which doubly reinforced section have to be used are enumerated as follows.

1 When overall size of a section is limited according to structural head room and architectural requirement.

2 When the section is subjected to reversal of BM. e.g. pile, braces in water towers etc.

3 When members are subjected to shock, impact or accidental lateral loads.

4 When members are subjected to eccentric loading as in case of columns subjected to wind load.

5 When beams continuous over several supports, it has to be designed as double reinforced at supports.

In the design of doubly reinforced beams all the basic rules which are given in previous case are applicable.

The compressive reinforcement shall not more than 4% of the cross sectional area of rib. The compressive bars should be accord effectively by providing stirrups. The spacing of stirrups should be as follows.

1 16 times the dia of compression bar.

2 48 times the dia of stirrups. Whichever is less should be adopted.

Covers in R.C.C beams

Beams may be simply supported, singly or doubly reinforced, continuous or cantilever, covers are provided as under.

1 End cover for each reinforcing bar is not less than 25 mm. or twice the diameter of bar whichever is greater.

2 Clear cover for longitudinal bars is not less than 25mm. or diameter of the bar whichever is greater.

Effective span: In case of freely supported beams, the distance between centres of supports i.e. clear span plus one bearing is taken as effective span. For design purposes the effective span is taken as clear span plus the effective depth of beam.

In case of cantilever beams: The distance between free end and the edge of support i.e. portion projecting beyond support is termed as effective span.

Beam dimensions: Following ratio between span to the depth of beams are kept as a measure of effective design.

Beams description	Max. value of span ratio/depth
Simply supported beams	20
Continuous beams	25
Cantilever beams	10

Reinforcement details: The minimum area of tension reinforcement shall not be less than that given by the following.

A_{st}/b d = 0.85 /f_y

Ast = minimum area of steel

b = breath of beam

d = Eff. depth

f_y = characteristic strength of reinforcement in N/mm^2

Maximum reinforcement in tension zone shall not exceed 0.04 bd

Side face reinforcement: Where the depth of the web in a beam exceeds 750 mm side face reinforcement shall be provide along the two faces. The total area of such reinforcement shall be not less than 0.1% of the web area and shall be distributed equally on two faces at a spacing not exceeding 300 mm or web thickness whichever is less.

Transverse reinforcement: Minimum shear reinforcement in the form of stirrups shall be provided such that

[A_{sv}/b_{sv}] = [0.4/0.87 fy].

A_{sv} = cross sectional area of stirrup leg effective in shear.

S_v = Stirrups spacing along the length of the member.

b = Breadth of the beam or breadth of the web of flanged beam.

f_y = Characteristic strength of the stirrup reinforcement in N/mm^2.

Reinforcement

i Minimum tensile steel = 0.3% of the gross sectional area of the beam. [For plain mild steel bars]

ii Minimum tensile steel = 0.2% of the gross sectional area of the beam. [For deformed or ribbed steel bars]

Gross sectional area means the product of overall depth and width.

iii Minimum steel at top near the support = 2 times the main steel at bottom.

iv Minimum steel to be carried straight on supports = 50% of main steel used for tension.

v Diameter of main bars = 10 mm. to 40 mm.

Minimum 2 number of bars are provided in a beam as main bars.

vi Diameter of stirrups = 6 to 10 mm.dia.
Min. spacing of stirrups = 100 mm.
Max. spacing of stirrups = Lever arm of the beam.

Spacing between main bars

a Horizontally = Maximum diameter of bar or size of coarse aggregate plus 6 mm. Whichever is greater.

b Vertically = Due to restricted space the main bars are sometimes placed in layers or tiers one above the other with space in between. This is termed as vertical spacing.

Vertical spacing = 15 mm.

OR = Max. size of coarse aggregate.

OR = Max. size of the bar.

To achieve this, spacer bars are placed at 1.00 m.c/c interval and tied down with main bars.

Shear reinforcement

Shear reinforcement in the form of inclined bars and vertical stirrups are provided when i.e. shear stress is in between the safe limit and 4 times limit.

i Bending up of bars or cranks: The distance from centre of span to the bending up bars is determined as:

$x = \frac{1}{2}\sqrt{\frac{N_X}{N_O}}$, Where bars are bent only for shear stresses and not for bending stresses.

x = distance from the centre of span

l = effective span

N_x = Number of bars to be bent up

N_o = Number of main bars at centre.

ii As a thumb rule bars are bent at l/7 to l/4 near supports, where l is the effective span.

iii Maximum spacing of shear reinforcement: i.e. spacing between stirrups: IS: 456 - 1978

a For vertical stirrups = 0.75 d or 450 mm whichever is less.

b For inclined stirrups; d or 240 mm whichever is less.

iv Dia. of vertical stirrups = 6 mm to 12mm.

v Shapes of stirrups - see Fig 10 (a) to (e).

Preparing drawings of R.C.C beams

The detailed drawing of a beam consists of:

i A longitudinal sectional elevation: It shows the effective and clear spans, main longitudinal bars bending up of bars, stirrups, hanger bars end and side covers and bearings. Stirrup are shown in dotted lines or thin - single lines. Compression longitudinal bars are also shown in case of doubly reinforced beams.

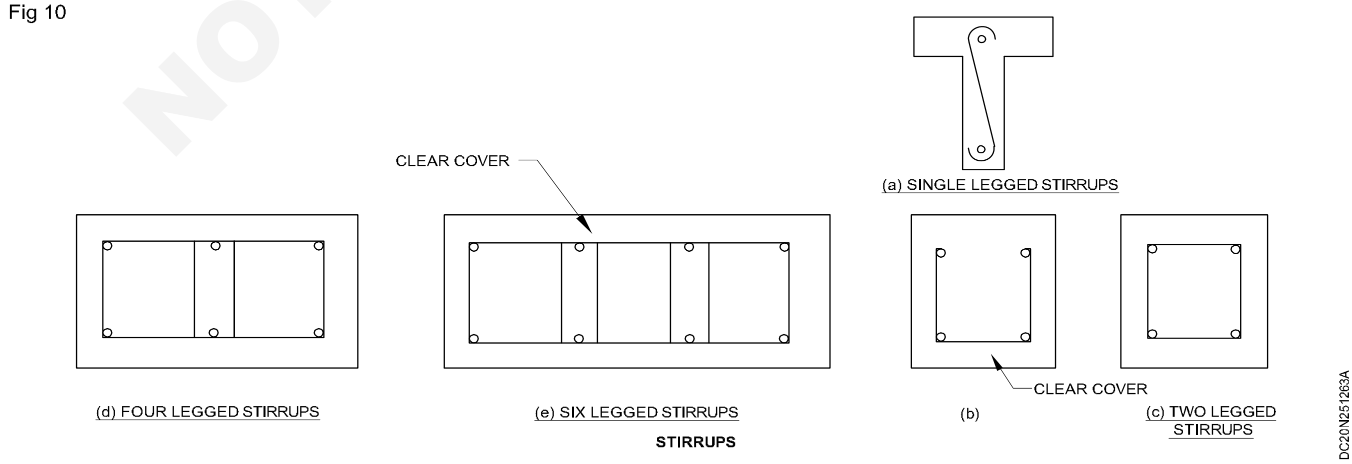
Important note: In case of torque steel no end hooks are provided.

ii Mix 20 i.e. 1:1 ½:3 is used throughout. Same be shown in all solutions. Vertical stirrups in beams and horizontal stirrups in column be shown by thin lines, in all solutions.

Cross - sections: Cross sections are taken near the centre and near the supports. These show overall and effective depths, width and number of bars of a beam. If longitudinal bars are placed in tiers is one above the other, these are also shown in x - sections. Side face reinforcement is also shown.

Stirrups are also shown in the X - sections by solid thin lines.

Fig 10



Tee - beam and inverted 'T' beam

Objectives: At the end of this lesson you shall be able to
- **define tee - beam and inverted beam**
- **explain general detailing of tee beam and inverted beam.**

Introduction

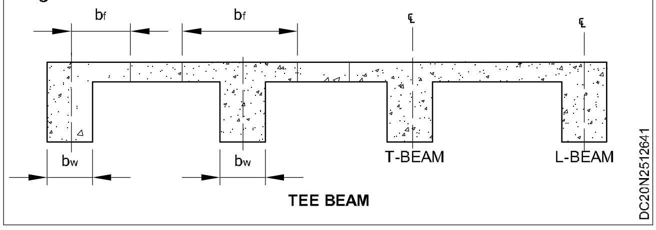
In this type of beams, the R.C.C floor or roof slab is cast monolithic with the beam. The stirrups and the bent up bars of the beam extend into the slab and a portion of the slab acts with the beam for resisting compressive stresses. This results in increasing the moment of resistance of the beam.

Definition

The slab cast integrally with the beam is called flange of the beam and the part of the beam projecting below the slab or flange is known as rib or web of the beam.

In general (Fig 1)

Fig 1



TEE BEAM

In case of simply supported beams the bending moment is of sagging nature throughout its length. Hence the slab forming the flange of the T- beam is subjected to compression all along the span and the beam behaves as a T- beam throughout the span. On the other hand in case of continuous beams the bending moment is of sagging nature at mid - span and it is of hogging nature at the supports. In the span portion the beam top remains under compression between the points of zero bending moment and hence the contribution of flange remains effective within the mid - length (l_o) of the beam upto the points of zero bending moment. (This length can be assumed to be equal to 0.7 times the effective span) and the beam thus behaves as T- beam only for this length. Beyond the points of zero BM and over the supports, the flange of the beam is subjected to tension.

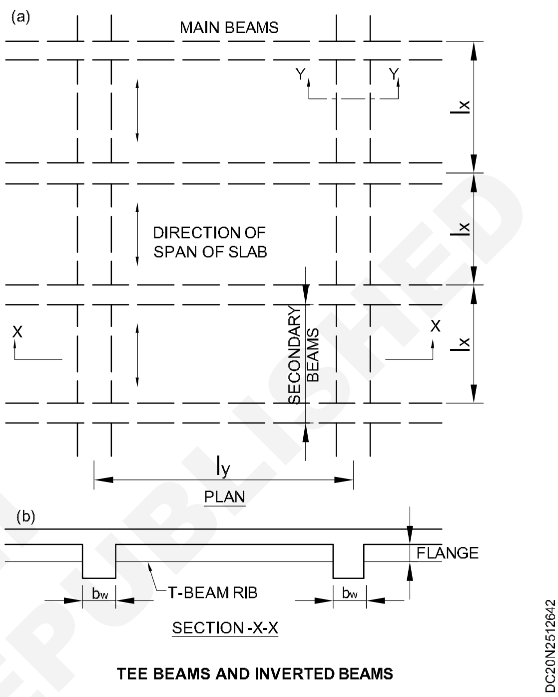
Dimensions of a T - beam Figures 2 & 3 shows the important dimensions of a T - beam which are as under:

Thickness of the flange (df). This is equal to the overall depth of the slab forming the flange of the T - beam.

Breadth of web (bw) This is the breadth of the beam projecting below the slab. The breadth of web should be sufficient to accommodate the tensile reinforcement in the beam with suitable spacing between the bars.

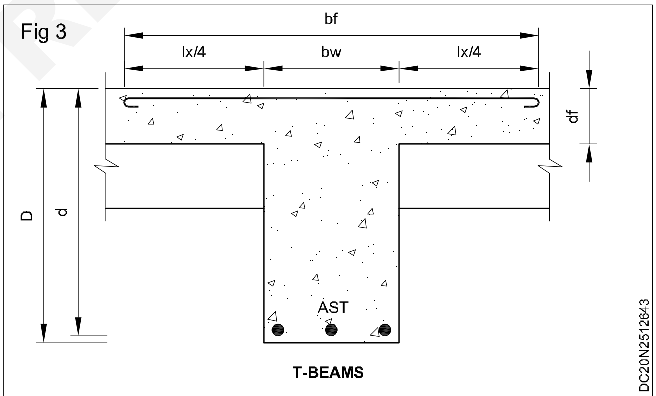
Over - all depth of beam (D) The over - all depth of the beam depends upon the span as well as loading conditions. In case of simply supported beams it may be assumed to be 1/12 to 1/15 of the span. In case of continuous beam, the assumed overall depth may be taken as 1/15 to 1/20 of span for light loads; 1/12 to 1/15 of span for medium loads and 1/10 to 1/12 of span for heavy loads.

Fig 2



TEE BEAMS AND INVERTED BEAMS

Fig 3



T-BEAMS

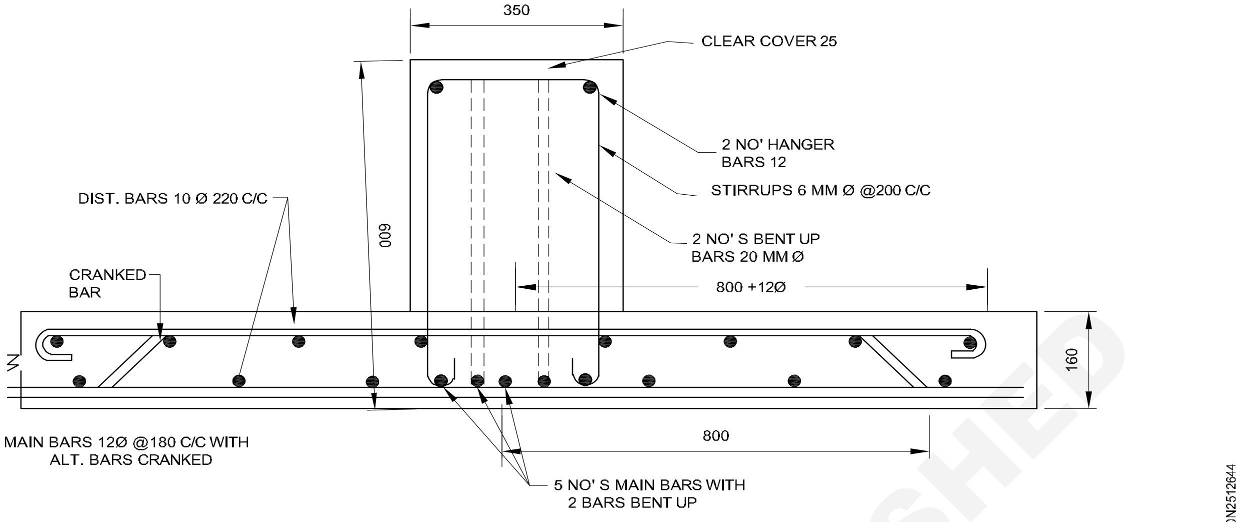
Effective width of flange (bf). It is obvious that the portion of slab (acting as flange) away from the beam web is stressed lesser than the portion immediately above the web. In order to simplify calculations certain width of flange (which normally works out to be less than actual width) is considered to be under uniform stress and hence effective for resisting compression in the beam. This width is termed as effective width of flange. The effective width of flange mainly depends upon the span, breadth of web and the thickness of slab acting as flange.

For continuous beams and frames l_o may be assumed as 0.7 times the effective span.

Inverted 'T' beam (Fig 4)

Technically speaking, in inverted beam the top reinforcement is heavier than bottom reinforcement as the top reinforcement is in tension & bottom reinforcement is in compression, however in normal beam the loading conditions are reverse.

Fig 4



INVERTED BEAM

Generally inverted beam is used in cantilever slabs & for special architectural effects.

In inverted beam the deflection will take place in top of the beam. So, major reinforcement will be provided very opposite to the normal beam as load bearing condition is reverse.

Definition: We have seen that if the size of room is large, we may use monolithic beam slab, construction, forming the tee - beam roof. However in some cases the provision of the beam (i.e rib) below the slab may be undesirable from architectural point of view. In this case the beam is provided above the slab, forming what is known as the inverted T - beam system. In such a case , the ceiling composed of roof slab, is plane and the beam projects above the top of the slab. The slab is thus provided at the "tension" side of the beam and is therefore, not helpful in resting the tensile stresses in the beam. The beam therefore, acts as a simple rectangular beam, which may be either be singly reinforced or doubly reinforced. The depth of these beams is equal to the depth measured between top of the beam and bottom of the slab. Though the slab is cast monolithic with the beam, it is tied to the beam by providing suitable vertical ties or stirrups. The design of the slab however, is done in the same as for any ordinary T - beam roof.

Design of inverted T - beam roof : In some cases the ceiling of the roof slab is required to be plain (i.e, without any beam projections below) to meet the architectural requirements. In case the size of room is small one can provide one - way or two - way slab depending upon the length to breadth ratio. In case the size of room is large, beam and slab type of construction becomes inevitable. As explained earlier, in case the beams project below the slab, the slab contributes to bear the compressive stresses and the beam behaves as a T - beam. In case the beam cannot be projected below the slab (to have plain ceiling) the roof slab can be supported by providing upstand or inverted beams projecting above the roof slab. In such a case the slab and beams are cast monolithically and the slab virtually hangs from the beams.

This type of construction is termed as inverted T - beam and slab construction. In this case the slab is designed exactly in the same manner as in case of T- beam and slab construction. However, the slab being located on the tension face of the beam, is not able to bear the compressive stress and hence the beam acts as a simple rectangular beam. The depth of the beam is considered upto the bottom of the slab.

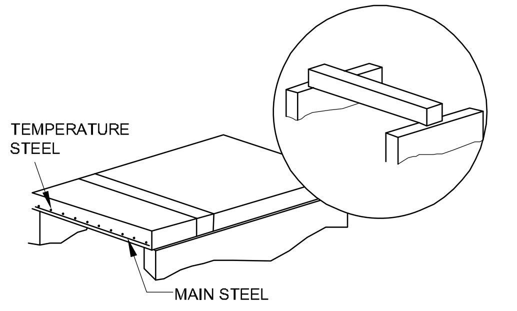
R.C.C one way slab

Objectives: At the end of this lesson you shall be able to
- **define one way slab**
- **explain types of one way slab**
- **describe reinforcement detailing and arrangement of one way slab.**

Introduction: The slab provides a horizontal surface and is usually supported by columns, beams or walls. Slabs can be categorized into two main types: one - way slabs and two - way slabs.

One - way slab is the most basic and common type of slab. One - way slabs are supported by two opposite sides and bending occurs in one direction only. Two way slabs are supported on four sides and bending occurs in two directions. One - way slabs are designed as rectangular beams placed side by side (Fig.1).

Fig 1



ONE - WAY SLAB DESIGN CONCEPT

However, slabs supported by four sides may be assumed as one - way slab when the ratio of lengths to width of two perpendicular sides exceeds 2.

Even though such slabs supported in four directions, nearly all load is transferred in the short direction.

Definition: A concrete slab is said to be spanning in one direction when it is supported on two opposite sides. A slab, when supported on all four sides and if the length of the slab exceeds two times its width, is also said to be spanning in one way slab.

General: For small spans say upto 3.75 m in width, which are not subjected to heavy loadings, a simple slab may suffice. When the ratio of the length of a room to its breadth is greater than 2, most of the load is carried by the short span (i.e. the width the room) and as such the slab is designed to span along the width of the room as a one - way slab. In case of one - way slab the main reinforcement of the slab, span along the width of the room while the distribution bars, laid at right angles to the main reinforcement, lie parallel to the length of the room.

One - way beam and slab / one - way flat slab (Fig 2)

These slabs are supported on two opposite sides and all bending moment and deflections are resisted in the short direction. A slab supported on four sides with length to width ratio greater than two, should be designed as one way slab.

One - way joist floor system

This type of slab, also called ribbed slab, is supported by reinforced concrete ribs or joists. The ribs are usually tapered and uniformly spaced and supported on girders that rest on columns.

Effective span

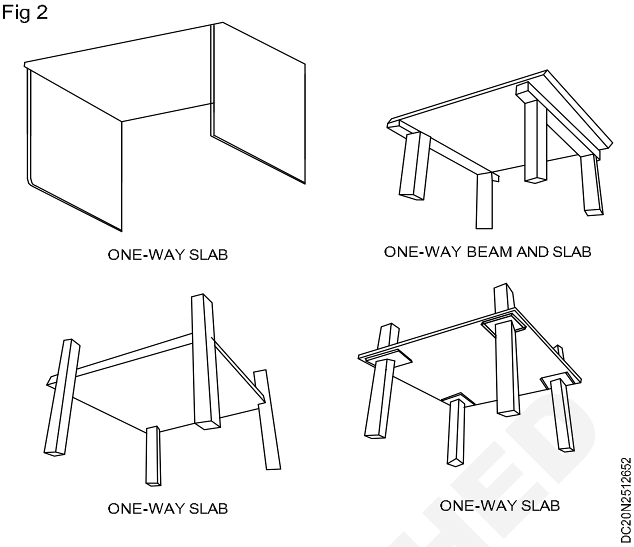
Effective span = clear span + effective depth.

= distance between the centre of supports.

or

The smallest of the two values is adopted for design purposes.

Fig 2



Slab depth

Minimum depth of slab, d = span/30.

Effective depth = 4 cm. per metre of span for load intensity upto 500 kg/m^2

6 cm. per metre of span for load intensity upto 1000 kg/m^2

The ratio of effective span to overall depth should not exceed the following value.

Slab type	Maximum of effective span/over all depth
Simply supported	30
Continuous	35
Cantilever	12

Minimum reinforcement

The reinforcement in either direction shall not be less than 0.15% and 0.12% of the cross sectional area of the concrete when using mild steel bars and deformed bars respectively.

Maximum diameter

The diameter of reinforcing bars shall not exceed one eight of the total thickness of the slab.

Spacing of main steel

Spacing of the bars of main tensile reinforcement in solid slabs shall not be more than three times the effective depth or 450 mm whichever is small. Alternate bars should be cranked at a distance of L/7 and L/5 from face of support for partially fixed and continuous slab respectively.

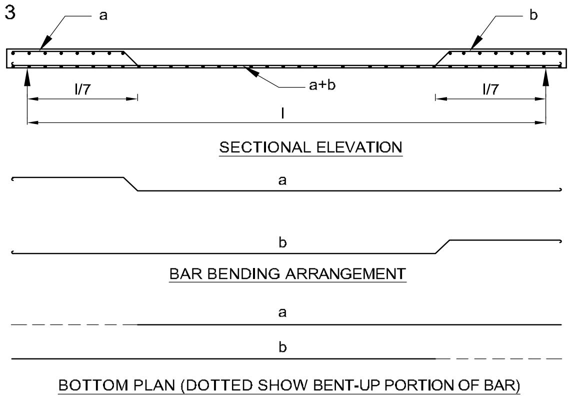
Distribution steel

Spacing of the distribution or secondary steel provided for shrinkage and temperature shall not be more than five times the effective depth of such slabs or 450 mm whichever is smaller. Details of reinforcement arrangement are given in the figure attached.

Arrangement of reinforcements in slabs

A standard bar bending arrangement of the designed reinforcement for a one-way slab has been shown in Fig.3

Fig 3



BAR BENDING ARRANGEMENT FOR A ONE-WAY SLAB

DC20N2512653

Two way slab (R.C.C)

Objectives: At the end of this lesson you shall be able to
- **define two way slab**
- **explain types of two way slab**
- **explain the reinforcement details of two way slab**
- **explain torsion reinforcement.**

Introduction

When the length of slab is less than twice the breadth, slab have tendency to bend along both the spans. So the amount of maximum BM and deflection are very much reduced and as such comparatively thinner slabs are required. But reinforcement has to be provided in both the directions.

Definition

A slab which supported on all four edges and the ratio of long span to short span is not more than two is called a two way slab.

Two- way slabs carry the load to two directions, and the bending moment in each direction in less than the bending moment of one-way slabs. Also two-way slabs have less deflection than one-way slabs. Compared to one way slabs, calculation of two-way slabs is more complex.

In case the slab is supported along all the four sides, it has tendency to bend into a dished surface when loaded. Thus at any point the slab is curved in two principle directions or develops bending moment in two directions. Such a slab has to be reinforced at the bottom for tension in two direction perpendicular to each other. The load from the slab in such a case is obviously transferred on all the four supporting sides.

This type of behaviour holds good when the ratio between length and breadth of the slab is less than two. For increased ratio of sides, the slabs virtually spans along the shorter side and it is designed as one way slab.

Types of two way slab

Two way slabs may be divided into following three categories.

1 Simply supported on all four edges and corners are free to lift.

2 Simply supported on all four edges and corners are held down.

3 Edges fixed or continuous.

Roof slab of an individual room of a single storied building is best example for category- 1. In this slab corners are free to lift and so no torsion stresses are developed and as such no torsion reinforcement is required.

Category -2 is the intermediate floor slab of a multistoried building having single room on each floor or slab monolithic with beams on all edges. Here the corners are held down or corners not free to lift and so torsion stress will develop. Torsion reinforcement in the form of mesh both near top and bottom should be provided at each corner.

Continuous or fixed slabs are usually coming in framed structures. These slabs may have different end conditions as follows.

1 One edge continuous other edges discontinuous.

2 All edges continuous.

3 Adjacent two edges continuous other two edges discontinuous.

4 Three edges continuous one edge discontinuous.

According to these conditions coefficients for BM and SF are obtained from the IS code and proper design steps are adopted.

Typical type of two way slab

1 Two - way beam and slab (Fig 1a)

If the slab is supported by beams on all four sides, the loads are transferred to all four beams, assuming rebar in both directions.

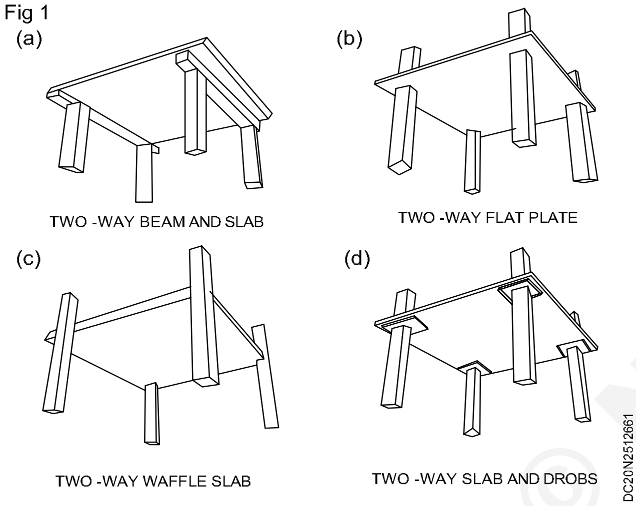
2 Two - way flat slab (Fig 1b)

A flat slab usually does not have beams or girders but is supported by drop panels or column capitals directly. All loads are transferred to the supporting column, with punching shear resisted by drop panels.

3 Two - way waffle slab: (Fig 1c)

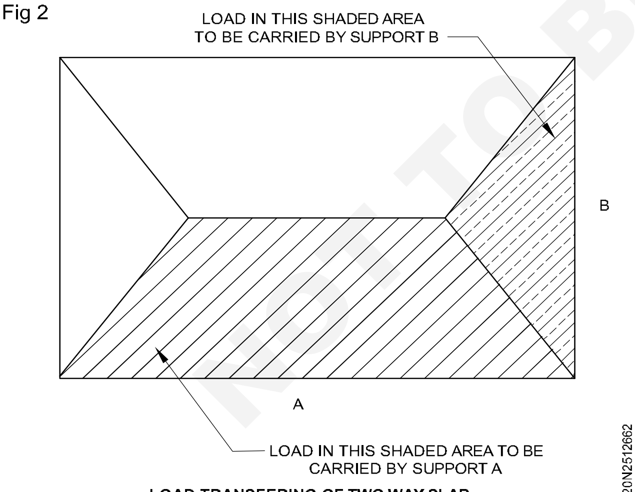
This type of slab consists of a floor slab with a length - to - width ratio less than 2, supported by waffles in two directions.

Fig 1



Load transferring of two way slab (Fig 2)

Fig 2



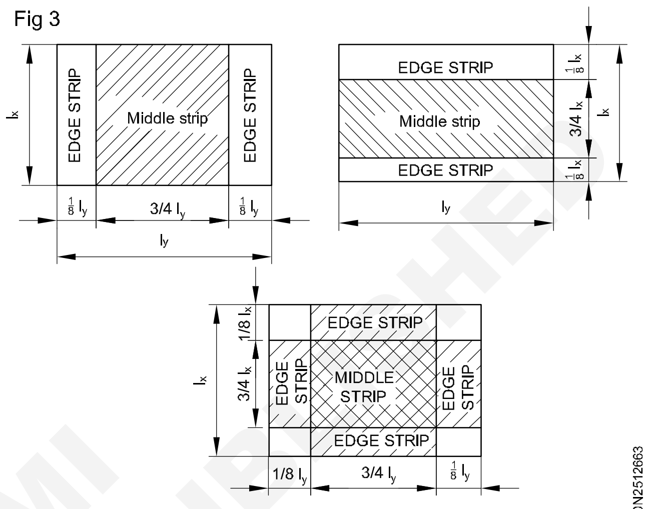
LOAD TRANSFERING OF TWO WAY SLAB

The loads on beams or walls supporting solid slabs spanning in two directions at right angles and supporting UDL may be assumed to be in accordance with the figure given below.

Arrangement of reinforcement in R.C.C two way slab

For providing reinforcement, the slab is considered to be divided in each direction into middle strips and edge strips. The width of the middle strips along each span (long or 3/4th short span) is 3/4th width of slab in the respective span. The width of each edge strip is similarly 1/8th of the width of slab in the respective span. Each middle strip contains the reinforcement calculated based on consideration of maximum bending moment for the respective strip. (Fig 3)

Fig 3



ARRANGEMENT OF REINFORCEMENT IN R.C.C. TWO WAY SALB

In the edge strip minimum area of reinforcements as per rules should be provided.

The following point as given in code have to be taken note of while detailing reinforcement in the slab.

1 The maximum bending moment worked out based on above formula apply only to the middle strips and no distribution is allowed.

2 The tension reinforcement provided at mid - span in the middle strip, shall extend in the lower part of the slab to within 0.25 l of a continuous edge or 0.15 l of a discontinuous edge.

3 Over the continuous edges of a middle strip, the tension reinforcement shall extend in the upper of the slab a distance of 0.15l from the support and at least 50% of the bars shall extend a distance of 0.3l.

4 At the discontinuous edge, - ve moments may arise. They depend on the degree of fixity at the edge of the slab but, in general, tension reinforcement equal to 50% of that provided at mid - span extending 0.1 l into the span will be sufficient.

Torsion reinforcement

Reinforcement which is provided to counteract the tensional stress developed at corners of slabs is called torsion reinforcement. They should be provided as follows.

1 Torsion reinforcement shall be provided at any corner where the slab is simply supported on both edges meeting at that corner. Size of torsion mesh should be 1/5th of short span and the area of steel should be 75% of the area at mid span in short span.

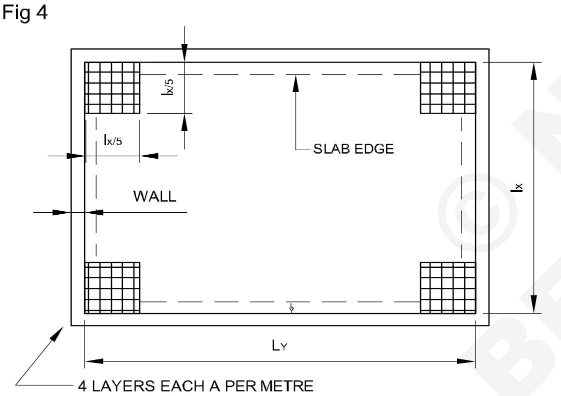
2 Torsion reinforcement equal to half of above shall be provided at a corner contained by edges over only one which the slab is continuous.

3 Torsion reinforcements need not be provided at any corner contained by edges over both of which the slab is continuous.

For the design purpose slabs is considered as divided in each direction into middle strips and edge strips, the middle strip being 3/4 of corresponding span. Edge strips are 1/8 on each. Reinforcement arrangement of each of slab is given in figures attached.

Provision of torsion reinforcement. According to Indian standards code of practice (I.S. 456-1978) torsion reinforcement must be provided at the corners of restrained two way slab except at corners contained by edges over both of which the slab is continuous. The area of torsion reinforcement to be provided under different conditions of slab is given in Figs 4 & 5.

Fig 4

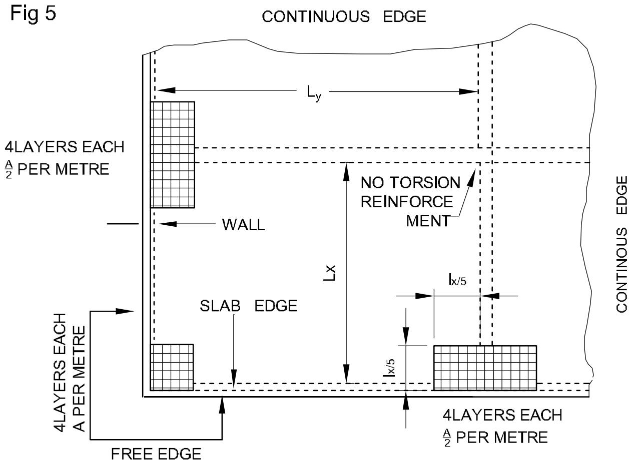


PLAN SHOWING ARRANGEMENT OF TORSIONAL REINFORCEMENT IN A NON-CONTINUOUS RESTRAINED SLAB WHERE A= $\frac{3}{4}$ AREA OF STEEL REQUIRED PER METRE WIDTH OF SLAB FOR MAXIMUM POSITIVE B.M. IN SLAB

PROVISION OF TORSION REINFORCEMENT

DC20N2512664

Fig 5



PLAN SHOWING ARRANGEMENT OF TORSIONAL REINFORCEMENT IN A CONTINUOUS RESTRAINED SLAB WHERE A = $\frac{3}{4}$ AREA OF STEEL REQUIRED PER METRE WIDTH OF SLAB FOR MAXIMUM POSITIVE BM.IN SLAB

PROVISION OF TORSION REINFORCEMENT

DC20N2512665

Incase of isolated slab, having no continuous edge, torsion reinforcement is provided in the form of square mesh placed both at the top and bottom face of the slab at each corner. Each square mesh of reinforcement consists of two layers of bars placed parallel to sides of the slab and extending in these directions for a distance equal to one-fifth of the shorter span. The area of bar per unit width of the slab in each layer of the mesh should be 3/4 of the area of steel required for the maximum positive bending moment in the slab.

At corners contained by the edges over only one of which slab is continuous, the area of bars per unit width of the slab in each layer of the mesh of torsion reinforcement should be 1/2 of the area of steel required in 9.4.2 (i) above.

The reinforcements available in the edge strips, which extend to the corners of the slab may be treated as a part of torsional reinforcement.

Bar bending schedule

Objectives: At the end of this lesson you shall be able to
- **explain bending of bars**
- **explain estimation of reinforcement**
- **explain bar bending and scheduling.**

Introduction

Preparation of highly detailed reinforcement drawing and bar bending schedule is an essential requirement in the construction field, all over the world. With this we can achieve a high level of quality control at site and will be advantageous in various aspects of construction.

In the use of high grade concrete and steel, quality plays a major role. In order to prepare the bar bending schedule, the design office can have the information from site about the stock lists for bar diameters and their lengths available at the site. Fe 500 bars cannot be bend acutely as we bend the Fe 415 bars. Also there are rebinding considerations to be followed. Proper scheduling, & bending with a mechanized system ensures this required quality level.

Let us focus on the detailed drawing to be done for reinforcement detailing (rebar) in reinforced cement concrete construction. Here rebars are drawn to 5mm accuracy as per the detailing rules in IS or British codes.

The reinforcing material for concrete should have the following qualities:

1 The reinforcing material should be capable of developing a good bond with the concrete.

2 Coefficient of thermal expansion should be nearly same as that of concrete.

3 It should have high tensile strength.

4 It should be easy to cut as bend.

5 It should be cheap and easily available.

Mild steel is commonly used as reinforcing material to RCC. Reinforcing steel is provided on tension side of the concrete member. The density of the concrete may be taken as 2440 kg/m^3 and that of steel as 78.5 q/m^3.

Bending of bars

In case of round bars used as reinforcement in concrete, hooks at the ends are provided.

Cover in reinforcement

The reinforcement bars are embedded in concrete so that it is fully covered. Minimum cover required for various structures as per IS - 456 - 1962 is as given below:

1 Clear cover at the end of bars = not less than twice the diametre of bars but minimum 2.5 mm.

2 Clear cover for slabs = 15 mm or diametre of bar whichever is more.

3 Clear cover for beams = 25 mm or diametre of bar whichever is more.

4 Clear cover for columns = 40 mm or diametre of longitudinal bar whichever is more.

5 Clear cover for foundation slabs and beams = 50 mm. When surfaces of concrete members are exposed to the action of harmful chemicals, acids, vapours, sulphurous smoke etc. the cover may be increased.

Purpose of distribution bars in slab

The distribution bars are provided in the slab for lateral distribution of loads on the slab and to take temperature and shrinkage stresses.

The percentage of reinforcement dispends on the design of the structure. In the absence of detailed design the percentage of steel for concrete may be taken approximately as given below.

Lintel slab - 0.721%

Beam - 1 to 2%

Column - 1 to 5%

Foundation raft footing etc - 0.5 to 0.8%

Estimation of R.C.C

R.C.C work is usually estimated under two items:

The concrete in cubic metre and steel reinforcement in quintal. In structural members such as beams, lintels, slabs, etc steel bars are provided in the tensile zone. There are two types of reinforcement provided in a slab: Main reinforcement and distributors or temperature reinforcement. Main reinforcement is used for taking the loads (tensile load). These are provided in shorter span. In this, alternate bars are cranked for taking diagonal tension and are called cranked bars or bent up bars. Usually cranking is given at an angle of 45°. It varies from 30°to 60°. Generally cranking should be started at a distance of 3/4 to 1/7 of the span from the support. The diameter of main reinforcement may be 8mm to 12mm.

Distribution steels are provided at right angle to the main reinforcement, i.e: along the longer span.

In order to distribute the load and to reduce the temperature variation and shrinkage, distribution steels are also used. For distribution bars, 6 mm to 8 mm bars are used.

Hooks are provided at both ends of the reinforcement to get a proper anchorage (bond) with concrete. They may be at 'U' type or 'L' type. Generally 'U' type hooks are provided. Deformed bars (Twisted steel or tor steel) may be used without hooks. The length of one hook is approximately $\phi 9$ where ϕ is the diameter of the reinforcement.

The minimum cover is given as the greater of the following:

1 Diameter of rod

2 Size of coarse aggregate

3 Generally bottom and top cover should be given 20 mm and end cover should be 40 to 80 mm

Let 'L' is equal to the length of slab.

'l' is the effective length.

l = L - 2 end cover

length of straight bar = effective length + length of two hooks.

= l + 2 x length of one hook

= l + (2 x 9ϕ) = l + ϕ18

'D' is equal to depth of slab.

'd' is the effective depth = D - two cover - 1 dia of the main bar.

length of cranked bar = length of straight bar + two excess length (as shown in figure 1)

Excess length of the one side of the cranked bar

= 0.414d = 0.42d

length of cranked bar = length of straight bar + 2 x 0.42 d = l+18ϕ+0.84d

length of distributor bar = l + ϕ18

(Where 'l' is the effective length in longer span)

Number of bars,

Number of main bar $= \frac{l}{\text{Spacing}} + 1$

Where l = effective length in longer span.

Number of main bars = no. of straight bars + no. of cranked bars.

Number of distributors = Number of distributors over straight bars no. of distributors under cranked bars.

Number of distributors over straight bars $= \frac{l}{\text{Spacing}} + 1$

(where l is the effective length in shorter span)

Number of distributors under cranked bars

$$= 2\left[\frac{\times}{\text{Spacing}} + 1\right]$$

(Where 'x' is the length of cranked bar at top

Therefore, total number of distributor bars

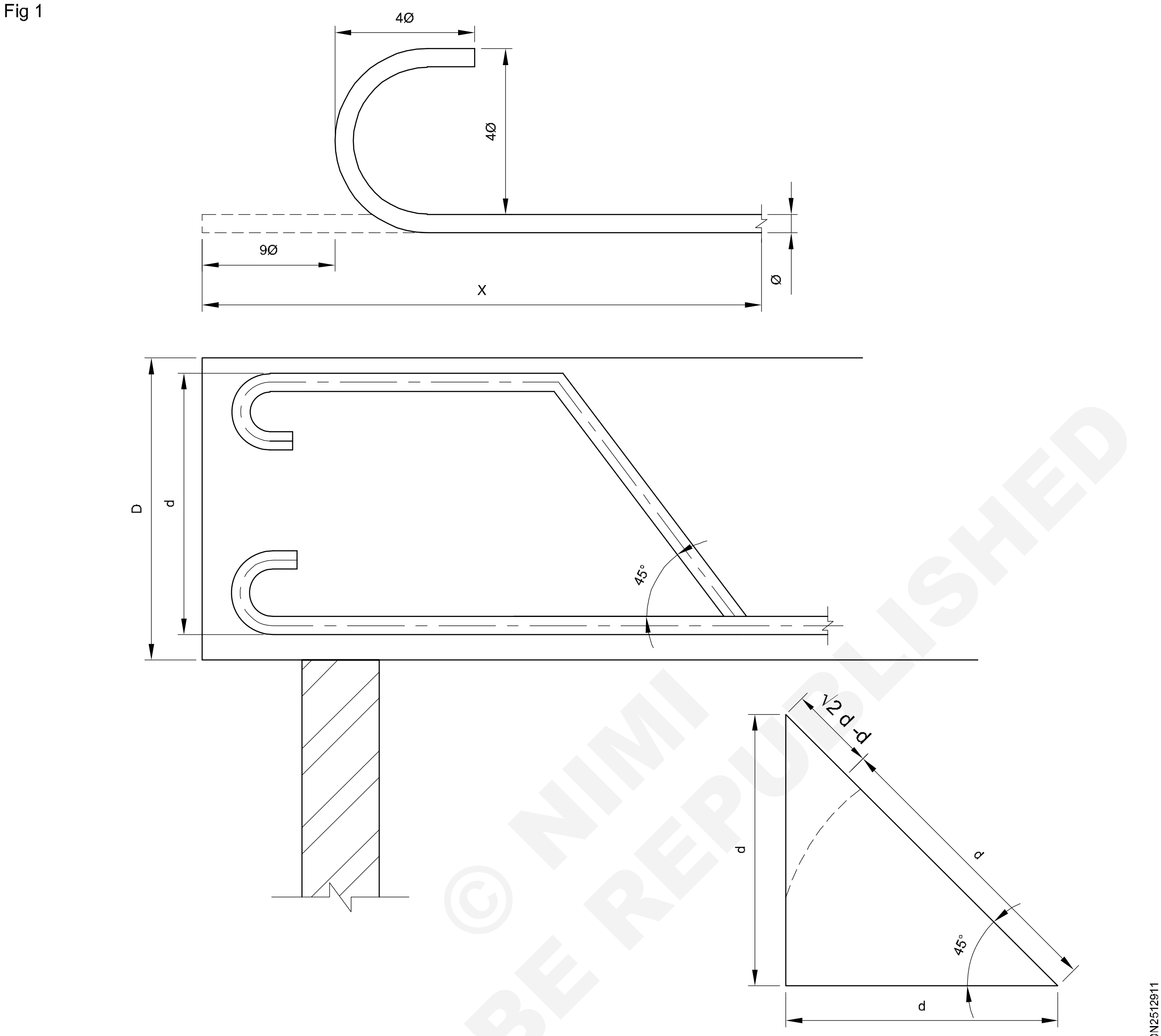
$$= \left[\frac{l}{\text{Spacing}} + 1\right] + 2\left[\frac{X}{\text{Spacing}} + 1\right]$$

Bar bending schedule or schedule of bar (Fig 1)

The schedule of bar is the list of reinforcement bars in a tabular form giving the description of bar, shape of bending with sketch, number, length of each bar, total length, weight per metre length and total weight for each R.C.C work. For each type of RCC work, bartending schedule is prepared. From the schedule of bar the requirement of different sizes of bars may be known and may be arranged and built during the construction.

Sl. No	Description/ particulars	Shape of bars with sketches	No. of bars	Length of each bar	Total length	Weight metre	Total weight

Fig 1



BARBENDING SCHEDULE OR SCHEDULE OF BAR

Weight / m of round bars

Diameter	Weight / m
6 mm	0.22 kg/m
8 mm	0.39 kg/m
10 mm	0.62 kg/m
12 mm	0.89 kg/m
16 mm	1.58 kg/m
18 mm	2.00 kg/m
20 mm	2.45 kg/m

This schedule can be used to cut and bend the bars to the required shape in a cut and bend factory and also in a site. As the steel can be cut and can be brought to the site in a readymade form, Author would like to call it ready mix steel as like our favorite ready mix concrete.Let us go through the different aspects of the preparation of BBS.

Bar bending scheduling (BBS) (Figs 2 3 & 4)

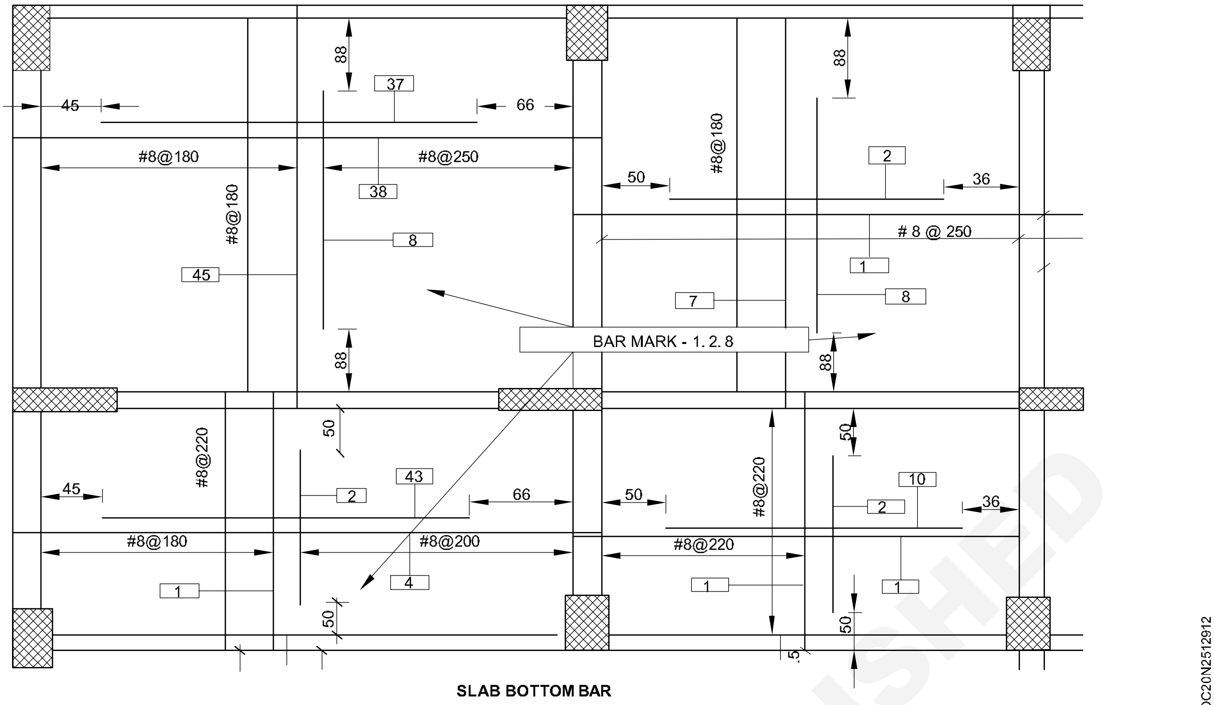
Part drawing of slab bottom reinforcement details is shown. As more details are put in the drawing it is ideal to show top and bottom bar separately in the drawings. Every bar is also marked with a number called 'bar mark' (Exambles-1, 2, 8 etc). This bar mark is the identifier for the bar in the BBS. Shape code defines the shape of the bar. For example shape code 37 or as per the IS code is shown below. The shape code 3A (IS: 2502-1963) means that it is a straight bar.

Advantages of bar bending schedules (BBS)

1 Scheduling and proper bending is strongly recommended for Fe 500. Fe 500 saves 10% compared to Fe 415 steel used presently.

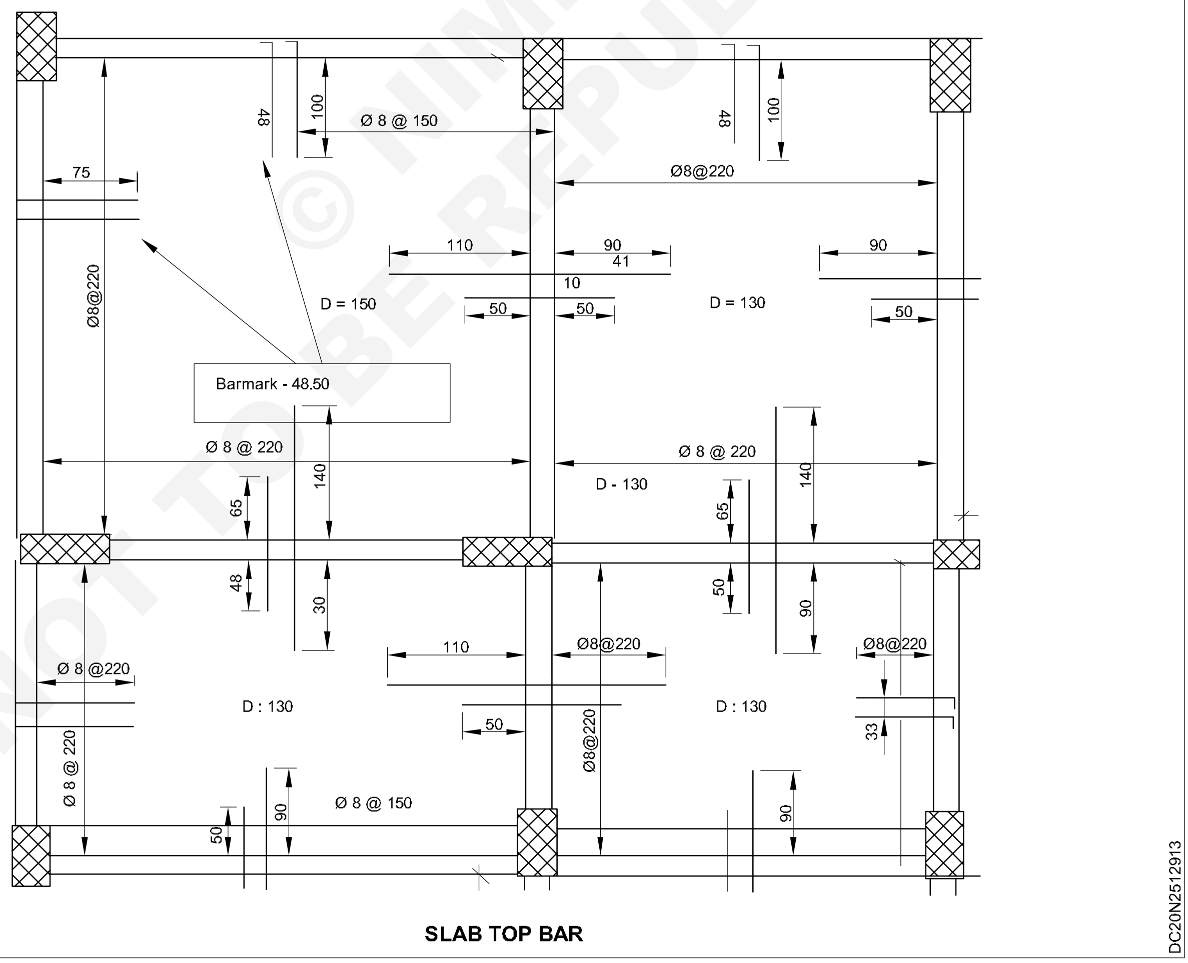
2 Cutting and bending in a cut and bend factory avoids the wastage completely (5-7 %). With BBS, bars can be cut with planning to reduce the wastage in a site with even the present setup.

Fig 2



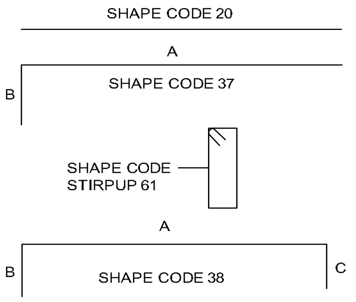
SLAB BOTTOM BAR

Fig 3



SLAB TOP BAR

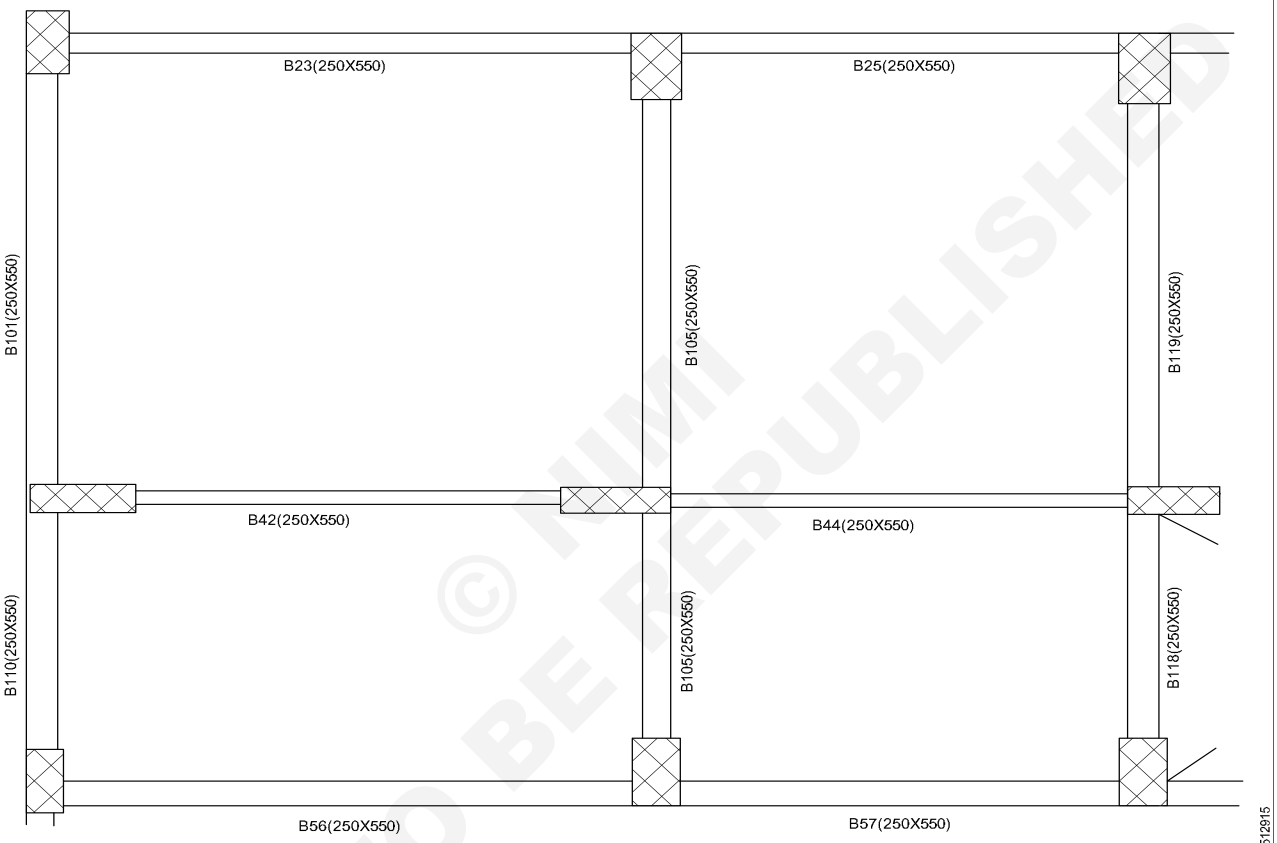
Fig 4



BAR BENDING AND SCHEDULING

3 There is a general tendency to group slabs and beams in the usual design methods. In BBS, it is a must to detail every member separately to account finer geometry and different forces coming on the structure in the modern design methods. Instead of grouping members as all members are detailed separately gives reduction in steel as every member is individually reinforced to resist what it has to. Finer detailing saves about 5 to 15% steel. (Figs 5 & 6)

Fig 5



BEAM LAYOUT

4 Better quality control at site.

5 Better estimation of steel.

6 Real time estimation data, with the design.

7 Better control on stock of steel actually required.

8 Theft and pilferage of steel can be reduced.

9 Economical order quantity for better project management

10 Bench marking quantity and quality requirements.

11 Optimize your design based on the quantity of steel.

12 Steel bending and cutting can commence even before the form work is done.

13 Steel bending can be done at a separate site, marked and then can be assembled at site, if there is space limitations.

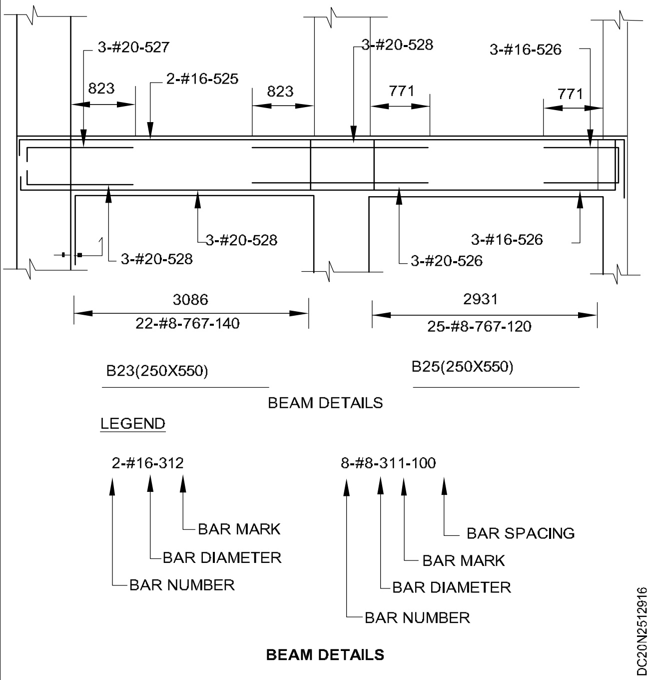
14 Project time can be reduced as the bars can be cut and bend before form work is done.

15 What you see in the drawing is what you get at the site.

16 With a quality data set, other management softwares (ERP systems) can work on it.

17 A paperless office concept in the construction industry and associated advantages.

Fig 6



18 Total length of bars calculated using engineering formula, leaves nothing to approximation.

19 Mechanization of bending and cutting is possible. (Cut and bend systems) reduces labour and time but increases the reliability.

20 As the works gets organized, smaller contractors can work on the project at lesser rate.

R.C.C retaining wall

Objectives: At the end of this lesson you shall be able to
- **define the R.C.C retaining wall**
- **explain types of retaining walls.**

Introduction

Retaining walls are structures constructed for the purpose of retaining earth or other materials like coal, ore, water etc. It may also be defined as a wall provided to maintain ground at two different levels. Provision of retaining walls become necessary in the construction of hill roads, embankments, bridge abutment, basement in buildings, water reservoir, in preventive measures against soil erosion, in landscapping etc. The material retained by the wall is generally known as backfill. The backfill may be horizontal i.e. levelled with the top of the wall or it may be inclined at certain angle to the top. The inclined fill is also known as surcharge. Besides loads due to retained material, the retaining wall may also be subjected to surcharged loads (due to automobile, railroad etc.) acting directly on the wall as well as on the backfill. The retaining will should be stable enough to resist all type of forces acting on it.

Definition

A RCC wall used to maintain the ground surfaces at different elevations on its either faces by supporting filled earth is known as RCC retaining wall.

The structure of the same type, which supports natural earth bank, is called breast wall.

Types of retaining wall

In general retaining walls are the following type.

1 Gravity walls.

2 Semi - gravity walls.

3 Cantilever walls.

4 Counter fort walls.

Among the above, first one is totally masonry wall with stone, brick or plain concrete. This wall withstands all the effects such as sliding, overturning etc. by its self - weight (gravitational force). So that these walls required heavy cross section and this may not be suitable for all conditions. Providing some reinforcements at appropriate positions can reduce the section of wall. This idea leads to the design and construction of different types of RCC retaining wall. In the general classification last three are the RCC retaining walls.

Components of retaining wall (Fig 1)

The important parts of a R.C.C retaining wall are the following.

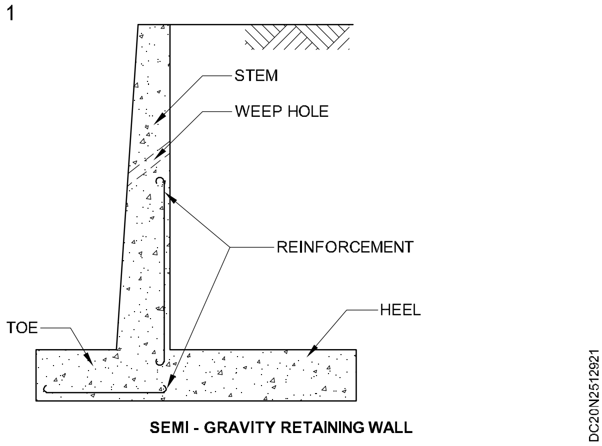
1 Stem - it is the upright part, which supports the earth.

2 Heel - portion of the base, which embedded below the supporting backfill.

3 Toe - portion of the base slab in front of the stem.

4 Heel beam (Shear key) - If the base slab width is not sufficient to with stand the shear force developed at the base of retaining wall a beam is provided below the stem projecting downward from the base slab.

Fig 1



SEMI - GRAVITY RETAINING WALL

5 Weep hole-These are the holes provided in the stem at regular interval from face to back to drain out the seepage.

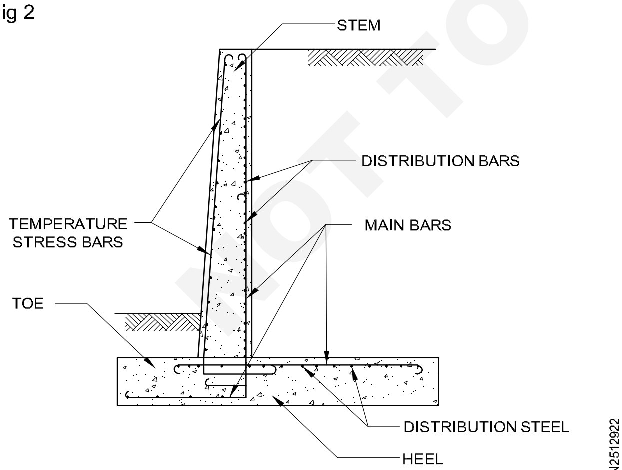
Semi-gravity walls

These are very similar to gravity walls but to reduce the heavy cross section of gravity wall some reinforcements are provided at toe and stem as shown.

Cantilever retaining wall

All the components, steam, heel, and toe is designed and construction as R.C.C cantilevers structure. The junction of three components will be the fixed end of cantilever. On stem pressure of backfill acts out word so reinforcement provided near the inner face of steam. Load on heel is the deadweight of backfill and it acts down word so that reinforcements are provided near the top surface of heel slab. While on toe there is no backfill and the load will be only the upward soil pressure so the reinforcement are provide near the bottom face of toe. Detailed arrangement of reinforcement is given in the Figure 2. To resist the temperature stress at the outer face of steam, a minimum reinforcement shall be provided.

Fig 2



CANTILEVER RETAINING WALL

Proportion of various components of a cantilever retaining wall

Minimum thickness of stem wall

At top ....20 cm

At base ....35 cm.

Width of base slab

With surcharge ....0.5H to 0.8H.

Without surcharge ....0.5H to 0.6H.

Thickness of base slab.

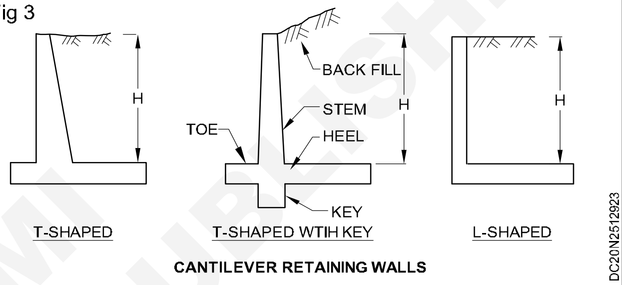
Minimum ......0.1H.

Toe projection beyond the outer face of the stem.

1/4 to 1/3 of the base width of slab.

Cantilever retaining walls are R.C.C. walls made in the form of an invented T. This type of wall proves to be economical for moderate heights say 6 to 7 m. The wall consists of three components. (Fig 3)

Fig 3



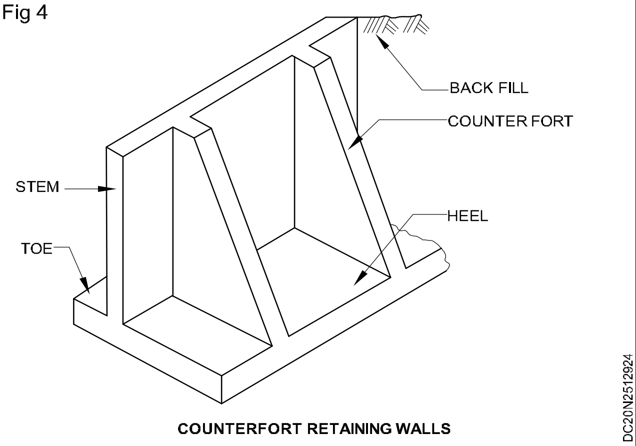
CANTILEVER RETAINING WALLS

the stem, the toe and the heal. Each of these components are designed as a cantilever. The stability of the wall is partially provided by the weight of earth on the heel. Sometimes the cantilever wall is constructed in the form of L.

Counter - fort retaining wall (Figs 4 & 5)

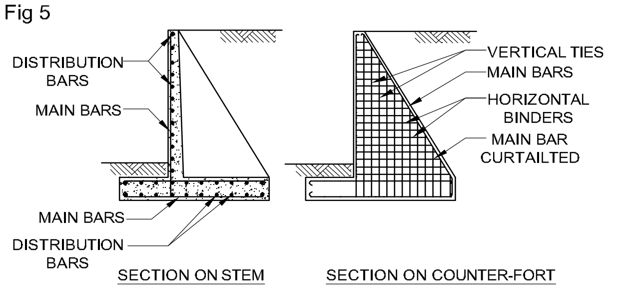
If retaining walls have height of filling more than 8m, is designed as cantilever type retaining wall, the thickness of stem wall becomes excessive and design proves uneconomical. Such walls should be designed as counter fort type retaining wall. In the case of counter- fort type retaining wall, both stem and heel act as continuous slabs supported on counter - forts. The action of counter - forts is to tie the vertical wall slab with heel slab.

Fig 4



COUNTERFORT RETAINING WALLS

Fig 5



COUNTERFORT RETAINING WALLS

The economical spacing of counter - forts varies ½ to 1/3 of the height of the stem wall. Normal spacing of counter forts varies from 2 to 3m. Counter - fort is designed as a cantilever beam taking load from the stem portion between two counter - forts. The effective depth of the counter - fort is measured at right angles to its sloping side. Main reinforcement bars are provided on the inclined side.

Stem and heel slabs are designed as continuous slabs supported on counter - forts. Bottom most 1 m height of stem slab is designed and same thickness is provided for the entire height. Toe slab is designed as cantilever slab as in the case of cantilever retaining wall.

When the height of the retaining wall to be provided exceed 6 to 7m, counterfort retaining wall prove to be economical. In this type of wall the base slab as well as the stem of the wall span horizontally as continuous slabs between vertical brackets known as counterforts. The counterforts are provided behind the wall (on the backfill side) and are subjected to tensile forces. The spacing of the counterforts may vary from 1/3 to ½ of the height of wall. The more the height of the wall, the closer should be the spacing of counterforts.

R.C.C formed structure

Objectives: At the end of this lesson you shall be able to
- **define portal frame**
- **explain method of portal frame**
- **illustrate advantages and advantages of portal frame**
- **explain R.C.C framed structure.**

Introduction

Structurally a building may consist of load bearing walls and floors. The floor slabs may be supported on beams which in turn may be supported on walls or columns. But for a multi - storeyed structure, a building frame either of steel or reinforced concrete is made. This frame is designed for all the vertical and horizontal loads transmitted to it. The openings between the columns, where necessary, will be filled with thin brick walls. A frame of this type will consist of columns and beams built monolithically forming a network. This provides rigidity to the connections of members. By this arrangement the bending moments for the members of the structure are reduced. Earthquake loads and other horizontal loads due to wind etc. are evenly distributed to the whole structure. This makes the structure not only safe but economical.

We shall now discuss the frames used in various types of buildings.

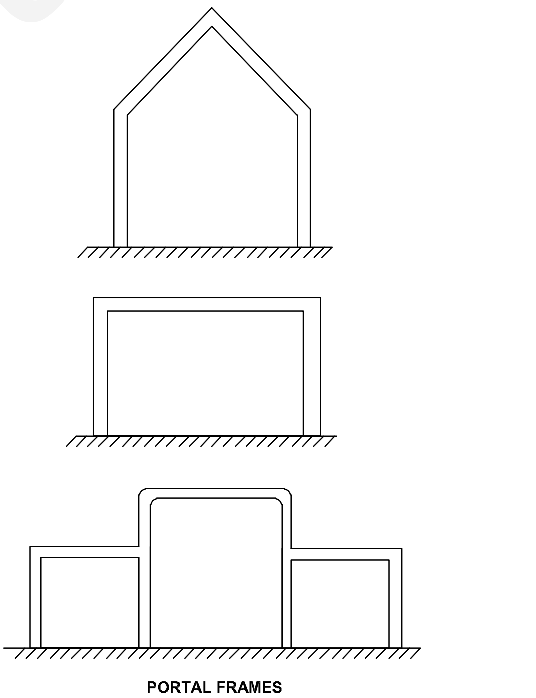
Definition

A structure in which components such as beam, column and footing are monolithic in design and construction is called portal frame.

Frames for single storey buildings portal frames

A portal frame consists of a beam built monolithically with the columns. Such units are used when the span of a building or hall is large. Sometimes instead of providing a horizontal beam, the portal frame may be provided with ridged beams. Fig.1 shows the types of portal frames used for different occasions.

Fig 1

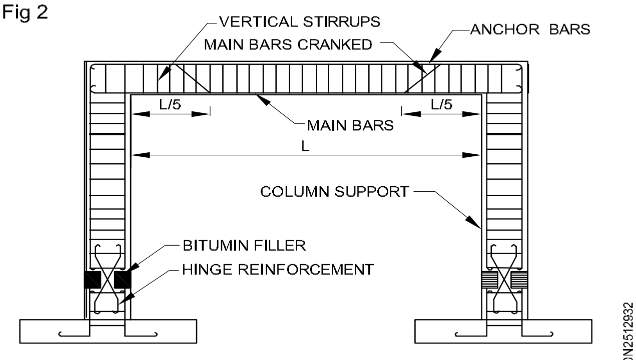


PORTAL FRAMES

Other alternative structures used for similar conditions are steel trusses, concrete trusses, sheds and arches.

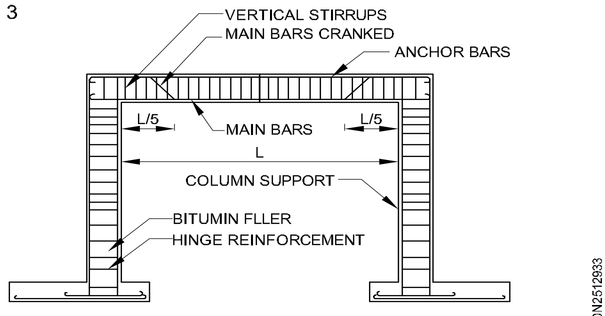
The portal frame may be analysed by any of the standard methods like the moment distribution method or column analogy method etc. The columns of the frame may be designed either for hinged end or fixed end conditions. Footings are provided to the supporting columns.

Fig 2



PORTAL FRAME WITH HINGE BASE

Fig 3



PORTAL FRAME WITH FIXED BASE

Connection of frame with foundation

In a portal frame column base is connected in foundation by any of the following method.

Fixed connection.

Hinged connection.

In fixed connection column is directly connected to footing as in the case or RCC column footing. But in design the BM at the base of column also should be accounted. Mostly footing will be an eccentric one because of this BM. A typical connection is given in the Figs 2 & 3.

As per theory of structure BM will be zero at hinged support and no BM will distributed to hinge from other ends. Taking advantages of the above an RCC hinge is introduced at the base of column to make a connection with the foundation. Hinge is designed to take the axial load and shear force developed at the base of column. Column reinforcements are terminated at the base of column and at hinge separate reinforcement is designed to with stand the shear force. These reinforcements are provides in the form of scissors as shown. Foundation is designed for the axial column load and the BM developed below the hinge. Reinforcements are provided as usual in RCC column footing. Dowel bars from footing are extended up to the bottom of hinge.

Advantages

There are following advantages of portal frames.

i Portal frames are easy to construct than walls or any other structures. It require less time to construct the portal frames.

ii They are economic in nature. The cost of maintenance is low.

iii They provide good floor to ceiling heights.

iv Portal frames saves time and money.

v Portal frames are easily available at all the places.

vi It is easy to carry the portal frame's equipment's from one place to another place. The material is easy to carry from one place to another place.

vii Portal frame structures provide good ventilation and lighting.

Disadvantages

Following are some limitations of the portal frames.

i It is not easy to build the portal frame anywhere. They can be constructed only hill, valley, and sloppy areas.

ii Sometime, they also depends on the type of structure. Building shape should be square, rectangular only.

iii Roof pitch should be shallow, steep, mono - pitch.

iv We cannot construct any structure above the portal frames. It is very difficult to construct structure above the portal frame, due to its sloppy head.

v Only skilled workers are required to construct the portal frames.

vi The strength of portal frame structure is less than RCC structure. It is very difficult to compare it with the reinforcement structure.

vii More accuracy required to build these types of structures. The portal frames are placed at regular intervals.

Requirement of portal frames

The portal frames are commonly used in the construction of industrial areas. Due to industrial growth more.

Material required, more man power required. If the requirement of material and man power increased then the requirement of portal frames also increase. It also increases due to increasing the construction work. Portal frames are easy to construct, so they are commonly used at all places.

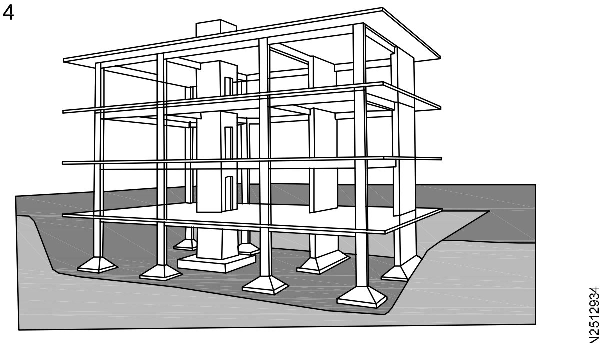
Conclusion

Portal frames are used where we want economy. They are also used for construction of ware houses. Rigid portal frames are used in the ware houses. They provide good ventilation and lightening. Now a days, most of portal frames structure are used in the industries. Portal frames save money and time.

R.C.C framed structures (Figs 4 & 5)

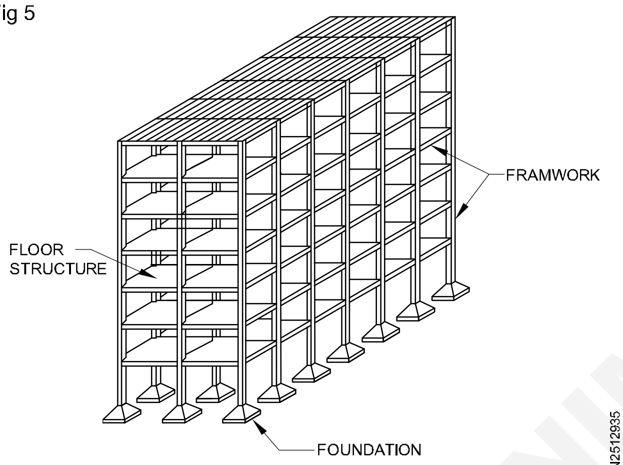
Concrete frame structures are a very common, or perhaps the most common, type of modern building. As the name suggests, this type of building consists of a frame or skeleton of concrete. Horizontal members of this frame are called beams, and vertical members are called

Fig 4



R.C.C FRAMED STRUCTURE

Fig 5



R.C.C FRAMED STRUCTURE

columns. Humans walk on flat planes of concrete called slabs. Of these, the column is the most important, as it is the primary load - carrying element of the building. If you damage a beam in a building, it will usually affect only one floor, but damage to a column could bring down the entire building.

When we say concrete in the building trade, we actually mean reinforced concrete. It full name is reinforced cement concrete, or RCC. RCC is concrete that contains steel bars, called reinforcement bars, or rebars. This combination works very well, as concrete is very strong in compression, easy to produce at site, and inexpensive, and steel is very strong in tension. To make reinforced concrete, one first makes a mould, called formwork, that will contain the liquid concrete and give it the form and shape we need. Then one looks at the structural engineer's drawings and places in the steel reinforcement bars, and ties them in place using wire. The tied steel is called a reinforcement cage, because it is shaped like one. Once the steel is in place, one can start to prepare the concrete, by mixing cement, sand, stone chips in a range of sizes, and water in a cement mixer, and pouring in the liquid concrete into the formwork till exactly the right level is reached. The concrete will become hard in a matter of hours, but takes a month to reach its full strength. Therefore it is usually propped up until that period. During this time the concrete must be cured, or supplied with water on its surface, which it needs for the chemical reactions within to proceed properly.

So the structure is actually a connected frame of members, each of which are firmly connected to each other.

In engineering parlance, these connections are called moment connections, which means that the two members are firmly connected to each other. There are other types of connections, including hinged connections, which are used in steel structures (/steel - frame - structures. html), but concrete frame structures have moment connections in 99.9% of cases. This frame becomes very strong, and must resist the various loads that act on a building during its life.

These loads include

- **Dead loads** the downwards force on the building coming from the weight of the building itself, including the structural elements, walls, facades, and the like.
- **Live loads** the downwards force on the building coming from the expected weight of the occupants and their possessions, including furniture, books, and so on. Normally these loads are specified in building codes and structural engineers must design buildings to carry these or greater loads. These loads will vary with the use of the space, for example, whether it is residential, office, industrial to name a few. It is common for codes to require live loads for residential to be a minimum of about 200 kg/m^2, offices to be 250 kg/m^2, and industrial to be 1000/m^2, which is the same as 1T/m^2. These live loads are sometimes called imposed loads.
- **Dynamic loads** these occur commonly in bridges and similar infrastructure, and are the loads created by traffic, including braking and accelerating loads.
- **Wind loads** This is a very important design factor, especially for tall buildings, or buildings with large surface area. Buildings are designed not to resist the everyday wind conditions, but extreme conditions that may occur once every 100 years or so. These are called design windspeeds, and are specified in building codes. A building can commonly be required to resist a wind force of 150 kg/m^2, which can be a very significant force when multiplied by the surface area of the building.
- **Earthquake loads:** in an earthquake, the ground vigorously shakes the building both horizontally and vertically, rather like a bucking horse shakes a rider in the sport of rodeo. This can cause the building to fall apart. The heavier the building, the greater the force on it. Its important to note that both wind and earthquake impose horizontal forces on the building, unlike the gravity forces it normally resists, which are vertical in direction.

The concrete frame rests on foundations, which transfer the forces - from the building and on the building - to the ground.

Some other important components of concrete frame structure are shear walls are important structural elements in high - rise buildings. Shear walls are essentially very large columns they could easily measure 400 mm thick by 3m long making them appear like walls rather than columns. Their function in a building is to help take care of horizontal forces on buildings like wind and earthquake loads. Normally, buildings are subject to vertical loads - gravity. Shear walls also carry vertical loads. It is important to understand that they only work for horizontal loads in one direction - the axis of the long dimension of the wall. These are usually not required in low-rise structures.

Elevator shafts are vertical boxes in which the elevators move up and down - normally each elevator is enclosed in its own concrete box. These shafts are also very good structural elements, helping to resist horizontal loads, and also carrying vertical loads.

Walls in concrete frame buildings

Concrete frame structures are strong and economical. Hence almost any walling materials can be used with them. The heavier options include masonry walls of brick, concrete block, or stone. The lighter options include drywall partitions made of light steel or wood studs covered with sheeting material. The former are used when strong, secure, and sound - proof enclosures are required, and the latter when quick, flexible lightweight partitions are needed.

When brick or concrete blocks are used, it is common to plaster the entire surface - brick and concrete - with a cement plaster to form a hard, long - lasting finish.

Cladding of concrete frame structures

Concrete frame buildings can be clad with any kind of cladding material. Common cladding materials are glass, aluminum panels, stone sheets, and ceramic facades.

Common form of steel sections

Objectives: At the end of this lesson you shall be able to
- **explain the term steel structures**
- **explain the advantages and disadvantages of steel structures**
- **explain the types of steel structures.**

Introduction

Steel structure is an assemblage of a group of members expected to sustain their share of applied forces and to transfer them safely to the ground.

Structural steel has been used in the construction of structures for well over a century. It is perhaps the most versatile of structural materials and has been used extensively in the construction of multistoreyed buildings, bridges, industrial structures, towers and other structures.

Advantages

The main advantages of structural steel are as follows

1 **High strength**: Due to the high strength of steel per unit weight, dead loads will be small.

This fact is of great importance for tall buildings and long span bridges, and for structures having poor foundation conditions.

2 **Adaptation to prefabrication:** Components of steel structures could be fabricated in workshop and transported over long distances and assembled at the site.

3 **Speed of erection:** Even long span structures can be erected in a very short time and structural steel is preferred to any other material when the construction is to be completed in a few hours or days.

The other advantages of structural steel are

4 Elasticity 5 Ductility 6 Weld ability 7 Toughness and fatigue strength 8 Possible reuse after a structure is dismantled and 9 Suitability to provide additions to existing structures.

Disadvantages

The disadvantages of steel as a structural material are as follows

Maintenance costs

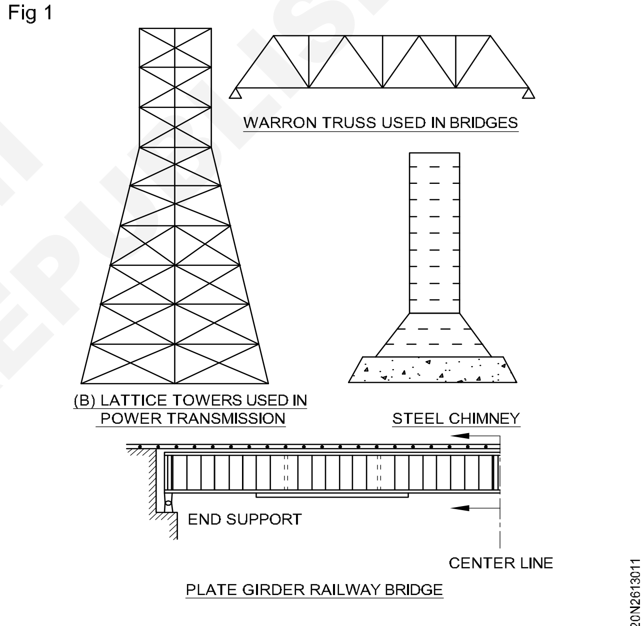
Structural steel tends to corrode when freely exposed to air and must be periodically painted.

Fire-proofing costs: The strength of steel is greatly reduced at temperatures which are commonly attained in fires. It is desirable that the steel frame of a building must be fire - proofed to get an appreciable fire rating which involves considerable additional expenditure.

Types of steel structures

Buildings, bridges, tanks, silos, cranes, transmission line towers etc. are examples of steel structures. Fig 1 shows how some typical steel structures. Although these structures are three dimensional, they are essentially made of one dimensional members (beams and columns) and two - dimensional members (frames, plates). These members are designed assuming that they behave independently to each other.

Fig 1



TYPICAL STEEL STRUCTURES

Standard sections

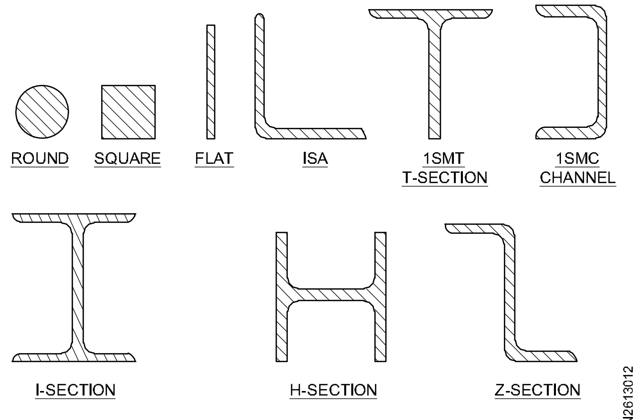
Steel structures are constructed using hot rolled steel sections of various shapes, which are readily available. Often composite sections are made by combining standard sections. The use of these standard sections is recommended for economical reasons.

Available standard sections are shown below

The properties of standard rolled sections are given in the hand book for structural engineers.

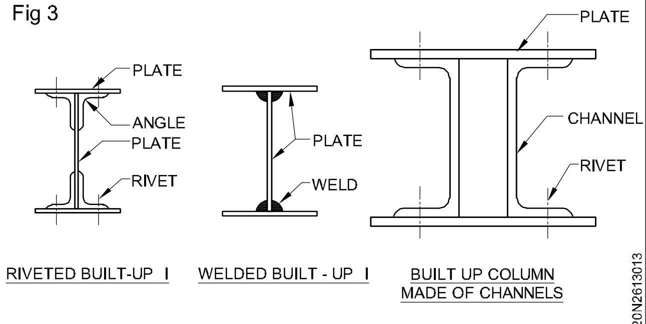
A structural member can be a standard rolled section given in Fig 2 or it may be built - up from a number of standard rolled shapes by connecting them by welding, riveting or bolting. Some built up sections are shown in Fig.3.

Fig 2



STANDARD STEEL SECTIONS

Fig 3



BUILT UP SECTIONS

Structural fasteners and joint

Objectives: At the end of this lesson you shall be able to
- **explain the term beam to beam connection and types**
- **explain the term column to beam connections and its types.**

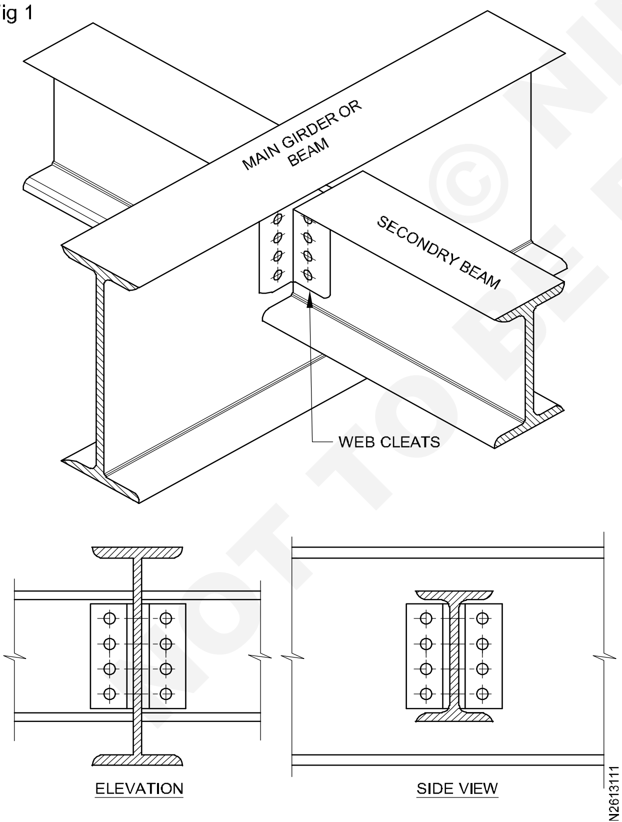
Beam to beam connections

Steel structures are preferred for large spans. Secondary beams of smaller sections are provided between the main beams so as to divide the covering area in small bays and thereby loads may be broken up in smaller units. This helps in selecting higher sections for the fabrication of frame work. To achieve thin smaller beams are to be connected to the main beams. Such connections are known as beam to beam connections. This beam to beam connection may be of two types.

i. Framed connection ii. Seated connection

Framed connection (Fig 1): In this type of beam to beam connection two angles placed on either side of the web of the beam are connected to the web of the main beam.

Fig 1

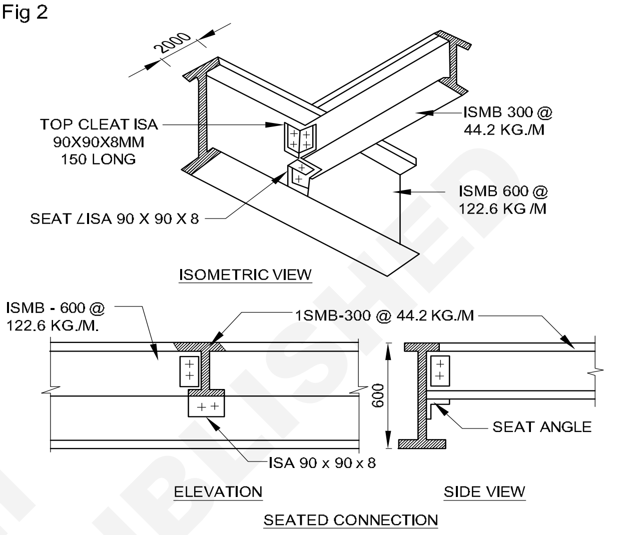


FRAMED CONNECTION

Seated connection (Fig 2)

In this type of beam to beam connection two angles are connected to the flanges of the beam also.

Fig 2



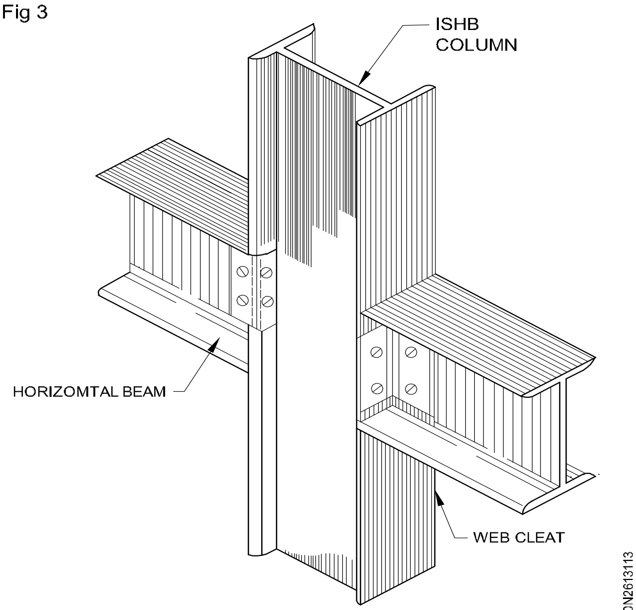
FRAMED CONNECTION

Column to beam connections: Steel beams are supported at the ends by masonry wall or steel columns. Mainly steel columns are used to supports the beams. A skeleton in the form of a frame is thus formed by vertical columns and horizontal beams. The beams may thus be riveted to the flanges or web of vertical column. Column to beam connections are of two types.

i Framed connections ii Seated connections

Framed connections (Fig 3)

Fig 3

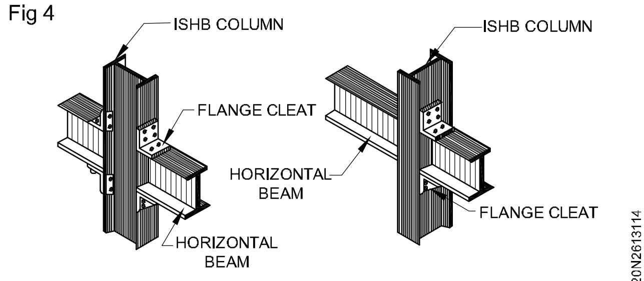


COLUMN TO BEAM FRAMED CONNECTION

When beam is connected to the column flanges by placing cleat angles on either side of the web of a beam, the connection is called framed connection.

Seated connections (Fig 4)

Fig 4



COLUMN TO BEAM SEATED CONNECTIONS

When beam is connected to the column by cleats with the flanges of the horizontal beam for joining it to column, the connection is called a seated connection. Beam may be connected to the web or flange of the column.

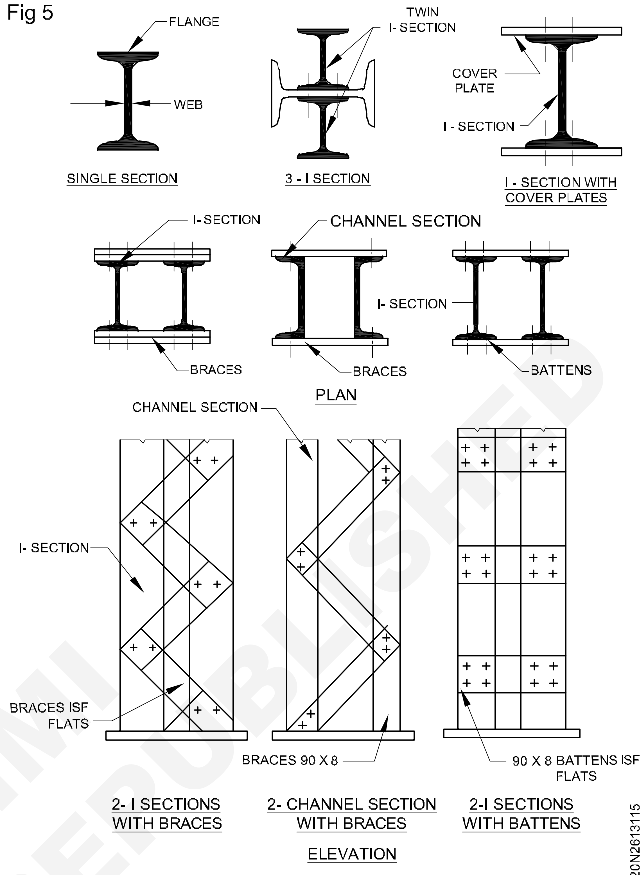
When the beam reaction is large, then the seat angle alone will not be sufficient. In such cases, the horizontal leg of the seat angle is stiffened by means of a vertical angle. Such a connection is called a stiffened seat connection. This is generally provided for reactions exceeding 150 KN.

Steel stanchion

When vertical supports is of circular cross section and of approximately cylindrical form it is known as column. Vertical compression members in a building if cast into rectilinear form or built up form rolled steel sections of rectilinear outlines, it is termed as stanchions.

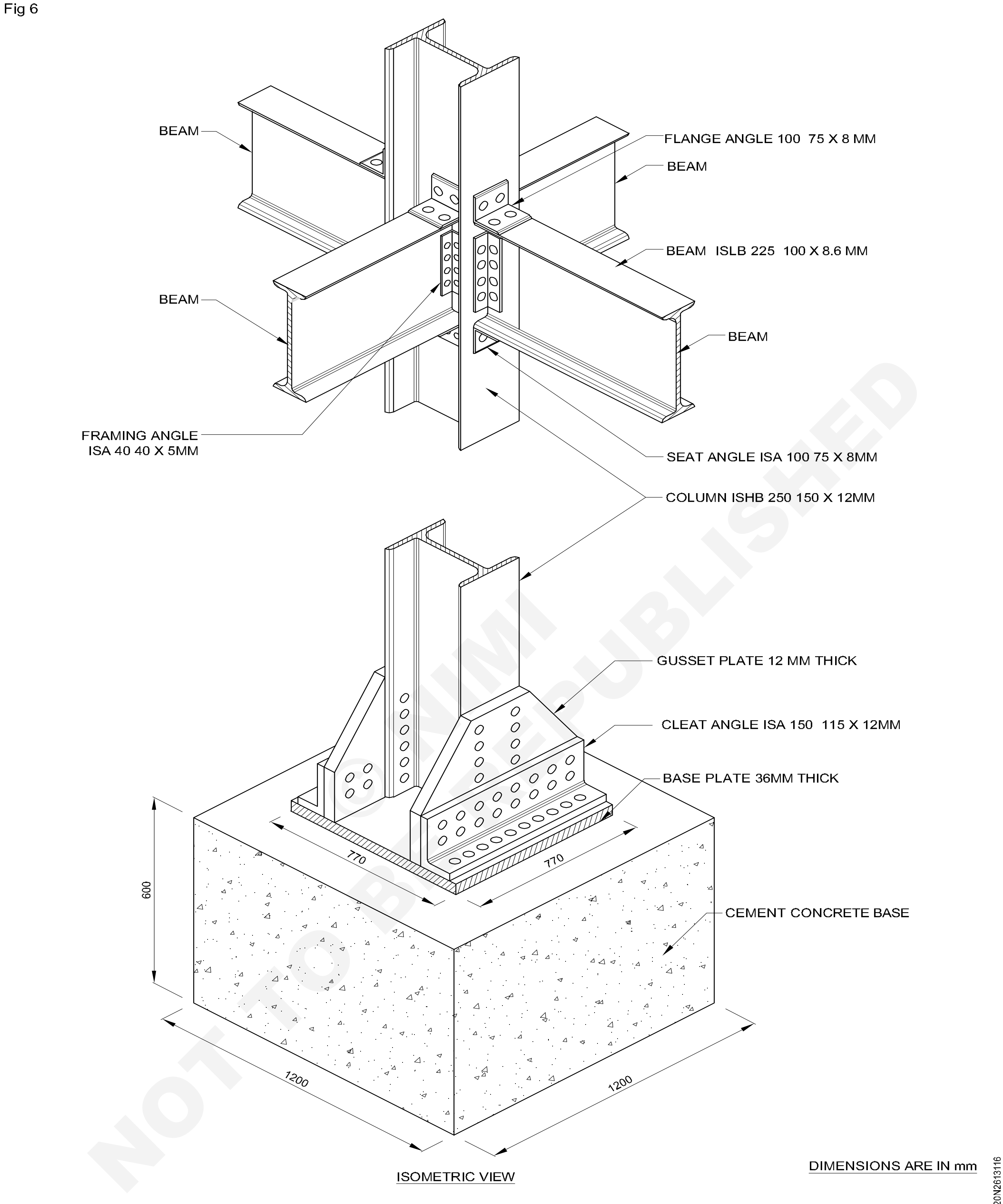
Steel stanchions may be of a single rolled steel section or compound sections of suitable sizes. Various forms are show in Figs 5 & 6.

Fig 5



VARIOUS FORMS OF STANCHION OR STEEL COLUMNS

Fig 6



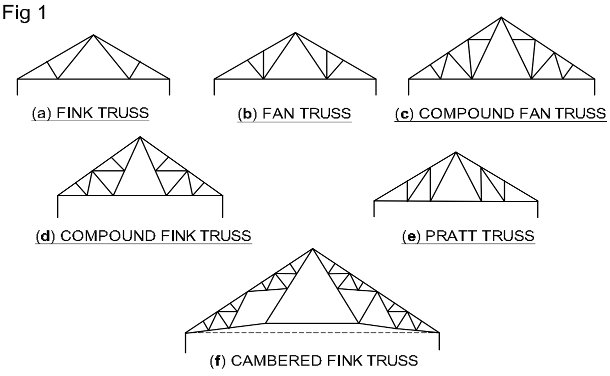
STEEL STANCHION

Roof truss

Objectives: At the end of this lesson you shall be able to
- **explain the term roof truss**
- **enumerate common types of steel trusses used now a days.**

Truss may be defined as a large deep beam with open web. They are usually formed by members arranged in triangles or groups of triangles. Some of the popular type of roof trusses are shown in Fig.1. They are designed to support the roof coverings or ceiling over long spans thereby avoiding the intermediate columns. Roof trusses are used in workshops, industrial buildings, auditoriums, godowns, warehouses and building where large column free spaces are required.

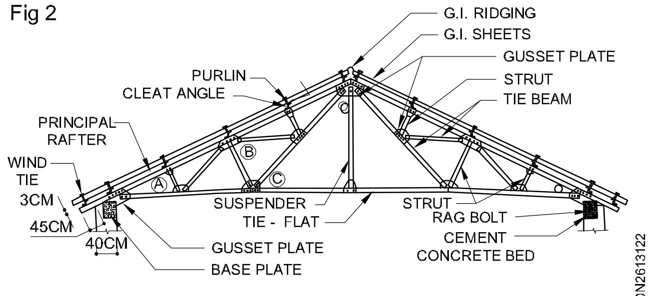
Fig 1



TYPICAL SKETCHES OF ROOF TRUSS

Details of the components of steel roof truss (Fig 2)

Fig 2



COMPONENTS OF STEEL ROOF TRUSS

Light gauge steel structures

Objectives: At the end of this lesson you shall be able to

- **explain advantages of cold formed steel structural members**
- **over hot rolled steel structural members**
- **explain the application of cold formed steel.**

Introduction: In cold forming, steel sheets of thickness generally in the range of 0.4 mm to 12.5 mm are formed into structural shapes. Cold formed structural members are being used in transportation and construction industry. The steel sheets conform to IS:1079 - 1968. The minimum guaranteed yield strength for such steels is 232 N/mm^2 and the ultimate strength is 390 N/mm^2.

Advantages of cold formed steel structural members over hot - rolled steel structural members

i Cold formed steel members can yield more economical designs for relatively light loads and for shorter spans.

ii Sections can be made to requirement resulting in favorable strength to weight ratio.

iii They provide surfaces and enclosed spaces for electric and other conduits.

iv Cold formed steel wall panels floors and roof decks, in addition to transferring loads normal to their surface, may also be used to withstand in - plane shear as diaphragms.

v if properly inter - connected with each other and with supporting members. This is commonly called as stressed skin design.

Advantages of cold formed steel members over reinforced concrete and timber

i Lighter with higher strength and stiffness

ii May be easily prefabricated in mass production

iii Amenable to fast and easy erection without delay even during bad weather

iv More accurate detailing and maintenance of uniform quality and tolerance are possible

v Non-shrinking and non-creeping at ambient temperature

vi Termite - proof and rot proof

vii Requires no formwork and it may be used in composite construction with concrete slabs thus eliminating formwork and tension reinforcement.

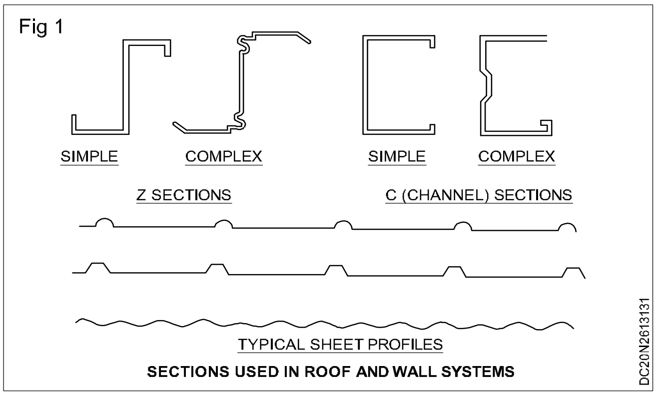
Application of cold formed steel:

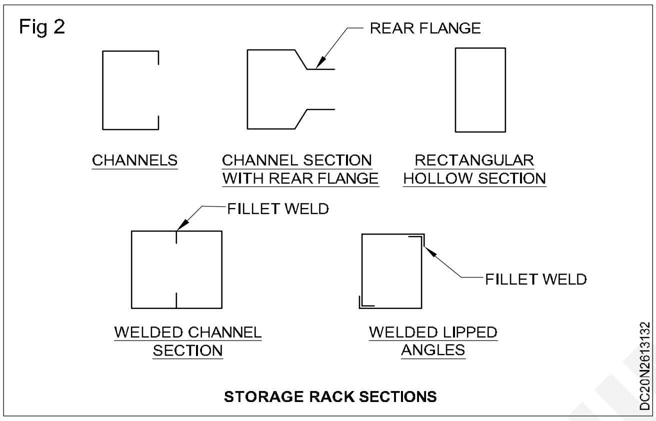
Normal uses of cold formed steel structural members are

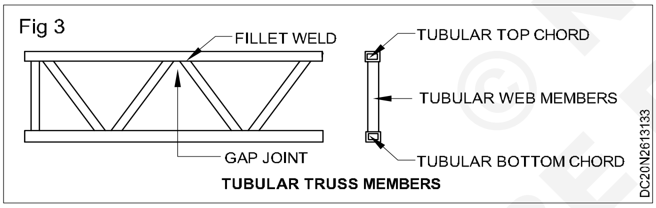
a **Roof and wall systems of industrial, rural and commercial buildings:** Examples of sections used in roof and wall systems are Z and C sections used as purlins, C section used as bracing, shallow and deep sheeting profiles spanning across purlins and screw fasteners or concealed fasteners used for the connections. (Fig 1) Channels are used for columns and trusses, and corrugated sheets for side clads. Fabricated box section using heavy channels are used in crane girders and columns and corrugated profiles are used for crane walkways. (Fig 1)

b **Storage racks:** Channels with or without rear flanges are used for uprights of storage racks (Fig 2)

c **Plane and space trusses:** Circular, square or rectangular hollow sections may be used as chords and webs, with welded joints. Channels section chord members can also be used with tubular braces bolted or welded into the open sections. Trusses can also be fabricated from cold formed angles. (Fig 3)







d Frameless stressed skin buildings sheet profiles with stiffened edges are used to form small structures like garden sheds.

e Housing lipped and unlipped channel sections are used as wall studs, top and bottom plates, hoggins etc. (Fig 4) flat steel straps may be used as bracing. Door and window frames are also fabricated using different sections.

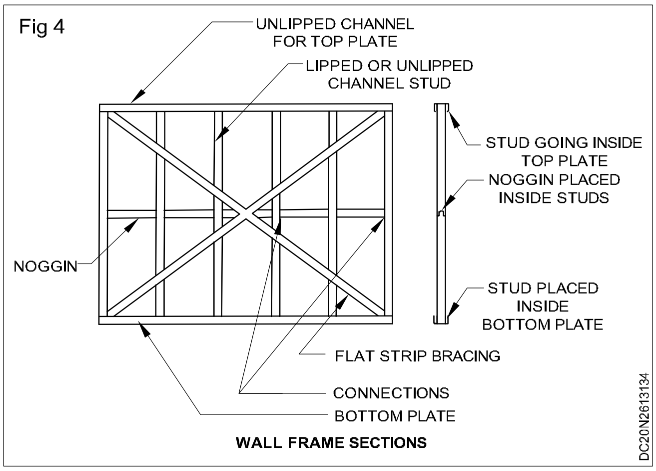
f Floor bearer and joist

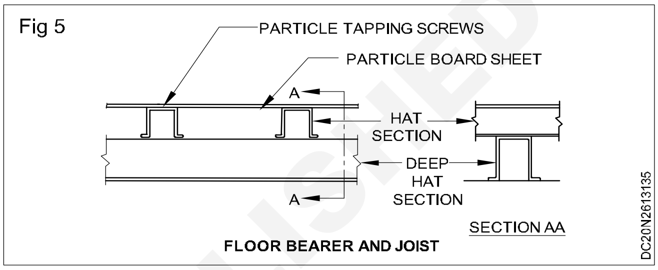
Usually hat sections are used. Alternately Z sections can also be used.

g Steel decking for composite construction (Fig 5)

Profiled sheeting with indentations is used in composite construction. The indentations enable proper bonding between concrete and steel to achieve composite action.

h Lighting towers: Tubular sections fabricated by welding are used. The section shape may be circular or polygonal.





i Automotive applications: All the major sections can be used but hat sections or box sections are more common. Channels are used for chairs, and corrugated panels for floor panel of light commercial vehicles (LCV). Channels and angles are also used for the rear body components of LCV. In bus body, chaises and top hat sections are used.

j Grain storage silos consists of shallow profile sheeting stiffened by hat or channel sections.

k Tubular members and hollow flange beams.

l Pollution control: Collecting electrodes for dust collection are made of rolled sections. Large channel are used as gas distribution screens.

m Rolling shutters: Side guide, Bottom plate and laths of rolling shutters are made of rolled sections.

n Railway coaches: Channels, Z sections, Top Hats, Floor Trough sections are used in rail coaches and wagon building industry.

o Electrical transmission towers: Heavy lipped and unlipped angles are used in transmission towers.

p Railway traction: Heavy channels fabricated into a box section are used as railway electrical masts.

q Marine container: Corrugated profiles, corner posts, channels and angles are used.

r Material handling: Heavy channels as conveyor frames, corrugated profiles as decking plates, trapezoidal sheets for boiler house structures, and channels for conveyer gallery structures are the main applications in material handling.

Tension and compression members

Objectives: At the end of this lesson you shall be able to
- **explain the classification of members based on the method of transmitting of force**
- **explain tension members**
- **explain compression members.**

Steel structures are three dimensional, they are mainly made of one dimensional members (beams and columns) and two dimensional members (frames, plates). These members are designed in such away that they behave independently to each other. Based on the method by which they transmit forces, they may be classified into

Tension members

Compression members

Beams

Beam - columns

Torsion members and

Plates

Tension members

A member which carries mainly a tensile force is called tension member. In practice tension members are often subjected to combined tension and bending actions. The bending moment is caused by eccentricity of connections, transverse loads, self weight of the members etc. Direct tensile load has tendency to straighten the member and reduce the eccentricity of load.

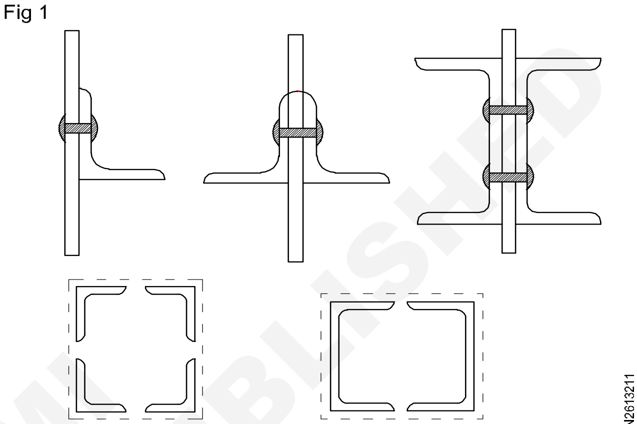
A member carrying direct tension is called a tie. Tension members are formed in roof trusses, towers, bridges and bracing systems. The distribution of stress on the cross - section of an axially loaded tie is uniform.

Typical forms of tension members

The form of a tension member is governed by the type of structure of which it is a part and the method adopted for joining it to the adjacent parts of the structure. The more common types are listed in table and fig 1.

Type	Use
Wire rope	Guy wires, floor suspenders in suspension bridges, hoisting lines.
Rods and bars	Bracing systems in towers, sag rods for purlins in sloping roof
Single angle	Roof trusses carrying light loads, bracings
Double angle/double channel	Roof trusses, foot bridge trusses
4 Angle members 2 channel members	Heavily loaded bridge trusses

Fig 1



TYPICAL FORMS OF TENSION MEMBERS

Compression members: A structural member which primarily transmits a compressive force is called a column. Vertical compression members in buildings are called columns. Posts are stanchions. Compression members in roof trusses are called struts.

A compression member has a tendency to bend even when the load is axial. This bending of column is called buckling. The load carrying capacity of a column depends on its slenderness ratio , which is the ratio of the effective length of the column and the least radius of gyration.

Choice of selection for compression members: The choice of section for a compression member depends on

Magnitude of loads acting of the compression member, and whether the load is applied axially or eccentrically.

Fig.2 shows different standard and composite sections used as compression members.

Beam: Beams are structural members subjected to Bending moment and shear force because transverse loads at on them. Normally no axial loads act on beams. According to their function, beams are called by different names. Some of the common types of beams are.

Joist: A beam that support the flooring but no other beams.

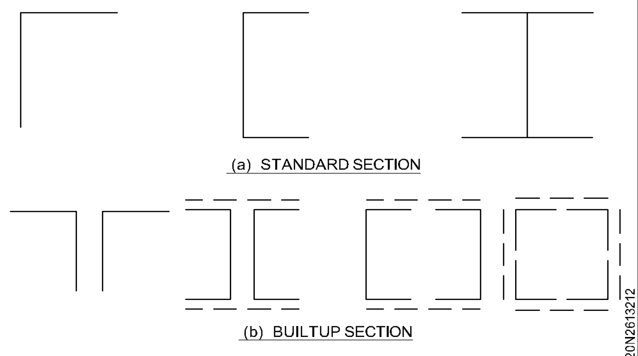
Floor beam: A major beam supporting other beams.

Girder: Any major beam in a structure.

Lintel: A beam which supports the wall over windows, doors and verandah openings.

Purlins: A beam supported by roof trusses.

Fig 2



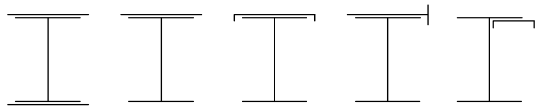
DIFFERENT SECTIONS USED AS COMPRESSION MEMBERS

Simple beams: Beams which consist of a single I section carrying the loads applied on them safely and economically are called simple beams.

Compound beams: When the maximum bending moment induced in a beam due to the loading is greater than the moment of resistance of the maximum available rolled steel section, or when the depth of the beam is to be restricted, compound beams are used. Compound beams are rolled beams in which plates are welded or riveted to the flanges.

Typical sections of compound beams are shown in fig.3

Fig 3



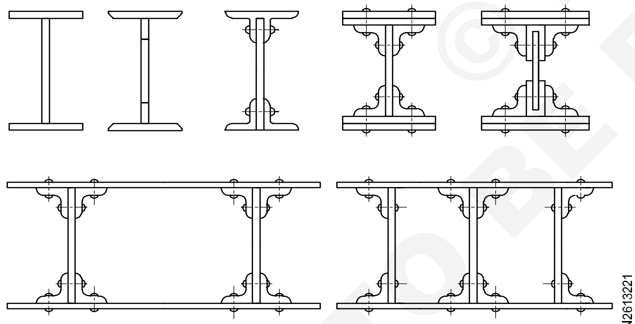
TYPICAL SECTIONS OF COMPOUND BEAMS

Plate girders

Objectives: At the end of this lesson you shall be able to,
- **explain the term plate girder**
- **explain the components of plate girder.**

Plate girder: When the span of the beam is large and load is heavy, rolled steel beam does not permit its use beyond a span of 20m. Plate girders are normally used for spans more than 20m. With the adoption of welded construction plate girders can be used upto 100 m span. Most common forms of plate girders are shown in Fig 1

Fig 1



COMMON FORMS OF PLATE GIRDERS

Components of plate girders

The components of plate girder are shown in Fig 2

They are

Web plate

Flange plates

Web splice

Flange splice

Vertical stiffeners

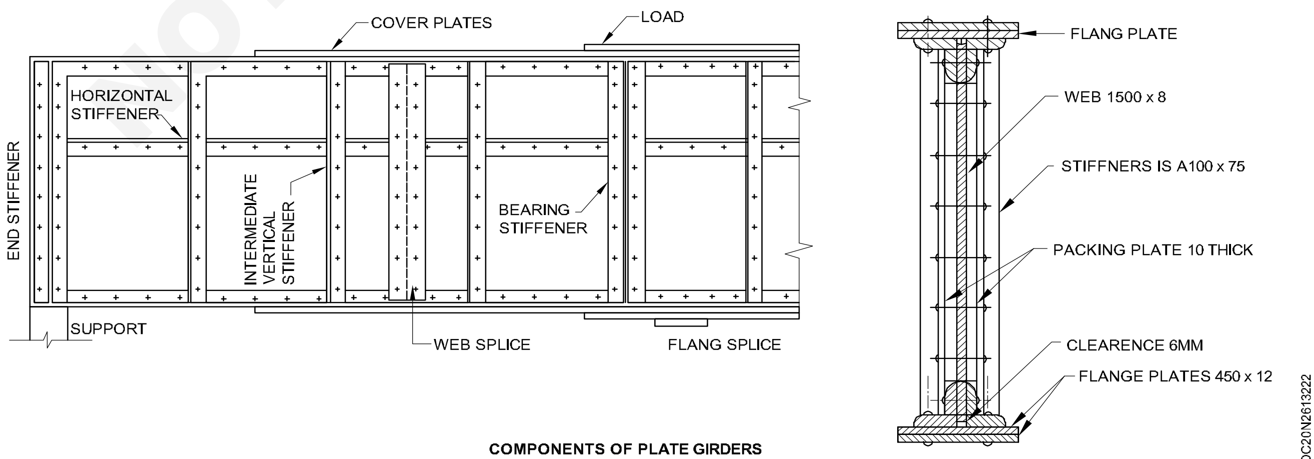
Horizontal stiffeners

Bearing stiffeners

Rivets connecting the flange and the web

Rivets connecting the flange angles and flange plates

Fig 2



COMPONENTS OF PLATE GIRDERS

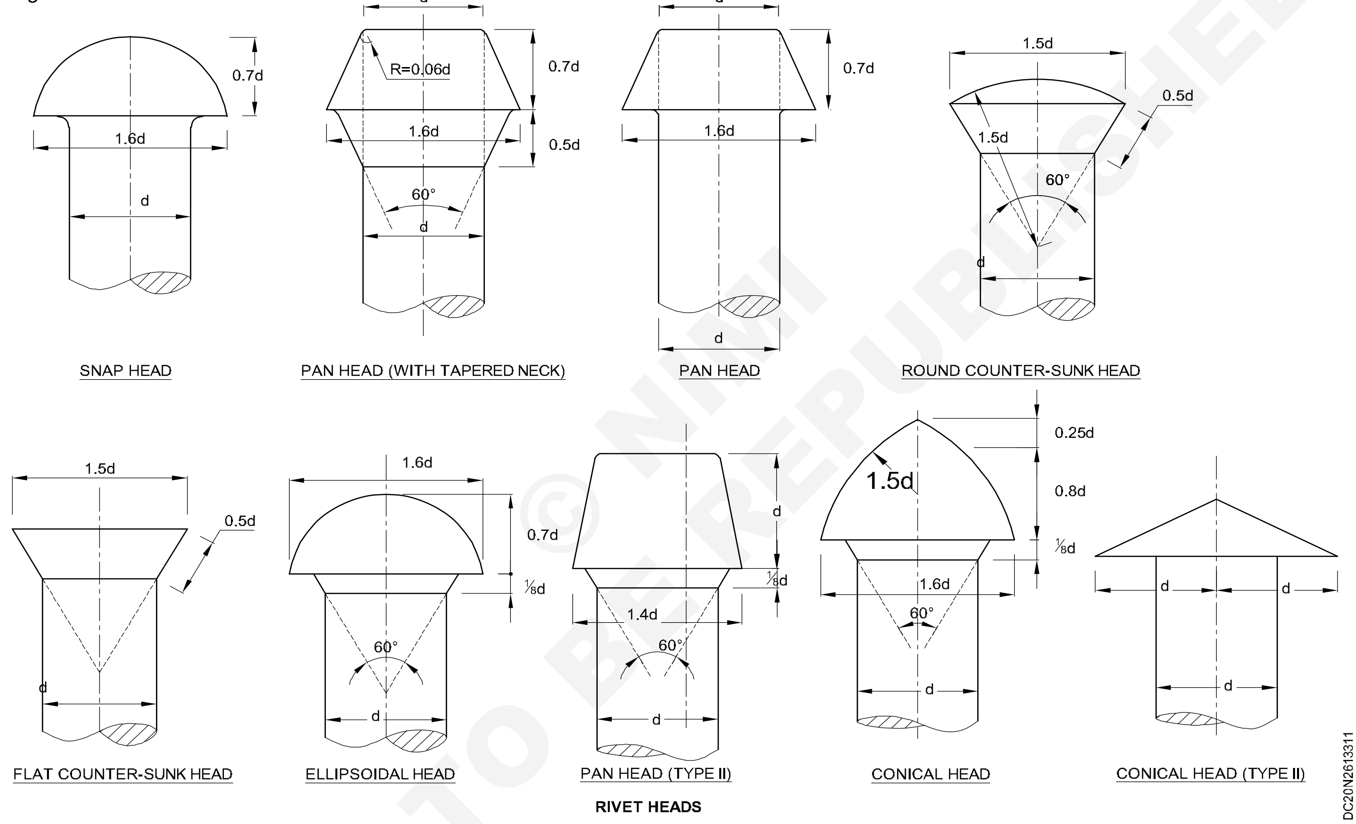
Fabrication and construction details

Objectives: At the end of this lesson you shall be able to
- **explain the various connections used steel structures**
- **explain the various types of rivets.**

Connections: Structural members are composed of various standard sections. These members are connected to each other by means of rivets, welds, pins or bolts.

Riveted connection: Rivets are made from mild steel rivet bars by a machine which forms the head and cuts the rivet of the desired length. Normally the head is round and is called "button head". The head is flattened if the clearance is limited. If flush surface is desired, 'countersunk' rivets are used. Different types of rivet heads are shown in Fig 1.

Fig 1



RIVET HEADS

Process of riveting: Holes are drilled in the plates to be connected at the appropriate places. The heated rivets (red hot, 550 1000°C) are inserted into the holes (Fig 2). The other end of the rivet is made using a jack or riveter. When the riveter compresses the shank, the shank fills the hole completely and head is formed on the other side also. When the rivet cools, it shrinks and presses the plates together.

Care must be taken to heat the rivet uniformly throughout the length. This is essential for uniform filling of the rivet hole. Rivets can also be driven cold using special equipment.

The diameter of the hole is kept 1.5 mm larger than the nominal diameter of the rivet, if the nominal diameter of rivet is less than or equal to 25 mm. For larger diameter rivets, the diameter of the hole should be 2.0 mm larger than the nominal diameter of the rivet.

Classification of rivets: The rivets may be of power driven or hand driven and the riveting work may be done in the workshop or at the work site (field).

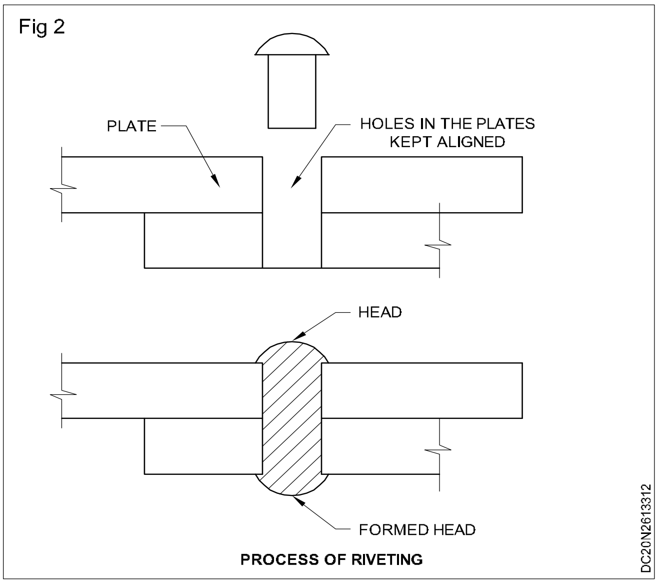
Accordingly rivets are classified as

1 Power driven shop rivets

2 Power driven field rivets.

3 Hand driven shop rivets, and

4 Hand driven field rivets.



PROCESS OF RIVETING

Power driven rivets are allowed larger permissible stresses than the hand- driven rivets, in view of better workmanship.

The permissible stresses for field rivets will be less than the permissible stresses for shop rivets by 10%.

Nominal diameter and gross diameter of rivet: The nominal diameter of a rivet means the diameter of the cold shank before driving. The gross or effective diameter of a rivet is the diameter of the hole or closed rivet. Strengths of rivets are based on the gross diameter.

Calculation of gross diameter: If nominal diameter $\leq$ 25mm

Gross diameter = nominal diameter + 1.5 mm

If nominal diameter > 25mm

Gross diameter = Nominal diameter + 2.0 mm

Calculation of diameter of rivet

Diameter of rivet depends on plate thickness. Several formula are available to calculate the diameter. The formulae are.

1 Unwin's formula

$d = 6.05\sqrt{t}$ where t is the thickness of the plate in mm.

Rivets are available in nominal diameters of 12,14,16,18,20,22,24,27,30 and 33 mm.

The French formula

d=1.5t+4

where t<15mm

The German formula

$d = \sqrt{50t - 2}$

Pitch of rivets

IS 800 - 1984 specifies the following.

Minimum pitch: The distance between centres of any two adjacent rivet holes should not be less than 2.5 times the nominal diameter of the rivet.

For convenience, this is often taken as 3 times the nominal diameter.

Maximum pitch: The distance between centres of any two adjacent rivets (including tacking rivets) connecting together members shall not exceed 32t or 300 mm whichever is less, where t is the thickness of the thinner plate.

The distance between centres of two adjacent rivets in a line lying in the direction of stress, shall not exceed 16t or 200 mm whichever is less in tension members and 12t or 200mm, whichever is less in compression members.

For compression members in which forces are transferred through butting faces, this distance shall not exceed 4.5 times the diameter of rivets for a distance from the abutting faces equal to 1.5 times the width of the members.

Edge distance: A rivet hole must be sufficiently distant from the nearest edge of the member. This is to prevent the cracking and subsequent failure of the plate along the edge, e.g., if diameter of hole is 13.5mm and below the distance to the sheared or hand flame cut edge shall be 19 mm.

Tacking rivets or stitch rivets: When truss members consist of combined sections like double angles, with some distance between them, it is necessary to connect the component members at suitable intervals along its length. Such rivets are called tacking rivets. This is to ensure, that the composite section acts as a single unit. This is very important in case of compression members.

Riveted joints

Objectives: At the end of this lesson you shall be able to

- **explain the different types of riveted joints**
- **explain the failure of riveted joints.**

Types of riveted joints: There are two types of riveted joints namely:

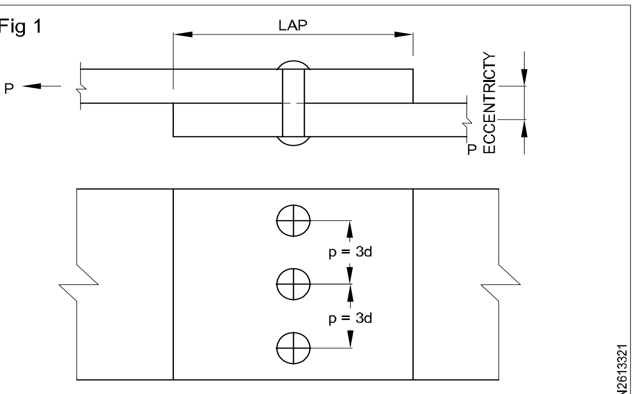
- Lap joint
- Butt joint

Single riveted lap joint: It consists of a single row of rivets parallel to the edge of the over lapped plates (Fig 1)

Double riveted single lap joint: There are two parallel rows of rivets where rivets are just opposite each other (Fig 2)

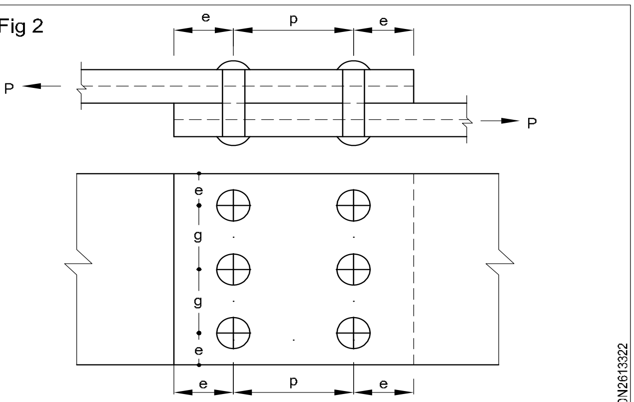
Double riveted single lap staggered or zigzag joint where the rivets are staggered. (Fig 3)

Fig 1



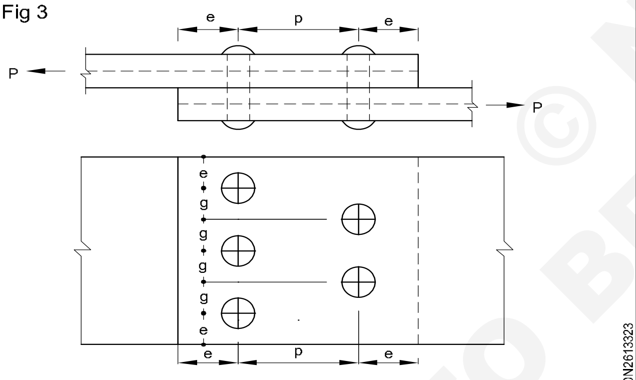
SINGLE RIVETED LAP JOINT

Fig 2



DOUBLE RIVETED SINGLE LAP JOINT

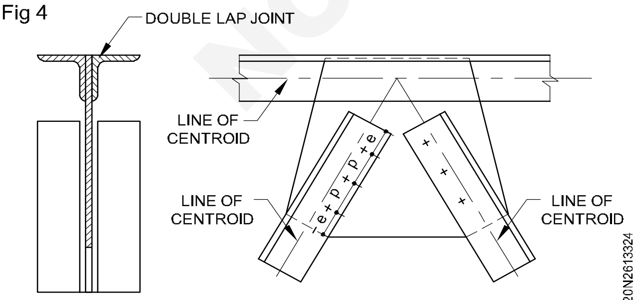
Fig 3



DOUBLE RIVETED SINGLE LAP ZIGZAG JOINT

Double lap joint commonly used in trusses, where combined section consisting of two angles is connected to a gusset plate (Fig 4)

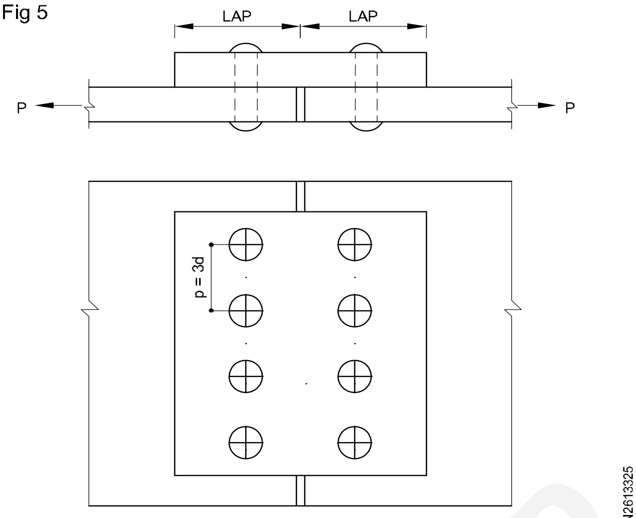
Fig 4



DOUBLE LAP JOINT

Single cover butt joints (Fig 5). The plates to be connected are kept butting against each other. They are connected through cover plates kept on one side only.

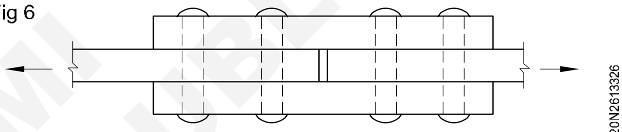
Fig 5



SINGLE COVER BUTT JOINT

Double cover butt joint (Fig 6) This connection is similar to the single cover butt joint. The difference being that there are two cover plates, one on each side of the plates to be connected. Half the applied force is transmitted through each cover plate.

Fig 6



DOUBLE COVER BUTT JOINT

Failure of riveted joint

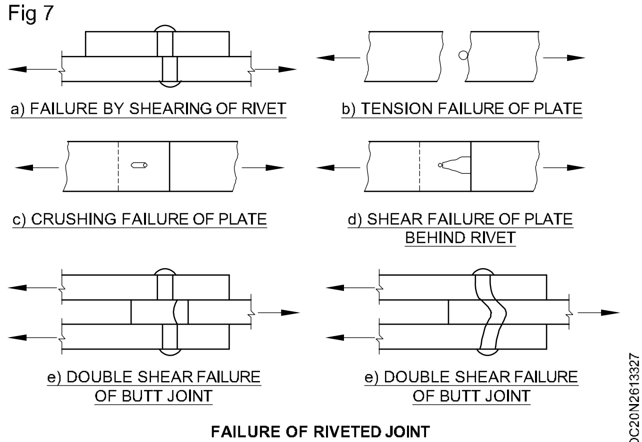
A riveted joint will fail when either the rivet or the plate fails. The failure of a rivet may be due to shearing of rivet or crushing of rivet.

The plate may fail by tearing of the plate or crushing of the plate (i.e.,) due to the bearing between the rivet and the plate.

If the rivet is quite long compared to its diameter, it may fail in bending, before it fails in shear or bearing.

Fig 7 shows the various ways of failure of riveted joints.

Fig 7



FAILURE OF RIVETED JOINT

Bolted connections: These are connections made using bolts which is a steel pin with head at one end and threaded at the other. Square/hexagonal nut is used at the threaded end to make connection. Bolts also transmit loads from one component to the other. The specifications for pitch and minimum edge distance are the same as for rivets. (Fig 2)

Advantages of bolted connections are: (i) No need for hammering or heating, (ii) Very quick work and Most useful in temporary connections, to keep together components during fabrication.

Disadvantages are: (i) Liable to become loose causing reduction in strength, (ii) the diameter of a bolt is not uniform, (iii) the strength of a bolt in tension is less due to its reduced area at the root of the threads and (iv) since the bolt hole is made 1.5 mm greater than the bolt diameter, a clearance exists in bolted connections.

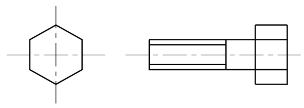
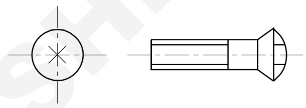
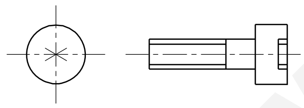
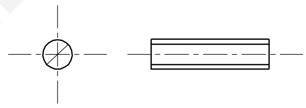
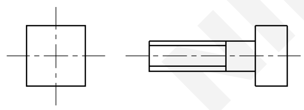
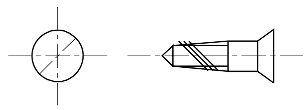
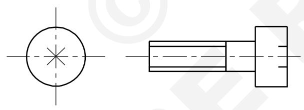
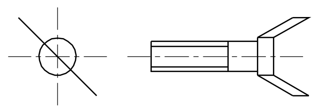
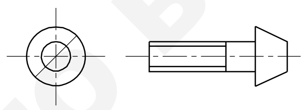
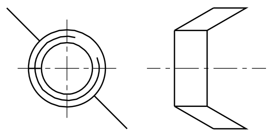
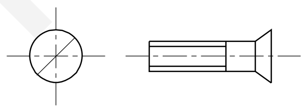
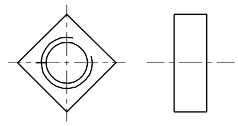
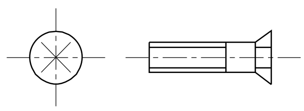
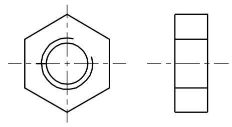
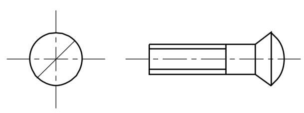
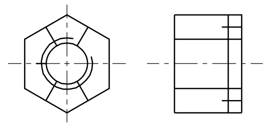
Pinned connections: A pin consists of a cylindrical rod meant for connecting two or more components. A pin has freedom to turn in the connections. Pins range from 8 mm diameter to 300 mm diameter.

Examples of use of pinned connections are

For connecting plates and

Bridge truss members.

Fig 2

NO.	TYPE	CONVENTIONAL SYMBOL	NO.	TYPE	CONVENTIONAL SYMBOL
1	HEXAGONAL BEADED BOLT		9	OVAL COUNTERSUNK HEADED SCREW CROSS SLOT	
2	HEXAGONAL SOCKET BOLT		10	SET SCREW SLOT	
3	SQUARE HEADED BOLT		11	WOOD AND SELT-TAPPING SCREW SLOT	
4	CYLINDER SCREW CROSS SLOT		12	WING SCREW	
5	CYLINDER SCREW PAN HEAD TYPE SLOT		13	WING NUT	
6	COUNTERSUNK HEADED SCREW SLOT		14	SQUARE NUT	
7	COUNTERSUNK HEADED SCREW CROSS SLOT		15	HEXAGONAL NUT	
8	OVAL COUNTERSUNK HEADED SCREW SLOT		16	CROWN NUT	

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CONVENTIONAL SYMBOLS FOR NUTS AND BOLTS

Public health and sanitation

Objectives: At the end of this lesson you shall be able to
- **define technical terms in public health engineering**
- **define purpose of sanitation**
- **define types of sewage and shape of sewers.**

Introduction

The essential elements of the existence of living beings are air, water, food, shelter, clothing etc. Out of the above water is the second one. Water is required for satisfactory functioning of the physiological organisms, as a circulatory fluid to maintain temperature, to carry nourishing food, and to remove the waste products from the body. Now a days, water is required to perform many functions like supply of physical needs, preserve bodily cleanliness, ensure cleanliness of all personal and municipal environments, furnish a means of fire protection and meet the needs of the industry. The sewage and refuse of some of the cities are disposed off in water courses. Such disposal pollutes the water courses and render them unsafe for domestic use without treatment. Hence steps are taken to treat the sewage and dispose it suitably. The engineering which concerns to the water supply and sanitation of communities is called public health engineering. Water supply engineering comprises of storage of water, purification of water and its distribution for its proper use, while sanitary engineering starts where water supply engineering ends. Sanitary engineering concerns with the cleanliness of the cities such as collection, conveyance, treatment and disposal of refuses in a harmless manner.

Technical terms: Wholesome water The water which is unpolluted, free from toxic substances, excessive amounts of minerals and organic matter, pleasant and safe to drink. This is also known as potable water.

Potable water: Wholesome water is also known as potable water.

Safe water: Water which is unpalatable and free from disease producing bacteria.

Distilled water: Distilled water is safe water which is bacteriologically and chemically pure.

Rate of demand: It is the per capita consumption. The total water requirement for the domestic use, public or civic use, industrial use, commercial use and water loss and waste are usually expressed in terms of per capita consumption per day. Also the water requirement for domestic animals and other live stocks are expressed in terms of animal per day.

Fire demand: This is the quantity of water required for firefighting purpose. The quantity of water required for fire prevention is taken as 1 litre per capita per day which is about 5% to 10% of total consumption.

Design period: It is the future period for which various service units of water supply or sanitary works are designed.

Detention period: It is the theoretical time taken by a particle to pass between entry and exit of a sedimentation basin.

Precipitation: Precipitation is the water falling from the atmosphere to the surface of the earth in the form of rain, hail, etc. Rainfall is the most important part of precipitation.

Water bearing stratum: It is an aquifer holding water. It is the underground natural water storage reservoir, from which water can be withdrawn.

Water table: It is the upper surface of free water in top soil. It is also known as ground water level.

Intakes: Intakes are structures used to collect water from the surface sources which are relatively clean, free from pollution, sand and other objectionable floating materials.

Water pollution and contamination of water: Water pollution indicates the act of destroying or spoiling the purity and sanctity of natural water bodies. Hence water pollution makes water fowl and filthy. Contamination is the presence of bacteria from the intestinal tract of warm blooded animals including human beings. The presence of bacteria is an indication of water containing human disease germs.

S.No	Pollution	Contamination
1	General term which includes contamination also.	Specific term which indicates pollution.
2	Makes water unfit for the best use.	Makes water unsafe and unreliable for use.
3	Makes water objection able to human senses of sight, odour, taste,etc	Does not make apparently objection able.
4	Saline water,turbidwater, etc are examples for polluted water.	Water containing high concentration of pathogenes, etc, is an example for contaminated water.

Water main: Principal pipe in a system of pipes for conveying water, especially one installed underground.

Storage tank: A tank or cistern for storage of water which is connected to the water main by means of a supply pipe.

House plumbing: The materials and system used for the installation, maintenance, extension, alteration of pipe system of a house or building is called house plumbing.

Plumbing system: It includes supply and distribution pipes, fixtures, taps, valves, soil, vent and waste pipes, drains, sewers and all their connections.

Available head: It is the water head available from a water main to the plinth level of the building.

Air gap: An air gap, is the unobstructed vertical space between the water outlet and the flood level of a fixture.

Back flow It is a term in plumbing for an unwanted flow of water in the reverse direction. It can be a serious health risk for the contamination of potable water supplies with foul water. In the most obvious case, a toilet flush cistern and its water supply must be isolated from the toilet bowl.

Back syphonage: Back siphonage is the reverse flow of water within a water supply system due to negative pressures in the pipe system enabling atmospheric pressure to force the flow of water backwards through a siphon action.

Residual head: It is the pressure available at the tail end of the distribution system.

Wash out valve: Valve in a pipeline or a dam that can be opened occasionally to clear out sediment.

Down take tap: It is tap fitted to a system of piping which is not subjected to water pressure from the water main.

Barrel: It is that portion of a pipe in which its diameter and wall thickness remain uniform throughout.

Bedding It is the support provided to pipe on the trench floor by concrete or any other suitable material.

Benching: The sloped floor of a man hole or inspection chamber on both side and above the top of the channel is called benching.

Anti syphonage: It is the device provided in a trap to preserve its water seal.

Dry weather flow (D.W.F): It is the normal flow of sewage during the dry season of the year.

Wet weather flow (W.W.F): It is the normal flow of sewage during the rainy season of the year

Drain: It is the line of assembled pipes with all fittings and equipments like manhole, trap and gully's etc.

Drainage: It is the system by which used and contaminated water is removed by means of drains.

Sewer: It is a separate underground carriage system specifically for transporting sewage from houses and commercial buildings to treatment or disposal.

Sewage: It includes all types of liquid wastes in a building. It may be storm sewage or sanitary sewage.

Sludge: It is the organic matter deposited at the bottom of the sedimentation tank during the treatment of the sewage.

Sewerage Sewerage refers to the infrastructure that conveys sewage. It encompasses components such as receiving drains, manholes, pumping stations, storm overflows, and screening chambers of the sanitary sewer. Sewerage ends at the entry to a sewage treatment plant or at the point of discharge into the environment.

Sub soil water drain: It is the drain which carries sub soil water

Surface water drain: It is the drain which carries surface water and storm water for its disposal

Soil pipe: Drain that conveys liquid waste from toilets, etc.

Vent pipe: It is a pipe which is used to provide flow of air to or from drainage system. It provides circulation to the system and protects trap seals from the syphonage or back flow

Refuse: It includes all types of house waste and garbage in dry form

Garbage: It is the solid or semi solid waste from a house, like peelings of vegetables and fruits, wastes of foods etc.

Rubbish: It includes solid wastes like waste papers, broken furniture and pottery, waste materials of building etc.

Ashes: It is the residual substance obtained after burning the wood, coal, coke etc in hearths and furnaces etc - in the building.

Storm water: It is the rain water of the locality

Sub soil water: It is the ground water which finds its entry in to sewers through leaks

Man hole: It is hole or shaft provided in a drain, sewer or any other closed structure in which a man may enter for inspection, cleaning or maintenance operation. A manhole is provided with a cover at top

Cleaning eye: It is an opening in a drain or sewer which is used for cleaning any obstruction in it by means of drain rod. It is provided with removable cover

Soak pit: It is a pit which is suitably prepared to receive soil waste water or partially treated sewage for seepage into the ground

Importance of sanitary engineering: Sanitary engineering came into existence and it mainly concerns with the cleanliness of the cities. This project is divided into four stages namely collection, conveyance, treatment and disposal. The refuse from industrial and residential areas are collected and conveyed for disposal outside the city either by mechanical transport or with the help of water, depending upon the stage of waste. The wastes are made less harmful by treatment. The treated wastes are finally disposed by any suitable method.

Purpose of sanitation: The purpose of sanitation is to promote and preserve good health of the people by preventing the spread of communicable diseases. This is achieved by the scientific and methodical collection. Conveyance, treatment and disposal of the waste matter as detailed below.

Proper disposal of human excrete to a safe place before it starts decomposition causing insanitary conditions in the locality.

To take out all kinds of waste water from the locality immediately so that flies, mosquitoes, bacteria's etc. may not breed in it and cause nuisance.

Final disposal of sewage on land or in nearly water course after some treatment so that the receiving land sub - soil or water may not get polluted.

The fertilizing elements of sewage may be used to grow crops through sewage farming.

In unsewered areas, the treatment of sewage of individual houses should be done in septic tanks and the effluent should be disposed off.

Classification of dry refuse

The dry refuse includes house refuse, trade refuse and street refuse in dry state as far as possible. It is classified as.

i organic or combustible and

ii inorganic or mineral or non - combustible

i Organic or combustible

Organic dry refuse includes dry animal and vegetable refuse like cow dung. Excreta of birds, leaves of trees, papers, etc. It also includes condemned meat, spoiled food stuff, bad fish, slaughter house waste, market refuse etc. It is highly dangerous to public health but has great value as a fertilizer.

ii Inorganic or mineral or non - combustible

The inorganic refuse includes non - combustible material so like grit, dust, mud pieces of metals, glass, tiles, waste building materials, etc. This refuse is not liable to any decay and hence it is not harmful to the public health.

Types of sewage

1 Fresh sewage

It is the sewage which has been recently produced.

2 Crude or raw sewage

It is the untreated sewage.

3 Dilute or weak sewage

It is the sewage containing small amounts of suspended matter.

4 Septic sewage

It is the sewage which is undergoing decomposition emitting offensive odours.

5 Domestic or sanitary sewage

It is the liquid waste from residences, institutions and business buildings.

6 Storm water or storm sewage

It is the surface runoff collected during and immediately following a rainfall.

7 Industrial sewage

It is the liquid wastes from industries.

8 Combined sewage

It is the combination of sanitary sewage and storm sewage with or without industrials wastes.

Classification of sewer

i Classification according to type of sewage.

ii Classification according to layout.

Classification according to type of sewage

1 Sanitary sewer

It is the sewer intended to carry the sanitary or domestic sewage, and industrial wastes if permitted.

2 Storm sewer

It is the sewer that carries only storm water.

3 Combined sewer

It is the sewer that carries domestic sewage, industrial sewage and storm water.

Classification according to layout

1 House sewer

It is a sewer which carries sewage from buildings or houses into the public sewer or street sewer.

2 Lateral sewer or lateral

It is a sewer, collecting sewage from houses or flow from streets, but does not receive sewage from any other sewer.

3 Sub - main sewer

It is a branch sewer which receives discharge from two or more lateral sewers.

4 Main sewer or trunk sewer

It is a sewer which collects the flow from two or more sub main sewers and which serves as an outlet for a large area.

5 Intercepting sewer

When it is not desirable to have the sewers discharge directly into a body of water the sewage from a number of separate sewers and combined sewers is discharged into a sewer. Such a sewer is known as intercepting sewer.

6 Outfall sewer

It is that sewer which carries sewage from the lower end of a collecting system to a treatment plant or to the point of disposal.

7 Relief sewer

It is the sewer which is to carry the excess storm sewage from an existing combined sewer.

8 Depressed sewer

When an obstruction is met with, the sewer is constructed lower than the adjacent section. Such a section of sewer is called a depressed sewer.

Materials for sewers

Based on the sewer materials, the following are the different kinds

1 Asbestos cement sewers
2 Brick sewers
3 Cement concrete (plain or reinforced) sewers
4 Cast - iron sewers
5 Corrugated iron sewers
6 Stoneware sewers
7 Steel sewers
8 Plastic sewers
9 Wooden sewers

Shape of sewers: The sewer sections are broadly classified into, (1) circular sections and (2) non circular sections.

Circular sewer sections (Fig 1): Mostly sewers of circular shape are used in all the sewerage systems, as they can be easily constructed and handled. They are best suitable for diameter upto 1.5m. Comparing to non - circular sewer sections, they give the least perimeter for a given area of flow and, therefore, have the maximum hydraulic mean depth for running full and half - full conditions. They are very much useful in a separate system. Where discharge is more or less constant.

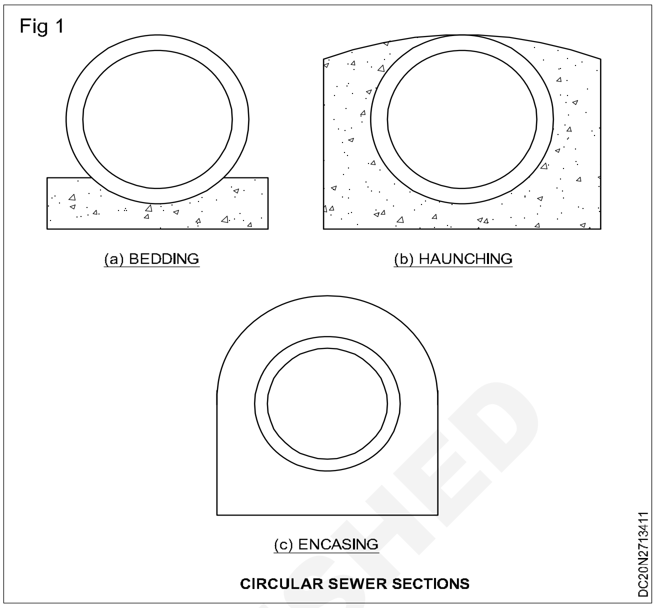
Non - circular sewer sections (Figs 2-9)

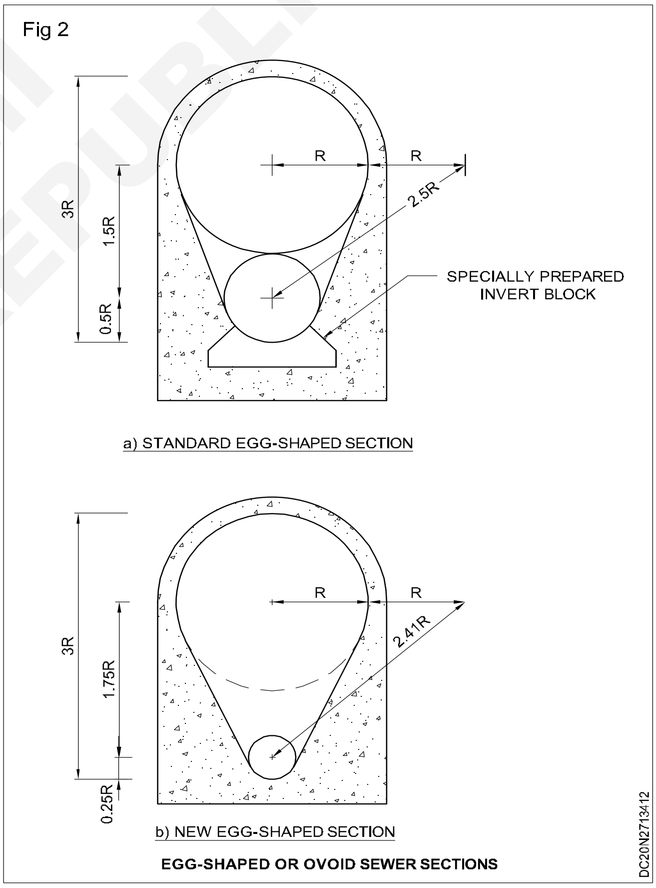
1 Egg - shaped or ovoid sewer section
2 Box or rectangular sewer section
3 Semi - elliptical sewer section
4 Semi - circular sewer section
5 Parabolic sewer section
6 Horse - shoe sewer section
7 Basket - handle sewer section
8 U - shaped sewer section

1 Egg - shaped or ovoid sewer section (Fig 2)

The egg - shaped or ovoid sewer section is available in two forms, namely (1) standard and (2) new egg - shaped.

The egg - shaped section has got better hydraulic properties, but costly. It is difficult and requires more materials for construction. It is less stable. Hence, it requires good foundation for its better stability. It is most suited in the case of combined sewers. Its main advantage is that it gives a slightly higher velocity during low flow than a circular sewer of the same capacity.

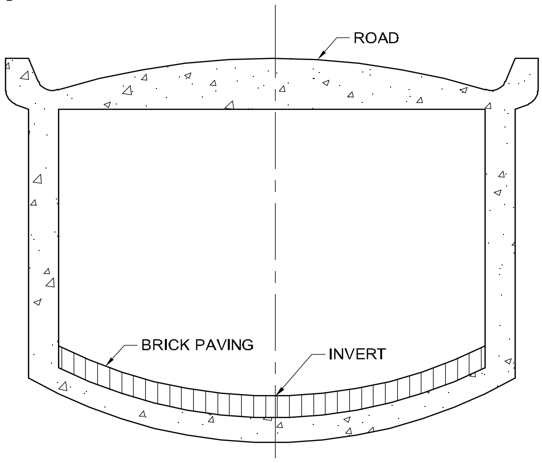




2 Box or rectangular sewer section (Fig 3)

This shape possesses very good hydraulic properties until it is filled. It is easier to construct and is economical. It is mainly used as out fall sewer. They are most suitable for large size storm sewers.

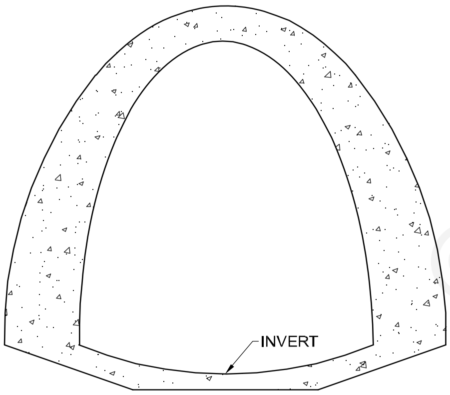
Fig 3



RECTANGULAR OR BOX SEWER SECTION

3 Semi - elliptical sewer section: As this shape of sewers are more stable, they are adopted for soft soils. This shape possesses good hydraulic properties except at low depths. It is normally adopted for sewers having diameters greater than 1.80 m or so. This section is not suitable for carrying small quantity of sewage. (Fig 4)

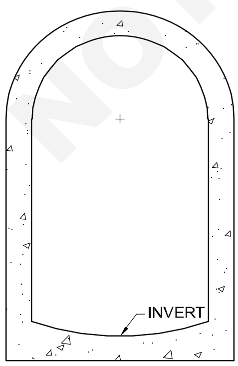
Fig 4



SEMI-ELLIPTICAL SEWER SECTION

4 Semi - circular sewer section This shape of sewer section gives a wider base at the bottom. Hence, suitable for constructing large sewers with less available head room. It possesses better hydraulic properties.(Fig 5)

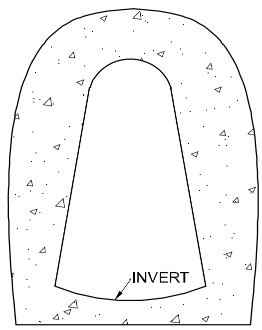
Fig 5



SEMI - CIRCULAR SEWER SECTION

5 Parabolic sewer section (Fig 6)

Fig 6

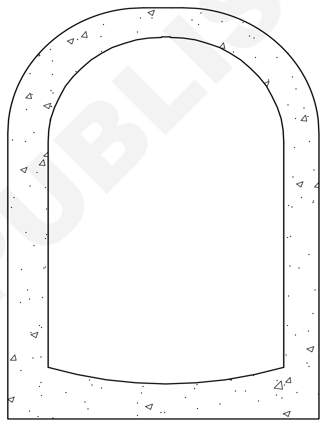


PARABOLIC SEWER SECTION

In this type of sewer sections, the upper arch takes the shape of a parabola. This shape is considered suitable for carrying small quantity of sewage and it is found to be economical in construction.

6 Horse shoe sewer section (Fig 7)

Fig 7

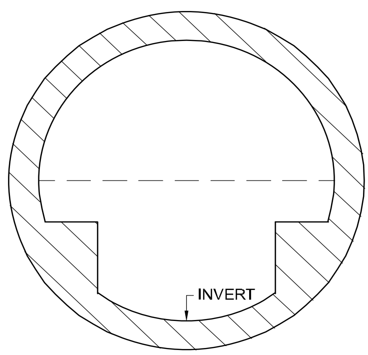


HORSE - SHOE SEWER SECTION

This type of sewer section is used for the construction of large sewers with heavy discharges such as outfall or trunk sewers. Its height is more than width. It is mostly used for sewers in tunnels. The top surface of the sewer is usually semi - circular with sides inclined or vertical. The bottom may be flat, circular or paraboloid.

7 Basket - handle sewer section (Fig 8)

Fig 8

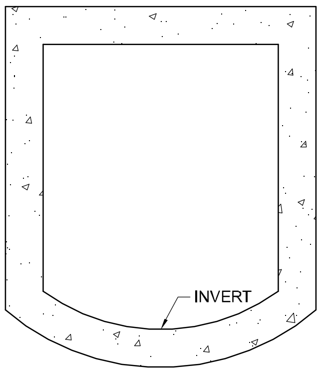


BASKET - HANDLE SEWER SECTION

In this type of sewer section, the upper portion of sewer has got the shape of a basket - handle. Small discharges flow through the bottom narrower portion. During rainy seasons, the combined sewage flows in the full section. This shape of sewer is not generally used at present.

8 U - shaped sewer section (Fig 9)

Fig 9



U-SHAPED SEWER SECTION

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U - shaped sewers are easy to construct, especially in an open cut. The invert may be semi - circular or flat. The sides are vertical and the top is flat.

Importance of water supply system: The water is a good solvent. If water contains impurities, excessive amount of minerals and poisonous substance etc., it will cause so many health hazards and difficulties to the public. Therefore water should be safe, whole some and free from disease producing bacteria, poisonous substances and excessive amount of minerals and organic matters.

Objectives of public water supply system

The broad objectives of a public water supply system are,

1 To ensure safe wholesome water to the public adequately.

2 To provide assured supply of water easily to the users.

3 To minimize the loss during transmission.

4 To eliminate the chances of water contamination.

5 To achieve the necessary flushing action in the sewerage system and

6 To provide adequate supply for fire - fighting.

The water should satisfy the criteria of being least harmful upon consumption and should be safe and wholesome. The source of water supply should be permanent and reliable with minimum impurities. The capacities of intakes and other water supply units should be properly designed, constructed and maintained. The intakes should be so located that the chances of contamination and bacterial infection are minimum. If necessary, water should be treated for its palatability. Water should be carried through pipes from source to treatment plant and to distribution system in order to avoid contamination and transmission loss considerably. By good planning, design and construction of a distribution system, the water should be made available to the consumers easily.

Pipes and pipe joints for underground drainage

Objectives: At the end of this lesson you shall be able to
- **list out the various factors considered for selection of pipe materials**
- **name the stresses in water pipes**
- **enumerate the types of pipes**
- **explain different types of pipe joints**
- **describe various operations involved in laying of pipes and pressure test.**

Pipes These are circular conduits in which water flows under pressure or under gravity. If the pipes do not run full, the flow will be under gravity, provided they are given a longitudinal slope. The pipes which run full are said to be flowing under pressure.

Selection of pipe materials

The selection of materials for the pipe is done on the following considerations.

Carrying capacity of the pipe.

Durability and life of the pipe.

Qualities of water to be conveyed.

Availability of funds.

Maintenance cost, repair, etc.

Resistance to corrosion.

Ease of transportation.

Stresses in water pipes

1 Stress due to change of direction.

2 Stress due to internal water pressure.

3 Stress due to the soil above the pipe.

4 Stress due to water hammer.

5 Stress due to yield of soil below the pipes.

6 Stress due to temperature changes.

Types of pipes

The following are the types of pipes based on the materials.

1 Asbestos cement pipes

2 Cast - iron pipes

3 Cement lined cast - iron pipes

4 Cement concrete pipes

5 Copper pipes

6 Galvanized iron pipes

7 Lead pipes

8 Plastic pipes

9 Steel pipes

10 Vitrified - clay pipes

11 Wooden pipes

12 Wrought - iron pipes

Pipe joints: Pipe joints are required to join together pipes of small lengths to make one continuous length of pipe line. The bell and spigot joint, using lead as filling material, is mostly used for C.I. pipes. Welded, riveted, flanged or screwed joints are used for steel pipes. Special types of joints are used for jointing R.C.C. and asbestos pipes. Flexible type of joints are used if the joint supports are likely to settle. Victaulic or dresser coupling joint should be used to bear shocks and vibrations.

Types of pipe joints

1 Collar joint

2 Expansion joint

3 Flanged joint

4 Flexible joint

5 Mechanical joint

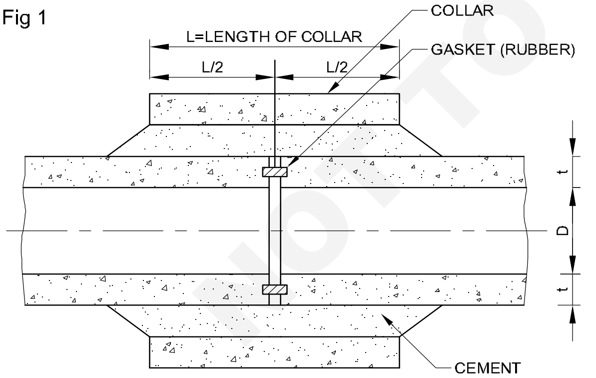
6 Screwed joint

7 Simplex joint

8 Spigot and socket joint

1 Collar joint (Fig 1)

Fig 1

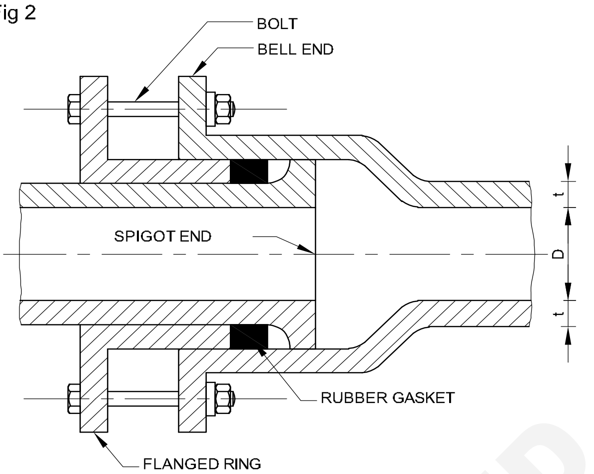


COLLAR JOINT

This type of joint is mostly used for jointing large diameter concrete and asbestos pipes. The, ends of the two pipes are brought in level. Then rubber gasket is placed between curves, as the pipes at rope soaked in cement is kept in the groove. Then the collar is placed at the joint so that it has equal laps over the joint. The space between the pipe and the collar is packed with cement mortar. 1:1 mix.

2 Expansion joint (Fig 2)

Fig 2

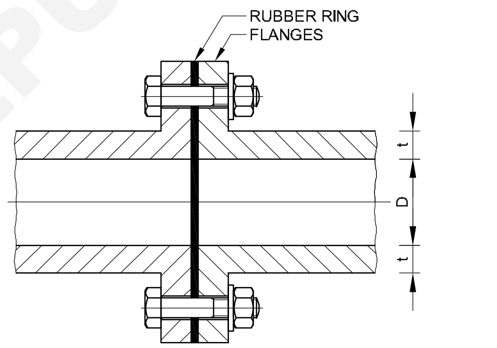


EXPANSION JOINT

Expansion joint is used where the pipes expand or contract due to change in temperature. An elastic rubber gasket is tightly, pressed between the angular space of spigot and bell ends to make the joint water - tight. The flanged ring is bolted to bell end and it expands or contracts along with the bell end. The elastic rubber gasket in every position keeps the joint water tight.

3 Flanged joint (Fig 3)

Fig 3



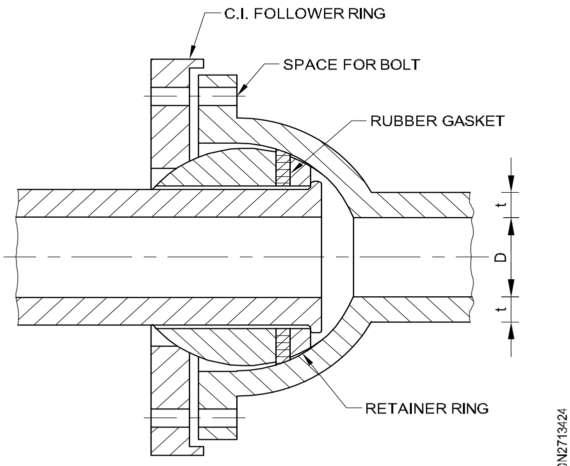
FLANGED JOINT

Flanged joint is used for connecting pipes carrying water under high pressure. The ends of pipes are provided with wide flanges which are bolted together. The two ends of the pipes to be jointed are brought together in level. Then a hard rubber gasket is inserted between the flanges to make the joint water - tight and the flanges are bolted together. Flanged joints are generally used in places where it is required to dismantle and reassemble the pipe lines.

4 Flexible joint (Fig 4)

Flexible joint is used at such places where settlement is expected after laying and on curves, as the pipes at the joint can be laid at angle. The socket end is cast in a spherical shape. The spigot end is plain, but has a bead at the end. For assembling, the spigot end is placed in the spherical shaped socket end. After this, a retainer ring is slipped and stretched over the bead. A rubber gasket is placed against the retainer ring. Then a split cast iron gland ring is placed, the outer surface of which has the same shape as inner surface of socket end. Over this, cast iron follower ring is moved and is fixed to the socket end by means of bolt it is also known as universal joint.

Fig 4



FLEXIBLE JOINT (UNIVERSAL JOINT)

5 Mechanical joint (Figs 5 & 6)

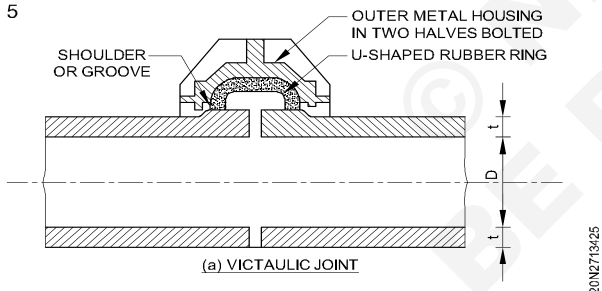
Mechanical joint is used when both the ends of the pipes are plain or spigot. There are two types of mechanical joints.

a Victaulic joint

b Dresser coupling joint

a Victaulic joint (Fig 5)

Fig 5



(a) VICTAULIC JOINT

MECHANICAL JOINT

In this type of joint, a U - shaped rubber ring is slipped over both the ends of the pipes to make the joint water tight. Two half housings or couplings engage grooves near the pipe ends and enclose the rubber ring. The couplings are bolted around the pipe. The ends of the pipes are kept sufficiently apart to allow for free expansion, contraction and deflection. This joint can bear shocks, vibrations, etc.

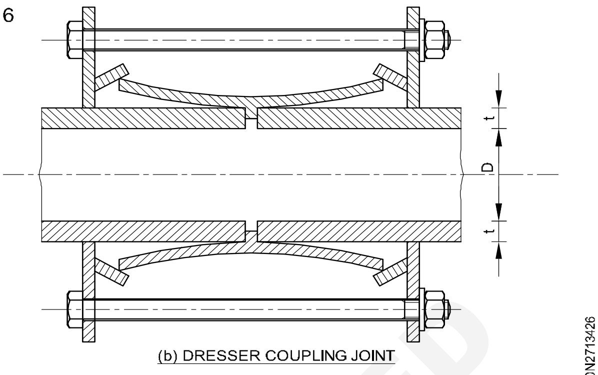
b Dresser coupling joint (Fig 6)

This joint consists of a middle ring, two follower rings and two rubber gaskets. The two follower rings are connected together by bolts. When the bolts are tightened, they press both the gaskets tightly below the ends of the middle ring to make the joint water - tight.

6 Screwed joint (Fig 7)

This joint is used for connecting small diameter cast iron. Wrought iron or galvanized iron pipes. The ends of the pipes to be jointed, have threads on outside. The socket or coupling has threads on the inner side. The same socket is screwed on both the ends of the pipes to be jointed. To ensure water tightness, jute soaked in white lead is placed in the threads before screwing the socket over the pipes.

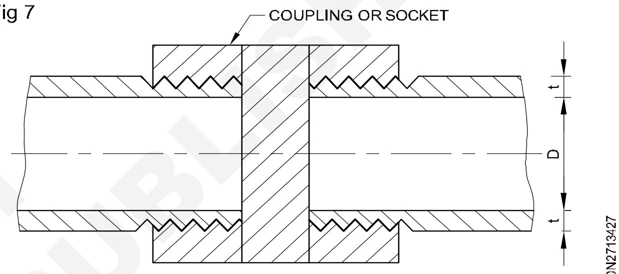
Fig 6



(b) DRESSER COUPLING JOINT

MECHANICAL JOINT

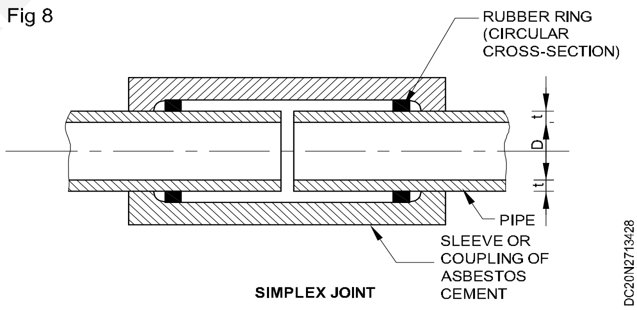
Fig 7



SCREWED JOINT

7 Simplex joint (Fig 8)

Fig 8



SIMPLEX JOINT

In this joint, the two plain ends of the pipes butt against each other. Then the rubber rings are slipped over the pipes. Next a coupling will be pushed over the rubber rings. This makes a water - tight and flexible joint which can be completed easily in a dry condition or under water.

8 Spigot and socket joint (Fig 9)

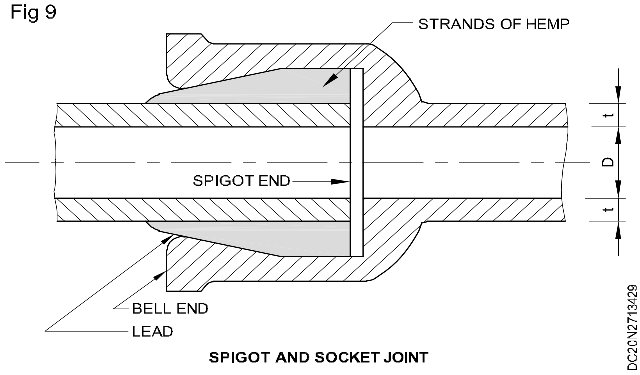
This joint is otherwise known as bell and spigot joint and is mostly used for jointing cast iron pipes. The spigot of one pipe is slipped into the socket or bell of the proceeding pipe. Tarred gasket or hemp yarn is then wrapped around the spigot. It is then yarned tightly home with a yarning tool. A joint runner or a kneaded clay mould is then formed around the barrel and against the face of the socket.

The molten lead or its substitute is poured through the hole at top to fill the remaining annular space of the socket. When the lead has hardened, the runner of the clay mould is removed. The lead is caulked by caulking tool to make the joint water - tight. It should preferably be finished 3 mm beyond the socket face.

Laying of pipes

The various operations involved in the laying of pipes are as below

Fig 9



SPIGOT AND SOCKET JOINT

1 Preparation of detailed maps

2 Fixing the alignment

3 Excavation of trenches

4 Bottoming of trenches

5 Lowering of pipes

6 Laying of pipes

7 Jointing of pipes

8 Anchoring of pipes

9 Back - filling

1 Preparation of detailed maps

Detailed maps regarding roads and streets showing clearly the position of sewer lines, existing water mains, gas pipes, electrical cables, and curbs are to be prepared.

2 Fixing the alignment

The exact location of the proposed alignment is then marked on the ground. The trench line is marked by driving stakes and the centre line by driving pegs or stakes at intervals 30 m apart on straight reaches and at 7.5 to 15 m apart on curves.

3 Excavation of trenches

The trenches are then excavated to sufficient width so that the pipes can be properly laid and easily jointed. The width of the trench should be at least 0.3 to 0.5 m greater than the external diameter of the pipe. The trenches are excavated to the predetermined depth. The pipe should have a top cover of about 0.9 to 1 m to ground.

4 Bottoming of trenches

The bottom of the trenches should be prepared carefully so that the pipe can be laid in alignment and gradient to its entire length on a firm bed. To prevent any possible settlement and to provide a hard and even surface, a concrete bed of 150 mm thick is provided. Joint holes are left at suitable spacings in the bed for jointing the pipes latter.

5 Lowing of pipes

The pipes are lowered carefully into the trenches after they are cleaned internally and externally.

6 Laying of pipes

The pipes are laid in alignment along the ground profile to avoid troubles due to air - lock.

7 Jointing of pipes

The. joints are finished as per the description given under "pipe joints".

8 Anchoring of pipes

Concrete thrust blocks are constructed, at all bends, tee junctions, valves and at places where branch connections are to be provided, to distribute the hydraulic thrust over a larger area on the ground. For better anchorage, the pipes are rigidly secured with steel straps.

9 Back - filling

The sides and the upper portions of the trenches are refilled with excavated earth in layers of 150 mm thick, watered and rammed well. The top of refilling is finished slightly above the original level for future settlement.

Pressure test to water pipes

The sequence of operations involves in the pressure test to water pipes are as below.

1 A section of pipe line between two sluice valves is taken up for testing at a time.

2 Keeping one of the valves closed, water is filled, without any air lock, into the pipe through the second valve.

3 The pipe line is isolated from the rest, by closing the second valve.

4 Pressure recording devices are then fitted at intervals of 800 to 1000 m at the crown through holes left for the purpose.

5 The delivery side of a pump is connected to the test pipe through a small bypass valve.

6 The pump is worked till the inside pressure reaches the designed value (1.5N/mm^2 or the maximum working pressure plus 50% whichever is greater) which can be observed from the previously fixed pressure recording devices.

7 After attaining the desired pressure, the pump is disconnected and the pipe line is checked for 24 hours under this pressure for any defects or leakage. This can be read from the fall in pressure in the pressure recording devices.

8 Then the water is emptied through the scour valves. The defects, if any, are rectified.

During testing, the open end of the pipe line should be kept closed water - tight with a plug.

System of sanitation

Objectives: At the end of this lesson you shall be able to
- **explain the system of sanitation**
- **explain the system of sewerage.**

System of sanitation

Sanitation systems are a combination of functional units that together allow managing and reusing or disposing the different waste flows (i.e. waste, organic waste, excreta, etc.) from households, institutions, agriculture or industries in order to protect people and the environment. Sanitation systems are more than the toilets and have to do with management issues including treatment and reuse of waste and wastewaters, comfort, affordability, health aspects, gender aspects, etc.

Methods of collection

1 Conservancy system or dry system

2 Water carriage system or modern system or flush down system

Conservancy system (Dry system)

In conservancy system, garbage is collected, carried and disposed off by burning or burying. Sullage is collected in open drain and let off in natural water. Night soil is removed by labour and conveyed outside the town to form manure.

Merits

i It is cheap

ii It can be adopted for small towns and villages

iii It can be adopted where water is scarce

Demerits

i Unhygienic aspects are involved in the manual removal of human excreta.

ii Nuisance due to bad smell from the decomposed night soil.

iii Insanitation due to the transportation of night soil through streets.

iv Does not permit compact design and safety as the toilets are to be constructed away from the building.

v Risk of epidemics due to improper disposal of the night soil.

vi Misuse of sullage drains to dispose of garbage and other solid waste.

vii Considerably more land is required for disposal.

viii Contamination of underground water.

ix Though initial cost is less, maintenance cost is more.

2 Water carriage system: It is the most hygienic system. In this system sewage is collected in a system of pipes and transported for treatment and disposal in a harmless manner without causing any nuisance.

Merits

i It is hygienic, since the sewage is carried in covered conduits.

ii The effluent can be safely used to develop sewage farms.

iii The final solid matter obtained after treatment is a very good manure.

iv Less area is required for treatment and disposal.

v The risk off outbreak of epidemics is reduced as the sewage collected is properly treated and disposed off.

Demerits

i Needs large quantity of water

ii Costlier

iii Needs sophisticated and costly treatment methods

iv The effluent after treatment should be properly disposed off to prevent pollution of water resource of land.

Systems of sewerage

1 Separate system of sewerage

2 Combined system of sewerage

3 Partially combined or partially separate system of sewerage

1 Separate system of sewerage

In this system, two sets of sewers are laid. One sewer is meant for carrying sewage. While the other for carrying storm water.

Merits of separate system

i Sewer sizes are small.

ii Sewage load on treatment units is small.

iii River or stream waters are not polluted.

iv Without any treatment, rainwater or storm water can be discharged into streams or rivers.

v When sewage has to be pumped. This system proves to be economical.

Demerits

i It is costly, because it requires two set of sewers.

ii Sewers being small, it is difficult to clean them.

iii Sewers are likely to choke frequently.

iv Storm water sewers are used only during rains. Therefore during non - rainfall season they may become the dumping places for garbage and may get choked up.

2 Combined system of sewerage

In this system, only one set of sewer is laid to carry both sewage and storm water.

Merits of combined system

i Rain water keeps sewage fresh making it easier and more economical for treatment.

ii Dilution itself is a method of treatment.

iii Automatic flushing is provided by water.

iv Because of the bigger size of the sewer, cleaning is easier.

v This is a simple method of collection and house plumbing is economical.

vi Maintenance cost is reasonable.

vii Only one set of sewers is required in this system.

Demerits of combined system

i The bigger size of sewer would involve larger excavation.

ii The D.W.F. being a small amount of the total flow the larger size of the sewer would often result in causing silting up due to low velocity.

iii Cost of pumping and treatment is more, since large quantity of sewage is to be handled.

iv Over flowing under worst conditions may endanger public health.

v Load on treatment units increases.

vi Storm water is unnecessarily polluted.

3 Partially combined or partially separate system of sewerage

In this system also, only one set of sewer is laid. During small rain falls, the rain water is collected and conveyed along with sanitary sewage. If the amount of storm water exceeds certain limit, it is collected and conveyed in open drains. While sewage continues to flow through sewers.

Merits of partially combined system

i It simplifies the drainage of the house.

ii It provides reasonable sizes of sewers.

iii It is economical.

iv The rain water avoids silting in sewers.

v It has the advantages of both separate and combined systems.

Demerits of partially combined system

i Low velocity during dry period.

ii Storm - overflows may be found necessary.

iii Load on pumping and treatment unit is increased due to the admission of storm water.

iv Storm water is polluted unnecessarily.

System of house drainage

Objectives: At the end of this lesson you shall be able to
- **explain the aim of house plumbing**
- **explain the principles of house drainage**
- **define the terms related to house plumbing**
- **explain the system of plumbing.**

House plumbing

House plumbing is the collection and conveyance of liquid refuse upto the public drain and sewers. Certain part of the building are set apart for this purpose. The positions of various sanitary conveyances and other conveniences are marked on the plan of the building. The drainage lines from the places of collection, leading to the sewer are also shown on the same plan with necessary appurtenances. Sanitary conveyances include lavatory blocks comprising of water closets and urinals, and bath rooms. Other conveniences comprise kitchen sinks and washing places.

Aim of building drainage

1 To dispose off liquid waste as early as possible

2 To prevent entry of foul gases from the sewer to the building

3 To dispose off the storm water into open surface drain

4 To facilitate quick removal of foul matter

5 To provided health condition in the building

Principles of house drainage

1 For proper design and construction of house drainage system, the following general principles are adopted.

2 The entrances to drains should be outside the building.

3 The drainage systems should have proper ventilation.

4 The drains should not pass through building, but should pass by the side of the building.

5 The drains should not be laid close to trees.

6 The drain should be laid at gradients for self cleansing.

7 The drain should be laid straight between points of access. All changes of direction or gradient should be open for inspection.

8 Branch drains should be as small as possible.

9 All the connections should be oblique, so that the incoming drain faces the direction of flow of the sewage.

10 The size of drains should be just sufficient to meet the requirements.

11 The pipe joints should be water tight and made from non - absorbent materials.

12 The house drain should be connected to public sewer only when the public sewer is deeper than the house drain.

13 The house drain should contain sufficient number of traps at suitable points.

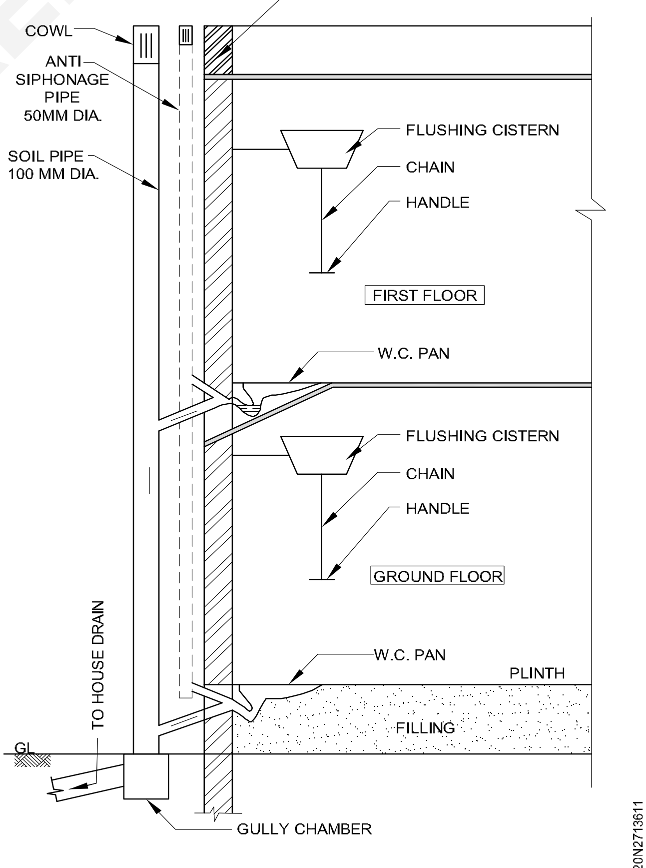
14 The house drain should be separated from the public sewer by a trap to prevent the entry of foul gas in to houses.

15 It is preferable to provide a separate system of drains to take the rain water.

Terms related to house drainage (Fig 1)

Anti - siphonage pipe - It is a pipe which is installed in the house drainage to preserve the water of traps. It maintains proper ventilation. It does not allow the siphonic action to take place.

Fig 1



ANTISIPHONAGE PIPE

Cowl - It is provided at the top of vent pipe. It prevents the birds from building the nests. It is provided with slits or narrow openings. It escapes the foul gas from septic tank or the drainage line.

Fixture drain - It is the outlet pipe from the trap of a fixture to make its connection any other drainage pipe.

Fresh air inlet - This is provided at the last manhole, which connects the house drain with the public sewer for admitting fresh air. This dilutes the sewage gases. It is kept at about 2 metres high above the ground level. It is provided with mica flap one way valve at its top. This valve opens inwards and admits fresh air.

Horizontal branch - It is a drain pipe extending laterally from a soil or waste stack or house drain. It receives the discharge from one or more fixture drains and conduct it to the soil or waste stack or house drain.

Horizontal pipe -It is any pipe or fitting which make an angle of less than 45° with the horizontal.

House drain or building drain- It is that part of the lowest horizontal piping of a plumbing drainage system. It receives discharge from soil, waste and other drainage pipes within the building and conveys it to the house sewer.

House sewer or building sewer - It is that part of the horizontal piping of a plumbing drainage system that extend from the end of the house drain or building drain to the public sewer or other outlet.

Siphonage - Due to siphonic action, water seal or traps may break. This is known as siphonage and it is induced when water is suddenly discharged from a fixture on the upper floor.

Soil pipe - It is any drainage pipe that carries liquid wastes containing human excreta.

Stack - A stack is any vertical line of drainage i.e., soil waste or vent pipe.

Vent pipe - The pipe installed for ventilation of sewers is known as vent pipe. It is provided to protect the water seal of traps against siphonage and back flow.

Waste pipe - The waste pipe is any drainage pipe that carries liquid wastes that do not include human excreta.

System of plumbing - There are four system adopted in plumbing of drainage work in a building.

1 Single stack system

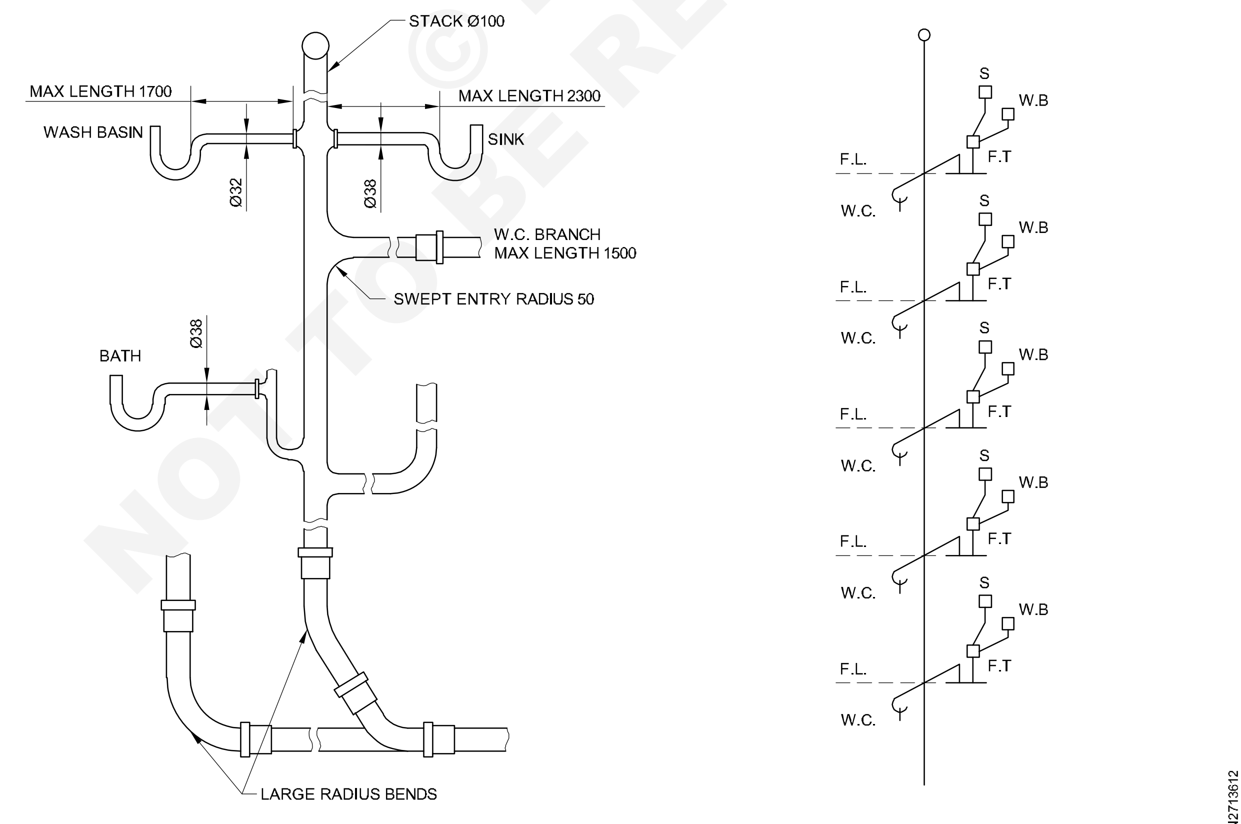
2 One pipe system

3 One pipe system partially ventilated

4 Two pipe system

1. The single stack system - This is the name given to a simplified one - pipe system. All ventilating pipes are committed. The stack itself provides ventilation by restricting the flow into the stack upto certain limits. (Fig 2)

Fig 2

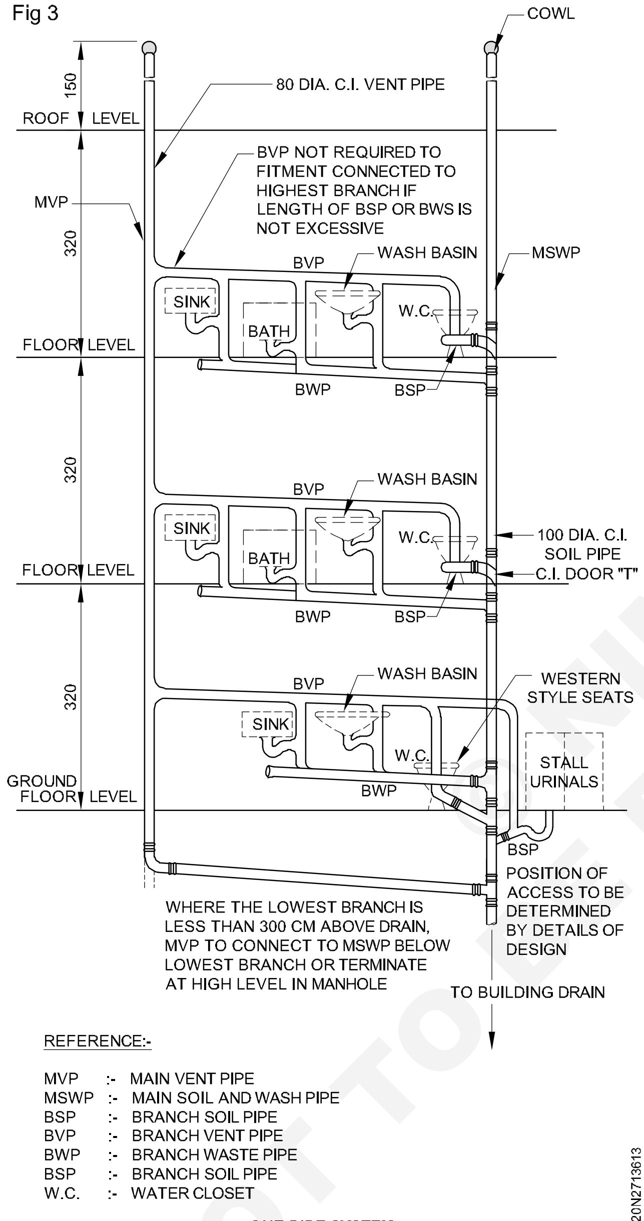


SINGLE STACK SYSTEM

The single stack system is used only in buildings with a maximum ground floor and four upper floors having two bathroom units and two sinks at each floor.

2. The one - pipe system - In this system a single soil waste pipe conveys both soil and waste from all appliances directly into the building drain. It is an easy to install and economical system. Fig 3 shows a single pipe system.

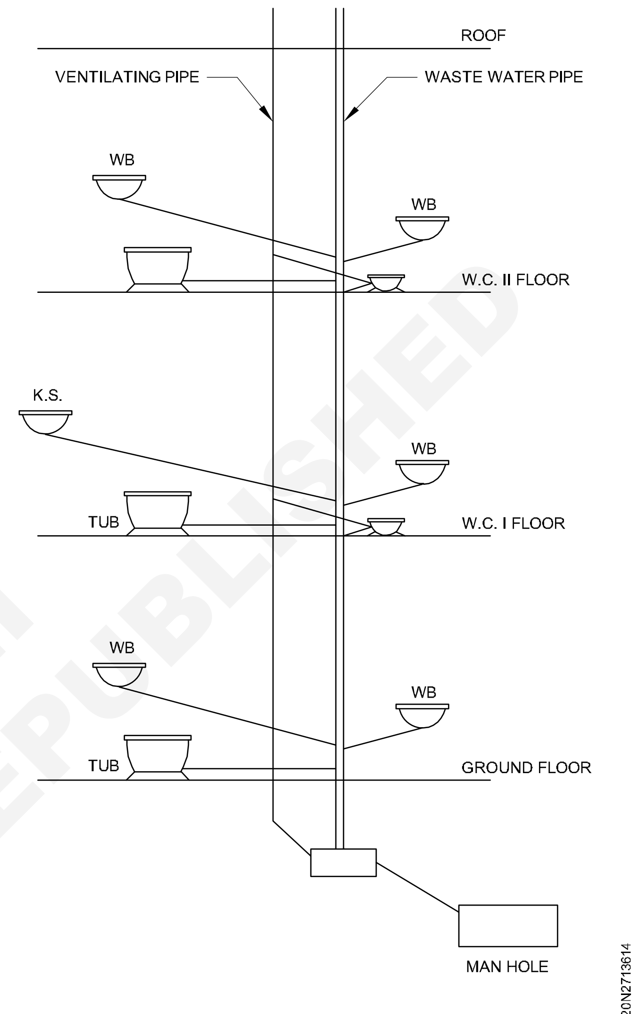
Fig 3



ONE PIPE SYSTEM

3. One pipe system partially ventilated - This system combines both the one - pipe and single stack system. In this system, only one soil waste pipe conveys both soil and waste. The separate vent pipe provides ventilation only to the traps of water closets.(Fig 4)

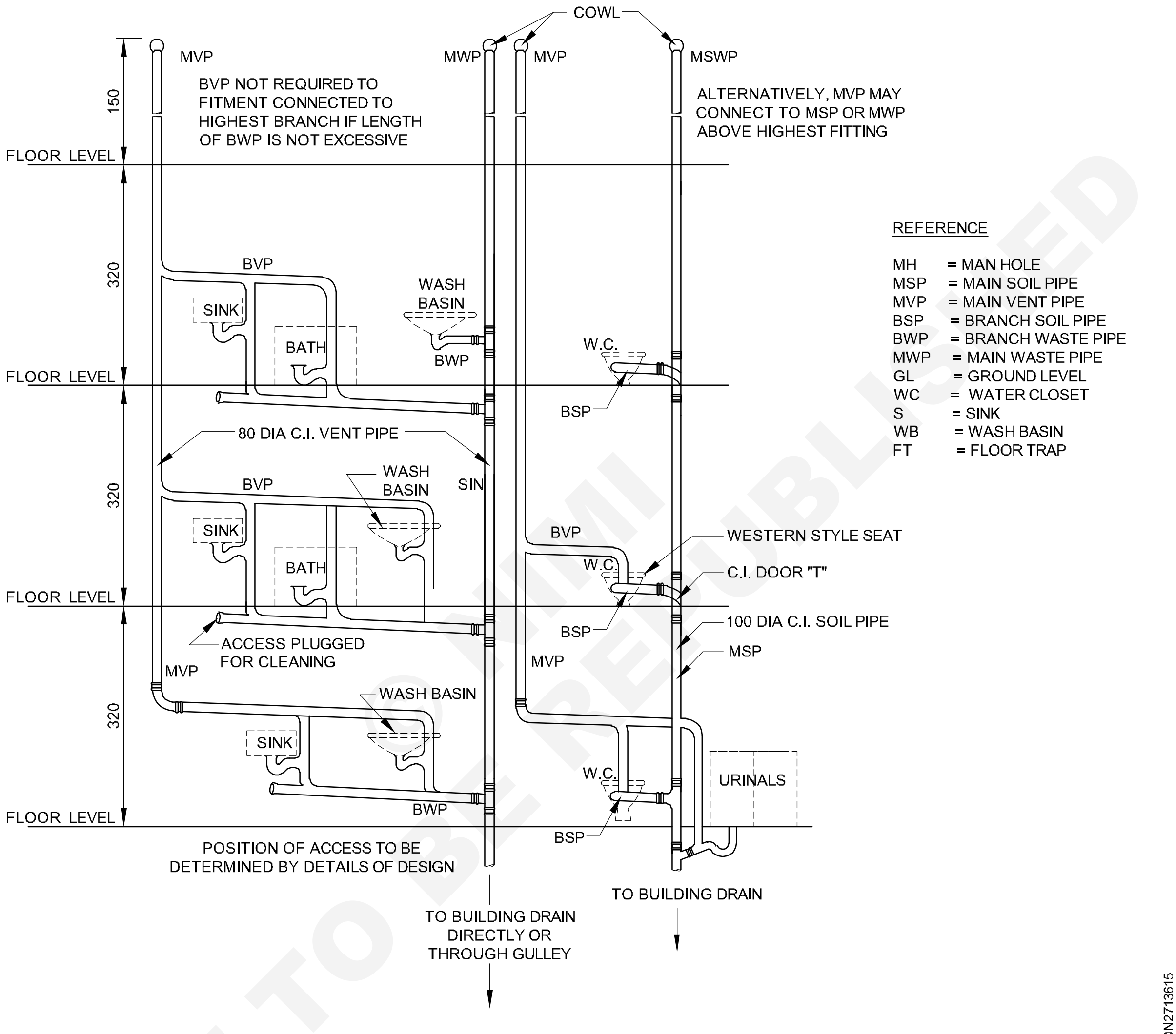
Fig 4



ONE PIPE SYSTEM (PARTIALLY VENTILATED

4 The two - pipe system (Fig 5) - Different waste pipes are used for drainage of waste from bath, kitchen and W.C's. The soil pipe conveys discharges from water closets, urinals, and similar soil appliances directly to the drainage system. The waste pipe conveys waste from ablutionary and culinary (sinks, wash basins, showers, bathrooms and kitchens) appliances to the drainage system directly or through a trapped gully where desired. This system is installed on the face of a side wall or a pipe duct in the case of multistoreyed buildings. In multistoreyed buildings where the number of floors exceeds four, this system is preferred.

Fig 5



TWO PIPE SYSTEM

Plumbing sanitary fittings

Objective: At the end of this lesson you shall be able to
- **explain different sanitary fittings.**

Sanitary fittings

The fittings required in a building for the efficient utility, collection and removal of water are called sanitary fittings.

These fittings are available in the market under many branded names and in variety of sizes, colours and designs. Only an outline is given here.

Traps

Fittings or sanitary appliances and accessories

Traps

The depression or bend provided in a drainage system which is always full of water and prevents the entry of foul gases into the atmosphere is termed as a trap. The water inside the trap is called seal. Traps are made of glazed earthen ware, vitreous, porceline, cast iron, and P.V.C. or hi - density polythelene. According to the shape the traps are classified as

P trap This trap has a shape of letter 'P'. The legs of trap are at right angles to each other(Fig 1)

Q trap This trap has the shape of letter 'Q'. the legs of trap meet at an angle other than a right angle.(Fig 1)

S trap This trap has the shape of letter 'S'. The legs of trap are parallel. The two legs of traps are at right angles (Fig.1).

Classification according to use

According to use, traps are of the following types:

1 Floor trap (Fig 2c)

2 Gully trap (Fig 2a)

3 Intercepting trap (Fig 2b)

Requirements of good trap

1 It should be easily fixed and cleaned.

2 It should facilitate easy flow of sewage.

3 It should be simple in construction.

4 It should possess adequate water seal and self cleansing properties.

5 The internal and external surface should be finished smooth.

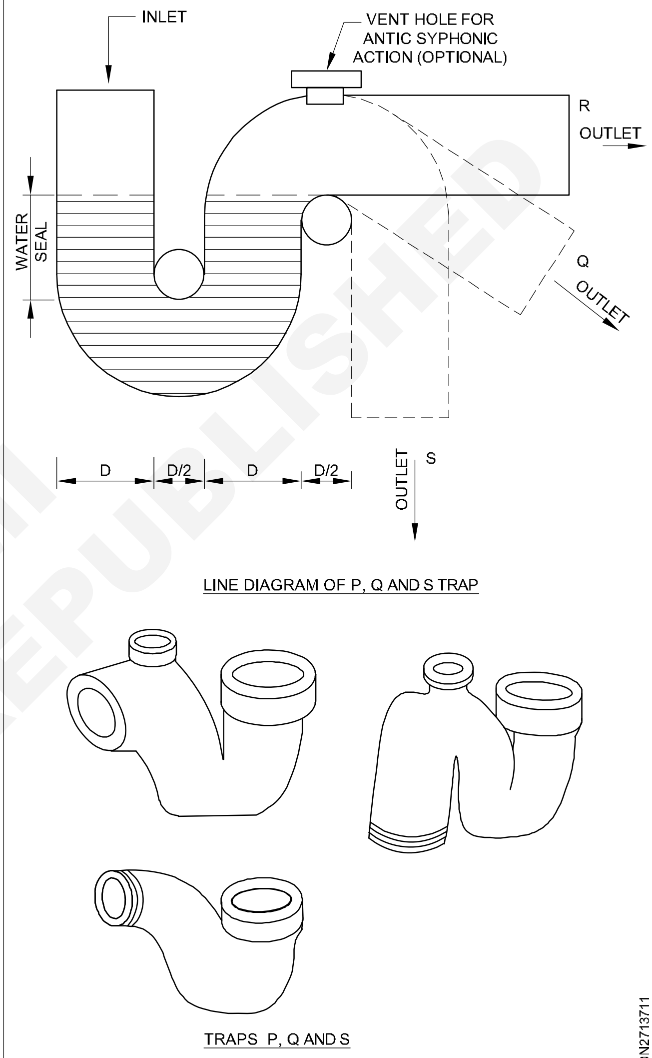
6 It should be easily fixed with the drain.

7 It should be free from any inside projections.

Fittings or sanitary appliances and accessories

Following are the common sanitary fittings which are provided in a building.

Fig 1



TRAPS

1 Wash basin.

2 Bath rub.

3 Sink

4 Bathroom fittings such as

   i Shower
   ii Shower stall
   iii Towel rail or ring
   iv Toilet roll stand or holder

5 Drinking fountain

6 W.C seats

   i Squatting type
   ii Chair - type or raised wash - down water closet.

7 W.C flushing cistern

i High level

ii Low level.

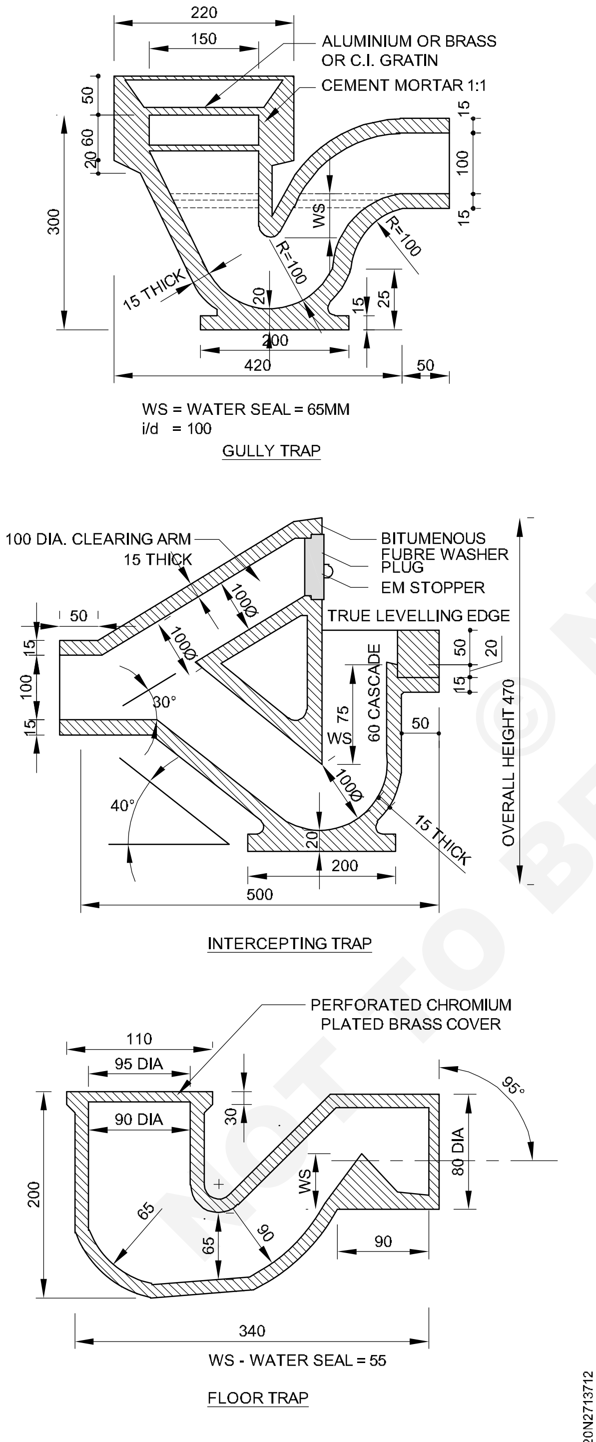
8 Automatic urinal flushing cistern.

9 Urinals

i Bowl pattern.

ii Urinal stalls.

Fig 2



TYPES OF TRAPS

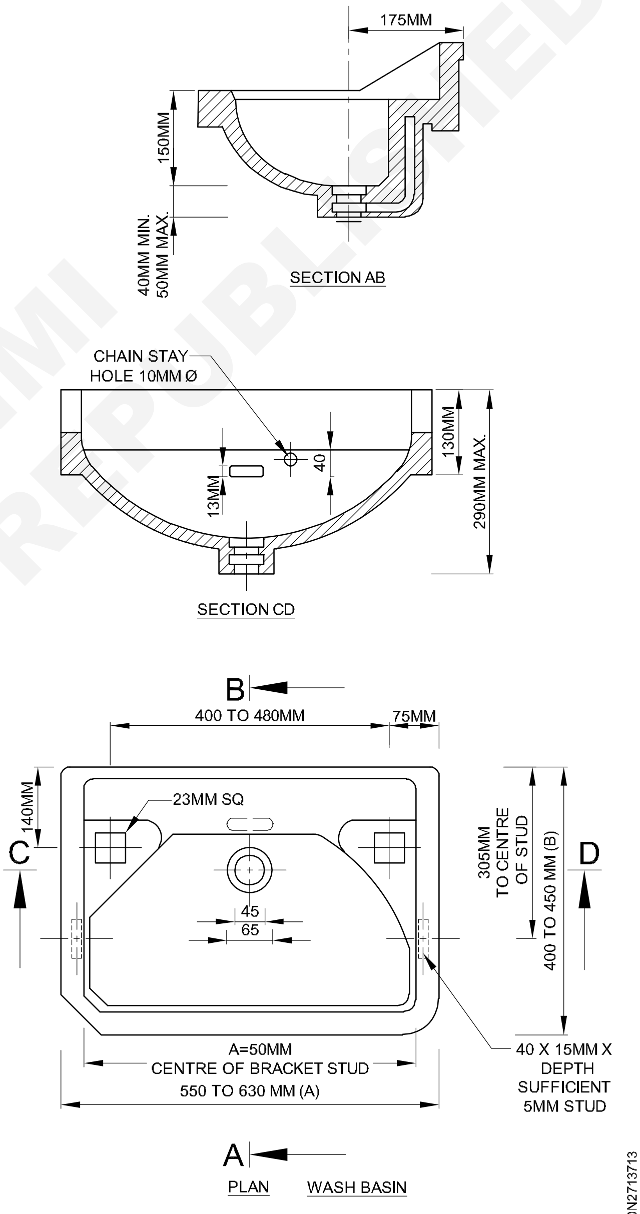
10 Bidet.

All these appliances are manufactured in various sizes, elegant designs and attractive colours. The illustrations given here just give an idea about the space to be provided for installing different appliances.

Pictorial and three - dimensional views are given so that a layman can understand the shape of these fittings. Symbolic representation of each fitting is also given along the sketch.

1 Wash hand basin: Wash hand basins are available in various designs and sizes. These are mainly of two patterns. Fig 3 i.e. Flat back and angle back. Flat wash basins are mounted on walls while angle back

Fig 3

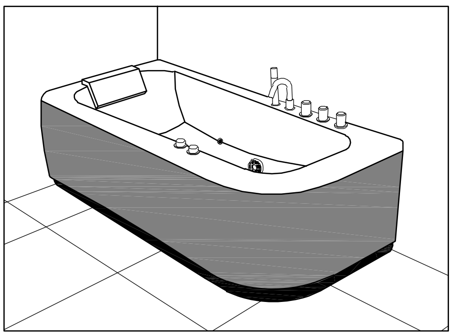


SANITARY FITTINGS

type are fixed at the junctions of two walls. Wash basins are made of fire clay, stoneware, earthen ware or vitreous china. Now a days steel and aluminium wash basins are also available in the market. A wash basin has syphonic trap underneath. A discharge pipe attached to it is left over floor trap. A wash hand basin with dimensions as per I.S. standard.

2 **Bath tub:** A bath tub is a luxurious item in the bath rooms which is used for taking bath. It is made of cast iron, enamelled iron, plastic marble, fire clay, steel or aluminium etc. It has a porcelain enamelled finishing inside. It is 170 to 185 cm long, 70 to 75 cm wide and inside depth at waste is 43 to 45 cm. Bath if fitted with over flow pipe and waste pipe of not less than 25 mm diameter and inside slope towards the outlet. Sometimes a bath is provided with hot and cold water taps. A bath tub is shown in Fig 4.

Fig 4



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3 **Sink:** A sink is used in the kitchen for washing utensils. It is also used in laboratories. A sink may be of one piece constructed with or without rim, including a combined over flow of weir type and their inverts shall be 30 mm below the top edge. A circular waste hole is provided in the sink. A drain board is also provided with all the kitchen sinks. A sink with its sizes as per I.S standards is shown in Fig 5.

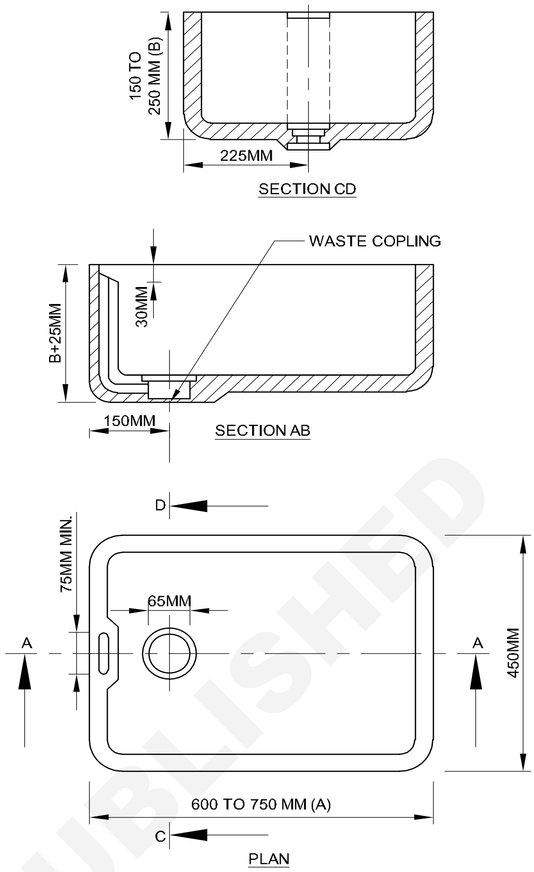
4 **Bath room fittings:** Inspite of usual bathroom fittings, some additional fittings are also provided in the bath room which are as given below.

i **Shower:** It is used for taking bath. A shower head 10 to 20 cm dia with 70 holes of 1 mm dia each is fixed at a height of 2.20 m from floor level to the water supply pipe as shown in Fig 6.

ii **Towel rail:** It is provided for keeping towel in the bath room. The size of towel rail is generally 75 cm x 18 mm or 60 cm x 18 mm. This is fixed by means of screws to wooden cleats firmly which are embedded in the wall. See Fig 7.

iii **Mirrors:** it is fixed at a suitable height having a size of about 60 x 45 cms. It is mounted on asbestos sheet ground and is fixed in position by means of 4 Nos. of brass screws and washers placed over rubber washers. Wooden pegs are firmly embedded in the wall to fix the mirror firmly. Fig 8

Fig 5



SINK

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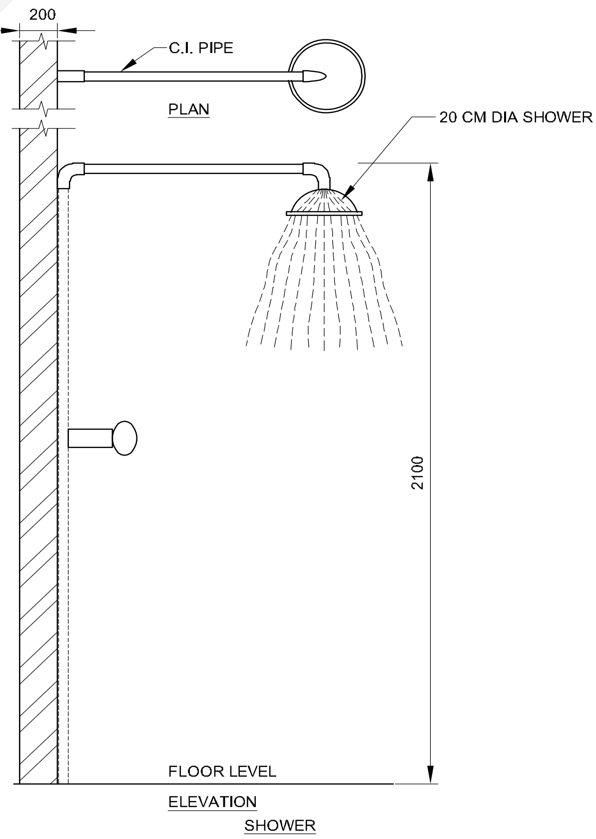
Fig 6



SHOWER

SANITARY FITTINGS

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Fig 7

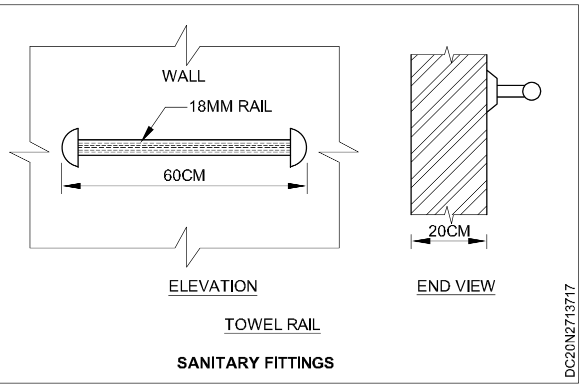
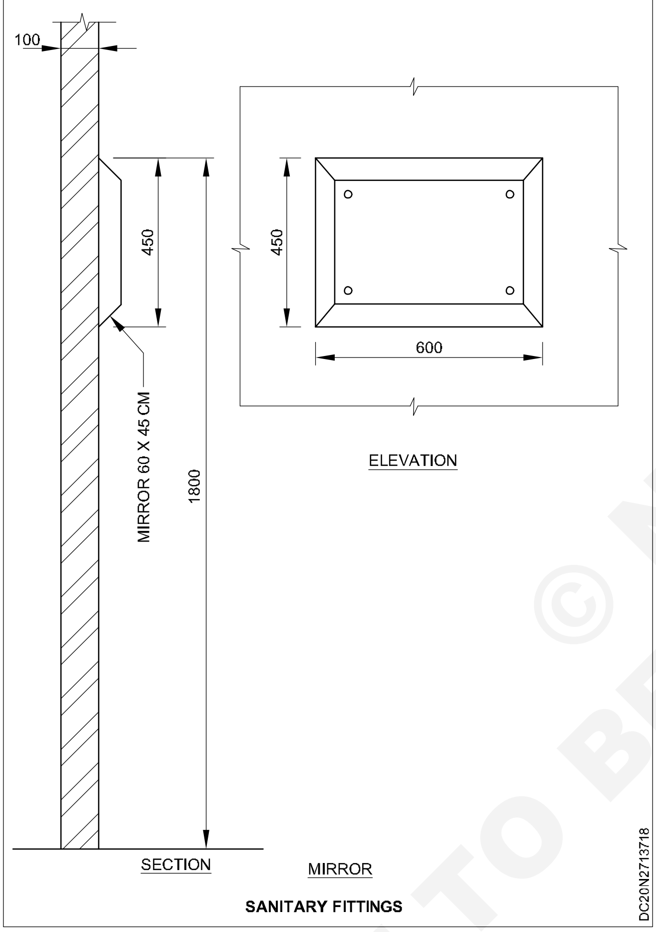


Fig 8



Drinking fountain Fig 9

In schools, public buildings, factories, etc., drinking fountains are provided to supply drinking water. This is a simple arrangements and wastage of water is avoided. When the valve is pushed the water comes from the tap. After a part being consumed the remaining falls on the plat form. It is conveyed to the floor trap through the grating.

Water closet It is the sanitary engineering appliance which is used to receive human excreta directly and connected to a soil pipe by means of a trap. There are two main types of the water closet. Fig 10

i Indian type (long pattern squatting pan) Fig 10

ii European type Fig10a

Fig 9

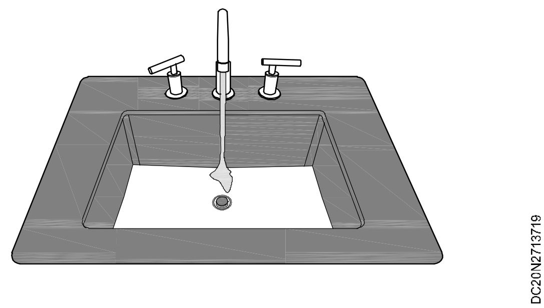


Fig 10

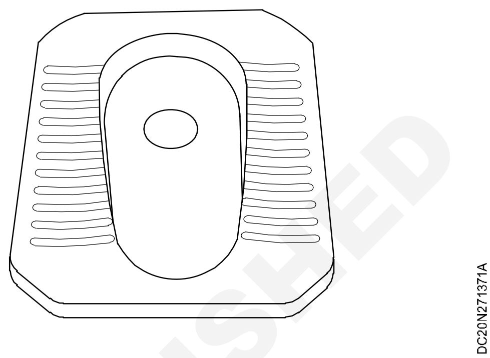
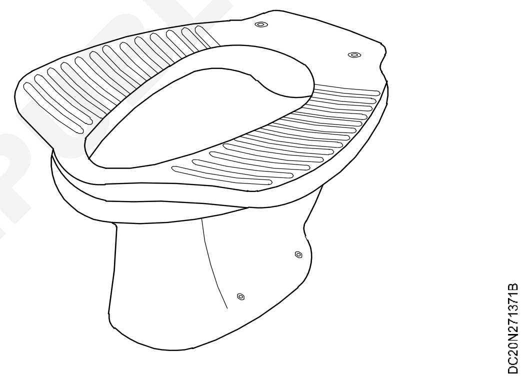
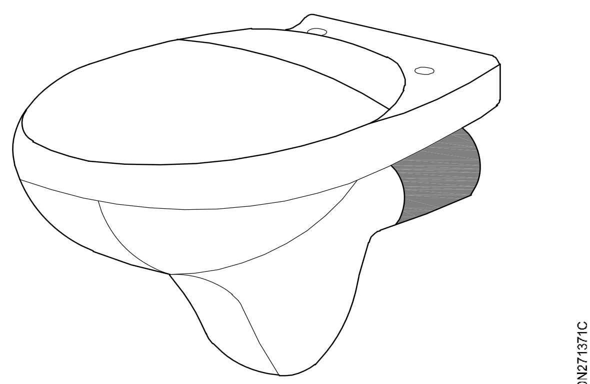


Fig 11



The Indian type consists of a pan or basin and a trap. The pan is of impervious and smooth material preferably white glazed. It should have a sufficient depth of water. The trap should have a minimum water seal of 45 mm. The pan should have also a sufficient slope towards the outlet for quick disposal during flushing. The top of the trap is attached to anti - syphonage pipe or vent pipe. An Indian type and European type water closets are shown in Fig 11.

Fig 12



Flushing cistern (Fig 12)

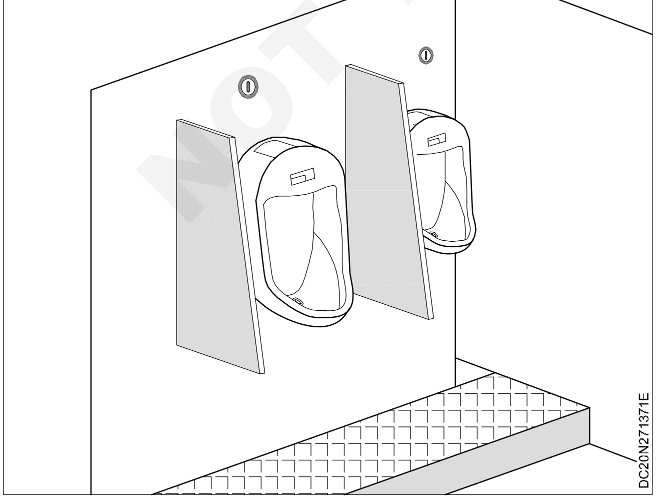
It is meant for flushing water closets and is made of cast iron of minimum thickness as 5 mm. The flushing capacity of the cistern is 10 to 15 litres. There are several varieties of flushing cisterns. They may be high level and low level cisterns. Plastic cisterns are also available now a days.

Fig 13

It is operated by pulling a chain by hand which due to lever action raises the ball inside the chamber. This causes partial vacuum inside the ball upto the top. As it happens water flows down into the flush pipe and thus the syphonage action starts. Water in the tank, goes on entering the ball through the bottom. The actual flush however will not take place unless the chain is released suddenly which forces down the water into the flush pipe with a splash. If the chain is not released, the partial vacuum created in the top of ball shall be destroyed by the entry of air from the flush pipe.

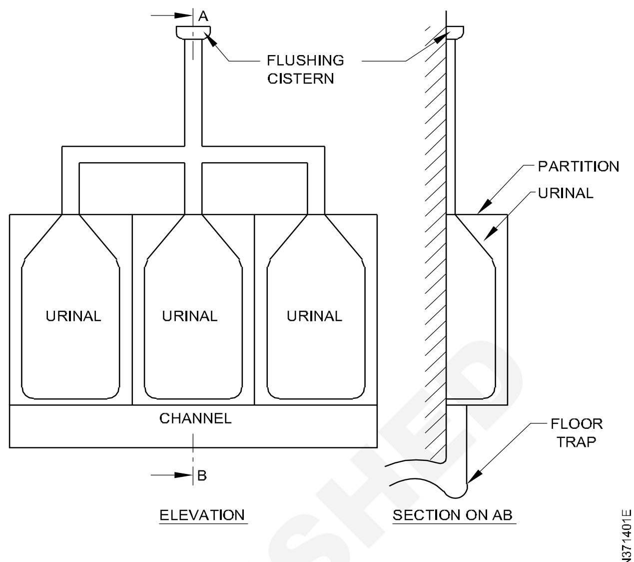
Urinals Urinals are constructed in various types. They may be bowl type, slab and stall type and squating plate type. Bowl type urinals are constructed as one piece construction. These are fixed against wall. It has a regular and smooth inside surface for efficient flushing. A slope is provided at the bottom towards outlet for efficient drainage of the urine. An automatic flushing cistern is provided at the top for flushing purposes Fig 13.

Fig 14



The slab and stall type urinals are provided in public places like, bus stands, railway stations, restaurants, offices and cinema houses etc Fig 14.

Fig 14



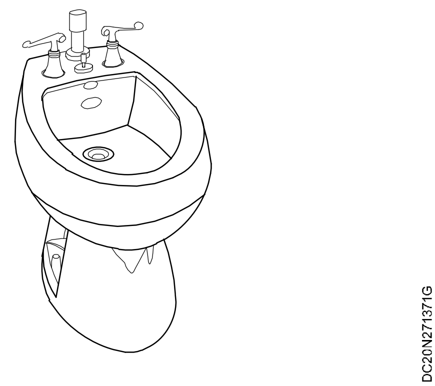
STALL TYPE URINAL

The squatting plate urinals are mostly used in ladies toilets. They are generally one piece construction.

Bidet (Fig 15)

The bidet is pronounced as "beday". The bidet is designed for cleanliness of localised parts of the body especially of genitor urinary cleanliness. The bidet is equipped with valves for both hot and cold water and with popup waste plug, a flushing rim, an integral jet operated by means of valve. When the jet is "ON" a stream of water flows upward from bottom section of bowl enabling cleaning.

Fig 16



New technologies in sewer appurtenances-system of plumbing

Objectives: At the end of this lesson you shall be able to
- **explain smart plumbing**
- **explain rain water harvesting tank.**

The concept of smart plumbing or green plumbing is the reduction of use of water through resourceful landscaping, wastewater technology and high-efficiency plumbing design.

Water and energy conservation are the two conservation issues of a plumbing system in a green-built home. Changing climate and weather patterns have made water a precious commodity and are an incentive for efficient plumbing systems. The goal of water efficient plumbing is to reduce potable water use. For this

i Fit all sink and lavatory faucets and showers with water restricting aerators.

ii Install high - efficiency toilets consume more water than any other fixture in the house. Users will save money on their water bill. These toilets are installed in the same manner as any other toilet. Dual flush toilets are more expensive, but are available at home improvement stores.

iii Install flow reducers on faucets and shower heads.

iv Install on - demand circulation systems. So customers will get hot water without the wait. Saves energy by only heating the water as it is needed.

v Install drain water heat recovery systems Heat is recovered from waste water resulting in energy and water savings.

vi Pre - plumb for future grey water systems save money for the homeowner in the future (grey water systems mean less potable water used flushing toilets or for outdoor watering. Grey water is only legal in a few areas of the country as water shortages occur due to climate change, municipalities will be encouraged to legalize grey water).

Technology is playing an important role in the plumbing department whether in the form of products designed to make the kitchen and bath more comfortable, keep living spaces more sanitary. The cost of water is rising, increasing 6 to 7 percent a year, so it is necessary to finding ways to conserve and reuse water. One way to make this transition is through a grey water recycling system.

This system uses water from showers, sinks, washing machines and dishwashers that is relatively clean, containing very few pathogens. This water (unlike black water which comes from toilets) requires very little treatment before it can be reused for non-drinking purposes, such as for toilet flushing and lawn watering with sprinkler systems. Another eco-friendly product that continuous to gain popularity in the plumbing category is the tankless water heater.

In addition to some of the newer, technologically advanced green products mentioned above, green practices in plumbing have led to a new program, called water sense, from the united states Environment Protection Act (EPA). The water sense program was created to find ways to use water efficiency for consumers, communities and the environment, while helping conserve resources for the future.

In the bathroom, a touchless toilet allows the user to wave their hand above the toilet to flush it. After they're finished, the toilet lid will automatically close without slamming. Technological advancements also have had an impact on water filtration both for the whole house and at point of use.

Water collection

Storm water capture, storage and use systems collect rainwater and reuse it in the building's non-potable water fixtures, such as landscape, toilets and fire suppression storage. However, because the system requires two plumbing systems, it is best suited for new construction in areas where rainfall is substantial. For this, construct rain water harvesting tank.

Rain water harvesting tank

It is a water tank used to collect and store rain water runoff, typically from roof tops via rain gutters. A rainwater catchment or collection (also known as "rainwater harvesting") system can yield 2358 litres (623 gal) of water from 2.54 cm (1 in) of rain on a 93 m^2 (1,000 sq ft) roof. Rainwater harvesting tanks are devices for collecting and maintaining harvested rain.

Rainwater tanks are installed to make use of rainwater for later use, reduce mains water use for economic or environmental reasons, and aid self - sufficiency. Stored water may be used for water gardens, agriculture, flushing toilets, in washing machines, washing cars, and also for drinking, especially when other water supplies are unavailable, expensive, or of poor quality, and when adequate care is taken that the water is not contaminated and is adequately filtered.

Types of sewer appurtenances and manhole

Objectives: At the end of this lesson you shall be able to
- **explain the important sewer appurtenances, drop/deep/shallow manhole**
- **components parts of manholes and functions.**

General: In order to make the construction process easy and to have efficient working and maintenances the sewer system requires various structures known as sewer appurtenances.

Following are the important sewer appurtenances

1 Manholes
2 Drop manholes
3 Lamp holes
4 Catch basins
5 Clean - outs
6 Flushing tanks
7 Grease and oil traps
8 Inlets
9 Storm regulators and weirs
10 Inverted siphons
11 Junction chambers
12 Outlets

1 Manholes

They are openings in the sewer line for a man to enter through its.

Purpose

The purpose of manholes is to inspect, clean and for other maintenance operations in connection with sewers.

Location

Man holes are located:

1 At every change in gradient, direction alignment or diameter.
2 At junctions of sewers.
3 At street intersections and
4 At intervals of 45 m to 90 m in straight reaches.

Component parts of manholes and their functions (Fig 1)

i Access shaft

It is the upper portion of a deep manhole. It provides an access to the working chamber below.

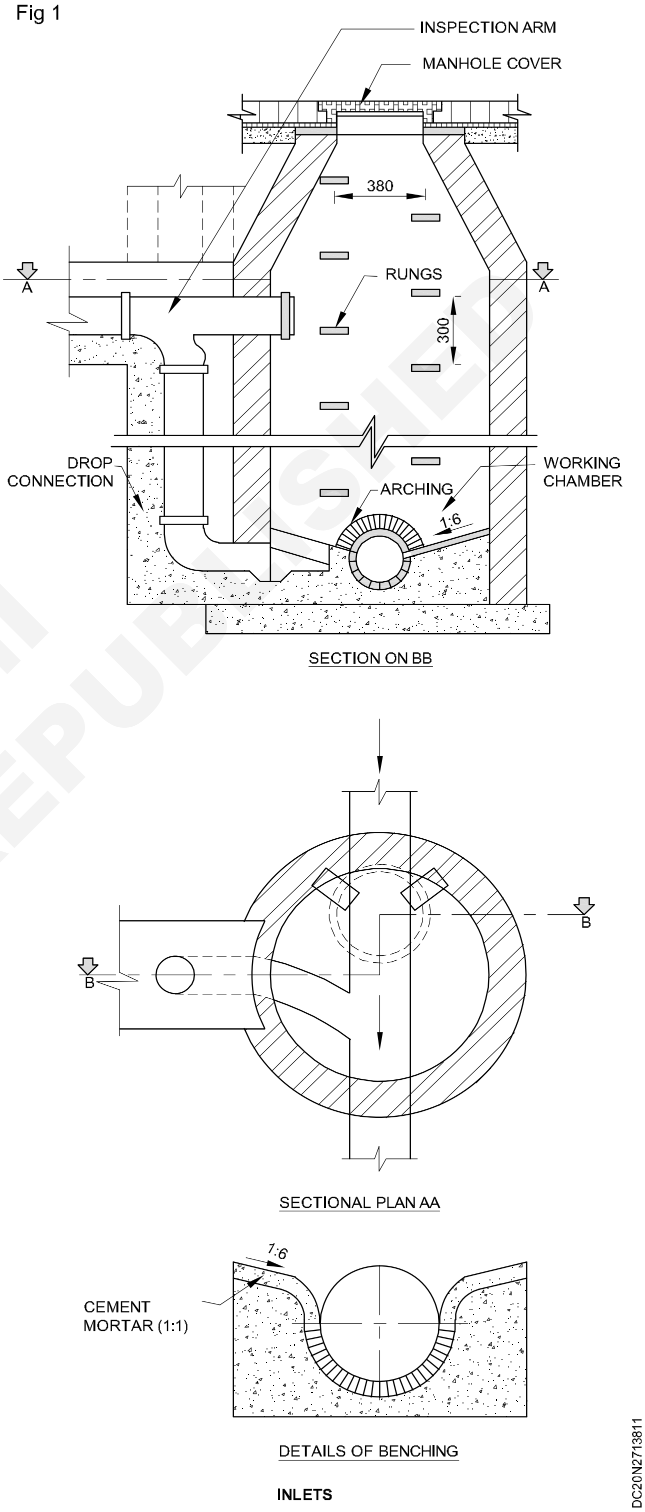
ii Bottom or invert

It is the bottom of the manhole. It is constructed of cement concrete or brick paving, over which the sewage flows.

iii Cover and frame

They are provided at the top of manholes. They provide an entry to the manhole whenever required. During other periods, these form the surface of the road. They prevent the accident of falling into the manholes.

Fig 1



iv Steps or ladder

They are provided to make the entry and exit of men easy. They are staggered two vertical runs, 200 mm apart horizontally and 300 mm vertically. They are also called rungs.

v Walls

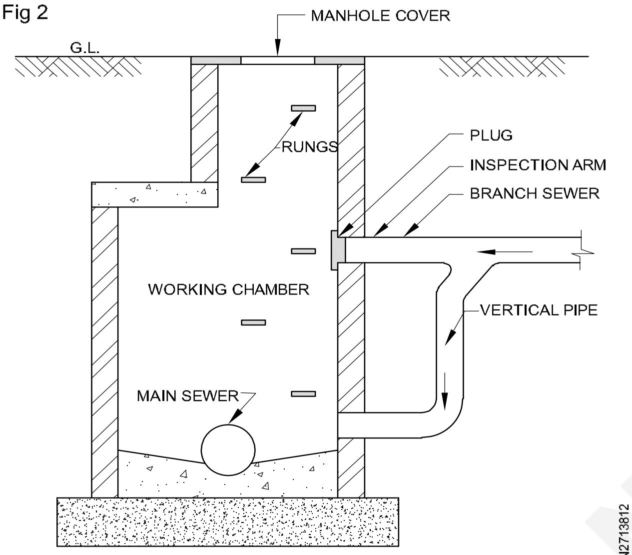
They are constructed of brick work or stone work or cement concrete. They form the structure of the manhole. They support the components above, retain the soil from the sides and enclose the sewers.

vi Working chamber

It is the lower portion of a deep manhole. It provides a working space for a man to stand inside and to carryout cleaning and inspection of sewer lines. It may be circular or rectangular in plan.

2 Drop manholes (Fig 2)

Fig 2



DROP MAN HOLE

Purpose

The purpose of drop manholes is to avoid unnecessary steep gradient of branch sewer and thus reducing the quantity of earth work. Also, they avoid the splashing of sewage on the man working and on the masonry work.

Location

Drop manholes are located,

1 Where inlet and outlet pipe sewers have to be connected at different levels.

2 In places where it is desired to drop the level of invert of the incoming sewer.

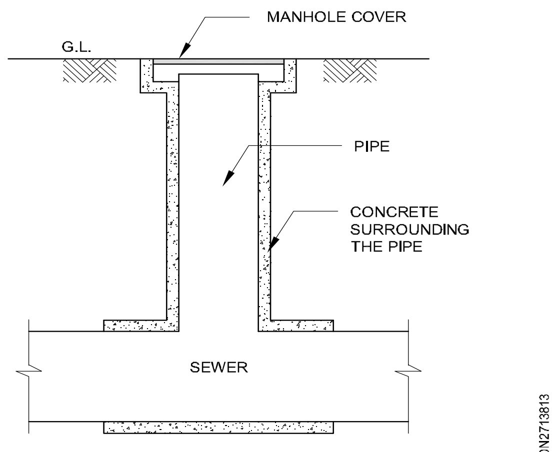
The length of the pipe between the vertical shaft and the wall is called inspection arm. Opening the plug, it is used for inspecting and clearing of the vertical shaft, the vertical shaft is carried upto the ground level.

Lamp holes (Fig 3)

Purpose

The lamphole is intended to detect the obstruction in the sewer. It is done by inserting a lamp in the lamphole and viewing it from the adjacent manholes. Also they incidentally serve as fresh - air inlets and for flushing.

Fig 3



LAMP HOLE

Location

Suitable locations for lamp holes are,

i In places where a bend is necessarily to be inserted.

ii In places where construction of manhole is difficult.

iii When straight length between manholes is considerably more and,

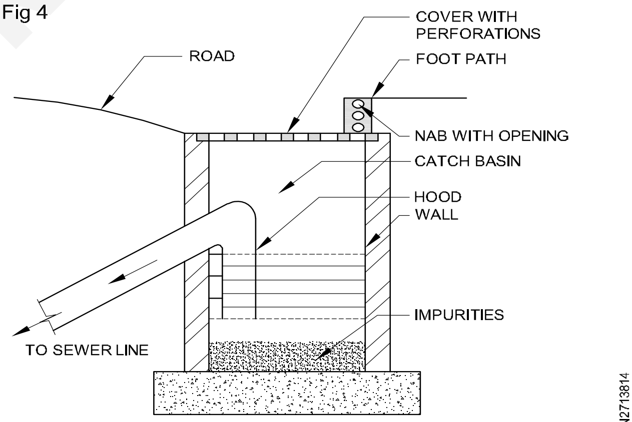
iv For flushing the sewer line in the absence of any other flushing devices.

The use of lampholes should be recommended only under special circumstances.

There use should be as far as possible avoided.

4 Catch basins (Fig 4)

Fig 4

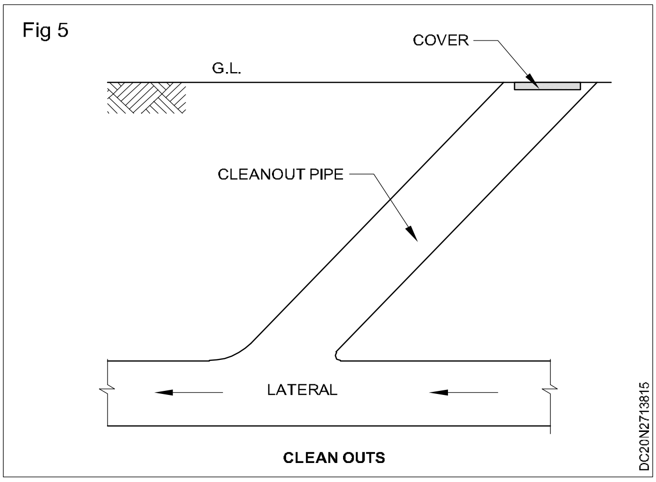


CATCH BASIN

It is a structure constructed in the form of a chamber along the sewer line to admit clear rain water into the combined sewer. It also prevents the escape of sewer gases. It consists of a chamber constructed of walls. The silt, grit, etc, settles in the bottom and clear water alone flows into the sewer. At the top, a cover with perforations is fixed at the pavement, edge. A hood is provided which prevents the escape of sewer gases into the basin. It provides a temporary storage for impurities in rain water. Hence, it is cleaned after each storm.

5 Clean - outs (Fig 5)

Fig 5



CLEAN OUTS

It is a pipe, one end is connected to the underground sewer and the other end is brought upto ground level and is covered. It is generally provided at the upper ends of lateral sewers in place of manholes.

For working, the cover is removed and water is forced through clean out pipe into lateral sewers to remove obstacles in the sewer line. Flexible rods may also be inserted through the cleanouts and moved back and forwarded to remove obstructions.

6 Flushing tanks

These are devices or arrangements used to store and then to throw water into the sewer to produce self cleansing velocity for flushing the sewer. Sometimes sewage is to be stored for a short period before allowed into the sewer line. Flushing tanks are used to store sewage temporarily and then discharge at intervals to flush the sewers. They are provided near the dead ends of sewers. Their capacity is about 10% of the cubical contents of the sewer line served by it.

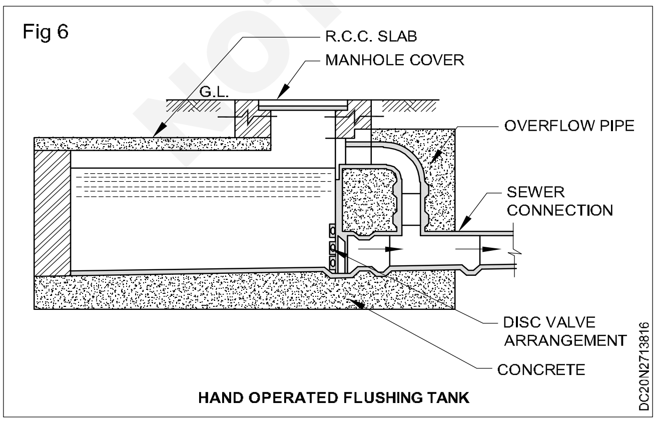
The flushing tanks are of the following two types

1 **Hand operated flushing tanks**

2 **Automatic flushing tanks**

Hand operated flushing tanks (Fig 6)

Fig 6

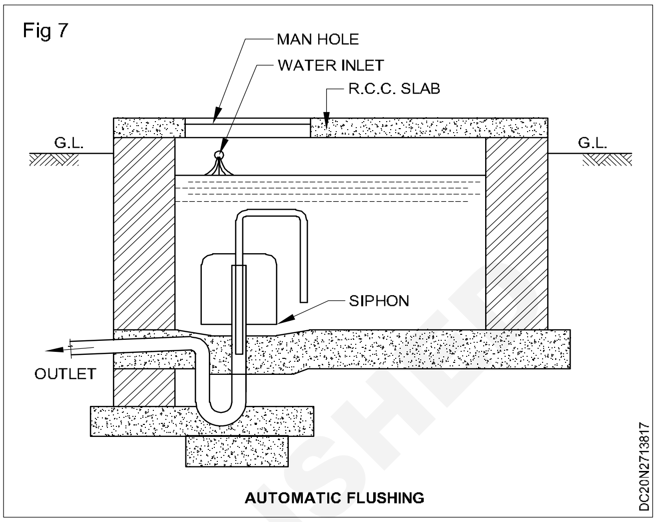


HAND OPERATED FLUSHING TANK

The flushing is done manually at intervals. Both the outlet and inlet ends of the manhole are closed. Then the manhole is filled with water completely. The lower end of the manhole is then opened and the water under pressure cleans of flushes the sewer line.

Automatic flushing tank (Fig 7)

Fig 7



AUTOMATIC FLUSHING

The tank is like a manhole with a siphonic arrangement fixed at bottom. Water supply is regulated to flow at a constant rate through a connection made in the side wall. When the tank is full, the siphon goes into operation and quickly discharges the water into the sewer.

Working

The water rising above the level of the sniff hole entraps and compresses air in the bell. The compressed air of the bell presses down water in the U - shaped trap. When the water level at the level of sniff hole goes down to the bottom of U - shaped trap, the air of the bell bubbles out with violence. Also, water tickles out through the outer limb of the U - tube into the sewer. More water now rushes into the bell. When the water level is above the lip of the trap pipe in the bell siphonic action begins.

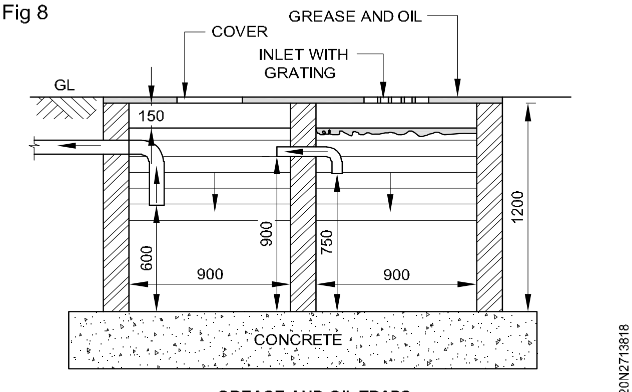
This action continues till water level in the tank falls below the level of the swift hole. Air again enters the bell and the siphonic action is stopped. Thus, the cycle is repeated.

Grease and oil traps (Fig 8)

They are chambers on the sewer line to exclude grease and oil from sewage before it enters the sewer. These substances being light in weight, float on the surface of sewage. If the outlet draws sewage from lower level, grease and oil are excluded. Hence the outlet level is located near the bottom of chamber. Grease and oil traps are located near automobile workshops, grease and oil producing industries garages, etc.

If grease and oil enter the sewers, they stick to the sides of sewer and may cause explosions. Also the suspended impurities stick to the grease. Consequent the capacity of the sewer reduces.

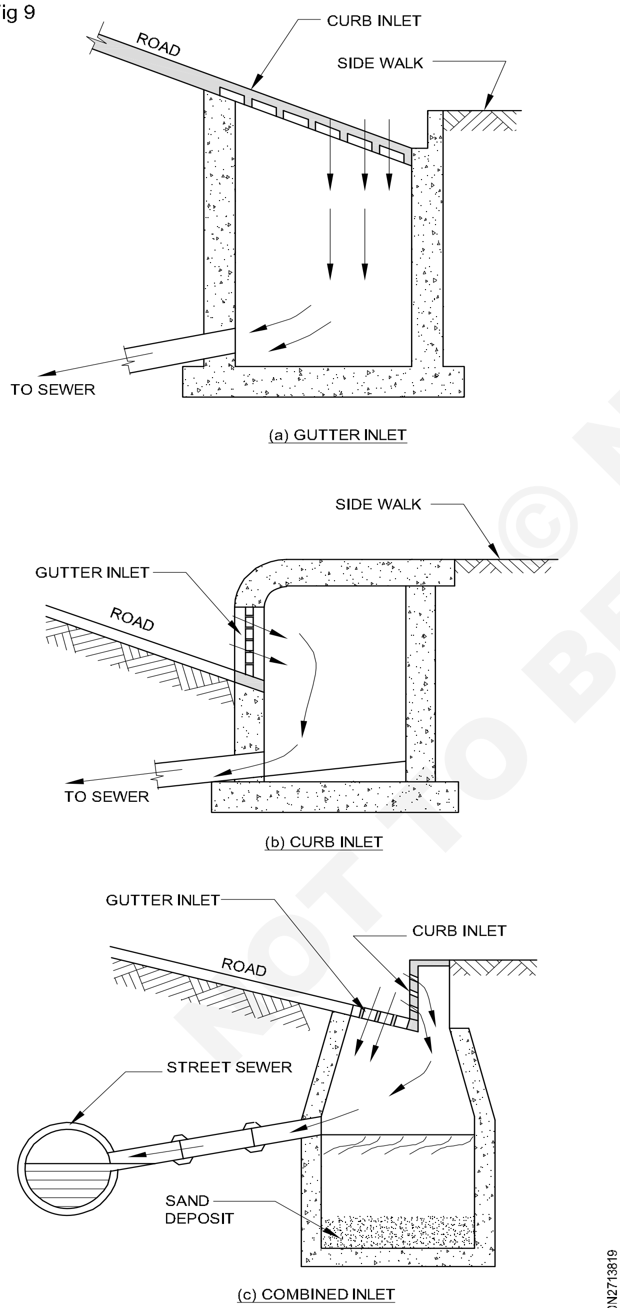
Fig 8



GREASE AND OIL TRAPS

8 Inlets (Fig 9)

Fig 9



(a) GUTTER INLET

(b) CURB INLET

(c) COMBINED INLET

INLETS

They are openings, through which storm water is admitted and conveyed to storm water sewer. They are located near the sides of the roads at 30 to 60 m centres. They are connected by pipes to the nearby manholes. They consist of concrete box with provision for admitting storm water.

They are of the following three types

1 Gutter inlet

In this type of inlet, a horizontal grating is provided at the top (Fig 9a).This type of inlets are suitable for roads having steep slope. This inlet is also known as horizontal inlet.

2 Curb inlet

In this type of inlet, a vertical grating is provided at curb (Fig 9b) It is also called vertical inlet.

3 Combined inlet

In this type of inlet, storm water can enter from both gutter and curb (Fig 9c)

9 Storm regulators and weirs

The structure used to divert a portion of the flow of sewage from a combined or storm sewer are called storm regulators. Storm regulators come into operation when the discharge exceeds a certain limit. The excess storm water is diverted to natural streams. Thus, they reduce the load on the pumping stations.

Following are the three types of storm regulators

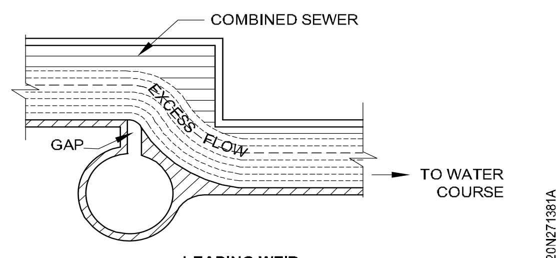
i Leaping weir

ii Overflow weir

iii Siphon spillway

Leaping weir (Fig 10): Leaping weir is one, in which the normal dry weather flow falls into the sanitary sewer through an opening provided in its crown. The excess quantity of storm or sewage leap or jump over the opening on to the water course. The leaping weir does not have any moving parts. A grating may be provided on the gap to prevent stones, debris, etc. from entering into the intercepting sewer.

Fig 10

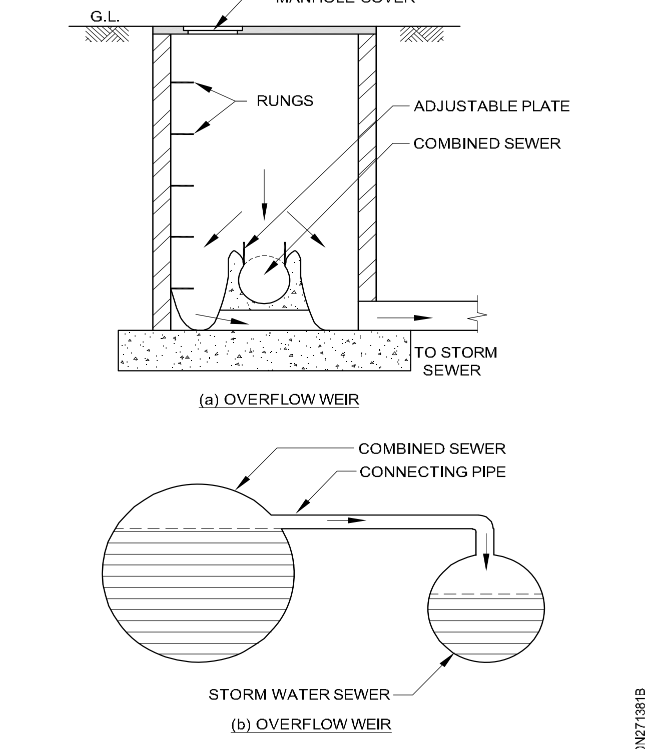


LEAPING WEIR

2 Overflow weir

Overflow weir is one, in which the extra quantity of sewage or storm water spills over the weir to pass off into another overflow sewer. The normal dry weather flow flows to the sewer outlet. Various types of overflow weirs are shown in (Fig 11a, b).

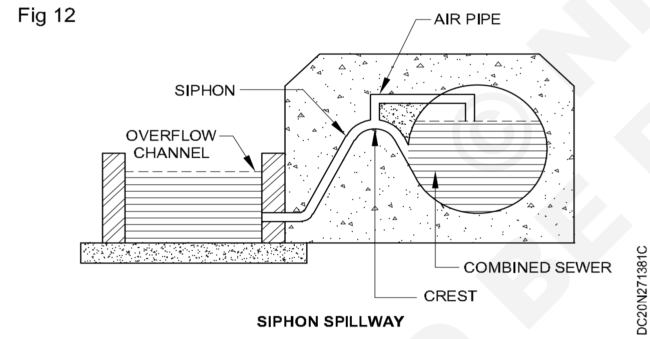
Fig 11



TYPES OF OVERFLOW WEIR

3 Siphon spillway (Fig 12)

Fig 12



SIPHON SPILLWAY

It works on the principle of siphonic action and it works automatically. The rise of sewage is the combined sewer is thus controlled well. The overflow channel is connected to the combined sewer through the siphon. An air pipe is provided at the crest level of siphon.

Working

The level of crest of siphon is kept at the level reached by the flow in combined sewer during the period of maximum dry weather flow.

When the level is combined sewer goes beyond the crest level of siphon, the mouth of air pipe is closed and the air contained in the siphon is suddenly carried away and develops siphonic action. Water commences to flow into the overflow channel until the water level falls below the mouth of connecting pipe.

10 Inverted siphons (Fig 13)

Inverted siphons are ordinary pipes running under pressure. They are constructed for conveying the sewage under streams, railways, rivers, and such other obstructions. They are also called "depressed sewers".

Two manholes are built one at each end of the inverted siphon. These two structures are connected by the siphon pipe or pipes. An overflow pipe is provided to divert the sewage flow, when the inverted siphon is choked.

While designing the siphon, the following points should be considered.

1 The construction of the siphon should be simple.

2 Changes of direction should be easy and gradual.

3 The velocity of average flow should be atleast. 1 metre per second so that there will be no deposition of solids.

4 Siphons should be built with two or three pipes of different sizes. (These should be arranged in such a way that they come into servicing and in proportion to the amount of flow.

5 The total length of the siphon is not the straight length from inlet to outlet, but includes the fall, bends and rise.

6 The siphon must be considered as a pipe running full under pressure. (For this, the maximum head available must be known).

7 Allowance should be made for losses of head due to bends and due to increased friction on account of roughness in the siphon caused by silting.

8 For the selection of the proper size of pipes for an inverted siphon, the minimum, average, and maximum flows in the sewer should be considered.

9 To avoid danger of silting, facilities should be provided for easy cleaning of the pipes. This can be achieved by.

i providing screens and detritus pits above the siphon inlet.

ii duplication of the pipe line for diversion of flows and

iii laying the pipes in such a way that they could be drained to some lower point

10 overflow provision should be made to deal with the surcharge, in case the siphon is choked.

11 Junction chambers

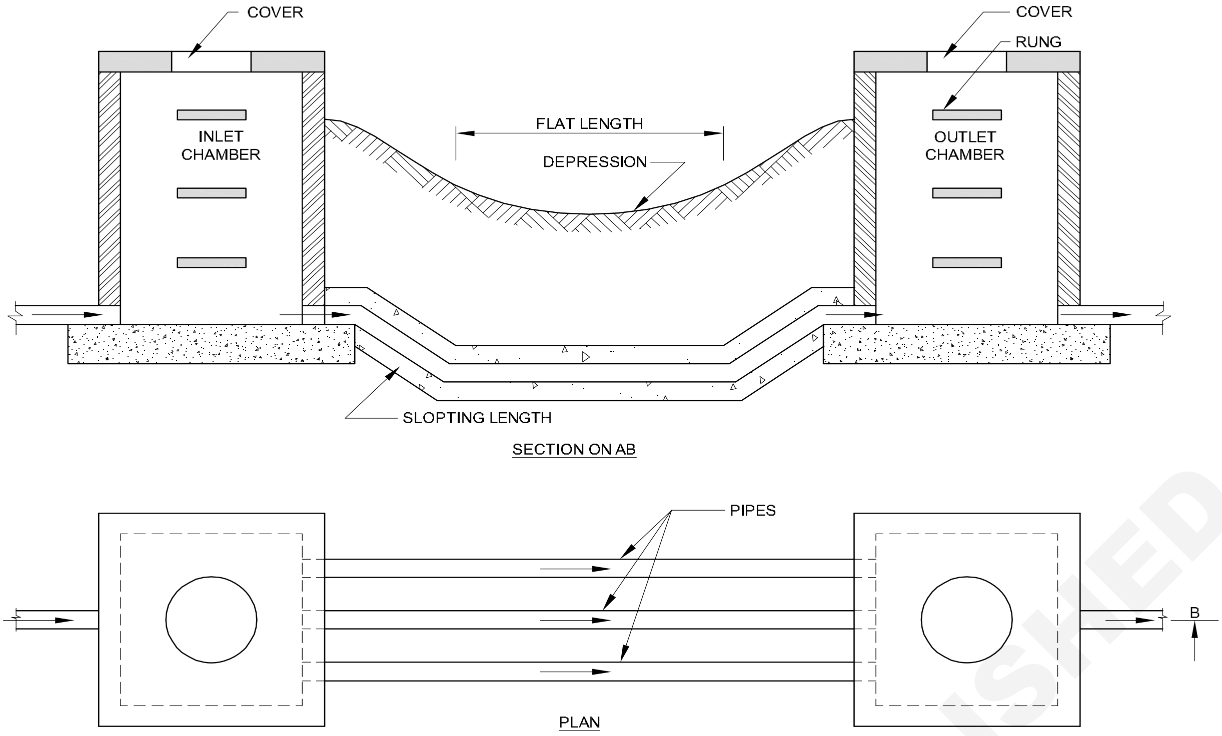
They are chambers constructed to facilitate the junction of two or more sewers. They are large enough for a man to enter. They are provided where sewer intersect with horizontal angles between their axes to be less than 30°, so that ordinary type of junction is difficult to be constructed. They are classified based on the shape of the top surface.

There are two types of junction chambers

i Bell - mouthed sewer junction.(Fig 14)

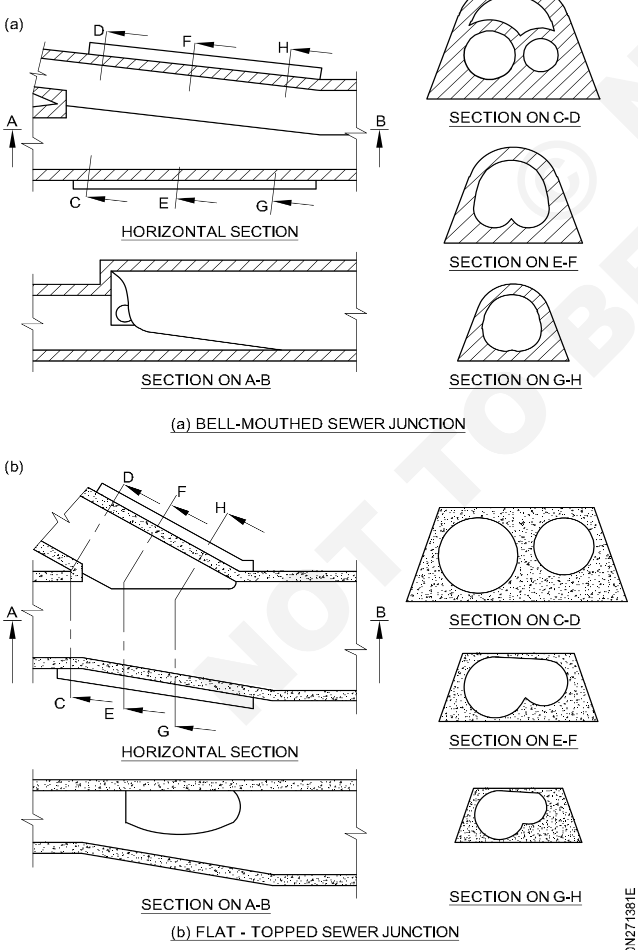
ii Flat - top sewer junction.(Fig 15)

Fig 13



INVERTED SIPHON

Fig 14



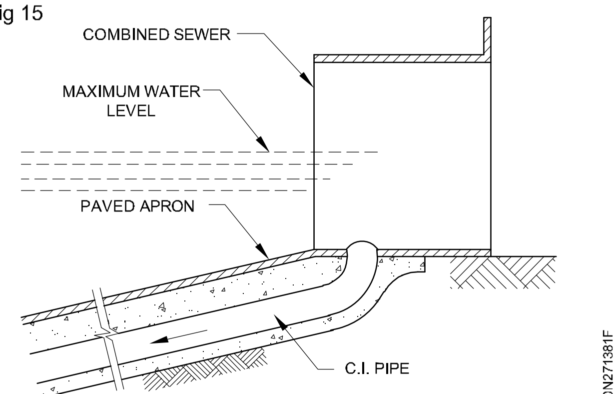
JUNCTION CHAMBERS

The former type is now obsolete because of the greater skill and cost involved. The latter type is commonly used.

12 Outlets (Fig 16)

In a separate sewerage system, the storm water, discharges directly on the bank while the sewer outlet, which simply consists of cast iron pipe extending into the body of water from a manhole in the bank. In a combined system, it is considered more economical to separate out storm water overflow and discharge it into river bank or lake and the domestic sewage into the deep water.

Fig 15



OUTLETS

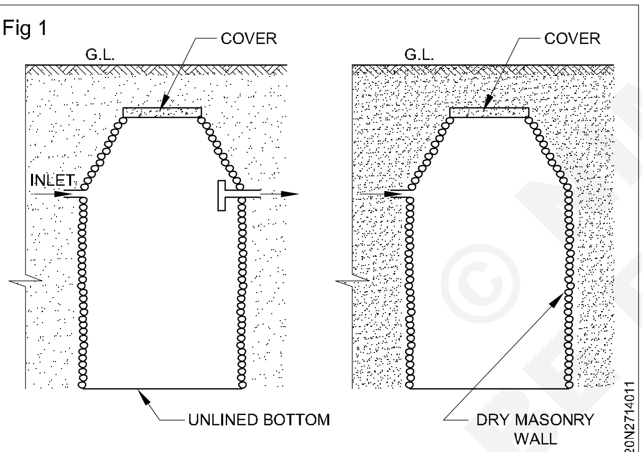
Septic tank

Objectives: At the end of this lesson you shall be able to
- **explain cess pool**
- **explain septic tank**
- **explain the principle of septic tank**
- **explain the disposal of septic tank effluent**
- **explain the construction details of septic tank**
- **design a septic tank.**

Cess pools

The water - carried wastes of small habitations may be disposed off by means of cess pools. These are masonry pits, usually not less than 1.5 m in diameter and 1.8 to 3m deep. Inner surfaces are plastered and covered by an air - tight cover at top. When the pool is filled up, it is emptied and cleaned. The contents obtained are conveyed in carts for further disposal. This is a tedious job and it results in extra cost. At the time of collection, it creates lot of nuisance due to bad smell and spillage (Fig.1).

Fig 1



CESS POOLS

Cess pools should be located on leeward side and away at least by 15 to 20m from residential buildings and wells of drinking water. They should also be properly ventilated.

Septic tank - The septic tank is a water tight underground tank. Sewage is admitted in to it for treatment. It is suitable for disposing excreta and liquid wastes from individual dwellings, small groups of houses and institutions.

Principle and working of a septic tank

Septic tank is just like a horizontal continuous flow plain sedimentation tank. The sewage moves very slowly. The flow is continuous from the inlet to the outlet. During the detention period, the solids settle down in the tank as sludge. The lighter solids rise to the surface as scum. The baffle wall prevents the scum from leaving the tank with the effluent. The solids get attacked by anaerobic bacteria and fungi. They are broken down into simpler chemical compound. This is the first stage of purification called anaerobic digestion. It renders sludge stable and inoffensive. The digested sludge from the tank is periodically removed and disposed off in a suitable manner.

A portion of the solids is converted into liquids and gases. The gases rise to the surface in the form of bubbles causing bad smell. Hence septic tanks are covered at top. They are provided with high vent shaft for the escape of gases.

The liquid which passes out of the outlet pipe is called the effluent. It is highly odours and rich in Biochemical Oxygen Demand (B.O.D). It has finely divided solid contents with numerous highly infectious pathogenic bacteria. For further treatment it is allowed to percolate into the subsoil through soak pit or dispersion trench. The aerobic bacteria in the upper layer of soil oxidize the organic matter into stable end products. This stage of purification is called aerobic oxidation.

Disposal of septic tank effluent

The effluent from septic tank contains a large amount of harmful organic matter and its B.O.D is high. Therefore the effluent should be disposed off carefully to cause minimum nuisance to public health.

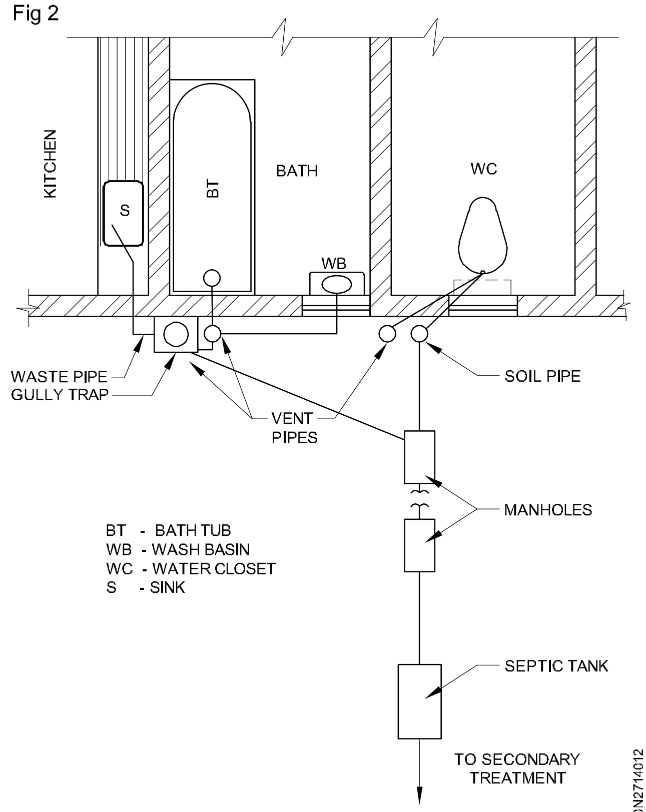
Septic tank effluent is more commonly disposed off on land by the following methods.

Disposal in absorption trenches In this method the effluent is allowed to percolate into the subsoil by means of perforated or open jointed pipes laid in trenches. The trenches are about 1 m deep and 1 m wide excavated with slight gradient. The trenches are filled with gravel, well graded aggregate and ordinary soil. The effluent percolates into the surrounding media. The organic matter present in the effluent is oxidised by the bacteria present in the upper layers of the soil. The clearer water get dispersed into the surrounding soil.

Disposal into soak pit

Soak pit is a covered circular pit. The effluent is allowed into it and gets soaked or absorbed into the surrounding soil. The pit may be kept either empty or filled up with brick bats or stone aggregates. When empty, the pit is lined with brick, stone or concrete blocks with dry open joints. It is provided with at least 75 mm backing of coarse aggregate below the inlet level to support the lining. When filled, no lining is required except for the top masonry ring.

Fig 2



LAYOUT OF A SEPTIC TANK SEWERAGE SYSTEM

Construction details of septic tank

i Dimensions of septic tank

Width = 750 mm. minimum

Length = 2 to 4 times width.

Depth = 1000 to 1300 mm. minimum below water level + 300 to 450 freeboard.

Total maximum depth = 1800 + 450 = 2250 mm.

Capacity = 1 cubic metre minimum.

ii Suitable sizes of septic tanks for use of 5,10,15,20 and 50 persons. See fig 2 which gives a typical layout of a septic tank sewerage system.

iii Detention period of 24 to 48 hours is usually available in a septic tank. The rate of flow of effluent must be equal to the rate of flow of influent.

iv The floor is of cement concrete 1:2:4 and laid with a slope of 5 to 10% towards sludge outlet or sludge collecting sump; if provided. Tank is cleaned of sludge every 6 to 12 months.

v **Inlet pipe** An elbow or T - pipe if 100 mm. diameter of stone ware or asbestos is used. It is laid at the time of construction of walls of the tank. The T - pipe is submerged to a depth of 250 to 600 mm below the liquid level.

vi **Outlet pipe** An elbow or T- pipe of 100 mm. diameter submerged to a depth of 200 to 500 mm below the liquid level is provided.

vii **Baffle walls** For small tanks, R.C.C hanging type of scum baffle walls are provided. Baffle walls are provided near the inlet as well as outlet. The inlet baffle is generally placed at a distance of L/5 from the end wall, where L is the length of the tank. The baffle wall is generally extended 150 mm above scum level and 400 to 700 mm. below it. Its thickness may vary from 40 to 80 mm. Flag stone slabs can also be used. For large tanks baffle walls are made of 100 thick brick walls with honey combed bottom courses to allow the flow of sludge.

viii **Roofing slab** The top of the tank is covered with an R.C.C slab of 80 mm. thickness. For the purpose of inspection and desludging, access openings are provided. In case of circular openings the clear opening is kept 500 mm. in diameter and if rectangular, the opening is kept 600 x 450 mm.

ix **Ventilating pipe** A cast iron or asbestos pipe of 50 to 100 mm. diameter is used as a ventilating pipe. It is extended upto 2 m. minimum above G.L. Top of the ventilating pipe is provided with a mosquito proof wire mesh or cowl.

x The effluent from the septic tank is disposed off by seepage pit or dispersion channels.

xi The septic tank is exclusively used for residential buildings or such living units where there are no other sewerage disposal arrangements.

Design of septic tank (Fig.3)

Design of septic tank consists or providing chamber for

1 Settling of incoming sewage.

2 Digestion of settled sewage.

3 Storage of digested sludge.

4 Storage of scum.

1 Space for settling

This is calculated for the average flow and detention period. Smaller tanks are designed on the basis of average flow and 24 hours detention period and larger tanks, 12 hours detention period. If latrines are connected to septic tank, average flow per capita per day may be taken as 45 litres. On the other hand, if all the waste water of the houses is to be treated in septic tank, the average flow should be taken depending on the water supply. The volume of setting also depends on the clear space available. The clear space is the space between the upper level of the sludge and lower level of scum. The vertical height of the clear space may vary from 0.23 m to 0.30 m. The clear space multiplied by the plan area of the tank gives the minimum tank volume for settling.

2 Space for digestion

Sludge digestion capacity varies from $0.028m^3$ & $0.056m^3$/capita.

Space for digested sludge

The space for digested sludge produced per capita in different periods are shown in table.

Period of cleaning	Storage capacity
6 months	0.0283 m^3
1 year	0.0490 m^3
2 years	0.0708 m^3
3 years	0.0850 m^3

The space for storage digested sludge designed on the basis of cleaning and number of persons using the tank.

Space of scum For scum storage 0.01 m^3 per capita is required.

Example No1

Design a septic tank for 50 users (Fig 3**).**

Assuming the usage of water 135 litre per/capita/day

No.of users = 50

Total quantity of sewage = 135 x 50 = 6750.00 litres = 6.75 m^3

Assuming a detention period = 24 hours (normal range 12.00 - to - 24.00 hours)

$$\text{Tank capacity} = 6.75 \times \frac{24}{24} = 6.75\text{m}^3$$

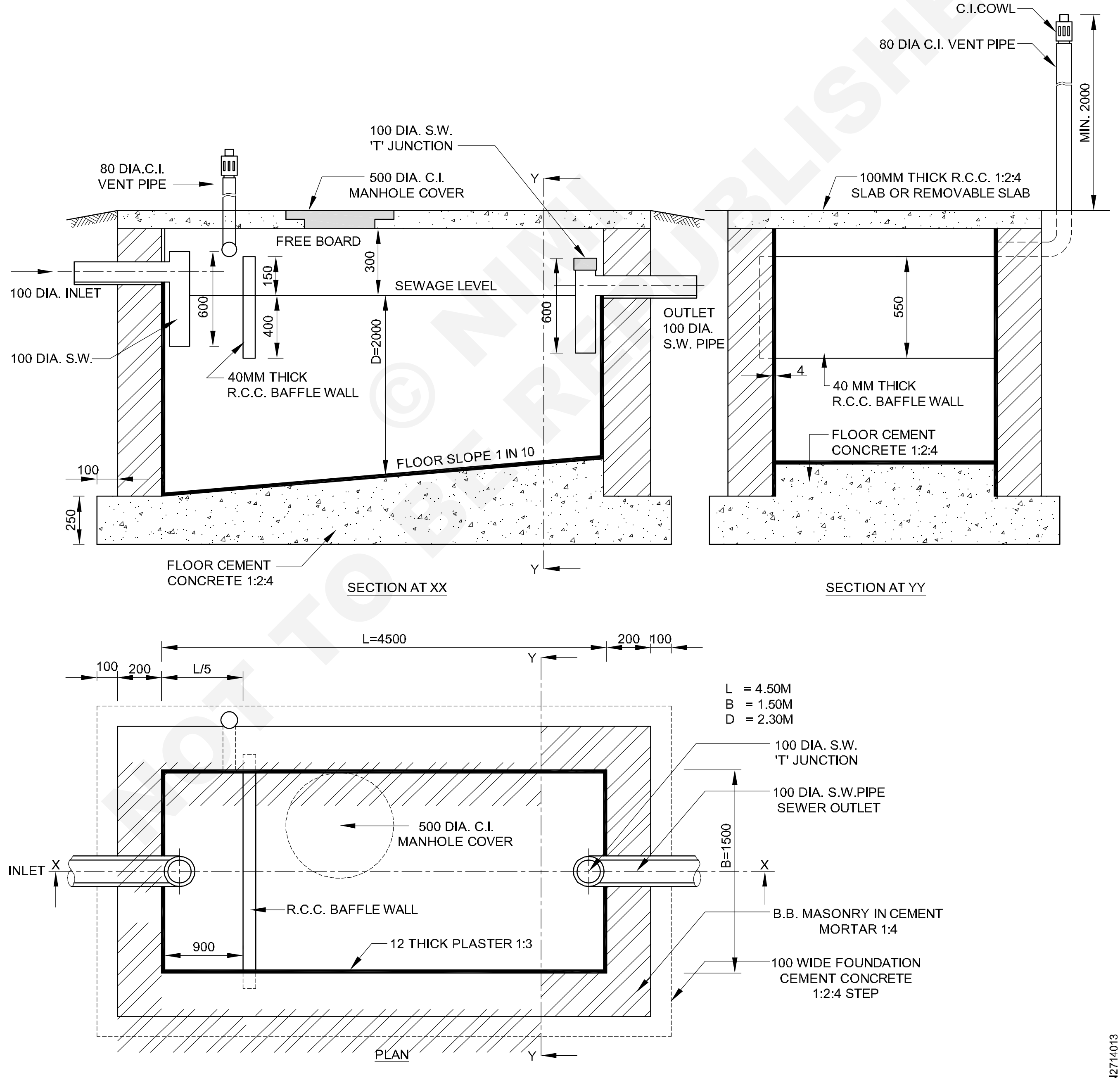
Assuming the tank is cleaning period = 2 years

The sludge storage per capita = 0.0708 m^3

Sludge storage required = 50 x 0.0708 = 3.54 m^3

Total capacity = 6.75 + 3.54 = 10.30m^3

Fig 3



SEPTIC TANK

Add 25% extra for future expansion

Then total design capacity

$$= \frac{10.30 \times 125}{100} = 12.88\,m^3 = 12.90\,m^3$$

Assuming the depth of septic tank........say 2.00 metre

Then the area of septic tank = 12.9/2.00 = 6.45m^2

Length - width ratio........ = 3:1 (ratio may be in between 2.0 - to -4.00)

Length x breadth = 3 x breadth x breadth = 6.45m^2

$(\text{Breadth})^2$ = 6.45/3 = 2.15

Breadth = 1.46 m say 1.50m

Length = 1.50 x 3 = 4.50m

Assuming free board of 30.00 cm (normal range 40.00 cm - to - 60.00 cm)

Total depth = 2.00 + 0.30 = 2.30 m

Hence provide septic tank of size (4.50 x 1.50 x 2.30) m

Check for spaces

Sedimentation volume for clear space of 0.30 m deep

= clear space x surface area = 0.30 x 6.45 = 1.935 m^3

Scum storage 0.01m^3/capita = 50 x 0.01 = 0.50 m^3

Sludge digestion at 0.028m^3/capita = 50 x 0.028 = 1.40m^3

Sludge storage at 0.0708m^3/capita for 2 years of cleaning interval = 50 x 0.0708

= 3.54 m^3

Total space = 1.935 + 0.5 + 1.40 + 3.54 = 7.38m^3 against tank capacity of 10.3m^3

Hence the design is correct.

Soak pit (Fig 4 & Fig.5)

Flow of sewage/day = 6.75 m^3

Add 25% for future expansion,

Then total flow of sewage/day

$$= \frac{6.75 \times 125}{100} = 8.44\,m^3 = 8.5\,m^3$$

Assume the percolating capacity of filter media of well as 1.25m^3/m^3/ per day

Volume required for soak pit = 8.5/1.25 = 6.8 m^3....say 7.00 m^3

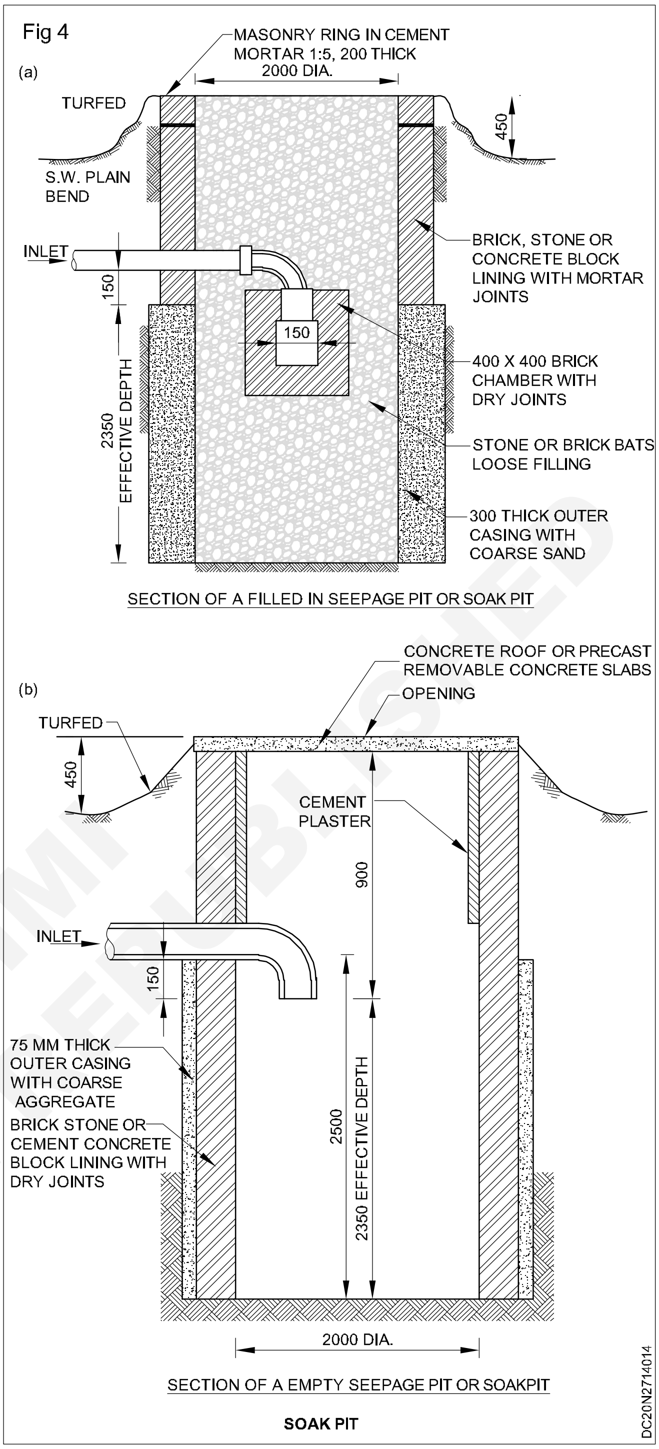
If the depth of soak pit is 2.50 metre

Area of soak pit = 7.00/2.50 = 2.80 m^2

$$\pi \frac{d^2}{4} = 2.80\,m^2$$

D = 1.90 m say 2.00 m diameter

A soak pit of diameter 2 m and 2.5 m deep below the invert level of the inlet pipe may be provided.



SOAK PIT

Design of depression trench (Fig 6)

Flow of sewage in the trench per day = 8.5 m^3

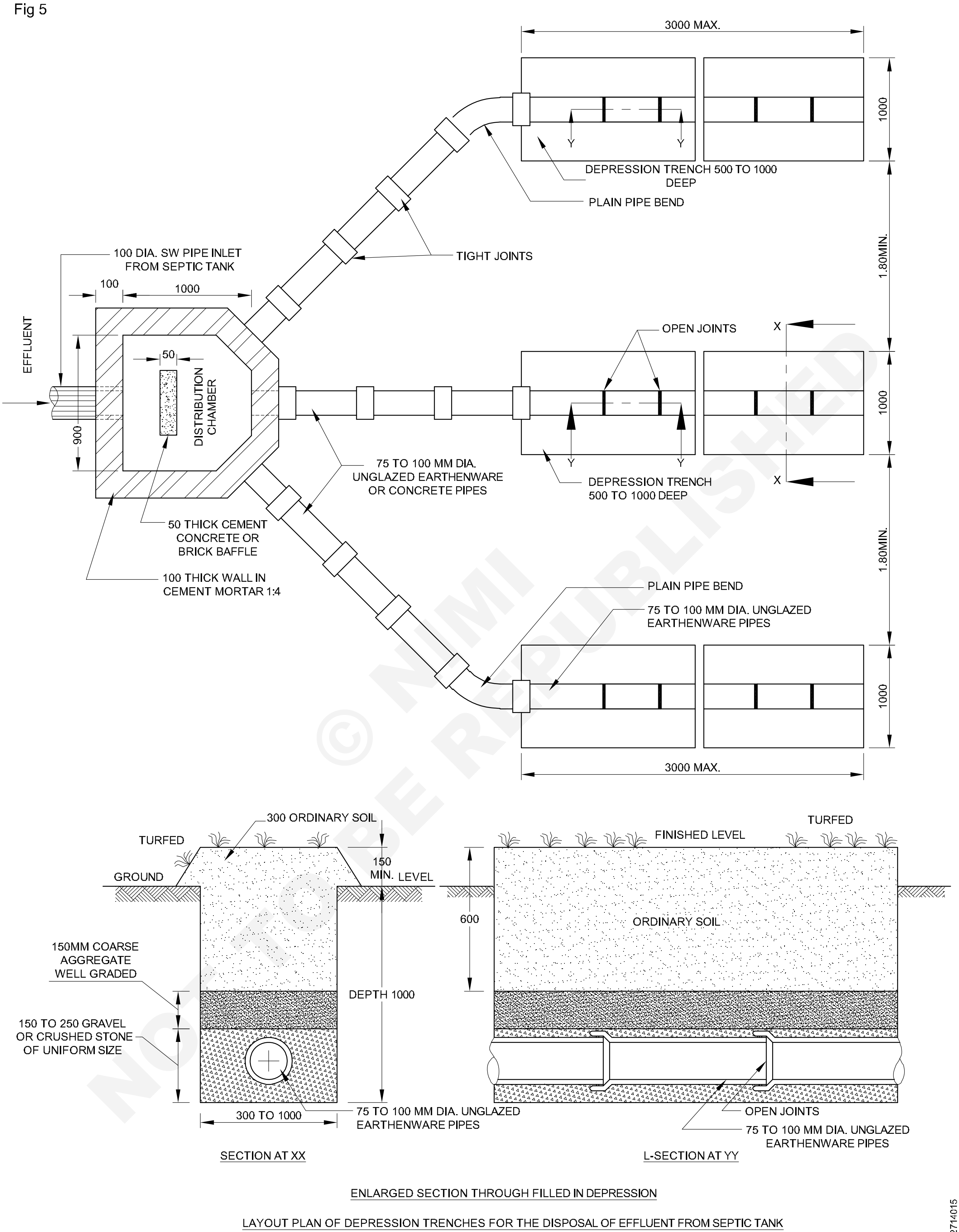
Assume width of depression trench = 1m

Percolation rate of sewage is 0.204 m^3/day (Assume)

$$\text{Length of trench required} = \frac{8.5}{0.204} \times 1 = 41.7\,m \text{ say } 42\,m$$

Provide 3 trenches of 14m in length

Fig 5



DEPRESSION TRENCHES

Water and sewage treatment plant

Objective: At the end of this lesson you shall be able to
- **explain the water supply system**
- **explain the quality of water**
- **explain the sedimentation and filtration**
- **explain the types of filtration**
- **explain softening of water**
- **explain general requirement of a distribution system**
- **explain pipe apputenances.**

Water supply system: It is the infrastructure for the collection, transmission, treatment, storage, and distribution of water for homes, commercial establishments, industry, and irrigation, as well as for such public needs as fire fighting and street flushing.

The prime factor in the design of any water supply system is the estimation of the probable total quantity of water that will be required by the community after the completion of the works. The quantity can be estimated by studying the design period, rate of demand and population.

Sources of water: The success of water supply scheme depends upon the adequate sources of water supply. The chief source of all water supplies is precipitation. The sources of water supply may be classified as.

1 Surface sources

Rivers

Lakes and streams

Seas

Ponds

Waste water reclamation

Stored rainwater in cisterns.

2 Subsurface sources or ground sources

Springs

Infiltration galleries

Porous pipe galleries

Infiltration wells

Wells

Intakes and transmission of water: Intakes are structures used to collect water from the surface sources, which are relatively clean, free from pollution, sand and other objectionable floating materials. Transmission of water indicates the conveyance of water from the source to purification plants and from treatment plant to consumers.

Intakes are structures constructed with stone masonry or brick masonry or RCC blocks across the surface source of water. They essentially consist of a conduit with protective works, screens at open ends and gates and valves to regulate the flow. Transmission comprises of pipes, aqueducts, flumes and open channels, pipe joints, special pipes etc.

Quality of water: The water required for public water supplies should be potable. For domestic purpose, the water should be highly pure, free from bacteria, suspended impurities etc.

Impurities in water may be classified as physical impurities, chemical impurities and bacteriological impurities.

i **Physical impurities:** They are due to the presence of inorganic substances like clay, pebbles, sand, silt, etc in finely divided conditions. They imparts color, odour, and taste to water. They are not serious and can be easily detected and removed.

ii **Chemical impurities:** They may be either organic or inorganic. They may be present in either suspended or dissolved form. The chemical impurities are due to the presence of decayed or melting of vegetables or animals, or minerals in water.

iii **Bacteriological impurities:** These are caused by the presence of bacteria. Bacterias may be harmful or harmless. Harmless bacteria's are called non pathogens. Harmful bacteria's are called pathogens. These are responsible for water - borne diseases and are also known as disease producing bacteria.

Analysis of water: The analysis of water carried out in order to establish its quality. The analysis of raw water is required to render the water fit and safe for use by suitable treatment and to design corresponding treatment works and water supply scheme as a whole. For analysis samples are collected and then subjected to tests for determining the physical, chemical or bacteriological impurities present in them.

Treatment of water: The raw water requires treatment to make it safe for use. The nature of treatment depends upon the initial quality of raw water and the purpose for which it is to be used.

Treatment process

No	Treatment	Impurities removed
1	Screening	Floating matters such as leaves, trees, dead bodies of animals etc.
2	Plain sedimentation	Large suspended matters such as silt, clay, sand etc.
3	Sedimentation with coagulation	Fine suspended and electrically charged colloidal particles and some bacteria.
4	Filtration	Very fine colloidal and suspended particles and micro organisms
5	Chemical treatment followed by filtration	Dissolved matter
6	Aeriation and chemical treatment	Dissolved gases, taste and odour
7	Softening	Hardness
8	Disinfection	Living organisms including pathogens.

Sedimentation: It is the process of causing heavier particles in suspension, both organic and inorganic to settle by retaining water in a basin.

Theory of sedimentation: The particles heavier than water tend to settle down due to force of gravity. Impurities in water are held in suspension due to the turbulance of the moving water. When this turbulance is checked and the velocity of flow is reduced, the suspended particles tend to settle down at the bottom of the tank. This phenomenon of setting down of particles at the bottom of the tanks is known as hydraulic subsidence. At this stage, the particles travel with a constant vertical velocity called the setting velocity or velocity of subsidence.

The setting velocity depends upon

1 The horizontal velocity of flow

2 The shape and size of the particle

3 The specific gravity of the particle and

4 The temperature of water.

Types of sedimentation

Sedimentations are

1 Plain sedimentation and

2 Sedimentation with coagulation

Plain sedimentation The raw water is retained for some time quiescent in a basin for the suspended particles are settled by the action of gravity.

Sedimentation with coagulation Some chemical compounds called coagulants are added to water to assist sedimentation. Common coagulants are aluminium sulphate or alum called filter alum, sodium aluminates, ferric sulphate and lime, ferric chloride, magnesium carbonate, fullers earth etc.

Filtration Filtration is the process of passing the water through filter beds. Filtration removes colour, odour, turbidity and pathogenic bacteria from water. Filters are used for filtration.

Types of filters These are rapid sand filters, slow sand filters and pressure filters. Rapid sand filter and pressure filters are used for high rate filtration. But slow sand filter used for low rate filtration.

Slow sand filter (Fig 2)

A slow sand filter is a water - tight tank of 2.5 to 3.5 m in depth. It has a sand bed of 1 to 1.5 m thick, supported by a 0.3 to 0.75m thick layer of graded gravel or broken stone (25 to 50 mm size, of 0.30 to 0.60m thick) laid in layers. Beneath this, an under - drainage system consisting of open - jointed drains is laid over a concrete bed sloping towards a central longitudinal drain. The filtration is effected by gravity.

The rate of filtration is 100 to 200ℓ/m2/hour. Its bacterial efficiency is 98 to 99%. The filter bed is cleaned by scraping. Unsuitable for waters having turbidity more than 50 ppm.

Construction

A typical longitudinal section of a slow sand filter is shown in Fig 2. It consists of the following essential parts.

1 Enclosure tank.

2 Filter media.

3 Base material.

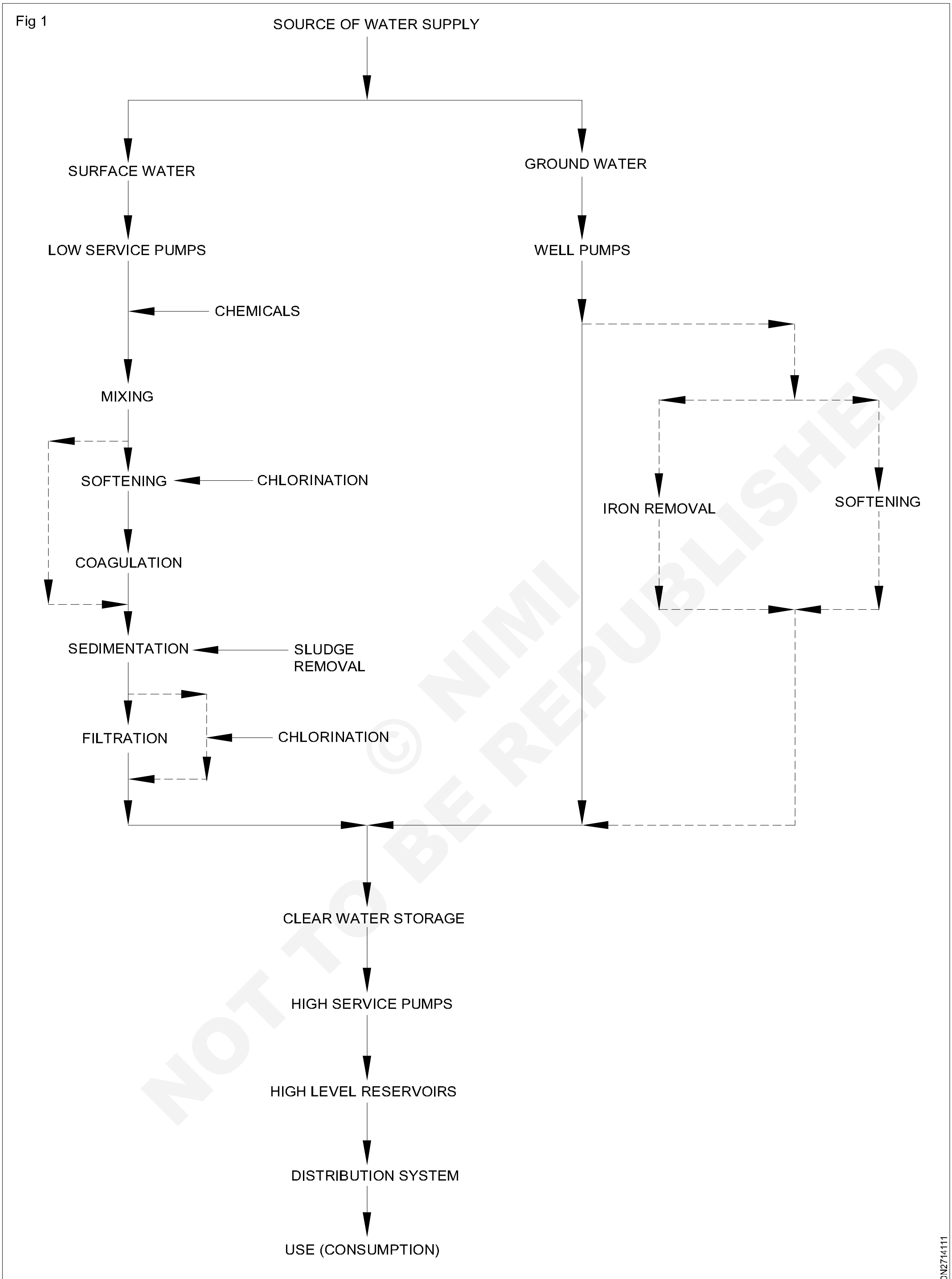
4 Under - drainage system.

5 Inlet and outlet arrangement.

6 Other appurtenances.

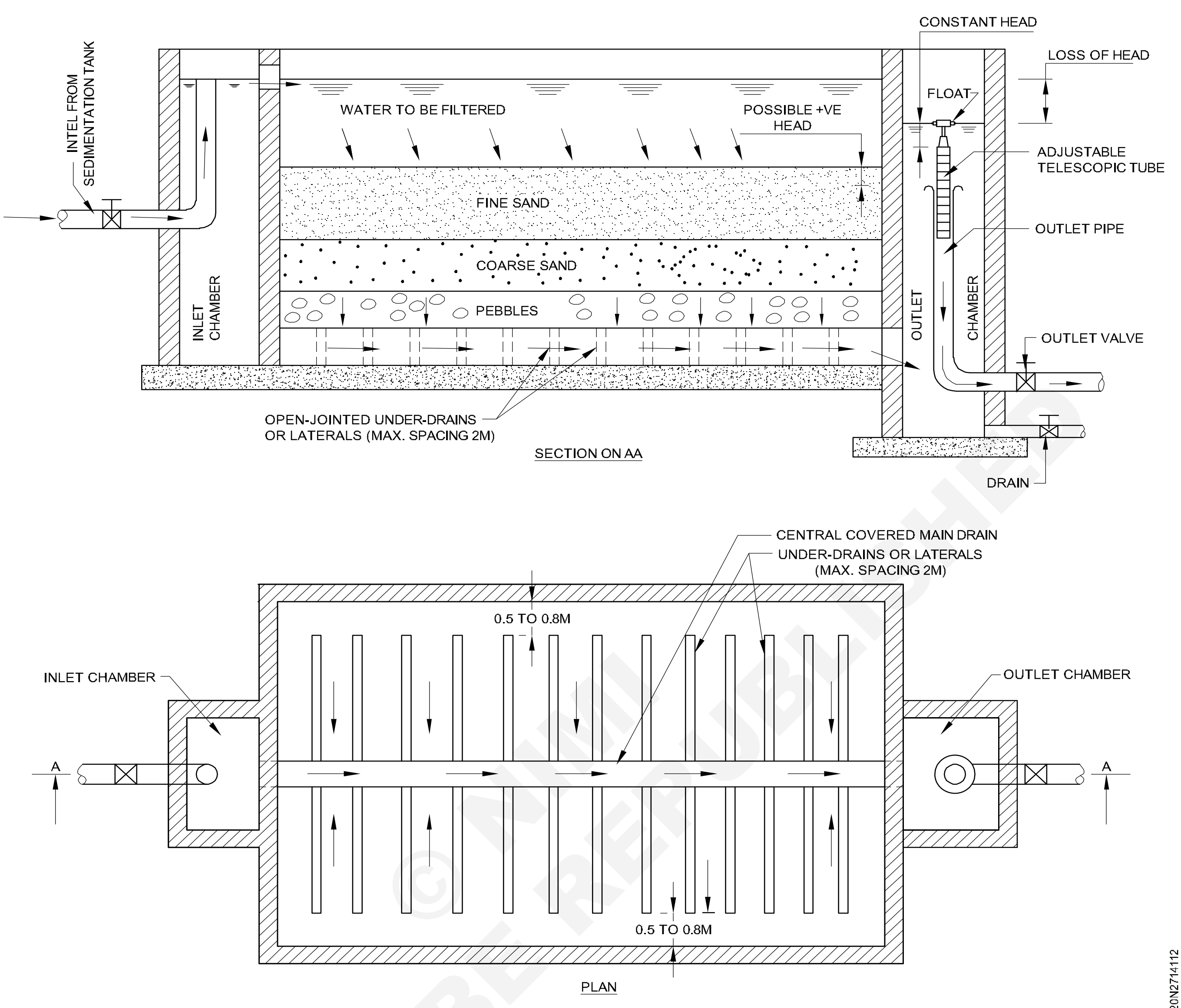
1 Enclosure tank

It consists of an open watertight rectangular tank, built of masonry or concrete. The sides and floor are coated with waterproof material. The bed slope is about 1 in 200 to 1 in 100 towards the central main drain. The depth may be 2.5 to 3.5m. The surface area may be 100 to 2000 m^2 or more.



TREATMENT PROCESS - FLOW CHART

Fig 2



SLOW SAND FILTER

2 Filter media

It consists of sand layers of 0.6 to 1 m thick, laid over gravel support. The effective size of sand is 0.25 to 0.35 mm and uniformity coefficient is 2 to 3. The top 150 mm layer of this sand is generally finer. The finer the sand used, the purer the water will be obtained.

3 Base material

It consists of 150 mm layers of graded gravel of 0.30 to 0.75 m thick layer or 25 to 50 mm size broken stone, 0.3 to 0.6m thick layer. It supports the sand bed. The coarsest gravel is used in the bottom most layer and the finest in the top most layer.

Top most layer - 150 mm thick - 3 mm to 6 mm size

Intermediate layers - 150 mm thick - 6 mm to 20 mm size

- 150 mm thick - 20 mm to 40 mm size

Bottom most layer - 150 mm thick - 40 mm to 65 mm size

4 Under - drainage system

The gravel support is laid on the top of an under - drainage system Fig.2 The under - drainage system is laid on a concrete floor sloping towards the central covered main drain. The lateral drains are open - jointed pipes or porous pipes placed at a maximum spacing of 2m. Their ends are stopped at a distance of 0.5 to 0.8 m from the walls.

5 Inlet and outlet arrangements

An inlet chamber is constructed to receive the discharge from the plain sedimentation tank and to distribute it uniformly over the sand bed. Mostly, the inlet pipe is carried vertically in the body of the filter with the mouth of the inlet pipe flush with the water level.

A filtered water outlet well is also constructed on the outlet side to collect the filtered water coming out from the central covered main drain. To maintain a constant discharge through the filter, an adjustable telescopic pipe is used. Generally, both inlets and outlets are governed by automatic valves.

6 Other appurtenances

In addition to the above arrangements, certain other appurtenances are provided for the efficient working of the filter. Vertical air pipes passing through the layers of sand may be provided to help in proper functioning of filter media. Similarly, arrangements are made to control the depth of water above the sand layer (1 to 1.5 m). Besides these, a meter to measure the flow and a gauge to measure loss of head are also to be provided. When the loss of head becomes high (0.7 to 1.2 m), the filter is to be put out of service and be cleaned.

Working: The treated water from the sedimentation tank is allowed into the inlet chamber. It is uniformly distributed over the sand bed to a depth of 1 to 1.5m. without any disturbance. The water percolates through the filter media and gets filtered. Now, the water enters the base material and comes out as filtered water. It gets collected in the laterals and discharged into the central main covered drain. From where it is finally discharged into the filtered water well. The standard rate of filtration (100 to 200l/m2/hour) is continued until the difference between the water levels in the filter and the outlet chamber is slightly less than the depth of water above the sand or the loss of head reaches 0.7 to 1.2 m.

Cleaning

During working of the filter, if the loss of head reaches the permissible limit, the working is stopped. About 20 to 30 mm sand is scraped from the top of the filter bed. The top surface is finally raked, roughened, cleaned and washed with pure water till the sand depth reduces to 0.4 m or so. Then more clean sand is added to have a minimum sand depth of about 0.45 m. The interval of cleaning may vary from 1 to 3 months.

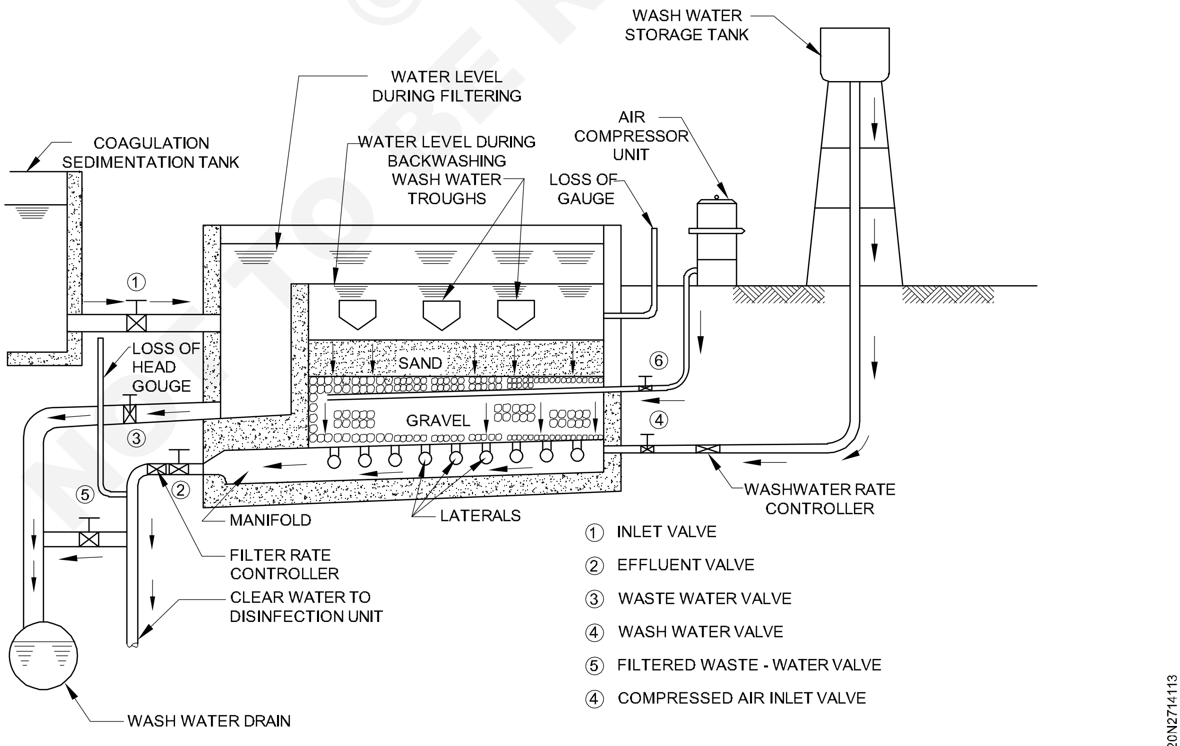
After every cleaning, the initial filling is done by admitting filtered water from the bottom till it rises about 0.8 m above the sand. Then the fresh water is allowed to enter from the top. The amount of filtered water required is about 0.2 to 0.6% of the total water filtered.

Rapid sand filters (Fig 3): In rapid sand filters, the yield is about 30 times the yield given by slow sand filters for the same filter area. This is achieved by increasing the size of sand. They are also known as mechanical sand filters.

A rapid sand filter is an open watertight chamber, 3 to 3.5 m deep. It has coarse sand filter media, 0.6 to 0.75 m thick, laid on 0.45 m thick graded gravel. The under drainage system is supported by concrete floor. The under drainage system consists manifold with strainers mounted on top and laterals. Laterals have perforations on sides. The filtration is effected by gravity.

The rate of filtration is about 3000 to 6000ℓ/m2/hour. Its bacterial efficiency is 80 to 90%. Removes turbidity upto 30 to 40 ppm.

Fig 3



RAPID SAND FILTER

Construction: A typical longitudinal section of a rapid sand gravity filter is shown in fig 3. The following are its essential parts.

1 Enclosure tank.

2 Filter media.

3 Base material.

4 Under - drainage system.

5 Appurtenances.

1 Enclosure tank

It is an open watertight tank built either of masonry or concrete. The sides and floor are coated with water proof material. It is about 2.5 to 3.5 m deep 3.5 to 6 m wide and 6 to 9m long. The usual plan size is12 m x 9 m. The units are arranged in series. The surface area may be 10 to 80 m2.

2 Filter media

It consists of sand layers of 0.6 to 0.9 m thick, supported over graded gravel layer. The effective size is 0.35

0.35 to 0.6 mm and uniformity coefficient is 1.2. to 1.7. The finer sand is placed at top and coarser variety at bottom.

3 Base material

Durable, hard, round, strong and clean graded gravel free of clay, dust, silt and vegetable matter is used as base material. It is placed on the top of an under - drainage system to a thickness of 0.45 to 0.9 m.

Top most layer - 150 mm thick - 3 mm to 6 mm size

Intermediate layers- 150 mm thick - 6 mm to 12 mm size

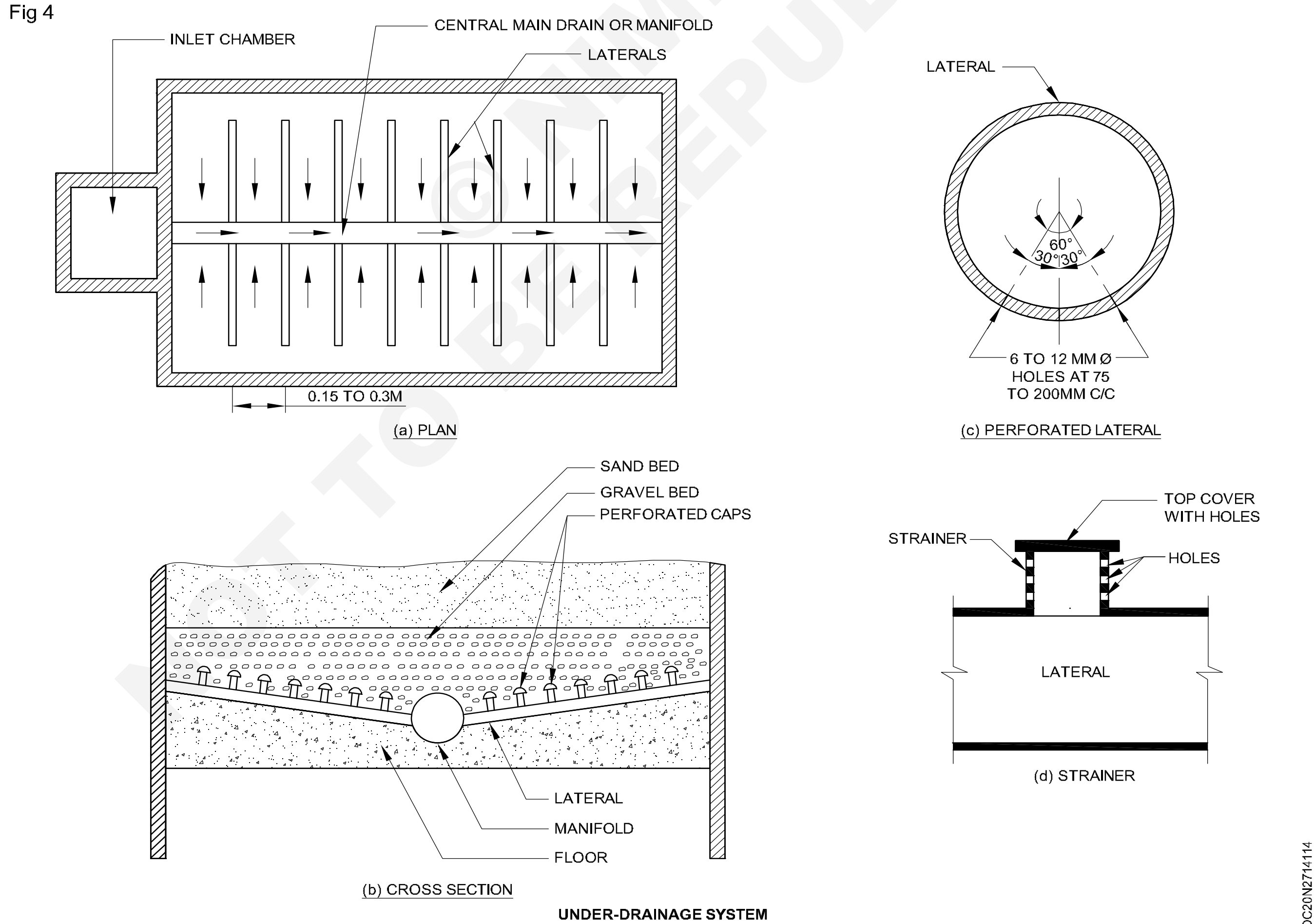
- 150 mm thick - 12 mm to 20 mm size

Bottom most layer - 150 mm thick - 20 mm to 40 mm size

4 Under - drainage system (Fig 4)

It consists of a cast iron central longitudinal conduit or manifold with laterals branching off at right angles to it. Laterals are smaller diameter pipes fixed at 150 to 300 mm centres. They are provided with 6 to 12 mm diameter holes at an angle of 30° to the vertical at 75 to 200 mm centres. In another system, strainers are placed on laterals. Strainer is a small brass pipe, closed at top. It has holes on its top and sides.

Fig 4



UNDER-DRAINAGE SYSTEM

5 Appurtenances

The following are the most important appurtenances of a rapid sand gravity filter.

1 Air compressor

2 Rate controller

3 Wash water troughs

4 Miscellaneous accessories

Air compressors

These are employed to agitate the sand grains of the filter during backwashing. The compressed air is supplied either through laterals or through a separate pipe system. Generally, they should supply compressed air at the rate of 0.6 to 0.8 m3/m2/minute for about 5 minutes.

The agitation of sand grains may also be carried out by water jet or by mechanical rakes.

Rate controller

It is used to control the rate of flow. Most popular device is a "venture rate controller". It works on the principle of venturimeter.

Wash water troughs

They collect the dirty water after washing of filter. They are placed with their bottom at 0.45 to 0.75 m above sand bed level. They are placed at 1.3 to 1.8 m apart. For efficient functioning, they should be large and should be laid at suitable slopes.

Miscellaneous accessories

Additional devices such as head loss indicators, flow rate meters, etc. are to be installed.

Working

The working of a rapid sand filter is explained with reference to the fig.3.

Action during filtration

Inlet valve (1) is opened and water from coagulated sedimentation tank is allowed to enter the filter. Effluent valve (2) is opened to carry filtered water to clear water reservoir. During this, all other valves remain closed. Only, inlet and effluent valves are open.

Action during backwashing

Backwashing is done when the loss of head reaches the maximum permissible limit (2.5 to 3.5m). The filter is drained out, leaving a very small depth of water standing above the filter bed. Now, compressed air is sent under pressure through the under - drainage system for about 2 to 3 minutes. This agitates the mass of water. The agitated water loosens the dirt from the surface of sand grains. Now, an upward flow of water from a high level tank is sent through the bed. This causes the sand bed to expand, agitate the sand grains and wash off the surface deposits. The deposits are carried by wash water troughs and disposed through wash water drains. During backwashing, valve positions are as below

1 Inlet valve (1) and effluent valve (2) are closed.

2 Waste water valve (3) and wash water valve (4) are opened.

3 Filtered waste water valve (5) is kept closed till the wash water is fairly clear.

4 Waste water valve (3) and wash water valve (4) are closed.

5 Inlet valve (1) and filtered waste water valve (5) are opened for rewash.

6 Filtered waste water valve (5) is closed and the effluent valve (2) is opened for the operation of the filter.

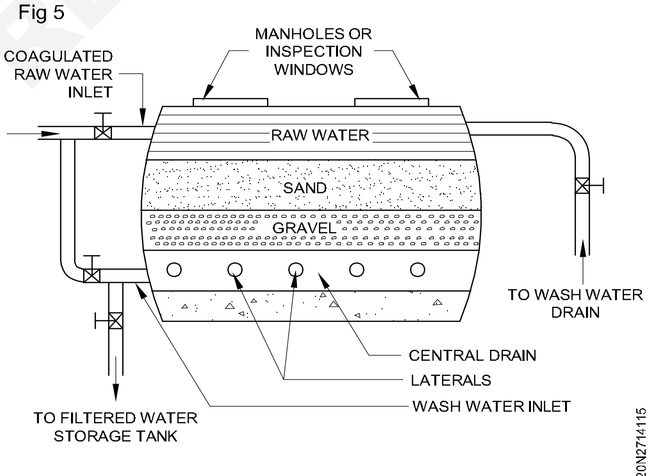
The amount of water required for washing a rapid sand gravity filter is 1 to 5% of the total amount of water filtered. It is to be cleaned every 1 to 3 days.

Pressure filters

They consist of closed water - tight cylindrical metal tanks of 1.5 to 3m diameter and length or height 3.5 to 8 m, containing filter media as for a rapid sand gravity filter. The raw water mixed with a dose or coagulant is pumped into the filter under a pressure of 300 to 700 KN/m

After filtration, water comes out under high pressure. The rate of filtration is 6000 to 15000 l/m^2/hour. They are of horizontal or vertical type. They are more suitable for small installations like industries, private estates, etc. They are less efficient than slow and rapid sand gravity filters. Inspection windows are provided at top. A horizontal type of filter is shown in Fig 5.

Fig 5



HORIZONTAL PRESSURE FILTER

Working

The coagulated water under pressure is directly admitted to the pressure filter through inlet valve (1). The filtered water comes out through the outlet valve (2). It is collected in the central drain and conveyed to filtered water storage tank. During normal working, only the valves for raw water and filtered water are kept open.

The cleaning of the filter may be carried out by backwashing as for the rapid sand filter. The compressed air may be used to agitate sand grains. For cleaning, inlet and outlet valves (1) and (2) are closed. The wash water valve (3) and wash water gutter valve (4) are opened. The cleaning is done more frequently.

Compact automatic pressure filters are also available. The cleaning is done automatically at a predetermined interval of time or loss of head.

Disinfection of water

Disinfection is the process of removal of pathogenic bacteria from water by chemicals or other means. The chemicals used for killing disease producing bacteria's are called disinfectants. Sterilization is the process of killing all bacteria's by boiling.

Necessity of disinfection

Even the filtered water may contain some harmful impurities such as disease producing bacterias, dissolved inorganic salts, colour, odour, taste, iron and manganese.

The bacterially contaminated waters will spread various diseases and their epidemics causing disaster to public life. Hence, disinfection is most essential. Further, disinfection not only kills the existing bacteria's from water, but also prevents its contamination during its transit from the treatment plant to place of its consumption.

The disinfection should be able to retain a residual sterilizing effect for a long period to prevent recontamination. Also, it should be harmless, unobjectionable, economical and measurable by simple tests.

Methods of disinfection

a Chlorination

Chlorination is the treatment of water with chlorine or chlorine compounds. Chlorine is a powerful disinfectant and also it removes colour, odour, unpleasant taste and prevents the growth of weeds in water. This treatment is cheap and reliable. It produces desired effects and last long. It is also easy to measure and handle.

Disinfecting action of chlorine

On reaction with water, chlorine produces hypochlorous acid (HOCI) and hypochlorite ion (OCI). Together, they are known as free available chlorine. The actions that take place are

When ammonia is also present, monochloramine (NH2Cl) and dichlramine (NHCl2) compounds are formed. These are together known as combined available chlorine. The above resulting chlorine compounds interfere with certain enzymes in the bacterial cell - wall. This forms into a toxic chloro compound destroying the bacteria's completely.

Forms of chlorination: Chlorine is generally applied to water in one of the following forms.

1 As bleaching powder or hypochlorites.

2 As chloramines.

3 As chlorine - di - oxide.

4 As free chlorine gas.

5 As liquid chlorine.

b Excess lime treatment

Addition of excess lime to water removes salts and also kills the bacteria's. After disinfection, this method requires some suitable method to remove the excess lime from water. This method cannot protect water from recontamination.

c Iodine and bromine treatment

Iodine and bromine used as water disinfectant. These are unsuitable for large scale pubic supplies. These are suitable for small water supplies like swimming pools, private plants etc.

d Ozone treatment

Ozone gas is passed through water removes the organic matter and the bacterias from water. This method is costlier and not adopted for treating water on large scale.

e Potassium permanganate treatment

Potassium permanganate kills bacteria's and oxidizing the taste producing organisms. It also remove colour and iron from water. In due course, it produces dark precipitate.

f Silver treatment

Metallic silver ions are introduced in water. It is a strong germicide. It is safe against future contamination. It do not produce any harmful effect on human body. This method is very costly. This method is not adopted for public water supplies.

g Ultra - violet ray treatment

This is an effective method of disinfecting clear water. This treatment impart any colour or taste in water. Also, there is no danger of overdose. It is costly.

h Boiling

Continued boiling of water for a long time above certain temperature kills the bacteria. It is the most effective method of disinfection. It is not suitable for public water supplies.

Softening of water

Water softening is the process of reduction or removal of hardness from water.

Hardness of potable water is 5 to 8 degrees. Hardness is the characteristic which prevents the lathering of soap. It is caused by the presence of certain salts of calcium and magnesium dissolved in water.

Purpose of water softening

Water softening is done to achieve the following objectives.

1 To reduce soap consumption.

2 To reduce corrosion and incrustation of pipes and fittings.

3 To improve the taste of food preparations.

4 To reduce scaling in boilers.

5 To minimize its interference in dying systems.

Hardness of potable water is 5 to 8 degrees. Hardness less than 5 degrees is tasteless and above 8 degrees produces undesirable effects. One degree of hardness = 14.25 ppm.

Types of hardness

a Temporary hardness or carbonate hardness

It is due to the presence of carbonates and bicarbonates of calcium and magnesium. Temporary hardness can be removed by boiling or by adding lime called lime process.

b Permanent hardness or non - carbonate hardness

It is caused by the presence of sulphates, chlorides and nitrates of calcium and magnesium. It can be removed by special methods of water softening such as lime soda process, zeolite process, or demineralization.

Removal of - temporary hardness: The temporary hardness can be removed by boiling or by adding lime called lime process. Lime process is otherwise known as clark process.

The principle involved in this process is the neutralization of carbon - di - oxide with milk of lime. This forms normal carbonates which precipitate out when present in excess. These precipitates are insoluble in water. They are removed by sedimentation and filtration. Boiling of water on large scales is highly impracticable. Hence, lime process is preferred.

Removal of hardness - permanent hardness: The permanent hardness can be removed by special methods of water softening. Any of the following methods can be adopted.

1 Lime - soda process.

2 Zeolite process or base exchange process.

3 Demineralisation.

1 Lime - soda process

In this process, lime (Ca (OH)2) and soda ash (Na2CO3) are used to remove permanent hardness from water. They react with calcium and magnesium salts and form insoluble precipitates of calcium carbonate and magnesium hydroxide. The precipitates can be removed by sedimentation. The reactions are

Advantages

1 The pH value of treated water increases which decreases corrosion of distribution system.

2 Minimizes coagulant dosage.

3 Removes iron and manganese to some extent.

4 Reduces total mineral content of water.

5 Removes pathogenic bacteria by some amount.

6 The process is economical.

Disadvantages

1 Disposal of the sludge formed is very difficult.

2 Requires skilled supervision.

3 Requires recarbonation.

4 Cannot produce zero hardness.

Zeolite process

The process is also known as base - exchange or ion - exchange process. The zeolites are compounds of aluminium, silica and soda. They have excellent property of interchanging base.

In this process, hard water is passed through a zeolite sand bed. There exchanges its Ca and Mg for Na in the zeolite until Na is exhausted. Na is then restored by regenerating zeolite with a solution a common salt (NaCl). This results in the reversal of ionic reactions.

The reactions are

For softening

(Sodium zeolite)

The zeolite softeners are very much similar to the rapid sand gravity filters. The zeolite bed is 1.2 to 1.8 m in thickness. This process is applicable to clear waters only.

Advantages

1 No sludge formation.

2 The zeolite unit is very compact.

3 Requires no skilled supervision.

4 No deposition of layer of calcium carbonate in the distribution system.

5 Zero hundred is achieved.

6 Water of any hardness can be prepared.

7 Completely automatic.

Disadvantages

1 Unsuitable for turbid water.

2 Unsuitable for water containing iron and manganese.

3 Requires careful operation to avoid damage of unit.

Demineralization: This process is otherwise known as de-ionisation process. In this process, hydrogen is exchanged for metallic ions. The hard water is passed through a bed of resin or carbonaceous material in the hydrogen form.

After the reactions, the effluent from the equipment contains diluted carbonic acid, sulphuric acid or hydrochloric acid. These acids can be removed by mixing the treated water in the required proportion of alkaline water.

The water produced is completely free from mineral salts. It is like distilled water. When the hydrogen content of the material is exhausted, it is regenerated by passing a solution of suitable strength of sulphuric acid or hydrochloric acid. This process is too costly. It is used for preparing water for industrial purpose.

Miscellaneous methods of treatment: Besides the normal treatments, sometimes water requires certain other special treatments to remove minerals, tastes, odours, colours etc. from water. For this purpose the methods adopted are aeration, activate carbon treatment, copper sulphate treatment, oxidation of organic matter etc.

Distribution of water: Distribution of water is the supply of safe and whole some water to all parts of the area served at adequate pressure and quantity. Hence the distribution system may consist the following

a **Pipe lines** of different sizes to convey water.

b **Valves** for controlling the flow in the pipe lines.

c **Meters** for measuring the consumption.

d **Hydrants** for providing connections with water mains for releasing water during fires.

e **Service** connections to the individual houses.

f **Pumps** for lifting and forcing the water into the distribution pipes.

g **Service reservoirs** for storing the treated water and feeding to the distribution pipes. These are surface reservoirs and overhead reservoirs.

General requirement of a distribution system

A Distribution system should satisfy the following general requirements:

1 It should be capable supplying water in adequate quantities and pressure at all points of the area served.

2 It should meet the demands of water supply for fire - fighting purposes.

3 It should be thoroughly reliable.

4 It should be economical in its design, lay - out and construction.

5 It should be easy and simple to operate and repair.

6 It should be safe against any future pollution of water.

7 It should be water - tight.

8 It should be safe as not to cause the failure of the pipe lines.

9 It should provide free circulation of water and the number of dead ends should be very few.

10 The pipe lines should be laid away from sewers at least by 2 m vertically and 3 m horizontally.

11 It should not have any unsafe cross connections.

12 The sanitation of the water distribution area should be good so that the possibilities of pollution are remote during repairs or replacements of pipes.

House service connection (Fig 6)

This is also called service pipe or house connection. This connects the street main with the interior pipe line of the consumers. This consists of

1 Furrule

2 Goose neck

3 Service pipe

4 Stop cock

5 Water meter

1 Ferrule

It is a right - angled sleeve of brass or gun metal jointed to an opening drilled in the water main. It is screwed down with a plug. It size is 10 to 50 mm bore. For all other connections of more than 50 mm bore, a tee branch connection of the water main is used instead of a ferrule.

2 Goose neck

It is a small sized curved pipe of flexible material like lead. It is about 750 mm in length. It forms a flexible connection between the water main and the service pipe.

3 Service pipe

It is a galvanised iron pipe of 50 mm or less in diameter. It is laid underground in a trench in which no sewer or drainage pipe is laid. It is connected to the main through the goose neck and ferrule. It supplies water from the municipal street main to the building.

4 Stop cock

It is fixed in an accessible position just outside the compound. It is housed in a chamber provided with a removable cover. Its size is according to the size of the service pipe. It is used to stop the water supply of defaulters. Sometimes, it is also called curb valve.

5 Water meter

It is used to measure the water consumption. It is housed in a chamber provided with a removable iron cover. It is fixed inside the compound.

Sometimes, a stop valve may be provided by the owner just before the water meter. It is used to close down the water supply to the buildings when repairs are going on in the house fittings.

Pipe appurtenances: These accessories or devices are provided in the distribution system for its efficient control and easy and effective functioning. Following are some of such appurtenances.

1 Air valves

2 Bib cocks

3 Fire hydrants

4 Reflux valves

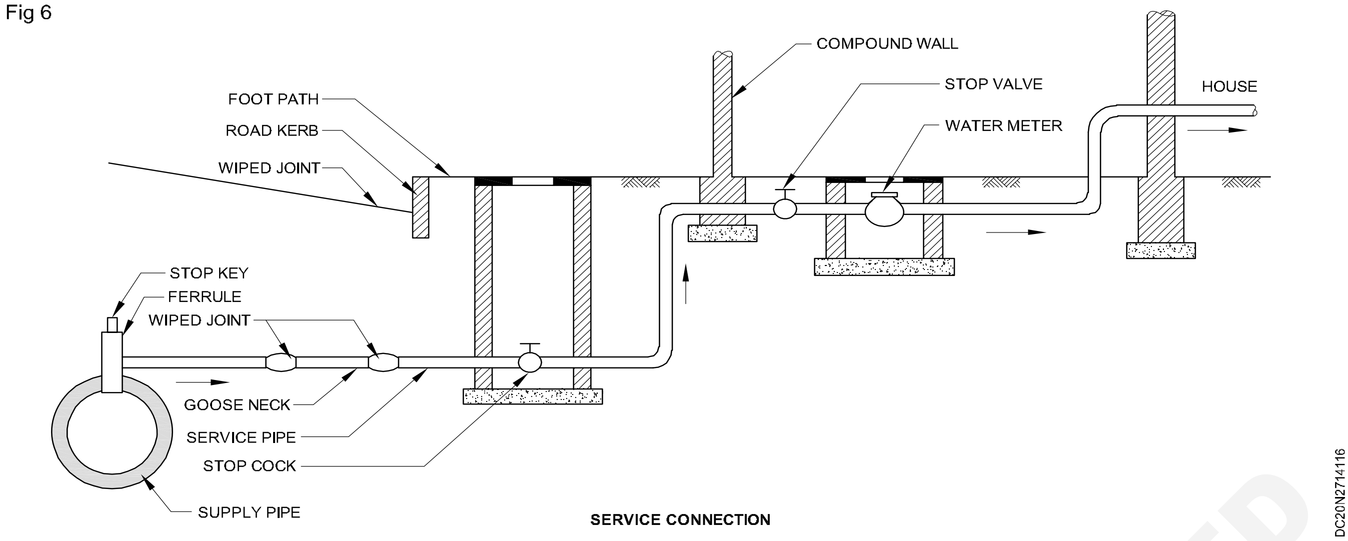
5 Relief valves

6 Scour valves

7 Sluice valves

8 Stop cocks

Fig 6



SERVICE CONNECTION

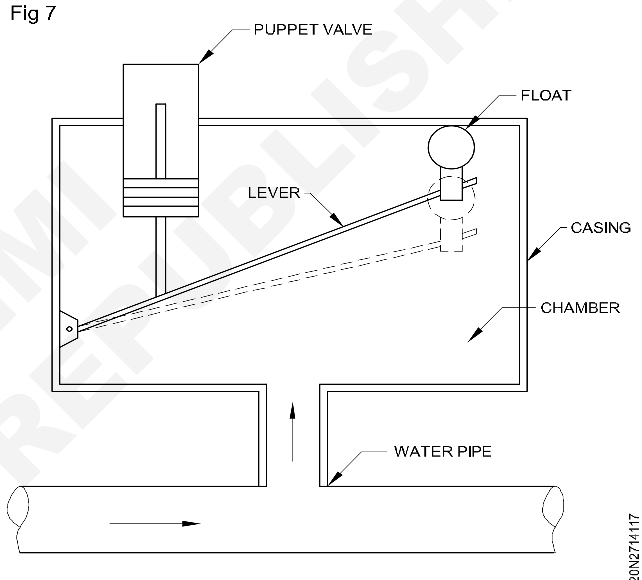
1 Air valves (Fig 7)

These are also known as air relief valves. They are provided at all summits along the water pipe. If they are not provided, pipes may be air - locked. The air - locking will reduce the effective area of flow.

Air can automatically escape under pressure from the pipe due to this valve. Similarly, air is sucked in when there is vacuum in the pipe. They prevent the collapse of pipes due to vacuum on sudden stoppage of water supply.

An air valve consists of a cast iron chamber, float, lever and a puppet valve. Air from the pipe line accumulates above the water surface in the chamber. The coming down of the float causes the puppet valve open and air escapes. Water rises again in the chamber. Float also rises closing the puppet valve before water escapes through it.

Fig 7



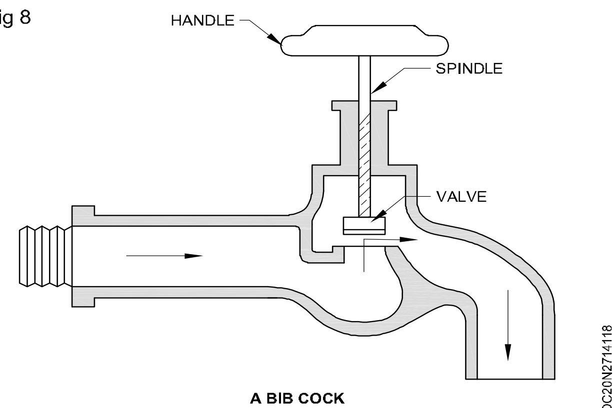
AIR VALVE

2 Bib cocks (Fig 8)

These are the water taps. They are fixed at the end of water pipes. Water is obtained from them. They have regulating arrangements. A typical bib cock is shown fig.8.

It is operated using a handle. It is a screwing type. Push types are also available. They are also known as waste - not taps.

Fig 8



A BIB COCK

3 Fire hydrants

These are the protected mountings or outlets provided in water mains for tapping water mainly for fire - extinguishing. Generally, they are located at all street junctions so that they can command 60 to 90 m radius.

Types

The fire hydrants are of two types.

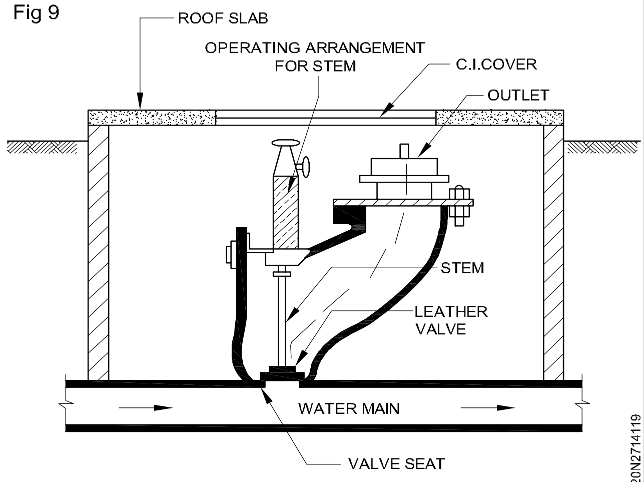
i Flush hydrants.

ii Post hydrants.

Flush hydrant

It is provided below the foot path or street level. It is covered by a cast iron box or brick masonry chamber, constructed flush with the ground surface. It is more secure though less prominent. For easy location, a plate with letters. F.H. (Fire hydrant) may be fixed to any nearby permanent structure. Fig 9 shows a flush hydrant.

Fig 9

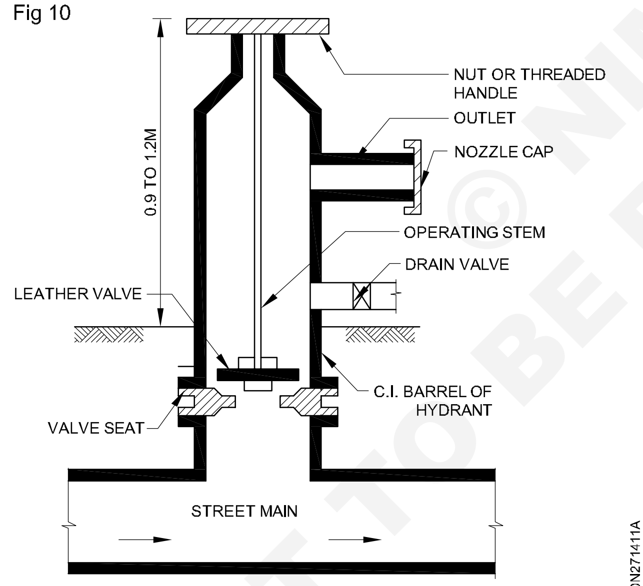


A FLUSH FIRE HYDRANT

Post hydrant

It is set at the back of the kerb line. Its barrel projects above the ground surface by 0.9 to 1.2 m. The nut at its top is opened and the fire hose is attached to it. On opening the nut, the stem is lifted. This opens the valve. It is very prominent and is very easy to locate. But, it is likely to be damaged or misused. A typical post hydrant is shown in Fig 10.

Fig 10



A POST FIRE HYDRANT

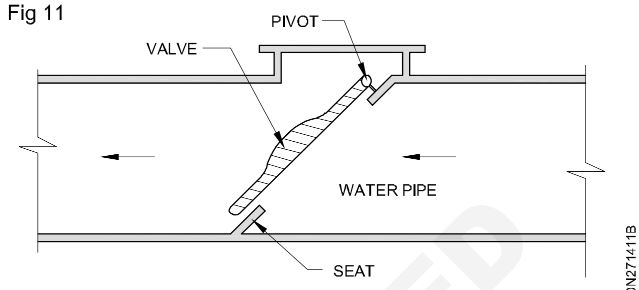
Working

The nut is operated by a key. The valve lowers down. Water enters fills up the barrel. Then water is delivered from the outlet. A fire - hose of the same diameter as the outlet is attached to it. After use, the nut is closed by the key. The valve rises up and prevents the entry of water from the pipe to barrel. The water remaining in the barrel is drained.

4 Reflux valves

These are also known as check valves or non - return valves. They are automatic valves. They allow the flow in one direction only. They are installed on the delivery side of pumps. They prevent the damage to the pumps from the water hammer due to sudden stoppage of pumps. A typical reflux valve is shown in fig 11.

Fig 11



REFLUX VALVE

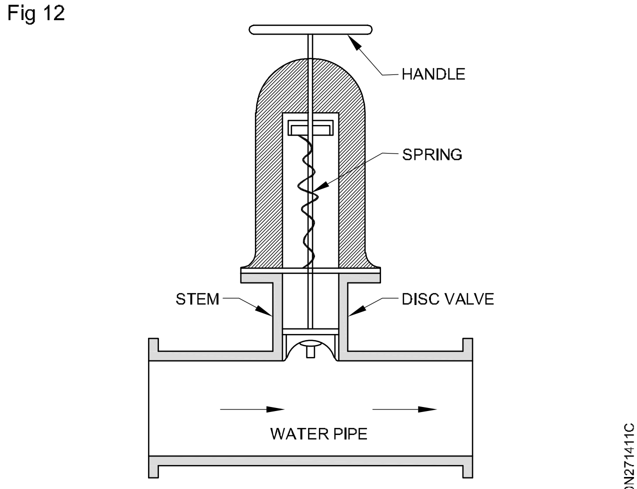
Working

When the water flows in the direction of arrows, the valve swings around the pivot and remains open due to water pressure. When the flow stops, the valve comes back to its seat due its self weight and backward water pressure. Thus, it prevents the reverse flow of water.

5 Relief valves (Fig 12)

These are also called safety valves, pressure reducing valves or automatic cutoff valves. They are located at points of maximum pressure. They are mostly loaded by springs. When the pressure exceeds a predetermined limit, they open automatically. Thus, they save the pipes from bursting. Fig shows a relief valve. They are also located at entry points to low - lying areas.

Fig 12



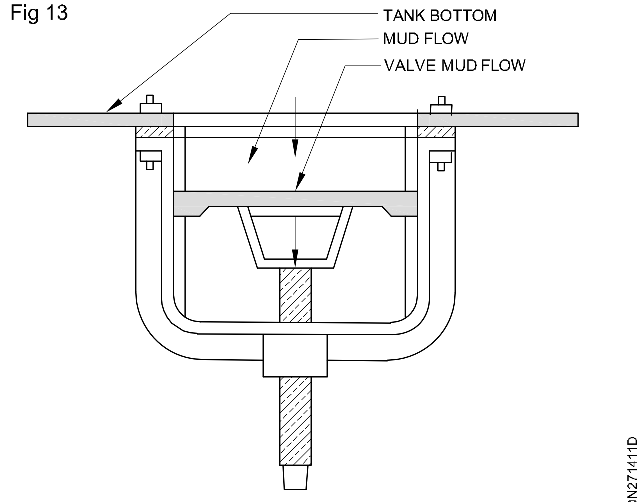
A RELIEF VALVE

6 Scour vales

These are also known as mud valves, blow - off valves or wash - out valves.

They are sluice valves. They are provided at all dead ends, and all depressions or lowest points in the mains. They are operated to remove the accumulated silt by allowing water under pressure until it becomes clear. Fig 13 shows a scour valve.

Fig 13



SCOUR VALVE

7 Sluice valves

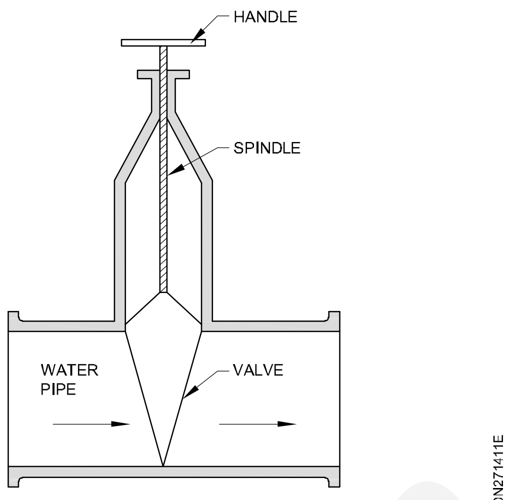
These are also known as gate valves, shut off valves or stop valves. They are used to control the flow of water. They divide the mains into several sections. They help in carrying out repairs in one section without affecting the other sections. They are also very useful in intermittent system of supply of water. Fig 14 shows a typical sluice valve. The rising and lowering of the valve is carried out by rotating the handle from top.

8 Stop cocks

These are small sized screw down type of sluice valves. They are installed in service connections. A typical stop cock is shown in fig 15.

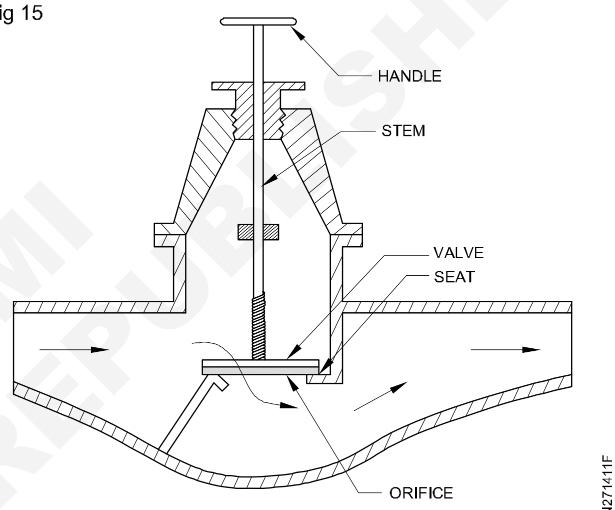
The water passes through an orifice when the valve is raised. When it is lowered to stop the supply, it rests on the seat closing the orifice. They are also installed on pipes leading to flushing tanks, wash - basins, water tanks, etc.

Fig 14



SLUICE VALVE

Fig 15



STOP COCK

Introduction to road Engineering and History of Highway Department

Objectives : At the end of this lesson you shall be able to
- **sate different modes of transportation**
- **define road**
- **define highway engineering**
- **define necessity and characteristics of road.**

Transportation contributes an important role in the economic, industrial and cultural development of a country. The means of transportation of a country is comparable to the vein in the human body. Just as veins in the human body maintain health by circulation of blood to different part of the body. Similarly means of transportation keep the people moving from one place to another place.

Modes of transportation

The three basic mediums of transportation is land, water and air. Land has given scope for the development of road and rail transport while water and air have developed water ways and airways respectively.

Four different modes of transportation are

1 Roadways

2 Railways

3 Waterways

4 Airways

Roadways

Roadways are the means of transportation or communication on land for conveying men, materials and information from one part to another part of the country. It not only includes the modern highway. System but also city streets, feeder roads and village roads, catering for a wide range of vehicles and the pedestrians. The transportations by road is the only mode which can give maximum service to one and all. This mode of transportation has the maximum flexibility for travel with respect to route, directions, time and speed of travel etc.

Highway engineering

It is the one of the important branches of transportation system which deals with the planning, design, construction and maintenance of road system.

Necessity of road to a country

Road of a country are comparable to the veins in the human body because it conveys men, material and information.

The following are the main necessity of roads

1 A network of roads is an asset to the defense of a country during war days

2 It facilitates the movement of men and material from one place to another

3 Better law and order can be maintained with the help or road.

4 Educational and cultural contact can be maintained

5 Help the growth of trade and other economic

6 Road serve as a feeds for railways, airways, and waterways.

7 National resources of one are can be easily tapped and improved

8 They enhance land value and thus help in bringing better revenue.

History of highway development

Objectives: At the end of this lesson you shall be able to
- **explain the history of highway development in the world**
- **explain the development of roads in India.**

Introduction: It is significant to note that the network of highway existed in all parts of the world for the flow of men and materials. The initial carrier on a highway was may himself followed by the camel, donkey, horse and after the invention of wheel, the cast and many other wheeled vehicles

History of highway development in the world: The techniques of highway engineering is known to the mankind for thousands of years. Most of the countries used this techniques and maintained roads for their day today affairs. The problems of highway engineering such as constructing, maintaining, managing, financing, controlling the traffic etc, were also faced by our predecessors and they were capable of solving these problems in their own way to satisfy their requirements. They were aware of the fact that highways are the most important infrastructure needed for development.

History of road construction

Roman roads

It is understood that the ancient roads built by the Romans were remarkable for their straightness and bold inception. The Roman conception of roads was based on their military importance. The chariots of the Romans and their advanced highway networks were well known.

The appain Way which was built by the Romans in 312 B.C. extended over a length of about 580 km and it was the earliest and best constructed road of those times.

Roads in France

A French engineer Pierre Tresaguet (1716-1796) developed improved method of road construction in France in 1764. He was the Inspector General of Roads in Frances from 1775 to 1785 and this method of road construction was adopted in that country in 1775. He contended that the total thickness of road construction should only be 300 mm and thus he laid the foundation for the modern road construction technique. He also emphasised for due consideration of sub grade moisture condition and provision of camber at top to drain of the surface water.

History of road construction in England

John Metcalf (1717-1810) was responsible for the construction of road in England. He constructed about 290 kilo meters of roads in northern region of England but as he was blind. Much of his work could not be recorded.

Telford construction

Thomas telford (1757-1834) who founded the institution of Civil Engineers at London, U.K. was a Scottish Engineer and he advocated in 1820, the idea of providing heavy foundation stones above the soil subgrade to achieve firmness of road base. He also insisted to have a definite cross slope at top surface of pavement by varying the thickness of foundation stones.

Macadam construction

John Macadam (1756-1836) an other Scottish engineer suggested a method of road construction in 1816 after studying the stone-road construction scientifically. He realised that the stresses due to wheel load of traffic gets decreased at lower layers of the roads cross-section and hence, it was not necessary to provide large foundation stones. He also insisted that the subgrade should be provided with the necessary cross- slope to take care of the percolated water.

Development of Roads in India.

The development of reads in India in various stages can be briefly reviewed as follows.

i Roads in ancient India.

ii Roads in Mughal period.

iii Roads in development during British rule.

iv Road development in free India.

1 Roads in ancient India

The historical records indicate that the science of road construction was known to us since long period. The excavation of Mohanjo-daro and Harappa have established firmly that the technique of road construction existed in India even 3500 years B.C. about 300 B.C Kautilya wrote Artha Shastra in this book he has mentioned the specification for road widths, road surfaces traffic control, etc. He had also laid down the rules for punishment to those who violated the traffic rules At one stage, he has compared the profile or cross-section of road with back of tortoise and it is thus clear that he knew the importance of upward convexity of top surface of road for drainage.

Chandra Gupta Maurya also formed a special communication department to look after roads and he managed to fix some pillars and sign boards on the road side for the guidance of road users. He also constructed a national highway connecting N.W.E province to his capital city of Patna.

During the regime of Ashoka, about 269 years B.C., there was a good network of roads in India. The trees were planted on either side of roads for giving shade to the travellers and the rest houses were provided at a distance of about 5 km to 7 km along the road.

2 Roads in Mughal period

During Mugal period, the muslim rulers improved the reads of India to a great extent. The muslim ruler Mohamad Tughlaq constructed a road connecting Delhi to Daulatabad. Shershah was very famous for construction of several reads. He constructed the longest road of his time connecting Lahore in Punjab to Sunargaon in Bengal.

3 Road development during British rule

At the beginning of British rule, the roads were in deteriorated condition and as such, the East India Company took little interest in road construction. It was Lord William Bentinck who revived the idea of constructing roads and in his period military boards used to look after the roads. Lord Dalhousie created a central public works department more or less of the same pattern as it exists today, to look after the roads and in 1855, such departments were created in other provinces also. Lord Mayo and Lord Rippon also contributed to road development to a great extent.

With the introduction of railways in 1853, the road construction received a serious setback as the entire energy of Government was directed towards the opening of new railway lines. In 1919, the Central Government transferred the subject to roads to the provincial Governments and it looked after the roads of military importance only.

After the First World War, the circumstances changed and it was found that a better road network was essentially required to take care of bullock cart traffic as well as motor vehicles. In 1927, the Central Government appointed a committee under the chairmanship of Dr.M.R Jayakar to investigate and report about the then existing roads and about the road development in the country. The committee submitted its report in 1928 with the following important recommendations.

i The Central, Government should look after at least the important roads of national importance.

ii An extra petrol tax surcharge should be imposed to build up a road development fund to be designated as Central Road Fund.

iii A transport advisory committee consisting of the representative of central and provincial governments should be set up to co-ordinate the ideas or road construction form various parts of the country.

iv A central organisation of information and research should be set up for carrying out research in road development.

Most of the recommendations made by the Jayakar Committee were accepted and implemented by the Central Government. A central read organisation was set up in 1930 and in 1935, a transport advisory committee was formed. In 1931, a road conference was called for the first time and in 1934, a semi-official body named as Indian Roads Congress (I.R.C) was wet up to provide a forum for the regular pooling of experiences and ideas in all matters affecting the design, constructions and maintenance of roads and also to recommend standard specification for roads and to provide a platform for expressing professional opinions on the matters relating to road engineering.

Indian Road Congress (IRC)

It is the premier technical body of highway engineers in the country the IRC was west up in December 1934 on the recommendations of the Indian Road Development committee best known as Jaykar committee set up by the government of India with the objective of Road Development in India. As the activities of IRC expanded it was formally registered as a society in 1937 under the societies Registration Act of 1860.

A conference of all the chief engineers of all the States and Provinces was convened by the Central Government on 15th December 1943 at Nagpur on the recommendation of I.R.C after second World War. This was the first attempt to prepare a co-ordinated read development programmed in a planned manner. This conference prepared the first 20 years road development plan and it has come

4 Road development in free India

There has been considerable development in road after the country got independence. In 1950, the Central Road Research Institute (C.R.R.I)was started in New Delhi for carrying out research in various aspects of road engineering. In 1956, the National Highway Act was passed for empowering the Central Government to develop and maintain national highways. In 1973, the highway research board of the IRC was set up to give proper guidance to road research activities in the country. The activities of IRC were also expanded and it has attained the status of an important body looking after the overall development of roads in the country.

The targets of Nagpur plan for period (1943-1963) were achieved in about 1961, i.e., two years ahead of schedule. The second twenty year plan (1961-1981)was initiated by the I.R.C and it was finalised in 1959 at a meeting of the Chief Engineers. The target of read length achieved at the end of the second plan was nearly double than that of previous Nagpur plan and considerable improvement in road construction took place during this second twenty year road plan.

To push up the road development still further, the IRC had prepared the third twenty year road development plan for the period (1981-2001)

National Highway Authority of India has prepared and implemented National Highway Development Project (NHDP) consisting seven phases to be executed during 2000 to 2010. This project covers upgradation, widening and strengthening of National Highways, new BOT (Build, Operator and Transfer)and DBFO (Design, Build, Finance and Operate) projects, expressways, ring roads, flyovers, bypasses, etc.

Technical Terms used in road engineering and Several Principles of Alignment

Objectives : At the end of this lesson you shall be able to
- **define read and its advantages**
- **define the various terms used in road engineering**
- **describe the various advantages of roads**
- **illustrate the terms used.**

Road

It is a public through fare over which pedestrian, cyclists and other vehicles etc may move lawfully from one place to another is called a road highway.

Advantages of roads

The importance or the necessity of highway transportation can be judged from the following advantages of roads.

i The roads facilitate the movements of people, goods, raw materials and finished articles etc. easily and speedily from one place to another.

ii They establish contact between towns and villages and help in growth of trade and other economic activities in and outside villages and towns.

iii Due to mobility of goods all over the country, they help in keeping the price stable.

iv They help in reducing distress among people which cause due to famine, by supplying medicines, food and clothing very quickly.

v They help in maintaining better law and order in the country

vi They hlep in providing efficient distribution of agricultural products and other natural resources all over the country.

vii They help in making social and cultural advancement of people.

viii They help in making the villagers active and alert members of society.

ix They help to provide improved medical facilities to the people especially to the people living in rural areas

x They play a very important role in the defense of a country during war days.

xi They serve as feeders for airways, railways, and waterways.

xii They enhance land value, and thus help in bringing better revenue.

xiii They provide more employment opportunities to the people

xiv They help in providing national unity among people of different states.

So it can be said that the roads are the symbol of country's progress and hence the development made by any country can be judged by the quality and network of its road system.

Technical terms used in road engineering

Typical cross-section of a road in embankment (Fig 1)

1 **Land width (A):** The total width of land acquired for the road along its alingment. It is also known as right way and it depends upon the importance of the road and its possible future development.

2 **Roadways (B):** It is a portion of the road used for the traffic and includes carriage way.

3 **Carriageway (C):** The portion of the road way designed and or constructed for vehicular traffic is called carriage way.

4 **Drainage (D):** Removal and diversion of water from a high way is called high way drainage.

5 **Arboriculture (E) :** Planting tress on the road sides is called arboriculture.

6 **Formation (F):** The prepared surface of the ground in its final shape after the completion of earth work. The height of embankment or filling in the figure its 'H' and it should be 60cm above the maximum floor level at that area.

7 **Shoulders (G):** The space on both sides of the carriage way to protect the road is known as shoulders. The width of each shoulders varies form 1.25m to 2.0 m. Generally they are in level with the roads having a cross slope of 1 in 20 for proper drainage.

8 **Camber (H):** The slope provided to the road surface in transverse direction is called chamber, or cross fall of a road. It is provided to drain off the rain water from the carriage way. The level difference between the outer edge and cross is the amount of camber.

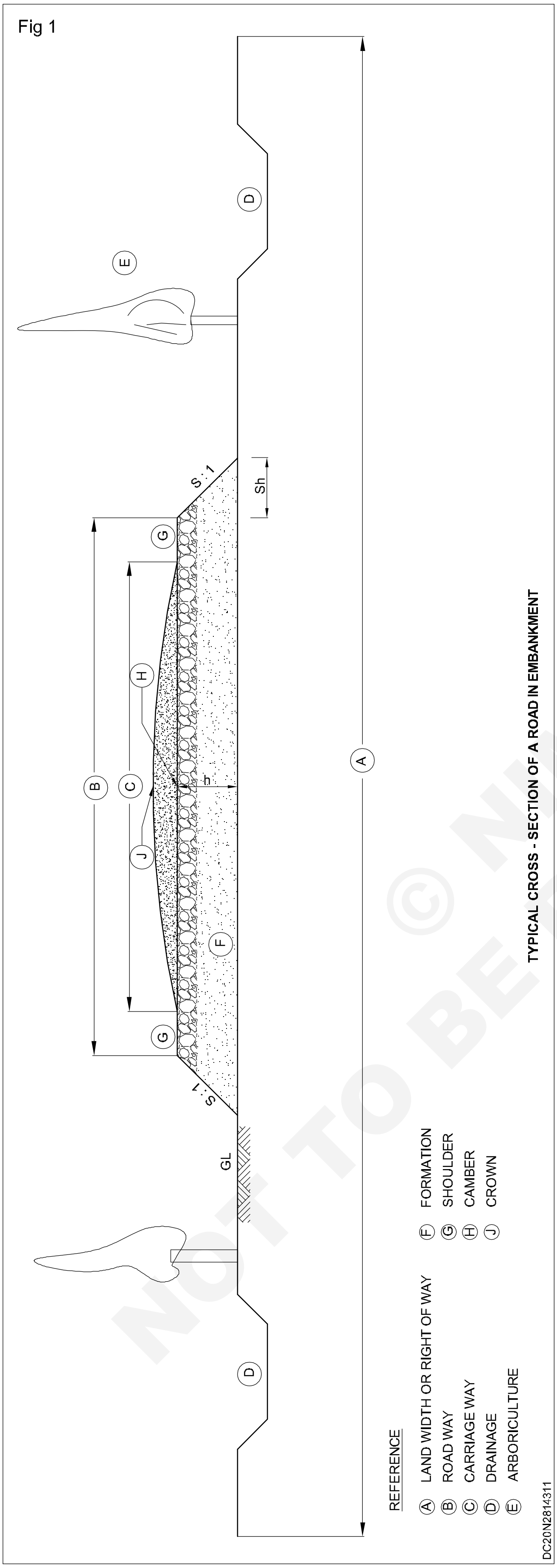
9 **Alignment :** The lay out or route of the centre line of the road on the ground is called alignment of the road. It should be carefully decided before the construction of road.

10 **Angle of repose:** The angle at which a soil can stand without any support is called angle of the repose.

11 **Acceleration lanes:** Important loads lane of sufficient width and length are provided to enable vehicles to accelerate to the design speed of the road after emerging out the intersection. Such lane are called acceleration.

12 **crown(J) :** The highest point of a cross section of a high way is called a crown.

Fig 1



13 **Formation width(F) :** It is the sum of the widths of carriage way and shoulders on both sides. In other words it is top width of a high way on a embankment.

14 **Sub base :** A layer of broken stones placed over the sub grade to give structural stability to the pavement is called sub base. Actually it is foundation layer. These are used under flexible pavements to improve their load supporting capacity.

15 **Base course :** The layer of road structure laid over the soling or layer which lies immediately under the wearing course is called the base course.

16 **Base coat :** The intermediate layer between the base course and the wearing coat is called base coat. It is an optionable coat.

17 **Surfacing or wearing course :** The top most layer on which the traffic directly travelling is called road surfacing the main function of road surfacing is to provide a smooth and stable running surface. It is also known as carpet

18 **Binder course :** An intermediate course of asphalt mix between the base course and the wearing course is called binder course.

19 **Asphalt :** It is defined as the mixture of refinery bitumen and inert mineral matter. It is used as a binding material during the construction of road.

20 **Footpath :** The portion of a roadway of an urban road which is reserved for the pedestrians is called foot path.

21 **Motor way :** The portion of an urban road which is used by high speed and power driven vehicles is called motor way.

22 **Trunk road arterial road :** It is the main road forming the essential part of highway system of a country.

23 **By -pass road :** A road provided around the congested area is called by-pass road.

24 **Ring road :** To enable free movement of traffic around an urban area, a cirumferential road is constructed which is called ring road.

25 **Loop roads :** These are alternative roads provided to divert traffic to avoid obstructions.

26 **Road margins :** The portion of land on either side of the formation width of a road are known as road margins.

27 **Bitumen :** It is a viscous material having adhesive properties obtained either natural or by refinery processes and is soluble in carbon disulphide. As per I.S.I in India, only the refinery product is termed as bitumen.

28 **Capacity :** The maximum number of vehicles on a road that can pass a given point in on hour is defined as the capacity of road lane. It depends upon the traffic conditions.

29 **Carpet :** The top layer or wearing coat of a bitumen or tar concrete is called carpet. It's thickness varies from 2 cms to 2.5 cms.

30 **Cause way :** These are submersible bridges usually provided for cross drainage on unimportant roads. They allow water to flow across the road surface during floods.

31 **Design speed:** The safe permissible speed on a given category of road is called design speed.

32 **District road:** Road constructed within the boundaries of the district connecting its various towns, industrial areas, thasil head quarter, high ways and railways etc are called district roads. They are comparatively less important.

33 **Drive way:** A road constructed to secure access from a road to a private property is called drive way.

34 **Earth roads:** The roads whose foundation as well as wearing course are made of soil available at the site are called earth roads.

35 **Earth work:** The preparation of the subgrade to the desired grade and camber is known as earth work for the road.

36 **Felling:** The process of removing stress is called felling

37 **Flash point"** The lowest temperature at which the vapours of a substance catch fire momentarily in the form of a flash under specified conditions of test is called the flash point.

38 **Flexible pavements:** The pavements which reflect the deformation of subgrade and of subsequent layers on the top surface are called flexible pavements.

39 **Foot paths:** In the urban roads, separate space is provided for the use of pedestrians either in the midele or on edges of the road is called footpath. Generally foot paths are higher than the road by 15 to 25 cms.

40 **Fly over:** The road junction designed to divide the traffic to pass over or under each other is called fly over.

41 **Geometric design of high ways:** The design of road elements with which the high way user is directly connected is called the geometric design of a high way

42 **Gradient:** The rate of rise or fall along the length of the road with respect to the horizontal length is called gradient.

43 **High way:** An important road of a road system is called high way.

44 **Lane width:** The width of carriage way is called lane width. It comprises of vehicles width and minimum side clearance provided for safety considerations. Usually for a single lane, its width is kept as 3.8m.

45 **Macadam water bound:** In this method of road construction, the broken stones of the base and surface course are bound by the stone dust in the presence of moisture.

46 **Mandatory signs:** The regulatory sings which are compulsory are called mandatory signs installed at 2.8m above the ground level. It is a defects in road pavement.

47 **Map cracking:** It is the defect in road pavement the cracking of bituminous srufaces due to fatigue in an irregular fashion is called map cracking.

48 **Mastic asphalt:** A mixture of bitumen, fine aggregates and filler in suitable proportion which gives a void less and impermeable mass is called mastic asphalt.

49 **Optimum moisture content:** The amount of moisture at which the maximum dry density of a particular soil is attained for a particular amount of compaction is called optimum moisture content.

50 **Native asphalt:** The asphalts which occur in pure or nearly pue state in nature is called native asphalt.

51 **National high way:** Main high way running through the length and breadth of a country connecting ports, capitals of states, and other strategic points for defense purpose are called National high ways.

52 **Obligatory points:** these are the points which govern the alignment of the high ways.

53 **Over pass:** When the major high way is taken above general ground level by contstructing a over bridge across an other high way then it is called a over pass.

54 **Patch repair:** Repair of localized damaged surface is called patch repair.

55 **Perception time**: Time required for a driver to realise the necessity of applying brakes to the vehicles, is called perception time.

56 **Pot holes:** When the stone aggregate are lost from the base course of a pavement the holes formed are called pot holes.

57 **Prime coat:** A bituminous wearing surface placed upon a previously untreated compacted foundation layer is called prime coat. Its function are to seal the pores and to make the underlying layer water proof and to develop interface bonding.

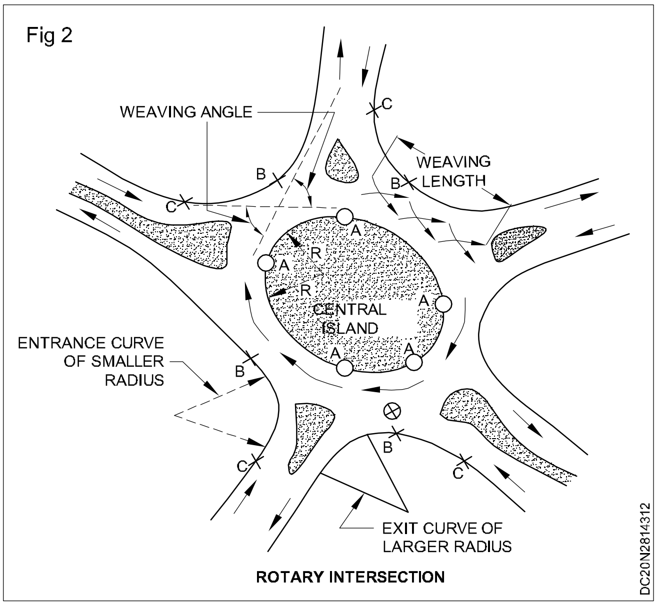
58 **Primer:** The adhesive material which penetrates into the capillary voids of the existing base and plug them is called primer.

59 **Return wall:** Wall provided at right angles to the abutments to support earth fill at their back are called return walls.

60 **Reflection cracks:** These cracks are developed in bituminous surfacing laid over existing cement concrete pavements.

61 **Rigid pavements:** The pavements in which deformation of the sub grade are not reflected on the surface are called rigid pavements. In this case the load is distributed over a wide area of sub grade soil.

62 **Rotary intersection or traffic rotary:** A rotary intersection is an enlarged road intersection where all coverging vehicles are forced to move round a large central island in one direction only before they get into their respective directions radiating from the central island (Fig 2).



ROTARY INTERSECTION

63 Ruling gradient: The maximum gradient with in which the designer attempts to design the vertical profile of the road is called ruling gradient. In plains its value is 1 in 30.

64 Seal coat: A biuminous thin layer applied over an existing biumen pavement is called seal coat. Its main function is to seal the surface against increases of water.

65 Sheet asphalt: A carpet of sand and bitumen mix containing no coarse aggregate is known as sheet asphalt. It is used for a bearing course.

66 Skid: When wheels slide without revolving the phenomenon is called skidding.

67 Summit curves: Curves whose convexity is upwards are called summit curves.

68 Tack coat: An single application of bituminous material on an existing surfaces such as cement concrete, bituminous or brick surface etc. to ensure proper bond between the new and old surface is called tack coat.

69 Tar: It is a viscous liquid obtained from the destructive distillation of coal or wood in the absence of air.

70 Traffic: All types of vehicles using road such as buses, trucks, carts, cycles etc. and pedestrians together form traffic.

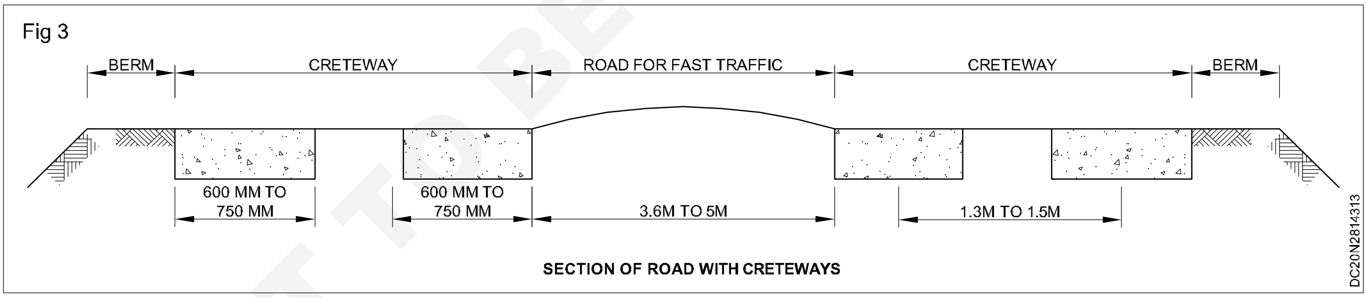
71 Transition curve: Curve provided between a circular curve and straight portion of a road is called transition curve. Its radius varies from infinite at the straight to finite value at circular curve for providing easy change of direction of the road.

72 Valley curves: Curves with convexity downwards are called valley curves.

73 Vertical curves: Curves provided at the intersection of different grades in the vertical alignment of a highway are called vertical curves those curves provide easy change in gradients for fast moving vehicles.

74 Wing wall: Walls provided at an angle of 30° to 45° to the abutments to retain earth fill at their backs and to direct the flow to the culvert at the up stream end are called wing walls.

75 Crete ways: Where bullock cart traffic is heavy and construction of biuminous or other type of road is costly, a type of trackway or wheeler is found out to segregate the slow moving traffic. Such a road is known as crete way and it is in the form of concrete slabs. (Fig 3)



SECTION OF ROAD WITH CRETEWAYS

76 Kerbs: To show the boundary between the road pavement and shoulder or footpath or islands, kerbs and provided. For rural roads, the provision of submerged kerbs at pavement edges between the road pavement and shoulders will increase the lateral stability of the granular base course and flexible pavements.

77 Traffic separators or medians: For two sets of traffic lanes intended to serve traffic moving in opposite directions, the traffic separators or medians are sometimes provided for the following purpose:

I To avoid head-on collision between vehicles moving in opposite directions

II To channelize traffic into streams at intersections

III To protect pedestrians

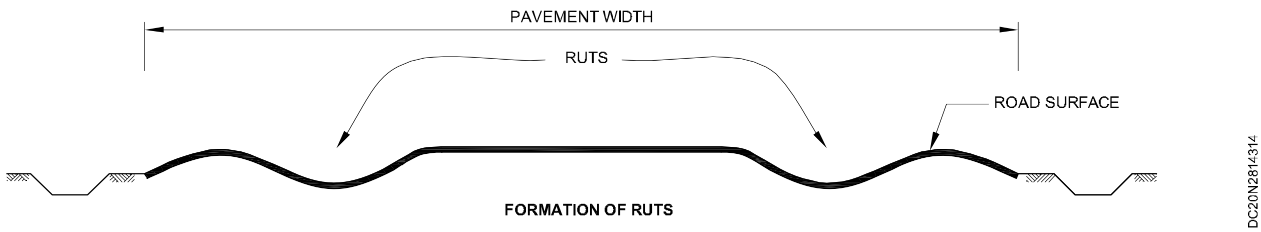
IV To segregate slow traffic and

V To shadow the crossing and turning traffic

77 Rutting: These are longitudinal depression that form due to repeated application of loads on the same portion of road. They are also known as consideration of pavement layers. (Fig 4)

78 Traffic island: Traffic islands are raised areas constructed within the carriageway to provide physical channels to guide the vehicular traffic.

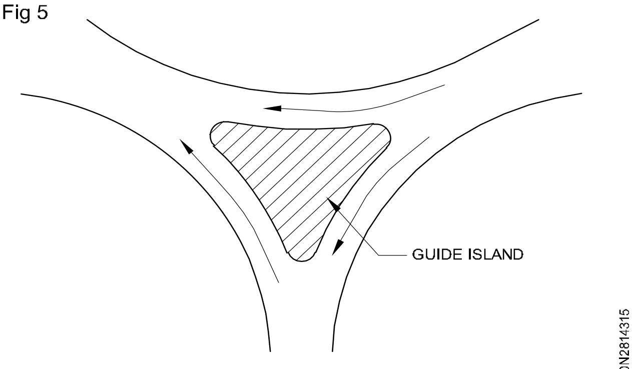
Fig 4



FORMATION OF RUTS

79 Guide island: This is also called channellising island. These islands are used to guide the traffic into proper channels through the intersection area. Guide islands are very useful as traffic control device for intersections. The size and shape of the guide islands will depend upon the layout and dimension of the intersections. Guide island serves the following purpose. (Fig 5)

Fig 5



GUIDE ISLAND

I Control of speed

II Control of angle or conflict

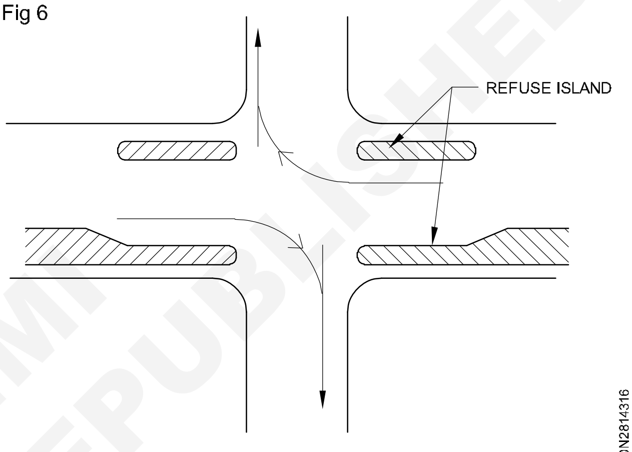
III Separation of conflicts

IV Protection of traffic for vehicles leaving or crossing the main traffic system

V Protection of pedestrians

80 Refuse island: An island provided at or near a cross walk to aid protect pedistrian crossing the roadway is called a Refuse pedestrian island. Refuse islands make crossing much safer in multilane roads. Refuse islands are provided after two or three lanes in a multilane road (Fig 6).

Fig 6



REFUSE ISLAND

Principles of road alignment

Objectives: At the end of this lesson you shall be able to
- **define alignment of road**
- **express the principles of highway alignment**
- **enumerate the factors affecting highway alignment**
- **explain the different survey required for alignment.**

Introduction

Highway engineer have an important role in the selection of route. The way and means of this selection may consider different fact and factor.

Definition

The course or route, position along which the centre line of a road is located in the plan is called "Road Alignment". Before starting the actual construction the centre line of the road is first marked on the plan and then on the site.

Principle or factors effecting highway alignment

The following are the four guiding principles applied for an highway alignment

Easiness: flexible in construction and maintenance

Economic: Construction and maintenance cost should be less

Safety: Ensure safety during the construction and also the time of utilisation

Shortness: As far as possible straight and level alignment

1 The alignment of the road should be as short as possible

2 The alignment should be as straight as possible which ensure higher speed traffic

3 The alignment should be easy for construction maintenance and traffic operation

4 The alignment should cross the railway lines and other roads and bridges at right angles.

5 It should cross the rivers, canals or streams etc. at place where its width is minimum and where good the durable foundation available.

6 The alignment serves maximum population by connecting intermediate important towns and group of villages.

7 The alignment should be such that is crosses the minimum number of bridges crossing culvers, and embankment places

8 It should provide smooth curves and easy gradients

9 It should be such that minimum earth work in embankment or cutting

10 The alignment should provide good sight distance

11 It should be free from obstruction like ponds, lakes, wells, monumental and historical building etc.

12 The alignment should run through such places where materials of road construction and labour are easily available.

13 Marshy and low lying land having poor drainage may be avoided

14 The alignment region should offer facilitation for means day to day activities.

15 Unnecessary Zigzags in alignment should be avoided.

16 The alignment should not have lengthily straight routes to avoid monotomy

Alignment of hilly area road

1 The location should be such that he ruling gradient is attained in most of the length

2 As far as possible steep terrain and inaccessible areas should be avoided

3 Unstable hilly features and areas having perennial and slide or settlement should be avoided.

4 The alignment should involve least number of hair pin bends, if unavoidable the bends should be located on stable and flat hill slopes.

5 If alignment is to be made through tunnels in high mountain rages, the decision should be based on relative economics or strategic consideration.

6 While crossing mountain ridges, the highway should cross the ridges at their lowest elevations

7 An alignment should receive plenty of sun shine.

8 Areas liable to snow drifts should be avoided.

9 As far as possible un-necessary rise and fall should be avoided.

Surveys for road alignment

The starting point and terminating point on road alignment is given by a high way engineer may be economical route connecting them. For this purpose engineering surveys will have to be carried out. The vaious engineering surveys which area carryout for the choice of route of a new highway are

1 Reconnaissance survey

2 Preliminary survey

3 Location Survey

1 Reconnaissance survey

A reconnaissance survey is the first engineering survey that is carried out in territory which has not been previously surveyed object of reconnaissance survey are

To obtain general knowledge of the whole territory

To obtain information regarding the salient feature of the territory

By reconnaissance survey, a number of possible alternative routes between two points can be worked out.

2 Preliminary survey

The object of preliminary survey is to conduct the survey work along the alternative routes found out by reconnaissance survey and to determine with the greater accuracy the cost of highway along the alternative route to decide which route will be the most economical. The preliminary survey decides the final route and should be done with great precision as it depends the alignment of the final route.

3 Location survey

The main object of location survey is to carry out the detailed survey along the route which has been found and fixed as the most economical route from the data of the preliminary survey. It established the centre line of the actual highway to be laid and hence as so location survey is completed the construction work started.

Classification of roads

Objectives : At the end of this lesson you shall be able to
- **define the way of classification of roads**
- **describe the different classification of roads.**

Classifiction of highways

The highways are classified as follows

1 According to location and function

2 According to importance

3 According to traffic

4 According to transported tonnage

Roads are also classified as per the desired strength of the pavement needed for the intensity of the traffic or as per the material used as follows

1 Earth roads

2 Gravel road

3 Water bound mecadam (WBM) roads

4 Bituminous roads

5 Cement concrete roads

Classification according to location and function

Actually the classification based on location and function is more rational. According to Nagpur plan, Indian roads have been classified into five categories as follow:

1 National highway (NH)

2 State highways (SH)

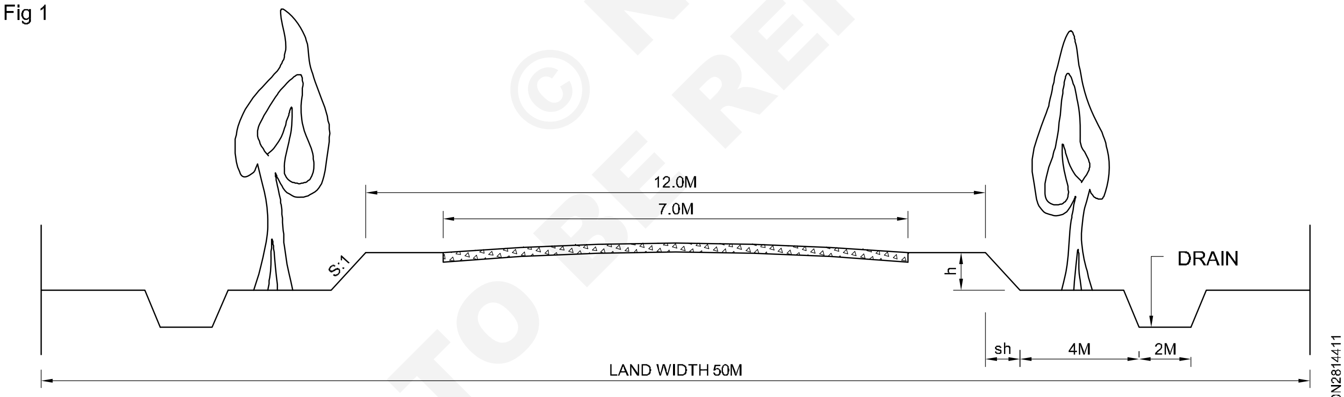
3 Major district roads (M.D.R)

4 Minor or other district roads (O.D.R)

5 Village roads (V.R)

1 National highways: These are the important roads of the country connecting ports, capitals, foreign highways and important cities etc. They run through the length and breadth of the country. Generally the National Highway should have two lanes of at least 8m width and at least 2 m wide shoulders on both sides. (Fig 1).

Fig 1



TYPICAL CROSS SECTION OF NATIONAL HIGHWAY

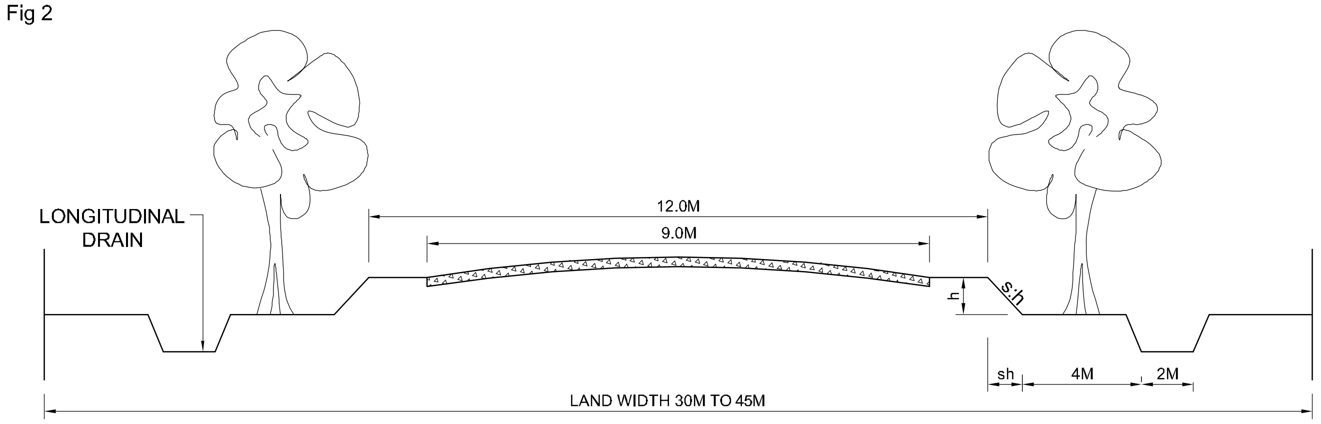
2 State highways (SH): These are the main roads within the State and they connect important towns and cities of the State. They also connect the cities of the State to National highway and serve as the main arteries of traffic to and from the district roads. (Fig 2)

3 Major district roads (MDR): These roads are constructed with nearly the same specification as those of the State highways. They are intended to connect areas of the production and markets with State highways and railways. These roads should be fit to be used throughout the year and they should be designed to take traffic into the heart of the rural area. (Fig 3)

4 Other district roads (ODR): These roads are some what of lower specification as compared to major district roads. They are connected to major district roads and railways. They are intended to serve the interior rural population of the district. (Figs 3&4)

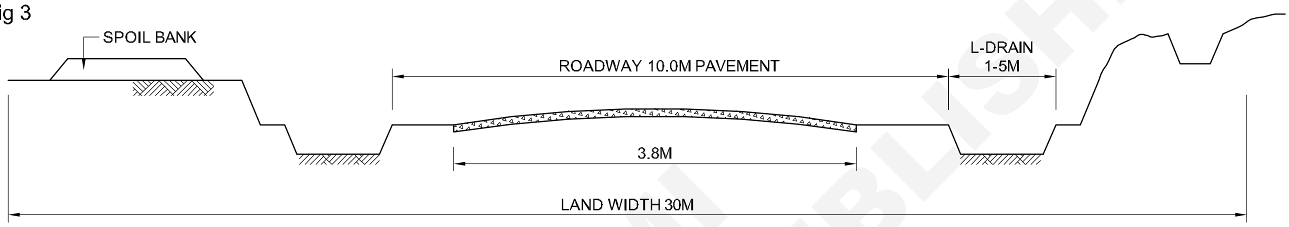
5 Village roads (VR): These roads connect village and groups of villages with each other and also to the nearest district road, National highway, railway or river ghat. They are mostly un-metalled roads, so during monsoon, these roads become unusable. A metalled road, which passes near a village and is connected by a kachha road, is known as the village approach road. It is maintained by the village panchayat (Fig 5).

Fig 2



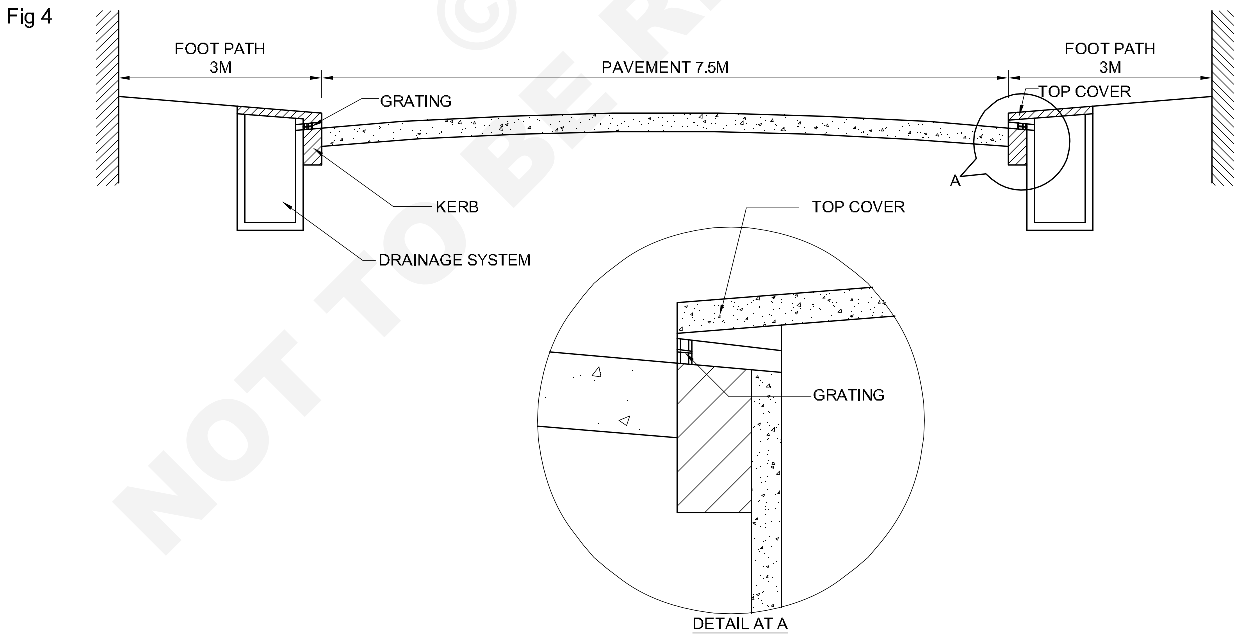
TYPICAL CROSS SECTION OF A STATE HIGHWAY

Fig 3



TYPICAL CROSS-SECTION OF A MAJOR DISTRICT ROADS

Fig 4

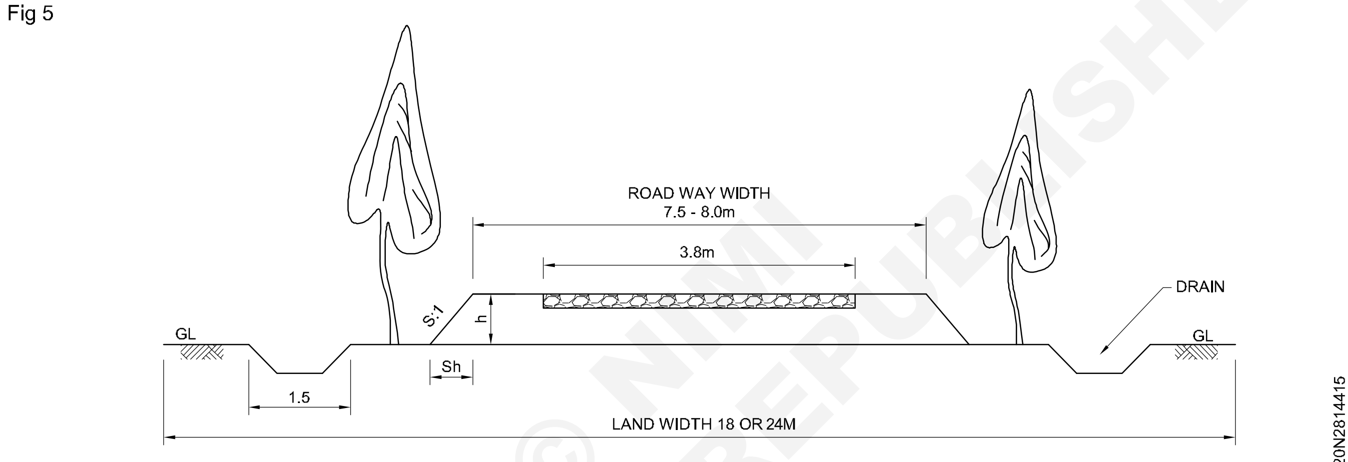


TYPICAL CROSS-SECTION OF A DISTRICT ROAD

Recommended Land width of different classes of roads (in metres)

Sl.No	Road Construction	Plain and rolling terrain				Mountainous and Steep terrain	
		Open areas		Built areas		open areas	Built up areas
		Normal	Range	Normal	Range	Normal	Normal
1	National and state Highways	45	30-60	30	30-60	24	20
2	Major district roads	25	25-30	20	15-25	18	15
3	Other district roads	15	15-25	15	15-20	15	12
4	Village roads	12	12-18	10	10-15	9	9

Fig 5



TYPICAL CROSS-SECTION OF A VILLAGE ROAD

6 **Border roads:** These roads are constructed by the Border Road organisation and maintained by the Border Roads Development Organisation (BRDO). From the nations defense point of view these roads are of much importance. Total length of border roads is over 7961 km. The Manali (Himachal Pradesh) to Leh (Capital of Ladakh) is the highest border roads.

7 **Express highways:** To meet with the present day fast moving traffic, the express highway or expressways have been constructed for connecting important places. These expressways have controlled access and grade separation at all road and rail crossing. Under the National Highway Development Programme (NHDP) plans have been made to build 4 to 6 lane express highways since 1991. A major part of NHDP is the Golden Quadrilateral project. It entails upgrading and widening of 6000 km of highways connecting the four major metropolitan cities of Delhi, Mumbai Chennai and Kolkata. Following are the three National Express Highways, which have been constructed under NDHP.

i **The Golden Quadrilateral:** This project entails upgrading and widening of about 6000 km of highways connecting the four major metropolitan cities of Delhi, Mumbai, Chennai and Kolkata. There is no railway crossing on the entire length, but it will have 75 railway over bridges.

ii **North South Corridor:** This express highway is form the Srinagar to kanyakumari.

iii **West East Corridor:** This express highway is from Porbandar (Saurashtra, Gujarat) to Silchar (Assam). Total length of these two corridors will be around 7300 km.

Classification according to traffic

The three important characteristics to be considered under this classification are as follows:

Character of traffic: this is determind by the type of vehicles which use the road. IF the traffic vehicles include fast moving trucks, cycles, bullock carts, etc. it is known as mixed traffic and is designated by letter M. Similarly the letters T and P will indicate respectively that the traffic consists mostly of trucks and passenger vehicles.

Designed speed: This is indicated by a figure. For instance, the figure 60 would mean that the road has designed speed of 60 km ph.

Traffic density: The number of vehicles using the road per hour or per day is known as traffic density and it is generally based on per day basis. For instance, the traffic density of 1200 would mean that 1200 vehicles per day use that road.

With the above three characteristics, the classification of highways can be made suitably and it will give at a glance the facilities provided for the user of the road. For instance, 1200 M60 would mean that the highway has mixed traffic of 1200 vehicles per day and it is designed for a speed of 60 km p.h.

III According to importance

A 1st Class road

B 2nd Class road

C 3rd Class road

A Very heavy traffic road: Which carry above 600 vehicles a day

B Heavy traffic road: Which carry 251 to 600 vehicles

C Medium traffic road: Which carry 70 to 250 vehicles a day

D Light traffic road: Which carry below 70 vehicles a day

Table

Tonnage Limits

No.	Type of road	class	Tonnage limit per day
1	NH	A	1500 to 2500
		B	2500 to 5000
		C	Above 5000
2	SH	-	1000 to 1500
3	MDR	A	500 to 750
		B	750 to 1000
4	ODR	-	200 to 500
5	VR	-	Below 200

IV Classification according to transported tonnage

This classification is based on the total average weight of the vehicles passing over the highway per day. Table shows the tonnage limits for various types of roads.

Thus NH B 60 would mean that the National highway has tonnage between 2500 to 5000 per day for the designed speed of 60 km p.h. In a similar way, MDR A 50 would mean major district road for tonnage between 500 to 750 per day for the designed speed of 50 km p.h.

With the above discussion, it is clear that the classifications based on traffic and transported tonnage are important from the engineering point of view only. The classification based on location and function is well-defined and hence, it is found to be popular and acceptable in practice

Build, operate and transfer (BOT) project in India

The Central Government of India has decided to introduce the concept of revenue sharing in the construction of express highway undertaken by private operators on the build, operate and transfer (BOT) format under the direct tolling method. Under this policy, the private companies build the express highways and after an agreed period or concession period of time, when they have recovered their investments and profits, the express highway is transferred over to the government.

Following are some of the major BOT projects of India;

1 **Kundi Mansard Palwal (kmp) express way:** It is also known as the western peripheral expressing and it is the largest expressing BOT project in the country.

2 **Delhi- Gurgaon express way:** The project envisage conversion of the Delhi-Gurgaon section of NH8 into an access controlled 6 to 8 lane highway with service lane across certain section and strengthening of existing lane from 14.3 to 42 km, falling partly in Delhi and Haryana.

3 **Gwalio - Jhansi highway BOT (Annuity):** The project aimed for the up gradation from the existing two lanes to four lanes of Gwalior - Jhansi section from 16 km to 96km on NH 75 under north south corridor in the states of Uttar Pradesh and Mathya Pradesh.

4 **Lucknow - Sitapur Highway:** The size of project is 76 km work involves improvement operation and maintenance including strengthing and winding of the existing two lane road into four lane on NH 24.

Classification of roads - materials used and construction of different type of Roads

Objectives : At the end of this lesson you shall be able to
- **define the different classificaion of road as per material used**
- **explain the method of construction of various roads.**

1 Earth roads

Earth road is one whose foundations as well as wearing course are made out of the soil available at site. The road prepared from natural soil available at site is the cheapest.

In India, earth roads are used to a great extent as they are cheap and easy in construction and maintenance. These roads are fair weather roads as they become muddy in rainy seasons and dusty in dry weather. They are suitable for bullock cart traffic. The type of construction depends on the type of soil available at site. The camber provided in earth roads is very steep and varies between 1 in 20 to 1 in 25. In order to provide good drainage to earth roads, a steep cross scope is very essential. The maximum slope of 1 in 20 is recommended to avoid erosion due to rain water and formation of cross ruts.

Methods of construction: Following procedure is adopted in the construction of an earth road.

a The soil survey is carried out and the borrow pits are normally selected outside the land width. The centreline is fixed and reference pegs are driven for the guidance of vertical profile of road.

b The ground is cleared of shrubs, trees, grass and other organic matter including top soil before starting the excavation for earth road.

c The subgrade is prepared and it is provided with necessary camber and longitudinal gradient. Depending upon the thickness of pavement construction, the desired depth of subgrade is decided.

d The subgrade is properly compacted before the laying of pavement layers is commenced.

e The prepared earth is then mixed with water and laid in layers in such a way that the compacted thickness of each layer does not exceed 100mm. It is usually laid in two layers.

f The camber of the finished pavement surface is checked and it is corrected, if found necessary.

g The compacted earth road is allowed to dry for a period of about 5 to 10 days before opening it for traffic.

Advantages of earth roads

a They can be constructed speedily.

b They involve the use of locally available earth and it can be so arranged that earth obtained from cutting is equal to earth required for filling. This is known as balancing of earthwork and it may be obtained by proper selection of gradient.

c They prove cheap in construction cost.

d When the traffic increases, they provide good foundation for other type of good road over them.

Disadvantages of earth roads.

a Most of the earth roads in our country are fair weather roads and they become useless in monsoons.

b They are useful for light traffic only.

c They wear out quickly. Hence their repair and maintenance costs are high.

2 Gravel roads

General: A gravelled road consists of a carriageway made of a layer of compacted gravel.

Gravel occurs naturally as rounded particles of many verieties of stone and it is usually associated with finer material which acts as a binder to hold the bigger material. These roads are superior to earth roads and as such, they are considered intermidiate between earth roads and metalled roads.

Following three considerations govern the construction of gravel roads.

a Drainage: The carrage way of the gravel road should be provided with a camber of 1 in 25 to 1 in 30 to achieve good drainage of the road surface.

b Gravel: It should be composed of pebbles which are hard, tough and durable rock particles to resist abrasion. The most durable pebbles come form quartz. But pebbles from hard limestone and good trap are also good material. The least durable pebbles are those from sand stones, shales or soft slates.

c Quality of binder: For making a good road surface, the pebbles should be held together by some cementing material such as clay which is the most generally available binder. But certain gravels occur in nature in which pebbles are held together by either lime or contains high percentage of oxide of iron.

Method of constructions: Following procedure is adopted in the construction of gravel road.

a The material to be used for the construction of road is stacked along the sides of the proposed road. For obtaining a satisfactory gravel surface, the pebbles should be graded in size so as to from a good compact mixture with the addition of a small amount of binder.

b The peg is of driven to show the limits of excavation. The site is cleared and subgrade is then prepared to receive the layer of gravel.

c The first is layer of gravel is spread in the prepared trench. The compacted depth of gravel road is generally 200mm and it is obtained in two layers, each of compacted thickness of about 100mm. The layer is rolled by using smooth wheeled light rollers starting from the edges and proceeding towards the centre. Two rollers may be used on either side and rolling is done in such a way that an overlap of at least half the width of roller is obtained in the longitudinal direction. The use of rollers heavier than 8 tonnes for consolidation is not advisable as the gravel is found to get crushed or the surface to become wavy and corrugated.

d Some quantity of water is sprayed and rolling is done again. It should be seen that the quantity of water to effect consolidation is just sufficient to secure a satisfactory bond between the pebbles and binder without softening the subgrade. The sprinkling of water should be done through a fine nose or nozzle.

e The camber is checked at intervals and it is corrected, if necessary with the help of template or a camber board.

f The final rolling is carried out when the moisture content is at its optimum so that the completed surface which is formed in firm and unyielding.

g There are two types of construction for a gravel road, namely, trench type and feather edge type. Fig 1 shows the trench type construction in which the subgrade is prepared by excavating a shallow depth. Fig 2 shows the feather edge type construction in which the gravel is spread on the existing base without cutting a trench such that the edges are thinner than the centre. In the case of impermeable sub grades, the feather edge type construction provides an easy outlet for the surface water to drain into outlets or sides while in the trench type construction, the water will not get easily and readily drained because the sides of the trench prevent lateral flow of water. However, the gravel will be confined in a better way in trench type construciton and hence, it is generally adopted. When the gravel road is to be formed in more than two layers, it will be advantageous to combine both the methods. The bottom layers may be formed by the trench type construction and the top layer may be formed by the feather edge construction.

h A thin layer of sand of about 5 mm to 10 mm thickness is provided before opening the road to traffic. The newly made surface should be watched carefully for several months and defects developed under traffic should be corrected immediately.

Advantages of gravel roads

a A good gravel road is smooth, somewhat re silient and pleasing in appearance.

b It is found that a well compacted gravel road gives good transaction and is not slippery when wet for moderate speeds.

c The capacity of gravel road may be taken as about 100 tonnes of pneumatic tired vehicles or 60 tonnes of iron tyred vehicles per day lane.

Disadvantages of gravel roads

a They may become impassable, if drainaged is bad.

b They get dusty in dry weather.

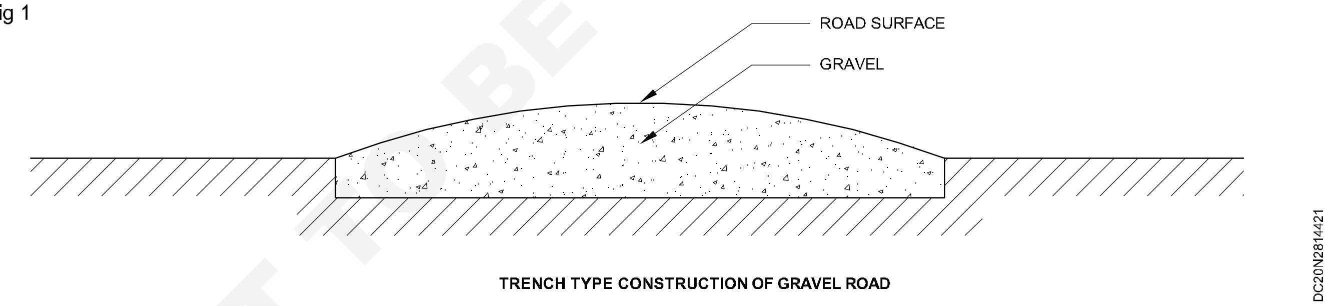
c They require frequent reshaping in the form of filling up pot holes, ruts and depressions.

d They tend to become soft in continuous wet weather.

Water bound macadam roads

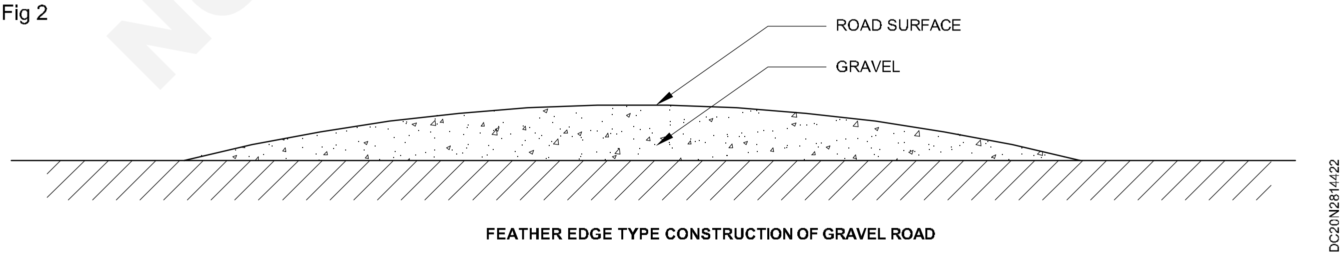
General: The oldest type of highway pavement used in modern, times is known as Macadam after the name of John Macadam, a Scottish Engineer. The term Macadam in the present time means the road surface and bases constructed of crushed or broken aggregates cemented together by the action of rolling and water. The binding action in W.B.M is achieved by stone screening used as filler in the presence of water. Water bound macadam is constructed in thickness varying from 8 to 30 cm depending upon the design requirements. The surface course of W.B.M. gets deteriorated very soon under the action of mixed traffic. So now a days the W.B.M is used as base course for the superior type of pavement such as bituminous or cement concrete surfacing. Generally the layers in W.B.M. are laid in 12 to 15 cm thickness. The total thickness may be upto 30 to 35 cm depending upon the design requirements. Each layer is compacted to 75 to 80% of its loose thickness by smoothed wheel rollers. In W.B.M. roads generally camber is provided of the order 1 in 36 to 1 in 48.

Fig 1



TRENCH TYPE CONSTRUCTION OF GRAVEL ROAD

Fig 2



FEATHER EDGE TYPE CONSTRUCTION OF GRAVEL ROAD

Types of Macadam Road

Macadam roads may be classified into four groups as follows depending upon the method of binding action.

1 **Water bound macadam:** It is the layer of broken stone aggregates bound together by stone dust or screening and water applied during construction, and compacted by heavy smoothed wheel rollers.

2 **Traffic bound macadam:** It is the wearing surface composed of broken stones or gravel, consolidated by the action of traffic. This type of surface generally is built gradually by successive application of two or more layers. The compacted thickness of each layer may very from 2.5 to 5.0 cms.

3 **Bituminous macadam:** It is the compacted layer of clean crushed stone of reasonably uniform in size. Over this layer a second layer of crushed stone together with bitminous material heavily sprayed. Much of the bituminous material penetrates into the voids and binds the stones together. To fill the surface voids of the first course, a uniform thin layer of smaller aggregate is spread and rolled. Then again a light application of bituminous material is applied and a thin layer of smaller aggregates is spread and rolled . This is generally known as penetration macadam.

4 **Cement macadam:** It is similar to bituminous macadam. Only difference is that in this case cement is used in place of bitumen.

Method of construction: Following procedure is adopted in the construction of a W.B.M. road

a The subgrade or base course is prepared to the required grade and camber. The depressions and pot holes on the existing road surfaces are filled up and the corrugations are removed by scarifying and reshaping the surface to the reuired grade and camber as necessary. If W.B.M road is to be provided on existing bituminous surfacing, furrows 50mm*50mm are cut at one metre intervals at 45° to the centre-line of the carrage way, before laying the coarse aggregate.

b For providing lateral confinement of aggregates, the shoulders having thickness equal to the compacted W.B.M. layer should be constructed in advance. Good earth or moorum may be used in the construction of shoulders. They are prepared and rolled so as to retain the road structure between them. The practice of constructing W.B.M. in a bench section excavated in the finished formation must be totally discouraged.

c The coarse aggregates which are stored along the road or which are brought in vehicles are then spread uniformly and evenly upon the prepared base in required quantities. The number of layers and total thickness of W.B.M. road will depend on the details of design of pavement. For ordinary roads, a single layer of compacted thickness 75 mm may be sufficient and for important roads two layers or equivalent 150mm copmacted thickness may be provided. For aggregates having grading no.1 the compacted thickness of layer may be increased to 100mm.

d After spreading the aggregates, the rolling is carried out for compaction. It may be done with the help of a three wheeled power roller of 6 to 10 tonnes capacity or an equivalent vibratory roller. The process of rolling is a skilled operation and on the depends the proper finish of W.B.M. road surface. The roller should pass equally over the entire surface and its speed should be slow and uniform. The rolling should start from the edge of road and it should be taken to the crown. Each successive strip must overlap the preceding strip to avoid formation of weak points. The effects of faulty rolling are.

   i There is formation of corrugations on road surface.

   ii There is unequal finish of the road surface

   iii The road starts wearing out very fast at places where the metal is not properly compacted.

If the road is to be provided with super-elevation, the rolling should start from the lower edge and it should gradually progress towards the upper edge of the pavement.

e After the compaction of coarse aggregates, the screening are applied to fill up the interstices. The screenings are applied in three or more layers and each layer is compacted by dry rolling. The screenings should be spread uniformly. The rolling and booming of each layer of screening should be carried out carefully.

f After the application of screening, the road surfaces sprinkled with plenty of water and it is then swept and rolled. The hand brooms are used to sweep the wet screenings into the voids. The additional screenings are applied and rolled till the coarse aggregates are well bonded and firmly set.

g The binding material is then applied at a uniform and slow rate in two or more successive thin layers. After each application of binding material, the surfaces is sprinkled with plenty of water and the wet slurry formed is swept with the help of hand brooms or mechanical brooms to fill up the voids. This is followed by rolling with a 6 to 10 tonnes roller and during rolling, water is applied to the wheel of rollers to wash down the binding material which has stuck to the surfaces of roller. The process of rolling is continued till the slurry of binding material and water forms a wave ahead of the wheel of the moving roller.

h The road surface is then allowed to cure or set overnight after final rolling. If spots or depression are found on the next day, they are filled up with screenings or binding material, as found necessary and after lightly sparkling with water, they are rolled.

i The road is then opened to traffic. But care should be taken to see that no traffic is allowed till W.B.M. layer sets and dries out. If the road surface is to be coated with bituminous dressing, the W.B.M. layer should be allowed to dry completely before laying the bituminous surfacing over it.

Advantages of W.B.M. roads: Following are the advantages of W.B.M. roads.

a If in good condition it can take a composite traffic of about 900 tonnes per lane day.

b If W.B.M. surfacing is maintained its designed profile and grade by regular repairs, it is found to give service for a long time.

c Their initial cost is low.

d They make use of locally available material and labour.

Disadvantage of W.B.M. roads: Following are the disadvantages of W.B.M. roads.

a Due to depressions on road surface, small water pools are formed. The motor vehicles because of their speed and impact churn these water pools and scatter and the road metal. The bullock cart traffic then grinds this loosened metal into dust particles. This chain of destruction goes on and finally it results in a complete disintegration goes on and finally it results in a complete disintegration of the road surface.

b Poor maintained WBM road causes inconvenience and danger to the traffic.

c Maintenance cost of the WBM road is high.

d The failure of WBM road mainly occurs due to intensive traffic insufficient foundation, poor drainage system, unsuitable broken aggregates, dirty binding material weak launches or suppports for resisting lateral pressure and perviousness of surface.

e They are permeable to rain water and it leads to the softening and yielding of subsoil.

4 Bituminous roads

A bituminous road is defined as a road in which bitumen is used in one form or the other as a binder to keep together the coarse aggregates or road metal. Such a load is also sometimes referred to as black top road because it exhibits a black appearance due to presence of bitumen.

Bitumen

It is a mixture of natural pyrogenous hydrocarbons and their non-metallic derivates which may be solids. Liquid viscous or gaseous but must be completely soluble in carbon disulphide or simply it is a hydro carbon compound in solid or semi-solid state. It is obtained by partial distillation of crude petroleum either by nature or artificially in refinery.

The bituminous material or bitumen in the form of asphalt and tar products is one of the major highway construction materials in the world. The three important qualities of bitumen which have made bitumen a popular binding material are as follows:

i It gives an impermeable surface

ii It has proved an excellent binding material

iii It softens when heated

Method of construction

Surface dressing can be done on a new W.B.M. or an existing surface. If the surface is to be given to a new W.B.M.road surface then in the construction process the bandage and bindage layers are omitted. In this case, the road metals are properly rolled after sprinkling water and the surface dressing is applied.

In case of an old road or existing W.B.M. the surface is recondition, i.e, brought to proper gradient and camber after repairing all defects. It is then cleaned with wire brush so that all dust is removed and the aggregates exposed at least upto a depth of 1.25 cm but they should not be loosened. Surface dressing can be done in a single coat or in double coat. Surface dressing is done only in dry and clear weather at or above the atmospheric temperature of 16°C.

Preparation of Surface: The existing surface is reconditoin as explained above. If the existing base course is made of porous aggregates or stabilized soil, a prime coat is applied.

Application of binder: On the prepared surface a uniform layer of bituminous binder is applied at the suitable rate. Generally 2 kg binder per square metre surface is sufficient. Binder should not be excessive on any portion as it would cause bleeding.

Application on chippings: After spraying binder chippings are spread as per specification in a uniform layer over the entire surface.

Rolling of 1st layer or final coat: Rolling is started from the edge towards the centre longitudinally with overlapping not less than 1/2 of the width of rolling wheel. When the half surface is rolled, then rolling again is started from the other edge. The rolling should be continued till the particles are firmly interlocked. This is called final rolling if single coat is required. If double coat is required the second binder is applied to the prepared surface and chippings spread as per requirement. Finally it is rolled.

Finishing: The surface so prepared is checked for its cross profile etc. and opened to traffic after 24 hours.

Advantages of bituminous roads

Following are the advantages or good qualities of bituminous roads which are responsible for making them very popular and for granting them a distinct place as an important flexible pavement in highway engineering:

i Depending upon the method of construction, they considerably increase the strength of pavement.

ii The cracks are not formed on the surface of bituminous roads and the surface can be prevented from splitting.

iii The maintenance costs of bituminous roads are comparatively less.

iv The surface of bituminous roads is non-slippery.

v They can effectively resist the adverse effects or rain, changes in temperature and wind.

vi They grant water proof surface.

vii They provide smooth, durable and comfortable road surface for traffic.

viii They resist the detrimental action of moisture of the underlying layers of soil as well as water used during construction.

ix When the bituminous layer is provided on the top of an existing low coat road, it eliminates the dust nuisance.

Disadvantages of bituminous roads

1 Costly in construction.

2 If the bituminous materials is in excess over the optimum value for a given mix it becomes harmful to the good performance of the bituminous roads.

3 The viscosity of the bitumen-aggregate mixture plays a great role in determining the performance of bituminous roads. So the control of the quantity is absolutely necessary. It is tedious during mixing.

Rubberized asphalt concrete road

It is modified method of construction used instead of bituminous road, for improving the quantity of road pavement.

Rubberized asphalt concrete (RAC) also known as asphalt rubber or just rubberized asphalt is a pavement material that consists of regular asphalt concrete mixed with crumb rubber-ground. It is used for pavement construction and such road are known as rubberized asphalt concrete road.

Advantages of rubberized asphalt concrete road

1 Reduces reflective cracking in asphalt overlays.

2 Reduces the maintenance costs.

3 Improves resistance to cracking in new pavements.

4 Improve pavement life.

5 Skid resistance is more when compressed to the other pavement.

6 Reduces the road noise.

5 Cement concrerete roads

General

The cement concrete roads are in the form of monolithic slabs of cement concreter which serve two functions simultaneously, namely as the load carrying base and as the wearing surface. According to the structural behaviour, the pavements can be classified as flexible pavement or rigid pavement. The bituminous concrete is one of flexible pavement layer material. Various other types of bituminous roads are considered as flexible pavements. The cement concrete roads, on the other hand, are treated as rigid pavements because of their rigidity. The cement concrete road provides a highly rigid surface and hence, for the success of such roads, the following two conditions should be satisfied.

i They should rest on non-rigid surface having uniform bearing capacity.

ii The combined thickness or depth of the concrete pavement and the non-rigid base should be sufficient to distribute the wheel load on a sufficient area of the sub-base so that the pressure on unit area remains within the permissible safe bearing capacity of the soil.

Definition

Concrete roads are the roads in which the carriage way is made up by a concerte slab of required thickness and strength.

Construction procedure for cement concrete roads

Following procedure is adopted for the construction of cement concrete roads

1 **Preparation of sub grade and sub base:** The sub grade is the natural soil on which the concrete slab is laid. It must be cleaned, shaped and levelled. It is properly and uniformly compact with roller. On the prepared sub grade an insulating layer of 75mm thick sand is provided.

2 **Placing of forms:** The form may be of steel or timber. The steel forms are of mild steel channel sections and their depth is equal to the thickness of the pavement. They are usually in 3m length. The timber forms are dressed on side. They should be firmly nailed to the stakes to resist the pressure of concrete.

3 **Watering the prepared sub grade or sub base:**

After the forms are fixed, the prepared surface to received concrete is made moist. It is advisable to wet the surface at least 12 hour in advance of placing the concrete.

4 **Mixing and placing of concrete** The ingredients of concrete are mixed in proper proportion in a dry state. Gereally 1:2:4 mixes us used with proper water and cement ratio. The mixing should preferable by done in concrete mixer.

5 **Compacting and finishing:** After the concrete is placed in its position it should be brought in its proper position by a heavy screed or temper fitted with suitable handles the straight edging and refloating are continued until the entire surface is true to camber and grade.

6 **Belting booming and edging:** The surface is further finished by a rubber or canvas belt 150mm to 3000mm wide and to sufficient length longer than the width of the road. It fitted with handles at both ends. It is desired to have a rough surface the booming is carried out by a fibers broom brush after belting. Before road surface is opened to traffic brick edging is constructed to protect the slab.

7 **Curing:** After 12 hours or so finished surface is covered with wet gunny7 bags for duration of 4 hours. The surface is kept thoroughly wet for 14 days.

8 **Opening to traffic:** The expansion joints are suitably finished. The edges of road are provided with suitable shoulders of macadam, hard moorum or bricks.

The edging protects rthe road slab. The road is then opened to traffic after 28 days of consolidation and finishing of concrete or when the concrete attains the required strength.

Methods of construcion of cement concrete roads

The cement concrete roads can either be constructed in single course or in two course. In single course pavement,the entire depth of concrete is composed of homogeneous material. In two course method, the concrete is laid in two courses or layers of equal or differrent depth with different composition of concrete.

Following are the three methods of construction of cement concrete roads:

1 Alternate bay method

2 Continuous bay method

3 Expansion joint and strip method

1 **Alternate bay method:** In this method, if the road is of single lane, it is divided into suitable bays of 6m to 8 m length and the construction work is carried out in alternative bays as shown in Fig 3.

If the road is of double lane, the construction work is carried out in odd bays of one lane and even bays of the other lane as shown in figure. The construction of next bays is commenced after the concrete laid in earlier bays dries out i.e. nearly after one week or so (Fig 4).

Fig 3

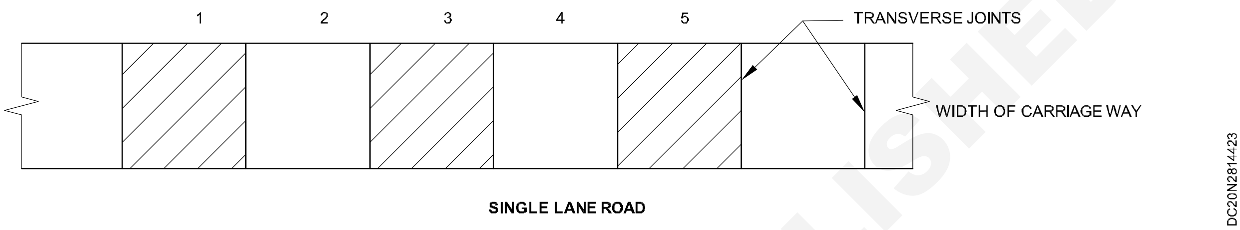
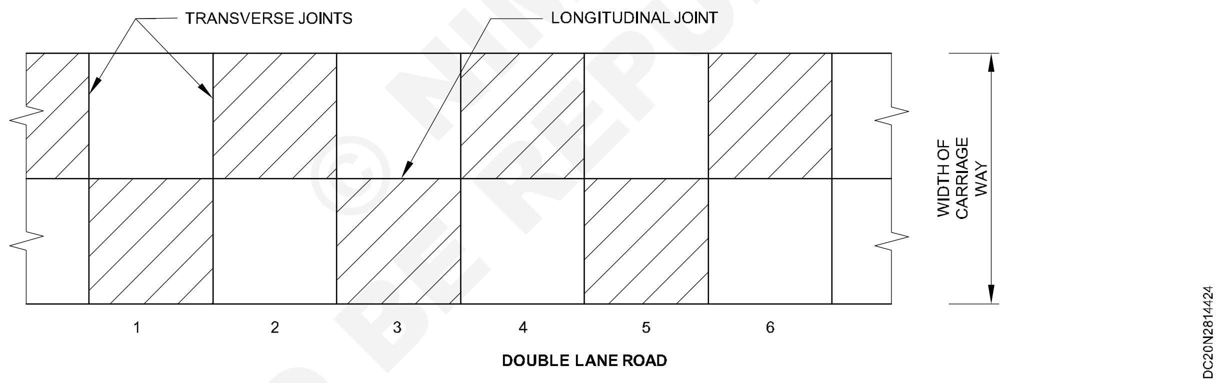


Fig 4



2 **Continuous bay method:** This is also known as strip method or full width method. The entire width of the road is constructed continuously from one end to the other. No provision for expansion joint is made. However, a construction joint is provided where the new concrete meets the previously laid concrete.

This method is suitable for roads having width not exceeding 4.5m and it is very simple in construction.

However, it does not stand a high temperature variation as no provision is made for expansion and contraction.

It also requires the provision the provision of a temporary diversion road since the entire road with is under construction. This method is generally not favoured (Fig 5).

3 **Expansion joint and strip method:** In this method the road is divided into longitudinal strips and transverse bays by means of timber formwork as shown in Fig 5.

The joints are then suitably filled up with fillers like asphalt and finished so as to provide for the expansion of the concrete slab.

By this method, any width of road can be constructed at ease and it gives better alignment and finish. It also carries the traffic during construction and hence, no temporary diversion road is necessary. There has been considerable improvement in the technology of joints in concrete roads and hence, most of the modern concrete roads are constructed by this method.

Advantages of cement concrete pavement

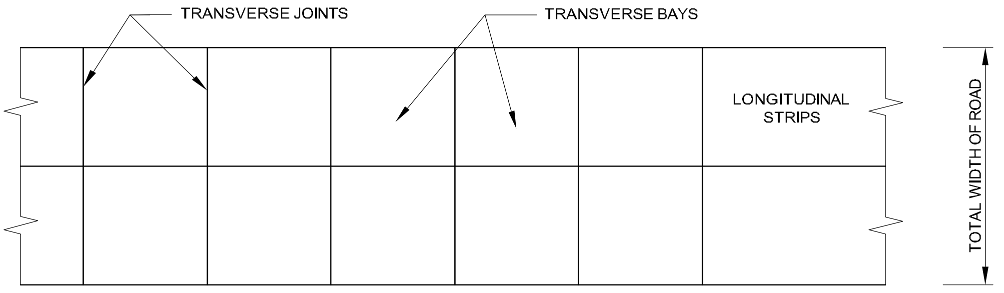
1 It provides a good riding surface.

2 Life of cement concrete pavement is more i.e., between 30 to 40 years.

3 Maintenance cost is low.

4 The vehicle operation cost is minimum.

Fig 5



LONGITUDINAL JOINT, EXPANSION JOINT AND STRIP METHOD

5 Tractive or rolling resistance is low.

6 It provides high night time visibility.

Disadvantages of cement concrete pavement

1 Initial cost of construction is very high

2 It requires skilled person for construction

3 Construction time required is more

4 It takes more time for opening to traffic after construction.

Requisite of a good road

A good road surface irrespective of material used for construction should possess the following characteristics

1 It should remain dry throughout the year

2 It should have good carriage way

3 It should have smooth gradients, smooth and large curves

4 It's initial cost and maintenance cost should be minimum

5 It should have a good impervious wearing surface.

6 It should contain erected traffic signs and should make sufficient provision for the safety of pedestrians and vehicles

7 It should grand various amenities to the road used such as sufficient lighting, watering, fuelling places, shady avenues parking facilities etc.

8 The curves along the road should be properly designed.

9 The formation of road should be stable enough to carry the foundation and traffic load.

10 It should possess not slippery surface

11 It should neither dusty nor muddy and easy for cleaning and repairing.

12 It should offer least resistance to traffic.

Curves - Types - Designation

Objectives : At the end of this lesson you shall be able to
- **define curve**
- **explain the different types of curves**
- **enumerate the elements of simple curve.**

Introduction

It is neither practicable nor feasible to have straight highways in a country. Their alignment require some changes in direction due to the nature of the terrain, cultural feature or other unavoidable reasons. Such changes in direction cannot be at sharp corners but have to be gradual which necessitates the introduction of curves in between the straights.

Curves

Curves are the regular bent or curved path provided in the line of communication, say railway or highway alignment.

A curve may be either circular, parabolic or spiral and is always tangential to the two straight directions at its ends.

Necessity of providing curves

Curves are provided at the change in alignment or gradient of a road due to the following reasons.

a To lay the road according to topography of the country.

b To avoid costly land.

c To avoid excessive cutting and filling.

d To avoid certain important structures.

e To make use of the existing road, bridges etc.

f To provide access to the particular place.

Types of curves

A horizontal curve is a curve in plant to provide change in direction to the central line of a road. The minimum radius of a horizontal curve depends on the permissible design speed for the road. The values of minimum radii for various categories of roads in different areas, recommended by the I.R.C. are given in table.

The following types of horizontal curves are used in the alignment of highway

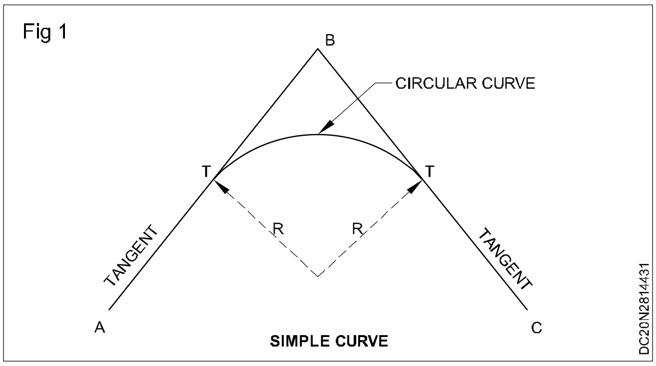
a Simple curve

b Compound curve

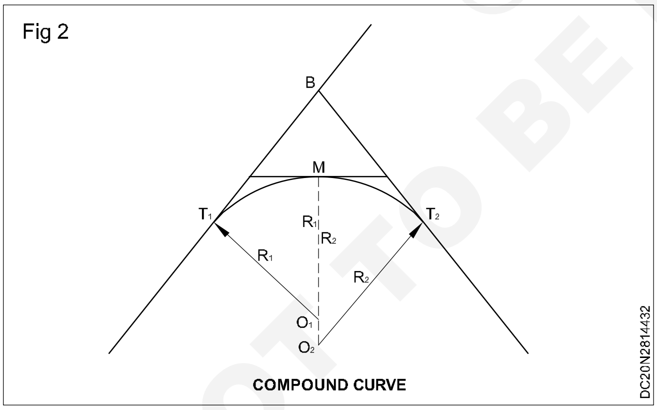
c Reverse curve

d Transition curve

a Simple curve: It is a circular curve which consists of a single arc of uniform radius. It is tangential to both the at straights AB and BC. (Fig 1).

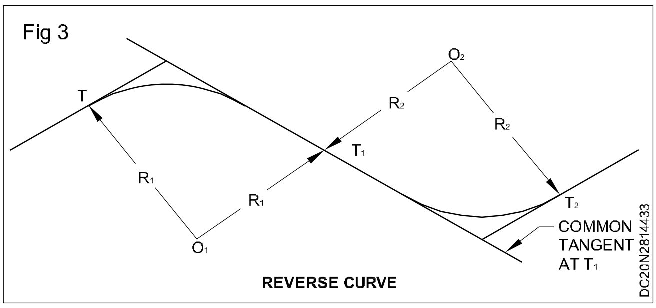


b Compound curve: This is a circular curve which is comprised of a series of two or more simple curves of different radii which turn in the same direction. This type of curve is used to avoid cutting through hard rocks, heavy cutting or filling etc. Refer fig. T_1 M and MT_2 are two adjacent simple curves of radius R_1 and R_2 respectively and have a common tangent a M (Fig 2).



c Reverse curve: This is circular curve consisting of two simple curves of same or different radii which turn in the opposite direction. These curves are suitable for highways lying in hilly regions. Refer Fig 3 T and T_1T_2 are two adjacent simple curves having a common tangent at T_1 and their centres lie on opposite side of the curve.

d Transition curve: A transition curve is the curve having a radius which decreases from infinity at the tangent point to a designed radius of the circular curve. This type of curves is generally introduced on highway between a straight and circular curve to provide ease and gradual change in direction of a road alignment.



Objects of providing transition curve

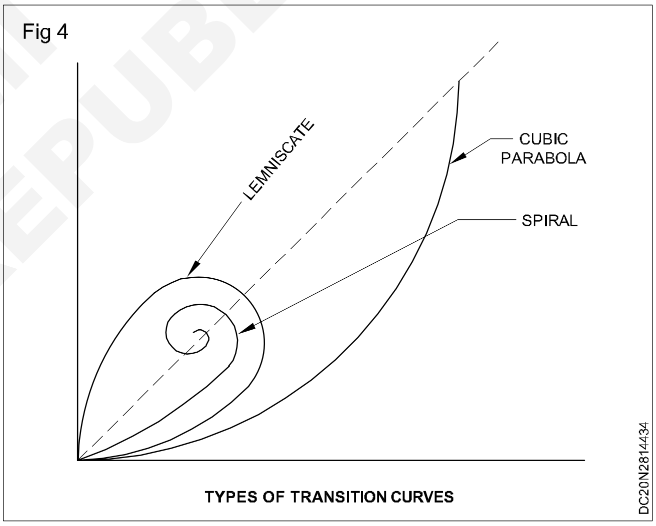
a To provide gradual and easy transformation from straight to circular curve and from circular curve to the straight roads

b To provide a gradual change of curvature from zero at the tangent point, to that of circular curve at their junction point.

c To enable gradual introduction of the designed super elevation and extra widening of pavement at the start of the circular curve.

d To improve the aesthetic appearance of the road.

Types of transitions curves (Fig 4)



The following types of transition curves are commonly adopted in horizontal alignment.

a Lemniscate

b Spiral

c Cubic parabola

The shapes of three curves are shown in Fig 4 out of the three transition curves, the I.R.C. has recommended the used of spiral in the horizontal alignment of highway.

Vertical curves

Vertical curves are the curves provided at the intersections of different grades in the vertical alignment of highway. This is introduced to smoothen out the vertical profile and thus to ease off the changes in gradients for the fast moving vehicles.

Types of vertical curves

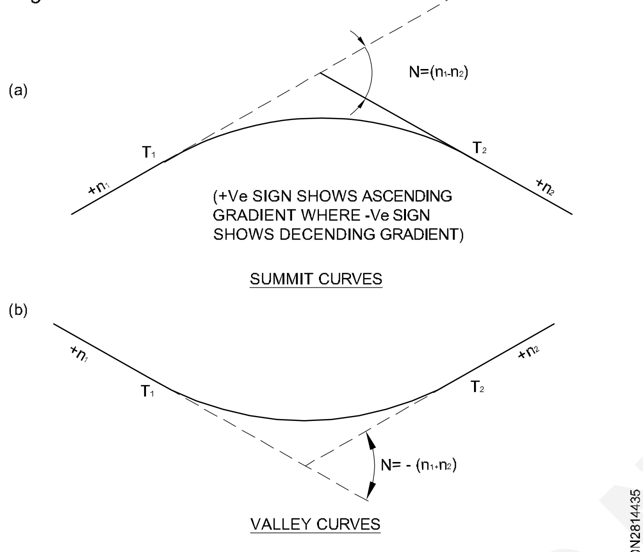
Vertical curves are of two types

i a Summit curves

ii b Valley curves

Summit curves: Summit curves are vertical curves having their convexity upward. The centrifugal force will act upwards against gravity when a fast moving vehicle travels along a summit curve and there will be no problem of discomfort to the passengers. At the time of designing the length of summit curve the stopping sight distance and overtaking sight distance are considered separately (Fig.5).

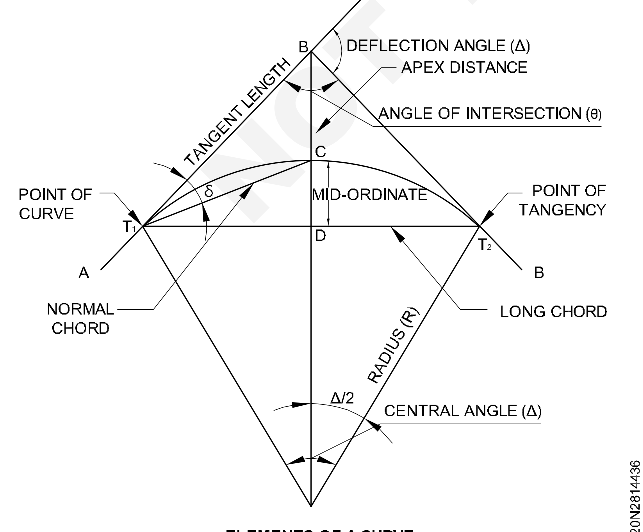
Fig 5



TYPES OF VERTICAL CURVES

Valley curves: Valley curves are vertical curves having their convexity downward. This is also called sag curves. At the valley curves the centrifugal force acts downwards adding to the pressure on the suspensions in addition to the self weight of a vehicle moving on the curve. Hence the design of valley curve is governed by the allowable rate of change of centrifugal acceleration (Fig 6).

Fig 6



ELEMENTS OF A CURVE

1 **Back tangent:** The tangent T_1I tangent T_1I at T_1, the point of commencement of the curve, is called 'back tangent'.

2 **Forward tangent:** The tangent IT_2 at T_2, the end point of the curve is called 'forward tangent'.

3 **Point of intersection:** The point where back tangent when produced forward and the forward tangent when produced backward meet, is called the point of intersection.

4 **Angle of intersection:** The angle between the back tangent IT_1 and the forward tangent IT_2, is called the angle of intersection of the curve.

5 **Angle of deflection:** The angle through which forward tangent defects, is called angle of deflection of the curve. It may be either to the right or to the left (It is denoted by Δ.)

6 **Point of commencement:** The point T_1 where the curve originates from the back tangent, is called the point of commencement of the curve. It is also sometimes known as point of the curve.

7 **Point of tangency:** The point T_2 where the curve joints the forward tangent, is called point of tangency.

8 **Deflection angle to any point on the curve:** The angle between the back tangent and the chord joining the point of commencement to that point on the curve, is called deflection angle of the point. In fig.7 the deflection angle to the point A is IT_1A which is generally denoted by Δ.

9 **Tangent distances:** The distance between the point of intersection and point of commencement of the curve, or the distance between the point of intersection and point of tangency, are called the tangent distances.

10 **Length of the curve:** The total length of the curve from the point of tangency, is called length of the curve.

11 **Long chord:** The chord joining the point of the commencement and point of tangency, is called long chord.

12 **Mid - ordinate:** The ordinate joining the mid point of the curve and long chord, is called mid - ordinate.

13 **Normal chord:** A chord between two successive regular pegs on the curve, is called a normal chord.

14 **Sub - chord:** When a chord is shorter than the normal chord, it is called a sub - chord. These sub - chords generally occur at the beginning and tat the end of the curve.

15 **Apex - distance:** It is the distance between the center curve ie apex to the point of intersection of simple circular curve.

Minimum radii of horizontal curves as per I.R.C

S No	Road classification	Minimum radii of horizontal curves (metres)											
		Plain terrain		Rolling terrain		Mountainous terrain				Steep terrain			
						Area of affected by snow		snow bound area		Area of affected by snow		snow bound area	
		Ruling	Absolue	Ruling	Absolute	Ruling	Absolute	Ruling	Absolute	Ruling	Absolute	Ruling	Absolute
1	National and State high ways	360	230	230	155	80	50	90	60	50	30	60	33
2	Major district road	230	155	155	90	50	30	60	33	30	14	33	15
3	Other district roads	155	90	90	60	30	20	33	23	20	14	23	15
4	Village roads	90	60	60	45	20	14	23	15	20	14	23	15

Curves - Simple curve by successive by section of long chord and by offset from long chords

Objectives : At the end of this lesson you shall be able to
- **describe the method of designation of curves**
- **enumerate the different method of setting out simple circular curve**
- **explain the method of successive by section of long chord**
- **explain the method of offset from long chord.**

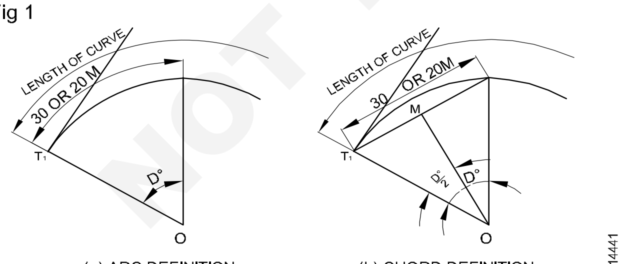
Designation

A simple circular curve may either be designated by radius (in feet, meters of chains) or by degree of the curve. The former system is adopted in UK and Australia, whereas that latter is in use in U.S.A., Canada, France and India.

Degree of curve

The degree of a curve can be defined either on the basis of an arc or a chord. According to the arc definition, the degree of a curve is defined as the central angle by an arc of 30 or 20 m length Fig 1a,b. According to the chord definition, chord of 30 or 20 m length.

Fig 1



(a) ARC DEFINITION (b) CHORD DEFINITION

DEGREE OF CURVE

In highways, it is customary to use the arc definition whereas the chord definition is utilized in railways.

Setting out a simple circular curve

Setting out a curve means locating various points at equal and convenient distances along the length of a curve. The distance between any curve. The distance between any two successive points is called peg interval. Since it is impractical to ,easier the peg interval along the arc, it is measured along the chord. Also,, if the chord length is less than 1/20 of the radius of the curve, the length along the chord is very nearly equal to the length of the arc. Usual peg intervals are of 20 or 30 m, but for sharp curves it may be reduced.

Let the chainage of the point of curve T_1 be m + n (i.e m chains + n links). Then, the first point on the curve will be at m+1 chains. The first chord, therefore, will be a subchord, so as to make the first point a full station. If the chainage of T_1 is M, then the first chord because a normal chord. The last chord will be a sub-chord and its length will depend upon the length of the curve and the chainage of the point of tangency T_2 For example, let the chainage of T_1 be 1845.5 m, let the length of curve be 740m and let the peg interval be 30 m. To make the first point on the curve a full station, a multiple of 30 m next to the chainage of 1845.5 m, i.e., 1860 m, is selected. Therefore, length of the fist sub-chord is 1860 - 1845.5 = 14.5 m. The remaining length of the curve = 740 - 14.5 = 725.5 m. Thus, the number of full chords = 725.5/30 = 24.183 (24+5.5). Hence last sub - chord =5.5m.

The method of setting out a simple circular curve are broadly classified as linear and angular methods. In the former method, only a chain or a tape is used and no angle measuring instrument is used. In the latter method, an angle measuring instrument, such as a theodolite, with without a chain/tape is used. The angular methods are preferred since they are more accurate.

Before setting out a curve in the field, the P.I., the P.C., and the point of tangency. P.T. are located. When the curves are setting out by using theodolite, first of all, P.I.. is located and a theodolite, is set up and leveled over it. The telescope is directed towards one of the straights and is transited by 180°. The telescope is then swing towards the other straight. The deflection angle can be noted from the horizontal scale reading of the theodolite. The tangent length is calculated by the formula

$$T = R\tan\frac{\Delta}{2}$$

The points, T_1 and T_2 can by established at

tangent length distances from the P.I. by providing line of sights along the two straights.

Linear methods

The various linear methods of setting out a simple circular curve are

1 Offsets from the long chord

2 Perpendicular offsets from the tangent

3 Radial offsets from the tangent

4 Successive bisection of arcs

5 Offsets from the chord produced.

Angular methods

Following angular methods are commonly used for setting out curves.

1 Rankin's method of deflection angle (one-theodolite method)

2 Two-theodolite method

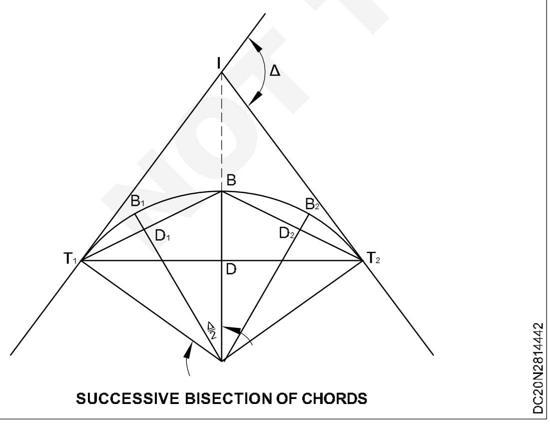
3 Tacheometric method.

Setting out a simple circular curve

Linear method Successive bisection of arcs

chords (Fig 2)

Fig 2



SUCCESSIVE BISECTION OF CHORDS

This is a simple method of setting out circular curve by linear operation. After fixing the tangent point T_1T_2, measure the length of long chord. Then the long chord T_1T_2 is bisected at D by any of the convenient method. Calculate the length of mid - ordinate by applying the formula

$$0_0 = R^2 - \left(\frac{L}{2}\right)^2 orR\left(1 - Cos\frac{\Delta}{2}\right)$$

To obtain the position of the point B, erect a perpendicular offset equal to mid - ordinate at 'D'. Now consider T_1B and T_2B independent portions of the curve having T_1B and T_2B as long chords. Divide T_1B and T_2B at D_1 and D_2 respectively.

It can be proved that offsets B2D2 are equal where

angle T_1OD_1 and T_2OD_2 are equal to $\frac{\Delta}{4}$

To locate B1 and B2, erect perpendicular offsets equal to

$R\left(1 - \text{Cos}\frac{\Delta}{4}\right)$ or calculate the corresponding mid

Coordinate as per, T1B, T2B as long chord by the linear formula,

$0_0 = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$ from D_1 and D_2 By

Further successive bisection of the chord T_1B_1, B_1B, BB_2, and B_2T_2 may obtain the location of other points on the curve.

Field operations : To set out a curve by successive bisection of chords, the following steps may be followed.

1 Locate the position of T_1 and T_2.

2 Measure T_1T_2 and find its mid point D.

3 Set out the perpendicular offset DB With an optical.

Square equal to $R\left(1 - \cos\frac{\Delta}{2}\right)$orR $- \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$

4 Measure chords T_1B and T_2B and find their mid points D_1 and D_2 respectively.

5 Set out the perpendicular offsets D_1B_1 and D_2B_2, each.

equal to $R\left(1 - \cos\frac{\Delta}{2}\right)$ with an optical square or

$R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$ where L is equal T_1B

6 The process may be continued till sufficient till sufficient number of points on the curve are fixed.

Note the following points may be noted.

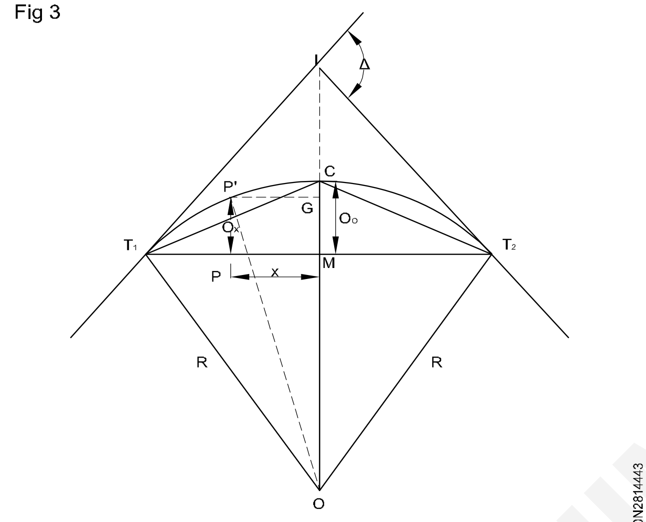
i Accuracy of the work depends upon the number of bisection of chords.

ii The length of $T_1B = T_2B = \sqrt{(T_1D)^2 + (BD)^2}$

Offsets from the long chord (Fig 3)

Let T_1 and T_2 be point of commencement and tangency of the curve, radius of curve is 'R' and centre of the curve is 'O' and let it be required to lay a curve, T_1CT_2. between the two intersecting straight T_1I and T_2I.

Fig 3



OFFSETS FROM THE LONG CHORD

T_1T_1 is the long chord =L;

Oo is the mid-ordinates and Ox the offset at a point 'P' at a distance 'x' from the mid-point (m) of the long chord.

From triangle OMT1

$$OM = \sqrt{\left(OT^{2}{}_{1} - MT^{2}{}_{1}\right)}$$

$$= \sqrt{\left(R^2 - \left(\frac{L}{2}\right)^2\right)}$$

Now, CM = OC - OM

or O_0 = R - OM

$$\text{or } O_0 = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

$$OG = \sqrt{\left(R^2 - X^2\right)} \text{ and } OM = R - O_0$$

The required offset

PP' = OG - OM The required

$$\text{Hence , } PP' = \sqrt{\left(R^2 - X^2\right) - \left(R - O_0\right)}$$

$$\text{or } O_X = \sqrt{\left(R^2 - X^2\right) - \left(R - O_0\right)} \text{ (exact expression)}$$

$$= R\left(1 - \frac{X^2}{R^2}\right)^{1/2} - R + O_0$$

$$= R\left(1 - X^2/\left(2R^2\right) + ... \;..\right) - R + O_0$$

OX = ordinate from a point ‘x’ distance from mid point m

$$= O_0 - \frac{X^2}{2R} \text{ .... approximate expression)}$$

By assigning different values to x, the corresponding values of offset ox can be calculated. The calculated offsets can be laid from the long chord and points can be established in the field which when joined produce the required curve.

Field operation To set out a circular curve with offsets from the long chord, the following steps are followed.

1 Erect ranging rods at T1, and T2

2 Divide the long chord T1T2 in equal parts of suitable length.

3 Calculate the lengths of the offsets corresponding to distances from the mid - point of the chord.

4 Erect perpendiculars with the help of an optical square and measure the calculated offset lengths. Along these perpendicular line and fix the required points of curves.

Road Margins - Shapes

Objectives : At the end of this lesson you shall be able to
- **define the term road margins**
- **describe the elements of road margins.**

Road margins

Road margins are the portions of land on either side of road way of a road. The various element included in the road margins are parking lane, frontage road, driveway, cycle track footpath guard rail and empavement slopes.

Elements of Road margins

Following are the various elements which are included in the road margins.

1 Cycle tracks

2 Driveways

3 Embankment slopes or side slopes

4 Footpaths

5 Frontage roads

6 Guard rails

7 Parking lanes

8 Shoulders

1 **Cycle tracks:** These are provided in urban areas where the volume of cycle traffic on the road is very high. A minimum width of 2 m is provided for the cycle track and it may be increased by 1 m for each additional track.

2 **Drive ways:** These connect the highway with commercial establishment like fuel stations, service stations etc. These should be properly designed and located, fairly away from an intersection.

3 **Side slopes or embankment slopes:** Side slopes are the slopes provided to the sides of earthwork of a road in embankment or in cutting for its stability. Side slopes in a road are so designed as to keep the earth work stable in embankment or in cutting. The nature of soil in earthwork, climatic condition, method of drainage provided etc. are the factors which affects the design of side slopes.

4 **Embankment:** Slopes are also provided for aesthetic reasons and improve the journey more pleasant.

5 **Foot paths:** These are also known as side walks and they are provided in urban roads with heavy vehicular as well as pedestrian traffic. They grant safety to the pedestrians and reduce the chances of accidents.They are usually placed on either side of the road with minimum width of 1.30 m and it can be increased depending on the volume of pedestrian traffic. surface of footpaths should be made smooth and comfortable as compared to that of adjacent traffic lane so that pedestrians are encouraged to use the footpaths.

6 **Frontage roads:** For granting access to properties situated on important highways, it becomes necessary to provide frontage roads. These roads run parallel to the highway and they are attached to the highway at selected points, preferably with grade separations.

7 **Guard rails:** When the height of hill exceeds 3 m, the guard rails are provided on the edge of shoulder so that the running of vehicles from the embankment is prevented. These are various forms and designs of guard rails in common use.

8 **Parking lanes:** For important urban roads, the provision is sometimes made for parking lanes which will allow on - street or kerb parking. If such lanes are not provided, the effective width of road will be decreased by the haphazard parking of vehicles. It is preferred to have parking lane parallel to road as compared to parking lane inclined to road.

9 **Shoulders:** Shoulders are the portions of the roadway between the outer edges of the carriageway and edges of the top surface of embankment or inner edges of the side drains in cutting. These are provided along the road edge to serve as an emergency lane for vehicle required to be taken out of the pavement or roadway. Shoulders also act as service lanes for breakdown vehicles. Minimum shoulder width of 4.6 m is desirable so that a vehicle stationed at the side of the shoulder would have a clearance of 1.85 m from the pavement edge.The minimum shoulder width recommended by I.R.C. is 2.5 m.

Camber - super elevation - sight distance - gradient

Objectives: At the end of this lesson you shall be able to
- **define camber**
- **explain super elevation**
- **discribe sight distance**
- **express gradient.**

Camber (Fig 1)

Camber is the transverse slope provided to the road surface to drain off the rain water from the road surface. It is also called cross - slope. One the straight roads camber is provided by raising the centre of the carriageway with respect the edges, thus forming a highest point or crown on the centre line of the carriageway. At horizontal curves camber is provided by raising the outer edge of the carriage way instead of raising centre. The rate of camber usually designated by 1 in n which means that the transverse slope is in the ratio of 1 vertical to n horizontal. Amount of camber mainly depends on.

i Type of road surface

ii Amount of rainfall

Camber should be just sufficient for the efficient drainage of rain water from the road surface. For pavements like cement concrete or bituminous concrete flat camber is enough. For sufaces like water bound macadam or earth road steeper camber is required as these allow surface water to get into the subgrade soil. Excessive camber is not desirable because of the following reasons.

i Rapid flow of water results into formation of cross cuts.

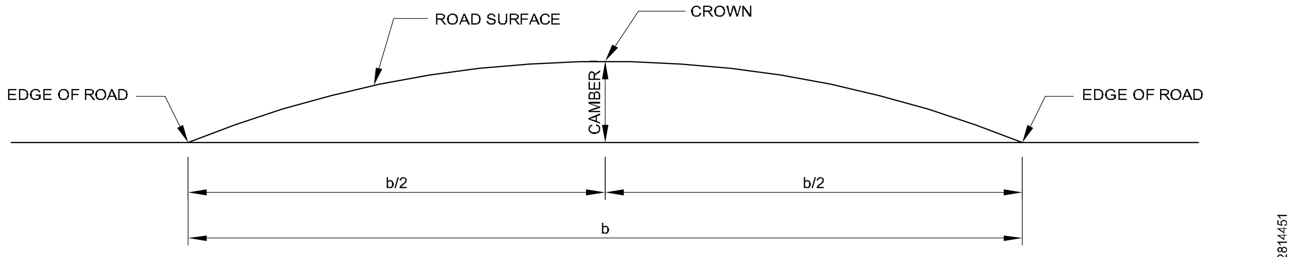
ii Problems of toppling over of highly laden bullock carts.

iii Due to excessive camber there is tendency of most of the vehicles to travel along the centre line.

iv During overtaking operation, vehicles tend to drag, causing uncomfortable conditions.

v Faster wear of the road surface along the edges than the central part.

Fig 1



CAMBER OR CROSS-FALL OF ROAD SURFACE

Necessary for providing camber

1 To prevent entry of moisture or water into the sub grade soil which will affect the stability or rod base.

2 To remove water from road surface so as to make it non slippery for the safe driving of vehicle at high speed.

Super elevation: When a fast moving vehicles negotiates a horizontal curves the centrifugal force acts on the vehicle from inside towards the outside of the curve and hence the vehicles has a tendency to overturn and skid. In such situation the outer edge of the pavement is raised with respect to the inner edge.

Rate of camber

Sl.No	Type of Road surface	Range or rates of camber	
		Slope 1 in n	Percentage or road width
1	Earth	1 in 25 to 1 in 33	4.0 to 3.0
2	Water bound macadam and gravel	1 in 33 to 1 in 40	3.0 to 2.5
3	Thin bituminous surface	1 in 40 to1 in 50	2.5 to 2.0
4	Cement conc, and high type bituminous surface	1 in 50 to 1 in 60	2.0 to 1.7

Super elevation is the inward transverse slope provided throughout the length of the horizontal curve by raising the outer edge of the pavement with respect to the inner edge. This is also called cant or banking and is generally denoted by 'e'.

It is provided to counteract the effect of centrifugal force and to reduce the vehicles to overturn or skid, when it is moving on the horizontal curve.

Advantages of super elevation

Following are the advantages of providing super - elevation on curves.

i It ensure smooth and safe movements of passengers and goods on the road.

ii In introduce the centripetal force to counteract the effect of the centrifugal force and hence, faster movement of vehicles on curves can safely be permitted.

iii It results in the increase of volume of traffic.

iv The maintenance cost or road on curve is reduced.

v There is decrease in the intensity of stresses on the foundation of road.

vi The water can be drained off easily because there is no necessity of providing drains of the outer edge of the road.

Sight distance (S.D) or visibility (Figs 2,3&4)

Sight distance is the actual distance along the road at which a driver has visibility of stationary or moving objects then a specified height above the carriageway. In other words, it is the length or road visible ahead to the driver at any distance.

On straight road, there is no problem or obstruction to the visibility. But sight distance may have been obstructing due to sharpness of horizontal curve, by objects obstructing vision at the inner side of the road or at vertical summit curves or road intersections, as shown in Fig 2.

Sight distance is an important aspect of road geometric design. The following sight distance situations are considered in the design.

i Stopping sight distance (Fig 3).

ii Passing sight distance or overtaking sight distance.

iii Sight distance at intersection(Fig 4).

iv Crossing sight distance.

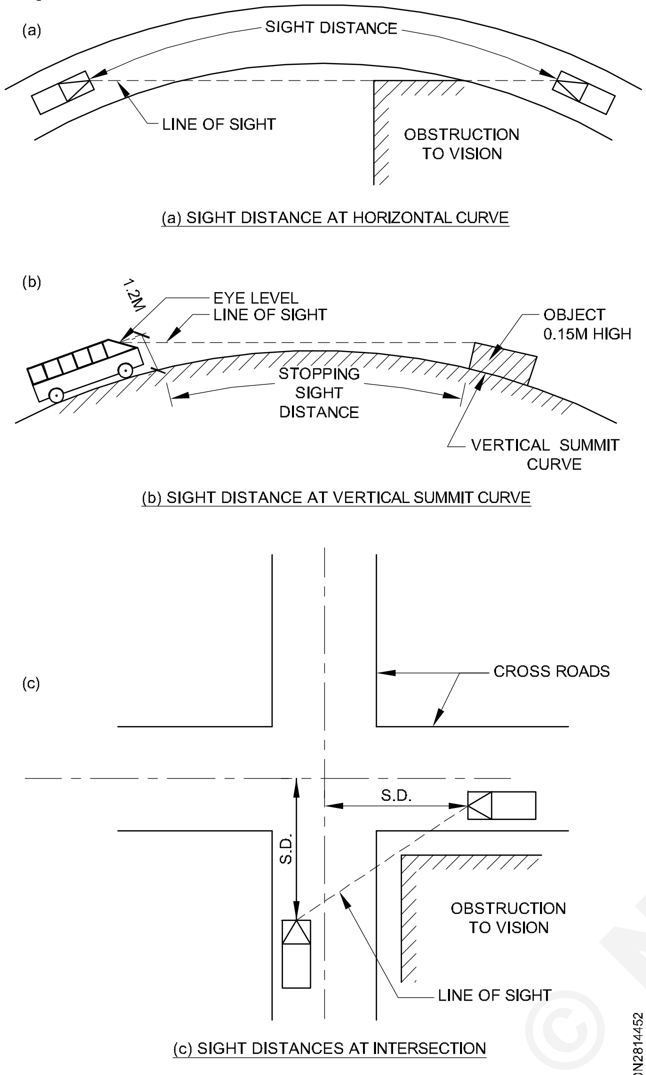
Apart from the above sight distances, the following sight distances are considered by the I.R.C in highway design.

v Intermediate sight distance

vi Head light sight distance.

i Stopping sight distance: Stopping sight distance is the minimum sight distance available on a road to stop vehicle without collision. This is also sometimes called non - passing sight distance.

Fig 2



SIGHT DISTANCE AT DIFFERENT SITUATIONS

The sight distance available on a road to a driver at any instance depends on

i Features of the road ahead, i.e., the horizontal alignment and vertical profile of the road, traffic condition and position of obstruction,

ii Height of the object above the road surface.

iii Height of the driver's eye above the road surface. I.R.C has suggested the height of eye level of driver as 1.2m and the height of the object as 0.15m above the road surface for the purpose of measuring stopping sight distance.

The stopping sight distance depends upon the following factors

i Total reaction time of the driver

ii Speed of vehicle

iii Efficiency of brakes

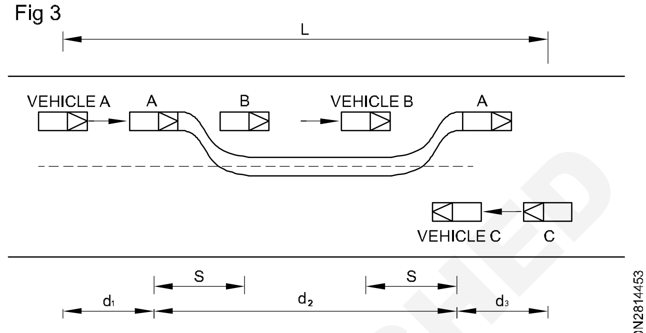
iv Slope of road surface

v Frictional resistance between the road and the tyres.

ii **Overtaking sight distance:** All the vehicle on a road do not move at the same speed and hence the problem of overtaking slow moving vehicle by fast moving vehicle is a common phenomena on all the roads.

The overtaking sight distance (OSD) may be defined as the distance required by a vehicle to overtake with safely another vehicle travelling, in the same direction. The OSD is also sometimes referred to as the passing sight distance (Fig 5).

Fig 3



OVERTAKING SIGHT DISTANCE

Sight distance at intersections: It is necessary to provide the necessary sight distance at important cross roads, especially uncontrolled ones, for avoiding accidents due to collusion of vehicles. For this purpose, the construction of buildings at the corners of roads should be allowed only after leaving sufficient margin form the boundary of road, as shown in Fig 6 Thus the unobstructed sight triangle with two sides as equal to sight distance and one side as sight line will be formed.

The design of intersections with respect to traffic control is governed by the installation of necessary traffic signs, devices to reduce speeds, etc. But from the consideration of sight distance, the following three possible conditions should be studied.

I.R.C. has recommended a minimum sight distance of 15m along the minor roads and for major roads, the minimum sight distances of 110 m, 180 m and 220 m are recommended for design speeds of 50 km p.h., 65 km, p.h., 80 km p.h. and 100 km p.h. respectively;

Crossing sight distance: On roads if two vehicles crossing in opposite directions on seeing each other they have to reduce their speed to unable each other to use the pavement edges or shoulders safety. This distance required for a vehicle to come stop is called crossing sight distance.

Road gradient

Definition the ground is never dead flat and level. Hence the road will have to be provided with rises and falls along its length. The rate of this or fall is called the gradient or glade. Thus the road gradient indicates the slope in longitudinal direction.

The road gradient is usually expressed as 1 in n, i.e., 1 vertical in n horizontal. Thus, if the road surface falls 2 m in 200 m horizontal distance measured along the length of a particular road, the road gradient in the portion of road length is said to be 1 in 100. It is also sometimes.

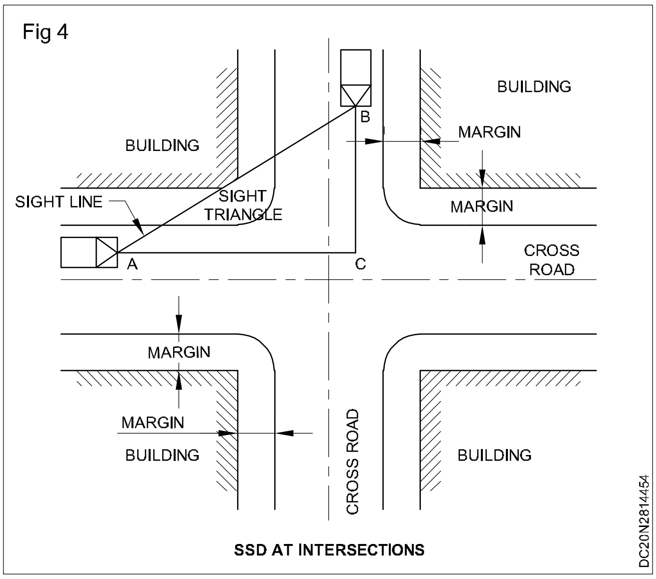


Fig 4

SSD AT INTERSECTIONS

Expressed as a percentage, i.e. $1 \times \frac{1}{100}$

In the above case gradient is 1 in 100 or 1 percent

Types of gradients: The road gradients are divided in the following six categories for the purpose of convenience

i Average gradient

ii Exceptional gradient

iii Floating gradient

iv Limiting gradient

v Minimum gradient

vi Ruling gradient

Each category will now be briefly described.

i Average gradient: The total rise or fall between any two points on the road divided by the road length is known as the average gradient and it is helpful in carrying out paper location or preliminary survey. It also assists in preliminary stages to determine the approximate length of the highway especially in hilly country.

ii Floating gradient: At certain points along the road, there is a combination of rise and fall. If a vehicle is descending a grade at constant speed and comes across an ascending grade such that it maintains the same speed without any attractive effort or without any application of the brakes, then such a gradient is known as a floating gradient.

iii Limiting gradient: A gradient which must never be exceeded in any part of a road is called the limiting gradient or maximum gradient. It should be provided for short stretches of road and as it can be covered by the vehicle due to its momentum, it is also sometimes referred to as momentum gradient. If the limiting gradient is continued for a long distance, it will result in the following undesirable effects.

a It will be very inconvenient for the pedestrians and animals.

b The load carrying capacity of vehicles will be reduced.

c There will be considerable loss of tractive power

d The road surface will wear out quickly due to high velocity of surface water.

e The wear and tar of vehicles using the road will increase especially due to braking action while going down the slope.

iv Minimum gradient: It has been found from practical considerations that the road with zero gradient or flat road is not efficient in removal of surface water of road. It is therefore necessary to provide a certain minimum gradient to achieve the purpose of easy drainage of road surface and its amount will depend on the nature of ground, rainfall, type of road surface and other site conditions. The value of minimum gradient is usually fixed at 1 in 200 or 0.5 percent.

vi Ruling gradient: The permissible gradient in the alignment of highway is called the ruling gradient and its value is fixed in such a way that all vehicles, whether animal driven or power driven, can overcome long distances of road without much fatigue or uneconomical fuel consumption. In fact, this is the gradient for which the road is designed and hence, it is also sometimes known as design gradient. The value of ruling gradient depends on various factors such as type of traffic, nature of ground, condition of the carriageway, presence of horizontal curves, etc. It is not possible to lay down precise standards of ruling gradient which will be applicable for the mixed traffic and for the country as a whole.

Table shows the ruling, limiting and exceptional gradients recommended by the I.R.C . for roads in different terrains.

Gradient of roads in different terrains

No	Type of terrain	Gradient		
		Ruling	Limiting	Exceptional
1	Plain or rolling	3.3% (1 in 30)	5% (1 in 20)	6.7% (1 in 15)
2	Mountainous terrain and steep terrain having elevation more than 3000 m above the mean level	5% (1 in 20)	6% (1 in 16.7)	7% (1 in 14.3)
3	Steep terrain upto 3000 m height above mean sea level	6% (1 in 16.7)	7% (1 in 14.3)	8% (1 in 12.5)

Road Drainage System

Objectives : At the end of this lesson you shall be able to
- **state drainage and surface drainage**
- **state four shapes of surface drainage.**
- **different types of road side drain**
- **drainage in rural/highway - urban hill**
- **function & design of culvert**
- **surface drainage system for highways.**

Drain

Collecting of sullage and storm water is called drain.

Surface drains

They are sometimes constructed to provide cheap arrangement for collecting impurities of water (sullage and storm water).

The following are the four shapes of surface drains are used in construction.

1 Rectangular surface drains

2 Semicircular surface drains

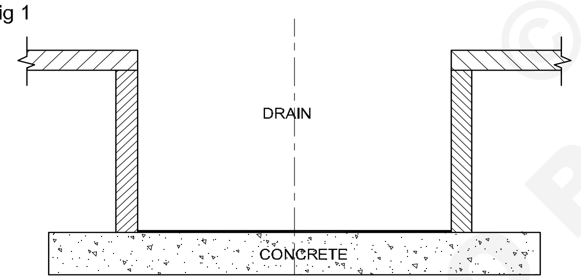
3 'U' shaped surface drains

4 V-shaped surface drains

1 Rectangular surface drains (Fig 1)

- It is suitable for carrying heavy discharge.
- It will not develop the required velocity when depth of flow is small and therefore it is easily deposited.

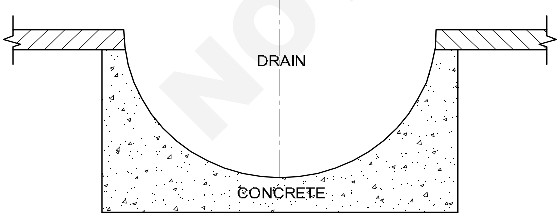
Fig 1



RECTANGULAR SURFACE DRAIN

2 Semicircular surface drains (Fig 2)

Fig 2

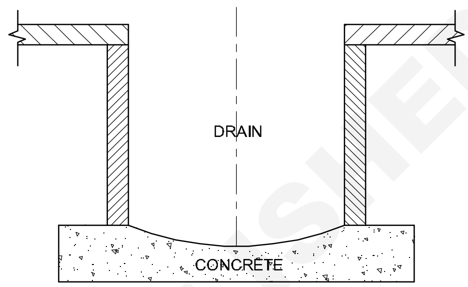


SEMI-CIRCULAR SURFACE DRAIN

- These are constructed easily.
- These drains are so formed by using readymade semicircular section of stone ware, concrete or asbestos cement pipes.
- These drains are suitable for small streets where the discharge is of small quantity.

3 'U' shaped surface drain (Fig 3)

Fig 3

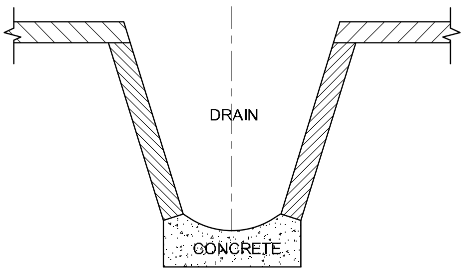


U - SHAPED SURFACE DRAIN

- It is in the form of letter 'U' in shape and therefore it is known as 'U' shaped surface drain.
- It is easy in construction
- It is the combination of semicircular drains and rectangular surface drains.
- The side of 'U' shaped drains are vertical.
- The bottom surface is curved.

4 'V' shaped surface drains (Fig 4)

Fig 4



V - SHAPED SURFACE DRAIN

- These drains are better in hydraulic properties.
- They are difficult to construct.
- These drains are in the shape of letter 'V' and therefore it is called as 'V' shaped surface drains.
- These drains will carry the fluctuating discharge without depositing solids at any point.
- During fair weather the less volume of sullage will be available on the bottom portion of the drain.

- These drains will be able to capable of producing a good velocity.

The surface drainage may be divided into 3 categories:

- **Drainage in rural/road highway (Figs 5, 6, 7)**

There is the provision of side drains in these areas which are generally open, unlined and trapezoidal cut to suitable cross section and longitudinal slopes. Camber is applied to the pavement to drain the surface water and has to drain across the shoulders which are provided with more cross. slope. Usually, drains are provided on one or both sides in embankments while drains are provided on bothsides in case of roads with cutting. Open drains are dangerous in the places where space is restricted in cutting and hence covered drains are used with layers of coarse sand gravel.

Fig 5

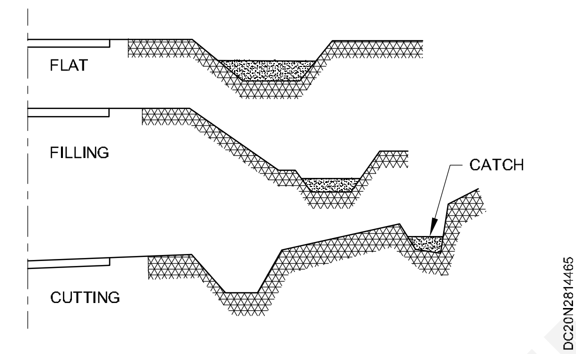


Fig 6

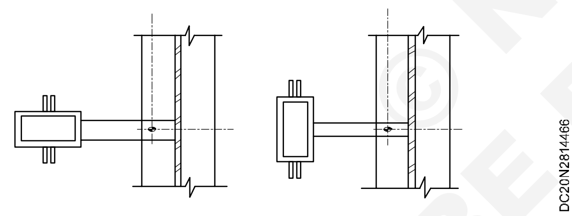
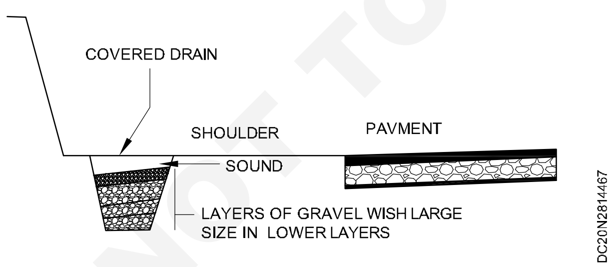


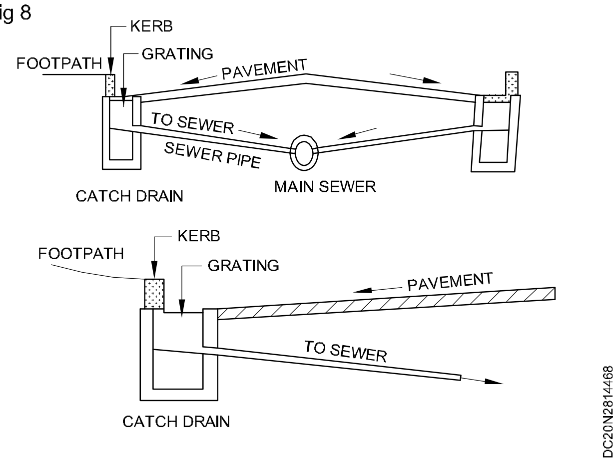
Fig 7



- **Drainage in urban roads (Fig 8)**

In urban roads, underground longitudinal drains are provided due to the limitation of land width, the presence of foot path, dividing island and other road facilities. This is provided where there is less number of natural water courses and in the presence of impervious surfaces. Water is collected in the catch pits at suitable intervals through the underground drainage pipes carried forward in the longitudinal direction between the curb and pavement.

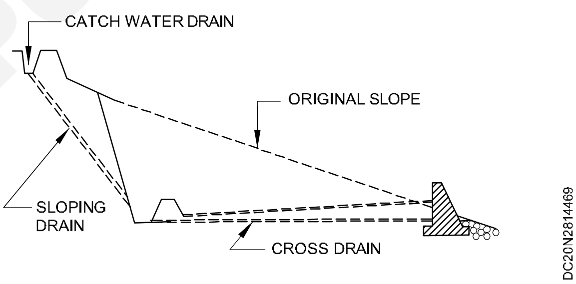
Fig 8



- **Drainage in hill roads (Fig 9)**

In hill roads, there are complex drainage problems. Water flowing down the hill has to be efficiently intercepted and disposed of downhill side by construction suitable cross drainage works. Catch water drains at the upper hill side, sloping drains and cross slopes are provided to drain out the water whereas side drains are provided only at the hill side. If hill roads are not properly drained, rockslides and slips may occur blocking the road during monsoon. The shapes of the side drains is made in such a way that vehicles can park at that space during emergency, crossing

Fig 9



or parking.

Cross drainage structures (Culverts and others)

Cross drainage structures are those structures which are provided whenever streams have to cross the roadway facility. The water from the side drains is also often taken across these structures in order to divert the water away from the road to a water course or a valley.

The different types of cross drainage structures are:

- Culverts
- Bridge
- Causeways
- Aqueduct
- Inverted siphon
- Culverts

A closed conduit placed under the embankment to carry water across the roadway is termed as culverts. Im NRS 2070, culverts are the bridging structures of linear waterway span less than about 6m. It is extensively used in road drainage system. In fact, more than 75% of the cross drainage structures are culverts. Culverts are more preferred than minor bridges because a bridge surface forms a part of a carriageway whereas the top of the culvert is always beneath the carriageway. A culvert is more hydraulically efficient than minor bridge and discharge through a culvert is more than a minor bridge. Bridges are designed to pass floating debris or vessels while culverts are designed for full flow under certain conditions.

Functions of culverts

The functions of culvert are:

- Collection and transport of water across the road so as to not cause damage to the road bank or the stream bed by scouring.
- To provide sufficient waterway to prevent heading up of water above the road surface.

Design of culverts

The design of culvert is a very complex work as it requires engineer's interpretation of field data and his personal judgment. The design of culverts requires the board knowledge of hydrology, hydraulics, and structural mechanics as well. Location of the culvert is based on the waterway shape. Once the locations and flow condition are set, the size of culvert can be easily determined to pass flood safely and efficiently. The culvert is designed regarding many aspects like comparative cost, suitability for the particular location, availability of materials, labours, etc. which must be properly judged by the engineer. The alignment of culvert during design should be close to that of the natural waterway in plan and profile. Culverts are designed to skew or right angled to the highway alignment. A skew design has more length so requires more construction cost so right angled design is more preferred. Diversion structures can be used to divert the strem so that right angled one can be used instead of skew. But they are chosen according to the economic consideration.

The design is done using capacity charts. It is a chart which correlates head of flow, discharge, and size of the culvert. For a given discharge, the size of the culvert is chosen from which head of flow is calculated. If the head of flow satisfies conditions of free flow then the size of the culvert is chosen otherwise the process is revised.

Parts of culverts

A culvert consists of mainly 3 parts:

- Inlet structure
- Culvert barrel
- Outlet structure

Culverts are laid depending on the type of the foundation which may be sand bedding, PCC, RCC, etc. RCC is used for weak soil conditions and sand bedding for pipe culverts. All the other culvert are generally made of PCC.

Introduction to bridge engineering

Objectives : At the end of this lesson you shall be able to
- **define a bridge and explain its purpose**
- **identify the component parts of a bridge**
- **illustrate the factors, which influence the choice of bridge**
- **enumerate the characteristics of an ideal bridge**
- **describe the points to be noted while aligning a bridge.**

Definition

A bridge is a structure providing passage over an obstacle such as valley, road, railway - line, canal, river etc. without closing the way beneath. The required passage may be for road, railway, canal, cycle track or tramway.

Purpose

1 Enable the free flow of traffic.

2 Provide additional communication facilities.

3 Provide more socio - economic benefits to the people.

4 Also enable movement of troops and military vehicles during hostilities.

Component parts of bridges (Fig 1&2)

1 **Abutments:** These are end supports of the superstructure of a bridge.

2 **Piers:** These are the intermediate supports of a bridge super structure.

3 **Foundation:** These are the structures which distribute the dead loads of the superstructure, piers and abutments along with the live loads which come on bridge over a large area of the sub - soil.

4 **Wing - walls:** These are the walls constructed on both the sides of the abutments to retain the embankment of approaches and also to protect them form the wave action of the stream water.

5 **Approaches:** These are the construction works on both the sides of the bridges to carry road or railway line up to the bridge.

6 **Span:** It is the centre to centre distance between two supports. The clear distance between two supports is known as clear span.

7 **Apron:** Layer of concrete, masonry stone etc. laid like flooring at the entrance outlet of culvert to prevent scour.

8 **Railings:** These are the short parapet walls or railings along the road or railway on both sides to prevent the persons or vehicles from falling from the bridge or culvert.

9 **Bearings:** These are the supports provided to the super structures of the bridge at the abutment and piers allowing for longitudinal angular movement to the main girders of the bridges.

10 **Clearance:** A water clearance (horizontal) is the minimum distance between the specified position on a bridge.

11 **Liner waterway:** It is the length which is available in the bridge between extreme edge of a water surface at the highest flood level time measured at right angle to the abutment faces.

12 **Free board:** It is vertical difference between the H.F.L. and the level of line passing through the crown of the road structure at its lowest point.

13 **Highest flood level (H.F.L):** It is the level of the highest flood ever recorded of a river or stream.

14 **Low water level (L.W.L):** It is the minimum water level of the river or stream in dry weathers.

15 **Ordinary flood level(O.F.L):** It is the flood level which normally occurs in the river or stream every year.

16 **Afflux**: It is the rise in the level of the river water level caused due to the obstruction by the bridge.

17 **Water - way:** The cross sectional area through which the water flows under a bridge is known as the water way of the bridge.

18 **Scour:** The vertical cutting of river - bed is known as scour.

19 **Run off:** The portion of the rain fall on a catchment area which flows to water course is known as run - off.

20 **Catchment area:** It is the area from which rainfall flows in to a drainage line, out fall or reservoirs, etc. The boundary line of this basin is called the water shed.

21 **Cribs:** It is the temporary pier made in the river bed.

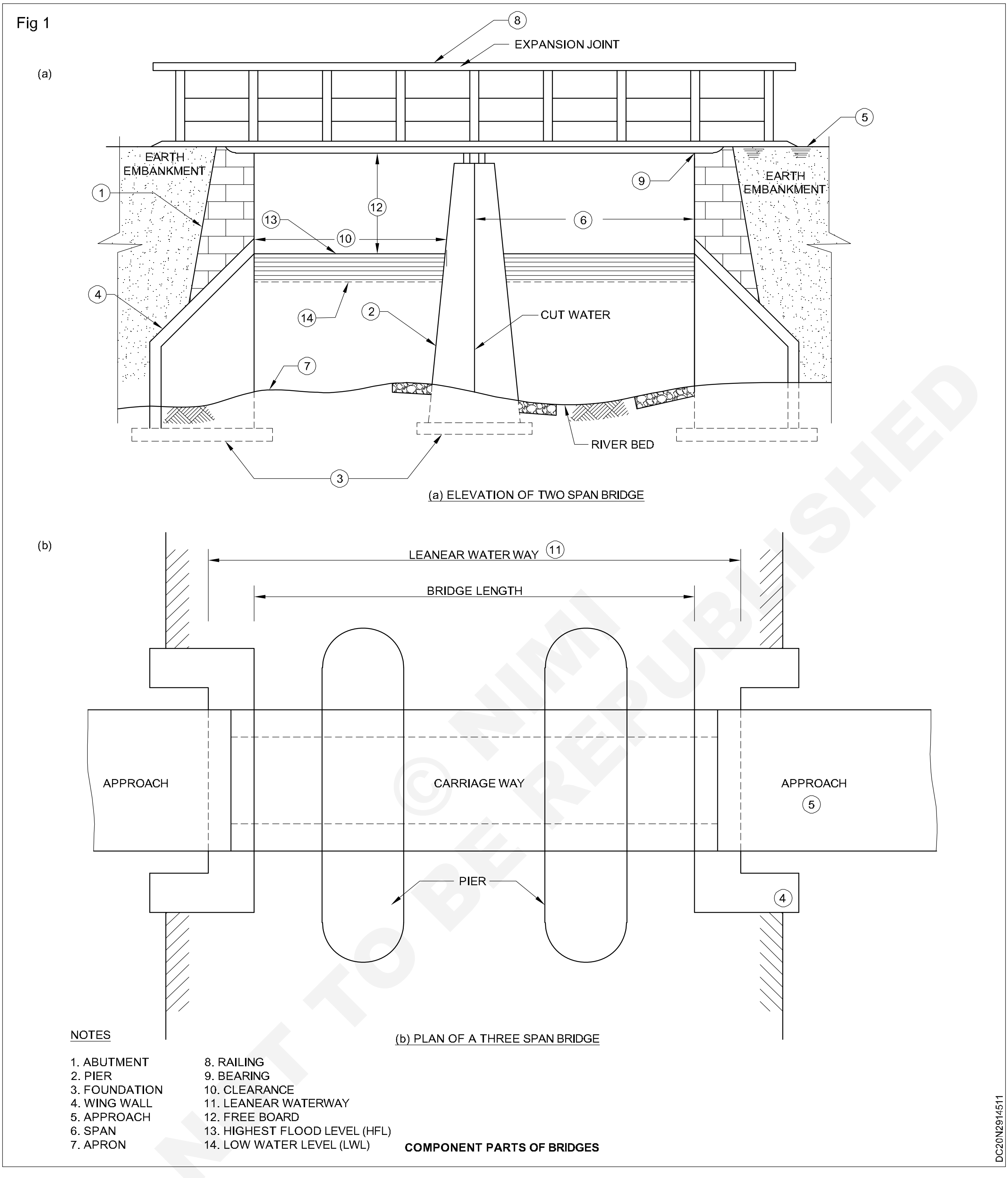
22 **Deck bridle:** The bridge having the carriage way constructed near the top level of the main supporting members of the superstructure.

23 **Kerb - inlet:** It is the apertures formed in a kern for conveying the storm water to a gulley.

24 **Sub - Structure:** The piers, abutments and wing walls along with their foundations as a whole, which support the superstructure of the bridge

25 **Water cushion:** It is a pool of water constructed on the downstream side of the dam, chute drop or other spilway structure and acts as cushion to absorb the impact of falling water.

Fig 1



COMPONENT PARTS OF BRIDGES

26 Revetment: This is made of stones or concrete blocks or mattresses, placed on the bottom or banks of a river for minimizing and controlling the erosion.

27 Scuppers: It is a miniature form of causeway which extends across the entire widtth of the formation.

28 Road Clearance: It is the distance between the maximum width and depth of moving vehicle and the structure.

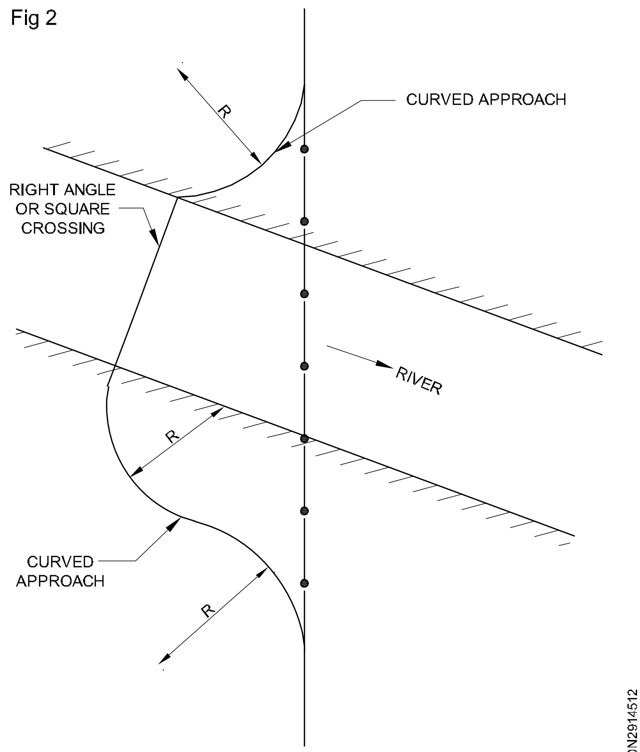
Selection of bridge site

An ideal site for a bridge across a river should have following characteristics.

1 At bridge site the reach of the stream should be straight.

2 The site should be geologically sound i.e. it should be away from fault zone, and should have unyielding, non erodible foundation for abutments and piers.

Fig 2



LAYOUT OF APPROACHES

3 At the site, the stream should be narrow with well defined and firm banks.

4 At site the river flow should be without whirls and cross currents.

5 At the site should be suitable high banks above high flood level on each side.

6 The approaches should be economical. They should not be very high or long or liable to flank attacks of the river during floods. They should be free from obstacles such as hills, frequent drainage crossings, built up areas, sacred areas as grave yards, or trouble some land acquisition etc.

7 The site should be at reasonable proximity to a direct alignment of the road to be connected.

8 There should be no sharp curves in the approaches,

9 Absence of costly river training works, where they are unavoidable they should be executed in dry as far as possible.

10 Avoidance of excessive under water construction work.

11 If it is un - avoidable necessary for the approaches of the bridge to cross the spill zone of a river, they should (while proceeding through the spill zone towards the river,) face down stream and not up stream. facing up stream will cause heading up, pocket formation, and danger to the approaches.

In reality ideal site never exists. Hence atleast objectionable site should be selected. Therefore to select such a site investigations for a number of probable alternative sites should be carried out.

Bridge alignment

After the site of bridge is decided, the next step is to set out or align the centre - line of bridge. Following aspects or the bridge alignment should be carefully studied.

1 Alignment on curve

2 Control of highest flood level

3 Effects of sitting and scouring

4 Layout of approaches

5 River training works

6 Skew bridge

1 **Alignment on curve:** Alignment on curve in hilly areas, it is not possible to avoid the alignment of bridge on a curve. In such cases, it is necessary to adopt R.C.C. or steel griders for the superstructure and it should be seen that the axis of each pier is nearly parallel to the centre line of river.

2 **Control of highest flood level:** The highest flood level or H.F.L of river plays a great role in fixing the height of bridge. It is possible to control H.F.L. either by diversing the extra flood water or by constructing a storage reservoir on upstream side of the river. It is found that with controlled H.F.L., the design of bridge with adverse alignment can be accurately made.

3 **Effects of silting and scouring:** necessary precautions should be taken along the bridge alignment to bring down the effects of silting and scouring to the minimum possible extent.

4 **Layout of approaches:** If the existing road alignment is such that it results in an inclined alignment, the curved approaches may be adopted, as shown in fig.3 to form right - angle or square crossing. The layout of approaches is made with suitable curve radii so as to cause the least inconvenience to the traffic using such approaches.

5 **River training works:** If necessary, the river training works should be carried out to form what are known as the nodal points i.e. points of minimum displacement in a system of stationary waves, along the bridge alignment. A nodal point is defined as the location where the river regime does not normally shift. The natural nodal points are established by the river flow over the years. The channels of the river shifting its course at the nodal points will be minimum and thus, the stability of the structure is insured. For this purpose, it is desirable to carry out experiments on the models to decide exactly the location of artificial river training works along the river.

6 **Skew bridges:** As far as possible, the skew bridges should be avoided. However, if it is not possible to adopt the right - angle crossing, great care should be taken in the design and execution of skew bridges. Analysis and design of a skew bridge, especially when the skew angle is more than 15^{o}, are more complicated and rigorous than those of a right - angled bridge. The conditions which force the adoption of skew bridges are excessive cost of land, acquisition for approaches, existing road alignment, length of bridge, nature of flow, importance of bridge, etc.

Foundation of bridges Selection - Caisson

Objectives : At the end of this lesson you shall be able to
- **define the foundation of bridge**
- **describe the essential requirements of bridge**
- **describe types of foundations.**

Foundations for bridges

The foundations are required to distribute equally and uniformly the total load of the bridge on the soil. The design of bridge foundation in general should conform to the standard specification and code of practice for bridges prescribed in IRC bridge code section - 7 (IRC:78 - 2000). In this chapter, brief description of the foundations for bridges in particular will be given.

Essential requirements of a good foundation

following are the three basic requirements to be fulfilled by a foundation to be satisfactory:

1 Location

2 Stability

3 Settlement

1 Location

The foundation structure should be so located that it is able to resist any unexpected future influence which may adversely affect its performance. This aspect requires careful engineering judgement.

2 Stability

The foundation structure should be stable or safe against any possible failure.

3 Settlement

The foundation structure should not settle or deflect to such an extent so as to impair its usefulness. It is, however, difficult to define the objectionable amount of settlement or deflection. It should also be seen than the differential settlement is so limited as not to cause any damage to the structure.

The term differential settlement is used to indicate the non - uniform settlements of different points of the same foundation or of two independent foundations. It is mainly due to prevailing foundation bed condition at site.

The above three requirements are independent of each other and for the foundation structure to be satisfactory, all three conditions should be simultaneously satisfied.

Types of foundations

The bridge foundations can be divided into the following three catagories.

1 Spread foundations

2 Pile foundations

3 Caisson and cofferdams.

1 Spread foundations

The spread foundations are sometimes referred to as the open foundations as the construction work is to be carried out in open excavation. In case of spread foundations, the concrete footing is provided with suitable projections. As the construction work is to be carried out in open, the spread foundations are adopted where depth of water is not more and good soil is available at shallow depth.

Following two precautions should be taken in the design of spread foundations

i It should be seen than no tension develops between the foundation bed and soil. For this purpose, it should be verified that the resultant force on the footing passes through the middle - third portion of the base.

ii The projections of concrete footing will be functioning as cantilevers and they will be subjected to uniform or non - uniform resistance from soil. In cases where reinforcement is not used, the depth of these projections should be such that bending moment and shear force due to cantilever action are safely resisted by them.

In actual practice, the different sections of the concrete footing are assumed by reference to similar bridges. The effects of various forces on them is then calculated. The most suitable section is then adopted.

2 Pile foundations

The term pile foundation is used to describe a construction for the foundation of bridge piers which in turn is supported on the piles. The piles may be placed separately or they may be placed in the form of a cluster throughout the length of the pier. The pile foundations are adopted when the loose soil extends to a great depth. The load of the structure is transmitted by the piles to hard stratum below or it is resisted by the friction developed on the sides of piles. The piles are generally driven vertically or in near vertical position.

3 Caissons

The word caisson is derived from the French word caises meaning a box. In civil engineering, a caisson is defined as a structure which is sunk through ground or water to exclude water and semi - fluid material during the process of excavation of foundations and which subsequently becomes an integral part of the substructure.

Uses of caissons

Following are the uses of caissons

i To reach the hard bearing stratum for transferring the load coming on supports for bridge piers and building columns.

ii To serve as an impervious core wall of earth dams, when placed adjacent to each other.

iii To provide an access to a deep shaft or a tunnel.

iv To provide an enclosure below water level for installing machinery, pump, etc.

Cofferdam and caisson

The main difference between a cofferdam and a caisson is that the former is a temporary structure while the latter forms the part of the permanent work. Following factor are to be considered while making a choice between cofferdam and caisson for a particular foundation work.

i A cofferdam becomes uneconomical in cases where the plan area of the foundation work is small as compared to the depth of water. Under such circumstances, a caisson would prove to be the most suitable.

ii At places where the cofferdams cannot be dewatered successfully, the caissons are used. This may be due to the following reasons.

  a depth of water,

  b nature of soil to be penetrated, and

  c permeability of soil below foundation level.

iii The process of constructing a cofferdam is greatly simplified in cases of soils which allow easily the driving of sheet piles. The caissons, on the other hand, are useful where obstructions or boulder would prevent the successful driving of the sheet piles.

iv For heavy foundation works which are to be provided at a depth of about 12 metres to 15 metres below the level of standing water surface, the caissons would prove to be more economical than the cofferdams.

Material used for the construction of caissons

The common materials which are usually employed for the construction of a caisson are as follows.

1 Cast - iron

2 Reinforced cement concrete

3 Steel

4 Timber

1 Cast - iron: The cast - iron is suitable for caissons of open well type. New segments of cast - iron are bolted as the caisson sinks. This material is unsuitable for pneumatic caissons as there is risk of failure due to tension developed by the compressed air. The cost also work out to be more in relation to the steel or R.C.C.

2 Reinforced cement concrete: The reinforced cement concrete is suitable for caisson shoes. This material has more weight and therefore it creates difficulties in handling and floating the caisson in the early stage of construction. It therefore becomes economical to construct a steel caisson with concrete filling.

3 Steel: The steel is found to be the most suitable material for the construction of a caisson. It is usually in the form of a double skin of steel plating and the hollow space is then filled with cement concrete.

4 Timber: The timber was used as a material for the construction of a caisson in the early stages of development of a caisson. But this material is now practically not adopted mainly because of its bulk and the risk of fire.

Classification of caisson (Fig 1)

The caisson are classified in the following way

Wells

A well is a caisson which is open at top as well as at bottom. It is provided with a cutting edge at the bottom so as to facilitate sinking. The shape of a well is generally decided by the requirements of the superstructure, vertical and horizontal forces on well, base of the pier or abutment, cost of sinking, changes of tilting and shifting during execution, etc. Fig 2 shows the common shapes which are adopted for the wells.

The circular well has the following advantage

i It has the minimum perimeter for a given dredge area and hence, the ratio of sinking effort to skin friction is maximum.

ii The sinking of well is more uniform as compared to other shapes because the perimeter is equipment at all points from the centre of the dredge hole.

The only drawback of a circular well is that it causes more obstruction to the waterway than the bridge pier. It is due the fact that the diameter of well is much more in the direction parallel to the span of the bridge to accommodate the bridge pier. A double - D shape is more economical than a single circular well for large piers as it has small dredge area. A twin circular well aims at combining the advantages of a circular well and a double - D well.

when few intermediate piers are to be constructed, the dimension of a single well become excessive due to heavy loads.In such cases, instead of a single well, a number of wells is provided. The pockets formed are used as dredging wells and the size and layout of these dredging units mainly depend on the nature of soil through which the well has to pass. If the number of wells is two, it is known as a twin well and two wells may be combined to form and elliptical well in plan. If the number of wells is very large, a monolith is formed.

Fig 1

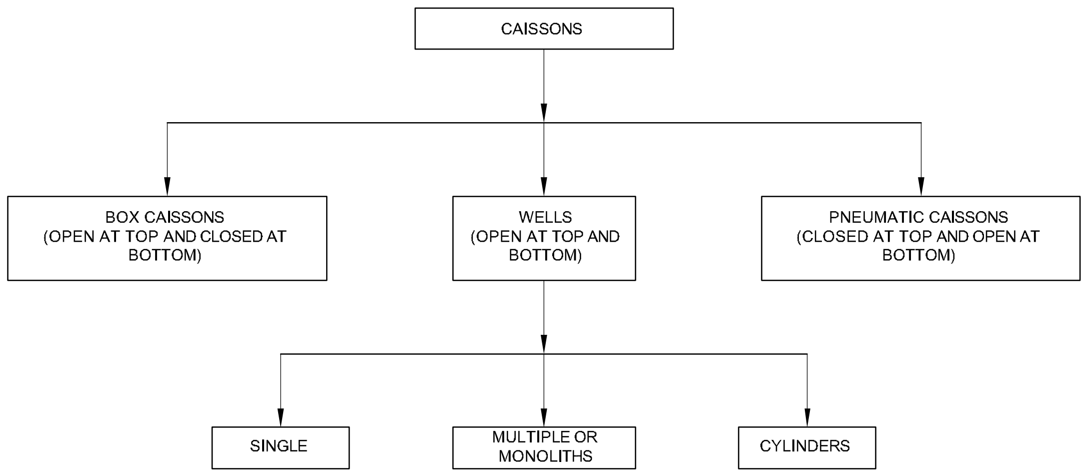


CHART SHOWING CLASSIFICATION OF CAISSONS

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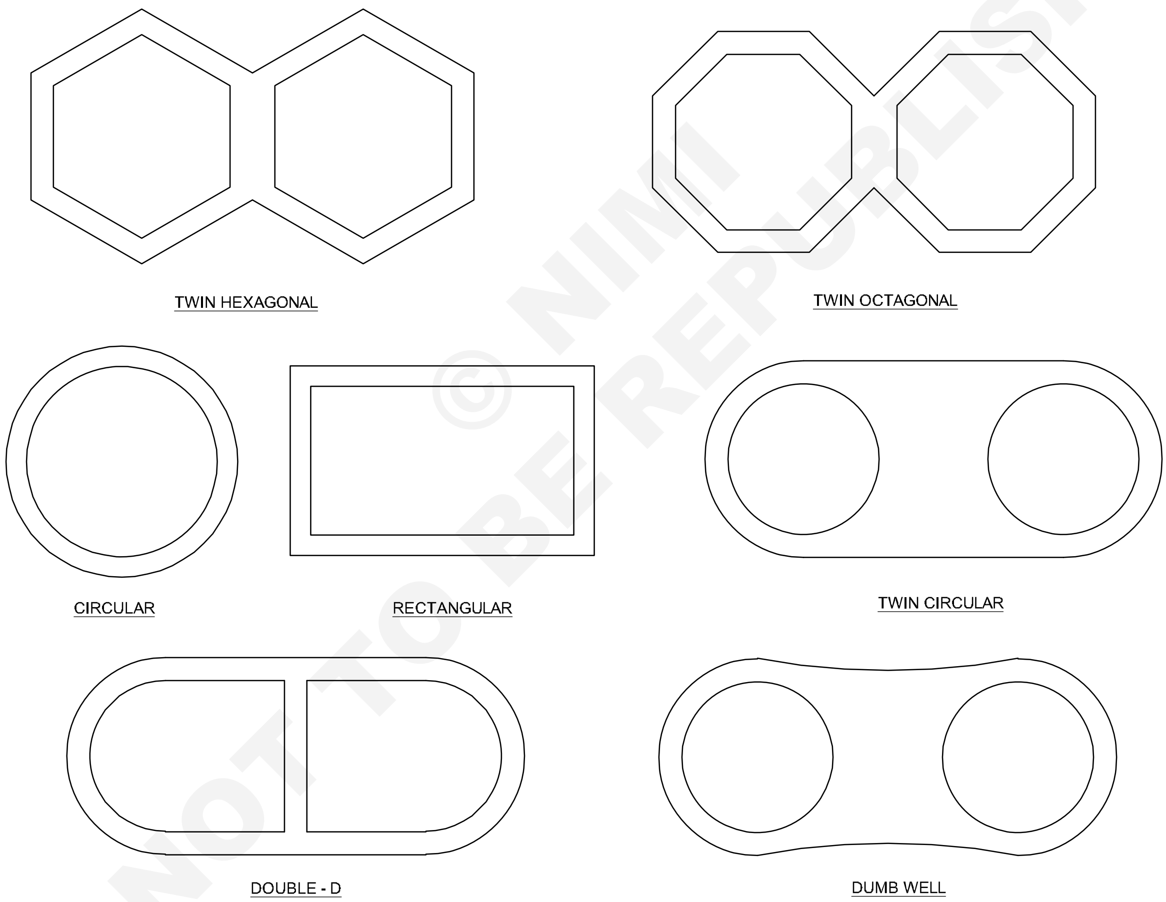
Fig 2



SHAPES OF WELL

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The well when to be sunk too deep becomes slender and it requires bigger dimensions. It then becomes excessively heavy in weight. In such cases, the metal wells are used instead of masonry or R.C.R. wells. Such a metal well of circular cross - section is known as a cylinder and it should be strong enough to resist the lateral pressure and side thrust.

Cofferdams

A cofferdams is defined as a temporary structure which is constructed so as to remove water and/or soil from an area and make it possible to carry on the construction work under reasonably dry conditions.

Following are the requirements of a cofferdam:

i The cofferdam should be reasonably watertight. It may either rest on impervious soil or may be extended to impervious strata through pervious soils. Otherwise, a layer of concrete may be laid at the bottom of a cofferdam and this layer should be allowed to harden sufficiently before pumping of water is started.

ii It should be noted that absolute water tightness is not desired in a cofferdam. It is not only impracticable but expensive too. The design and layout of a cofferdam should therefore be such that the total cost of construction, maintenance and pumping is minimum.

iii The cofferdam should be designed for the maximum water level and other destructive forces of as to make stable against bursting, overturning and sliding.

iv The water to be excluded by a cofferdam may be either ground water or water lying above ground level. It may be deep or shallow and still and concrete.

v The materials used in the construction of a cofferdam are earth, timber, steel and concrete.

vi The cofferdam is generally constructed at site of work.

vii The type of construction for cofferdam is dependent upon the depth, soil conditions, fluctuation in the water level, availability of material, etc.

viii The cofferdams are constructed with advantage where a large area of site is to be enclosed and the hard bed is at reasonable depth.

Uses of cofferdam

Following are the uses cofferdams:

i To facilitate pile driving operations.

ii To place grillage and raft foundations

iii To construct foundations for piers and abutments of bridges, dams, docks, etc.

iv To enclose a space for the removal of sunken vessels.

v To provide a working platform for the foundations of buildings when water is met with, and

vi To provide space for carrying out the foundation work without disturbing or damaging the adjoining structures such as buildings, pipelines, sewers, etc.

Types of cofferdams

A wide variety of different types of cofferdams is available. The factor which influence the choice of a particular type of cofferdam are follows.

i The area to be protected by a cofferdam i.e. a small area or a large area.

ii The depth of water to be dealt with i.e. shallow depth or deep depth.

iii The possibility of overtopping by floods, tides, etc.

iv The nature of bed on which the cofferdam is to rest. i.e. a previous layer or an impervious layer.

v The nature of velocity of flow i.e. water flowing with slow current or with swift current.

vi The chances of bed erosion due to reduction of waterway caused by the construction of a cofferdam.

vii The materials available at site of work for the construction of a cofferdam.

viii The facilities available for the transport of equipment and materials required for the construction of a cofferdam.

Following are the most common types of cofferdams

1 Dikes

2 Single wall cofferdams

3 Double wall cofferdams

4 Cellular cofferdams

5 Rock - filled crib cofferdams

6 Concrete cofferdams

7 Suspended cofferdams

Super structure of bridges and classification of bridges

Objectives : At the end of this lesson you shall be able to
- **define substructures**
- **describe the different substructure**
- **define super structures.**

Definition

The components of a bridge can be split up into three parts, namely, foundations, substructures and superstructures. The components designed to carry the total weight of the bridge are known as the foundations. The components of the bridge upto the level of bearings and above the level of bearings are respectively known as the substructures and the superstructures.

Following are the three substructures of a bridge

1 Abutments

2 Piers

3 Wing walls

Each of the above substructure will now be discussed in detail.

1 Abutments

Definition: The end support of a bridge superstructre is known as an abutment.

Functions: An abutment is provided for the following three purposes.

i To finish up to bridge so that it can be put for use,

ii To retail the earth, and

iii To transmit the reaction of superstructure to the foundations.

Types: The abutments are classified in the following two ways.

i According to the layout in plan.

ii According to the type of superstructure .

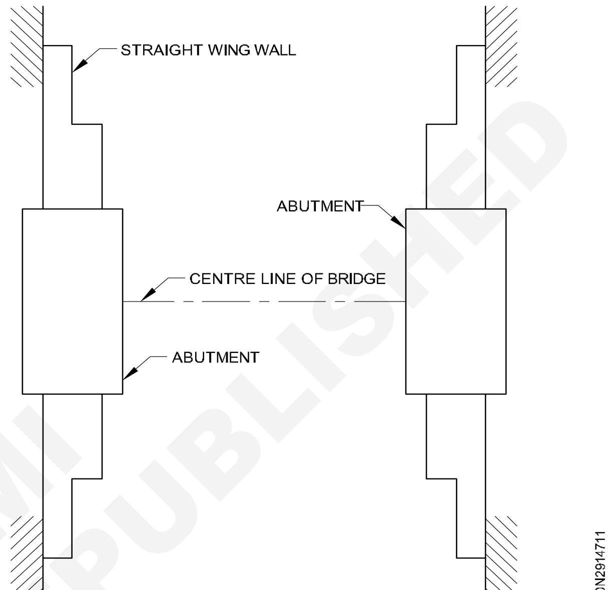
According to the layout in plan the abutments may be with or without the wing walls.

a When the abutments are with wing walls, they may be of three types as shown in Figs 1-3.

i Abutment with straight wing walls: Fig 1 shows as abutment with straight wing walls. In this case, the wing wall is in line with abutment. Such an abutment is unsuitable for bridge with waterway as the flowing water is likely to damage the embankment behind the wing wall. Hence, such type of abutment is adopted for railway or street crossings.

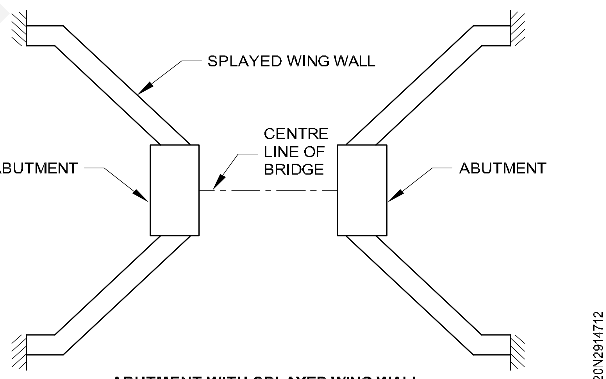
ii Abutment with splayed wing wall Fig 2 shows as abutment with splayed wing wall. Such an abutment is very common for the bridge with waterway as it permits smooth entry and exit of water under the bridge.

Fig 1



ABUTMENT WITH STRAIGHT WING WALL

Fig 2

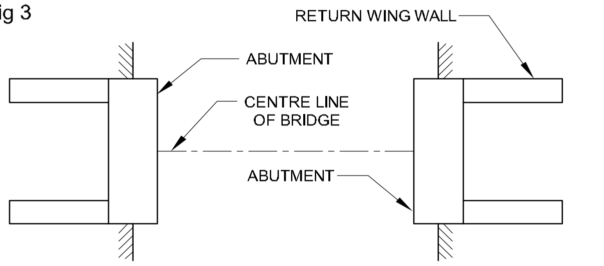


ABUTMENT WITH SPLAYED WING WALL

iii Abutment with return wing wall Fig 3 shows an abutment with return wing wall and it is also referred to as U - abutment as it resembles the letter U in plan. In this case, the wing walls are parallel to the centre -line of bridge and such an abutment proves to be economical for rivers having steep and rocky banks and not subject to erosion.

It is however not suitable for rivers or streams subjected to heavy floods as considerable portion of embankment outside the wing walls remains un protected from the scouring action of water and it will not be safe because there is a tendency for the flood water to damage the embankment.

Fig 3



ABUTMENT WITH RETURN WING WALL

The abutments with wing walls suffer from the following drawbacks

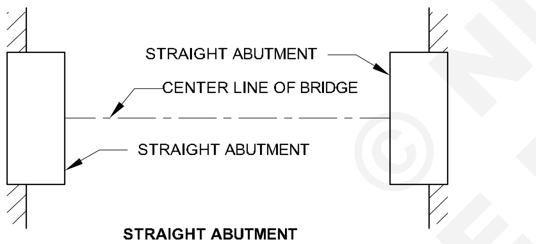
i It requires special care for the construction of connection between the abutment and wing walls to prevent cracks.

ii They tend to restrict the flood and hence, the scour is increased and the upstream flood level is raised. The increased depth of scour may require deeper foundations.

When the abutments are without the wing walls, they may be of two types as shown in Fig 4.

i Straight abutment without wing walls: Fig 4 shows a straight abutment without wing walls. Such an abutment will be useful for bridges without waterway or with negligible waterway.

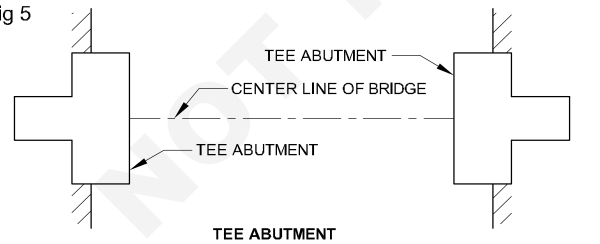
Fig 4



STRAIGHT ABUTMENT

ii Tee or T - abutment Fig 5 shows a tee or T - abutment as it resembles letter T in plan. The head of T - abutment supports the bridge and its stem carries the roadway for some distance beyond the embankment of river.

Fig 5



TEE ABUTMENT

It is usually not recommended because of the following disadvantages

1 It does not protect the embankment of river.

2 It gives a rigid formation over its stem portion.

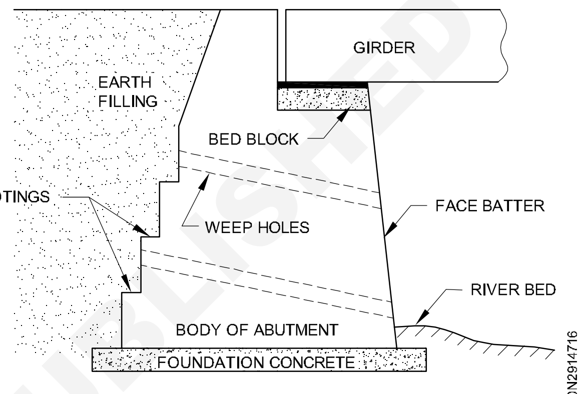
3 It is uneconomical.

4 The quantity of masonry required for its consrtuciton works out to be more in proportion to its function.

ii **According to the type of superstructure** The abutments may be provided for a girder bridge or an arch bridge.

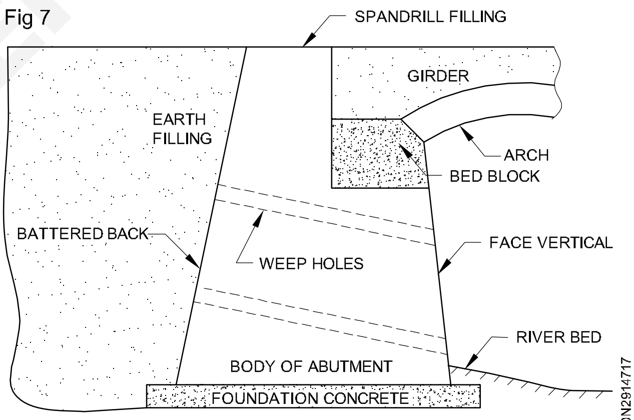
a **Abutment for a girder bridge** (Figs 6 & 7) shows a typical cross - section of an abutment for a girder bridge. A bed block of concrete is provided with a bearing plate to receive the end of girder. The breast wall or dwarf wall is constructed upto the approach level. The weep holes at different level are provided to drain off water which gets access to the earth filling. They are provided at vertical intervals of 1 m and at horizontal spacing's of 2 m. They are arranged in a staggered manner. The back side may be vertical or stepped. The face may be vertical or battered.

Fig 6



ABUTMENT OF A GIRDER BRIDGE

Fig 7



ABUTMENT FOR AN ARCH BRIDGE

2 Piers

1 **Definition:** The intermediate supports of a bridge superstructure are known as the piers.

2 **Function:** The only purpose of providing piers is to divide the total length of bridge onto suitable spans with minimum obstruction to the stream of river.

3 Types

Following are the usual types of the bridge piers.

i Column bents

ii Cylinder piers

iii Dumb - bell piers

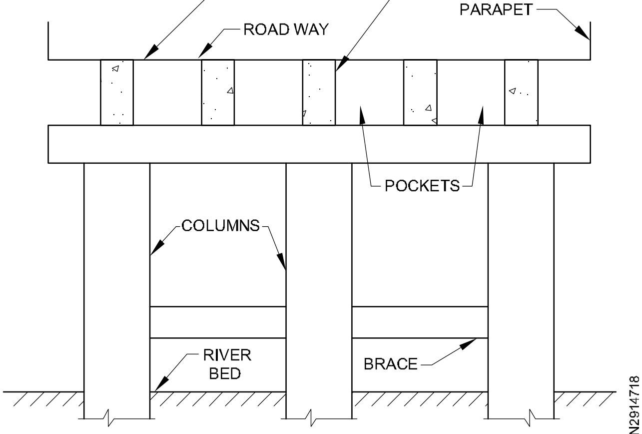
iv Pile bents

v Solid piers

vi Trestle bents

i Column bents: A column bent type of pier is adopted, if the longitudinal beams or girders of the superstructure of bridge are closely spaced. The term bent is used to indicate a supporting frame consisting of vertical members and braces. The transverse beams are provided to support the longitudinal beams and two or more colums on a solid foundation are constructed to support the transverse beams as shown in Fig 8.

Fig 8

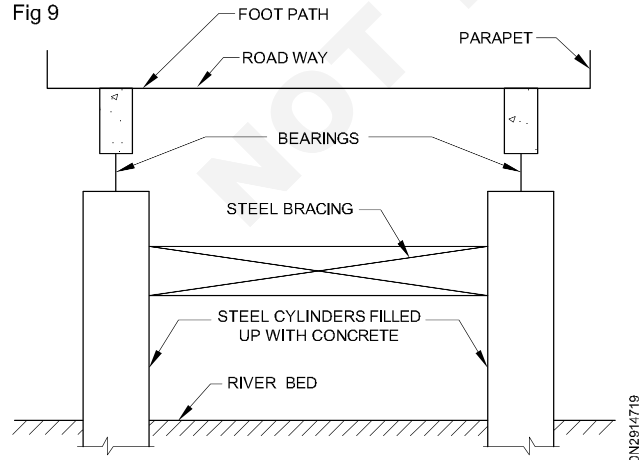


COLUMN BENTS

The pockets formed between the longitudinal beams may be used to carry gas pipes, sewage pipes or water pipes. The column bents are lighter than the masonry piers and are used for continuous spans.

ii Cylinder piers: A cylinder pier consists of mild steel cylinders connected by the horizontal and diagonal bracings as shown in Fig 9. These piers are adopted when foundations are of steel cylinders caisson type. The concrete is poured in the steel cylinders after being sunk and they support the girders of the bridge through suitable bearings.

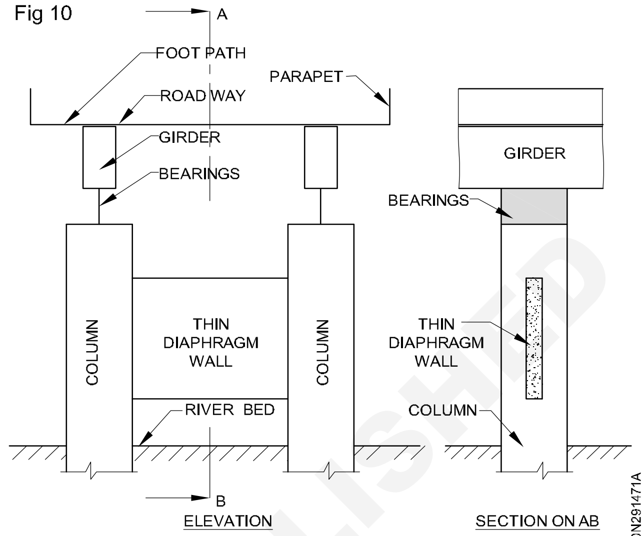
Fig 9



CYLINDER PIER

iii Dump - bell piers: A dump - bell pier has an appearance of a dump - bell i.e. a weight for RT for Exs, in plan. It is adopted when the superstructure of bridge is supported on the twin girders. A column is provided below each girder and the colums are connected by thin diaphragm wall along their height as shown in Fig 10.

Fig 10



DUMB-BELL PIER

Following are the advantage of the dump - bell piers

a As compared to its mass, a dump - bell piers maximum moment of inertia.

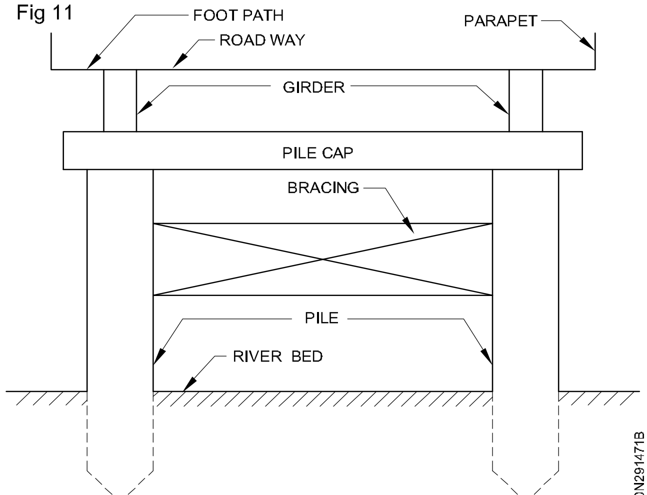
b The design of dumb - bell piers is simple and it leads to the light reinforcement.

c They are light in weight as compared to the solid mass concrete piers.

d They are very much suitable when the well foundations are adopted.

iv Pile bents: In case of pile bents, the girders of superstructure of bridge are supported on R.C.C. or steel piles. A pile cap is provided to connect piles at the top and they are suitably braced along their height as shown in Fig 11. The file bents are used for low piers over unstable or muddy ground.

Fig 11



PILE BENT

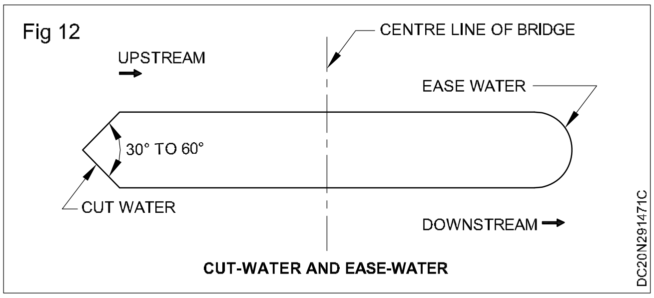
v **Solid piers:** In case of solid, the piers consists of the masonry or cement concrete of solid section throughout the entire length of pier. Such type of consturction of piers is very popular in the bridge construction, mainly for two reasons.

a It can be used for any type of superstructure of the bridge.

b It provides excellent resistance to the actions of floating bodies.

The ends of solid may be rectangular. But they may be given any suitable shaped to make the entry and passage of water easy and smooth. The end or nose or pier on upstream side is known as the cut - water and that on downstream side is known as the ease - water as shown in Fig 12.

Fig 12

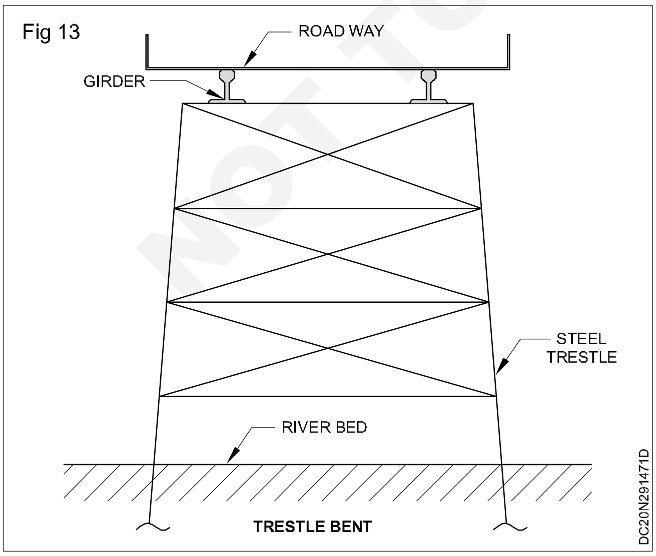


CUT-WATER AND EASE-WATER

The cut - waters are usually triangular in shape. The cut - water need not be very long and they should be carried down to the base. The ease - waters are usually semi - circular or they may consist of two parabolic arcs.

vi **Trestle bents:** A trestle is a framed pier and it consists of vertical, horizontal and diagonal members as shown in fig. 13 The trestle bents may be of steel or concretre, the former being very common. The trestle bents are useful for constructing piers for a bridge along a viaduct or incase of flyovers and elevated roads. A deep valley having non - perennial stream or river is known as a viaduct. The trestle bents with considerable height and narrow roadway are usually inclined for additional stability, as shown in Fig 13.

Fig 13



TRESTLE BENT

3 Wing walls

Definition

The abutment can be either buried or its front face can be left exposed. In the latter case, the walls constructed on either side of an abutment are known as the wing walls.

Functions

A wing wall has mainly to perform the following two function

i To provide a smooth entry into the bridge site, and

ii To support and protect the embankment.

Types

Following are the three types of wing walls

i Straight wing wall

ii Splayed wing wall

iii Return wind wall

Each of the above type of wing wall now be briefly described.

i **Straight wing wall:** When the wing walls are constructed in line with the abutment, as shown in Fig 1 they are known as the straight wing walls. Such type of wing wall is found to be economical when there is no danger of washing of the material from the bank of river. This type of wing wall is suitable for small bridges which are constructed across the drains having low banks.

ii **Splayed wing wall:** When wing walls are given inclination in plan, as shown in Fig 2. They are known as the splayed wing walls. The wing walls may also be curved, instead of being played. The splay or inclination is usually 45° and such types of wing walls offer the following three advantages.

It is not necessary for the splayed wing walls to have additional protections such as rubble filling and pitching of the embankment.

The height of splayed wing wall may be changed from point to point along its length. It may have minimum height at the far end from the abutment and maximum height equal to that of the abutment at the end near the abutment. Such an arrangement reduces the cost of splayed wing.

They provide smooth entry and exit to the flowing water.

The splayed wing walls are best suited when the width of road is to be reduced while crossing the bridge or at places where two or more roads meet at the approach.

Return wing wall

When angle of splay becomes 90°, as shown in fig 3 the wing walls are known as the return wing walls. Such wing walls are preferred to the splayed wing walls in case of very high embankments. When the return wing walls are as opted, it is possible to suitably extend the parapet walls on either side of the bridge beyond the abutment. The return wing walls are taken sufficiently inside so that the earth slope along them terminates outside the waterway. These walls confine the formation of the approaches and add to their strength.

Super structure

It is that part of the bridge over which the traffic moves safely. It consists of parapets, roadway and also the girders, archer, or trusses over which the road is supported.

Bridges (Classification of bridges)

Objectives : At the end of this lesson you shall be able to
- **classify the bridges**
- **explain the different types of bridges.**

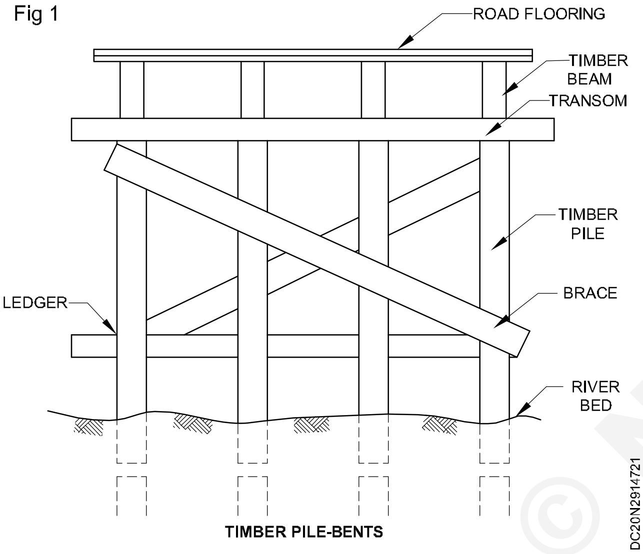
Classification of bridge

Based on the material of construction

Timber bridge (Fig 1)

The bridges which are constructed in timber substructrue and superstructure are called timber bridges. These have short life ie between 10 to 15 years. These are suitable in hilly areas where good quality timber is easily available. These are classified under IRC class B loading with no impact allowance.

Fig 1



TIMBER PILE-BENTS

Masonry bridge (Fig 2)

The super structure of masonry bridge consists of masonry arch over which the road way is constructed. Masonry arch may be of brick work, stone masonry or concrete. This arch rests on piers and abutments which are designed for this purpose. These are constructed for small span bridges where more head way is required during floods for the passing of boats below the bridge. These are simple to construct having long life and materials for their construction are cheaply available near the site of the bridge.

Depending upon the shape of the arch, the masonry arches of bridges can be classified as

1 Semicircular arch

2 Segmental bridge

3 Elliptical arches

Steel bridge: The bridges which are constructed in steel are called steel bridges. These have long life.

Following are the common types of steel bridges.

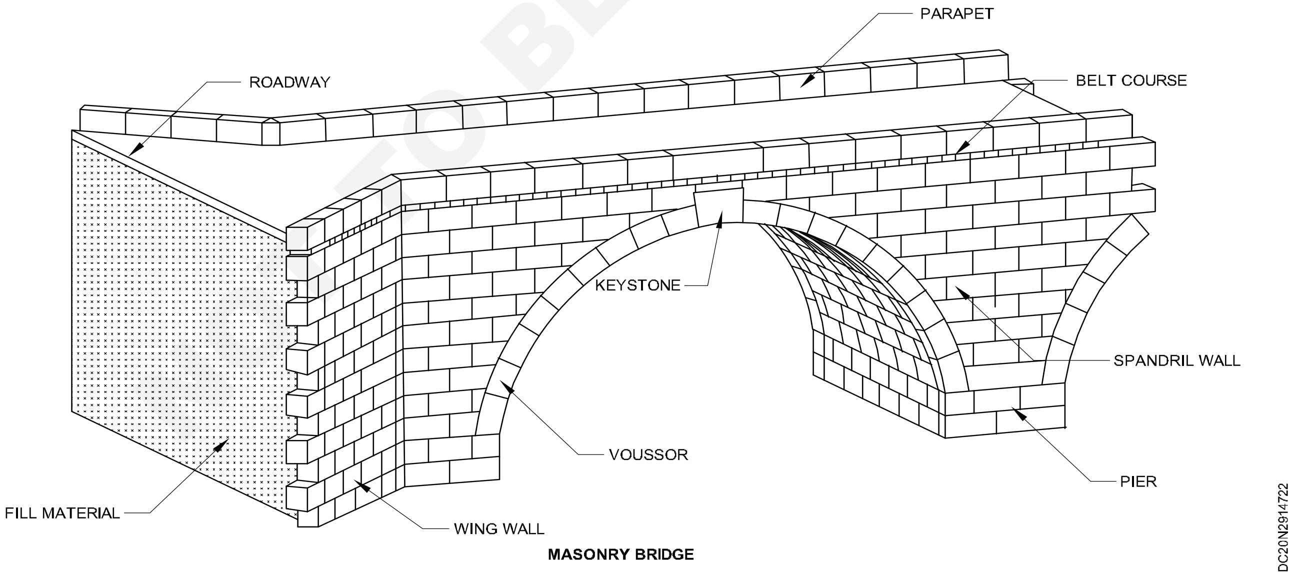
a Steel trough plate bridge

b Steel girder bridge

c Steel truss bridge

d Suspension bridge

Fig 2



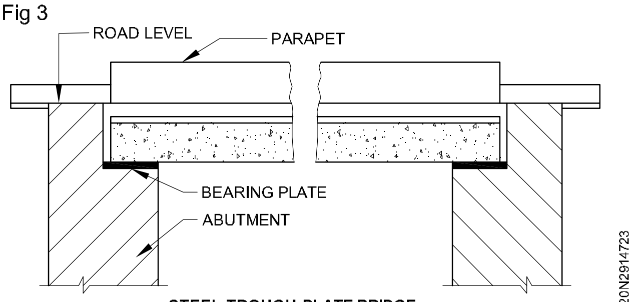
MASONRY BRIDGE

a Steel trough plate bridge (Fig 3)

The span of this bridges may be upto 50m. Steel trough of required sections are laid in the required width of the road or railways. Steel bars are used to keep trough in position.

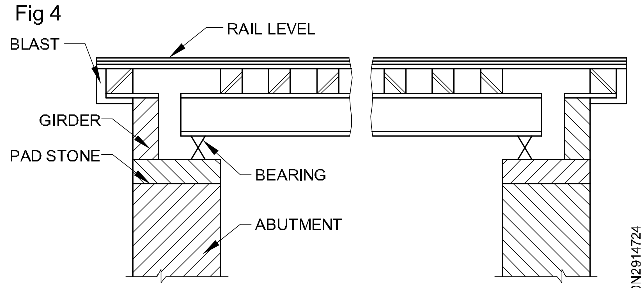
At both ends of the trough, bearing plates are fixed. They can transmit loads uniformly on the abutments. After placing steel trough in position cement concrete is filled in them.

Fig 3



STEEL TROUGH-PLATE BRIDGE

Fig 4



STEEL GIRDER BRIDGE

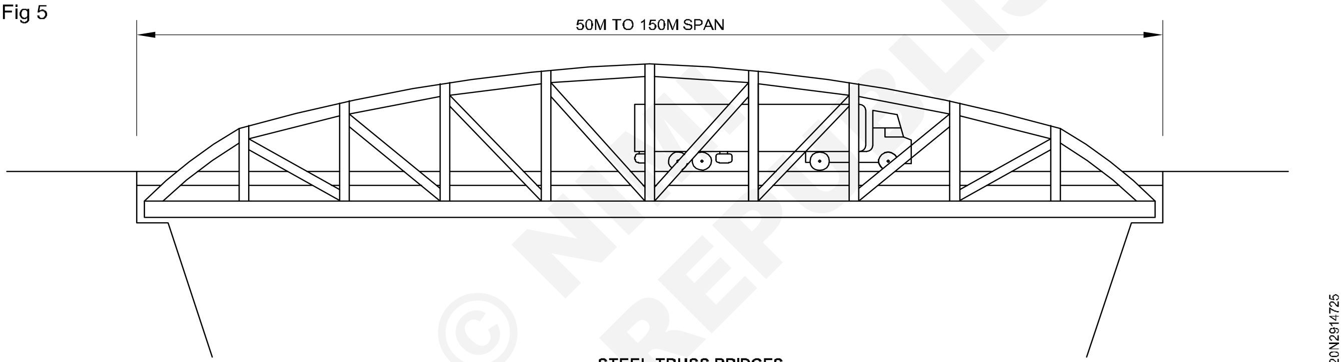
b Steel girder bridge (Fig 4)

Grinder bridges are mostly used for railway bridges of small spans. The girders used for bridges may be plate girders open, web or box girders. The main girders are braced together to prevent lateral buckling or side movements. Wooden sleepers are directly laid on the main girders over which the rails are laid so that the load is directly transmittd. Depending upon the span and the load of the traffic, the girder may be of rolled steel josists, plate girder or box girder.

c Steel truss bridge (Fig 5)

These bridges are used for long span railway bridges. Most of the railway bridges over big rivers are of this type and also these bridges are used for combined road and railway lines. All members of the trusses are of rolled steel or box girder type which are fabricated in the work shop. Truss girder bridges are used upto about 100m span. The main truss girder bridges are pratt. These trusses usually have a depth equal to 1/5 of span.

Fig 5

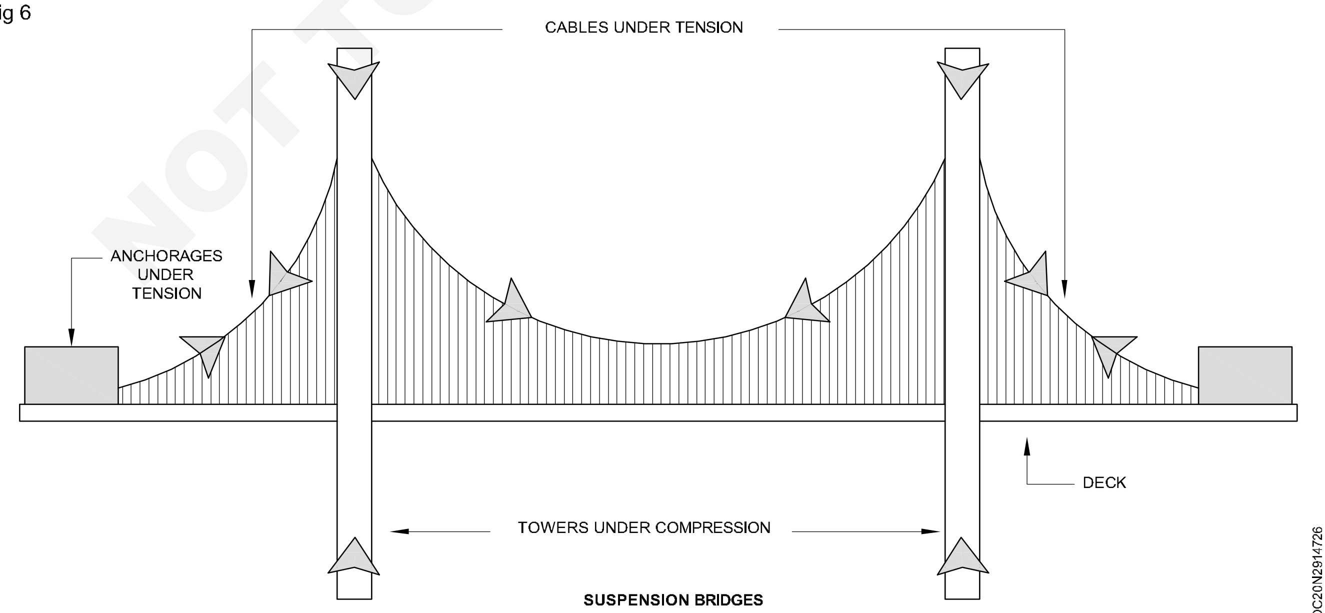


STEEL TRUSS BRIDGES

d Suspension bridges (Fig 6)

These bridges are used for light traffic for a very span. Suspension bridges utilize the wire ropes which support the road way by suspenders. These wire ropes or cables are carried over by saddles fixed on the top of the towers. The wire ropes after passing over the saddle are anchored to the jumpers left in good rock**s.**

Fig 6



SUSPENSION BRIDGES

R.C.C bridges

R.C.C bridges have nowadays largely used in the construction of the bridge. But R.C.C is poor in resisting shocks and vibrations. Therefore, it cannot be used for constructing major railway bridges.

Types of R.C.C bridges

Following are the various types of R.C.C bridges which are used in the bridge construction at various places.

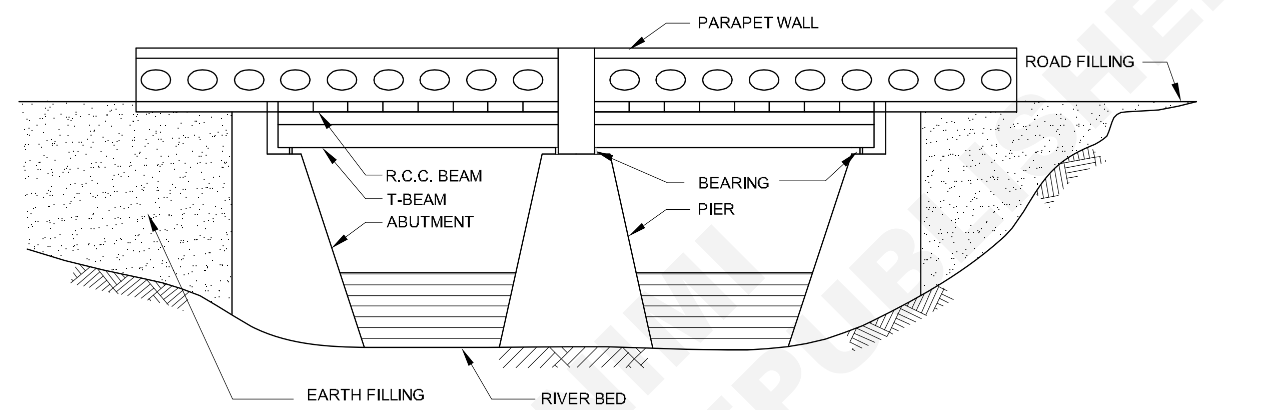
1 **R.C.C slab bridges**

This is the simple type of bridge in which the masonry abutment and piers are constructed, over which R.C.C. slab is laid with proper expansion joints. These types of bridges are only suitable for pedestrians and light traffic. In some cases, R.S. joists or built up girders are laid as main girders over which R.C.C. slab is laid. Wearing course of cement concrete is laid, which is replaced when worn out due to movement of the traffic Fig 7.

2 **R.C.C.T. Beam and slab bridge (Fig 7)**

These bridges are used up to span of 20.0m. The T-beams are simply supported over the abutment and piers. This is similar to T - beam and slab roof. T - bean and slab is most monolithic. This bridge is cheaper than slab type bridge as the span of the slab for design purpose is reduced. Usually in such bridge the central portion of the bridge is designed for the vehicular traffic. On both the sides of the bridge, raised paths for pedestrian traffic are constructed. The road kerbs are also provided. The wearing course is provided, which is replaced when it is worn out.

Fig 7

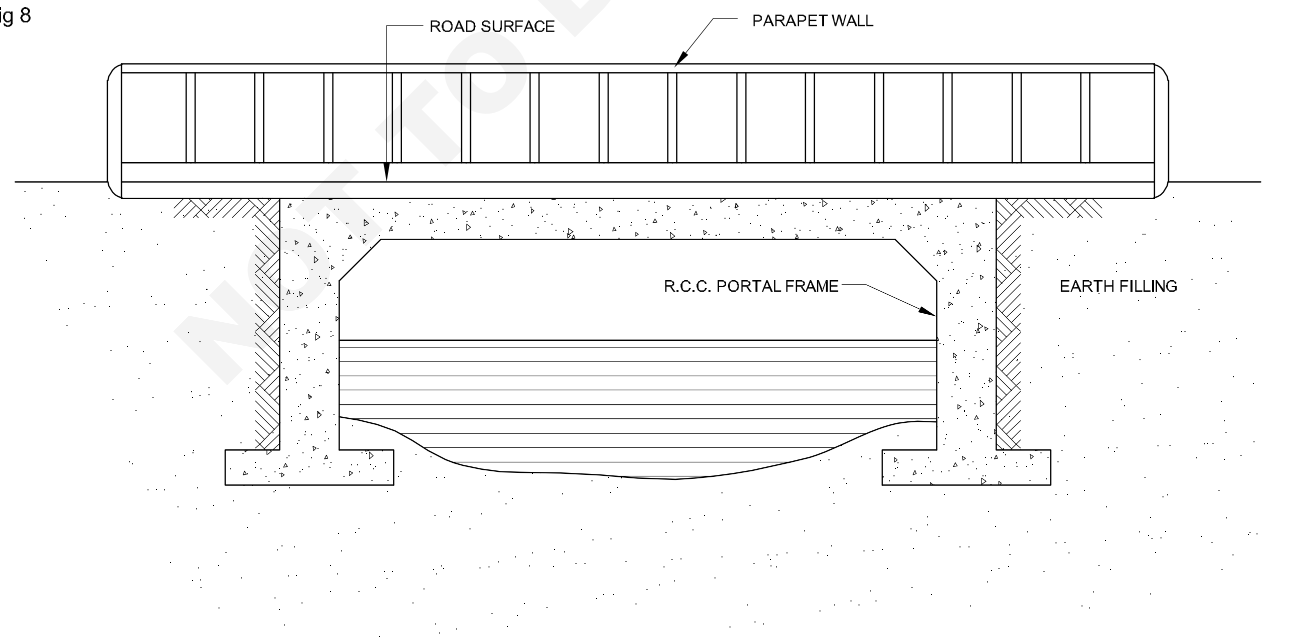


R.C.C. T-BEAM AND SLAB BRIDGE

R.C.C rigid frame bridge (Fig 8)

In this type of bridge the horizontal deck slab is made monolithic with the vertical abutment walls. Such types of bridges are also common for rail-road crossings. This bridge has maximum span of one way as 20m. This bridges is suitable for spans below 10m and also for very long spans.

Fig 8

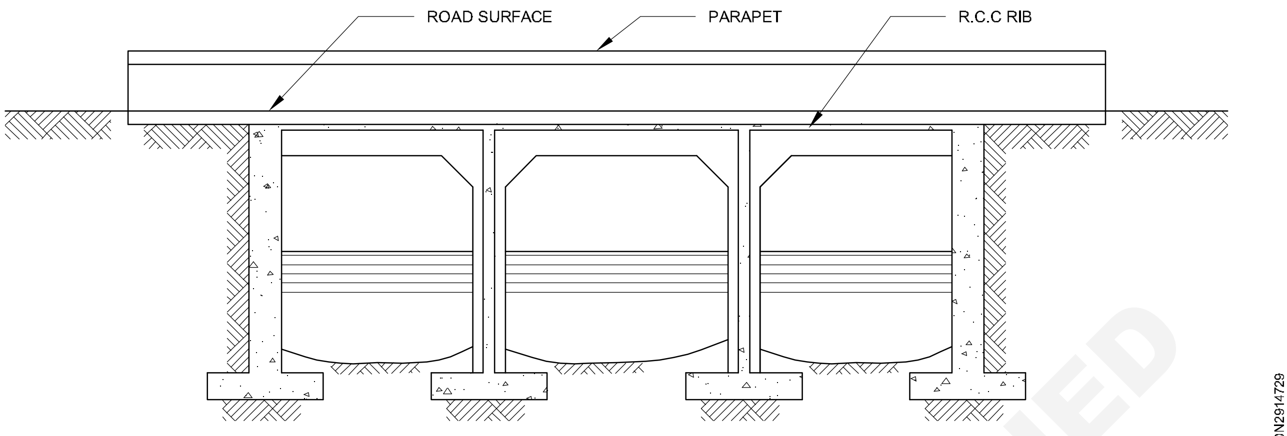


R.C.C. RIGID FRAME BRIDGE

R.C.C multiple - span portal bridges (Fig 9)

This bridge should not have more than 16m span of each way. It essentially consists of continuous span in which the super structure is made monolithic with the supporting abutment and piers. This bridge is suitable when the foundation soil is better and there are no chances of foundation settlement.

Fig 9

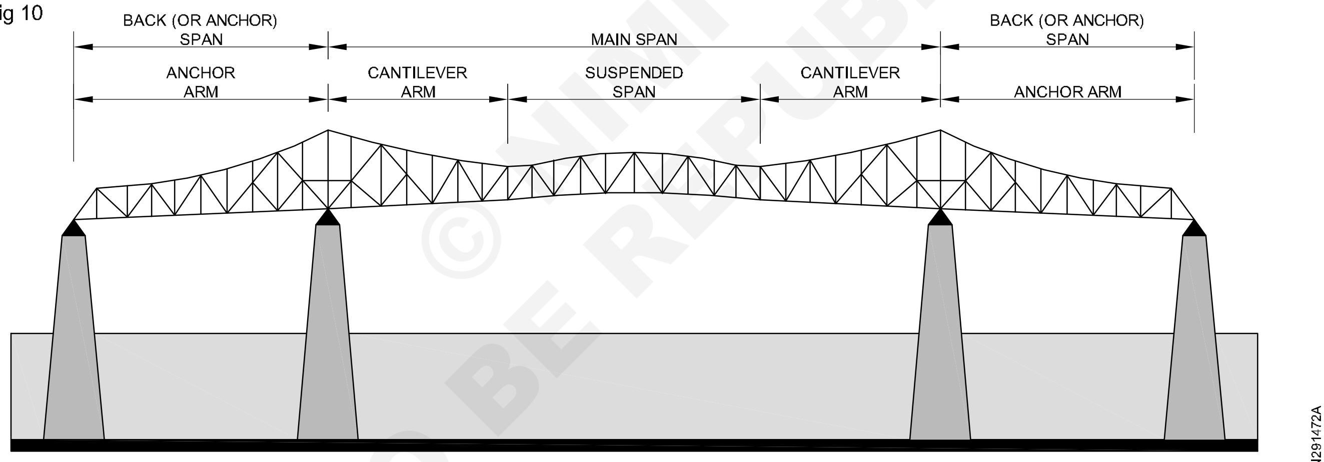


MULTIPLE SPAN PORTAL FRAME BRIDGE

R.C.C Double cantilever bridge (Fig 10)

This is suitable for long bridges having many spans. The span of such bridge can upto 70.0m. Sometime this bridge is also known as balanced cantilever bridge.

Fig 10



R.C.C DOUBLE CANTILEVER BRIDGE

R.C.C. Bowstring girder bridge (Fig 11 & 12)

In this bridge the arch ribs are constructed above the deck level of the bridge. Horizontal ties are provided to resist the horizontal thrust caused by the arches. The thrust of the arches is taken by the tie beam. These bridges require simple abutments for taking the vertical loads of the bridge only. Bowstring girder bridges are suitable up to 100 m span.

Based on the nature of life

1 **Temporary bridge**

2 **Permanent bridge**

1 Temporary bridge

These are low cost bridges and have short span of life. These are generally made of timber but they may also be constructed of steel wires, old rails hemp rope etc. These are constructed under the following circumstances.

i When there is shortage of time.

ii When there is shortage of funds.

iii When a repair to permanent bridge is to be carried out.

iv When construction of new permanent bridge is to be facilitated.

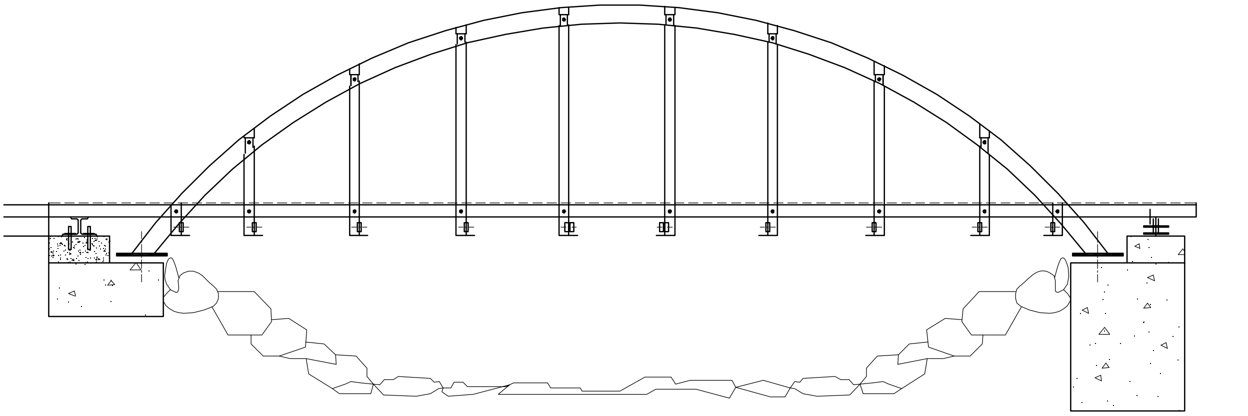
v in case of temporary needs to cross a stream.

vi When project surveys to the interior of a river is to be carried out.

2 Permanent bridge

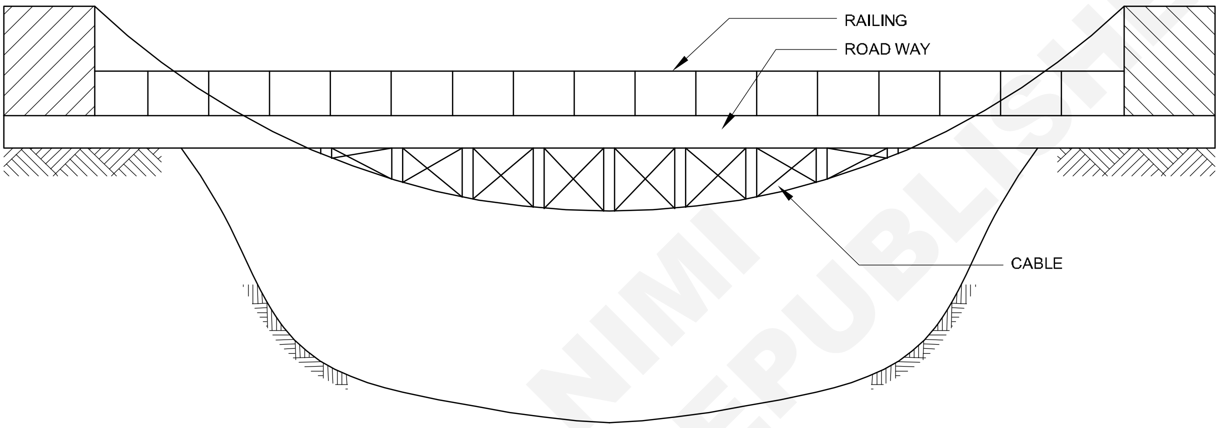
These bridges have a longer span of life and constructed at high construction cost.

Fig 11



R.C.C. BOWSTRING GIRDER BRIDGE

Fig 12



R.C.C. BOW-STRING TYPE BRIDGE

These may be constructed in masonry, stone, steel or concrete etc.

Permanent bridge is classified is classified according to the materials used for the construction, as follows

i Masonry bridge

ii Steel bridge, like trough plate bridge, girder bridge such as rolled joist bridge, plate girder bridge, box girder bridge.

iii Reinforced concrete bridge, such as slab bridge, girder bridge, arch bridge, and rigid frame bridge etc.

iv Pre stressed concrete bridges.

v Culverts such as pipe culverts, slab culverts, arch culverts and box culvert etc.

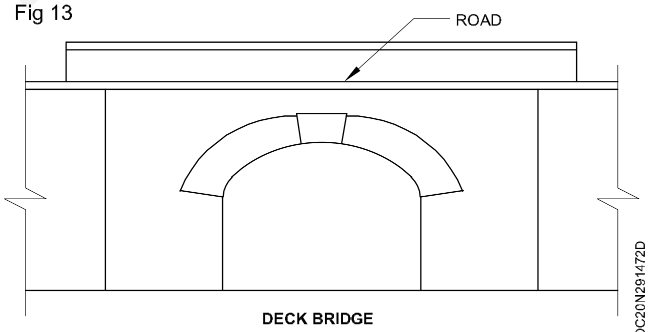
vi High level causeway.

Classification based on relative position of its floor

1 Deck bridge (Fig 13)

If the flooring for bridge which carries the traffic is supported at the top of main girders of the bridge or on the top of the load bearing superstructure, then the bridge is called as deck type bridge.

Fig 13



DECK BRIDGE

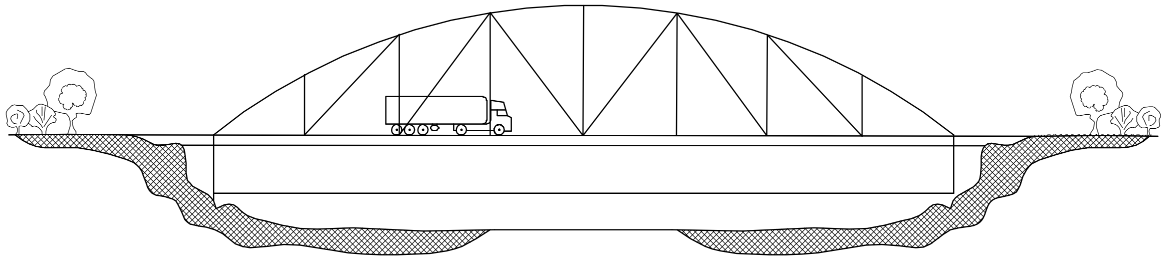
2 Through bridge (Fig 14)

When the flooring of the bride which carries the traffic is supported at the bottom of the main girders of the bridge or at the bottom of the load bearing superstructure then the bridge is called as through bridge.

3 Semi through bridge (Fig 15)

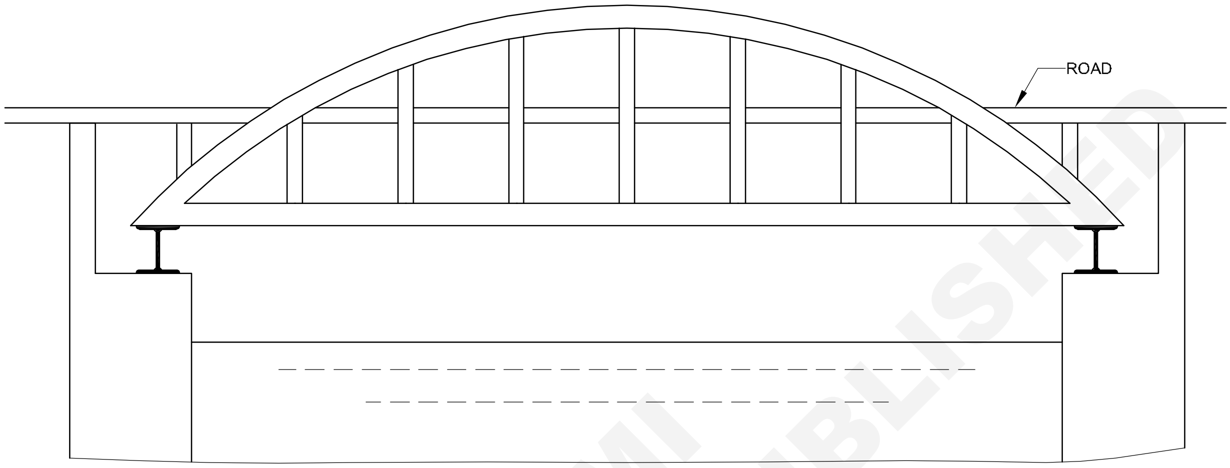
When the flooring of the bridge is supported at some intermediate level i.e. in between the top and bottom level of the main load bearing superstructure of the bridge, then it is known as semi through bridge.

Fig 14



THROUGH BRIDGE

Fig 15



SEMI THROUGH BRIDGE

Classification based on the function or purpose

i High way bridge.

ii Railway bridge.

iii Foot bridge.

iv Viaduct.

v Aqueduct.

vi High way & railway combined bridge.

i **High way bridge:** The bridge constructed along a high way across another highway, railway or waterway is called highway bridge.

ii **Railway bridge:** It is the bridge constructed along the railway line across a highway or a waterway.

iii **Foot bridge:** It is a bridge constructed for pedestrians across a roadway, railway or waterway.

iv **A viaduct:** It is a bridge composed of several small spans for crossing a valley.

v **an aqueduct:** It is a bridge constructed to convey water over an obstacle such as river or valley.

Classification based upon the length of span.

1 Major bridge

2 Minor bridge

3 Culverts

According to the engineers, the bridges are classified on the basis of lineal waterway as follows.

i Culverts - up to 6m.

ii Minor bride - 6 m to 30 m.

iii Major bridges - Over 30 m.

According to the Indian railways, the bridges are classified as follows

1 **Major bridges:** Total waterway more than 18 m or having any span of clear waterway of 12 m or over.

2 **Minor bridges:** Total waterway less than 18 m or having any span of clear waterway less than 12 m.

3 **Important bridges:** Those major brides having total waterway of 18 m and more; or more than 110 m2.

The cross - drainage structures for the purpose of investigation are grouped into the following three categories in our country.

1 Culverts and minor bridges having linear waterway upto 30 m.

2 Major bridges having linear waterway exceeding 30 m but on stable rivers and canals.

3 Important bridges having linear waterway exceeding 30 m but on major rivers or tributaries which are shifting in nature or which present some problems of stability.

Culverts

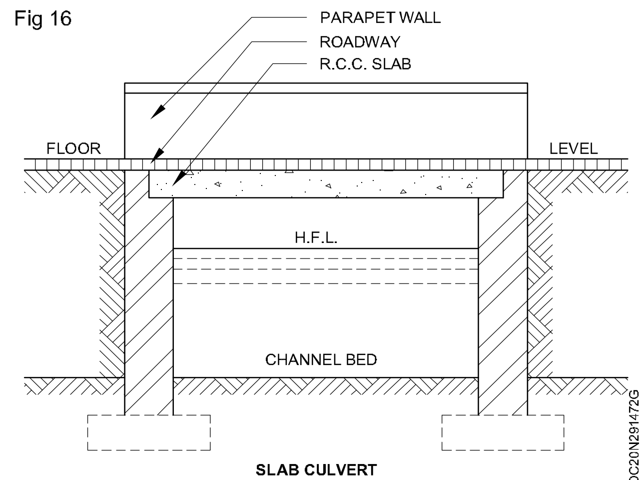
Culvert is a small bridge commonly used for carrying water from one side to another side in the embankment of railway or road. A culvert may have one, two, or three spans. Maximum span is 6.0 m between its abutments.

Classification of culverts

1 Slab culverts
2 Pipe culverts
3 Box culverts
4 Arch culverts
5 Steel girder culverts

1 Slab culverts: This is a masonry culvert with R.C.C. slab and is very common these days. These are easy in construction and maintenance. The construction of the slab may be in R.C.C, timber sleepers or stone. (Fig 16)

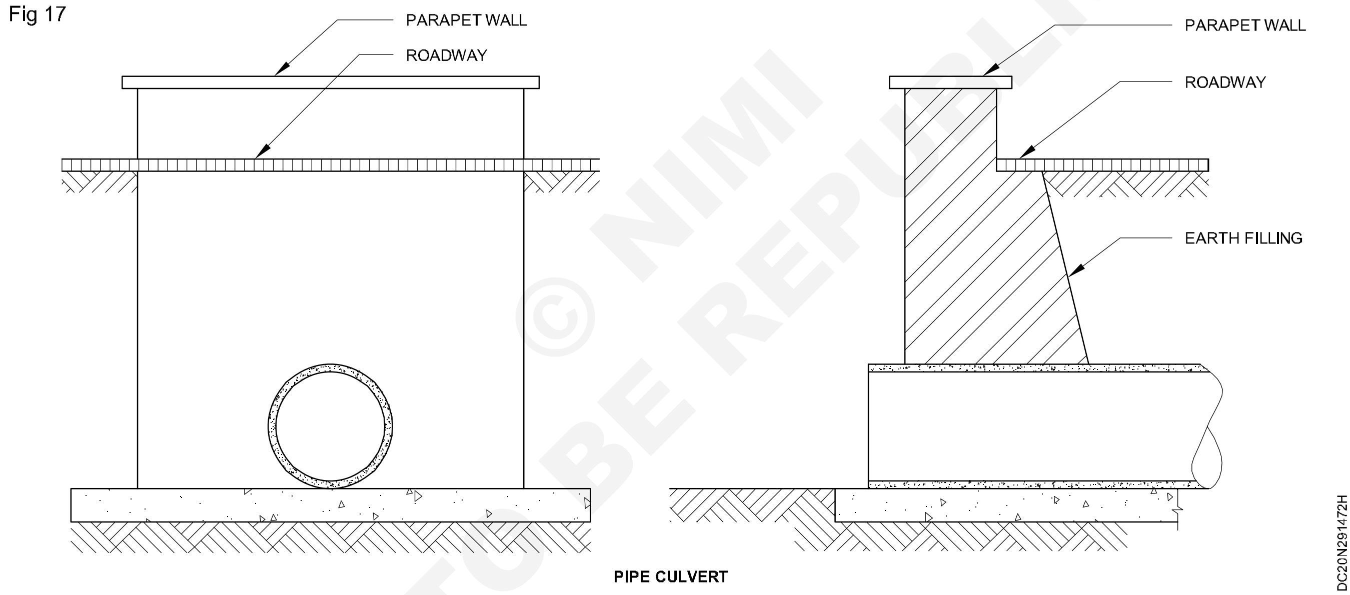
Fig 16



SLAB CULVERT

2 Pipe culverts: Pipe culverts are becoming more common due to easiness in construction. Hume pipes of various diameters are available. The kutch roads may be provided with pipe culverts, by simply laying the R.C.C. or Hume pipe in the position and filling the soil around it. (Fig 17)

Fig 17

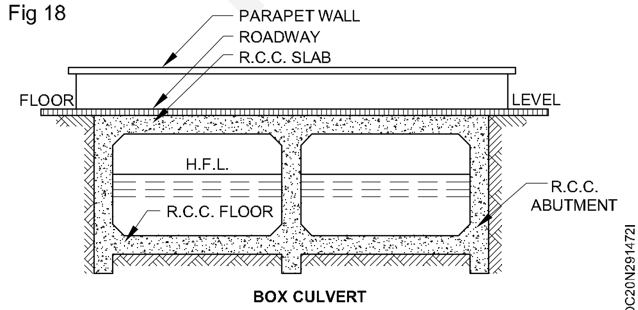


PIPE CULVERT

The exact number and diameter of the pipe for the pipe culverts are determined by the maximum discharge that will pass under this culverts and the height of the road embankment.

3 Box culverts (Fig 18)

Fig 18



BOX CULVERT

These culverts mainly consists of one or more number of square or rectangular openings for passing the water from one side to another. In soft soils where there is possibility of scoring and bearing capacity of the soil is poor, these culverts are commonly used.

4 Arch culverts (Fig 19)

These culverts mainly consists of foundation, abutments, wing walls, arches and the parapet. In case of poor bed soil, apron is provided against the erosion or scouring of the bed soil. The spandrel filling of these culverts is done in lime concrete.

5 Steel girder culvert (Fig. 20)

This type of culvert is only provided in railways. Two main girders are laid just below the rails. Wooden sleepers are provided between these girders and the rail.

Fig 19

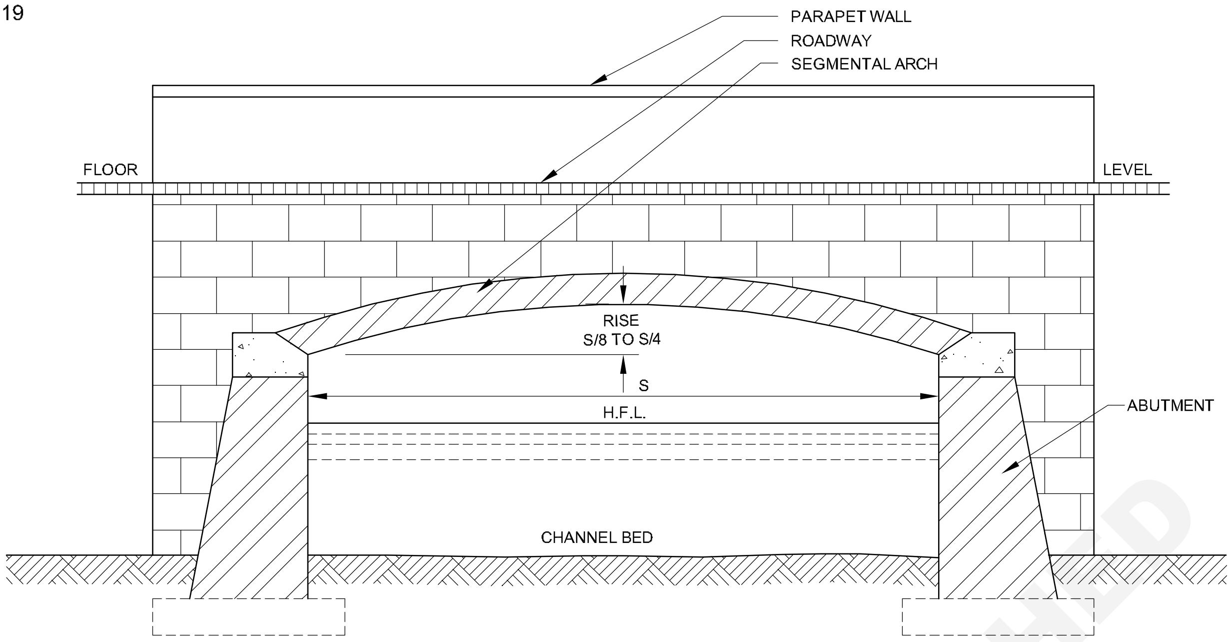
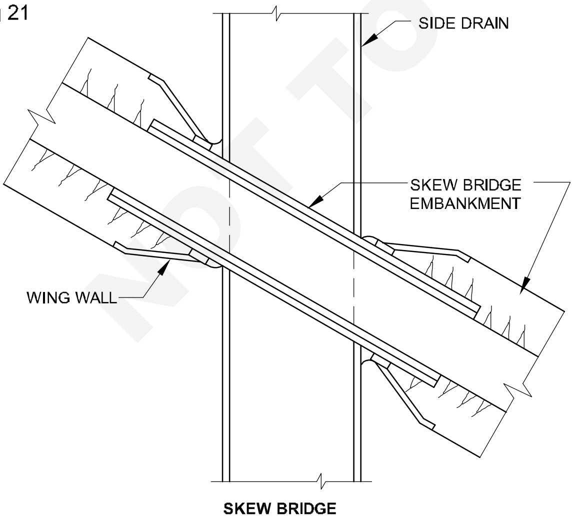


Fig 20

2 **Skew bridge:** If the bridge is constructed at an angle other than 90° to the direction of flow it is called skew bridge. (Fig 21)

Fig 21



Classification

According to the level at highways and railways the bridges are classification as.

1 Over bridge

2 Under bridge

Classification according to the alignment of bridge

1 Straight bridge

2 **Skew bridge**

1 Straight bridge: If the bridge is constructed at an angle 90° to the direction of flow it is called straight bridge.

Classification based upon flexibility of superstructure

i Fixed span superstructure

ii Movable span superstructure

i In case of fixed - span superstructures, the super structure remains in a fixed position and most of the bridges are of this category.

II In case of movable - span superstructure, the superstructure is lifted or moved with the help of some suitable arrangement.

Classification based on IRC loading

Revised I.R.C. has revised the old standard to meet with the requirements of the modern traffic. As per revised. I.R.C/ recommendations, the loadings are divided into the following four categories.

i Class AA loading

ii Class A loading

iii Class B loading

iv Class 70R loading

i **Class AA Loading:** The I.R.C. class AA loading is based on the heavy military vehicles likely to run on certain routes. It is to be adopted for bridges within municipal limits in certain existing industrial areas, certain specified highways, etc. It is the usual practice to design the structures on national and state highways for class AA loading. It is also desirable that the structures designed for class AA loading should be checked for class A loading because under certain conditions, it is likely to get heavier stresses under class A loading.

In class AA loading, the following two types of vehicles are specified.

i Tracked vehicle

ii Wheeled vehicle

ii Class A loading: The I.R.C. class A loading is based on the heaviest types of commercial vehicle which is considered likely to run on the Indian roads. Hence, all important permanent road bridges and culverts, which are not covered by class AA loading, are to be desinged for class A loading.

The train for class A loading consists of an engine and two bogies.

iii Class B loading: The method of application and other details of class B loading are same as class A loading. It is to be adopted for the design of temporary structures such as timber bridges, etc.

iv Class 70R loading: This is an additional loading which is sometimes specified for use in place of class AA loading. The letter 'R' indicates revised classification and it is based on one of the various other hypothetical vehicles as per revised classification.

Tunnel rules used for the different members

Objectives : At the end of this lesson you shall be able to
- **state specific areas covered in Tunnels an explain**
- **explain the areas covered in Tunnels.**

This section sets forth requirements for tunnel and shaft construction. It covers the following specific areas:

- General Requirements
- Emergency Provisions
- Ventilation
- Air Quality
- Dust Control
- Internal Combustion Engines
- Noise Control
- Fire Prevention and Control
- Excavation Operations
- Ground Support
- Transportation and Haulage
- Shafts
- Tunneling in Soil
- Compressed Air Work

General Requirements for Tunnel and Shaft Construction

In addition to complying with the safety requirements set forth in this section and other parts of these standards, comply with applicable provisions of the construct when excavating and constructing tunnels and shafts. Begin underground- related work only after an acceptable safety program or a detailed supplementary submittal specific to underground operation has covered all aspects of the operation.

Employee Identification: Entrances to all underground facilities must have a check-in and checkout system that provides the contractor with an accurate record of each person underground. The system must be able to identify each individual and general location. General locations include heading, train crew, track crew, maintenance area, storage area, survey station, etc. Additionally, when underground, all employees must carry or wear a positive means of identification, such as a metal disk or tag.

Illumination: Underground lighting and illumination intensities must adhere to the current ANSI/IES RP-7, "Recommended Practice for Industrial Lighting" and UL 924, "Emergency Lighting and Power Equipment." Use nonmetallic light fixtures and support lighting conductors on insulators located on the side to the tunnel or shaft opposite the firing line. Use acceptable portable lighting equipment within 50 feet of any underground heading during explosive handling.

Electrical Equipment. A professional engineer (PE) knowledgeable in underground wiring practices, must design and certify the underground electrical distribution system to meet good practice and applicable standards. Install and maintain all electrical equipment, including the section on "Electrical Safety," to meet applicable requirements. Permit only dry-type transformers underground and ensure they are protected from possible damage. Separate or insulate power lines from air and waterlines, metal ducts, telephone lines, and blasting lines.

Bonding and Grounding. Ground and bonding air and water piping, metal vent pipe, rails, and similar conductive devices at the portal or shaft head and at no more than 1,000-foot intervals.

Blasting. Blasting and explosive- handling operation must conform to the requirements in the "Blasting" section.

Personal Protective Equipment: Employees entering underground working must wear, as a minimum, hardhats, appropriate eye protection, and foot protection. Employees entering wet areas must wear rubber footwear; underground type raingear; and eye, face, and head protection as described in the section on "Personal Protective Equipment." When applicable, provide employees with other personal protective equipment, and ensure they wear them.

Emergency Provisions

Evacuation Plan. Develop and post emergency evacuation plans, including provisions for rescue equipment, at the portal or shaft head. Instruct employees in the emergency procedures.

Self-Rescuers. Provide employees and others with self-rescuers, approved by National Institute of Occupational Safety and Health (NIOSH) and/or Mine Safety and Health Administration (MSHA), or make them available at headings, shaft bottoms, and all other underground work areas. Provide at least one readily available self-rescuer for each employed and visitor. Ensure that employees and others have satisfactorily completed certified training before going underground. Visitors instructed in operating the self-rescuer and accompanied by a trained employee are exempt from this training requirement. Maintain self-rescuers in accordance with the manufacturer's requirements.

Emergency Hoists. Provide an emergency personnel hoist for shafts more than 50 feet deep. Design the hoist so that, as a minimum, the load hoist drum is powered in both directions and a brake automatically applies upon power release or failure. Provide the emergency hoist in a addition to the primary hoist.

Rescue Crews. As part of the emergency plan required in the section on "Emergency Planning," develop an emergency plan covering the possible emergencies requiring the use of a rescue crew. The plan must include the equipment, training, and organization of the rescue crews.

Emergency Lighting. Provide each employee and visitor entering underground workings with an MSHA approved portable hand or cap lamp and make sure the employee or visitor carries it. Providing hand or cap lamps does not take the place of meeting lighting requirements.

Designated Person. At least one designated person must be on duty above ground when personnel are underground. The designated person must be familiar with operating features of the lighting and ventilation system and the procedures for obtaining emergency service. The designee must remain within contact range of the communication system annunciator.

Requirements for Ventilation: Mechanically ventilate all areas of tunnels, shafts, and other underground workings with clean, breathable, non recirculated, outside air. Place the ventilation system in operation before employees enter any underground workings and keep the system in operation until all personnel have left the area serviced by the system.

Requirements for Air Quality

Underground air quality must meet the following specification:

a Oxygen concentration must be between 19.5 percent and 22.0 percent.

b Carbon monoxide concentrations must not exceed 25 parts per million (0.0025 percent).

c Carbon dioxide concentration must not exceed 5,000 parts per million (0.5 percent).

d Nitrogen dioxide concentration must not exceed 3 parts per million (0.0003 percent).

e Hydrogen sulfide must not exceed 10 parts per million (0.001 percent).

1 Conduct tests for hydrogen sulfide in the affected areas every 4 hours whenever hydrogen sulfide levels exceed 5 parts per million (0.0005 percent).

2 Use a continuous sampling hydrogen sulfide indicator with alarm to monitor the affected work area if hydrogen sulfide levels exceed 10 parts per million (0.001 percent).

3 Take steps to increase ventilation to reduce the concentration if the concentration of hydrogen sulfide exceeds 10 parts per million (0.001 percent) time-weighted average for an 8-hour period.

f Do not allow methane gas to exceed 20 percent of the lower explosive limit:

1 Whenever 5 percent or more of the lower explosive limit for methane or other flammable gases is detected, take steps to increase the ventilation rate or other steps to lower the methane concentration.

2 Whenever 10 percent of the lower explosive limit for methane or other flammable gases is detected, evacuate all employees except those necessary to eliminate the hazard, and disconnect electrical power except for explosion-proof pumps and ventilation equipment.

g Do not allow other flammable gases or vapors to exceed 10 percent of the lower explosive limit.

h Do not allow other airborne contaminants, including dust, to exceed the limits prescribed in the section on "Occupational Health."

Requirements for Dust Control

Carry out all drilling and excavation operations in a manner that meets the requirements of this subsection and control airborne dust concentrations within limits prescribed in the section on "Occupational Health." Quantitative testing is required for underground environments and operations to ensure effectiveness of dust control methods.

Requirements for Combustion Engines: Do not use internal combustion engines, other than approved diesel-powered equipment, underground. Provide written approvals or certifications before taking the equipment underground.

Requirements for Noise Control: Assess and control noise associated with underground operations, using the section on "Occupational Health."

Requirements for Fire Prevention and Control: In addition to the requirements set forth in the section, "Fire Prevention and Protection, "the following requirements apply to all underground operations.

Requirements for Excavation Operations: Before the start of excavation operations, trained employees in the safety requirements for the method of excavation to be used: include the equipment to be used, the ground support system, and the material handling systems in the training program.

Drilling Operations

a Examination and Scaling: Before starting the drill cycle, examine the face and lifters for misfires. If found, remove them before drilling. Don't drill lifters through loose rock or water. Inspect the heading, including the face, for loose rock, and scale it before mucking and drilling. Protect employees engaged in these activities from dislodgements by location, ground support, or other equivalent means.

b Equipment Inspection: Inspect drilling equipment each shift and correct defects affecting safety before using the equipment.

c **Drill Jumbos:** On jumbo decks, more than 6 feet high, install removable guardrails with pipe upright and chain handrails or equivalent protection on the open sides and back. Also provide safe access to the deck and cover the decks with solid, nonslip decking. When moving jumbos, do not permit riders on the deck unless they are assisting the operator.

1 Chock jumbos to prevent movement while employees are working on them.

2 Maintain walking working surfaces of jumbos to prevent slipping, tripping, and falling.

d **moving Drills:** Secure drill steel, tools, mast, and other equipment in a safe position when moving a drill to another area. Provide receptacles or racks for drill steel stored on drill jumbos.

e **Drill Masts:** Do not permit employees on the drill mast when the drill bit is in operation.

f **Column Drills:** Firmly anchor drills supported on columns before operation and retighten the drill frequently during operation.

g **Startup Warning:** Before the drill cycle begins, warn the employees working below the jumbo deck.

h **Lifting Material and Equipment:** Provide a mechanical means to raise heavy materials and equipment to the top decks of jumbos more than 4 feet high.

i **Air hose:** Secure all air hose with an inside diameter greater than 0.5-inch at each connection and at the drill with clips and wire rope, chain lashings, or an equivalent safety device.

Requirements for Ground Support

Tunnel Portals: Keep rock faces above and adjacent to portal areas thoroughly scaled, and remove all loose or overhanging rock. Provide chain link fabric on rock faces that are subject to spalling or raveling. Provide a fire-resistive protective canopy at all tunnel portals. The protective canopy must project at least 15 feet from the portal face and must withstand falling earth or rock.

Inspection and Scaling: At least once a shift, a competent person must inspect tunnels and shafts where employees are working. Scale and support them as required. Provide scaling bars and maintain them in good condition. A competent person must inspect the entire tunnel., including roof and walls at least weekly. Maintain weekly inspection records on the surface.

Loose Ground: Remove or support loose rock and earth. Employees scaling or installing supports must work from supproted areas or protect them with spiling, crown bars, shielding, or other equivalent protective systems.

Rock Bolting: A PE must design rock bolt support systems. Make torque meters and torque wrenches available where rock bolts are in use. Make sure a competent person establishes torque testing and retightening intervals, on the basis of rock conditions and existing vibration sources.

Damage Tunnel Supports: Immediately repair or replace damaged or dislodged tunnel supports of any description. Whenever possible, install new supports before removing the damaged supports.

Anchorage: Design and install all sets, including horseshoe-shaped or arched rib steel with the bottoms sufficiently anchored to prevent movement. Install lateral bracing between sets to stabilize the support.

Wood Supporting Structures: Do not use timber supports or wood lagging.

Requirements for Transportation and Haulage: The employer must develop a complete set of operating rules for all types of haulage equipment. Provide a copy of these rules and discuss them with all employees before they go underground. Do not implement operational changes affecting the rules until you change the rules.

Inspection: Maintain all haulage equipment in safe operating condition. A qualified person must inspect it at the beginning of each shift. Correct equipment defects affecting safe operation before using the equipment.

Requirements for Shafts:

In addition to other applicable provisions of this section, the following requirements apply to the excavation of vertical an inclined shafts. Support shaft more than 5 feet deep if employees must enter. A competent person must determine the method of support.

Requirements for Tunneling in Soil

Support. When excavating by conventional methods, do not extend the excavation more than 2 feet in advance of the tunnel supports. When using continuous mining machines, keep the support within 4 feet of the face or shield. Do not permit employees under unsupported or unshielded sections of the tunnel.

Voids. Fill, block, or brace voids ring beams, liner plates, or other supports to prevent caving.

Design of Suuport: A PE must design support systems for tunnels excavated in soil.

Requirements for Compressed-Air Work: The employer must comply with the requirements set forth in 29 CFR 1926.803, “Compressed Air,” when operation involve work in a compressed-air environment.

Indian railway gauge and technical terms

Objectives : At the end of this lesson you shall be able to
- **define rail way**
- **identify zones in railway**
- **state the gauges adopted in Indian railway**
- **define the technical terms railway.**

Introduction

One of the biggest mile stones in the modern civilization is the invention of steam engine in the 18th century. Before that the Romans were first to run the animal drawn vehicles over two parallel lines of stones and bricks embedded in the ground. More and more improvements were done with time in it and a new idea, for preventing the lateral movement of wheels by using angle iron was developed. Later on these angle irons were replaced by cast iron rails on raised flanges on outside, because those raised flanges were more useful in preventing the lateral movement of the vehicles.

After introducing a moderately good track, number of engineers tried to build a locomotive in the early days, but actually George Stephenson was the first man to get complete success in the design and running of locomotive. George Stephenson completely designed, planned, constructed and got success in running the first train of the world on 27th sep, 1825 in England.

Definition

Railways is a mean of land transport, in which the train moves on steel track laid on the ground to carry large number of passengers and bulk and heavy consumption, higher speed and economy, safe and comfort journey. (Fig 1).

Fig 1

Indian railways

Lord Dalhousie started the development of railways in India. The first train was run at 3.30 p.m. on 16th April 1853 between Bombay to Thana, a distance of 33 km. It carried 400 people in 14 coaches and was driven by three engines.

Zonal division of Indian railways

New railway zone

To increase the efficiency of the railways, the ministry of railways has set up six new railway zones.

Classification of Indian railways

The entire railway system was divided into nine zones

Sl. No	Railway zone	Head Quarters
1	Central Railway (C.R)	Mumbai
2	Eastern Railway (E.R.)	Calcutta
3	Northern Railway(N.R)	Delhi
4	Northern Eastern Railway(NER)	Gorakhpur
5	Northern East Frontier Railway (NFR) (Ghauhati)	Malegaon
6	Southern Railway(S.R)	Chennai
7	SouthernCentralRailway(S.C.R.)	Secunderabad
8	South Eastern Railway(S.E.R)	Calcutta
9	Western Railway(W.r.)	Mumbai

The railway lines are classified on the basis of the importance of routes, traffic carried and maximum permissible speed on the routes as such Indian railways are classified into the following main categories.

Sl.No	Name of railway zones	Head quarters
1	East coast railway	Bhuvaneshwer
2	East central railway	Hajipur
3	North central railway	Allahabad
4	North western railway	Jaipur
5	South western railway	Bangalore
6	West central railway	Jabalpur

a Trunk routes

b Main lines

c Branch lines

Indian railways are also classified based on speed criteria and divided into the following five groups

Group A

This group consists of those trunk routes on which the trains run at more 160 km.p.h.

Group B

In this group, the maximum speedd limit of the trains is limited to 130 km.p.h.

Group C

These consists of all suburban routes of Calcutta and Bombay.

Group D

All the routes whether broad gauge or metre gauge where maximum permissible spread is limited to 100km.ph. fall in this group.

Group E

All the other routes where the speed limit is less than 100 Km.p.h. are taken into this group.

Definition of gauge of track

In India, the gauge of a railway track is defined as the clear minimum horizontal distance between the inner faces of the two rails as shown in Fig 2. In other countries, the gauge is measured between the inner faces of the two rails at certain vertical distance from top of rail or rail table. In Europe, the gauge is measured at 14mm below the rail table; in America, it is measured at 15.88 mm below the rail table; and in Japan, it is measured at 16 mm below the rail table.

Gauges adopted on Indian railways

i The clear horizontal distance between inner faces of rails is knwon as the gauge of the track.

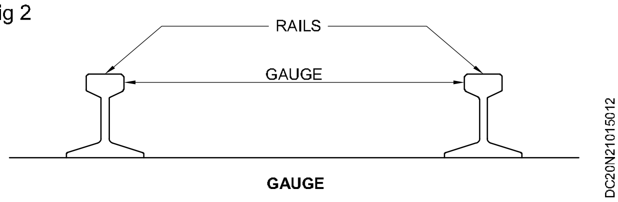
ii There are three types of gauges adopted in India.

iii Broad gauge 1.676 m was adopted for main cities and routes of maximum intensities.

iv Metre gauge 1.00 m. gauge was used for undeveloped areas or interior areas where traffic is very small and future pro spects are not very bright.

v In the hilly areas and very thinly populated areas where it was much uneconomical to use gauge, narrow gauge (N.G.) of 0.762 m. and 0.6096 m. was provided.

Fig 2



Advantages of railways

1 Ensure safe and comfort journey.

2 Easy access to important places of tourist attraction.

3 Due to easy to movements of the products in all part of country, the price stabilisation could be possible.

4 Railway have created the national mentality among the people of different religion, areas, tastes, customs and traditions.

5 Railway helps in mass migrations of people during emergency if required.

Name of gauge	Gauge in metre
Broad gauge	1.676 m.
Metre gauge	1.00 m.
Narrow gauge	0.762 or 0.61 m.

Technical terms

1 **Ballast:** It is the granular material which is used in packing under and around the sleeper for transferring the load to the formation.

2 **Ballast - crib:** The loose ballast between the two adjacent sleepers is known as “Ballast - crib”.

Comparison between railways and road ways

Sl. No	Items	Road way	Rail ways
1	Cost of transport	High cost	Cheaper
2	High area	Suitable	Not suitable
3	Employment	More	Less
4	Load handling capacity	Limited capacity	Large capacity
5	Maintenance	Occasional	Regular
6	Suitability	Suitable for public needs	Suitable for specific service
7	Construction cost	Low	High
8	Power requirement	High	Low
9	Accident	More	Few
10	Comfort	Less	More

3 **Bearing plates:** To reduce the pressure intensity on the soft timber sleepers, steel plates are provided between the rail and the sleepers, which are known as “Bearing plates”.

4 **Broad gauge:** The common widest gauge used in Indian railway, which is 1676 m.m. between the faces of the top flanges of track.

5 **Bull - headed rail:** The rail having similar head and bottom shapes is known of bull - headed rail. It is used with rail chairs.

Fig 3

6 **Boxing:** It is the process of filling the ballast around the sleepers.

7 **Cant (or) super elevation:** It is also known as super elevation, which is provided on the curves to counteract the effect of centrifugal force. In this method the level of the outer rail is raised above the inner rail. This raising of the level of the outer rail over that of inner rail is called cant or super - elevation.

8 **Creep of rails** (Figs 4&5) **Rail creep:** Longitudinal movement of rails in a track in the direction of motion is called rail creep. It varies from negligible length to few centimetres. The rail may either move with respect to sleepers or sleepers may move along with rails.

Major causes of creep in rail

i Rail not properly fixed to sleepers.

ii Bad drainage of ballast

iii Bad quality of sleepers used

iv Improper consolidation of formation bed

v Gauge fixed too tight or too slack

vi Rails fixed too tight to carry the traffic

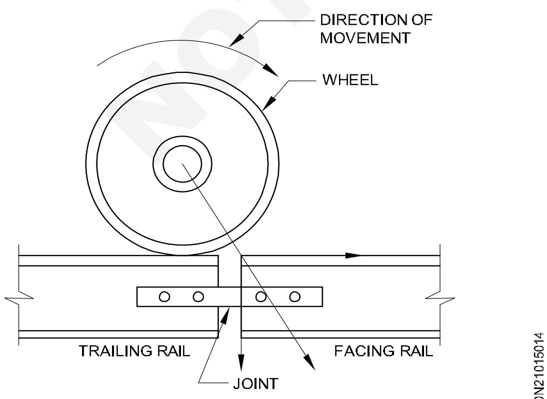
vii Incorrect adjustment of super elevation on outer rails at curves.

viii Incorrect allowance for rails expansion

ix rail joints maintained in bad conditions.

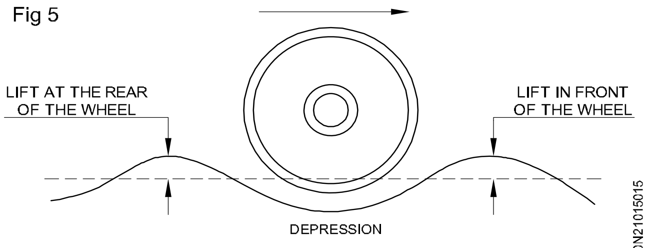
x Brakes

Fig 4



PERCUSSION THEORY OF CREEP

Fig 5



WAVE THEORY OF CREEP

a Due to forces while starting or stopping

b Starting - rails pushed backward

c Stopping - rails pushed forward

xi Wave motion of wheels

a Due to wheel loads rails deflect as continuous beam

b Crests at supports (i.e., sleepers)

xii Changes in temperature

a Unequal expansion and contraction

b Happens more during hot weather

Methods of correcting creep

Pulling back method

Fixing creep anchors

i Creep anchors should be strong to resist stresses.

ii Number of anchors depends upon expected intensity of creep.

iii Placed at originating points and not where the creep is observed.

iv Not placed on bridges. More should be provided on either side of the bridge.

v Additional creep anchors to be placed on railway stations and level crossings.

vi Defective creep anchors should be replaced when observed and accumulation of creep should be prevented.

9 **Fish plates:** These are plates used for joining the rails at rail joints.

10 **Flat - footed rails:** The rails having wider or flatter base, for directly fixing on the sleeper.

11 **Gauge:** Gauge is the minimum distance between the running or gauge faces of the two rails.

12 **Permanent track:** The complete rail road consisting of rails, its fittings, sleepers and ballast laid over the prepared formation, is known as permanent track.

13 **Crossing station:** The single line railway stations, where a loop line is provided to allow a train to stay and other to pass, are known as crossing stations.

14 **Gradien:** The slope provided on the track to reach at various elevations.

15 **Loop line:** When a branch line starting from the main line again joins same main line is called the loop line.

16 **Level crossing:** The place where the road and the railway line cross each other at the same level. (Fig 6)

17 **Point and crossing:** Point and crossing are arrangements, which allow the train to change from one route to another.

Fig 6

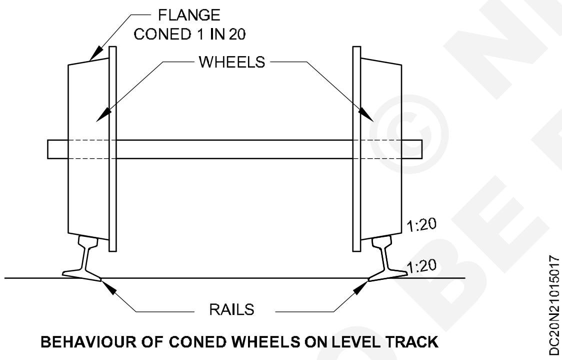
18 **Terminal station:** This is the last station of the routes at which the track terminates.

19 **Turn-table:** it is a revolving device used for turning the direction of the locomotive.

20 **Water column:** it is the vertical pipe with swivel horizontal arm fixed near the track and used for supplying water to locomotive.

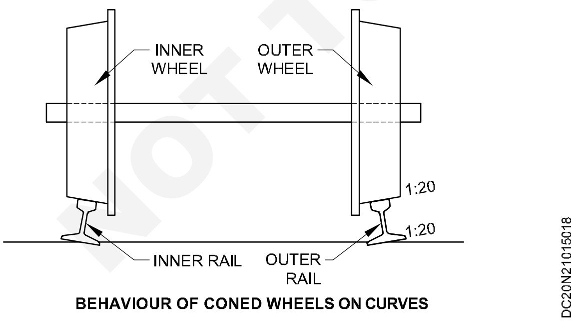
21 **Coning of wheels:** The outer rims of the railway wheel are coned at slope at a slope of 1 in 20, to prevent the rubbing of the wheel flanges with the side of the top flanges of the rails. Provision of this slope of 1 in 20 to the wheel rims prevents the lateral movement of the axle with its wheels which is called coning of wheel (Fig 7&8).

Fig 7



BEHAVIOUR OF CONED WHEELS ON LEVEL TRACK

Fig 8



BEHAVIOUR OF CONED WHEELS ON CURVES

22 **Kinks in rails:** These are formed at the joints of rails, when the adjoining rails move slightly out of position.

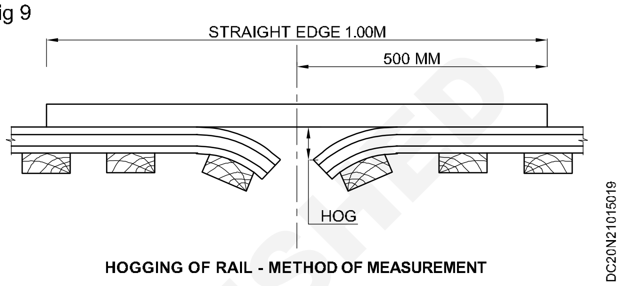
23 **Wear of rails:** The flow of rails metal due to abnormally heavy load is called wear of rails.

24 **Anti creepers:** These are rail fastenings which are fixed to the sleeper and foot of rails to prevent the longitudinal movement of rails.

25 **Check rail:** The rail provided on the inner sides of the main rails at the level crossing and other crossings for guiding the wheel to pass are known as guard rail or check rail.

26 **Hogging of rails:** A hogged rail is one with its end or ends bent in vertical direction. A hogged rail end in the track is ascertained by unfinishing the joints, removing the fastenings and then measuring the extent of hog at the rail end by placing a 1 meter long straight edge over the rail table, centrally over the joints as shown in the sketch above - measures taken to rectify defects: cropping, replacing, welding, dehogging (Fig 9).

Fig 9



HOGGING OF RAIL - METHOD OF MEASUREMENT

27 **Wear of rails:** The moving of a number of wheels of the vehicles causes what is known as the wear of rails. Depending upon its location, the wear of rails can be classified as follows.

1 Wear of rails on top or head of rail.

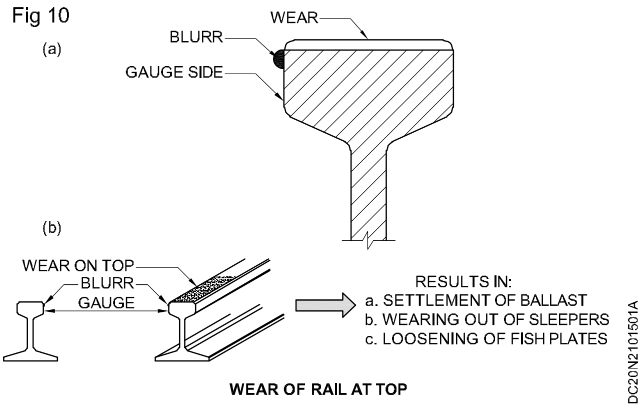
2 Wear of rails at ends of rails.

3 Wear of rail on the sides of the head of rail.

Each of the above type of wear of rails will now be described in brief.

Wear of rails on top or head of rail: The metal from the top of rail flows and forms projections. These are known as the burrs as shown in Figs 10 & 11.

Fig 10



WEAR OF RAIL AT TOP

Following are the causes for such type of wear of rails

i The rails are worn out on top due to abrasion of the rolling wheels over them.

ii The heavy wheel loads are concentrated on very small areas. This results into flow of metal from top.

iii The impact of heavy loads causes top of rail to wear.

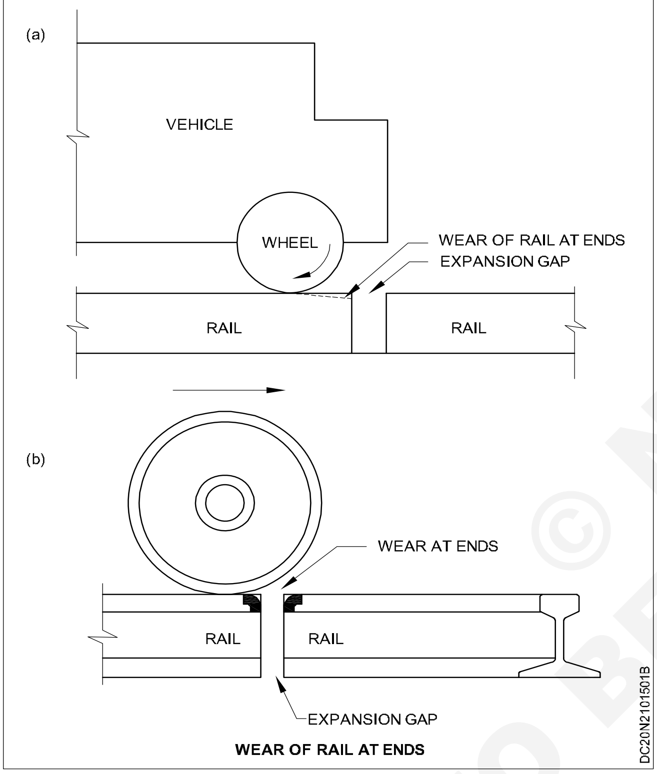
iv The grinding action of the sand particles between the rails and wheels help wear of rail on top.

v The corrosion of metal of rails, especially near sea, will cause wear of head of rails.

vi The metal of top of rail burns during starting when the wheels slip or when brakes are applied to the moving trains.

Wear of rails at ends of rails: This wear of rails takes places at the ends or rails and is found to be very much greater than the wear at top of rails. At the expansion gap, the wheels of the vehicle have go to take a jump and during this jump, they impart a blow to the ends of the rails as shown in figs 12 &13.

Fig 12



WEAR OF RAIL AT ENDS

This below is the main cause of the wear of rails at ends. Due to successive blows, the ends, of the rails are battered and the various other effects are seen which further increases this type of wear. These effects are as follows.

1 The fish - bolts and fish - plates become loose.

2 The contact surfaces between rail and sleepers are worn out.

3 The sleepers at expansion joints are depressed due to set ement of ballast at these points.

Wear of rail on the sides of the head of rail

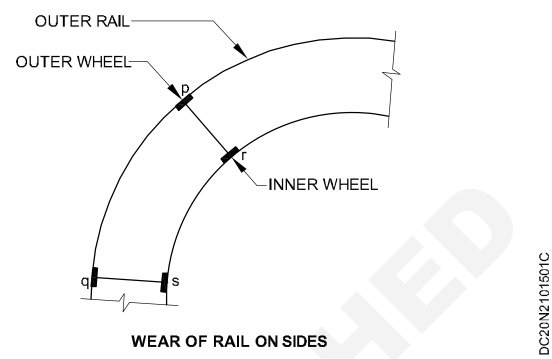
This is the most destructive type of wear and occurs when tracks are laid on curves. The causes of this type of wear are as follows.

i Due to curvature, the pressure due to centrifugal force causes grinding action of wheel flanges on the inner side of the head of the outer rail.

ii The vehicles do not bend to the shape of the curvature while moving over a curve. This results into the biting of the inner side of the head of outer rail by the wheel flanges.

iii The wear on inner side of head of inner rail is mainly due to the slipping action of wheel on curves. It is clear from that the outer wheel has to cover a longer distance than the inner wheel as pq is greater than rs Fig 14.

Fig 14



WEAR OF RAIL ON SIDES

But due to rigid connections between two wheels, they cover the same distance and hence the inner wheel slips over the inner rail, resulting in the wear of inner side of head of inner rail.

28 **Bending of rails:** It is the method of bending the rails section according to the curves required. (Fig 15).

Fig 15

29 **Welding of rails:** Welding is required to join two rails and thus increase the length of rails. It is also used to repair the worn out or damaged rails and thus increase their life and to build up the damaged components of points and crossing. The following methods are used for welding.

They are

1 Electric arc welding

2 Oxy - acetylene welding

3 Chemical or thermite welding

4 Flash butt welding.

Type of rail sections

Objectives : At the end of this lesson you shall be able to
- **define rails**
- **enlist the function of rails**
- **identify the type of rail sections.**

Rails

Definition

Rails are steel girders placed end to end to provide a level and continuous surface for the movement of trains.

Function of rails

1 The rails provide level and continuous surface for the movement of trains.

2 The rails provide a smooth pathway to train. This pathway has a very less friction.

3 The rails serve as a lateral guide for the running of wheel.

4 The rails bear the stresses developed due to vertical loads transmitted to it through axles and wheels.

5 The rails transmit the heavy load to the large area of formation through sleeper and ballast.

Requirements for rail section

1 The design of the rail section should be such that it can safely withstand the heavy lateral forces caused by the fast moving trains.

2 It should be so designed that it can safely bear the load coming over it without failure.

3 The head of the rail should be properly desinged with sufficient margin for the head wear for longer times.

4 The foot of rails should have sufficient width, making them stable against overturning.

Types of rail section

Rail can be classified into the following categories

i Double headed rail

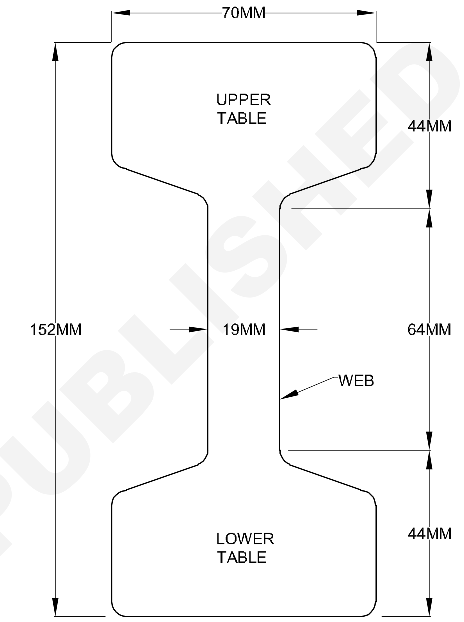
ii Bull headed rail

iii Flat footed rail

1 Double headed rail: Originally the rails used were double headed made of I section or dumb bell section, in which both the tables are identified the idea was that when the head of the rail is worn - out during the service period, the rail could be inverted and reused but later it was found that during the service the bottom table of the rail was dented and impossible to reuse it. This rail requires chairs for fixing it to the sleepers.

These are made of wrought iron with length varying from 6.10 m to 7.32 m(Fig 1)

Fig 1



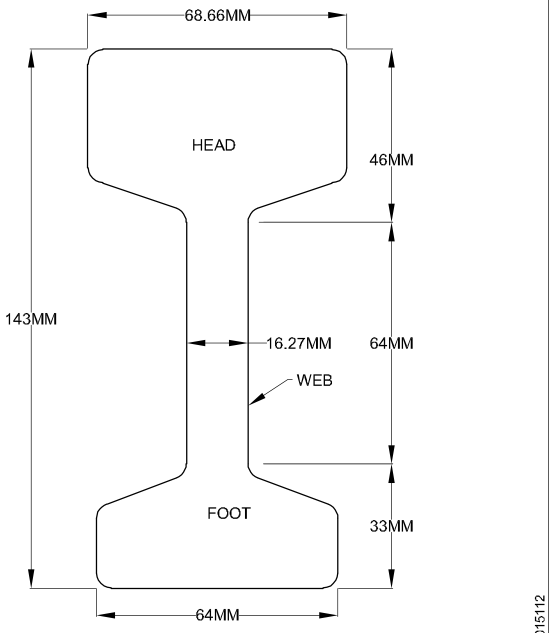
DOUBLE HEADED RAIL

TYPER OF RAILS

2 Bull headed rail (Fig 2) The bull headed rail is almost similar to double headed rail. The only difference between the double headed rail and bull headed rail is that more metal is added to the head to allow greater wear and tear. The lower head or table is kept of just sufficient size to be able to withstand the stresses. This rail requires chair for fixing it to the sleepers. The length of rail is generally 18.29 metres.

3 Flat footed rail (Fig 3) In flat footed rail the lower head is widened like inverted T shaped section. It does not requires chair for fixing. This form of rail was invented by charles vignoles in 1836 and sometimes known as vignoles rails. About 90% of railway track in the world is laid with this form of rails.

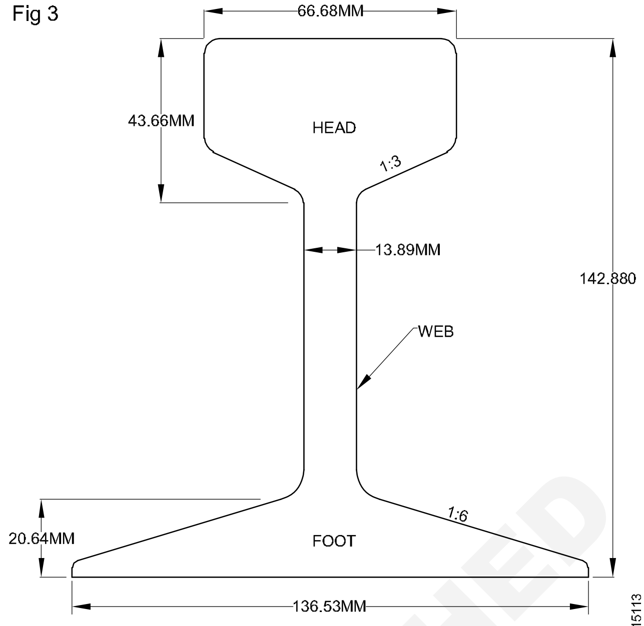
Fig 2



BULL HEADED RAIL

TYPER OF RAILS

Fig 3



FLAT FOOTED RAIL

TYPES OF RAILS

Permanent way

Objectives : At the end of this lesson you shall be able to
- **identify the parts of permanent way**
- **state requirements of good track**
- **understand the construction of permanent way**
- **draw the cross sections of railway tracks.**

Permanent way

Introduction

The permanent way is combination of rails, sleepers, ballast and sub grade. The rails are fitted on sleepers and are joined by fish plates. The sleepers are spaced properly on the ballast and the ballast rests on a prepared sub grade called formation. The rails, which act like girders, transmit the wheel loads to the sleepers. The sleepers distribute it to the ballast which holds the sleepers positions and distribute the load over the formation.

A track or permanent way consists of (Fig 1)

i Rails

ii Rail fastenings

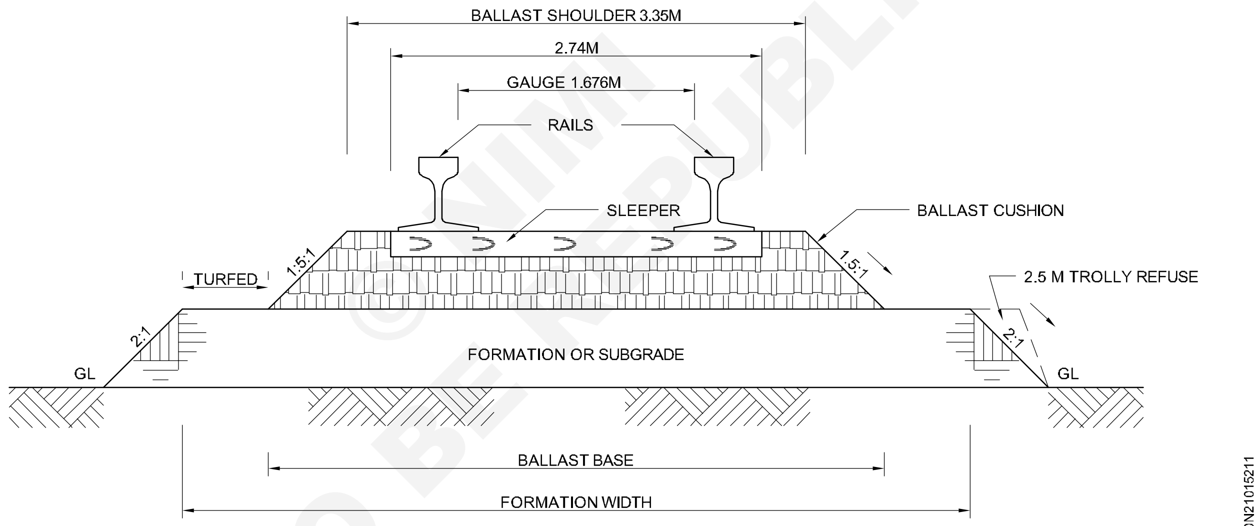
iii Sleepers

iv Ballast

v Formation

Each components of the track has basic function to perform.

Fig 1



A PERMANENT WAY IN EMBANKMENT

Requirement of good track

1 It should have correct and uniform gauge.

2 It should have proper level of two rails on straight track.

3 It should have certain amount of elasticity.

4 It should have perfect drainage system.

5 The joint and point and crossing should be designed properly.

6 The alignment of the track should be correct.

7 The track should be designed in such a way that the load of the train should be distributed uniformly over it.

8 Adequate provision of repair and replacement and renewal of damage portion should be provided.

Construction of permanent way

A new track is constructed in three stages.

Earth work and consolidation

i After deciding the alignment, start the work of permanent way.

ii The process of earth work is started in cutting or in embankment. The formation may either be on embankment or in cutting.

iii Maintain a proper drainage. The height of embankment above highest flood level in the area should not be less than 60 cm.

iv The side slope of embankment, in average soil may be

2:1 and in cutting, it may be 1:1 to 1:5:1

v After laying the earth in embankment, start the process of consolidation by using mechanical devices. Sufficient quantity of water is used, while consolidating.

vi Then the formation should be left open for at least two monsoons.

Plate laying

i Plate laying is the process of laying rails and sleepers over the prepared formation.

ii The ballast is generally laid after two to three monsoons of plate laying.

iii Plate laying is carried out by 3 different methods.

1 Tram line or side method.

2 Telescopic method

3 American method.

Laying of ballast

i The loaded wagons of ballast are taken to the site

ii Ballast is unloaded into a number of heaps at suitable intervals along the track.

iii The spreading of ballast on track is done by ballast trains and packing is done by labour force.

iv The minimum depth of ballast should be 20 cm. for broad gauge.

Cross section of rail way track

i The top of embankments and the floor of the cutting is known as the formation, over which track is laid. Before laying of the track, first a formation is prepared.

ii The width of the formation depends upon the gauge of track, number of tracks and the space between tracks. Side slopes in embankments and cutting should suit the soil conditions.

iii On sides of the embankment and cutting sufficient drains should be provided to carry away the rain water. If possible the barrow pits placed on the upper side of the cross section of the ground and the spoil bank on the lower side.

iv Indian railway board has recommended the following dimensions of board gauge.

a Minimum distance, centre to centre of track = 4. 725 m.

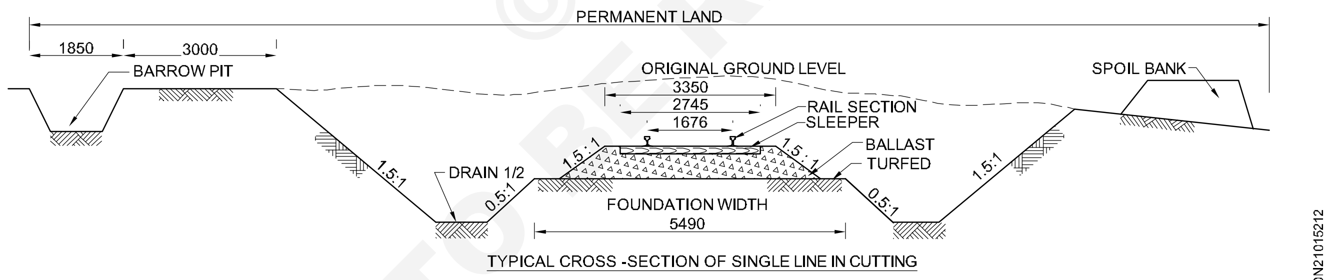
b Minimum formation width in embankment (single line) = 6.10 m (Fig 4).

c Minimum formation width in cutting (single line) - 5.49 m (Fig 2).

d Minimum formation width in embankment (double line) = 10.82 m (Fig 3).

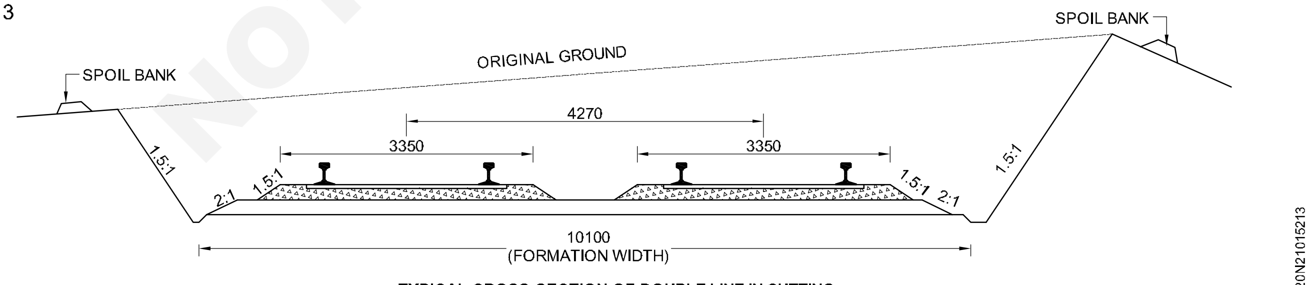
e Minimum formation width in cutting (double line) = 10.058 m (Fig 3).

Fig 2



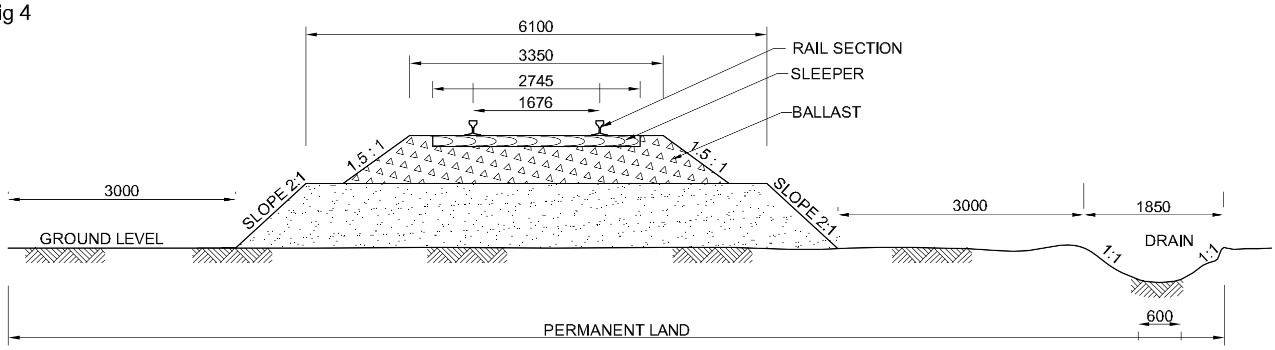
TYPICAL CROSS-SECTION OF SINGLE LINE IN CUTTING

Fig 3



TYPICAL CROSS-SECTION OF DOUBLE LINE IN CUTTING

Fig 4



TYPICAL CROSS-SECTION OF SINGLE LINE IN EMBANKMENT

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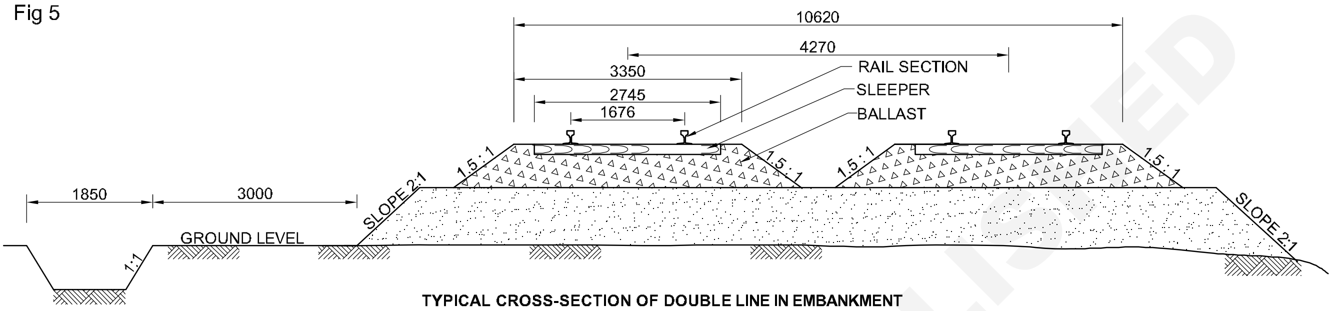
Fig 5



TYPICAL CROSS-SECTION OF DOUBLE LINE IN EMBANKMENT

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Sleepers

Objectives : At the end of this lesson you shall be able to

- **define the sleepers**
- **state the function of sleepers**
- **state the requirements of good sleeper**
- **identify the types of sleepers.**

Sleepers

Rails require some support on which they can be laid and fixed. These transverse supports for rails are known as sleepers which keep the rails apart at required distance.

Function of sleeper

1 It holds the rails at proper gauge.

2 It transfers the load of the trains from rails to the ballast or girders of bridge.

3 It provides stability to the track.

4 It acts as an elastic medium between the rails and the ballast.

5 It hold the rails in proper level.

Requirements of good sleeper

1 They should maintain correct gauge.

2 The rails should be such that they can be easily fixed and taken out from the sleepers without moving them.

3 They should provide sufficient bearing area for the rails.

4 They should be sufficiently strong to act as a beam under load.

5 They should have sufficient weight for stability.

6 They should be economical in initial as well as maintenance cost.

7 They should not be too heavy nor light in weight.

Types of sleepers

Different types of sleepers are used in Indian railway depending upon location and materials.

Depending upon location

a Liongitudinal sleepers

b Transverse sleepers

a Longitudinal sleepers

These are early forms of sleepers. These are made of slabs of stones or pieces of timber placed parallel to the rail.

Transverse sleepers

These are otherwise known as cross sleepers and are now in use all over the world. These are placed at right angle under the rails. The maximum spacing between sleepers is 500 mm, 300 mm and 250 mm for BG, M.G and N.G respectively.

Depending upon materials

Differential types of sleepers are used in Indian railway depending on their availability, suitability, economy and design. The following are the different types of sleepers, based on the material of construction.

1 Wooden sleepers

These are made of hard wood like, teak wood, rose etc. Wooden sleepers are cheap and easy to manufacture and more useful for heavy loads and high speed. Their serviceable life is about 12 to 15 years.

Size of wooden sleepers

Gauge	Size in cm	Bearing area per Sleeper in cm^2	App.wt.in kg	
			U	T
B.G	275 x 25 x13	4645	73	56
M.G	180 x 20 x 11.5	3096	33	26
N.G	150 x 18 x 11.5	2100	24	19

The fitness of timber is indicated by C.S.I number (Composite Sleeper Index). Mostly used timber is teak.

Advantages

Following are the advantages of the timber sleepers:

1 The fittings for timber sleepers are few and simple in design.

C.S.I of timber species

No	Name of timber	C.S.I
1	Chir	54
2	Deodar	63
3	Fir	58
4	Sal	112
5	Teak	82

2 They are suitable for all types of ballast.

3 They are easy to lay, relay, pack lift and maintain.

4 They give less noisy track because they are able to resist the shocks and vibrations due to heavy moving loads.

5 They prove to be overall economical

6 They can be obtained in different sizes and lengths for easy adaptability at special locations like points and crossings, bridges, ash-pits, etc.

7 They permit track-circuiting because they are good insulators.

8 The damages during derailment is less when these sleepers are used.

9 They can be used on yieding formation because of their large bearing area.

10 It is possible to widen the gauge with the wooden sleepers.

Disadvantages

Following are the disadvantages of the time sleepers

1 It is difficult to maintain gauge.

2 The maintenance cost is high as compared to other types of sleepers

3 The useful period of timber sleepers is less as compared to other types of sleepers

4 They are easily disturbed from their positions

5 They are subjected to wear and decay due to various forces such as white ants, vermins, rail cutting, warping cracking etc.

6 They require special treatment for fire protection

7 They possess less scrap value

2 Steel Sleepers: The steel sleepers are extensively used on the Indian railways, with excellent results. (Fig 1)

3 Cast iron sleepers: Cast iron sleepers are extensively used in Indian railway. They are easy to manufacture. Its service life is about 50 to 60 years.

Types of cast iron sleepers

a Pot sleepers

Pot sleepers are in the form of two bowls placed under each rail and connected together by a tie bar.

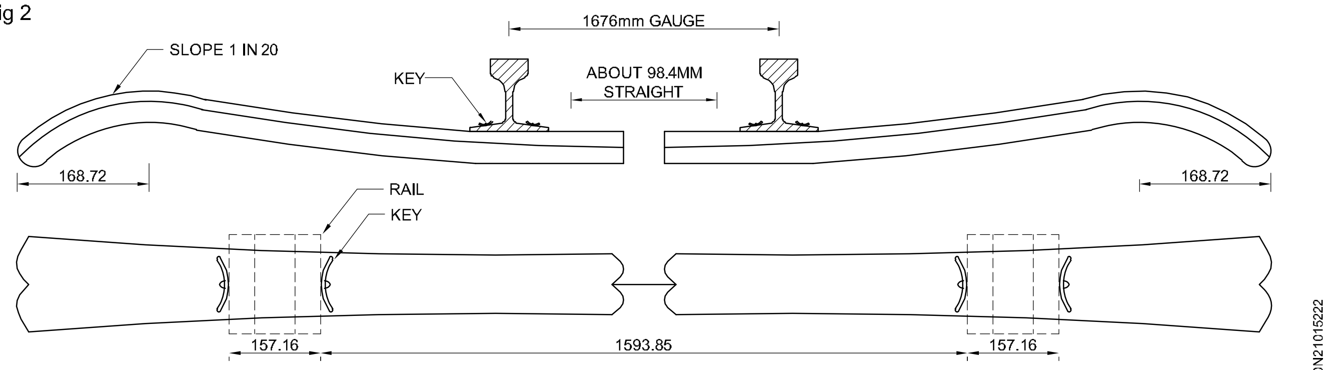
b Plate sleeper (Fig 2)

It consists of a plate of 851 mm X 254 mm in dimensions with 254 mm side parallel to the rails. The plate is provided with projecting rib at the bottom to provide a grip. The sleeper plates are connected across the track by means of a tie bar.

c C.S.T. - Sleeper(Central Standard Trial-9) (Fig 3)

This sleeper is a combination of pot, plate and box sleepers.

Fig 2



STEEL SLEEPER

Fig 3

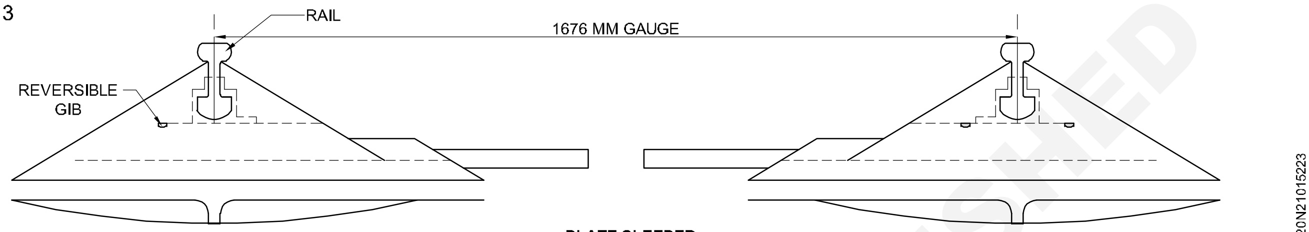
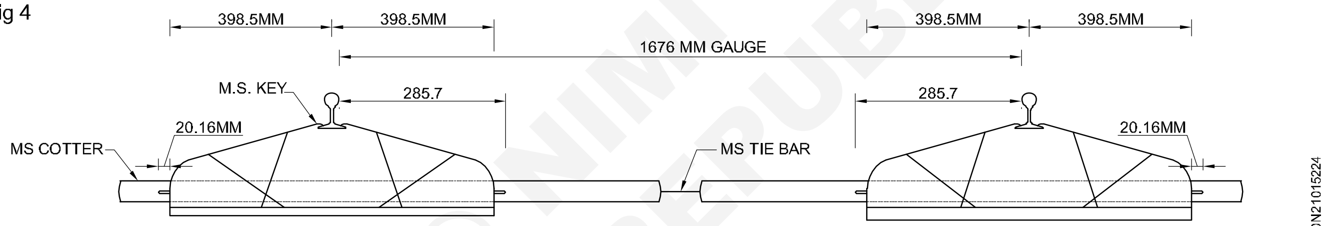


PLATE SLEEPER

Fig 4

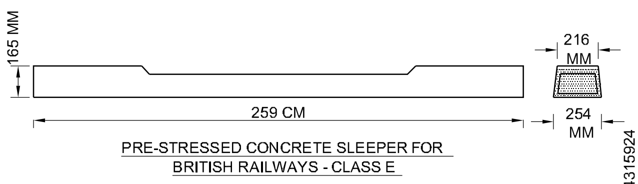


C.S.T. - 9 SLEEPER

Reinforced concrete sleepers (Fig 4)

There are two types of RCC sleepers. First type is like a wooden sleeper. In the second type two R.C.C slabs are jointed together by means of a tie bar.

Fig 4



PRE-STRESSED CONCRETE SLEEPER FOR BRITISH RAILWAYS - CLASS E

R.C.C. SLEEPER

Ballast

Objectives : At the end of this lesson you shall be able to
- **define the ballast**
- **state the functions of ballast**
- **state the characteristics of good ballast**
- **identify the types of ballast used in railway.**

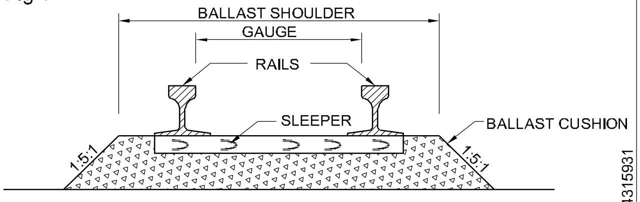
Ballast (Fig 1)

It is layer of broken stone, moorum or any other material placed under and around the sleepers to distribute the load from the sleepers to the formation and for providing drainage as well as providing lateral and longitudinal stability to the track.

Packing and boxing

Some portion of the ballast it tightly rammed under the sleepers to transmit the load of the train from the sleeper, which is known as packing. The portion of the ballast loosely filled on the slopes and thrown around the sleepers to prevent the lateral and longitudinal movement of sleepers is known as boxing.

Fig 1



BALLAST SECTION

Functions of ballast

i It provides a suitable foundation to the sleepers.

ii It transfers and distributes loads from sleepers to a large area of formation.

iii It increases the elasticity and resilience for the track for the getting good riding comfort.

iv It provides lateral and longitudinal stability to the track.

v It provides an easy means of maintaining evenness and alignment of the track.

vi It provide effective drainage to the track.

vii It helps in protecting the top surface of the formation.

viii It prevents the growth of weeds inside the track.

Characteristics of good ballast

i It should be hard, tough and wear resistant

ii It should not get crushed under moving loads

iii It should be non porous and non absorbent of water.

iv It should be cheap easily available

v It should have sufficient elasticity.

vi It should have sufficient grip over the sleeper to prevent their horizontal movement. It should provide good drainage of water.

Ballast material

Material for ballast which are generally used on Indian Railway are:

i Broken stone

ii Gravel

iii Sand

iv Ashes

v Moorum

vi Kankar

vii Brick bats

viii Slag

The best material for ballast is non-porous, hard and angular stone and therefore the stone ballast is used on all important tracks.

I **Broken stone:** It is the most expensive but best type of ballast. Due to its high inter locking action it holds the track to the correct alignment.

ii **Gravel:** It consists of smooth rounded fragments obtained from river beds.

iii **Sand:** It is used on unimportant lines, sidings and marshalling yards.

iv **Moorum:** It is obtained by the decomposition of laterite and is used on unimportant lines and sidings.

v **Coal ashes:** These are waste products obtained from steam locomotive. It is used only in sidings and unimportant lines.

vi **Kankar:** These are impure lime stone in the form of nodules and used in restricted places.

vii **Brick ballast:** At some places where stone or other good ballast materials are not available over burnt brick ballast is used.

viii **Slag:** It is waste product obtained from the blast furnaces and is widely used in foreign countries.

Standard size of ballast for various sleepers

Size of ballast	Type of sleepers
50 mm	Wooden and C.I. post sleepers
40 mm	C.T.S. -9 and steel sleepers
25 MM	Points and crossing

Fixtures and fastenings

Objectives : At the end of this lesson you shall be able to
- **describe fish plate and fish bolt**
- **describe rail chair and bearing plates**
- **state the types of elastic fastenings.**

Rail fastening

Rail fastenings and fixtures are used to connect the rail and sleepers together in their proper positions

a Fish plates (Figs 1,2 & 3)

Rails are manufactured in certain fixed lengths keeping in view the economy and ease in tansportation. These rails are then joined together to form one long contiunous rail. For joining the rail, fish - plates are used.

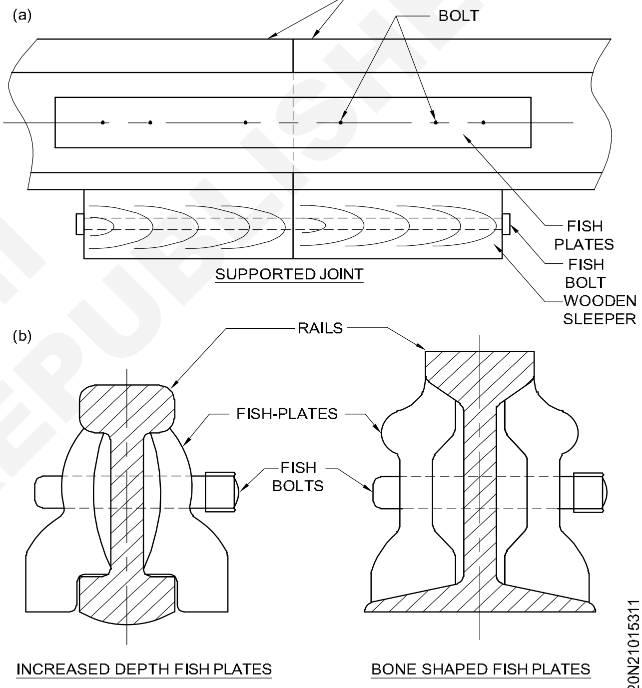
Two types of fish-plates are commonly used on Indian Railways for joining F.F. Rails and B.H. rails. Two fish plates are fixed at each joint with four bolts. These fish-plates are so designed that they fit the underside of the rails head and the top of the rails foot of F.F. Rails.

Fig 4

b Fish bolts (Fig 4)

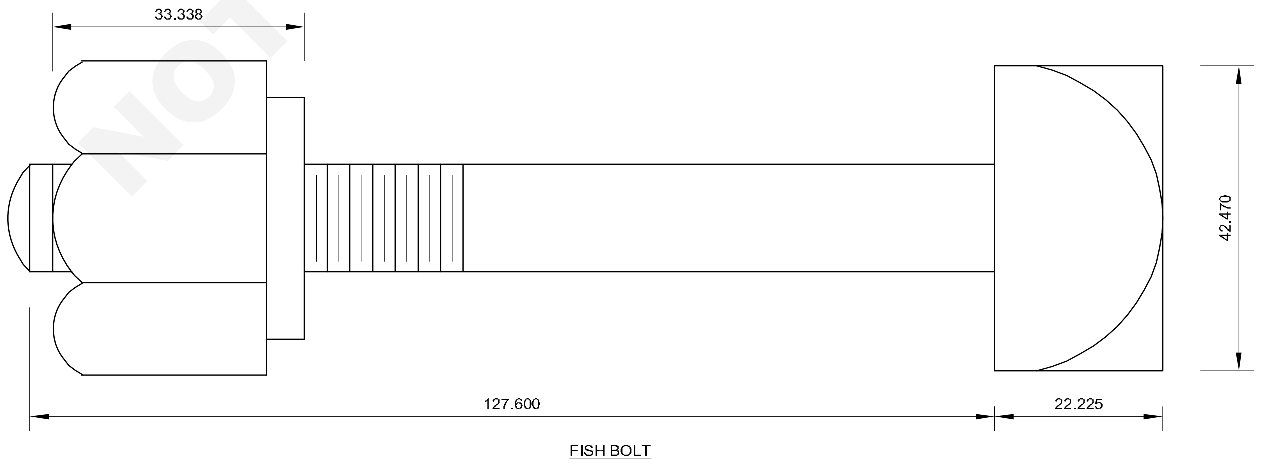
Fish plate are connected to the rails with the help of fish-bolts. With each pair of the fish plates four or six bolts used. But on Indian Railways four number of fish bolts are used. To with stand heavy stresses, they are made of medium or high carbon steel. The length of fish bolt depends of the type of fish-plates. These bolts generally get loose by the vibration caused by the moving loads and require tightening from time to time.

Fig 1



FISH - PLATES

Fig 2



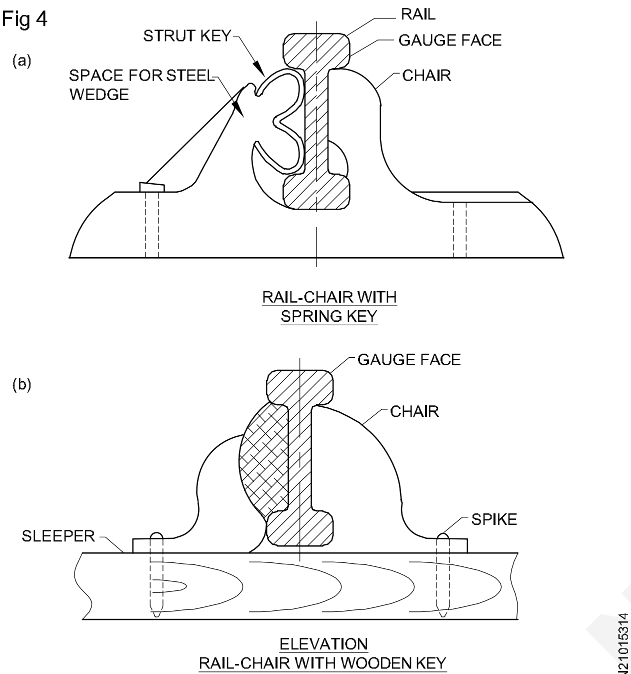
FISH - BOLTS

c Rail-chairs (Fig 5&6)

It is device which is used to fix the double headed and bull headed rails on the sleepers. The chairs are generally made of cast iron.

Two types of rail chairs are commonly used. The rail is placed between the jaws in such a way that the inner jaw should remain in contract with the web of rial. In this space left between outer jaw and the web of rail, slightly tapered steel or wooden key is driven.

Fig 4



RAIL-CHAIRS

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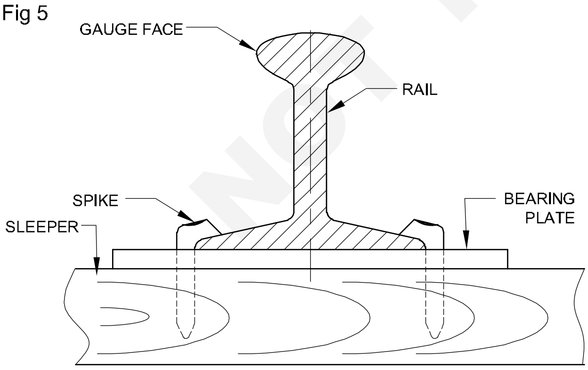
d Bearing plates (Fig 7)

Flat footed rails can be directly fixed on sleepers of hardwood, but very heavy loads of train's cause the rail to sink in the sleeper and thus loosen the spike. In the case of soft wood sleepers, the timber fibres are crushed under loads. To overcome this difficulty bearing plates are fixed to sleepers by spikes. They may be of cast iron or steel.

Fig 5



BEARING PLATES

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They distribute the pressure over a wider area and prevent the crushing of sleepers by preventing the rubbing action on the rails.

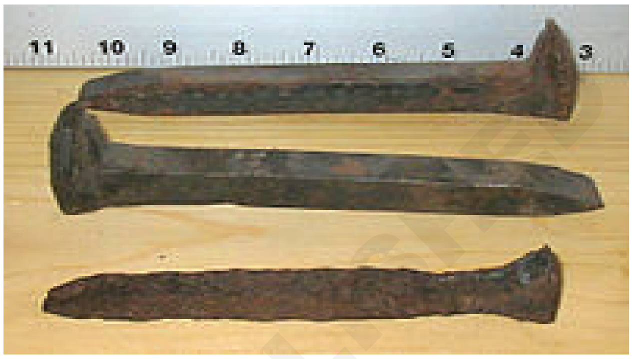
e Spikes

These are used for fixing the rails to the wooden sleepers. Various types of spikes are commonly used in the railways. There are -

i Dog-spikes (Fig 8a)

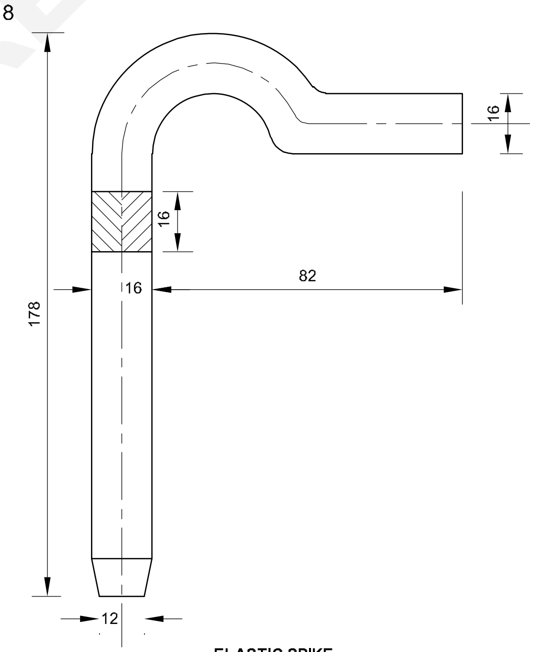
ii Round spikes (Fig 8b)

iii Screw spikes (Fig 8c)



Elastic spike: These are the special types of fastenings used for holding rails to the sleepers firmly at a constant pressure without affecting the track structure for sufficient time. These are suitable for high speed track. These spikes are not used in Indian railways (Fig 9).

Fig 8



ELASTIC SPIKE

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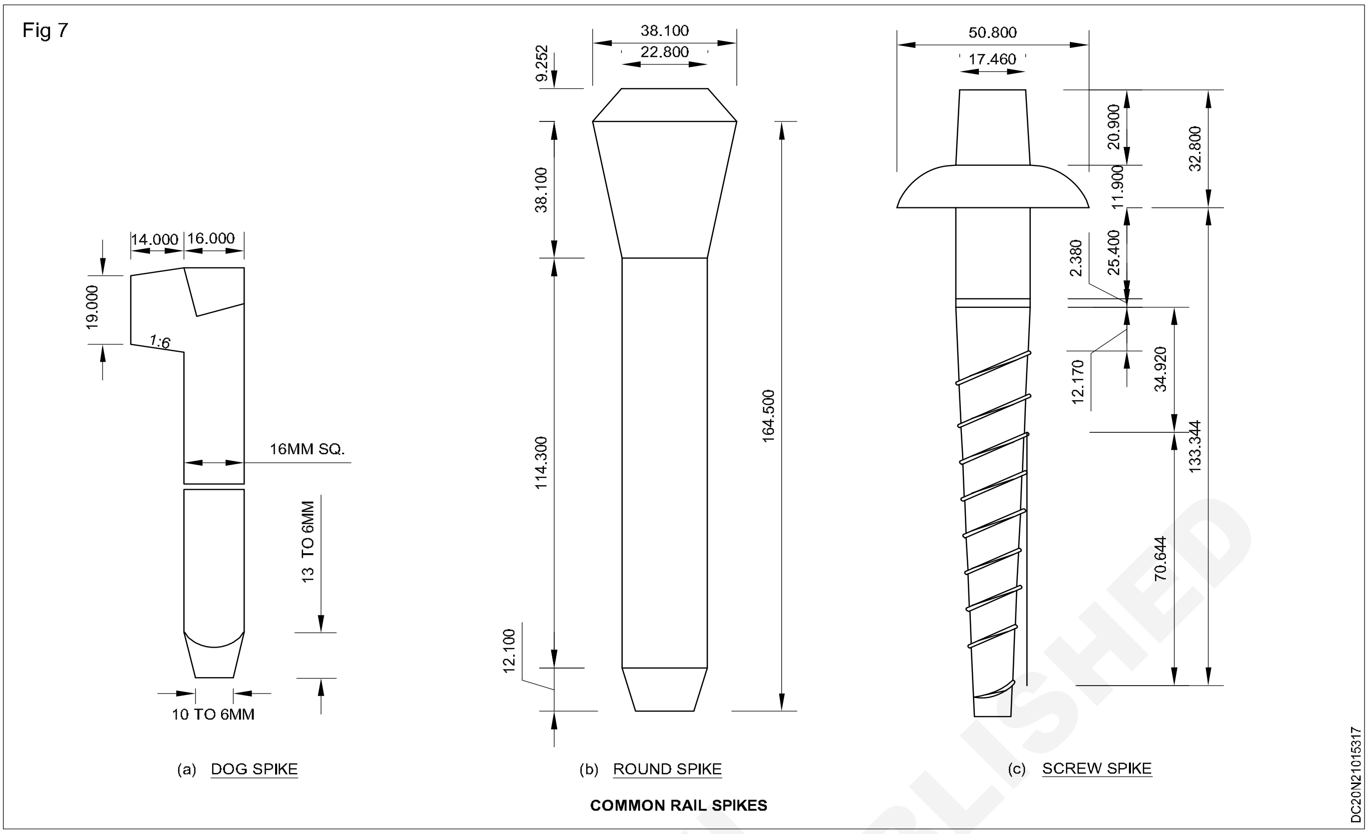
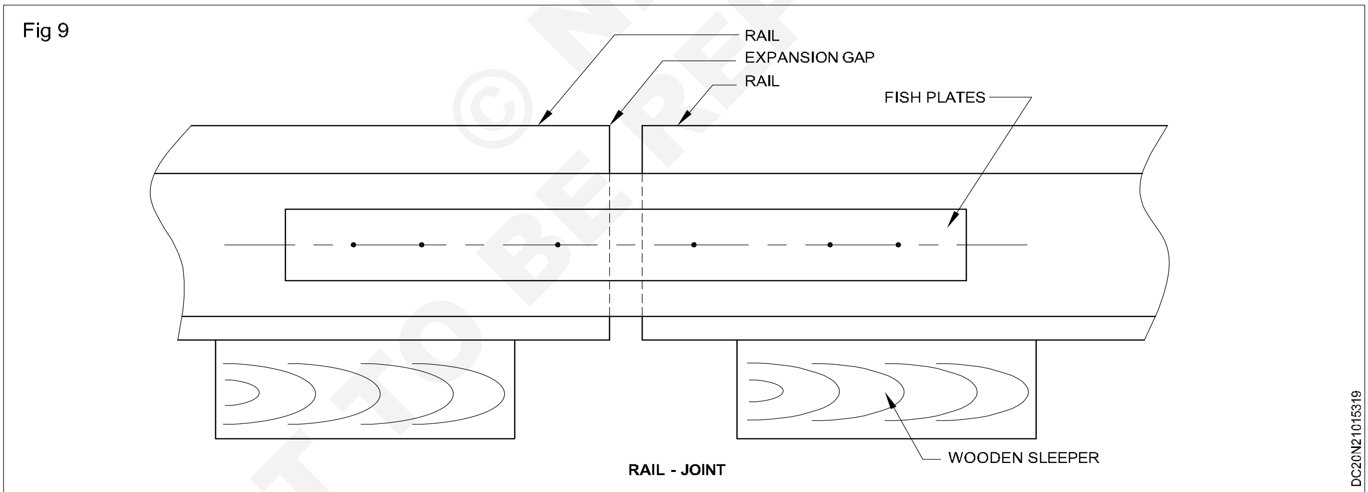
Rail joint: It is impossible to construct track without rail joint. Rails are manufactured in suitable length and are jointed together after laying. The rails can be jointed

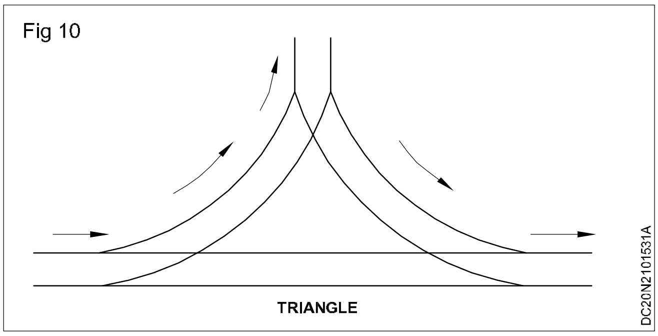


together with the help of fish plate and bolts or welding. Between two rails 1.5 to 3mm gap is provided. generally for giving more strength, sleepers near rail joint are placed closer together (Fig 10).



Turn tables and triangles (Fig 11)

These are used for changing the direction of engine. Tum tables are very costly and cannot be everywhere for turning the direction of engine. At small stations where small numbers of engines are to be turned, a tringle can be used. This consists, of three short lengths of tracks laid to form a triangle. If one engine moves completely round the triangle its direction is automatically changes.



Creep - Screw spikes - Washers

Objectives : At the end of this lesson you shall be able to
- **define Creep**
- **explain Screws - Spikes & washers.**

What is Rail Creep

Creep in rail is defined as the longitudinal movement of the rails in the track in the direction of motion of locomotives. Creep is common to all railways and its value varies from almost nothing to about 6 inches or 16 cm.

Causes of Creep

The causes of rail creep can be broadly classified into two categories

1 Major Causes of Creep

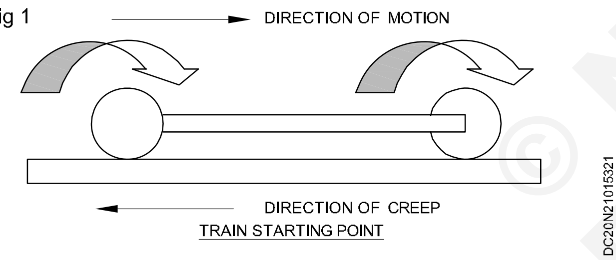
2 Minor Causes of Creep

Major Causes of Creep

Major causes of creep also known as principal causes of creep. Follows are the major causes of creep in rail

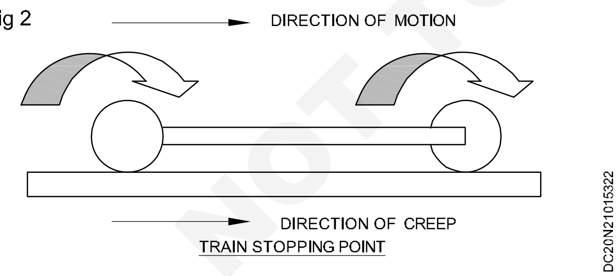
1 Creep may be developed due to forces that come into operation when the train is starting or stopping by application of brakes. Increase so starting the wheels pushes the rail backward and hence the direction of creep is in backward direction. (Fig 1)

Fig 1



When brakes are applied then the wheels of the vehicles push the rails in forward direction and hence the creep is in forward direction. (Fig 2)

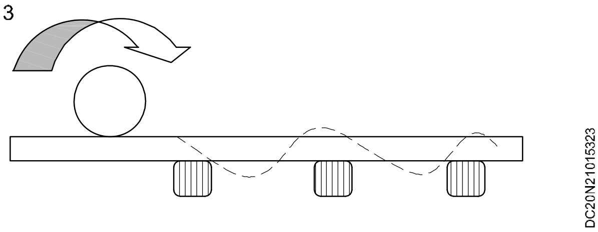
Fig 2



2 Creep is also developed due to wave motions. When the wheels of the vehicles strikes the crests, creep is developed. (Fig 3)

3 Another reason creep develops because of unequal expansion and contraction owing to change in temperature.

Fig 3



Minor Causes Creep

Some of the minor causes of creep in rail are below:

1 Rails not properly fixed to sleepers

2 Bad drainage of ballast

3 Bad quality of sleepers used

4 Improper consolidation of formation bed

5 Gauge fixed too tight or too slack

6 Rails fixed too tight to carry the traffic

7 Incorrect adjustment of super elevation on outer rails at curves

8 Incorrect allowance for rails expansion

9 Rail joints maintained in bad condition

Magnitude and Direction of Creep

Creep is not constant over a given period, it is not contune in one direction or at uniform rate. Both the rails of the track may creep in same direction, perhaps both the rails reverse the direction of creep or one rail creep in opposite direction to that of other.

Results and Consequence of Creep

Following are some of the undesirable consequences of creep

1 The most serious effect of creep is the buckling of track in lateral direction. If unattended and not properly removed then it causes derailments which leads to accidents.

Correction of Creep | Methods against Creep

There are two methods used for the correction of creep. These are

1 Pulling back Method

2 Use of Creep Anchors / Anti Creepers

Tags rails way ngineering's

Railway Sleepers Definition, Characteristics, Treatment

Railway Sleepers Density (Fig 4)

Railway Sleepers - Types of Sleepers (Fig 5)

Fig 24

Fig 25

Different types of rail anchors including “T” type, used where the fastenings system requires extra creep resisting arrangement. There are various shapes of the anchor made of rolled bars of various sections. The anchors when driven in rail feet, grip the rail firmly and when set against sleepers resists longitudinal movement of Rails Caused by passing trains. (Figs 6 & 7)

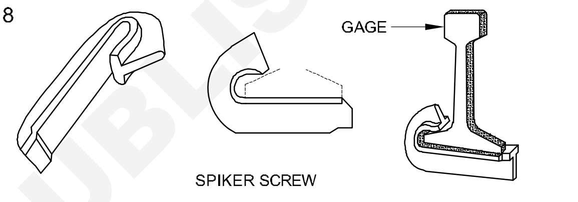
Fig 26

Fig 27

Screw Spike/Coach Screw (Fig 8)

One of the most popular rigid rail fixation item, are extensively used to tighten the rail track on wooden or concrete tie. Screw Spikes are used for fixing tie plates on the wooden ties in pre-bored holes and with plastic inserts pre-cast in concrete sleepers. They are extensively used on high-speed tracks with the extremely popular H.M. fastening

Fig 8



Washers

Different type of Washers (Plain & Spring) in accordance to International Level specification including IS, BS, EN , GOST and others. The spring washers are manufactured from spring steel bars.

Functions

- Providing greater bolt tension per unit of applied tighter assemblies.
- Providing hardened bearing surface to create more uniform torque control.
- Providing uniform load distribution through controlled radii-section-cutoff.
- protection against looseness resulting from vibration & Corrosion.

Terms used in irrigation & Hydrology - Hydrograph and intensity of irrigation

Objectives : At the end of this lesson you shall be able to
- **explain Hydrograph**
- **explain in density of irrigation**
- **define irrigation**
- **state the advantages, disadvantages and ill effects of irrigation**
- **identify the different types of irrigation**
- **define different technical terms used in irrigation.**

Definition of hydrology

1 Introduction

Where is the greatest resources of humanity. It only helps in survival but also helps in making life comfortable and luxurious. Besides various other uses of water, the largest use of water in the world is made for irrigating lands. Irrigation, leads - When sufficient and timely water does not become available to the crops, the crops fade away, resulting in lesser crop yield, consequently creating famines and disasters. Irrigation can, thus save us from such disasters.

The fact that the provision of irrigation facilities can enhance the yield of our crops by large extent, can be found from the fact that in some states of India the crops yield is in greater percentage when compared to some other states because, proper irrigation facilities are available, even though the land available for irrigation in these states is less.

It can, therefore, be concluded that if full irrigation facilities are not developed, reduced crops yield shall be obtained. And, if sufficient food grains are not available, virtually, the entire progress of the humanity shall be hampered. In the light of these facts, it can be easily emphasised that "irrigation" is inevitable, at least in every tropical or subtropical country like India.

2 Definition of irrigation

Plants are living beings and do require water and air for their survival, as do human beings require. Their requirement of water varies with their type. Different types of plants require different quantities of water, and at different times, till they grow up completely. Water is normally supplied to these plants by nature through direct rain or through the flood waters of rivers which inundate large land areas during floods. The flood water may saturate the land before the flood is subsided. The water absorbed by the land during floods, supplements the water requirements of the crop during dry season. Sometimes there may be very heavy rains creating serious floods and damaging the crops, and sometimes, there may not be any rains at all, creating scarcity of water for the crops. Thus, famine and scarcity conditions are created. In his bid to control the nature, man discovered various methods by which the water can be stored during the periods of excess rainfall and to use that extra water during periods of excess rainfall and to use that extra water during periods of 'no rainfall' or 'less rainfall'. The art or the science by which it is accomplished. is generally, termed, as irrigation. Irrigation may, therefore, be defined as the science of artificial application of water to the land, in accordance with the 'crop requirements' throughout the 'crop period' for full-fledged nourishment of the crops.

3 Necessity of irrigation in India

India is a tropical country with a vast diversity of climate, topography and vegetation. The quantity of rain fall varies considerably depending upon its place of occurance. Crops cannot, therefore, be raised successfully, over the entire land, without ensuring artificial irrigation of fields.

More than seventy percent of our population, directly depends on agriculture, and the remaining depends indirectly on agriculture. Out of a total geographical area of about 328 million hectares, about 180 million hectares is the cultivable area. In order to save this area from the complete wishes of nature, and to ensure full growth of crops, it is necessary that adequate artificial irrigation facilities are ensured. In order to achieve this, the Indian Government is trying hard and spending enormously to provide irrigation facilities for the entire cultivable land.

4 Irrigation engineering

Irrigation engineering is a science that tells us about the ways and means adopted by the irrigation engineer to achieve the application of irrigation water. An irrigation engineer is one who helps to bring irrigation water from its source of supply to agriculture land.

5a Advantages of irrigation

The advantages of irrigation are summarised below

1 **Increase in food production:** Irrigation helps in increasing crop yields, and hence, to attain self-sufficiency in food.

2 **Optimum benefits:** Irrigation helps in increasing crop yields, and hence, to attain self-sufficiency in food. By optimum utilisation, we generally mean, obtaining maximum crop yield with lesser amount of water. In other words, yield will be smaller for any quantity lesser than optimum quantity.

3 **Elimination of mixed cropping:** In the areas, where irrigation is not assured, generally mixed cropping is

adopted. By mixed cropping, we mean, sowing together of two or more crops in the same field. If the weather conditions are not favourable to one of the crops, they may be better suitable for the other, and thus, the farmer gets at least some yield. Mixed cropping, is thus, found necessary and also economical when irrigation facilities are lacking, and especially during Crash programmes in under-developed countries. But if the irrigation is assured, mixed cropping can be eliminated or reduced.

Mixed cropping is generally not acceptable, because different crops require different types of field preparations and different types of watering, manurings, etc. If two crops are mixied together, the field preparations, watering, manuring, etc. cannot be made to suit the special needs of either. Moreover, during the time of harvesting, the crops get intermixed with each other, reducing the purity of each other. But, when regular and permanent water supply is assured, a single superior crop can be sown, depending upon the conditions of the soil and the needs of the country.

4 **General prosperity:** Revenue returns, are sometimes, quite high and helps in all round development of the country and prosperity of the entire nation and community.

5 **Generation of hydro-electric power:** Cheaper power generation can be obtained on projects, primarily designed for irrigation alone. Canal falls can be used for ever generation. Ganga and Sarda canals, construced for irrigation, are now generating hydro-electric power as a side product, up to about 80,000 kilo-watts.

6 **Domestic water supply:** Irrigation helps in augmenting the town water supply, where water is available with a great difficulty. It also provides water for swimming, bathing, cattle drinking, etc.

7 **Facilities of communications:** Irrigation channels are generally provided with embankments and inspection roads. These inspection paths provide good roadways to the villagers for walking, cycling or sometimes ever for motoring.

8 **Inland navigation:** Sometimes, larger irrigation canals can be used and developed for navigation purpose.

9 **Afforestation:** Trees are generally grown along the banks of the channels, which increase the timber wealth of the country and also help in reducing soil erosion and airpollution.

5b Disadvantages and Ill-effects of irrigation

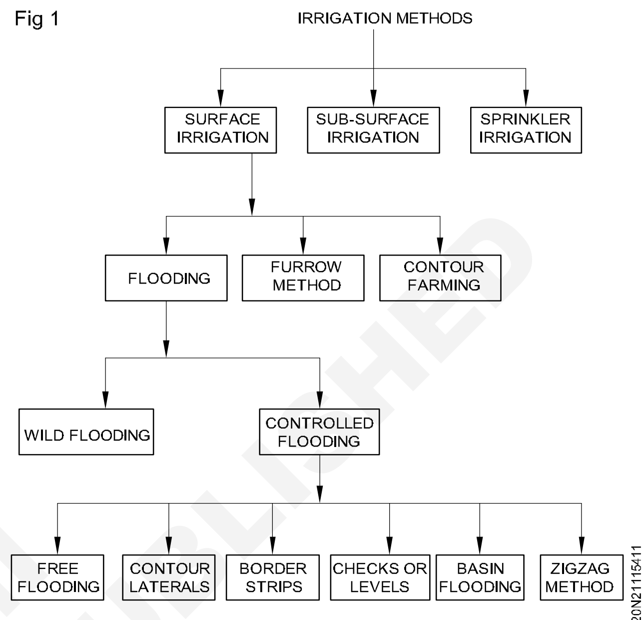
i irrigation may contribute in various way to the problem of water pollution. One of these is the seepage into the ground water of the nitrates, that have been applied to the solid as fertilizer. Sometimes, upto 50% of the nitrates applied to the soil, sinks into the underground reservoir. The underground water may thus get polluted, and if consumed by people through wells, etc., it is likely to cause disease such as anemia. It will ultimately affect the finishing, as the tides carried the polluted water out into the ocean, is still of research.

ii Irrigation may result in colder and damper climate, causing outbreak of diseases like malaria.

iii Over-irrigation may lead to water-logging and may reduce cropy yields.

iv Irrigation is complex and expensive in itself. Sometimes, cheaper water is to be provided at the cost of the government and revenue returns are low.

Fig 1



METHODS OF IRRIGATION

Method of irrigation

Classification of irrigation: Irrigation may broadly be classified into

1 Surface irrigation and

2 Sub-surface irrigation

1 **Surface irrigation:** This can be further classified into

a **Flow irrigation:** When the water is available at a higher level, and it is supplied to lower level by the mere action of gravity, then it is called Flow Irrigation.

b **Lift irrigation:** If the water is lifted up by some mechanical or manual means, such as pumps, etc. and then supplied for irrigation, then it is called Lift Irrigation.

Flow irrigation can be further sub-divided into:

i Perennial irrigation and

ii Flood irrigation on inundation irrigation

i **Perennial irrigation:** In perennial system of irrigation, constant and continuous water supply is assured ton the crops in accordance with the requirements of the crop, throughout the 'crop-period'. In this system of irrigation, water is supplied through storage canal head works and canal distribution system.

When the water is directed into the canal by construction a weir or a barrage across the river, it is called Direct Irrigation. Ganga Canal System is an example of this type of irrigation. But, if a dam is constructed across a river to store water during monsoons, so as to supply water in the off taking channels during periods of low flow, then it is termed as Storage Irrigation. Ram-Ganga Dam project in U.P. is an example of this type of irrigation system. This perennial system of irrigation is most important and is mostly practiced in India.

ii Flood irrigation: This kind of irrigation, is sometimes called a inundation irrigation. In this method or irrigation, soil is kept submerged and through saturation of the land. The moisture soaked by the soil, when occasionally supplanted by natural rainfall or minor watering, brings the crop to maturity.

2 Sub-surface irrigation: It is termed as sub-surface irrigation, because in this type of irrigation, water does not wet the soil surface. The underground water nourishes the plant roots by capillarity. It may be divided into the following two types:

a Natural sub-irrigation and

b Artificial sub-irrigation

a Natural sub-irrigation: Leakage water from channels, etc., goes underground, and during passage through the sub-soil, it may irrigate crops, sown on lower lands, by capillarity. Sometimes, leakage causes the water-table to rise up, which helps in irrigation of crops by capillarity. When underground irrigation is achieved, simply by natural processes, without any additional extra efrort, it is called natural sub-irrigation.

b Artificial sub-irrigation: When a system of open jointed drains is artificially laid below the soil, so as to supply water to the crops by capillarity, then it is known as artificial sub-irrigation. It is a very costly process and hence, adopted in India on a very small scale. It may be recommended only in some special cases with favorable soil conditions and for cash crops of very high return. Sometimes, irrigations water may be intentionally collected in some ditches near the fields; the percolation water may then come up to the roots through capillarity.

8 Techniques of water distribution in the farms

There are various ways in which the irrigation water can be applied to the fields. Their classification is as follows

i Free flooding

ii Border flooding

iii Check flooding

iv Basin flooding

v Furrow irrigation method

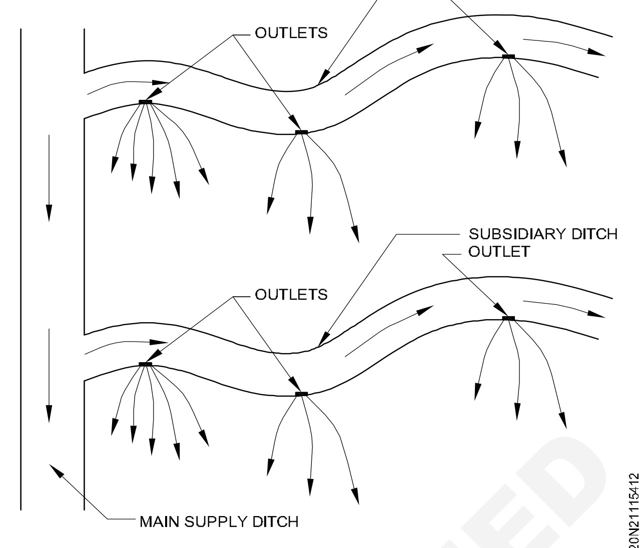
vi Sprinkler irrigation method

vii Drip irrigation method

These methods are briefly discussed below:

i Free flooding or Ordinary flooding: In this method, ditches are excaved in the field, and they may be either on the contour or up and down the slope. Water from these ditches, flows across the field. After the water leaves the ditches, no attempt is made to control the flow by means of leaves, etc. Since the movement of water is not restricted, it is sometimes called wild flooding. Although the initial cost of land preparation is low, labour requirements are usually high and water application efficiency is also low. Wild flooding, is most suitable for close growing crops, pastures, etc. particularly where the land is steep. Contour ditches called laterals or subsidiary.

Fig 2



FREE FLOODING (PLAN VIEW)

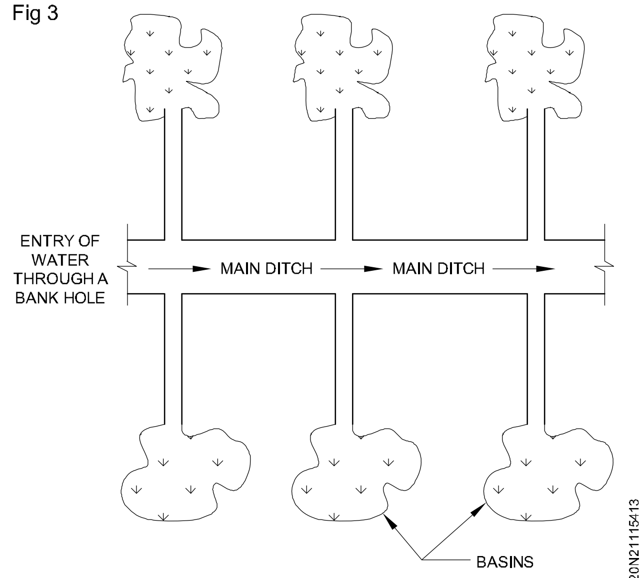
ii Border flooding/Border strip method: In the border strip flooding method, the farm is divided into a series of strips 10 to 20 metres wide and 100 to 300 metres long. These strips are separated by low lever apes or borders (low flat dikes) and run down the predominant or any other desired slope. To irrigate, water (discharge varying from 0.014 to 0.028 cumcss) is turned from the supply ditch onto the head of the border. Water advances-confined and guided by two borders in a thin sheet towards the lower end of the strip. The surface is essentially level between two borders so that the advancing sheet of water covers the entire width of the strip.

iii Check flooding: Check flooding is similar to ordinary flooding except that the water is controlled by surrounding the check area with low and flat levees. Levees are generally constructed along the contours, having vertical interval of about 5 to 10 cm. These levees are connected with cross-leaves at convenient places.

This method is suitable for more permeable soils as well as for less permeable soils.

iv Basin flooding: The basin flooding is a special form of check flooding adapted to orchard. The basins are formed for each tree; in some cases one basin may be formed for two or more tree. Water is supplied to these basins through a supply ditch. In some cases, a number of basins are inter-connected. Portable pipes or larges hoses may also be used in place or ditches.

Fig 3



BASIN FLOODING

v Furrow irrigation: Furrows are narrow field ditches, excavated between rows of plants and carry irrigation water through them. Hence only one-fifth to one half of the land surfaces is wetted by water. It results less evaporation, less pudding of soil and permits cultivation sooner after irrigation. It is used for row crops like, maize, jowar, sugarcane, cotton, tobacco, etc.

vi Sprinkler irrigation method: In this farm-water application method, water is applied to the soil in the form of a spray through a network of pipes and pumps. It is a kind of an artificial rain and therefore, gives very good results. It is costly process. It can be used for all types of soils and for widely different topographics and slopes. It can advantageously be used for many crops, because it fulfils the normal requirement of uniform distribution of water.

vii Drip irrigation method: Drip irrigation, also called trickle irrigation, is the latest field irrigation technique, and is meant for adoption at places where there exists acute scarcity of irrigation water and other salt problems. In this methods, water is slowly and directly applied to the root zone of the plants, thereby minimising the losses by evaporation and percolation.

This system involves laying of a system of head, mains, sub-mains, laterals, and drop nozzles. Water oozed out of these small drip nozzles uniformly and at a very small rate, directly into the plant roots area.

9 Technical terms in irrigation

i Hygroscopic water: When an oven-dried sample is kept open in the atmosphere, it absorbs some mount of water from the atmosphere. This is known as hygroscopic water, and is not capable of movement by the gravity or capillary forces.

ii Capillary water: It is that part in excess of hygroscopic water which exists in the pore space of the soil by molecular attraction.

iii Gravitational water: It is that part in excess of hygroscopic and capillary water which will move out of the soil if favourable drainage is provided.

iv Kharif season: It is a season in which the crops are sown by the beginning of south west-monsoon and they are harvested in autumn. The period is in between 1st April to 30th September.

v Rabi season: Season in which the crops are sown in autumn and they are harvested in spring. (1st October to 31st March)

vi Crop ratio: The ratio of the area irrigated in rabi season to the area irrigated in Kharif season is known as crop ratio.

vii Duty and delta

Duty: The maturing capacity of one cumec of irrigation water when it is supplied to the crop continuously throughout its base period. (Duty represents the irrigation capacity of a unit of water). It is the relation between the area of crop irrigated and the quantity of irrigation water required during the entire period of the growth of the crop.

Delta: It is the total depth of water in centimeter required by a crop during the entire period of the crop is in the field and is denoted by the symbol.

viii Base period

The time between first watering of a crop at the time of sowing to its last watering before harvesting, is called base or base period of the crop and is usually expressed in days.

Relation between duty and delta:

Let Δ = Delta for crop in metres.

D = Duty for this crop in hectares/cumec

B = Base period of this crops in days

Δ = 8.64 (B/D) metres

ix Crop period: The time that a crop takes from the instant of its sowing to that of its harvest is called its period of growth or crop period.

Based period of a crop is thus slightly less than its crop period but for all practical purposes, both may be considered as equivalent.

x Areas

a Gross commanded Area (G.C.A): An area is usually divided into a number divided into a number of watersheds and drainage valleys. The canal usually turns of the watershed and water can flow from it, on both sides, due to gravitational action only up to drainage boundaries. Thus in a particular area lying under the canal system, the irrigation can be done only upto the drainage boundries. “The gross commanded areas is thus the total area lying between drainage boundaries which can be commanded or irrigated by a canal system”.

b **Culturable Commanded Area (C.C.A):** The gross commanded area also contains unfertile barren land, alkaline soil, local ponds, villages and other areas as habitation. These areas are known as uncultivable areas. The remaining area on which crops can be grown satisfactorily is known as culturable Commanded Area (C.C.A)

Thus G.C.A. = C.C.A. + Un culturable area.

The culturable commanded area can further be classified as culturable cultivated area and culturable uncultivated area.

c **Culturable Cultivated Area:** It is the area in which crop is grown at a particular time or crop season.

d **Culturable Inactivated Area:** It is that area in which crop is not sown in particular season. Such area is kept under no cultivation due to the following reasons:

1 to incrase the fertility of the soil which has been reduced due to intense cultivation.

2 To provide pasture land for animals

3 The crop to be sown in that land has different crop season.

4 To protect the land from the possible danger of water logging.

e **intensity or irrigation:** The entire culturable commanded area, is not proposed to be irrigated at one time mansoon for this is that intensive irrigation (i.e. irrigation all the fields of the same area at the same time) causes over irrigation and water logging. Secondly, due to shortage of irrigation water, extensive irrigation is preferred to intensive irrigation, which is confined only to a particular pocket/area.

Due to such reasons, only a certain percentage of the culturable land is brought under irrigation seasonally, say hardly 30% to 40% of C.C.A will be irrigated every season. This percentage of C.C.A proposed to be irrigated seasonally is called intensity of irrigation.

The intensity of irrigation is therefore, defined as the ratio of the actually irrigated area during a crop season to the net culturable irrigable (culturable commanded) area.

xi **Hydrology:** Hydrology deals with the behaviour and distribution of water in atmosphere and on earth. Engineering hydrology deals with the distribution and behaviour of water on earth. In its ordinary sense, hydrology is a science regarding rainfall, losses, surface runoff and other water surveys.

xii **Rainfall and runoff:** Rainfall: Rainfall on an area during a certain interval of time (i.e. day, month, season or year) is expressed as so many millimetres or centimetres of water-depth over the entire area. We can therefore find out its quantity in cubic meters, if we know the area on which it falls. A portion of this total rain water falling on the area is lost due to evaporation and part due to percolation. The latter part percolates through the surface strata and lower down the above said area, it may come up above ground in some cases by seepage. The losses due to evaporation, percolation and some other causes (e.g interception by vegetation on the area and by depressions on the area) are called the rainfall losses and are expressed in centimeters of water-depth over the entire area of rainfall.

Runoff: It is the quantity of water flows through the surface of the earth a rainfall.

Runoff = Quantity of rainfall - Rainfall losses

xiii **Paleo:** It is the first watering before sowing the crop. This is done in order to add sufficient moisture to the unsaturated zone of the soil and is required for the initial growth of the crop.

xiv **Kor-watering:** The first watering which is given to a crop, when the crop is a few centimetres height is called Kor-Watering. It is usually the maximum single watering followed by the other watering at usually intervals, are required by drying of leaves.

xv **Isohyets:** Isohyet is a line on rainfall map, joining places having the same average annual rainfall. From these isohyets or isohyets marked on the rainfall map of a country, we can get, at a glance, an idea of the average annual rainfall at any place of the country.

xvi **Rain gauges:** Rain gauge is an instrument for measuring the rainfall, in millimetres, falling on an area during an interval of time. The extent of above said area will be that which is in the charge of a rain gauge.

There are two types of rain gauges.

a Non-recording or non-automatic rain gauge

b Recording or automatic rain gauge

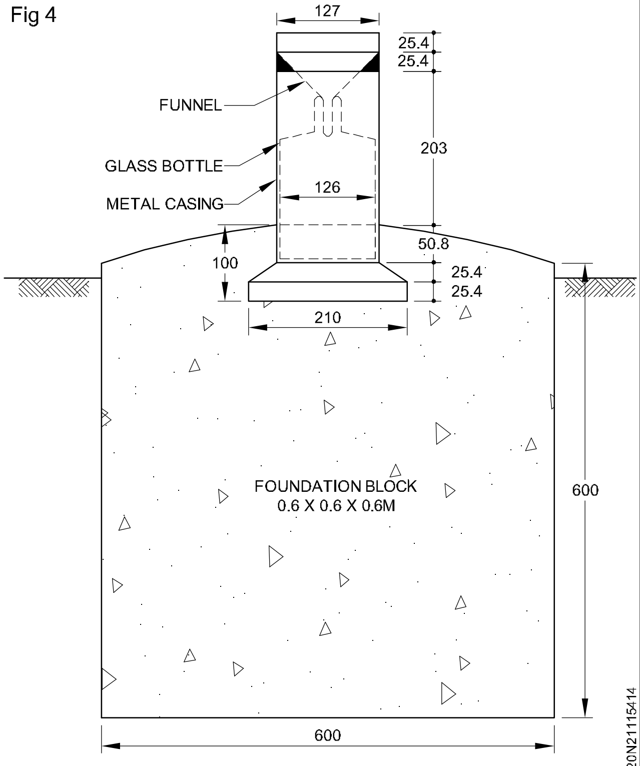
a **Non-recording or non-automatic rain gauge:** Non recording rain gauge is more common in India and the one that is most used in India is called the Simon's rain gauge (Fig 4).

xvii **Unit hydrograph:** Unit Hydrograph is defined as a hydrograph which represents one cm of runoff from a rainfall of some duration falling over the specified area of the catchment.

xvii **Catchment area:** Catchment area is an extent or an area of land where surface water from rain, melting snow, or ice converages to a single point at a lower elevation, usually the exit of the basin, where the waters join another water body, such as a river, lake, reservoir, etc. It is also know as drainage basin or catchment basin.

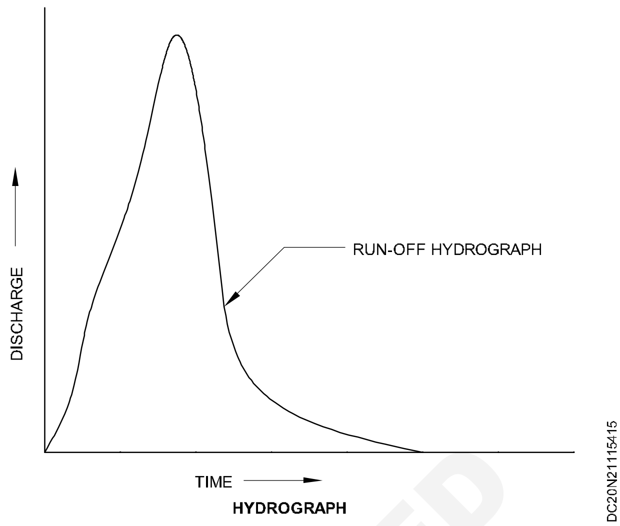
xix **Hydrograph:** Hydrograph is the graphical representation of average rainfall and rainfall excess (i.e. rainfall minus infiltration) rates over specified area during successive unit time intervals during a storm. Such hydrograph are plotted above the runoff hydrographs.

Fig 4



SIMON'S RAIN GAUGE

Fig 5



HYDROGRAPH

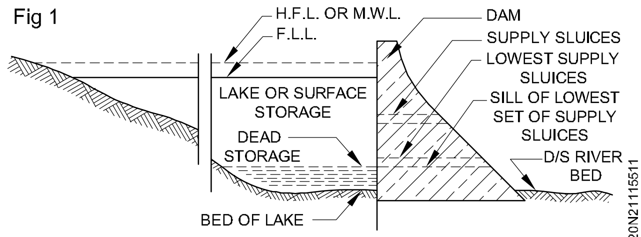
Reservior and Types of Reservior and Dams

Objectives : At the end of this lesson you shall be able to
- **define reservior and dam**
- **describe the factors affecting site for reservior**
- **explain the different types of dam**
- **define spillway.**

Definition: Dam is a fairly impervious barrier construted across the river or a natural drainage to create an artificial lake or reservior behind it.

The main difference between a storage weir and a dam is only in height and the duration for which the supply is stored. A dam stores the supply for a comparatively longer duration with a higher elevated barrier than a weir.

Fig 1



STORAGE RESERVOIR WITH MASONRY DAM

Select of site for a reservoir

The final selection of site for a resevoir depends upon the following factors:

1 The geological condition of the catchment area should be such that percolation losses are minimum and maximum run-off is obtained.

2 The reservoir site should be such that quantity of leak age through it is a minimum. Reservoir site having the presence of highly permeable rocks reduce the water tightness of the reservoir. Rocks which are not likely to allow passage of much water include shales and slates, schits, gneisses, and crystalline ingneous rocks such as granite.

3 Suitable dam site must exist. The dam should be founded on sound watertight rock base, and percolation below the dam should be minimum. The cost of the dam is often a controlling factor in selection of a site.

4 The reservoir basin should have narrow opening, in the valley so that the length of the dam is less.

5 The cost of real estate for the reservoir, including road, rail road, dwelling re-location etc. must be as less as possible.

6 The topograpy of the reservoir site should be such that it has adequate capacity without submerging excessive land and other properties.

7 The site should be such that a deep reservoir is formed. A deep reservoir is preferable to a shallow one becasue of (i) lower cost of land submerged per unit of capacity, (ii) less evaporation losses because of reduction in the water spread area, and (iii) less likelihood weed growth.

8 The reservoir site should be such that it avoids or excludes water from those tributaries which carry a high percentage of silt in water.

9 The reservoir site should be such that the water stored in it is suitable for the purpose for which the project is undertaken. The soil and rock mass at the reservoir site must not contain any objectionable minerals and salts.

Classification of dams

Dams may be classified in different ways, such as

1 Classification According to the usage

2 Classfication According to the hydraulic design

3 Classification According to materials

1 Classification according to usage

Based on use, dams are classified as follows

i Storage dam

ii Deversion dam

iii Detention dam

i Storage dam Fig 2: This is the most common type of dam normally constructed. Storage dam is constructed to impound water to its upstream side during the periods of excess supply in the river (i.e. during rainy season) and is used in periods of deficient supply. Behind such a dam, a reservoir or lake is formed. The storage dams may be constructed for various purpose, such as for irrigation, water power generation or for water supply for public health-purpose, or it may be for a multi-purpose project. a storage dam may be constructed of wide variety of materials, such as stone, concrete, earth and rockfill etc.

ii Diversion dam Fig 3: The purpose of a diversion dam is essentially different. While a storage dam stores water as its upstream for future use, a diversion dam simply raises water level slightly in the river and thus provides head for carrying or derting water into ditches, canals, or other conveyance systems to the place of use. A diversion dam is, therefore, or smaller height and no reservoir is formed to store water. The common examples of diversion dams are weirs and barrages. During floods, water passes over or through these eiversion dams while during periods of normal flow, the river water, partly or wholly, is diverted to irrigation or municipal or industrial uses.

Fig 2

iii Detention dam Fig 4: A detention dam is constructed to store water during floods and release it gadually at a safe rate, when the flood recedes. It may also be used as a storage dam. When seepage water is sufficient for the growth of the crop and if no addition surface watering is necessary, such a detention dam is called **water spread dam.**

Fig 3

Soemtimes, detention dams are constructed across tributaries carrying large silt and sediment. In such case it is known as **debris dam.**

2 Classification according to hydraulic design

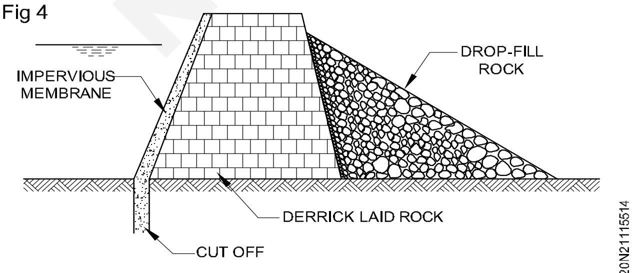
According to hydraulic design dams may be classified as follow:

i Non-overflow dam

ii Over flow dam

i Non-overflow dam: A non-overflow dam is the one in

Fig 4



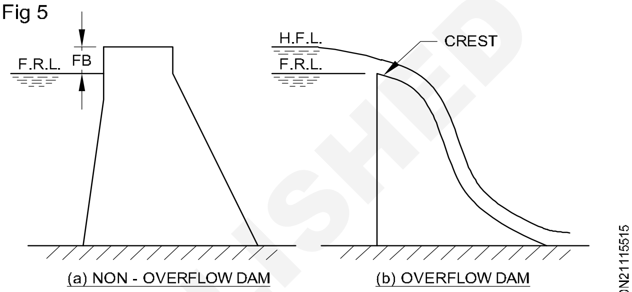
ROCKFILL DAM

which the top the dam is kept at a higher elevation than the maximum expected high flood level. Water is not permitted to overtop the dam. Hence a non-over flow dam may be constructed of wide variety of materials, such as earth, rockfill masonry, concrete etc. Figure show a typical non-overflow type concrete gravity dams Fig 5a.

ii Overflow dams: An overflow dam is the one which is desinged to carry surplus discharge (including floods) over its crest. Its crest level is kept lower thant the top of the other portion of the dam (i.e. non-overflow dam).Since water glides over its downstream face it should be made of such a material which is not easily eroded by flowing water. Such dams are generally made of concrete or masonry. An overflow dam is commonly known as spillway Fig 5b.

Very often, in a river vally project, the two types of dams

Fig 5



CLASSIFICATION OF DAMS

are combined the main dam is kept as non-overflow dam made of either rigid materials such as earth and rockfill and some portion of dam is kept as overflow dam (spillway) at some suitable location along the main dam.

3 Classification according to material

According to this most common classification, the dam may be classified as follows:

i Rigid dams

ii Non-rigid dams

i Rigid dams: Rigid dams are those which are constructed of rigid materials such as masonry, concrete, steel or timber. Rigid dams may be further classified as follows:

a Solid masonry or concrete gravity dam

b Arched masonry or concrete dam

c Concrete buttress dam

d Steel dam

e Timber dam

ii Non-rigid dams: Non-rigid dams are those which are constructed of non-rigid materials such as earth and/ or rockfill. The common types of non-rigid dams are:

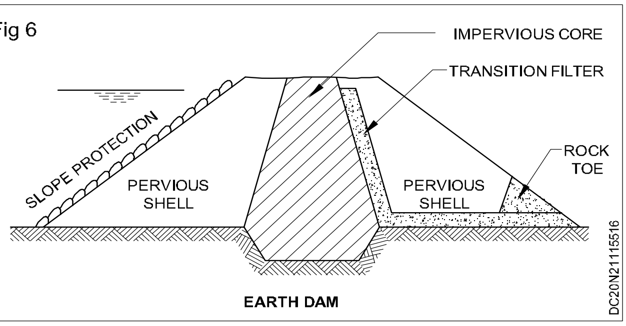
a Earth dams

b Rockfill dams

c Combined earth and rockfill dams (Fig 6)

Gravity dams: A gravity dam is the one in which the external forces (such as water pressure, waver pressure, silt pressure, uplift pressure etc.) are resisted by the weight of the dam itself. Thus the forces disturbing the stability of the dam are resisted by the gravity forces of the mass of the dam. A gravity dam may be constructed either of masonry or of concrete. Masonry gravity dams are now-a-days consturcted of only small heights. All major and important gravity dams are now constructed of concrete only. A gravity dam may be either straight or reserved in plan.

Fig 6



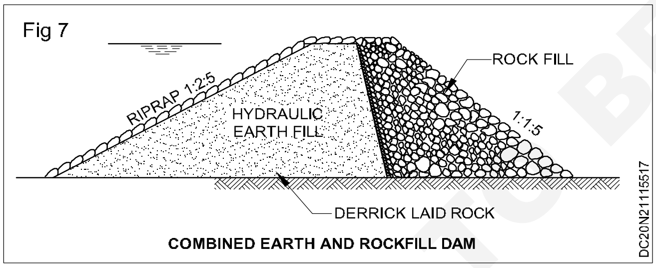
EARTH DAM

Arch dams: An arch damis a dam curved in plan and carries manor parts of its water load horizontally to the abutment by arch acton.

Butteress dam: A butteress dam consists of a number of buttresses or piers dividing the space to be dammed into a number of spans to hold up water and retain the water between these buttresses, panels are constructed of horizontal arches or flat slabs. When the panels consists of arches, it is known as multiple arches type butress dam. If the panels consists of flat slab, it is know as deck type buttress dam.

Earth dams and Rockfill dams: Earth dams are made of locally available soils and gravels and therfore, are most common types of dams used upto moderate heights. Their construction involves utilization of materials in the natural stage requiring minimum equipment, earth dams are now becoming more common, even for higher heights. The foundation requirements of earth dams are less stringent than for other types. Fig 7

Fig 7



COMBINED EARTH AND ROCKFILL DAM

A rockfill dam is an embakment which uses variable sizes of rock to provide stability and an impervious membrane to provide water tightness. In modern practice, the rockfill dam has the following fundamental parts. (1) dumped rockfill at the downstream, (2) upstream rubble cushion of laid-up sotne bounding into the dumped rock, (3) upstream impervious facing resting on rubble cushion.

Reservoir

Dams and weirs are some of the barriers which when constructed across the rivers and streams, casue accumlation of water behind them. The water thus accumulated in the form of an aritificial lake is knwon as reservoir Fig 8.

Purpose of reservoirs

The reservoirs are constructed to serve many purposes.

1 Flood control.

2 Irrigation.

3 Development of hydroelectric power.

4 Navigation.

5 Water supply for domestic and industrial use.

6 Recreation.

7 Development of fish wild life.

8 Soil conservation.

Fig 8

Spillway: A spillway is the overflow portion of dam, over which surplus discharge flows from the reservoir to the downstream. A spillaway is, therfore, called a surplussing work, designed to carry this flood water not required to be stored in the reservoir, safely to the river lower down. Spillways are invariably provided for all storage and detention dams. Ordinarily, this surplus water is drawn from the top of the pool (or reservoir) created by the dam. Spillway are very important structures; many failures of the dams have been caused by improperly designed spillways or by spillways of insufficient capacity, a spillway is thus the safety valve for a dam.

Various types of spillways

Depending upon the type of the structure construed for disposing of the surplus water, the spillways can be of the following major types:

i Straight Drop Spillway

ii Overflow Spillway generally called Ogee Spillway

iii Side Channel Spillway

iv Syphon Spillway

Capacity of reservoir

Capacity of reservoir can be calculated by the details of contour surveying at the time of construction and applying the volume calculation using prismoidal formula or by trapezoided formula.

Trapezoidal formula

$$\text{Volume} = \frac{d}{2}\left(A_1 + A_V + 2\left(A_2 + A_3 + \ldots\ldots A_{V-1}\right)\right)$$

Prismoidel formula

$$= \frac{d}{2}\begin{pmatrix} A_1 + A_n + 4\left(A_2 + A_4 + A_6 + \ldots A_{n-1}\right) \\ + 2\left(A_3 + A_5 + A_7 + A_{n-2}\right) \end{pmatrix}$$

where d_2 contour, A_1, A_2, A_3 ..... Area of contour.

Weir & Barrages - types purpose

Objectives : At the end of this lesson you shall be able to
- **define Barrage**
- **define weir**
- **comparison between weir & Barages**
- **define notch-difference between notches an weirs flow**
- **difference between ORIFICE and mouth PIECE flow.**

- What is a Barrage:

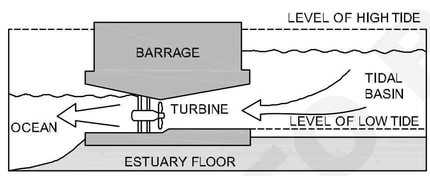
A Barrage is a barrier with low crest provided with series of Gates across the river to regular water surface level and pattern of flow upstream and other purpose distinguished from a weir in that it is gated over its entire lngth and way or may not have a raised sill.

- An artificial Structure obstruction placed in river or water course, to increase the depth of water (to some feet), so that the water can be diverted into canals is called barrage.
- A barrage is a type of low-head, diversion dam which consists of a number of large gates that can be opened or closed to control the amount of water.
- It is useful irrigation and other system.
- A barrage is built for diverting water, and raise.

What is a Tidal Barrages?

A barrage is a dam that impounds seawater from the rising tide in a tidal basin or estuary. The seawater is held in the basin until low tide, when it is released to power hydro turbines to generate electricity. (Fig1)

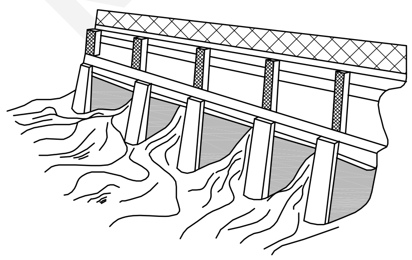
Fig 1



Fuction of a Barrage (Fig 2)

- Function of a Barrage is similar to a weir.
- There is no solid obstruction across river (damrs and weirs have a solid obstruction across the river).

Fig 2

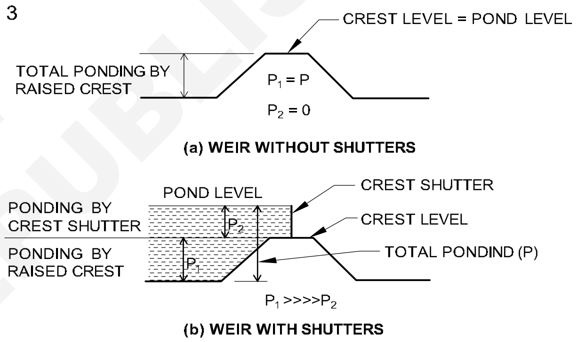


- Raising of water level for diversion in to a canal is done by gates alone, which are set between flanking piers and are responsible for supporting the water load.
- Crest level in barrage is kept low
- Barrages are much more costlier than the weirs
- Can be used to regulate water flow in a lagoon or estuary

Weir:

If major part or the entire ponding of water is achieved by a raised crest and a smaller part is achieved by the shutters, then this barrier is known as weir. (Fig 3)

Fig 3

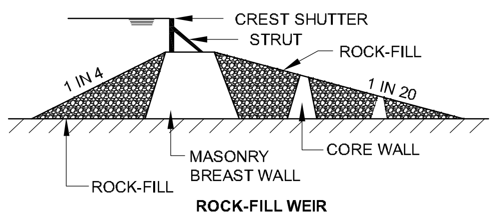


Dry store stopping weir (Fig4)

Weir

- Normally the water level of any perennial river is such that it cannot be diverted to the irrigation canal.
- The bed level of the canal may be higher than the existing water level of the river.
- In such cases weir is constructed across the river to raise the water level.
- Surplus water pass over the crest of weir.
- Adjustable shutters are provided on the crest to raise the water level to some required height.

Fig 4



Camparision between weir & a barrage

Weir	Barrage
Low cost	High cost
Low control on flow	Relatively high control on flow and water levels by operation of gates
No provision for transport communication across the river	Usually, a road or a rail bridge can be conveniently and economically combined with a barrage wherever neccessary
Chances of silting on the upstream	Silting may be controlled by judicial operation of gates is more
Afflux created is high due to relatively high weir crest	Due to low crest of the weirs (the ponding being done mostly by gate operation), the afflux during high floods is low. Since the gates may be lifted up fully even above the high level.

Storage and diversion head work and head regulators

Objectives : At the end of this lesson you shall be able to
- **define storage and diversion head work**
- **enumerate the purposes of storage works**
- **define weir and barrage**
- **illustrate the layout of a diversion head works and its components.**

Introduction

As per the concept of irrigation, water required for the corps should be supplied in time to the cultivated land for this, sufficient quantity of water may be stored in a suitable place or diversion head work may be arraged conveniently. The structure constructed for these purpose comes under the group of storage or diversion head work.

Storage head works: An impervious high barrier or wall constructed across a river at a suitable site for the purpose of collecting water, which can be used as and when required. E.g DAM

Diversion head works: The works, which are conducted at the head of the canal, in order to divert the river water towards the canal, so as to ensure a regulated continuous supply of silt-free water with a certain minimum head into the canal, are known as Diversion Head Works, Eg. Weir.

Purpose of storage work

Storage works are constructed to serve many purposes, which include.

1 Storage and control of water for irrigation
2 Storage and diversion of water for domestic uses
3 Water supplied for industrial uses
4 Devleopment of hydroelectric power
5 Increasing water depths for navigation
6 Storage space for flood control
7 Reclamation of low-lying lands
8 Debris control
9 Preservation and cultivation of useful aquatic life
10 Recreation

Weir: The weir is a solid obstructionn put across the river to raise its water level and divert the water into the canal (Fig 1). If a weir also stores water for tiding over small periods of short supplied, it is called a storage weir. The main difference between a storage weir and a dam is only in height and the duration for which the supply is stored. a dam stores the supply for a comparatively longer duration.

Barrage: The function of a barrage is similar to that of weir, but the heading up of water is effected by the gates alone (Fig 2). No solid obstruction is put across the river. The crest level in the barrage is kept at a low level. During the floods, the gates are raised to clear off the high flood lever, enabling the high flood to pass downstream with maximum . When the flood recedes, the gate are lowered and the flow is obstructed, thus raising the water level to the upstream of the barrage. Due to this, there is less silting and better control over the levels. However, barrages are much more costlier than the weirs.

Fig 1

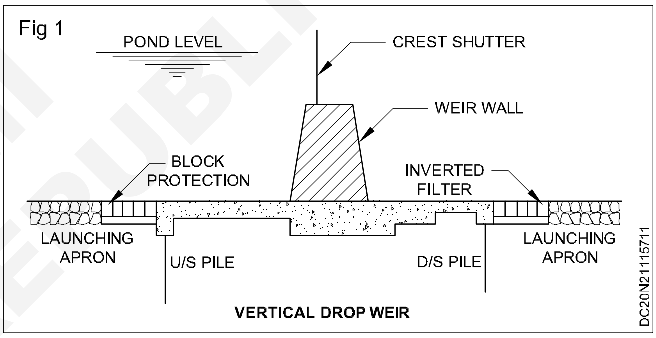
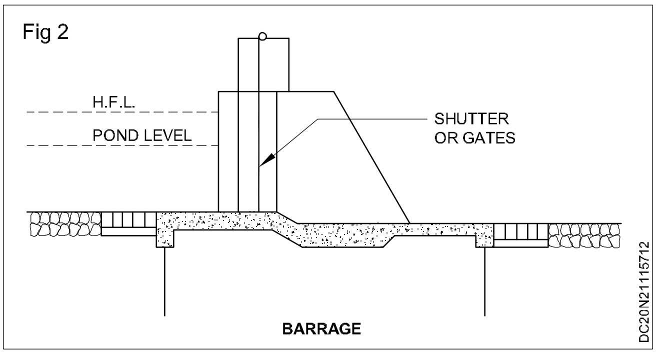


Fig 2



Layout of a diversion Head Works and its Components Fig 3 :

A typical layout of a canal head-works is shown in Fig 3. Such a head-works consist of

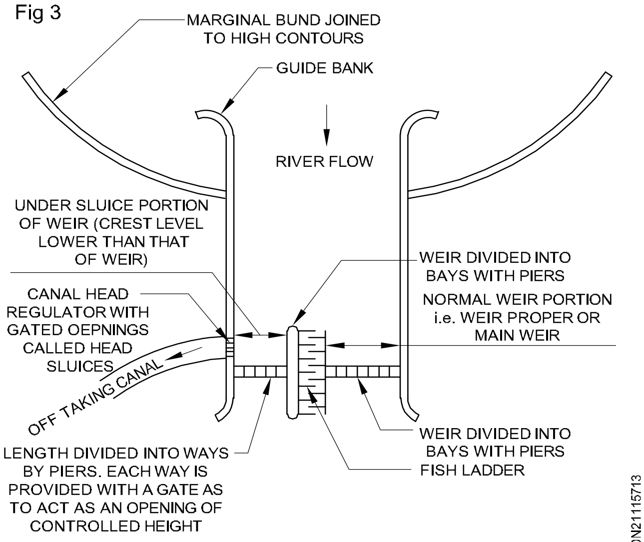
1 Weir proper
2 Under-sluices
3 Divide wall
4 River training works, such as marginal bunds, guide banks, groynes, etc.
5 Fish lader

6 Canal Head Regulator

7 Weir's ancillary works, such as shutters, gates etc.

8 Silt Regulation Works.

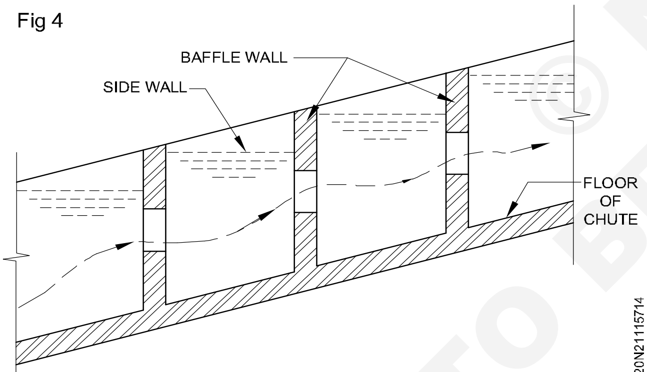
Fig 3



TYPICAL LAYOUT OF DIVERSION HEAD-WORKS

Fish lader: On one flank of storage dam or overflow dam, a fish-way (i.e. fish pass) is provided to allow fish to go from upstream to downstream of dam and vice versa this fish-way consists of an inclined chute from dam to the downstream river bed and divided into compartments by cross walls (Fig 4).

Fig 4



SECTIONAL VIEW OF A FISH LADDER

Under-sluices Fig 5

The weir proper is consturcted in the middle portion of the diversion headworks. At the ends, undersluice section are provided adjacent to the canal head regulators. If the canal takes off only from one side, the undersluice section is provided near that end only. There is a divide wall between the weir proper and the undersluice section to separate the two portions and to avoid cross flows.

Undersluice are a sort of outlets in the diversion head works. The undersluice section is similar to the sloping weir section, but its crest is at a lower lever (Fig 5). Most of the dry weather flow passes through the undersluices because the bed level of the undersluices portion of the river is usually lower. Since relativlely clear water is supplied to the canal, some silt gets deposited in the pocket just upstream of the head regulator near the undersluices. The deposited silt is periodically washed through the undersluices.

Fuctions: The function of undersluices may be summarised as follows:

1 They maintain a well-defined river channel near the canal head regulator.

2 They are used to scour away the silt deposited in front of the head regulator.

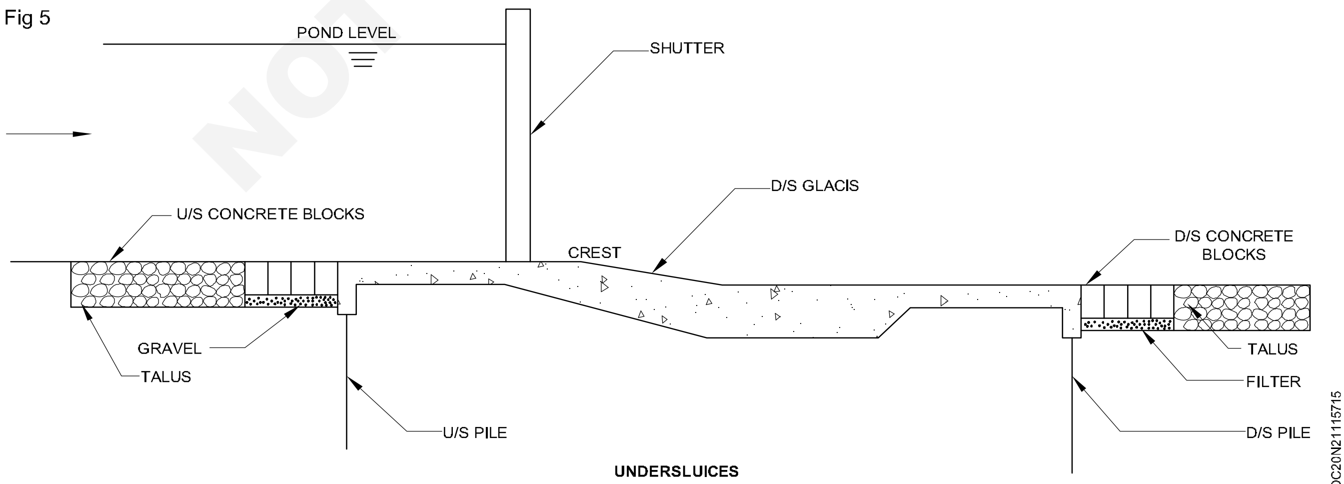
3 They can be used to pass small floods to the downstram, without dropping the shutters of the main weir.

4 They may be designed to pass a portion of flood, about 10 to 20% of the design flood, during rainy season.

5 They are useful for quick lowering the upstream high flood level because the discharge intensity over the sluice portion is greater than that in the weir portion.

6 The crest a still pocket of water near the head regulator, and, therefore, the effect of the main river current on the head regulator is minimised.

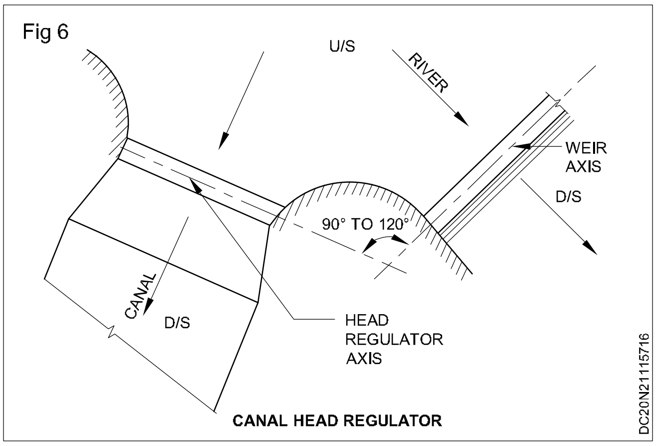
Fig 5



UNDERSLUICES

Canal head regulator Fig 6

A canal head regulator is provided at the head of each main canal off taking from the diversion head works. The canal head regulator should be aligned so as to reduce silt entry into the canal and to avoid backflow and the formation of stagnant zones in the river pocket. The axis of the head regulator usually makes an angle of 90° to 120° with the axis of the weir. (i.e. the direction of flow of river makes an angle of 90° to 60° with the direcitonof flow of canal) (Fig 6).



Functions: A canal head regulator serves the following purpses:

1 It regulates the supply of water into the canal.

2 It control the entry of silt into the canal.

3 It prevents the river floods from entering the canal.

4 It can be used to stop the canal supplies when the slilt charge in the river water exceeds a certain limit.

Divide wall

A divide wall is a wall cosntructed parallel to the direction of flow of river to separate the weir proper section and the undersluices section. If there are undersluice at both the sides, there are two divide walls. The divide walls should extend on the upstram to a point little upstream of the point opposite to the head regulator. On the downstream, it usually extends upto the end of the loose protection. It is necessary to ensure adequate tail water depth in the undersluices for the formation of the hydraulic jump and to avoid cross flow in the close vicinity of the structure which may result in the objectonable scour. The length of the divide wall on the upstram equal to 1/2 to 2/3 times the width of the head only one canal takes off from that side. The exact length of the divide wall is usually determined by conducting model studies.

Functions: The functions of the divide wall may be summarised as follows:

1 It separate the floor of the scouring sluice from that of the weir proper which is at a higher level.

2 It provides a comparatively still pocket in front of the canal head regulator so that silt gets deposited in it and relatively clear water enters the canal.

3 It isolates the pocket upstream of the head regulator to facilitate scouring operations.

4 It prevents formation of cross currents and the flow parallel to the weir axis, which may cause the formation of cortices and deep scour.

5 It helps in concentrating the scour action of the undersluice for flushing out the deposited silt in the pocket by ensuring a straight approach to the pocket.

6 It helps in minimising the effect of the main river current on the flow conditions is the head regulator.

7 It serves as one side of the fish ladder.

Guide banks and marginal bank

(a) Guide banks: Guide banks are provided on either side of the diversion headworks in alluvial soils for a smooth non-tortuous approach to the diversion headworks and to prevent the river from outflanking the work. The length, alignment and shape of the guide banks are usually determined after conducting model studies. The following points should be considered while designing guide banks.

1 The length and curvature of guide banks in wide alluvial rivers should be such that the worst meander loop is away from the canal embankment as well as approach embankments.

2 In case the alluvial banks of the river are close to the weir, the guide banks should be suitably tied to them.

3 If there are outcrops of the bed rock on the river banks, the guide banks should be tied to them.

(b) Marginal (or afflux) embankments: Marginal embankments are provided on either bank of the river u/s of diversion headworkd in alluvial soils to protect the land and property which is likely to be sunmerged during ponding of water of during floods. The layout of marginal embankments should be selected to economise the overall cost of the river training works, including their maintanence.

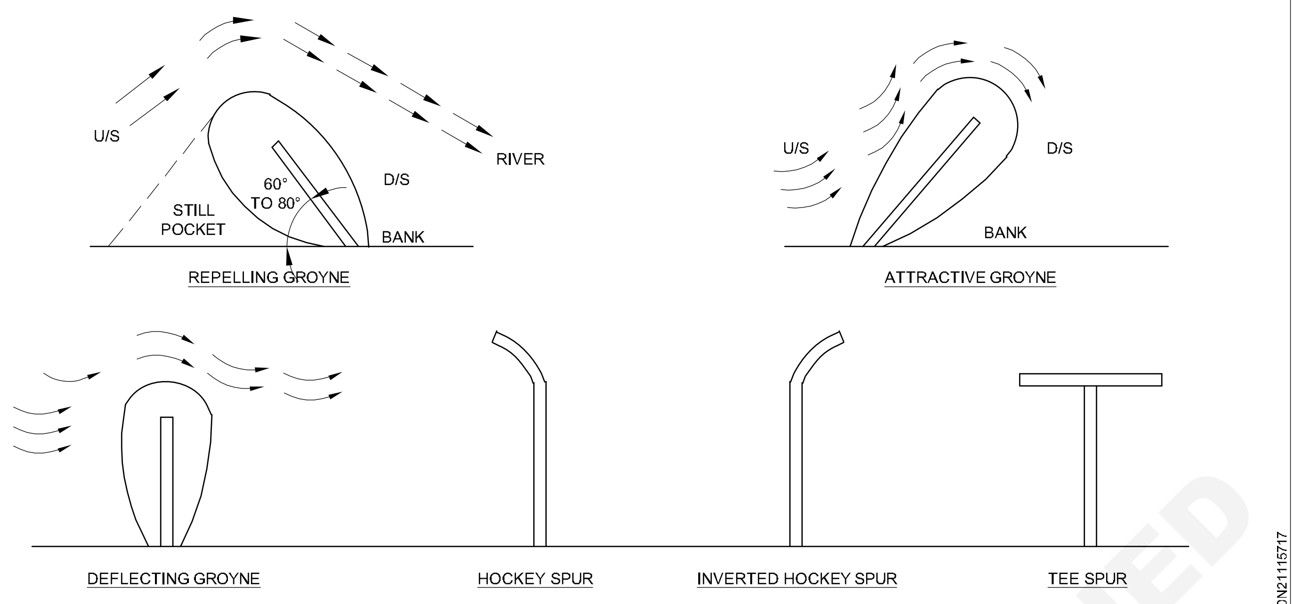
Supr or Groynes: Spurs or groynes are constructed to protect the river banks by keeping flow away and creating a still pond for silting up the area. They extend from bank of the river. They may be of repelling type or attracting types. When it points upstream it is repelling type and when it points towards D/s it is called attracting type as shown in Fig 7. the other types of spurs may be deflecting. Hockey spur, and 'T' headed spurs as shown in Fig.7.

Silt excluder

The silt excluder is a structure in the undersluice pocket to pass the silt ladders water to the downstream through undersluice so that only clear water enters the head regulators. The alignment of the silt excluder is parallel to the axis of the head regulator. The silt excluder prevents the entry of silt into the canal. The bottom layers of water, which are highly charged with silt, pass down the silt excluder and escape through the undersluices.

A silt excluder should not be confused with a silt extractor (silt ejector) which provided in the canal, to remove the silt already entered the canal

Fig 7



SPUR OR GROYNES

Cross - drainage works - Supper passage-siphon-inlet and outlet

Objectives : At the end of this lesson you shall be able to
- **define supper passage an siphon**
- **explain inlet an outlet**
- **define cross-drainage works**
- **explain the different types of cross-drinage works**
- **explain the factors considered for selection of suitable type of cross-works.**

1 Introduction

A cross-drianage work (also called C-D work) is a structure built on a canal where it is crosses a natural drainage, such as a stream or a river. Sometimes, a cross drinage work is required when the canal crosses another canal. The cross-drainage work is required to dispose of the drainage water so that the canal supply remains uninterrupted. A cross-drainage work is also called as drainage crossing. The canal at a cross-drainage work is generally taken either over or below the drainage. however, it can also be at the same level as the drainage.

The canals are usually aligned on the watershed so that there are no drainage corssings. However, it is not possible to avoid the drainage in the initial reach of a main canal because it takes off from a diversion headworks (or storage works) located on a river which is a valley. The canal, therefore, requires a certain distance before it can mount the watershed (or ridge). In this initial reach, the canal is usually a contour canal and it intercepts a number of natural drainage flowing from the watershed to the river.

After the canal has mounted the watershed, no crossdrinage work will normally be required, because all the drainage originate from the watershed and flow away from it. However, in some cases, it may be necessary for the canal to leave the watershed and flow away from it. It may be necessary for the canal to leave the watershed is a short distance where the watershed takes a sudden small loop. In that case, the canal intercepts the drainages which carry the water of the pocket between the canal and the watershed and hence the cross-drainage works are required.

A cross-drinage work is an expensive structure and should be avoided as far as possible. The number of cross-drainage works can be reduced to some extent by changing the alignment of the canal. However, it may increase the length and hence the cost of the canal may be increased. sometimes it is possible to reduce the number of cross-drainage works by diverting the small drainages into large drainages or by constructing of two drainages by shiflting the alignment. However, the suitablty of the site for the consturction of the structure should also be considered while deciding the location of the cros-drainage works.

2 Tyeps of cross-drinages works

Depending upon the relative positions of the canal and the drainage, the cross-drinage works may be broadly clssified into 3 categories. In each category, there are further sub-types:

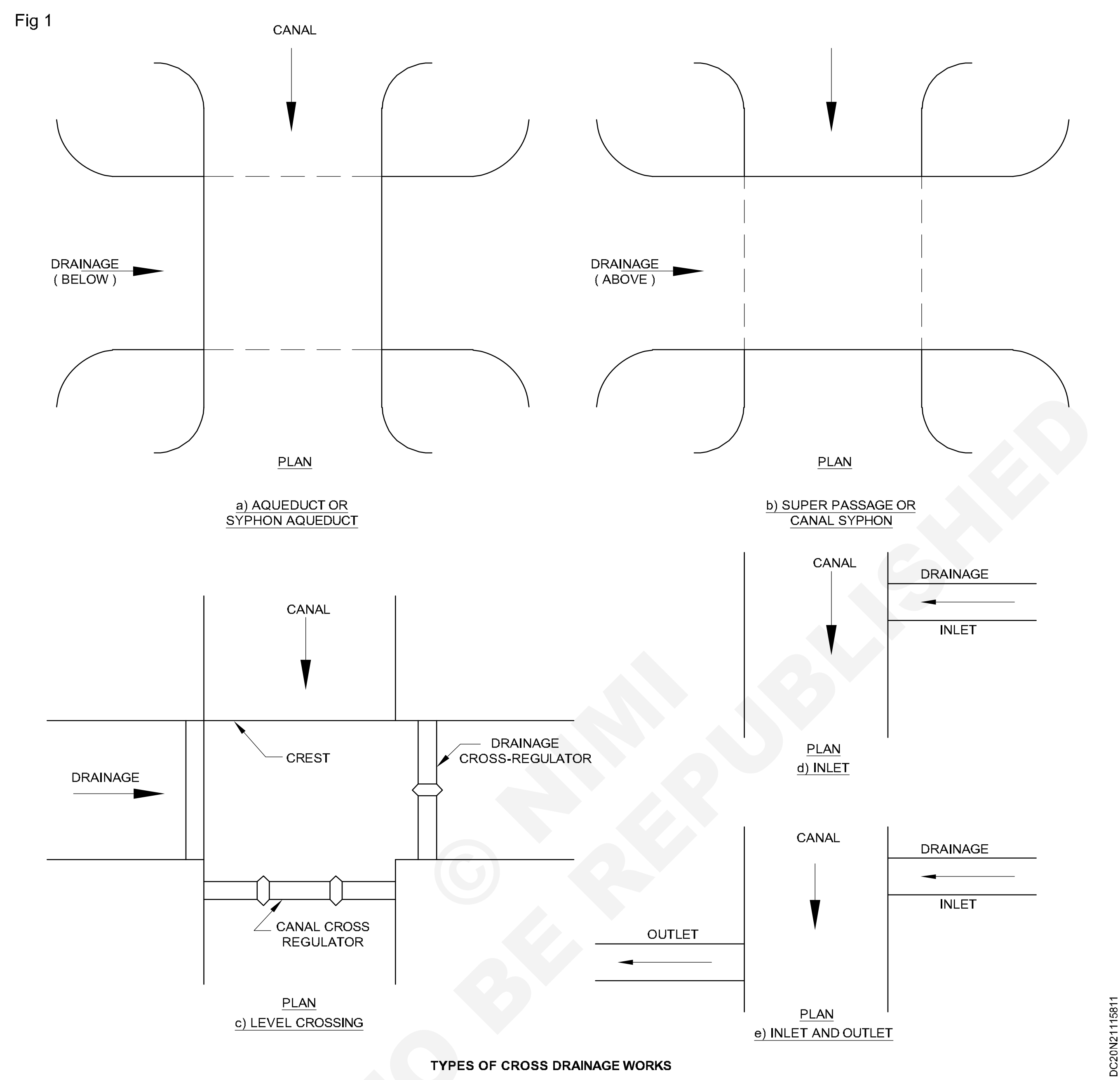
1 Canal over the drainage
 i Aqueduct
 ii Siphon aqueduct
2 Canal below the drainage
 i Superpassage
 ii Canal siphon
3 Canal at the same level as drainage
 i Level crossing
 ii Inlet
 iii Inlet and outlet

1 Canal over the drinage Fig 2

i Aqueduct: An aqueduct is a structure in which the canal flows over the drainage and the flow of the drainage in the barrel is open channel flow. An aqueduct is similar to an ordinary road bridge (or railway) across a drainage, but in this case, the canal is taken over the drainage instead of a road (or a railway). The canal is taken over the drainage in a trough supported over the piers cosntructed on the drinage bed. An aqueduct is provided when the canal bed level is higher than the H.F.L. of the drainage.

> **In the case of an aqueduct, the term culvert is commonly used for the barrel.**

ii Siphon aqueduct: In a siphon aqueduct also the canal is taken over the drainage, but the flow in the barrel of the drainage is pipe flow. A siphon aqueduct is consturcted when the H.F.L. of the drinage is higher than the canal bed level.



TYPES OF CROSS DRAINAGE WORKS

When sufficient level difference is not available between the canal bed and the H.F.L. of the drinage to pass the drainage water, the bed of the drainage may be depressed below its normal bed level. The drainage is provided with an imprevious floor at the crossing and thus a barrel is formed between the pipe to pass the drainage water under pressure. These barrels actually form an inverted siphon and not siphon. However, in the common usage, the term siphon is generally used.

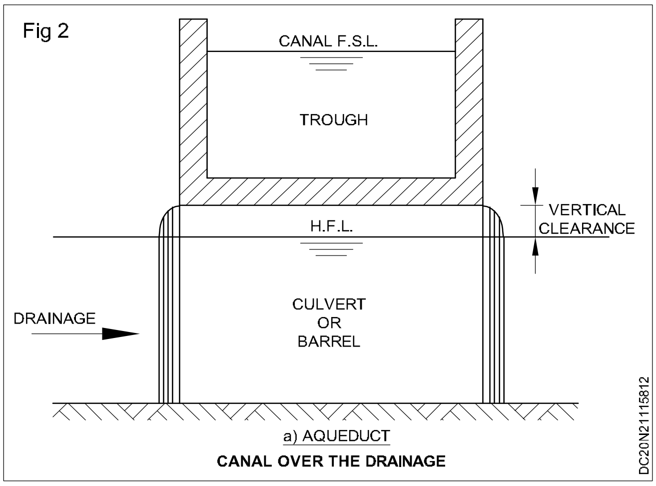
2 Canal below the drinage (Fig 3)

i Superpassage: In a superpassage, the canal is taken below the drinage and flow in the canal is open channel flow. A superpassage is thus reverse of an aqueduct.

A superpassage is required when the canal F.S.L. is below the drianage bed level. In this case, the drainage later is taken in a trough supported over the piers constructed on the canal bed.

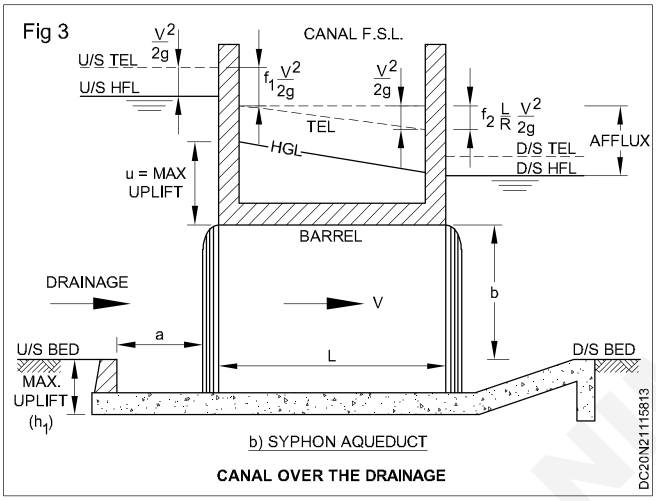
ii Canal siphon: A canal (Fig 4a) siphon (or simply sa siphon) is a structure in which the canal is taken below the drainage and the flow in the barrel of the canal is piple flow. It is thus the reverse of a siphon aqueduct.

A canal siphon is constructed when the F.S.L. of the canal is above the drainage bed level. Because some loss of head invariably occurs when the canal flows through the barrel of the canal siphon, the command of the canal is reduced. Moreover, there may be silting problem in the barrel. As far as possible, a canal siphon should be avoided.



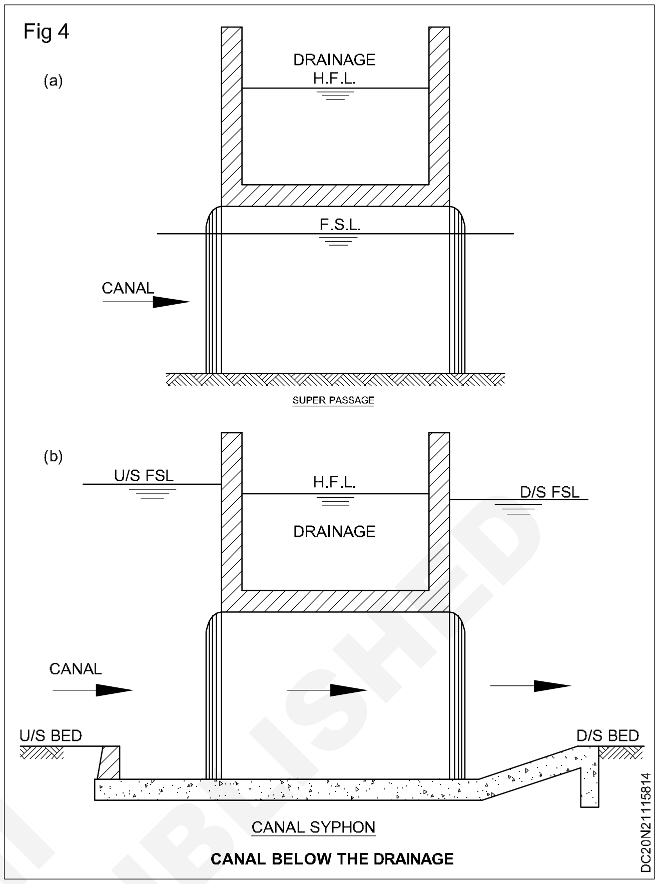
a) AQUEDUCT

CANAL OVER THE DRAINAGE



b) SYPHON AQUEDUCT

CANAL OVER THE DRAINAGE



CANAL BELOW THE DRAINAGE

3 Canal at the same level as the drainage

i Level crossing: a level crossing is provided when the canal and the drainage are practically at the same level. In a level crossing, the drinage water is admited into the canal at one bank and is taken out at the opposite bank as shown in Fig 4b.

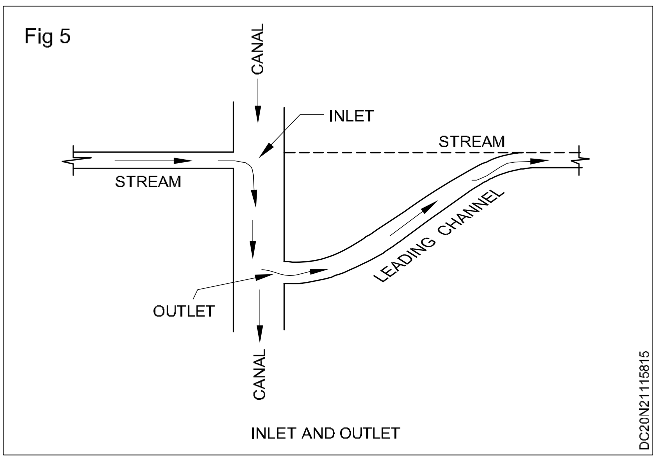
A level crossing usually consists of a crest wall provided across the drainage on the upstream of the junction with its crest level at the F.S.L. of the canal. The drainage water passes over the crest and enters the canal when ever the water level in the drainage rises above the F.S.L. of the canal. there is a drinage regulator on the drainage at the d/s of the junction and a cross-regulator on the canal at the d/s of the junction for regulating the outflows.

A level crossing is provided on the canal when it is more or less at the same level as the drinage and there is a large discharge in the drainage for a short duration. The main disadvantage of a level crossing is that an operator is required to regulate the discharge.

ii Inlet: An inlet alone is sometimes provided when the drainage is very small with a very low discharge and it does not bring heavy silt load. Of course, it increases the discharge in the canal, which is absorbed in the space provided as the free board above the F.S.L.

iii Inlet and outlets Fig 5: An inlet-outlet structure is provided when the drainage and the canal are almost at the same level, and the discharge in the drinage is small. The drainage water is admitted into the canal at a suitable site

Where the drainage bed is at the F.S. of the canal. The excess water is discharged out the canal through an outlet provided on the canal at some distance downstream of the junciton as shown in Fig. An outlet is usually combined with some other masonry work where as arragement for removing the excess water is even otherwise required.



INLET AND OUTLET

Canals Longitudinal Section Distributaries

Objectives: At the end of this lesson you shall be able to
- **define canal**
- **classify the different canal**
- **illustrate the canal sections in cutting and filling.**

Canals

A canal is an artificial channel, generally trapezoidal in shape constructed on the ground to carry water to the fields either from the river of from a tank or reservoir.

Canals Fall

Irrigation canals are designed for a prescribed bed slope so that velocity becomes nil silting or scouring. But if the ground topography is such that in order to maintain the canal designed slope, indefinite filling from falling ground level is to be made. This indefinite filling is avoided by constructing a hydraulic structure in the place of sudde bed level. This hydraulic structure is called fall or drop. Beyond the canal fall, canal again maintains its designed slope.

Classification

a Classification based on the nature of source of supply Fig 1

1 Permanent canal

2 Inundation canal

A canal is said to be permanent when it is fed by a permanent source of supply. The canal is a well made up regular graded channel. It has also permanent masonry works of regulation and distribution of supplies. A permanent canal is also sometimes known as perennial canal when the sources from which canal take is an ice fed perennial river.

Inundation Canals usually draw their supplies from rivers whenever there is a high stage in the river. They are not provided with any headworks for diversion of river water to the canal. They are, however, provided with a canal head regulator. The head of the canal has to be changed sometimes to suit the changing pattern of river course.

b Classification based on financial output

1 Productive canal

2 Protective canal

Productive canals are those which yield a net revenue to the nation after full development of irrigation in the area. Protective canal is a sort of relief work constructed with the idea of protecting a particular area from famine.

c Classification based on the function of the canal

1 Irrigation canal

2 Carrier canal

3 Feeder canal

4 Navigation canal

5 Power canal

An irrigation canal carried water to the agricultural fields. A carrier canal besides doing irrigation, carries water for another canal. Upper Chenab canal in West Punjab (Pakistan) is the example of one such canal. A feeder canal is constructed with the idea of feeding two or more canals. Examples of such canals are: Rajasthan feeder canal and Sirhind feeder.

d Classification based on the discharge and its relative importance in a given network of canals

1 Main canal

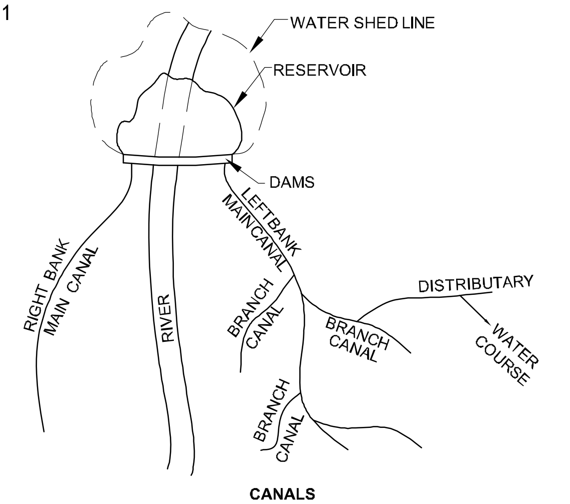
2 Branch canal

3 Major distributary

4 Minor distributary

5 Water course

Fig 1



CANALS

Main canal generally carries water directly from the river. Such a canal carries heavy supplies and is not used for direct irrigation except in exceptional circumstances. Main canals act as water carriers to feed supplies to branch canals and major distributaries.

Branch canals are the branches of the main canal in either direction taking off at regular intervals. In general, branch canals also do not carry out any direct irrigation, but at times direct outlets may be provided. Branch canals are usually carry a discharge of over 5 cumecs.

Major distributaries usually called Rajbha, take off from a branch canal. They may also sometimes take off from the main canal, but their discharge is generally lesser than branch canals. They are real irrigation channels in the sense that they supply water for irrigation to the field through outlets provided along them. Their discharge varies from 1/4 to 5 cumecs.

Cross-section of an irrigation channel Fig 2

A canal is generally taken in such a way that its section is partly in cutting and partly in filling in order to approach close to the balancing depth. Many times, however, the canal has to be carried through deep cutting or filling. A channel section may, therefore, be either:

1 In cutting

2 In filling

3 In partial cutting and filling

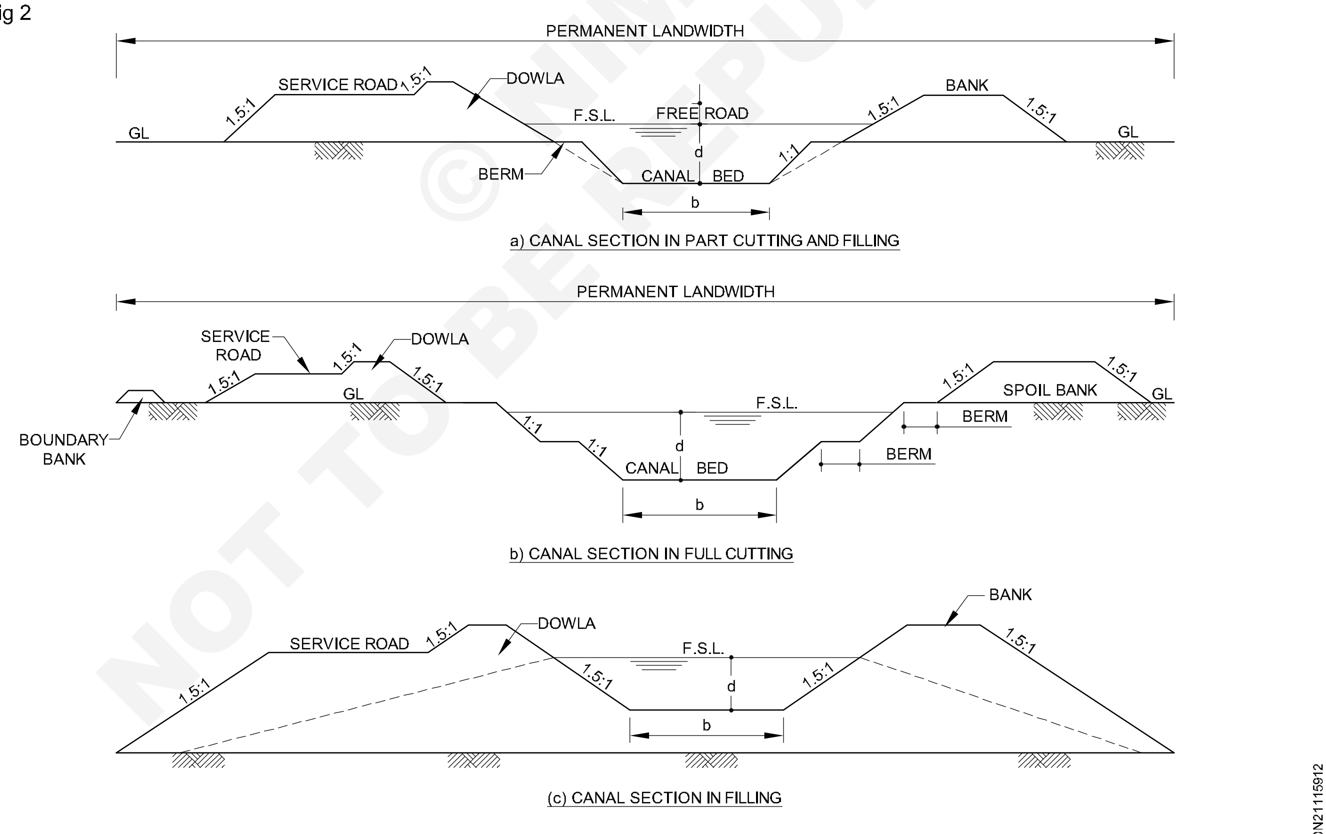
The channel section in these three conditions are shown in Fig 2. When the ground level is above the top of the bank, the canal is said to be in cutting. Similarly, when the ground level is below the bed level of canal, it is said to be in filling. A canal is in partial cutting or filling when the ground level is in between bed level and top of bank.

A canal can have a section on one side or a bank section on both sides. The section may also be designed to have a bank section on one side and section on the other side. Usually the left bank of canal has a section and service road and right bank of the canal has a bank section.

Minor distributaries called minors take off from branch canals or from distributaries. Their discharge is usually less than 1/4 cumecs. They supply water to the water courses through outlets provided along them.

A water course is a small channel which ultimately feeds the water to irrigation fields. Depending upon the size and extent of the irrigation scheme, a field channel may take off from a distributary or minor. Sometimes, it may even take off from the branch canal for the field situated very near to the branch canal.

Fig 2



CANAL SECTIONS

Longitudinal section of a channel Fig 3

After the channel has been designed, the longitudinal section (L-section) is drawn. Before drawing the L-section, ground levels are taken along the final alignment of the channel. Generally,double levelling is done. The cross-sections are also taken at every 20 m or so.

The following procedure is used to draw the L-section (Fig).

1 A suitable datum line is selected somewhere in the

middle of the drawing sheet. The ground levels along the alignment of the channel are then plotted after selecting suitable horizontal and vertical scales.

IS: 5968-1970 recommends a horizontal scale of 1 in 10000 to 1 in 20000 (i.e. 1cm = 100m to 200m), and a vertical scale of 1 in 100 (i.e. 1cm=1m). In actual practice, the vertical scale is selected after considering the fall in the ground level from the head to the tail end. The vertical scale may actually vary from 1 in 50 to 1 in 200.

2 The plotted ground levels points are joined by the smooth lines.

The bed level and full supply leverl (F.S.L.) of the parent canal are also marked just upstream of the head of the off taking channel of which the L-section is being drawn.

3 The full supply level (F.S.L.) of the off-taking channel is then marked keeping the following points in mind:

i The F.S.L. of the off-taking channel is kept about 15 cm to 30 cm lower than the F.S.L. of the parent canal. For the main canals which take off directly from the diversion headworks, it is usually kept about 1 m lower than the pond level.

The F.S.L. of the off taking channel is kept lower than that of the parent channel for the following reasons:

a To account for the loss of head at the head regulator or the distributary head regulator.

b To meet the demand of extra supplies in the channel in future.

c To maintain the flow at full supply discharge even if the bed gets silted up to some extent in its head reaches.

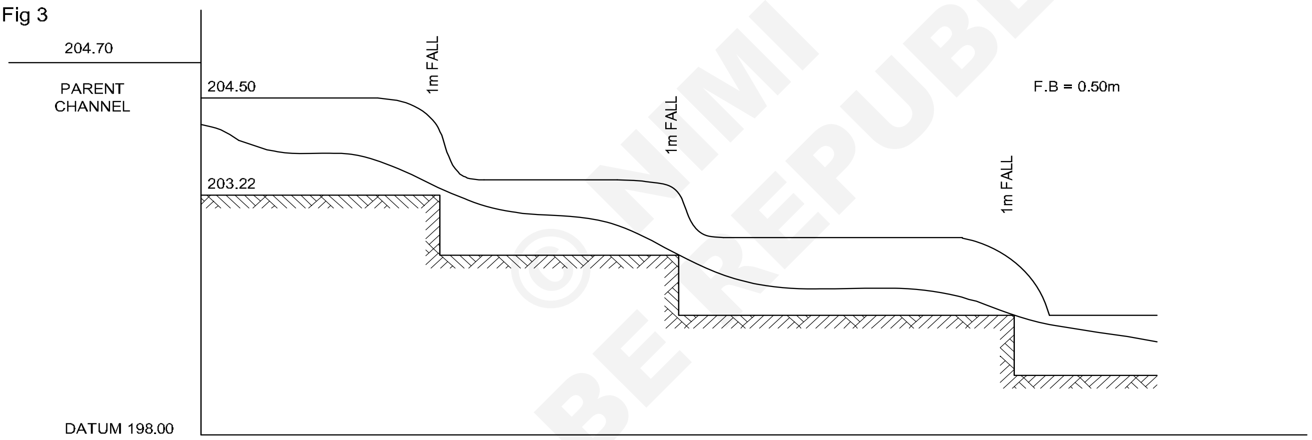
ii The F.S.L. of the off-taking channel should be at least 10 to 25 cm higher than the ground level for most of its reach to have flow irrigation. However, the F.S.L. need not be taken above isolated high patches of ground. Such areas can be irrigated by lift irrigation, if required. However, the F.S.L. Should not be kept too high above the ground. If the F.S.L. is kept too high above the ground level, the following disadvantage may occur.

a Water logging of adjoining land may occur because of excessive seepage.

b The section becomes uneconomical because of excess earth filling.

c The breaches in the high banks may occur.

Fig 3



BED SLOPE	22.5cm/km	22.5cm/km	22.5cm/km	22.5cm/km	22.5cm/km
F.S. DEPTH	1.28m	1.25m	1.15m	1.12m	1.10m
BED WIDTH	5.30m	5.30m	5.30m	5.25m	5.25m
DESIGN DISCHARGE	4.80m³/S	4.60m³/S	4.10m³/S	3.90m³/S	3.70m³/S

FILLING	0.80	0.95	1.21	1.26	1.32	1.67 0.67	0.92	1.08	1.43	1.59	1.74 0.74	0.89	0.95	1.00	1.16	1.21	1.36	1.41	1.40 0.40	0.81	0.97
DIGGING	0.98	0.83	0.57	0.52	0.46	0.11 1.01	0.83	0.67	0.32	0.16	0.01 1.01	0.76	0.70	0.65	0.49	0.44	0.26	0.21	0.06 1.06	0.81	0.65
F.S.L.	204.50	204.45	204.41	204.36	204.32	204.27 203.27	203.22	203.18	203.13	203.09	203.04 202.04	201.89	201.85	201.80	201.76	201.71	201.66	201.61	201.56 200.56	200.51	200.47
BED LEVEL	203.22	203.17	203.13	203.08	203.04	202.99 201.99	201.97	201.93	201.87	201.84	201.79 200.79	200.74	200.70	200.65	200.61	200.56	200.54	200.49	200.44 199.44	199.39	199.35
RL OF GROUND	204.20	204.00	203.70	203.60	203.50	203.10	202.80	202.60	202.20	202.00	201.80	201.50	201.40	201.30	201.10	201.00	200.80	200.70	200.50	200.20	200.00
R. DISTANCE (km)	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0

LONGITUDINAL SECTION OF A CHANNEL

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On the other hand, if the F.S.L. is kept below the ground surface, gravity flow will not occur in the field channels (or offtaking distributaries).

iii The channel should be in the balanced earthwork in most of the reach. for the balanced earthwork, the depth of cutting should be such that the earthwork in cutting is approximately equal to that in the filling.

iv to prevent entry of silt into the off taking channel, the bed level of the off-taking channel should be kept higher than the bed level of the parent channel.

4 The bed slope (also the slope of F.S.L.) provided in the off taking channel should be chosen approximately equal to Lacey's slope.

a If the actual ground slope exceeds the bed slope, canal falls are provided to lower the bed of the canal at suitable locations along the channel. A canal fall is usually provided at a location where the bed of the channel comes into filling. The magnitude of the drop (or fall) is usually fixed such that the F.S.L. of the channel d/s of the fall does not remain below the ground level for a distance greater than about 0.5 km before emerging out of the ground level.

Sometimes the location falls in fixed considering the commanded areas. The procedure is to fix F.S.L. required at the head of all small off take channels and to mark them on the L-section. The F.S.L. of the channel being designed is then fixed so that it is higher than F.S.L. of all small offtake channels.

b If the ground slope is less than the required slope by Lacey's theory or Wood's normal table, then the maximum slope which is actually available for the ground should be provided and an attempt should be made to reduce the silt factor by preventing the entry of coarser silt into the head of the channel. As already discussed, the required bed slope is less for finer silt (lower f).

5 Head losses at falls, escapes, canal syphons, etc. should be determined from their designs and marked on the L-section Fig 3.

6 The following data are entered in different rows below the datum line on the L-section. (Fig)

i Reduced distances (R.D.) measured from the head

ii Natural surface levels (N.S.L.) or ground levels (G.L.)

iii Bed level of the channel

iv Full supply level of the channel

v Full supply depth

vi Bed width

vii Bed slope

viii Full supply discharge

ix Velocity

x) Depth of filling

xi Depth of cutting

xii Name of villages

xiii Location of outlets (or modules)

7 The table of schedule of area statistics and the channel dimensions is usually drawn on the L-section at one corner of the drawing sheet.

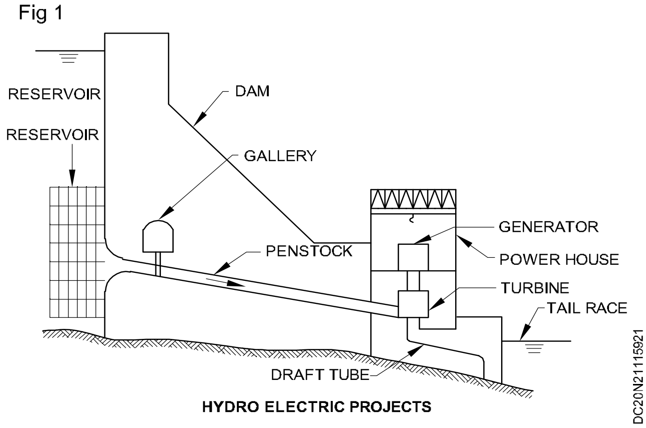
Hydro electric projects and Turbines

Objectives : At the end of this lesson you shall be able to
- **describe hydro electric projects**
- **explain the different component structure of hydro electric projects.**

Introduction

Water power (or hydropower) is generated by utilising the energy of water (or hydraulic energy). Hydropower is obtained from the genrators coupled to water turbines which convert the hydraulic energy into the mechanical energy. High head required for running the turbines is created by constructing a dam across the river Fig 1.

Fig 1



HYDRO ELECTRIC PROJECTS

Most of the multi-purpose schemes have hydropower as one of the major funtions. Sometimes single-purpose projects only for hydropower are also undertaken if economically Justified. The electricalpower generatied in the power house located downstream of the dam is transmitted by a network of transmission lines to far off regions where it is utilised for various purpose.

Hydropower plants may be run-of-river plants or storage plants. Run-of-river- hydropower plants are those which utilise the river water as it comes, without any storage. These plants are feasible only on perennial rivers. In india, most of the hydropower plants are the storage plants in which water is supplied from large storage reservoirs created by construction of dams across rivers. In these reservoirs, the water available in the river during the floods is stored and later utilised for the generation of power and other purpose.

Hydropower is next to only the thermal power in importance. It is estimated that about 30% of the total power in the world is hydropower. According to one estimate, the total theoretical hydropower potential of the world is about 5609

MkW at 100% efficiency and utilisation. According to another recent assessment, the world's technically exploitable hydropower potential is only about 2724 MkW. This latter figure which is based on practical consideration is more accurate than the former which is based on theoretical consideration. The present installed capacity of hydropower is about 200 Mkw, which is about 9% of the expoitable hydropower potential. Thus there is a vast scope for exploitaion of hydropower potential.

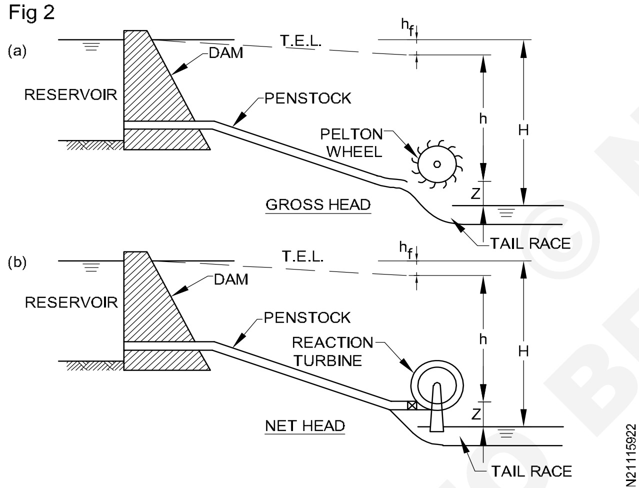
Basic terms and definitions

The following terms are commonly used in hydropower engineering.

1 **Grosss head (h):** The gross head is the difference of the water level in the head race and the water level in the tail race. In a storage plant, the gross head is equal to the difference of water level in the reservoir and water level in the tail race (Fig 2). In a run-of-river plant, gross head is the difference in water level at the point of diversion of water for the hydropower plant and the water level at the point where is returned back to river.

2 **Net head (h):** The net head (or effective head) is the head available for the turbine. it is equal to the difference of total head at the point of entry and at the point of exit of the turbine Fig 2b.

Fig 2



BASIC TERMS USED IN HYDROPOWER ENGINEERING

3 **Operating head:** The operating head is equal to the. difference of the water level in the forebay (or foreway) and that in the tail race.

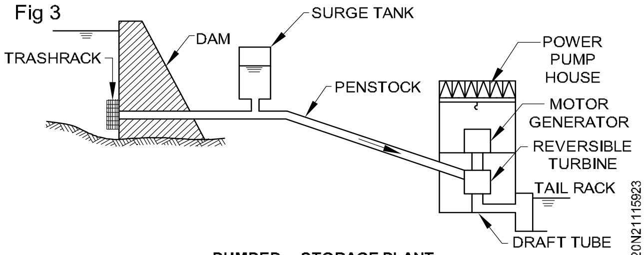
4 **Hydraulic efficiency of plant:** The hydraulic efficiency of a hydropower scheme is equal to the ratio of the net head to the grossd head.

5 **Overall efficiency of hydropower scheme:** The overall efficiency of a hydropower scheme is equal to the product of the hydraulic efficiency, the turbine efficiency and the generator efficiency.

For most of the schemes at the Optimum conditions, the overall efficiency of the scheme is usually beteween 60 to 70 percent.

6 **Overall efficiency of the plant:** The overall efficiency of the plant is equal to the product of the trubine efficiency and the generator efficiency. Its average value is about 80% Fig 3.

Fig 3



PUMPED - STORAGE PLANT

7 **Installed capacity:** The installed capacity (or plant capacity) is the maximum power which can be developed by all the generators of the plant at the normal head and with full flow. Generally, the installed capacity is kept 1:1 times the peak load.

8 **Capacity factor:** The capacity factor (also called plant factor) is the raio of the average output of the plant for a given period of time to the ratio of energy actually produced by the plant for a given period of time to the energy it is capable of producing at full capacity.

Components of hydroelectric scheme

1 **Forebay:** Forbay is an enlarged body of water just in front of the intake. The main function of the forebay is to store, temporarily, the water rejected by the plant when the load is required and to meet the instantaneous increased demand when the load is instantaneously increased. Thus, the forebay absorbs the short interval variations of instake of water into turbines in accordance with fluctuating loards.

2 **Intake structure:** The water is conveyed from the forebay to the penstocks through the intake structure.

3 **Penstocks:** Water from the storage reservoir is carried through penstocks or canal to the power house. Penstocks are the pipes of large diameter, usally made of steel in various forms, reinforced concrete or wood, which carry water under pressure from the storage reservoir to the turbine. Penstocks may be subjected to water hammer pressure due to flucuations in the load. Short length penstocks are designed to take this extra pressure. In case of long penstocks surge tanks are provided to reduce the water hammer.

4 **Surge tank:** It is provided to reduce the water hammer pressure formed in the penstock.

5 **Turbines:** Hydraulic turbines are the machines which converts hydraulic energy developed by a turbine is used in running an electric generator which is directly coupled to the shaft of the turbine. The generator thus developes electric power is known as hydro electric power. A water turbine consist of a wheel called runner which is provided with specially designed blades or buckets. The water possessing large hydraulic energy when strikes the runner and causes it to rotate.

Hydraulic turbine is classified under two heads

1 Impulse or velocity turbines

2 Reaction or pressure turbines

6 **Power house:** Power house of hydroelectric scheme serves as a protective covering for the hydraulic and electrical equipment.

Estimation - Purpose - Technical Terms - Datas And Classification

Objectives : At the end of this lesson you shall be able to
- **define the term estimate**
- **state the importance and purpose of estimate**
- **define technical terms used in estimation**
- **state the datas for estimate.**
- **state the classification of estimate.**

Introduction

Before undertaking the construction of a project it is necessary to know its probable cost which is worked out by estimating. An estimate is a computation or calculation of the quantities required and expenditure likely to be incurred in the construction of work. The primary object of the estimate is to enable one to know beforehand; the cost of the work (building, sturctures etc.). The estimate is the probable cost of a work and is determined theoretically by mathematical calculations based on the plans and drawing and current rates. Approximate estimate may be prepared by various methods but accurate estimate is prepared by Detailed Estimate Method. The acutal cost should not differ much from the estimated cost worked out at the begining.

Accuracy in estimate is very important, if estimate is exceeded it becomes a very difficult problem for engineers to explain, to account for and arrange for the additional money. Inaccuracy in preparing estimate, omission of items, changes in design, improper rates, etc. are the reasons for exceeding the estimate, though increase in the rates in one of the main reason. In framing a correct omissions of any kind of work or part thereof. The rate of each item should be reason. In framing a correct omissions of any kind of work or part thereof. The rate of each item should be reasonable and workable. The rates in the estimate provide for the complete work, which consists of the cost of materials, cost of tools and plants, cost of labour, cost of scaffolding, cost and tools and plants, cost of water, taxes, establishment and supervision cost, reasonable profit of contractor, etc.

Estimate includes cost of material, cost of transportation, cost of labour, cost of temporary structure (scaffolding etc.), cost of tools, equipments and plant, establishment, supervision charges, cost of water, taxes, profit of contrator etc. Before starting the work of estimate it is important to study the drawing carefully.

Definition:

An art of calculating or computing the various items of work or project to find out its approximate cost likely to be incurred, the quantity required or various materials, requirement of labour etc. is called “Estimation.”

Importance of estimate

Estimate helps us in many ways before, during and after construction works. The use and importance of estimating are listed below:

- To give approxiamate cost of construction work.
- To know whether the work can be completed according to given specifications and within the financial limit.
- To invite tenders for work and arrange the contract.
- To get an idea of the material requirements.
- To check out work done by contractors during execution.
- To calculate the payment to the contractors according to the actual measurement compared with existing estimate.
- To calculate the sale value of buildings.
- To fix standard rent.

Technical terms

Project: Project means a full scheme consisting of detailed technical report, history, design, data and calculations, drawings, specifications, rates, project estimates etc. It is the detailed requirements of proposal or scheme. The project gives full details of all works involved for both structural and financial requirements.

It requires preliminary investigation and surveying and selection of site or alignment to start with and then the detailed surveying before taking up preparation of details of the project. Detailed estimate of all works are prepared separately and a general abstract of cost is prepared showing the cost of the whole project. Drawings of all works - plans, elevations, sectional elevations and necessary detailed drawings - and layout plan or index plan of the works are given seperately and detailed specifications of each item of works are also given to all works.

Besides the building, structures etc. provisions are made for external services as outer water supply and sanitary works, strom water drains, road, electric service lines, etc. Cost of land and levelling and dressing of land are also included. The cost of preliminary investigation work is also included in the project estimate.

For a big project in the interior, as for a dam project, the temprary accomodations for staff and a workmen are required and included in the project estimate. cost of the approach road with bridges and culverts have also included in the project estimate.

Provisions for contingencies, work charged establishment and tools and plants are also made in the estimate. Departmental charges 5% to 10% of the whole project estimate is added to meet the expenditure for the preparation and execution of the project.

State of financial return, rent statement, etc., are also prepared to justify the project.

Subwork: A large work or project may be consist of several buildings or small works and each of these work is known as sub-work. Detailed estimate of each sub-work is prepared seperately and accounts of expenditure are kept sub-work wise.

Site plan: For all building plans site plans are prepared to small scale of 1 cm = 5 m to 1 cm = 10 m showing the orientation of the building, boundries of land, position of roads, drains, sewer line, water pipe lines, and adjoining plots of lands with their ownership. the north direction line is also shown on one corner of the site plan to show the geographical orientation of the building. In site plan, the building and other details are drawn in line diagram. From the site plan, location of the wrok with respect to the surrounding is known.

Layout plan: For a project consisting of a number of buildings and structures a layout plan of the whole area is prepared to small scale of 1 cm = 10 m to 1 cm = 20 m with all proposed buildings, structures, etc. showing their sizes, positions, locations and orientations. Besides the buldings are sturctures the roads, lanes, drains, pipe lines, electric lines, parks, etc. are also shown in the layout plan with their proper notations. The boundary, the main approach roads and adjoining areas with their ownership, name, nature etc. are also shown in line diagram. The North direction line is also shown in one corner of the layout plan to indicate the geographical orientaion of the buildings. The layout plan gives a general idea of the project at a glance.

Index plan: For road project, irrigartion project, water super project, sanitary work project, major building project etc, an index plan to a scale 1 cm = 0.5 km is prepared showing alignment with position of culvets, outlets and other main works or main outlines of the whole work so that at a glance an idea of the project may be formed. For big project the index plan is drawn with a much small scale and is known as key plan.

Quantity survey: Quantity survey is a list of schedule of quantities of all the possible items of work required for construction of any building or sturcture. These quantites are worked form the plan and drawings of the structure. Thus the quantity survey indicates the quantites of work to be done under each item which when priced per unit gives the amount of cost. In short quantity survey means estimating of the quantites of different items of works.

Plinth area: Plinth area is the built up covered area of building measured at floor level of any storey. Plinth area is calculated by taking the external dimensions of the building at the floor level excluding plinth offsets if any Courtyard, open areas, balconies and cantilever projections are not included in the plinth area. Supported porches (other than cantilevered) are included in the plinth area.

The following shall be included in the plinth area

i All floors, area of wall at the floor level exculding plinth offsets, if any.

ii Internal shafts for sanitary installations provided these do not exceed 2 sq. m in area air condition ducts, lifts, etc.

iii The area of barasti and the area of mumty at terrace level.

iv Area of proches other than cantilevered.

The following shall not be included in the plinth area:

i Area of loft.

ii Internal sanitary shafts provided these are more than 2 sq.m. in area.

iii Unenclosed balconies.

iv Towers, turrets, domes etc. projecting above the terrace level not forming a storey at the terrace level.

v Architechtural bands, cornices etc.

vi Sunshades, Vertical sun breakers or box louvers projecting out.

Floor area: Floor area of a building is the total area of floor in between walls and consists of floor of all rooms, verandahs, passages, corridors, staircase room, entrance halls, kitchen, stores, bath and latrine (W.Cs.) etc Sills of doors and openings are not included in the floor area. Area occupied by wall, pillars, pilaster, and other intermediate supports are not included in the floor area. In short, floor area is equal to plinth area minus area occupied by walls.

For deduction of wall area from plinth area to obtain floor area, the wall area shall include:

i Door and other openings in the wall.

ii Intermediate pillars and supports.

iii Pilasters along walls exceeding 300 sq. m. in area.

iv Flues which are within walls.

But the following shall exculded from the walls areas:

i Pilaster along wall not exceeding 300 sq.m in area.

ii Fire place projecting beyond the face of wall in living rooms.

iii Chulla platforms projecting beyond the face of walls in kitchens.

The floor of each storey and different types of floor should be measured and taken seperately. The floor area of basement, mezzanines, barasties, mumties, porches, etc.

should be measured separately.

Circulation area: Circulation area is the floor area of verandahs, passages, corridors, balconies, entrance hall, porches, staircases, etc., which are used for movements of persons using the building. The circulation area of any floor shall comprise of the following;

a Verandahs and balconies

b Passages and corridors

c Entrance halls

d Staircase and mumties

e Shafts for lift

The circulation area may be divided into two parts (i) Horizontal circulation area and (ii) Vertical circulation area.

Horizontal circulation area: Horizontal circulation area of a building is the area of verandahs, passages, corridors, balconies, porches, etc., which are required for the horizontal movement of the users of the building. This may be 10% to 15% of the plinth area of the building.

Vertical circulation area: Vertical circulation area of a building is the area or space occupied by staircases, lifts and the entrance halls adjacents to them which are required for vertical movement of the users of the building. This may be 4% to 5% of the plinth area of the buildings.

Carpet area: Carpet area of building is the useful area or liveable area or lettable area. This is the total floor area minus the circulation area, verandahs, corridors, passages, staircase, lifts, entrance hall etc., and minus other non-usable areas as sanitary accommodations (Bath and W.Cs), air conditioning room etc. For office building carpet area is the lettable area or usable area and for residential building carpet area is the liveable area and should excluded the kitchen, pantry, stores and similar other room which are not used for living purposes.

The carpet area of building for any storey shall be the floor area excluding the following:

a Sanitary accomodation

b Verandahs

c Corridors and passages

d Kitchen and pantries

e Stories in domestic buildings

f Entrance hall and porches

g Staircase and mumties

h Shafts for lifts

i Barasties

j Garages

k Canteens

l Air conditioning ducts and air conditioning plant room

The carpet area of an office building may be 60% to 75% of plinth area of the building with a target of 75%. The planners should aim to achieve a target to 75% of the plinth area. The carpet area of residential building may be 50 to 65% of the plinth area of the building.

For a framed multi-storeyed building the area occupied by wall may be 5% to 10% of the plinth area (a standard 3% for external walls and 2% for internal walls). For ordinary building without frame, the area occupied by wall may be 10% to 15% of the plinth area.

External services: In a project besides the building structure, certain outside work are required which come under external services. External service or work include the following:

i Digging, filling, levelling and dressing of road.

ii Road including approach road, if any.

iii External sewerage, sewage, disposal of works.

iv Exrternal electrical service line with posts, if any.

v Storm water drains, fencing or compound wall, gate, etc.

vii Arboriculture plantation of trees.

The cost of external service works should be included in the complete estimate. The cost of external services works may vary from 10% to 20% depending on the nature and size of the project.

Contingencies: The term 'Contingencies; indicates incidental expenses of miscellaneous character which can not be classified under any distinct item sub-head, yet certain to the work as a whole.

In an estimate a certain amount in the form of contingencies of 3% to 5% of estimate cost, is provided to allow for the expenses for miscellaneous petty items which do not fall under any sub-head of items of works. Miscellaneous incidental expenses which cannot be classified under any sub-head or item, are met from the amout provided under contingencies.

If there is any saving against the amount provided under contingencies, this amount may be utilised with the sanction of the competent authority, to meet the expenses of extra items of work, if any unforeseen, expenditure, expenses to minor changes in design, etc.

Work-charged establishment: Work-charged establishment is the establishment which is charged to works directly. During the construction of building or a project, a certain number of work-supervisors, chaukidars mates munshies, etc., are required to be employed, and their salaries are paid from the amount of work-charged establishment a percentage of 1 1/2 to 2% of the estimated cost is included in the estimated. The work-charged employees are temporary staff and their appointment shall have to be sanctioned by the competent authority for a specific period. Their services are terminated at the expiry of the sanctioned period, if their services are required fresh sanction shall have to be taken. Their services can, however, be terminated at any time but usually one month's notice should be given.

Tools and plants (T. and P.): For big work or project a percentage of 1% to 1 1/2 % of the estimated cost is provided in the estimate for the purchase of tools and plants which will be required for the execution of the work. Normally the contractor has to arrange and use his own tools and plants.

Centage charges or Departmental charges: When the engineering department takes up the work of other department a percentage amount of 10% to 15% of the estimated cost is charged to meet the expenses of the establishment, designing, planning, supervision, etc., and this percentage charge is known as centage charge. The centage charge is provided in the estimate of the work of Central Government is undertaken of execution. These charges also known as supervision charges for works.

Complete set of estimate: Detailed estimate is prepared in standard forms and the complete set of estimate consists of:

i Title page giving name of the Engineering Department, division, district, of sub-division, Estimate No., Name of work, and Amount of estimate.

ii Index of contents and plan and drawings.

iii Report.

iv Design calculations.

v General specifications.

vi Detailed specifications.

vii Analysis of rates if required.

viii Details of measurement and calculations for quantities.

ix Abstract of Estimated Cost.

x General abstract of cost.

xi Drawings - plans, elevations, detailed drawing, site plan, index plan, etc.

At the end of the abstract of estimated cost or summary of estimated cost there should be signature of the assistant engineer, executive engineer and superintendent engineer and on the back page head of account should be given.

Schedule of rates: Schedule of rates is a list of rates of various items of works. To facilitate the preparation of estimates, and also to serve as a guide in setting rates in connection with contract agreement, a schedule of rates for all items of work is maintained in the engineering department in the form of a printed books known as "schedule of rate books."

Administrative approval or sanction: For any work or project required by a department, an approval or sanction of the competent authority of the department, with respect of the cost and work is necessary at the first instance. The approval authorises the engineering department to take up the work. Administrative approval denotes to formal acceptance by the department concerned of the proposal, and after the administrative approval is given the engineering department (P.W.D) take up the work and prepares detailed design, plans and estimates and then executes the work. The engineering department prepares approximate estimate and preliminary plans and submits to the department concerned for administrative approval.

Expenditure sanction: Expenditure sanction means the concurrence of the Government of the expenditure proposed and represents allotment of the money to meet the expenditure. No expenditure can be incurred before expenditure sanction is given. Expenditure sanction means allotment of fund or money for a specific work and is usually, accorded by the finance department.

Technical sanction: Technical sanction means the sanction of the detailed estimates, design calculation, quantities of works, rates and cost of the work by the competent authority of the engineering department. After the technical sanction of the estimate is given, then only the work is taken up for construction. In case of original work the counter signature of the local head of the department should be obtained in the plan and estimate before technical sanction is accorded by the engineering department. The power for technical sanction differs from State to State.

Bill of quantities: It is statement of the various items of work giving the description quantites and unit of rates. It is prepared in a tabular form similar to the 'abstract of estimated cost' of the detailed estimated, but the rate and amount columns are left blank (unfilled). When priced, that is, the rates and the amounts are filled up and totalled, this gives the estimated cost. It is primarily meant for inviting tender, and supplied to the contractor to fill up the rates and amounts columns. On receipt of the tenders the rates and amounts are compared and decision about entrusting the work is finalised.

Data for estimation: To make an estimate for a work following data are necessary:

i Drawing - Plan, Section, etc.

ii Specification.

iii Rates

i Drawings: Plan, Sectional elevations and detailed drawings to scale, fully dimensioned are required. The plan, elevation and sectional elevations are usually drawn to a scale of 1 cm = 1 m and detailed drawings are prepared to scales of 1 cm = 10 cm to 1 cm = 30 cm.

ii Specifications

a General specifications or brief specification: These give the nature, quality and class of work and materials, in general terms, to be used in the various parts of the work. General specifications help to form a general idea of the whole building or sturcture and are useful in preparing the detailed estimate.

b Detailed specification: These give the detailed description of the various items of work laying down the quantites and qualities of materials, their proporations, the method of preparation, workmanship and execution of work. Detailed specifications describe every item of work separately, in detail and are helpful for the execution of the different items of work.

iii **Rates:** The rates per unit of various items of work, the rates of various materials to be used in the construction and the wages of different categories of labour, skilled or unskilled a mason, carpenter, mazdoor, bhishti, etc., available for preparing estimate. The location of the work and its distance from the source of materials and the cost of transport should be known. These rates may be worked out by the “Analysis of rates” method.

Estimates are mailnly in two types. They are abstract estimate and item rate estimate.

Estimates

Rough Cost Estimates	**Item Rate Estimate**
1 Approximatel/Preliminary/ Abstract estimate	1 Detailed Estimate
2 Plinth Area Estimate	2 Revised Estimate
3 Cubical Content Estimate	3 Supplementary Estimate
4 Approximate Quantity Method Estimate	4 Supplementary and Revised Estimate
	5 Annual repair Estimate
	6 Extention and Improvement Estimate
	7 Extention and Improvement Estimate

Rough cost estimate: The estimate prepared without going into details of different items of work is called rough cost estimate. It is prepared by different methods.

i **Preliminary or Approximate or Abstract estimate:** Preliminary or approximate or abstract estimate is required for preliminary studies or various aspects of a work or project, to decide the financial position and policy for administrative saction by the compenent administrative authority. In case of commercial projects as irrigation projects, Residential building projects and similar projects which earn revenue income, the probable income may be worked out, and from the preliminary estimate the approximate cost may be known and then it may be seen whether the investment, on the project is justified or not. for non-commercial projects or for projects giving no direct return, their necessity, utility, availability of money, etc., may be considered before final decision is taken. The approximate estimate is prepared for the practical knowledge and cost of the similar works. This estimate is prepared showing separately the approximate cost of all important items of work as cost of land, cost of each building, cost of roads, water supply, sanitary works, electrification, etc., the estimate is accompanied by a brief report explaining the necessity and utility of the project and showing how the cost of separate items have been arrived at. This is also accompanied with a site plan or layout plan. A percentage of about 5% to 10% is added as contingencies.

ii **Plinth area estimate for building (P.A. estimate):** This is prepared on the basis of plinth area of building, the rate being deducted from the cost of similar building having similar specification, heights and construction, in the locality. Plinth area estimate is calculated by finding the plinth area of the building and muliplying by the plinth area rate. The plinth area should be calculated for the convered area by taking external dimension of the building at the floor level. Courtyard and other open area should not be included in the plinth area. Plinth area estimate is only approximate, and is preliminary estimate, to know the approximate cost before hand.

If the plan of the building is not ready or available, at the begining just prepare a proposal, floor area of rooms, etc. may be determined from the requirement and 30 to 40 percent of the total area thus found may be added for walls, circulation and waste to get the approximate total plinth area which multiplied by the plinth area rate gives the approximate cost of the building.

iii **Cubical rate estimate for building:** Cube rate estimate is a preliminary estimate or an approximate estimate, and is prepared on the basis of the cubical contents of the bulding the cube rate being deducted from the cost of the similar building having similar specifications and construction, in the locality.

This is calculated by finding the cubical content of the building (length x breadth x height) and multiplied it by the cube rate. the length and breadth should be taken as the external dimensions of the buildings at the floor level and the height should be taken from the floor level to top of roof (or half way of the sloped roof). For storeyed building the height should be taken between the floor level of one storey to top of next-higher floor. the foundation and plinth, and the parepet above roof are not taken into account in finding the cubical content.

Cube rate estimate is most accurate as compared to the plinth area estimate as the height of the building is also compared.

iv **Approximate quantity method estimate:** In this method approximate total length of walls is found in running metre and this total length multiplied by the rate per running metre of wall gives a fairly accurate cost. For this method the structure may be divided into two parts viz. (i) foundation including plinth and (ii) superstructure. The running metre rate should be multiplied by the total length of walls.

To find the running metre rate for foundation, the approximate quantities of items such as excavation, foundation, brickwork upto plinth, and damp proof course are calculated per running metre and by multiplying by the rates of these items the price or rate per running metre is determined.

Similarly for superstructure the price or rate per running metre is determined from the approximate quantities of brick work, wood works, roof, floor finishing etc.

For this method the plan or line plan of the structure should be available.

ii **Item rate estimates:** Item rate estimate is prepared in detail item wise. For this estimate, the work is divided into different items of work and quantities under each item are taken out and then an abstract of estimate cost is prepared at suitable rates.

1 **Detailed estimate:** Detailed estimate is an accurate estimate and consists of working out the quantities of each item of works, and working the cost. The dimensions, length, breadth and height of each item are taken out correctly from drawing and quantities of each item are calculated, and abstracting and building are done.

The detailed estimate is prepared in two stages.

a **Details of measurement and calculation of quantities:** The details of measurement of each item of work are taken out correctly from plan and drawings and quantities under each item are computed or calculated in a tabular form named as Details of Measurement Form (Table 1).

b **Abstract of estimate cost:** The cost of each item of work is calculated in a tabular form from the quantities already computed and total cost is worked out in abstract of estimate form (Table 2). The rates of different items of work are taken as per schedule of rates or current workable rates or analysed rates for finished items of work. A percentage usually 3% of the estimated cost is added to allow for contingencies for miscellaneous petty items which do not come under any classified head of items of work and a percentage of about 2% is provided for work-charged establishment. The grand total thus obtained gives the estimated cost of work.

The detailed estimate is usually prepared work-wise, under each sub-work as main building, servant quarters, garage, boundary walls etc.

The detailed estimate is accompanied with:

a Report

b General specifications

c Detailed specifications

d Drawings: Plan, elevation, sectional elevations, detailed drawings, site plan or layout plan or index plan etc.

e Calculation and designs: Designs of foundation, beam, slab, lintel, design of channel in case of irrigation channel, design of thickness of metal crust in case of road etc.

f Analysis of rates, if rates are not as per schedule of rates or for the non-scheduled items.

Detailed estimate is prepared for technical sanction of the competent authority, for arranging contract and for the execution of work.

2 **Revised estimate:** Revised Estimate is detailed estimate and is required to be prepared under any one of the following circumstances.

i When the original sanctioned estimate is exceeded or likely to exceed by more than 5%.

ii When the expenditure on a work exceeds or likely to exceed the amount of administrative sanction by more than 10%

iii When there are material deviation from the original proposal, even though the cost may be met from the sanctioned amount.

The revised estimate should be accompanied by a comparative statement showing the variations of each item of works, its quantity, rate and cost under original and revised, side by side, the excess or saving and reason for variation.

3 **Supplementary estimate:** Supplementary estimate is a detailed estimate and is prepared when additional works are required to supplement the originalworks, or when further developments is required during the progress of work. This is a fresh detailed estimate of the additional works in addition to the original estimate. The abstract should show the amount of the original estimate and the total amount including the supplementary amount for which sanction is required.

4 **Supplementary and revised estimate:** When a work is partially abandoned and the estimated cost of the remaining work is less than 95 percent of the original work, that is less than 95% of the original sanctioned estimate, or when there are material deviations and changes in the design which may cause substantial saving in the estimate, then the amount of the original estimate is revised by the competent authority. A supplementary and Revised Estimate is then prepared and fresh technical sanction of the competent authority is obtained.

If at any time either before or during the execution of original work, it is found that the original estimate is excessive, then divisional officer may sanction a revised estimate of reduced amount. While giving such sanction the Accountant General and other higher authorities are informed.

5 **Annual repair or annual maintenance estimate (A.R. or A.M. Estimate):** Annual repair or annual maintenance estimate is a detailed estimate and is prepared to maintain the structure or work in proper order and safe condition. For building; this includes white washing, colour washing, painting, minor repairs etc. For road works the A.R. estimate provides for patch repairing, renewals, repairs of bridges and culvert, etc.

Further, there may be special repair estimate, monsoon damage repair estimate, etc.

Table 1: Details of measurement form

Item No.	Description	Nos	Length (m)	Breadth (m)	Height or depth (m)	Content or Quantity

Table 2: Abstract of estimate form

Item No.	Description or particlulars	Quantity	Unit	Rate	Amount

6 **Extension and improvement estimate:** When some changes and extensions are required to be made in the old work, the cost of which cannot be met by the annual repair/maintenance estimate, a detailed estimate is prepared for such work which is called as extension and improvement estimate.

Rules measurement of Technique

Objectives: At the end of this lesson you shall be able to
- **state the method of measurement of works and taking out quantities**
- **explain the unit of measurements and payments**
- **explain the main items of work.**

Rules and methods of measurements of works and taking out quantities

Measurement of works occupies a very important place in the planning and execution of any work or project, from the time of the first estimate are made until the completion and settlement of payments. The methods followed for the measurements are not uniform and the practices as prevalent differ considerably in different States. Even in the same State different departments follow different methods. for convenience, a uniform method should be followed throughout the country. the uniform method of measurement to be followed, which is applicable to the preparation of the estimates and bill of quantities and to the site measurement of completed works has been described below.

General rules

1 Measurement shall be item wise for the finished item of work and the description of each item shall be held to include materials, transport, labour, fabrication, hoisting, tools and plants, overheads and other incidental charges for finishing the work to the requisred shape, size, design and specifications. the nomenclature of each item shall be fully deseribed so that the work involved in item is self-explanatory.

2 In booking dimensions, the order shall be in the sequence of length, breadth and height or depth or thickness.

3 All work shall be measured net subject to following tolerances unless otherwise stated

a Dimensions shall be measured to nearest 0.01 metre i.e. 1 cm.

b Areas shall be measured to the nearest 0.01 sq. m.

c Cubic contents shall be worked out to the nearest 0.01 cu. m.

4 Same type of work under different conditions and nature shall be measured separately under separate items

5 The bill of quantities shall fully describe the materials proportions and workmanships, and accuratley respresent the work to be executed. Work which by its nature cannot be accuratley taken off or which requires site measurements, shall be described as provisional.

6 In case of structural concrete, brickwork or stone masonry, the work under the following categories shall be measured separately and the heights shall be described

a From foundation to plinth level.

b From plinth level to first floor level.

c From first floor level to second floor level and so on.

The parapet shall be measured with the corresponding items of the storey next below

Particulars of materials and works		Dimensions metric system
1	Bricks, stone blocks, etc.	All dimensions cm.
2	Tiles, slates, wall board, glass panes, A.C. sheets, sheets, etc.	Length and breadth in cm or m. Thickness in mm.
3	Door, Windows, etc.	Height and breadth in cm or m.
4	Parts of doors and windows as pannels, shutters.	cm or mm.
5	Timber	Length in m and cross-sectional dimensions in cm or mm.
6	Masonry (brickwork, stone masonry, etc.)	Length and height in m. Thickness or breadth in cm.
7	Cement concrete, Lime concrete, R.C.C. Flooring, etc.	Length and breadth in m. Thickness in cm.
8	White washing, colour washing, distempering, painting, etc.	Length and breadth or height in m.
9	Aggregates, ballast, grit, sand, etc.	Size in mm.
10	Rolled steel sections as I-beam, channel, angle, etc.	Length in m, section in mm.
11	Mild steel bars	Length in m, Dia. in mm.

Unit of measurements in metric system

The principle for dimensions and measurements is to use millimetre (mm) for minute dimensions, centimetre (cm) for small dimensions and metre (m) for big dimensions. Distances are measured in kilo metre (km).

The dimensional units for main item of materials and works for general construction works as used in metric system are as follows:

Principle of units: The unit of different works depends on their nature, size and shape. In general, the units of different terms of work are based on the following principles.

i Mass, voluminous and thick works shall be taken in cubic unit or volume. The measurement of length, breadth and height or depth shall be taken to compute the volume or cubic contents (cu. m).

ii Shallow, thin and surface work shall be taken in square units or area, the measurement of length and breadth or height shall be taken to compute the area (sq.m).

iii Long and thin work shall be taken in linear or running unit and linear measurement shall be taken (running metre).

iv Piece work, job work, etc., shall be enumerated, i.e. taken in a number.

S. No.	Particulars of Items	Units of measurement in MKS	Units of payment in MKS
	Earthwork		
1	Earthwork in excavation in ordinary soil, earth work is mixed soil with kankar, bajri, etc. earthwork in hard soil	cu. m.	Per % cu. m.
2	Rock excavation	cu. m.	Per % cu. m.
3	Earth filling in excavation in foundation	cu. m.	Per % cu. m.
4	Earth filling in foundation trenches (Usually not measured and not paid separately	cu. m.	Per % cu. m.
5	Earth filling in plinth	cu. m.	Per % cu. m.
6	Earth work in banking, cutting, in road and irrigation channel	cu. m.	Per % cu. m.
7	Surface dressing and levelling, cleaning etc.	sq. m.	Per sq. m.
8	Cutting of trees (Girth specified)	no.	Per no.
9	Puddling, Puddle clay core	cu. m.	Per % cu. m.
10	Sand filling	cu. m.	Per cu. m.
11	Quarrying of stone or boulder	cu. m.	Per cu. m.
12	Blasting or rock (Blasted stone stacked and then measured)	cu. m.	Per cu. m.
	For earth work, normal lead is 30m and normal lift is 1.5m		
	Concrete		
1	Lime concrete (L.C.) in foundation	cu. m.	per cu. m.
2	Lime concrete (L.C.) in roof terracing, thickness specified (May also be in volume basis as practice U.P.)	sq. m.	per sq. m.
3	Cement concrete (C.C.)	cu. m.	per cu. m.
4	Reinforced cement concrete (R.C.C.)	cu. m.	per cu. m.
5	C.C. or R.C.C. chajja, sun shade	cu. m.	per cu. m.
6	Precast C.C. or R.C.C.	cu. m.	per cu. m.
7	Jali work or jaffri work or C.C. tracery panels (Thickness specified)	sq. m.	per sq. m.
8	Cement concrete bed	cu. m.	per cu. m.
	D.P.C		
9	Damp proof course - Cement concrete Rich cement mortar, Asphalt, etc. (Thickness specified)	sq. m.	per sq. m.

S. No.	Particulars of Items	Units of Measurement in MKS	Units of payment in MKS
	Brick work		
1	Brickwork in foundation and plinth, in sperstructure, in arches, etc. in cement lime or mud mortar	cu. m.	per cu. m.
2	Sun dried brickwork	cu. m.	per cu. m.
3	Honey-comb brickwork, thickness specified (May also be in volume basis as practice in U.P.)	sq. m.	per sq. m.
4	Brickwork in jack arches, if measured separately	cu. m.	per cu. m.
5.	Jack arch roofing including top finishing	sq. m.	per sq. m.
6	Brickwork in well steining	cu. m.	per cu. m.
7	Half-brick work with or without reinforcement (May also be in cu. m. as practice in U.P.)	sq. m.	per sq. m.
8	Thin partition wall	sq. m.	per sq. m.
9	Reinforced brick work (R.B. work)	cu. m.	per cu. m.
10	String course, drip course, weather course, coping etc. (Projection specified)	metre	per m.
11	Cornice (Projection and type specified)	metre	per m.
12	Brickwork in Fire place, Chulla, Chimney	cu. m.	per cu. m.
13	Pargetting Chimney, fire place flue	metre	per m.
14	Brick edging (by road side)	metre	per m.
	Stone work		
1	Stone masonry, Random rubble masonry Coursed rubble masonry, ashlar masonry in walls, in arches, etc.	cu. m.	per cu. m.
2	Cut stone work in lintel, beam, etc.	cu. m.	per cu. m.
3	Stone slab in roof, shelve, etc, stone chajjas, stone sun shade, etc. (Thickness specified)	sq. m.	per sq. m.
4	Stone work in wall facing or lining (Thickness specified)	sq. m.	per sq. m.
	Wood work		
1	Wood work, door and window frame or chowkhat, rafters beams, roof trusses, etc.	cu. m.	per cu. m.
2	Door and window shutters or leaves, panelled, battened, glazed, part panelled and part glazed, wire gauged, etc. (Thickness specified)	sq. m.	per sq. m.
3	Door and window fittings as hinges tower bolts, sliding bolts, handles etc. (May also be on the basis of area of shutters as practice in U.P.)	no.	per no.
4	Timbering, Boarding (Thickness specified0	sq. m.	per sq. m.
5	Timbering of trenches (Area of face supported)	sq. m.	per sq. m.
6	Sawing of timber	sq. m.	per sq. m.
7	Woodwork in partition, Ply wood ect.	sq. m.	per sq. m.

S. No.	Particulars of Items	Units of Measurement in MKS	Units of payment in MKS
	Steel work		
1	Rolled steel joists, Channels, Angles, T-irons, Flats, Squares, Rounds etc.	quintal	per q.
2	Steel reinforcement bars, etc. in R.C.C., R.B. work	quintal	per q.
3	Bending, binding of steel reinforcement	quintal	per q.
4	Fabrication and hoisting of steel work	quintal	per q.
5	Expended Metal (X.P.M.) size work	sq. m.	per sq. m.
6	Fabric reinforcement, wire netting	sq. m.	per sq. m.
7	Iron work in struss	quintal	per q.
8	Gusset plate (Minimum rectangular size from which cut)	quintal	per q.
9	Cutting of Iron Joists, Channels	cm.	per cm.
10	Cutting, Angles, Tees, Plate	sq. m.	per sq. m.
11	Threading in iron	cm.	per cm.
12	Welding, Solder of sheets, plates (Welding of rails, steel, trusses, rods - per no.)	cm.	per cm.
13	Boring holes in iron	no.	per no.
14	Cast Iron (C.I.) pipe, Dia. specified	metre	per m.
15	Rivets, Bolts and nuts, Anchor bolts, Lewis bolts, Holding down bolts, etc.	quintal	per q.
16	Barbed wire fencing	metre	per m.
17	Iron gate (May also be by weight, quintal)	sq. m.	per sq. m.
18	Iron hold fast (May also be by no.)	quintal	per q.
19	Iron railing (Height and types specified)	meter	per m.
20	Iron grill, collapsible gate (may also be by weight, quintal)	sq. m.	sq. m.
21	Rolling shutter	sq. m.	sq. m.
22	Steel doors and windows (Type and fixing specified)	sq. m.	sq. m.
	Roofing		
1	Tiled roof - Allahabad tile, Faizabad tile, Mangalore tile, etc. including battens	sq. m.	per sq. m.
2	Country tile roof including bamboo jaffria.	sq. m.	per sq. m.
3	Corrugated iron (C.I.) roof, Asbestos cement (A.C.) sheet roof	sq. m.	per sq. m.
4	Slate roofing, timber roofing	sq. m.	per sq. m.
5	Thatch roofing including bamboo jaffri (Thickness specified)	sq. m.	per sq. m.
6	Eave Board (Thickness specified)	sq. m.	per sq. m.
7	R.C.C., R.B. slab roof (excluding steel)	cu. m.	per cu. m.
8	Lime concrete roof over and inclusive of tiles or brick, or stone slab, etc. (Thickness specified)	sq. m.	per sq. m.
9	Mud roof over and inclusive of tiles, or bricks or stone slab, etc. (Thickness and type specified)	sq. m.	per sq. m.
10	Ridges, valleys, gutters (Grith specified)	metre	per m.

S. No.	Particulars of Items	Units of Measurement in MKS	Units of payment in MKS
11	Tar felting, Bituminous painting	sq. m.	per sq. m.
12	Insulating layer in roof of sand and clay, asphalt, etc.	sq. m.	per sq. m.
13	Expansion, contraction or construction joint	metre	per m.
14	Ceiling - Timber, A.C. Sheet plain, Cloth, Cement plaster on PM, Paste board, etc.	sq. m.	per sq. m.
15	Centering and shuttering, Form work - Surface area of R.C.C. or R.B. work supported (May also be per cu. m. (cu. ft.) of R.C.C. or R.B. work)	sq. m.	per sq. m.
	Plastering, Pointing and Finishing		
1	Plastering - Cement mortar, Lime mortar, mud, etc. (Thickness, proportion specified)	sq. m.	per sq. m.
2	Pointing - Struck, Flush, Weather, etc.	sq. m.	per sq. m.
3	Dado (Thickness and type specified)	sq. m.	per sq. m.
4	Skirting (Thickness type and height specified)	metre	per m.
5	Cement mortar or lime mortar rubbing	sq. m.	per sq. m.
6	White washing, Colour washing, Cement washing (No. of coat specified)	sq. m.	per sq. m.
7	Distempering (No. of coat specified)	sq. m.	per sq. m.
8	Snow cement washing or finising (No. of coat specified)	sq. m.	per sq. m.
9	Painting, Varnishing (No. of coat specified)	sq. m.	per sq. m.
10	Polishing of wood work (No. of coat specified)	sq. m.	per sq. m.
11	Painting letters and figures (Height specified)	no.	per no.
12	Oiling and clearing of doors and windows	sq. m.	per sq. m.
13	Coal taring (No. of coat specified)	sq. m.	per sq. m.
14	Removing of paint or varnish	sq. m.	per sq. m.
15	Gobri lepping (Cow dung wash)	sq. m.	per sq. m.
	Flooring		
1	2.5 cm (1”) C.C. over 7.5 cm (3”) L.C. Floor (including L.C.)	sq. m.	per sq. m.
2	Conglomerate floor, artificial patent stone floor 2.5 cm. (1”) C.C. over 7.5 cm (3”) L.C. (including L.C.)	sq. m.	per sq. m.
3	4 cm (1½”) thick stone floor flag stone floor over 7.5 cm (3”) L.C. (including L.C.)	sq. m.	per sq. m.
4	2.5 cm (1”) marble flooring over 7.5 cm (3”) L.C. (including L.C.)	sq. m.	per sq. m.
5	Mosaic or terrazzo or granolithic floor over 7.5 cm (3”) L.C. (including L.C.)	sq. m.	per sq. m.
6	Brick flat floor over 7.5 cm (3”) L.C. (including L.C.)	sq. m.	per sq. m.
7	Brick on edge floor over 7.5 cm (3”) L.C. (including L.C.)	sq. m.	per sq. m.
8	2.5 cm (1”) or 4 cm (1½”) C.C. floor	sq. m.	per sq. m.
9	Mud flooring finished gobri lepping	sq. m.	per sq. m.

S. No.	Particulars of Items	Units of Measurement in MKS	Units of payment in MKS
10	Apron or Plinth protection (May be of C.C, L.C., brick, etc.)	sq. m.	per sq. m.
11	Door and window sill (C.C. or cement mortar plastered)	sq. m.	per sq. m.
	Miscellaneous Items		
1	Ornamental cornice (Projection, type specified)	metre	per m.
2	Moudling String course, Drip course, Beading, Throating, etc.	metre	per m.
3	Ornamental Pillar caps, Pillar base, Flowers, Brackets, etc.,	no.	per no.
4	Railing (Height and type specified)	metre	per m.
5	Surface drain small (size, material, etc. specified)	metre	per m.
6	Surface drain large (item wise) (i) Masonry	cu. m.	per cu. m.
	(ii) Plastering	sq. m.	per sq. m.
7	Pipe - rainwater, sanitary, water pipe, etc. (Dia. specified)	metre	per m.
8	Laying pipe line - sanitary, water pipe, etc. (Dia, depth, beeding etc. specified)	metre	per m.
9	Jungle clearance (May also be per km for road and irrigation channel)	sq. m. or hectare	per sq. m. or per hectare
10	Silt clearance in irrigation channels (Similar to earth work) (For thin layer upto 5 cm may be on area basis)	cu. m.	per % cu. m.
11	Trestel, Crate (Size, type, etc. specified)	no.	per no.
12	Cleaning flues	no.	per no.
13	Cotton cords in sky light (May also be by weight in kg)	no	per no.
14	Easing doors and windows	no.	per no.
15	Fixing doors and windows	no.	per no.
16	Supply and fixing of Hinges, Tower bolts, Hasp and staples, Handles, hardwares etc.	no.	per no.
17	Glazing	sq. m.	per sq. m.
18	Glass panes (supply)	sq m.	per sq. m.
19	Fixing of glass panels or cleaning	no.	per no.
20	Renewing of glass panels	no.	per no.
21	Well sinking (Masonary or tube well)	metre	per m.
22	Pile driving or sinking	metre	per m.
23	Furniture - Chairs, tables, etc. (size, shape specified)	no.	per no.
24	Painting furniture's	no.	per no.
25	Caning chairs	no.	per no.
26	Pitching of brick, stone, kankar, etc. (Brick pitching may also be on area basis in sq. m.)	cu. m.	per cu. m.
27	Lining of Irrigation Channel, Tunnel, etc. Materials, thickness specified (Thick lining may be in volume basis in cu. m.)	sq. m.	per sq. m.
28	Kankar quarrying, kankar supply	cu. m.	per cu. m.
29	Kankar consolidation, road metal consolidation	cu. m.	per cu. m.
30	Dag-belling (May also be per km)	metre	per m.
31	Bituminous road surfacing	sq. m.	per sq. m.
32	Dismantiling	Same as for different item	Same as for different item

S. No	Particulars of Items	Unitsof Measurement in MKS	Unitsof payment in MKS
33	Dismantling of brick masonry	cu. m.	cu. m.
34	Grouting (Bituminous grouting of road metal, cement grouting of concrete)	sq. m.	per sq. m.
35	Grouting of cracks, joints, etc.	metre	per m.
36	Electric Wiring of Electrification Light, Fan, Plug points	point	per point
37	Water closet (W.C.) Wash hand basin, Manhole, etc. (size specified)	no.	per no.
	Materials		
1	Supply of bricks	% nos	per % nos.
2	Supply of sand, surkhi, cinder, etc.	cu. m.	per cu. m.
3	Supply of cement	bag of 50 kg	per bag or per quintal or per ton
4	Supply of lime unslaked	quintal	per quintal
5	Supply of lime slaked (May also be in volume basis in cu. m.)	quintal	per quintal
6	Supply of brick ballast, stone ballast, Aggregate, etc.	cu. m.	per cu. m.
7	Broken bricks, kankar, etc.	cu. m.	per cu. m.
8	Supply of Timber	cu. m.	per cu. m.
9	supply of steel	quintal	per quintal
10	Supply of Bitumen, Tar	tonne	per tonne
11	Supply of coal	tonne	per tonne
12	Supply of A.C. sheet (measured flat)	sq. m.	per sq. m.
13	Supply of G.I. sheets	quintal	quintal
14	Supply of switches, plugs, ceiling roses, bulbs, brackets, etc.	no.	per no.
15	Supply of insulated electric wire (size specified0	quintal	per quintal
16	Supply of bare electric wire (size specified)	quintal	per quintal
17	Tents, sholdaries (size specified)	no.	per no.
18	Supply of water closet, W.C., (size specified)	no.	per no.
19	Supply of water hand basin (size specified)	no.	per no.
20	Supply of Cowl, Mica valve, Intercepting trap etc. (size specified)	no.	per no.
21	Supply of Bib cock, stop cock, ball cock, etc. (size specified)	no.	per no.
22	Supply of Ferrule, C.I. Tank, Water meter, etc. (size specified)	no.	per no.
23	Supply of pipe, C.I. pipe, S.W. pipe, Hume pipe, A.C. pipe, G.I. pipe, etc. (Dia. specified)	metre	per m.
24	Supply of lead, lead wool	kg or quintal	per kg or per quintal
25	Spun yarn	kg	per kg
26	Supply of varnish, oil, etc.	litre	per litre
27	Supply of paint ready mix	litre	per litre
28	Supply of stiff paint	kg.	per kg.
29	Explosive for blasting	kg.	per kg

Main items of work

1 **Earthwork:** Earthwork in excavation and earthwork in filling are usually taken out separately under different items, and quantities are calculated in cu. m. Foundation trenches are usually dug to the exact width of foundation with vertical sides. Earthwork in excavation in foundation is calculated by taking the dimensions of each trench **l**ength x **b**readth x **d**epth. Filling in trenches after the construction of foundation masonry is ordinarily neglected. If the trench filling is accounted, this may be calculated by deducting the masonry from the excavation.

Earthwork in plinth filling is calculated by taking the internal dimensions in between plinth wall (Length x Breadth) which are usually less than the internal dimensions of the room by two off-sets of plinth wall i.e. 10 cm and height is taken after deducting the thickness of concrete in floor, usually 7.5. If sand filling is done in plinth this should be taken separately. The length and breadth for each filling may be same as the internal dimensions of the room if there is no off-set in plinth wall.

Excavated earth is used in trench filling and plinth filling and usually not paid for separately, but may also be included under a separate item. “Return fill and ram or backfill” and paid at a lesser rate. Extra earth if required for filling is brought from outside. If there is surplus earth after trench and plinth filling, this may be utilised in levelling and dressing of site or carted away and removed.

Lead and lift: Normally earthwork is estimated for 30 m lead for distance and 1.5 m lift for height or depth, and this distance of 30 m and the height of 1.5 m are known as normal lead and lift. Normal rate for earth work is for 30 m lead and 1.5 m lift. For greater lead or lift the rates will be different (higher) for every unit of 30 m lead and for every unit of 1.5 m lift. The earth work is, thereorfe, estimated separately for every 30 m lead and for every 1.5 m lift.

2 **Concrete in-foundation:** The concrete is taken out in cu. m. by length x breadth x thickness. The length and breadth of foundation concrete are usually the same as for excavation, only the depth or thickness differs. The thickness of concrete varies from 20 cm to 45 cm, usually 30 cm. Foundaton concrete consists of lime concrete or weak cement concrete. The proportion of cement concrete in foundation may be 1:4:8 or 1:5:10.

3 **Soiling:** When the soil is soft or bad, one layer of dry brick or stone soling is applied below the foundation concrete. The soling layer is computed in sq. m. (Length x Breadth) specifying the thickness.

4 **Damp proof course:** D.P.C. usually of 2.5 cm thick rich cement concrete 1:1½ :3 or 2 cm, thick rich cement mortar 1:2, mixed with standard water proofing material, is provided at the plinth level to full width of plinth wall, and the quantities are computed in sq. m. (Length x Breadth). Usually D.P.C. is not provided at the sills of doors and verandah openings, for which deductions are made. (One kg of Cem-Seal or Impermo or other standard water proofing compound per bag of cement is generally used).

5 **Masonry:** Masonry is computed in cu. m. (Length x Breadth x Height). Foundation and plinth masonry is taken under one item, and masonry in superstructure is taken under a separate item. In storeyed building the masonry in each storey as ground floor above plinth level, first floor, etc. is computed separately. In taking out quantities the walls are measured as solid and then deductions are made for openings as doors, windows, etc. and such other portions as necessary. Masonry of different types or classes, masonry with different mortar, etc. are taken out under separate items. Arch masonry work is taken out separately. Splayed or rounded sides of wall are considered as rectangular and extreme dimensions are taken to find out the quantities. This partition wall is measured in sq. m. Honey comb brick wall is taken under a separate item in sq. m. no deduction is made for holes. Stone masonry is calculated in the same manner as for brick masonry.

Deduction for opening, bearings, etc. in masonry

No deduction is made for the following:

i Opening each up to 1000 sq. cm. or 0.1 sq. m.

ii Ends of beams, posts, rafters, purlins, etc. up to 500 sq. cm. or 0.05 sq. m. in section.

iii Bed plate, wall plate, bearing of chajjas and the like up to 10 cm depth.

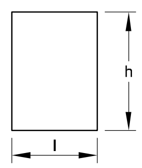
Bearings of floor and roof slabs are made in the following wall masonry.

For other openings deductions are made in the following manner:

Rectangular openings - Full deduction is made (Fig 1)

Deduct - l x h x thickness of wall

Fig 1



RECTANGULAR OPENINGS

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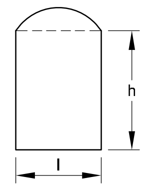
Doors and windows with small segmental arches (Fig 2)

Deduction is made for rectangular portion only up to the springing line. The segmental portion is considered as solid to allow for the extra expenses in constructing the arch, and the filling up with thin wall.

Deduction - l x h x thickness of wall.

Fig 2



DOORS AND WINDOWS

Segmental arch openings (Fig 3)

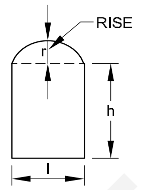
Deduction is made for the whole opening, the rectangular portion as well as the segmental portion.

$$\text{The area of segmental portion} = \frac{2}{3}lr + \frac{r^3}{2l}$$

But for deduction, the area of the sgemental portion is obtained approximately by taking 2/3 of span x rise, (2/3 x l x r) and the quantity for deduction is 2/3 x l x r x thickness of wall. ($r^3/2l$ being small is neglected for simplicity)

$$\text{The total deduction will be} = \left[(l+h)+\left(\frac{2}{3}\text{xlxr}\right)\right]\text{x} \left[\text{Thickness of wall}\right]$$

Fig 3



SEGMENTAL ARCH OPENINGS

Semi-circular arch openings (Fig 4)

The area of semi-circular portion = ½ πr^2

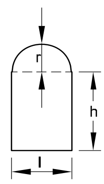
But for the deducation, the area of the semi-circular portion is obtained approximately by ¾ of span x rise, (¾ x l x r).

The total deduction will be = [9l x h) + (¾ x l x r)] x thickness of wall.

Elliptical arches may be considered as semi-circular arches and may be dealt in the same manner.

For large arches the actual area of opening should be calculated correctly by mensuration formulae, and deduction should be made for actual area.

Fig 4



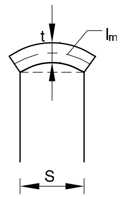
SEMI-CIRCULAR ARCH OPENINGS

6 **Arch masonry work:** Masonry work in arches is calculated in cu. m. separately by multiplying the mean length of the arch by the thickness of arch and by the breadth of the wall (Fig 5).

Quantity of arch masonry = l_m x t x thickness of wall.

Deduction = l_m x t x thinkness of wall.

Fig 5



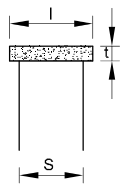
ARCH MASONRY WORK

7 **Lintels over openings:** Lintels are either of R.C.C. or of R.B. quantities are calculated in cu. m. Length of the lintel is equal to the clear span plus two bearings. If dimension of bearing is not given the bearing may be taken as same as the thickness of lintel with a minimum of 12 cm. Thus, the length of lintel, l = s +2t i.e. clear span plus two bearings (Fig 6).

Quantity of linter = l x t x thickness of wall

Deduction = l x t x thickness of wall

Fig 6



LINTELS OVER OPENINGS

8 **R.C.C. and R.B. work:** R.C.C. and R.B. work may be in roof or floor slab, in beams, lintels, column, foundations, etc. and the quantities are calculated in cu. m. Length, breadth and thickness are found correctly from the plan, elevation, and section or from other detailed drawings. Bearings are added with the clear span to get the dimensions. The quantities are calculated in cu. m. exclusive of steel reinforcement and its bending but inclusive of centering and shuttering and fixing and binding reinforcement inposition. The reinforcement including its bending is taken up separately under steel works in quintal. For this purpose 0.6% to 1% (usually 1%) of R.C.C. or R.B. work by volume may be taken for steel, if other details are not given. The volume of steel is not required to be deducted from the R.C.C. or R.B. work.

R.C.C. and R.B. works may also be estimated inclusive of steel and centering and shuttering for the complete works, if specified.

Centering and shuttering (from work) are usually included in the R.C.C. or R.B. work, but may also be taken separately in sq. m. of surface in contact with concrete.

In R.C.C. work plastering is not taken separately, but the exposed surface are finished with thin rich cement sand mortar plastering to give smooth and even surface, which usually is not taken into consideration.

9 Flooring and roofing

i **Ground floor** - the base lime concrete and floor finishing of C.C. or stone or marble or mosaic, etc. are usually taken as one job or one item (combined in one item), and the quantity is calculated in sq. m. multiplying the length by the breadth. The length and breadth are measured as inside dimensions from wall to wall of superstructure. Both the works of base concrete and floor finishing are paid under one item.

ii **1st floor, 2nd floor etc.:** Supproting structure is taken separately in cu. m. as R.C.c., R.B., ect. and the floor finishing is taken separately in sq. m. as 2.5 cm. or 4 cm. C.C. or marble or mosaic, etc, If a cushioning layer of lime concrete is given in between the slab and the floor, the cushioning concrete may be measured with the floor under one item or taken separately.

iii **Roof:** Supporting structure is taken separately in cum. and the lime concrete terracing is computed in sq.m. with thickness specified, under a separate item inculding surface rendering smooth. The compacted thickness of lime concrete terracing is 7.5 cm. to 12 cm. average, L.C. terracing may also be calculated in cu. m. with average thickness.

The bearing of roof or floor slab is given same as the thickness of slab, usually 10 cm. to 15 cm.

In case of tiled, galvanised iron sheet, or asbestos cement sheet roofing the roof coverings are taken out in sq. m. and measured that including overlaps with all fittings, and supporting trusses and members are taken under separate item.

Floor of door sills and sills of opening, should also be taken into account. In the case of ground floor, sills should be taken separtely, as there is no lime concrete in sills.

10 Plastering and pointing (Fig 7) : Plastering usually 12 mm thick is calculated in sq. m. For walls the measurements are taken for the whole face of the wall for both sides as solids, and deductions for openings are made in the following manner.

i No deduction is made for ends of beams, post, rafters, etc.

ii For small opening up to 0.5 sq.m. no deduction is made, and at the same time no additions are made for jambs, soffits and of sills of these openings.

iii For openings exceeding 0.5 sq.m. but not exceeding 3 sq. m. deduction is made for one face only, and the other face is allowed for jambs, soffits and sills which are not taken into account separately.

iv For openings above 3 sq. m. deduction is made for both faces of the opening, and the jambs, soffits and sills are taken into account and added.

As the outer jambs, etc. are much smaller than the inner ones, the deduction is usually made from the outer face.

For deduction of arch opening the same principle as for masonry work is followed. Plastering of ceiling usually of 12 mm. thick computed in sq. m. under a separate head as this work is done with richer mortar. For R.C.C. work usually no plastering is allowed but for fair finish a thin plaster of rich cement mortar may be allowed which should not be taken in the measurement separately. Thin rich cement mortar plastering in R.C.C. work may also be taken under a separate item, specially in the ceiling inside room.

Pointing: Pointing in walls is calculated in sq. m. for whole surface and deductions similar to plastering are made.

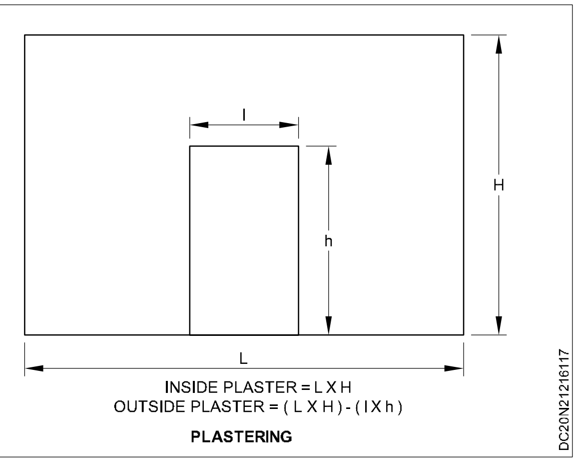
11 Cornice: Ornamental or large cornice is measured in running metre for the complete work which includes masonry, plastering, mouldings, etc. and paid for in r.m.

Similarly, string course, drip course, corbelling, coping, etc. are measured and paid for in running metre for the complete work.

12 Pillars: Pillars are taken separately in cu. m. for their net volume and quantities are calculated by correct geometrical measurements by simple mensuration method.

Quantity = Sec. area x ht.

Fig 7



$= \frac{\pi d^2}{4} \times ht. cu. m$ for round pillars, d is the dia.

$= a^2 \times$ ht. cu.m for square pillars, a is the side.

Hexagonal, octagonal, etc. pillars are dealt similarly.

Plastering in the pillars are calculated in sq. m. multiplying the circumference of perimeter by the height.

13 Doors and windows

i **Chowkhat or Frame:** Door and window frames or chowkhats are computed in cu. m. Length is obtained by adding the length of all the members of the chowkhat, top and two verticals if there is no sill member, and adding bottom also if there is sill, and this length is multiplied by the two dimensions of the cross-section of the member. If there is horn projection, these projections also should be added to the length. If there is no sill member, vertical members should be inserted into the floor by about 2.5 cm to 4 cm.

ii **Door or window leaves or shutters:** They are computed in sq. m. by multiplying the breadth by the height of the shutters, the rebates in the chowkhat should be taken into consideration in finding the breadth and height. A clearance of 6 mm may be allowed at the bottom of the door if there is no sill member. For estimating the clearance may not be taken into consideration, this may be neglected. But for measurement for payment the clearance should be taken into account. The rebates in the chowkhats may be taken as 12 mm to 20 mm. The central overlap is not taken into account.

The name of the timber used, the thickness of shutters, type of shutters and the nature of fittings (iron, brass, etc.) should be noted in the item. Shutters of different types as panelled, glazed; partly panelled and partly glazed, venetian, etc. should be computed separately as the rates differ.

Fittings are computed by number i.e. enumerated. Fittings may be included in the sq. m. rate of shutters. For estimate, the fittings may be taken under a separate item in sq. m. basis of shutters, or a lump sum provision may be made. Hold fasts are taken separately under a separate item by weight or by number.

It is better to purchase the fittings by the department to the choice and requirement, and to get them fitted by the contractors whose rate for shutters shall include the labour for fixing the fittings. In such case the rate of shutters, will exclude the cost of fittings but will include the cost of fixing them. In estimating the cost of fittings will be provided under a separate item fittings of doors and windows on area basis or on lump sum basis for the purchase of fittings.

14 Wood work: Wooden beams, Rafters, posts, wooden roof trusses, chowkhats, etc. come under this item, and the quantities are computed in cu. m. The dimensions of finished work shall be taken.

15 Iron work: This is computed in weight in kg or quintal and the quantities are calculated correctly by multiplying the weights per running metre by the length. The weight per r.m. can be obtained from the steel section book. For steel joint, the length is equal to the clear span plus two bearings, the bearing may be taken 3/4 thickness of wall or 20 cm to 30 cm.

Density of mild steel is equal to 7850 kn/cu. ,. Or 78.5 q/cu., Or 0.785 gram/cu. m.

Weight of iron hold fasts may be taken as 1 ½ kg. each. For doors 6 hold fasts (three on each side).

The weight of bolts and nuts and rivets with heads can be calculated by counting their numbers and sizes and consulting steel table. Sometimes certain percentage of the whole steel work is provided for rivets and bolts and nuts. For steel roof truss 5 percent of the steel work is usually provided for rivets and bolts and nuts.

16 White washing or colour washing or Distempering: The quantities are computed in sq. m. and are usually same as for plastering. The inside is usually white washed or distempered and this item will be same as for inside plaster. The outside is colour-washed and the quantities of colour-washing will be same as for outside plaster. These items need not be calculated separately, but simply written as same as for inside plaster or outside plaster. Numbers of coats of white-washing or colour-washing are taken as one job or work and the rates cover for the number of coats which should not be a multiplying factor. The number of coats should be mentioned in the item. Deductions are dealt in the same manner as for plastering. Other type of surface finishing may also be done and may be taken accordingly.

17 Painting: Painting or Varnishing of doors and windows are computed in sq. m. The dimensions should be taken for outer dimensions of the chowkhat i.e. outer dimensions of doors and windows. The area is measured flat (not girthed). No separate measurement is taken for the chowkhat, the area is same as the area of wall opening. For iron bars, grills, etc. the area of the clear opening inside the chowkhat is taken. For both faces of doors and windows, the simple area as measured above is multiplied by appropriate numbers as below.

i	Panelled, framed and braced ledged and battened or ledged battened and braced	___	2¼ times one surface area, for both sides.
ii	Fully glazed or gauged	___	1 time one surface area, for both sides.
iii	Partly panelled and partly glazed or gauged	___	2 times one surface area, for both sides.
iv	Flush door	___	2 times one surface area, for both sides.
v	Venetian	___	3 times one surface area, for both sides.
vi	Iron bars, grills in	___	1 time the are of

windows	clear opening in between chowkhat for over all.

This covers also for chowkhats on three faces. Painting is done in two or three coats. Usually over a coat of priming. The rate covers for the number of coats under one item. The number of coats should be mentioned in the description of item.

(The multiplying factors differ slightly from State to State. IS 1200 should be followed).

The concealed surface of the chowkhat which is in contact with the jamb of the wall is usually painted with two coats of coal tar or solignum, and this item is computed separately.

For beams, rafters, purlins, posts, etc., of timber or iron, the area of actual exposed surface is taken for painting.

Corrugated surface is taken as flat and a percentage increase is allowed.

Lump-sum-item – sometimes a lump-sum rate is provided for certain small items for which detailed quantities cannot be taken out easily or it takes sufficient time to find the details, as front architectural or decoration work of a building, fire-place, site cleaning and dressing etc.

Electrification and Sanitary and Water supply Works: For Sanitary and Water supply works 8% and for Electrification 8% of the estimated cost of the building works are usually provided in estimate.

Methods of building estimate

The dimensions, length, breadth and height or depth are to be taken out from the drawing – Plan, Elevation and Section. From the study of the drawings, the building is to be imagined and pictured in the mind and the dimensions are to be taken out correctly. There is no hard and fast rule for finding out dimensions from the drawing but the dimensions are to be taken out accurately. Junctions of wall at the corners and at the meeting points of the walls require special attention.

For symmetrical foundation which is the usual case, earth work in excavation in foundation, foundation concrete, brickwork in foundation and plinth, and brickwork in superstructure may be estimated by either of the following two methods.

Method I

Separate or individual wall method – In this method, measure of find out the external length of walls running in the longitudinal direction generally the long walls out-to-out, and the internal lengths of walls running in the transverse direction in-to-in i.e. of cross or short walls, in-to-in, and calculate quantities multiplying the length by the breadth and the height of wall. The same rule applies to the excavation in foundation, to concrete in foundation and to masonry. Care should be taken to not the difference in dimensions at different height due to offset, or footings.

It is convenient to imagine plans at different level of heights as foundation trench plan, foundation concrete plans of each footing, etc. and dealing each plan or part separately.

The simple method to take the long walls and short or cross walls separately and to find out the centre to centre lengths to long walls and short walls from the plan. For symmetrical footing on either sides, the centre line remains same for super structure and for foundation and plinth.

For long walls add to the centre length one breadth of wall, which gives the length of the wall out-to-out, multiply this length by the breadth and the height and get the quantities. Thus for finding the quantities of earthwork in excavation, for length of the trench out-to-out add to the centre length one breadth of foundation. Adopt the same process for foundation concrete, and for each footing. It should be noted that each footing is to be taken separately and the breadth of the particular footing is to be added to the centre length.

$$\begin{pmatrix}\text{Long wall length}\\ \text{out} - \text{to} - \text{out}\end{pmatrix} = (\text{Centre to centre length}) + (\text{half breadth on one side}) + (\text{half breadth on the other side})$$

$$= (\text{Centre to centre length}) + (\text{One breadth})$$

For short or cross walls subtract (instead of adding) from the centre length one breadth of walls, which gives the length in-to-in, and repeat the same process as for the long walls, subtracting one breadth instead of adding.

$$\begin{pmatrix}\text{Short wall length}\\ \text{in} - \text{to} - \text{in}\end{pmatrix} = (\text{Centre to centre length}) - (\text{one breadth})$$

That is, in case of long wall add one breadth and incase of short wall subtract one breadth from the centre length to get the corresponding lengths.

This method is simple and accurate and there is no chance of any mistake. This method may be named as LONG WALL and SHORT WALL method or general method.

Method II

Centre line method: In this method known as centre line method sum-total length of centre lines of walls, long and short, has to be found out. Find the total length of centre lines of walls, of same type, long and short having same type of foundations and footings and then find the quantities by multiplying the total centre length by the respective breadth and the height. In this method, the length will remain same for excavation in foundation, for concrete in foundation, for all footings and for superstructure (with slight difference when there are cross walls or number of junctions). This method is quick but requires special attention and consideration at the junctions, meeting points of partition or cross walls, etc.

Centre line length of each items = c/c length - no. of junctions x half width of each item.

This centre line long the multiplied by the width and height gives the quantity of each items.

For rectangular, circular polygonal (hexagonal, octagonal, etc.) buildings having no inter or cross walls, this method is quite simple. For buildings having cross or partition walls, for every junction or partition or cross walls with main wall, special consideration shall have to be made to find the correct quantity. For each junction half breadth of respective item or footing is to be deducted from the total centre length. Thus in the case of a building with one partition wall or cross wall having two junctions, for earthwork in foundation trench and foundation concrete deduct one breadth of trench or concrete from the total centre length (half breadth for one junction and one breadth (2 x ½ = one for two junctions). For footings, similarly deduct one breadth of footing for two junctions from the total centre length, and so on. If two walls come from opposite directions and meet a wall at the same point, then there will be two junctions.

For building having different types of walls, each set of walls shall have to be dealt separately. Find the total centre length of all walls of one type and proceed in the same manner as described above. Similarly find the total centre length of walls of second type and deal this separately, and so on.

Rate analysis - labour - materials - schedule of rates

Objectives: At the end of this lesson you shall be able to
- **enlist the purpose and necessity of rate analysis**
- **define rate analysis**
- **define task and task of different labours**
- **calculate the quantity of materials of different items of work**
- **prepare analysis of rate.**

Analysis of rates

The determination of rate per unit of a particular item of work, from the cost of quantities of materials, the cost of labourers and other miscellaneous petty expenses require for its completion is known as the analysis of rate. A reasonable profit, usually 10% for the contractor is also included in the analysis of rate. Rates of materials are usually taken as the rates delivered at the site of work and include the first cost (cost at origin), cost of transport, railway freight if any, taxes, etc. If the materials are to be carried from a distant place, more than 8 kms. then cost of transport is also added. The rates of materials and labour vary from place to place and therefore, the rates of different items of work also vary from place to place.

For the purpose of analysis, the details about all the operations involved in carrying out the work should be available, the quantities of materials required and their costs should be known and the number of different categories of labourers required and the capacity of doing work per labourer and their wages per day should be known. These can be known only from experience of practical works.

The rates of a particular item of work depends on the following:

i Specifications of works and materials, quality of materials, proportion of mortar, method of constructional operation, etc.

ii Quantities of materials and their rates, number of different types of labourer and their rates.

iii Location of the site of work and its distances from the sources of materials and the rate of transport, availability of water.

iv Profits and miscellaneous and overhead expenses of contractor.

Overhead costs: Overhead costs include general office expenses, rents, taxes, supervision and other costs which are indirect expenses and non productive expenses on the job.

The miscellaneous expenses on overheads may be under the following heads:

A General overheads

i Establishment (Office, Staff)

ii Stationary, Printing,Postages, etc.

iii Travelling expenses.

iv Telephone

v Rent and taxes.

B Job overheads

i Supervision (Salary of Engineers, Oversers, Supervision, etc.)

ii Handling of materials.

iii Repairs, carriage and depreciation of T and P.

iv Amenities of labour.

v Workmen's compensation, insurance, etc.

vi Interest on investment

vii Losses on advances.

The contractor may be allowed a net profit of 6 to 8 percent, and the miscellaneous overhead expenses may come to about 5 to 10 percent. For overhead expenses and contractors profit 15 percent of the actual cost may be reasonable amount but it is usual practice to add 10 percent for all these under the head profit. For small works overhead cost may be very little.

The analysis of rate is usually worked out for the unit of payment of the particular item of work under two heads.

i Materials and

ii Labour

and their costs added together give the cost of the items of work. The costs of the materials as delivered at site inclusive of the transport, local taxes and other charges. For tools and plants (T. and P.) and miscellaneous petty items (sundries) which cannot be accounted in details lump-sum provision is made. A provision for water charges @ 1½ of the total cost is made in the rate. Adding 10% to this cost as contractor's profit, the rate per unit of the item of work is obtained. If transport of matrials is to be done from a distant place more than 8 km analysis of transport work may be done separately. If cement and steel are supplied by the department and the contractor is not to invest any money on these, 10% profit it is not allowed on cement and steel. The cost of carriage of cement and steel from the godown to the site of work should be allowed to the contractor. But if cement and steel are to be arranged by the contractor for 10% should be added as profit on these materials also. 10% profit may be added over the whole cost of labour and materials including cement and steel, if it is not specified that these will be supplied departmentally.

Rate: Rates of different items in the estimate are the current rates for the completion of the items of work which include supply of materials, transport, labour scaffolding, overheads, contractor's profit, taxes, etc. The rates are usually taken from the P.W.D. "Schedule of Rates.:

Task or Out-turn work

Task: The capacity of doing work by an artisan or skilled labour in the form of quantity of work per day is known as the task-work or out-turn of the labour.

The out-turn of work per artisan varies to some extent according to the nature, size, height, situation, location, etc. In bigger cities where specialised and experienced labour is available the out-turn is greater that small towns and country sides. In well-organized work less labour is required.

The following may be taken as the approximate quantity of work or out-turn or task for an average artisan per day.

S. No.	Particulars of items	Quantity	Per day
1	Brickwork in lime or cement mortar in foundation and plinth	1.25 cu. m.	(45 cu. ft.) per mason
2	-Do- in superstructure	1.00 cu. m.	(35 cu. ft.) per mason
3	Brickwork in mud mortar in foundation and plinth	1.50 cu. m.	(55 cu. ft.) per mason
4	-Do- in superstructure	1.25 cu. m.	(45 cu. ft.) per mason
5	Brick in cement or lime mortar in arches	0.55 cu. m.	(20 cu. ft.) per mason
6	-Do- in jack arches	0.55 cu. m.	(20 cu. ft.) per mason
7	Half brick wall in partition	5.00 sq. m.	(50 sq. ft.) per mason
8	Coursed rubble stone masonry in lime or cement mortar Including dressing	0.80 cu. m.	(30 cu. ft.) per mason
9	Random rubble stone masonry in lime or cement mortar	1.00 cu. m.	(35 cu. ft.) per mason
10	Ashlar masonry in lime or cement mortar	0.40 cu. m.	(15 cu. ft.) per mason
11	Stone arch work	0.40 cu. m.	(15 cu. ft.) per mason
12	Lime concrete in foundation or floor	8.50 cu. m.	(300 cu. ft.) per mason
13	Lime concrete in roof terracing	6.00 cu. m.	(200 cu. ft.) per mason
14	Cement concrete 1 : 2 : 4	5.00 cu. m.	(175 cu. ft.) per mason
15	R.B. work	1.00 cu. m.	(32 cu. ft.) per mason
16	R.C.C. work	3.00 cu. m.	(125 cu. ft.) per mason
17	12 mm (½") plastering with cement or lime mortar	8.00 sq. m.	(80 sq. ft.) per mason
18	Pointing with cement or lime mortar	10.00 sq. m.	(100 sq. ft.) per mason
19	White washing or colour washing three coats	70.00 sq. m.	(700 sq. ft.) per washer
20	White washing or colour washing one coat	200.00 sq. m.	(2000 sq. ft.) per washer
21	Painting or varnishing doors or windows one coat	25.00 sq. m.	(250 sq. ft.) per painter
22	Coal tarring or solignum painting one coat	35.00 sq. m.	(350 sq. ft.) per painter
23	Painting large surface one coat	35.00 sq. m.	(350 sq. ft.) per painter
24	Distempering one coat	35.00 sq. m.	(350 sq. ft.) per painter
25	2.5 cm (1J C.C. floor	7.50 sq. m.	(75 sq. ft.) per painter
26	Flag stone floor laying with lime or cement mortar Excluding L.C.	10.00 sq. m.	(100 sq. ft.) per mason
27	Terrazo floor 6 mm thick mosaic work over 2 cm thick Cement concrete (1 : 2 : 4)	5.00 sq. m.	(50 sq. ft.) per mason

S.No.	Particulars of items	Quantity	Per day
28	Brick-on-edge in floor lime or cement mortar excluding L.C.	7.00 sq. m.	(70 sq. ft.) per mason
29	Brick flat floor as in above	8.00 sq. m.	(80 sq. ft.) per mason
30	Timber framing sal or teak wood	0.07 cu. m.	(2.5 cu. ft.) per carpenter
31	-Do- in country wood	0.15 cu. m.	(5 cu. ft.) per carpenter
32	Door and window shutters panelled or glazed	0.15 sq. m.	(1.5 sq. ft.) per carpenter
33	-Do- battened	0.80 sq. m.	(8 sq. ft.) per carpenter
34	Sawing of hard wood	4.00 sq. m.	(40 sq. ft.) per pair of sawers
35	Sawing of soft wood	6.00 sq. m.	(60 sq. ft.) per pair of sawers
36	Single Allahabad tiling or Mangalore tiling	6.00 sq. m.	(60 sq. ft.) per tile layer
37	Double Allahabad tiling	4.00 sq. m.	(40 sq. ft.) per tile layer
38	Breaking of brick ballast 40 mm (1½") gauge	0.75 cu. m.	(30 cu. ft.) per labourer or breaker
39	Breaking of stone ballast 25 mm (1") gauge	0.55 cu. m.	(20 cu. ft.) per labourer or breaker
40	Breaking of stone ballast 40 mm (1½") gauge	0.40 cu. m.	(10 cu. ft.) per labourer or breaker
41	Breaking of stone ballast 25 mm (1") gauge	0.25 cu. m.	(10 cu. ft.) per labourer or breaker
42	Ashlar stone dressing	0.70 cu. m.	(25 cu. ft.) per stone Cutter
43	Flag stone dressing	1.50 sq. m.	(15 sq. ft.) per stone Cutter
44	Earth work in excavation in ordinary soil	3.00 cu. m.	(100 cu. ft.) per beldar Mazdoor
45	Earth work in excavation in hard soil	2.00 cu. m.	(75 cu. ft.) per beldar Mazdoor
46	Excavation in rock	1.00 cu. m.	(35 cu. ft.) per beldar Mazdoor
47	Sand filling in plinth	4.00 cu. m.	(140 cu. ft.) per beldar Mazdoor
48	Number of bricks laid by a mason in brick work upto a Height of 3 m (10')	600bricks per mason	
49	Amount of work done by a mazdoor (helper) per day		
	i Mix	3 cu. m.	(100 cu. ft.) mortar per mazdoor
	ii Deliver brick	4000 nos. to a distance of 15 m (50')per mazdoor	
	Iii Deliver mortar	5.5 cu.m.	per mazdoor
50	Scaffolding cost for single storey building	Re.0.50	(Rs.1.5% cu. ft. of Per cu. m.brickwork)

Calculation of materials

Concrete

Calculation of materials for various items of works is done for the analysis of rates for the required item. Various mixes of cement concrete are used for different items of concrete such as 1:10:20, 1:8:16, 1:6:12, 1:4:8, 1:3:6, 1:2:4, 1:1½:3 etc. It is observed by the experiments and experience that the volume of dry materials required for one cu. m. of wet concrete are 1.52 cu. m. to 1.54 cu. m. because when water is added to dry mix, the cement goes into the voids of sand and both together go into the voids of aggregates to become a solid compact mass of concrete. So the quantities of various materials in a given concrete mix are calculated as under:

Let, C = Quantity of cement in cu. m.

S = Quantity of sand in cu. m.

A = Quantity of aggregate in cu. m.

The quantities of dry materials required for one cu. m. of consolidated for finished concrete are:

$$\text{Cement}(C) = \frac{1.54xC}{(C+S+A)}\,\text{cu.m.}$$

$$\text{Sand}(S) = \frac{1.54 \times S}{(C+S+A)}\,\text{cu.m.}$$

$$\text{Aggregates}(A) = \frac{1.54 \times A}{(C+S+A)}\,\text{cu.m}$$

Where (C + S + A) is the sum of the ratios in a mix of concrete i.e. in a concrete of mix 1:6:12, cement is taken 1, sand as 6 and aggregates 12 and sum of these ratios is, C + S + A = 1 + 6 + 12 = 19.

1 cu. m. of Portland cement = 30 bags (for practical purposes)

Quantity	**Per day**
4.00 cu.m.	per beldar (140 cu.ft) mazdoor
600 bricks per mason	
3 cu.m	(100 cu.ft) mortar per mazdoor
4000 nos to a distance of 15m (50') per mazdoor 5.5 cu.m (200 cu. ft) per mazdoor	
Re.0.50 per cu.m.	(Rs. 1.5% cu.ft. of brickwork)

1 bag of cement of 50kg- $\frac{1}{30}$ cu.m=0.034 cu.m

Example 1: find out the quantity of dry materials in a concrete mix 1 : 2 : 4

Quantity of dry materials required for one cu. m. of finished concrete = 1.54 cu. m.

Sum of ratio of ingredients in mix of 1:2:4

(C + S + A) = 1 + 2 + 4 = 7

$$\text{Quantity of Cement} = \frac{1.54 \times C}{(C+S+A)}$$

$$= \frac{1.54 \times 1}{7} = 0.22\,\text{cu.m. or } 6.4\,\text{bags}$$

$$\text{Quantity of Sand} = \frac{1.54 \times S}{C+S+A)}$$

$$= \frac{1.54 \times 2}{7} = 0.44\,\text{cu.m.}$$

$$\text{Quantity of Aggregate} = \frac{1.54 \times A}{(C+S+A)}$$

$$= \frac{1.54 \times 4}{7} = 0.88\,\text{cu.m.}$$

Quantity of materials for brick work

Brick work masonry is constructed either in mud, or lime surkhi or cement sand mortar. Various mixes of mortars are used in construction of brick masonry such as cement sand mixes of 1:2, 1:3, 1:4, 1:5, 1:6 and 1:7 etc. in which first figure denotes the cement and the second as sand. In case of lime mortar, the binding material is lime and surkhi is added in it in certain ratio to prepare lime surkhi mortar. Ratio of such mix may be 1:2, 1:3 etc. Sometimes lime sand surkhi mortar in the ration of 1:1:2 is prepared.

Dry materials required for cement sand mortar for 1 cu. m. of brick masonry = 0.30 cu. m.

[Volume of brick masonry – total volume of bricks = 1m^3 – 500 x (0.19 x 0.09 x 0.09) = 0.25 m^3

To get dry volume, increase the wet volume by 20%]

Wet materials required for 1 cu. m. of brick work – 0.25 cu. m.

$$\text{Factor to convert wet mortar into dry mortar} = \frac{0.30}{0.25} = 1.2$$

No. of metric bricks with size 20 cm x 10 cm x 10 cm required for one cu. m. = 500 Nos

Dry mortar required = 0.30 cu. m.

Example 2; Find out the quantity of cement, sand and bricks required for a brick masonry of 1 cu. m. in cement sand mortar of 1:5.

As given above, the No. of bricks for 1 cu. m. brick work = 500.

Quantity of dry mortar required = 0.30 cu. m.

Ratio of ingredients i.e. Cement : Sand = 1:5

Sum of ingredients = 1+5=6

$$\therefore \text{Cement required} = \frac{0.30x1}{(1+5)}$$

$$= 0.05\text{cu.m or } 1.5 \text{ bags}$$

$$\text{Sand required} = \frac{0.30x1}{(1+5)} = 0.25 \text{ cu.m}$$

Random rubble masonry and coursed rubble masonry

1 Material required for 1 cu. m. is:

i Stone including waste – 1.25 cu. m.

ii Mortar (Dry) – 0.4 cu. m.

Ashlas masonry

2 Material required for 1 cu. m. is:

i Stone including wastage – 1.25 cu. m.

ii Mortar (Dry) – 0.25 cu. m.

Plastering

Calculation of quantity of mortar and materials

Area x thickness gives the quantity of mortar for uniform thickness, for filling up the joints and to make up ununiform surface of wall, this may be increased by 30% which will get wet mixed mortar. To get the total dry volume of ingredient materials or mortar the wet volume may be further increased by 25%. The quantities of each material of the mortar may be found by usual methods, dividing the dry volume of mortar by the sum of the numerals of the proportions and multiplying by the individual numerals.

Materials for 12 mm thick plastering in wall for 100 sq. m.

Wets mixed mortar for uniform layer = 1.2 cu.m. Adding 30% to fill up joints, uneven surfaces, etc. the quantity of mortar comes to 1.2+0.36=1.56 CU. M. Increasing by 25% the total dry volume=1.95 cu.m. 2.00 cu.m. (say).

For 1:6 cement sand mortar, Cement=2/1+6=0.30 cu. m., sand=0.30 x 6=1.80 cu.m. Similarly, the quantities of materials for other proportions may be calculated. The quantities of materials for different proportions are given in the following pages.

Materials for 20 mm thick plastering in wall for 100 sq. m.

As the thickness of plaster is more, 20% of mortar may be taken to fill up the joints, unevenness etc. The quality of wet mortar is equal to 200 x 0.02 + 20% =2.00+0.40 = 2.40 cu. m. Increasing by 25% the dry volume=2.40+ 0.60=3.00 cu. m. the quantities of each material of mortar may be found by usual method.

Rich mortar

For rich mortar plastering, the quantities of materials will be less as the cement will be in excess than the voids in sand and the reduction in volume of dry mortar will be less.

Ceiling plastering 12mm thick for 100sq. m.

For plastering in R.C.C. ceiling the unevenness of surfaces will be less and 20% extra mortar may be taken to get even surface. The quantity of wet mortar is equal to 100x0.012+20%=1.2+0.24=1.44 cu.m. Increasing by 25% the dry volume=1.44+0.36=1.80 cu. m.

For 6mm thick plastering R.C.C. ceiling the quantity of dry mortar may be taken as 1.00 cu. m.

For plastering in floor over lime concrete the same quantity of mortar as for wall may be taken as there will be sufficient unevenness in the surface of lime concrete.

Neat cement flooring

For neat cement finishing in floor or dado or skirting, the thickness of neat cement layer may be taken as 1.5mm thick, therefore, the cement paste requirement for 100 sq. m.=100 x 0.0015 = 0.15 cu. m. Dry volume of cement increased by 25%=0.15+0.15x ¼ =0.19cu.m.2 cu. m. (say) 6 bags per 100 sq. m.

Pointing

For pointing in brickwork, the total volume of materials (dry mortar) is taken as 0.60 cu.m. for 100 sq. m. for raised pointing quality may be increased by 10%.

Materials for different items of works

The requirement of materials for different items of works is as given below:

In practice for analysis of rates the reduction in volume of finished concrete over the sum total volume of ingredient materials is taken as 50% to 55%. For 100 cu. m. of finished concrete the sum total volume of dry ingredient materials may be taken as 152 cu.m. to 154 cu.m.

S. No.	Particulars of items	Quantity
1	Bricks (9" x 4½" x 3"or 20 cm x 10 cm x 10 cm nominal size) For brick work	50000 Nos per % cu. m. (500 nos per cu. m.)
2	Dry mortar for brickwork 30%	30 cu. m. for 100 cu. m.
3	Stone for rubble stone masonry 125 %	125 cu. m. for 100 cu. m.
4	Dry mortar for rubble stone masonry 42%	42 cu. m. for 100 cu. m.
5	Bricks or brick-ballast for lime concrete	37000 Nos for 100 cu. m.
6	Brick-bats or brick-ballast for lime concrete	105 cu. m. for 100 cu. m.
7	Brick ballast for lime concrete	100 cu. m. for 100 cu. m.
8	Dry mortar for lime concrete in foundation and floor 35%	35 cu. m. for 100 cu. m.
9	Dry mortar for lime concrete in roof terracing 45%	45 cu. m. for 100 cu. m.
10	Materials for cement concrete 1:2:4	
	Ballast or grit 88%	88 cu. m. for 100 cu. m.
	Sand 44%	44 cu. m. for 100 cu. m.
	Cement 22%	22 cu. m. (60 bags) for 100 cu. m.
11	Materials for 2.5 cm (1") c.c. 1:2:4 floor	
	Stone grit	2.40 cu. m. for 100 cu. m.
	Sand	1.20 cu. m. for 100 cu. m.
	Cement	0.80 cu. m. (24 Bags) for 100 cu. m.
12	Bricks for R.B. work	(420 Nos for cu. m.) 42000 Nos Per cu. m.
13	Dry mortar for R.B. work 45%	45 cu. m. for 100 cu. m.
14	Dry mortar for 12 mm (½") plastering	2.00 cu. m. for 100 sq. m.
15	Dry mortar for pointing in brickwork	0.60 cu. m. for 100 sq. m.
16	Lime for white washing one coat	10 kg for 100 sq. m.
17	Dry distemper for 1st coat	6 ½ kg for 100 sq. m.
18	Dry distemper for 2nd coat	5 kg for 100 sq. m.
19	Snow-cem for 1st coat	30 kg for 100 sq. m.
20	Snow-cem for 2nd coat	20 kg for 100 sq. m.
21	Paint ready mixed for painting one coat	10 litre for 100 sq. m.
22	Paint (stiff) for painting one coat	10 kg for 100 sq. m.
23	Bricks (20 x 10 x 10 cm for brick floor or half brick wall)	5000 Nos. for 100 sq. m.
24	Dry mortar for brick floor or half brick wall	3.20 cu. m. for 100 sq. m.
25	Brick (9"x4½"x3") for brick flat floor	3500 Nos for 100 sq. m.
26	Dry mortar for brick flat floor	2.25 cu. m. for 100 sq. m.
27	Bricks (9"x 4½"x3") required for Honey comb wall	3250 Nos for 100 sq. m.
28	Dry mortar for Honey comb wall	2.25 cu. m. for 100 sq. m.

S. No.	Particulars of items	Quantity
29	Materials for 2 cm (¾”) thick damp proof course of 1:2 cement mortar –	
	Cement	0.90 cu. m. (27 bags) for 100 sq. m.
	Sand	1.80 cu. m. for 100 sq. m.
	Composeal or Impermo @ 1 kg per bag of cement	25 kg for 100 sq. m.
30	Materials for 2.5 cm (1") thick c.c. 1:1½:3 Damp proof course	
	Stone grit	2.25 cu. m. for 100 sq. m.
	Sand coarse	1.13 cu. m. for 100 sq. m.
	Cement	0.75 cu. m. (22½ bags) for 100 sq. m.
	Composeal or Impermo @ 1 kg per bag of cement	22½ kg for 100 sq. m.
31	Bitumen or Asphalt for painting on D.P.C. or on roof	
	1st Coat	150 kg for 100 sq. m.
	2nd Coat	100 kg for 100 sq. m.
32	G.C.I. sheet for roof	128 sq. m. for 100 sq. m.
33	A.C. corrugated sheet for roof	115 sq. m. for 100 sq. m.
34	Timber for panelled door shutter 4 cm (1½”) thick	4.5 cu. m. for 100 cu. m.
35	Timber for battened door shutter 4 cm (1½”) thick	4.0 cu. m. for 100 sq. m.
36	Timber for partly panelled and glazed shutter (1½”) thick	2.0 cu. m. for 100 sq. m.

Materials required for cement concrete of different proportions for 100 cu. m.

Proportion by volume	Cement (cu.m.)	Sand (coarse) (cu.m.)	Coarse aggregate (Stone) (cu.m.)	Quantity of concrete mixed with water (cu.m.)
1 : 2 : 4	21	42	84	100
1 : 3 : 6	14.00	44.00	88	100
1 : 4 : 8	11.25	45.00	90	100
1 : 5 : 10	9.20	46.00	92	100

Schedule of rates

It is a printed list of rates of various items of work for preparing detailed estimates and is maintained by the engineering department. It is in a book form and is called as “schedule of rates book”. These rates are prepared on the basis of analysis of rates. As these rates vary year after year, therefore, a premium of fixed percentage is allowed on the schedule of rates. If the variation in the workable rates and schedule of rates is much more the revision of rates is done and a new revised schedule of rates is prepared.

Preparing of analysis of rates

From the information regarding out-turn, materials requirements, rates, etc. the analysis of rates of different items of works may be worked out. The number of mazdoors, coolies, bhishties, etc. may be adopted from the general ideas and different operations of construction of the particular item of work. As for example, for brickwork 1½ to 2 mazdoors or helper may be taken per mason; for lime concrete in foundation mason’s work is very little, but requirement of mazdoor is greater for mixing, carrying, laying, ramming, etc., for lime concrete in roof terracing requirement of mazdoor is still greater for beating a number of days.

For mortar and concrete, the ingredient materials such as lime, cement, sand, surkhi, stone and brick aggregates, etc., have voids varying from 40% to 50% and the finer ingredient to fill up the voids in the coarse ones. For rich mortar or rich concrete the finer ingredients are in excess of the volume of voids in the coarser ones, hence the volume of the finished mortar or concrete will increase.

Dry volume of materials of mortar concrete, as taken in the calculation of analysis of rates, means sum total volume of each ingredient added together. In working out analysis of rates labour has been taken on daily wages basis for 8 hours working a day. When full day for a particular labourer is not required one labourer has to work part of a day, in such cases part labour of labourer has been taken into account. For example, one labourer for half day is equivalent to half labourer per day.

Rates worked out are for one storey building (Ground floor). Beyond one storey the rates may be increased by 1% for every subsequent storey. Height of one storey may be taken as 3.5 m to 4 m.

Analysis of rates

1 Lime concrete in foundation with 40 mm gauge brick ballast unit 1 cu. m. Take – 10 cu. m.

With white lime and surkhi 1:2 (Proportion – 16:32:100, i.e., 1:2:6 approx.)

Particulars	Qty. or Nos	Rate*	Cost
Materials			
Brick ballast 1st class 40 mm gauge	10 cu. m.	650.00 cu. m.	6500.00
White lime slaked	1.6 cu. m.	800.00 cu. m.	1280.00
Surkhi	3.2 cu. m.	500.00 cu. m.	1600.00
		Total	9380.00
Labour			
Matrial (Head Mason)	½ No.	350.00 per day	0175.00
Mason	1 No.	300.00 per day	0300.00
Mazdoor (Beldar)	12 Nos	220.00 per day	2640.00
Boy or woman coolie	12 Nos	200.00 per day	2400.00
Bhishti (Water-Man)	2 Nos	200.00 per day	0400.00
Sundries T. and P. etc. (Misc., Petty things)	Lump Sum	100.00 L.S.	0100.00
		Total	6012.00
	Total of materials and labour		15395.00
	Add 1½ % Water Charges		231.00
	Add 10% Contractor's Profit		1539.50
	Grand Total for 10 cu. m.		17165.50

Rate per cu. m. = 17165.50/10 = Rs.1716.50

***Rates may vary accordingly to the schedule of rates of different states**

Approximate calculation of materials for 100 cu. m. L.C. 1:2:6, Lime = 150/(1+2+6) 16.6 cu. m.

Valuation - Terms - Evaluation

Objectives: At the end of this lesson you shall be able to
- **define valuation**
- **define different terms incorporate with valuation**
- **evaluate a building in different methods.**

Definition: Valuation is the technique of estimating or determining the fair price or value of a property such as a building, other engineering structures of various types, land etc. By valuation the present value of a property is determined.

The value of property depends of its structure, life, maintenance, location, bank interest, legal control, demand, purpose for which valuation is required etc.

Purpose of valuation

1 **Buying or selling property:** When it is required to buy or to sell a property, it valuation is required.

2 **Taxation:** To assess the tax of a property, its valuation is required. Taxes may be municipal tax, wealth tax, property tax, etc.

3 **Rent fixation:** In order to determine the rent of a property, valuation is required. Rent is usually fixed in certain percentage of the amount of valuation (6% to 10%).

4 **Security of loans or mortgage:** When loans are taken against the security of the property, its valuation is required.

5 **Compulsory acquisition:** Whenever a property is acquired by law, compensation is paid to the owner. To determine the amount of compensation, valuation of the property is required.

6 **Insurance:** Valuation of a property is also required for insurance, betterment charges, etc.

Technical terms

Gross income: Gross income is the total income and includes all receipts from various sources. The out goings and the operational and collections charges are not deducted.

Net income or net return: This is the amount left after deducting all out goings, operational and collection expenses from the gross income or total receipt.

Net Income = Gross income - Out goings

Out goings: Out goings or the expenses are required to be incurred to maintain the revenue of the building. the various types of out goings are as follows:

a **Taxes:** These include municipal tax, property tax, wealth tax, etc., which are to be paid by owner of the property annually.

b **Repairs:** The repairs are required to be carried out every year to maintain a property in fit condition usually 10 to 15 percent of the gross income or 1% to 1.5% monthly rent or 1% to 1.5% of the total cost of construction may be taken.

c **Management and collection charges:** These include the expenses on rent collection, watchman, pump attendant, sweeper etc. (about 5% to 10%) of the gross rent. For small building none of these may be taken into account.

d **Sinking fund:** A certain amount of the gross rent is set aside annually as sinking fund to accumulate the total cost of construction when the life of the building is over.

e **Loss of rent:** The property may not be kept fully occupied in such a case, a suitable amount should be deducted from the gross rent under out goings.

f **Miscellaneous:** These include electric charges for running lift, pump, for lighting common place which are to be borne by the owner.

Scrap value: Scrap value is the value of dismantled materials. For a building when the life is over at the end of its utility period, the dismantled materials such as steel, bricks, timber, etc. will fetch a certain amount which is the scrap value of the building. The scrap value of a building may be about 10% of its total cost of construction.

Salvage value: It is the value at the end of utility period without being dismantled.

Market value: The market value of a property is the amount which can be offered from the open market. The market value will differ from time to time according to demand and supply.

Book value: Book value is the amount shown in the account book after allowing necessary depreciation. The book value of a property at a particular year is the original cost minus the amount of depreciation up to the previous year. It will be gradually reduced year after year and at the end of the utility period of the property the book value will be only scrap value.

Rateable value: Rateable value is the net annual letting value of a property which is obtained after deducting the amount of yearly from the gross income.

Capital cost: Capital cost is the total cost of construction including land or the original total amount required to possess a property. It is the original cost and does not change.

Capitalized value: It is the amount of money whose annual interest at the highest prevailing rate of interest will be equal to the net income from the property.

Annuity: It is the annual periodic payment for repayment of the capital amount invested by a party. (Annuity means annual payment)

Years purchase: Years purchase is defined as the capital sum required to be invested in order to receive an annuity of Rs.1.00 at certain rate of interest.

$$\text{Year purchase} = \frac{1}{i}$$

where i=rate of interest in decimal.

Valuation of building: The valuation of building is determined by working out its cost of construction at present day rate and allowing a susitable DEPRECIATION.

Before valuation, the age of the building should be obtained from record or by enquiries or from visual inspection. Present day cost may be determined by the following method.

1 **Cost from record:** The cost of construction may be determined from the estimate from the bill quantities from record at present day rate.

2 **Cost by detailed measurement:** If record is not available; the cost of construction may be calculated by preparing the bill of quantities of various items or works by detailed measurement at site and taking the rate.

3 **Cost by plinth area basis:** It is a simple method to calculate the cost on plinth area basis. The plinth area of the building is measured and the present day plinth area rate of similar building in the locality is obtained by enquires. Then cost is calculated (the cost may be calculated by cubical content method).

4 **Depreciation:** Depreciation is the decrease or loss in the value of a property due to structural deterioration, use, life, wear and tear, decay and obsolescence.

5 **Determination of depreciation:** After deciding the cost of the building by any one of the above methods it is necessary to allow a suitable depreciation on the cost.

Generally, for 5 - 10 year, there is little depreciation of the building, the depreciation increases with life.

Age of building	Depreciation per year	Total depreciation
0 - 5 years	Nil	Nil
5 - 10 years	0.5%	2.5%
10 - 20 years	0.75%	7.5%
20 - 40 years	1.0%	60%
40 - 80 years	1.5%	60%
	Total	**90%**

The balance 10% represents the net scrap value at the end of utility period.

S.No.	Details of items and works	Life of the works
	Masonry	
1	Brickwork in lime or cement, boulder masonry in lime or cement, cut stone work in lime or cement	100 years and above
2	Brick work in clay, coursed rubble in mud	100 years
3	Brick arches in lime or cement mortar, rubble stone arches in lime or cement mortar	100 years
4	Sundries brickwork in clay	75 years
	Flooring	
5	Brick-on-edge or flat flooring over 7.5 cm L.C.	40 years
6	Cement concrete floor, granolithic floor, stone flooring	50 years
7	Terraced floor or lime concrete	20 years
	Roofing	
8	R.C.C., R.B., terraced roofing over stone flags, jack arck roofing with L.C. terracing	75 years
9	Iron work in roofing	80 years
10	Sal wood work in roof	60 years
11	Country wood in work	15 years
12	Allahabad lock tiling	25 years
13	G. I. sheet roofing of 22 B.W.G. sheet	50 years

14	Sal ballies in roof	20 years
15	Pine wood ceiling	30 years
	Doors and windows	
16	Teak wood doors and windows, Sal wood doors and windows	40 years
17	Country wood doors and wondows	30 years
	Iron work	
18	Rolled steel joist	75 years
19	Wrought iron work	80 years

Method of valuation

1 **Rental method of valuation:** In this methods, the net income by way of rent is found out by deducting all out goings from the gross rent. A suitable rate of interest as prevailing in the market is assumed and years purchase is calculated. The net income multiplied by Y.P. gives the valuation of the property.

Net income = gross income - out goings

$$\text{Year purchase} = \frac{1}{i}$$

where i=rate of interest in decimal.

Capitalized value of the property = net income x Y.P.

2 **Direct comparison with the capital value:** This method may be adoped when the rental value is not available from the property concerned, but there are evidences of sale prices of properties as a whole. In such cases the capitalized value of the property value is fixed by direct comparison with capitalized value of similar property in the locality.

3 **Valuation based on profit:** This method of valuation is suitable for buildings like hotels, cinema theatres etc. for which the capitalized value depends on the profit.

In such cases, the net annual income is worked out after deducting from the gross income all possible expenses, out goings, interest on the capital invested etc. The net profit is multiplied by Y.P. to get the capitalized value.

Net annual income (Net profit) = Gross income - (expenses, out goings, inerest of capital invested, etc.)

Capitalized value = Net Profit x Y.P.

4 **Valuation based on cost:** In this method the actual cost incurred in constructing the building is taken as basis to determine the value of property. In such cases necessary depreciation should be allowed.

Capitalized value = Actual cost of construction - Depreciation.

5 **Development method of valuation:** This method of valuation is used for the properties which are in the undeveloped stages, or partly developed and partly undeveloped stage.

If a building is required to be renovated by making additions or improvements, this method of valuation may be used. The valuation of the property may be worked out from the anticipated future net income which it may fetch after renovation. The net income multiplied by the Y.P. will give the anticipated capitalized value.

6 **Depreciation method of valuation:** According to this method of valuation, cost of building is worked out on the present day rates. The life and rate of depreciation should be ascertained with help of table.

The valuation of property is determined by the formula

Where d = Depreciated value

P = Cost at present market rate

rd = Fixed percentage of depreciation

n = Age of the building

The values arrived at, will be exclusive of cost of land, water supply, electric and sanitary fitting etc. and will apply to those building only which have been properly maintained.

Depreciation table

Sl.No	Life of structure	Fixed percentage of depreciation (rd)
1	100 years	rd = 1.0
2	75 years	rd = 1.3
3	50 years	rd = 2.0
4	25 years	rd = 4.0

Specification

Objectives: At the end of this lesson you shall be able to
- **define and describe the importance of specifications**
- **classify the specification**
- **describe the general specification**
- **explain the detailed specification**
- **calculate the area and volume at irregular boundary.**

Specification: Specification specifies or describes the nature and the class of the work, materials to be used in the work, workmanship, etc. and is very important for the execution of the work. The cost of a work depends much on the specifications. Specifications should be clear, and there should not be any ambiguity anywhere. From the study of the specifications, one can be easily understand the nature of the work and what the work shall be. The drawings of the building or structure show that arrangement of the rooms and various parts and the dimensions - length, breadth and height with brief descriptions of different parts. Drawings do not furnish the details of different items of work, the quantity of materials, proportion of mortar and workmanship which are described in specifications. Thus the combinations of drawings and specifications define completely the structure. Drawings and specifications form important parts of contract document.

During writing specification attempts should be made to express all the requirement of the work clearly and in a concise form avoiding repetition. As far as possible, the clauses of the specification whould be arranged in the same order in which the work will be carried out. The specifications are wirtten in a language so that they indicate what the work should be, and words “shall be” or “should be” are used.

Specifications depend on the nature of the work, the purpose for whch the work is required, strength of the materials, availability of materials, quantity of materials etc.

Specifications are of two types

1 General specification or brief specification and

2 Detailed specification

General or brief specification: General specification gives the nature and class of the work and materials in general terms, to be used in the various parts of the work, from the foundation to the supersturcture. It is a short description of different parts of the work specifying materials, proportions, qualities, etc. General specifications give general idea of the whole work or structure and are useful for preparing the estimate.

For general idea, the general specifications of different class of the buildings are given below. These will of course vary according to the necessity and type of works.

General specifications of different class of buildings is as follows:

1 First class bulding: The first class building specifications are as follows.

S. No.	Items	Details
1	Foundation and Plinth	It shall be of first class brickwork (or random rubble masonry) in lime mortar or 1:6 cement mortars over lime concrete or 1:4:8 cement concrete
2	Damp Proof Course	It shall be 2.5 thick cement concrete 1:1.5:3 mixed with water proofing materials and painted with two coats of bitumen
3	Super Structure	It shall be of 1st class brick with lime mortar or 1:6 cement mortar. Lintels shall be of R.C.C.
4	Roofing	Roof shall be of R.C.C. slab with an insulation layer. Height of rooms not less than 3.7 m.
5	Flooring	Drawing and dining room floors shall be of mosaic, bath room and W.C. floors and dado shall be of mosaic. Bedroom shall be coloured and polished of 2.5 cm cement concrete over 7.5 lime concrete. Floor of others shall be of 2.5 cm. Cement concrete 7.5 cm. Lime concrete polished.
6	Finishing	Inside and outside walls shall be of 12 mm. Cement lime plastered 1:1:6 Drawing, Dining and Bed rooms inside shall be distempered and other inside white washed 3 coats. Outside shall be coloured snow cem washed 2 coats over 1 coat of white wash

S. No.	Items	Details
7	Doors and windows	Frame shall be teak wood. Shutters shall be teak wood 4.3 cm, thick panelled or partly glazed with additional wire gauge shutters. All fittings shall be of brass. Doors and windows shall be varnished or painted two coats with enamel paints over one coat or priming. Windows shall be provided with iron grills. Rain water pipes, 1st class sanitary and water fittings and electrical installations shall be provided. 1 metre wide 7.5 cm, thick C.C. 1 : 3 : 6 aprons shall be provided all around the building.
8	Miscellaneous	

2. **Second class buildings:** The second class building specifications are as follows

S. No.	Items	Details
1	Foundation and plinth	Foundation and plinth shall be of 1st class brickwork cement mortar over lime concrete
2	Damp proof course	It shall be of 2 cm. thick cement concrete 1 : 2 : 4 mixed with standard water proofing materials.
3	Superstructure	It shall be of 2nd class brick with lime mortar. Lintels shall be of R.B.
4	Roofing	Roof shall be of R.B. slab with 7.5 cm. Lime concrete terracing above. Verandah roof may be of A.C. sheet or Allahabad tiles.
5	Flooring	Floor shall be 2.5 cm. cement concrete over 7.5 L.C. verandah floor shall be of brick tiles finished cement pointed.
6	Finishing	Inside and outside walls shall be of 12 mm. Cement mortar plastered 1 : 6 ceiling shall be cement pastered 1 : 3.
7	Doors and windows	Frame shall be of R.C.C. or well seasoned sal wood, shutter of deodars wood 4 cm. thick panelled or partly glazed. Doors and windows shall be painted two coats over one coat of priming.
8	Miscellaneous	Rain water pipes shall be provided. Electrification, sanitary and water fittings may be provided if required.

3 **Third class buildings:** The specifications for the third class building are as follows

S. No.	Items	Details
1	Foundation and	It shall be of sun dried bricks and mud mortar. Opening shall be provided with superstructure arch of 2nd class brick work in lime mortar or with wooden planks. Inside and outside wall shall be water proof mud plastered.
2	Roofing	It shall be of tiles, over bamboo, and wooden support.
3	Flooring	If shall be earthen floor finished with gobris washing (cow dung lapping)
4	Doors and Windows	It shall be of chir or mango wood or country wood.

Detailed specification

The detailed specification is a detailed description and expresses the requirements in detail. The detailed specification of an item of work specifies the qualities and quantities of materials, the proportion of mortar, workmanship, the method of preparation and execution and the methods of measurement. The detailed specifications of different items of work are prepared separately, and describe what the works should be and how they shall be executed and constructed. Detailed specifications are written to express the requirements clearly concise form avoiding repetition and ambiguity.

The detailed specifications are arranged as far as possible in the same sequence of order as the work is carried out. The detailed specifications if prepared properly are very helpful for the execution of work. The detailed specifications form an important part of contract document.

Every engineering department prepares the detailed specifications of the various items of works, and get them printed in book form under the name "Detailed Specifications." When the work or a structure or project is taken up, instead of writing detailed specification every time. The printed Detailed Specifications are referred.

Example - The detailed specifications of Earth Work Excavation is given below.

1 **Earthwork in excavation in foundation:** Excavation - Foundation trenches shall be dug out to the exact width of foundation concrete and the sides shall be vertical. If the soil is not good and does not permit vertical sides, the sides should be sloped back or protected with timber shoring. Excavated earth shall not be placed within 1 m (3") of the edge of the trench.

2 **Finish of trench:** The bottom of foundation trenches shall be perfectly levelled both longitudinally and transversely and the sides of the trench shall be dressed perfectly vertical from bottom up to the least thickness of loose concrete so that concrete may be laid to the exact width as per design. The bed of the trench shall be lightly watered and well rammed. Excess digging if done through mistake shall be filled with concrete at the expense of the contractor. Soft or defective sports shall be dug out and removed filled with concrete or with stabilized soil. If rocks or boulders are found during excavation, these should be removed and the bed of the trenches shall be levelled and made hard by consolidating the earth. Foundation concrete shall not be laid before the inspection and approval of the trench by the engineer-in-charge.

Finds: Any treasure and valuables or materials found during the excavation, shall be property of the Government.

Water in foundation: Water, if any accumulates in the trench, should be bailed or pumped out without the extra payment and necessary precautions shall be taken to prevent surface water to enter into the trench.

Trench filling: After the concrete has been laid masonry has been constructed the remaining portion of the trenches shall be filled up with earth in layers of 15 cm (6") and watered and well rammed. The earth filling shall be free from rubbish and refuse matters and all clods shall be broken before filling. Surplus earth not required, shall be removed and disposed, and site shall be levelled and dressed.

Measurement: The measurement of the excavation shall be taken in cu. m. (cu. ft.) as for rectangular trench bottom width of concrete multiplied by the vertical depth of foundation from ground level and multiplied by the length of trenches even though the contractor might have excavated with sloping side for his convenience. Rate shall be for complete work for 30 m (100 ft.) lead and 1.50 m (5') lift, including all tools and plants required for the completion of the works. For every extra lead of 30 m and every extra lift of 1.5 m separate extra rate is provided.

Excavation in saturated soil: Excavation in saturated soil or below sub-soil water level shall be taken under a separate item and shall be carried out in the same manner as above. Pumping or bailing out of water and removal of slush shall be included in the item. Timbering of the sides of trenches if required shall be taken under a separate item and paid separately.

Computation of area and volume

Aim: One of the main objectives of the surveying is to compute the areas and volumes. Generally, the lands will be of irregular shaped ploygons. There are formulae readily available for regular polygons like, triangle, rectangle, square and other polygons. But for determining the areas of irregular polygons, different methods are used.

They are

1 Graphical method

2 Co-ordinate method

3 Planimeter method

Out of these methods, the co-ordinate method is popularly is used, in land surveying for computing catchment area, drainage area, cross-section of rivers, channels etc. Under this method the given area is split into two with a base line run at the centre. There are two important rules available.

1 Trapezoidal rule

In this method, boundries between the ends of ordinates are asssumed to be straight. Thus the area enclosed between these line and the irregular boundary lines are considered as trapezoids.

$$A = \frac{d}{2}\left[0_1 + 0_n + 2\left(0_2 + 0_3 + 0_4 + ... + 0_{n-1}\right)\right]$$

$$A = \frac{\text{dist.bet.ordinate}}{2}\left[\begin{matrix}(\text{first ordinate} + \text{last ordinate}) + \\ 2(\text{sum of other ordinates})\end{matrix}\right]$$

Simpson's rule

$$A = \frac{d}{3}\left[\begin{matrix}0_1 + 0_n + 4\left(0_2 + 0_4 + ... + 0_{n-2}\right) + \\ 2\left(0_3 + 0_5 + ...0_{n-1}\right)\end{matrix}\right]$$

$$A = \frac{\text{Common dist. (d)}}{3}\left[\begin{matrix}(\text{first ordinate} + \text{last ordinate}) + \\ 4(\text{sum of even ordinates}) + \\ 2(\text{sum of odd ordinates})\end{matrix}\right]$$

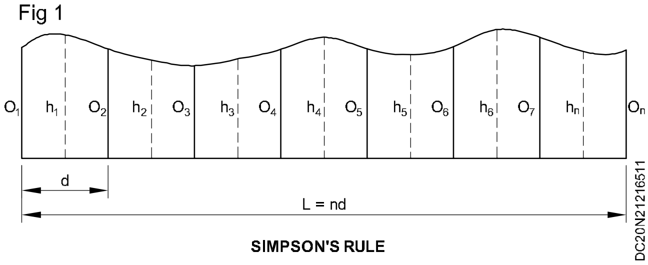
Laminations

The rule is applicable only when the number of divisions is even or the number of ordinates are odd sometimes one or both end ordinates may be zero. However, it must be taken into account while applying rules.

Workout problems

1 Following offsets were taken from a chain line to an irregular boundary line at an interval of 10 m. 0, 2.50, 3.50, 5.00, 4.60, 3.20, 0m. Compute the area between the chain line, the irregular boundary line and the end offsets by

Fig 1



SIMPSON'S RULE

a Trapezoidal rule

b Simpson's rule

a Trapezoidal rule

Here d = 10

$$\text{Area} = \frac{10}{2}\left[(0+0)+2(2.50+3.50+5.00+4.60+3.20)\right]$$

$$= 5 \times 37.60 = 188\,m^2$$

b Simpson's rule

Here d = 10

$$\text{Area} = \frac{10}{3}\left[(0+0)+4(2.50+5.00+3.20)+2(3.50+4.60)\right]$$

$$= \frac{10}{3} \times 59.00 = 196.66\,m^2$$

2 The following offsets were taken from a survey line to a curved boundary line

Distance (m)	0	5	10	15	20	30	40	60	80
Offset (m)	2.50	3.80	4.60	5.20	6.10	4.70	5.80	3.90	2.20

Find the area between the survey line, the curved boundary line and the first and last offsets by (a) Trapezoidal Rule and (b) Simpson's Rule.

Here, the intervals between the offsets are not regular throughout the length. So the section is divided into three compartments.

Let,

1 = Area of the 1st section

2 = Area of the 2nd section

3 = Area of the 3rd section

Here, d_1 = 5m; d_2 = 10m; d_3 = 20m.

a Trapezoidal rule

$$\Delta_1 = \frac{5}{2}\left[2.5+6.10+2(3.80+4.60+5.20)\right] = 89.5\,m^2$$

$$\Delta_2 = \frac{10}{2}\left[6.10+5.80+(2 \times 4.70)\right] = 106.5\,m^2$$

$$\Delta_3 = \frac{20}{2}\left[5.80+2.20+(2 \times 3.90)\right] = 158\,m^2$$

$$\text{Total area} = \Delta_1+\Delta_2+\Delta_3 = 89.5+106.5+158 = 354\,m^2$$

b Simpson's rule

$$\Delta_1 = \frac{d}{3}\left[O_1+O_n+4\left(O_2+O_4 \ldots..\right)+2\left(O_3+O_5+\ldots..\right)\right]$$

$$= \frac{5}{3}\left[2.5+6.10+4(3.80+5.20)+2(4.60)\right]$$

$$= 89.67\,m^2$$

$$\Delta_2 = \frac{10}{3}\left[(6.10+5.8)+(4 \times 4.70)+(2\text{x}0)\right] = 102.33\,m^2$$

$$\Delta_3 = \frac{20}{3}\left[(5.8+2.20)+(4 \times 3.90)+(2 \times 0)\right] = 157.3\,m^2$$

$$\text{Total area} = \Delta_1+\Delta_2+\Delta_3 =$$

$$89.67+102.33+157.3 = 349.30\,m^2$$

Computation of volumes

The computation of volumes of various quantities from the measurements done in the field is required the design and planning on many engineering works. The volume of earth work is required for suitable alignment of road works, canal and sewer lines, soil and water conservation works, farm pond and percolation pond consent.

The computation of volume of various materials such as coal, gravel and is required to check the stock files, volume computations are also required for estimation of capacities of bins, tanks etc.

For estimation of volume of earth work cross sections are at right angles to a fixed line, which runs continuously through the earth work. The spacing of the cross sections will depend upon the accuracy required. The volume of earth work is computed once the various cross-sections are known, adopting the following methods and using prismoidal rule and trapezoidal rule.

Method 1: Mid sectional area method - quantity =Area of mid - section x length.

Let d_1 and d_2 be the height of bank at two ends portion of embankment, 'L' the length of the section, 'B' the formation width and S:1 (horizontal:vertical) the side slope then,

Area of mid section = Area of rectangular portion + Area of two triangular portion.

$$= Bd_m + \tfrac{1}{2} sd_m^2 + \tfrac{1}{2} sd_m^2$$

$$= Bd_m + sd_m^2$$

$$\therefore \text{Quantity of earth work} = \left(Bd_m + sd_m^2\right) xL$$

General, Q=(Bd+sd2)xL, where d stands for mean height or depth.

The quantities of earthwork may be calculated in a tabular form as below

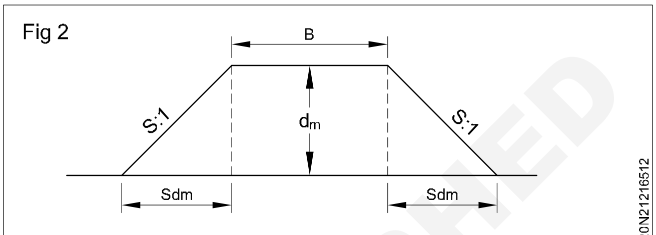
Area of side sloping surface

The area of sides which may require turfing or pitching, may be found by multiplying the mean sloping breadth of the length.

The mean sloping breadth $= \sqrt{\left(sd^2 + d^2\right)} = \sqrt{5^2 + 1}$

where d stands for mean d.

Area of both side slopes $= 2L_1 \, x \, d\sqrt{s^2 + 1}$



MID-SECTIONAL AREA METHOD

This also may be calculated in a tabular form

Stations or Chainage	Depth or Height	Mean depth or Height "d"	Area of central portion Bd	Area of sides sd^2	Total sectional area $Bd + sd^2$	Length between stations	Quantity $(bd + sd^2) \times L$	
							Embankment	Cutting

This table may be added to previous table or may be worked out separately, d being mean depth or height

Method II: Mean sectional area method: Quantity = Mean Sectional area x Length. Sectional area of one end,

$A_1 = Bd_1 + Sd_1^2$ Sectional area at one end,

$A_2 = Bd_2 + Sd_2^2$, d_1 and d_2 are the height or depth at the two ends.

$$\text{The mean sectional area } A = \frac{A_1 + A_2}{2}$$

$$\text{Quantity } Q = \frac{A_1 + A_2}{2} \text{ x Length}$$

Stations or Chainage	Depth or Height	Mean depth or Height	Breadth of side slopes $d\sqrt{s^2+1}$ sloping breadth	Length between stations (L)	Total area of both side slopes $2L_1 \, x \, d\sqrt{s^2+1}$

The quantities of earth work may be calculated in a tabular form as given above:

Method III - Prismodial formula method

$$\text{Quantity or Volume} = \frac{L}{6}\left(A_1 + A_2 + 4A_m\right)$$

where A_1 and A_2 are the cross sectional areas at the two ends of a portion or embankment of a road of length L, and A_m is the mid-sanctional area.

Let d_1 and d_2 be the heights of the banks at the two ends, and dm be the mean height at the md-section, B be the formation width and S:1 be the side slope.

Cross-sectional area at one end

$$A_1 = Bd_1 + Sd_1^2$$

Cross sectiona area at other end

Stations or chainage	Depth or Height	Mean depth or Height "d"	Area of central portion Bd	Area of sides sd^2	Total sectional area $Bd + sd^2$	Length between stations	Qualtity $(bd + sd^2)$ x L	
							Embankment	Cutting

$$A_2 = Bd_2 + Sd_2^2$$

Cross section at middle

$$d_m = \frac{d_1 + d_2}{2}$$

$$A_m = Bd_m + Sd_m^2$$

$$A_m = B\frac{d_1 + d_2}{2} + S\left(\frac{d_1 + d_2}{2}\right)^2$$

$$\text{Quantity} = \frac{L}{6}\left(A_1 + A_2 + 4A_m\right)$$

$$= \frac{L}{6}\left[\left(Bd_1 + Sd_1^2\right) + \left(Bd_2 + Sd_2^2\right) + 4\left\{B\left(\frac{d_1 + d_2}{2}\right) + S\left(\frac{d_1 + d_2}{2}\right)^2\right\}\right]$$

$$= \frac{L}{6}\left[\left(Bd_1 + Bd_2 + 4\frac{Bd_1}{2} + 4\frac{Bd_2}{2} + Sd_1^2 + Sd_2^2 + 4S\frac{d_1^2 + d_2^2 + 2d_1d_2}{4}\right)\right]$$

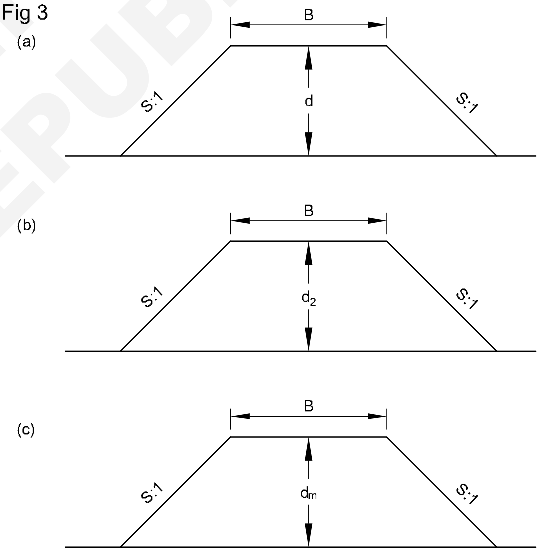
$$= \frac{L}{6}\left[\left(3Bd_1 + 3Bd_2\right) + 2Sd_1^2 + 2Sd_2^2 + 2d_1d_2\right]$$

$$= \frac{BL}{6}\left(d_1 + d_2\right) + \frac{2LS}{3}\left(d_1^2 + d_2^2 + d_1d_2\right)$$

$$= \frac{BL}{2}\left(d_1 + d_2\right) + \frac{LS}{3}\left(d_1^2 + d_2^2 + d_1d_2\right)$$

$$= \left[B\left(\frac{d_1 + d_2}{2}\right) + S\left(\frac{d_1^2 + d_2^2 + 2d_1d_2}{3}\right)\right] \text{x} L$$

Fig 3



PRISMOIDAL FORMULA METHOD

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The same is also applicable for cutting.

Earthwork calculated by the prismodial formula (Method III) is more accurate than calculated by the Method I and Method II but they will differ by less than 1 percent. As the earthwork is a cheap item, Method I and Method II is generally used as it is a simple and entails less labour, but where rates are high and greater accuracy is required prismoidal Formula may be used.

It may be noted that all the three methods, can be used for embankment as well as for cutting. Cross-sectional figures for banking if inverted give cross-sections for cutting.

Just to distinguish cutting and banking, the cutting is indicated by (-) sign, (minus sign).

Instead of calculating the quantities against each chainage and then totalling the areas may be totalled and then the total quantity is calculated by multiplying the total area by the common length. But it is better to calculate the quantities against each chainage which help during the execution of the work for controlling by comparing the actual quantity after execution, with the estimated quantity against each chainage.

Trapezoidal formula and prismoidal formulae Methods for a series of cross-sections

When a series of cross-section areas calculated at equidistant points, the volume may be worked out by trapezoidal formula.

Notations: A_1, A_2, A_3 A_4,..........A_n are the areas of cross-sections; D = Distance between the section: V= volume of cutting or banking.

i Volume by trapezoidal formulae method

$$V = \frac{D}{2}\left(A_1 + 2A_2 + 2A_3 + \ldots\ldots + 2A_{n-1} + A_n\right)$$

$$V = D\left(\frac{A_1 + A_n}{2} + A_1 + A_2 + A_3 + \ldots\ldots + A_{n-1}\right) \text{or}$$

$$V = \frac{D}{2}\left\{A_1 + A_n + 2\left(A_2 + A_3 \ldots\ldots + A_{n-1}\right)\right\}$$

ii Volume by prismoidal formulae method

$$V = \frac{D}{3}\left(A_1 + A_n + 4\left(A_2 + A_4 + \ldots\ldots + A_{n-2}\right) + 2\left(A_3 + A_5 + \ldots\ldots + A_{n-1}\right)\right)$$

$$= \frac{D}{3}\left(\text{First area} + \text{Last area} + 4\sum \text{Even areas} + 2\sum \text{Odd areas}\right)$$

It may be noted that in the case of the prismoidal formulae, it is necessary to have an odd number of sectional area. If there is an even number of section, the end strip should be treated separately, and the volume of the remaining strips should be calculated by prismoidal formulae.

To calculate the volume of earthwork from contour plan, for filling a depression or pond and for cutting a hill, primoidal formulae may be used conveniently. The areas with every contour may be found by using a planimeter or a tracing paper containing squares. Then the prismoidal formulae may be applied to calculate the volume, the distance between the two sections will be the contour intervals, i.e., the difference of level between two consecutive contours.

Example 1: Calculate the quantity of earthwork for 200 metre length for a portion of a road in an uniform ground the heights of banks at the two ends being 1.00 m and 1.60 m. the formation width is 10 metre and side slopes 2:1 (Horizontal:Vertical). Assume that there is no transverse slope.

By Method 1

B = 10 m, s = 2, L = 200 m,

d = mean depth

$$d = \frac{1.00 + 1.60}{2} = 1.30\text{m}$$

= (10 x 1.3 + 2 x 1.3^2) x 200

= (13 + 3.38) x 200

= 16.38 x 200 = 3276 cu. m.

By Method 2

$$\text{Quantity} = \frac{L}{6}\left(A_1 + A_2 + 4A_m\right)$$

$$A_1 = \text{Sec. Area at one end}$$

$$A_1 = Bd_1 + SD_1^2$$

$$= 10 \times 1 + 2 \times 1^2 = 12\,\text{sq. m.}$$

$$A_2 = \text{Sec. Area at other end}$$

$$A_2 = Bd_2 + Sd_2^2$$

$$= 10 \times 1.60 + 2 \times 1.6^2 = 21.12\,\text{sq. m.}$$

$$A_m = \text{Mid. Sec.Area}$$

$$A_m = Bd_m + Sd_m^2$$

$$\text{where } d_m = \frac{d_1 + d_2}{2} = \frac{1.00 + 1.60}{2} = 1.30\,\text{m}$$

$$A_m = 10 \times 1.30 + 2 \times 1.30^2 = 16.38\,\text{sq. m.}$$

$$\therefore \text{Quantity} = \frac{200}{6}\left(12 + 21.12 + 4 \times 16.38\right)$$

$$= \frac{200}{6} \times 98.64 = \frac{19728}{6} = 3288\,\text{cu. m.}$$

The difference by methods 1 and 3 is less than ½ percent, the difference by methods 2 and 3 is less than 1 percent.

Introduction to total station

Objectives : At the end of this lesson you shall be able to
- **get introduced to the total station**
- **learn the evolution of total station from the conventional equipment**
- **explain the benefits and uses of total station.**

General

At present the analogue methods of recording data for conventional surveying is changed to digital data collection methods. Previously plane table is used as the best way to map a small area. But the output of a plane table is just a low precision analogue drawing in case of plane table the map is drawn directly on a sheet in a fixed scale, there was no way to replot the map to different scales and the quantity of topographic data collected was few. But these limitations can be overcome by the use of modern electronic total stations. With the use of total stations we can use fastest digital data collection methods.

Definition

Total station is an assembly of a short to medium range EDM instrument installed in the framework of an electronic theodolite with all components under the control of a built-in micro processor. This single instrument permits observing distances and directions from a single setup.

Important parts of total station

- EDM with laser generator
- Endless drives
- Trigger keys
- Tribrach with foot screws
- Communication side cover
- Bluetooth
- Battery downloading port

Fig 1

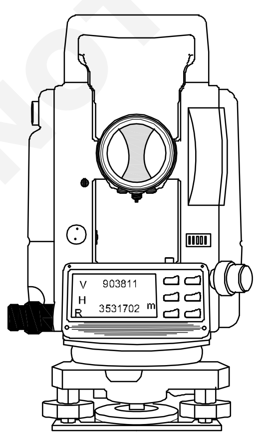

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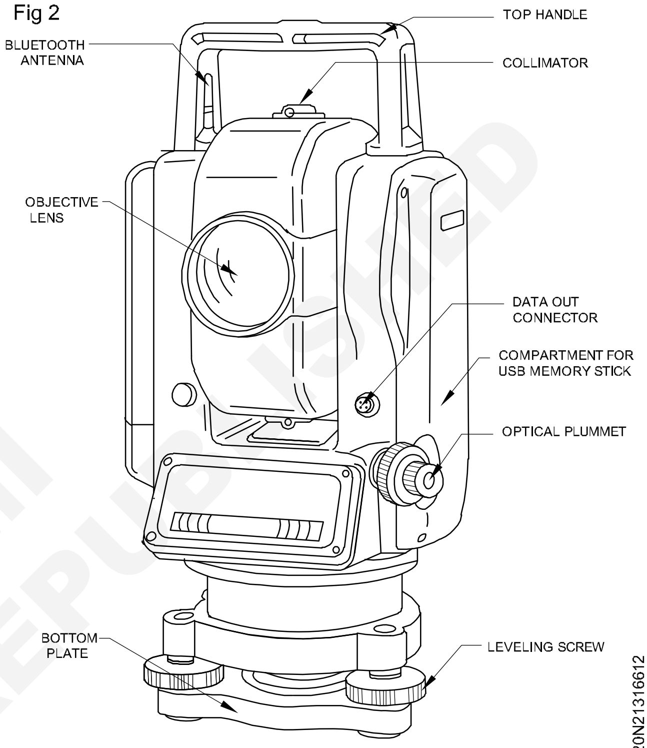
Fig 2



TOTAL STATION - INSTRUMENT COMPONENTS

DC20N21316612

Features of total station

1 The theodolite is offering a complete product family. It is easy for a user to switch between models without learning a new operation.

2 Absolute circle reading.

3 Excellent hardware features, such as laser plummet, endless drives on both sides for Hz and V, brilliant optics with 30x magnification.

4 Dual-Axis compensation for reliable Hz and V reading

5 New and intuitive software.

6 Unique levelling guidence for fast and convenient setup.

7 Hight resolution LCD display.

8 Audible notice for 900 turns and layout.

9 Electronic laser distance measurement.

10 Graphic sketches.

11 Hassle-free EDM measurement with red laser on any target or on the flar-prism.

12 Enter the data at the office and simply call up at the site.

13 Upload and transfer data via on board data connection.

14 Data editing and exchange in total stations.

15 Connectivity to 3rd party devices.

Use of total station

The instrument is mounted on a tripod and is levelled

by operating levelling screws.

Within a small range instrument is capable of adjusting itself to the level positon. Then vertical and horizontal reference directions are indexed using on board keys. It is possible to set required units for distance, temperature and pressure (FPs or SI). Surveyor can select measurement mode like fine, coarse, single or repeated.

When target sighted, horizontal and vertical angles as well as sloping distances are measured and by pressing appropriated keys they are recorded along with point number. Heights of instrument and targets can be keyed in after measuring them with tapes. Then processor computes various information about the point and displays on screen. This information is also stored in electronic note book. At the end of the day or whenever downloaded to computers, the point data downloaded to the computer can be used for further processing. There are software's like auto civil and auto plotter clubbed with AutoCAD which can be used for plotting contours at any specified interval and for plotting cross-section along any specified line.

Types of total station

Objectives : At the end of this lesson you shall be able to
- **explain the advantages and disadvantages of total station**
- **explain the types of total stations**
- **explain the precautions to be taken while using total station.**

Advantages of total station

The advantages of total station include:

1 Quick setting of the instrument on the tripod using laser plummet.

2 On-board area computation programmed to compute the area of the field.

3 Greater accuracy in area computation because of the possibility of taking arcs in area computation.

4 Graphical view of plots and land for quick visualization.

5 Coding to do automated mapping. As soon as the field jobs are finished, the map of the area with dimensions is ready after data transfer.

6 Enormous plotting and area computation at any user.

7 Integration of database (exporting map to GIS packages)

8 Automation of old maps.

9 Full GIS creation (using map info software)

10 Local language support

Disadvantage of total station

1 Their use does not provide hard copies of field notes. Hence it may be difficult for the surveyor to look over and check the work while surveying.

2 For an overall check of the survey, it will be necessary to return to the office and prepare the drawings using appropriate software.

3 They should not be used for observations of the sun, unless special filters, such as the Troelof's prism, are used. If not, the EDM part of the instrument will be damaged.

4 The instrument is costly, and for conducting surveys using totals station, skilled persons are required.

Types of total staions

In the early days, three classes of total stations were available - manual, semi-automatic and automatic.

Manual total stations

It was necessary to read the horizontal and vertical angles manually in this type of instrument. The only value that could be read elevation of the slope distances.

Semi-automatic total stations

The user had to manually read the horizontal circle for these instruments, but the vertical circle readings were shown digitally. Slope distances were measured electronically and the instruments could, in most cases be used to reduce the values to horizontal and vertical components.

Automatic total stations

This type is most common total station used now-a-days. They sense both the horizontal and vertical angles electronically and measure the slope distances, compute the horizontal and vertical components of those distances, and determine the coordinates of observed points, it is necessary to properly orient the instrument of some known directions such as true north, magnetic north or to some known bearing. The coordinate information obtained can either be stored in the total station's memory or by using an external data collector.

Manual total stations and semi-automatic total stations are obsolete now. At present, it is the age of fully automatic total stations and robotic total stations.

Almost all total stations in the market use infrared as the carrier for distance measurement. The less expensive unit with a single prism reflector can measure distances up to 1000 m. Those in higher price range are capable of measuring distances up to 2000 m, when single prism is used. the accuracies of measurements witn the less expensive instruments probably run about 6 (5 mm/ 5 ppm) and the expensive total stations can run about 6 (1 mm/ 1 ppm.)

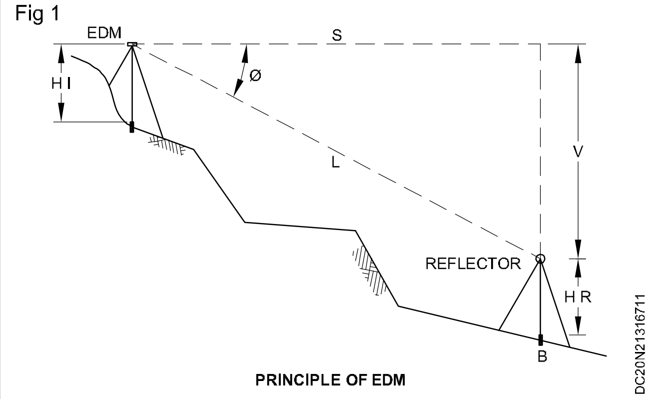
Principle of EDM (Fig 1)

Measurement of distance is accomplished with a modulated microwave of infrared carrier signal, generated by a small solid-state emitter within the instruments optical path, and reflected by a prism reflector or the objected under survey. the modulation pattern in the returning signal is read and interpreted by the onboard computer in the total station. The distance is determined by emitting and receiving multiple frequencies, and determining the integer number of wavelengths to the target for each frequency. Most total stations use purpose-built glass Porro prism reflectors for the EDM signal, and can measure distances to a few kilometers. The typical total station can measure distances to about 3 millimeters or 1/1000th of a foot..

Basics of total station (Fig 2)

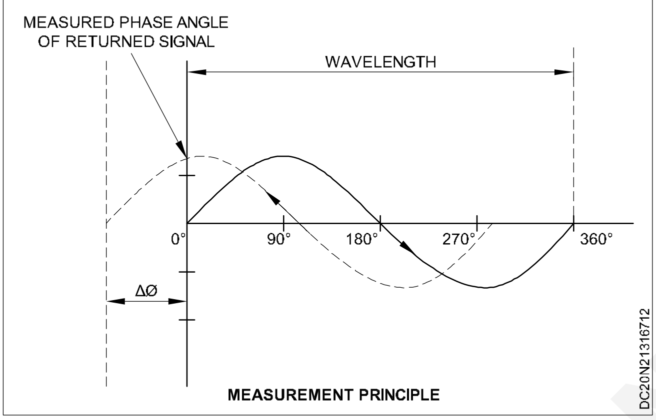
- Angles and distances are measured from the total station to points under survey, and the coordinates (X,Y, and Z or northing, easting and elevation) of surveyed points relative to the total station position are calculated using trigonometry and triangulation.

Fig 1



PRINCIPLE OF EDM

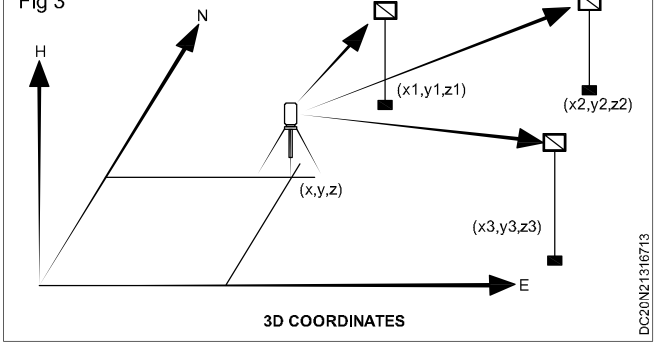
Fig 2



MEASUREMENT PRINCIPLE

- Most modern total station instruments measure angles by means of electro-optical scanning of extremely precise digital bar-codes etched on totaling glass cylinders or discs with in the instrument. The best quality total stations are capable of measuring angles to 0.5 arc-second. Inexpensive “construction grade’ total stations can generally measure angles to 5 or 10 arc-seconds.

Fig 3



3D COORDINATES

- Total Station - requires lines, the line of sight observations and must be set up over a known point or with line of sight 2 or more points with known location.

From the above figure (Fig 3)

- Where E & N gives the position and Z gives the reduced level
- Suppose we know (x,y,z)
- We need an algorithm to calculate positions of x1, y1,z1) ; (x2, y2, z2) & (x3, y3, z3) w.r.t. (x,y,z).
- For this algorithm we need inputs.

Inputs for the algorithm are

- Co-ordinates at which the instruments stands.
- Height of the instrument
- Orientation of the instrument (Hz = 0).
- Height of the reflector
- Angle at which the prism is placed w.r.t. orientation.
- or
- 00° 00’ 00”
- D° M’ S”
- Hi

Measurement with total station

Objectives : At the end of this lesson you shall be able to
- **explain the equipment required for total station surveying**
- **explain the procedure of measurement with total station.**

For using the modern electronic survey equipments, surveyors are need to be more maintenance conscious than they were in the past. They must have to thorough knowledge, about power sources, downloading data and the integrity of data.

For the survey of an area, the survey crew (two person crew, consisting of a party chief / rod person and a note keeper / instrument person) need the following equipment inventory.

1 Total station set

a Total station instrument in a hard case

b Battery charger

c Extra batteries

d Memory module / card, serial cable

e Rain cover

f User manuals

g Tripod

h Tape measure

2 Prism set

a Prism

b Prism holder

c Centering rod

3 Back sight set

a P rism

b Prism holder

c Prism carrier (to be fixed to tribrach, with optical / laser plummet)

d Tribrach (to exchange prism carrier and total station)

4 Data Processing

a Laptop computer with serial port or USB port

b Serial cable or USB-serial adaptor

c Terminal application

d Application programme: MS Excel, Adobe llustrator, Co-ordinate Converter, etc.

e Data backup device media (Zip, memory card, etc.)

5 Survey tools

a Stakes, nails, paint, marker

b Hammer

c Thermometer, barometer / multimeter

d A pair of radio (with hands- free head set)

e Clipboard, field note, pen

f Compass

Setup

The following steps followed for the setup of a total station, at a station point.

1 Choose an adequate instrument station. Make sure that an observer can safely operate the instrument without knocking it over. It is necessary to have the center of the instrument, which is the point of interscetion of the transverse axis of the instrument, directly over a given point on the ground (the instrument station).

2 Remove the plastic cap from the tripod, and leave the instrument in the case until the tripod is nearly level, Stretch the tripod legs 10 - 15 cm shorter than their maximum length.

3 Open the legs of the tripod to set the tripod head at the level of the operator's upper chest. When the total station is set up on the head, the operator's eye should be slightly above the eyepiece. The instrument height is important for an effective and comfortable survey. It differs in the looking down position and the looking up position. One should not touch or cling to the tripod during the survey.

4 At a new station without a reference point on the ground, level up the total station at an arbitrary point, where a stake can easily go in and be steady, and put down the stake at the centre using the plummet.

5 To occupy an existing station above a steady reference point, first roughly level up the tripod head right above the point. For levelling up, a small level is useful to find out the position, use a plumb bob or drop a stone through the hole in the tripod head.

6 Once roughly levelled and centered, push each tip of the tripod leg firmly into the ground, applying full weight of the observer on the step above the tip. Apply the weight along the tripod leg without bending it.

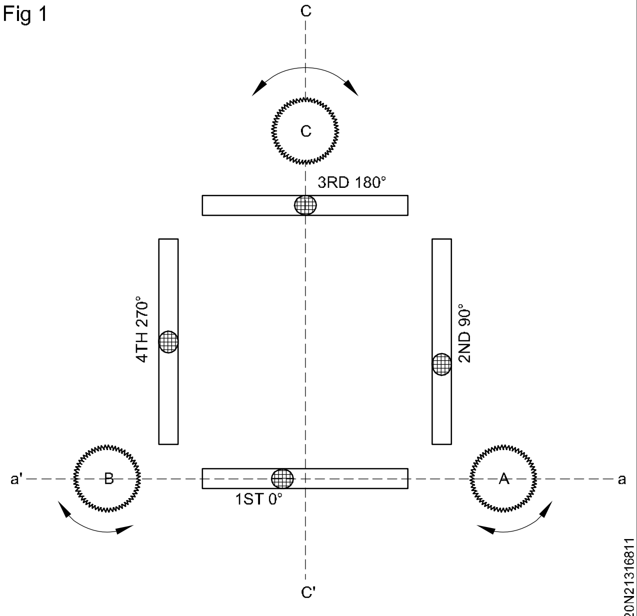
7 Check the level and center it again. Adjust the level by changing the leg length.

8 Fix a tribrach with a plummet, a tribrach and a prism carrier with a plummet or a total station with a built-in plummet on the tripod head.

9 Adjust the three screws of the tribrach to center the bubble of a spirit level with the following steps:

a Release the lock of the horizontal circle. Rotate the instrument to the plate level parallel to AB at the 1st position. (Fig 1)

Fig 1



FINE LEVELLING PROCEDURE

b Turn the foot screws A and B in the opposite direction, the same amount to center the plate level. This will adjust the tilt on the aa' axis.

c Rotate the instrument 90° to set the plate level, at the 2nd position.

d Turn the foot screw C to the centre plate level, adjusting the tilt along cc'.

e Rotate the instrument 90° to set the plate level in the 3rd position.

f Turn the foot screws A and B in the opposite direction, the same amount to eliminate half the centering error.

g Rotate the instrument 90° to set the plate level at the 4th position.

h Turn the foot screw C to eliminate half the centreing error.

i Repeat b to h until the plate level is centered in all directions (give a little time for slow movement of the bubble in viscous fluid).

10 Pull out the optical plummet and use the optic ring to focus at the graticule and then focus at the mark on the ground. Turn on the laser plummet. Rotate the plummet or the total station to check it is centered within 1cm from the reference point. If not, estimate the amount of offset and carefully translate the entire tripod as much as offset.Return to 4 and try to level and center, therefore, rough centering within 1 cm is necessary. Be careful to see that the center of the optical plummet or the laset point is on an axis perpendicular to the horizontal circle of the total station. If the total station is not level, the plummet line does not coincide with the plumb line.

11 Put the total station on the tribrach if it is not there.

12 Use the plate level for the final levelling of the total station. Follow the instructions given in Fig 1

13 When the total station is finely levelled up, use the plummet to check centering. If the plummet center is off the reference point, slightly loosen the fixing screw below the tripod head and translate the tribrach to place the plummet center on the exact point. Do not rotate. When the translation is done, tighten the fixing screw moderately. If any portion of the base of the tribrach goes outside the tripod head, return to 4.

14 Rotate the total station by 180°. If the plummet center goes away from the point, slightly loosen the fixing screw and slide the total station halfway to the center.

15 Repeat the setps 12 and 13 until the plummet center stays exactly on the center of the mark.

16 Tighten the fixing screw firmly without applying too much pressure. Never loosen the screw until all the measurements are finished.

17 Measure the instrument height. The centre of the total station is marked on the side of the alidade. The vertical distance between the mark and the ground is the instrument height.

18 Check the plate level from time to time during the measurement before the total station tilts beyond the automatic correction.

Setting up a back sight

A back sight is a reference point for the horizontal angle. At the beginning of a new survey, a back sight con be set at and arbitrary point and marked. The best way to set up a back sight is to use a prism carrier and tribrach on a tripod. the procedure for levelling up and centering of the prism is the same as that for the total station. If there is not plummet in the tribrach and the prism carrier, use the plummet of the total station and then exchange the total station above the tribrach with a prism carrier. A prism should be put right on the reference point when sighting is possible from the total station.

Measure the target height at the back sight. This height is the vertical distance between the centre of the target (prism) and the ground beneath. When the station and back sight are ready, measure the azimuth from the station to the back sight using a compass. The azimuth is between 0° and 360° measured clockwise from north. Correct the magnetic declination to get the true azimuth and record the true azimuth. If the geographic coordinate or grid coordinates of the point occupied by the total station and the target at the back sight is known, then the total station will automatically calculate the true azimuth, provided the station values are fed into the total station manually.

Measuremet with total station

When both the total station and back sight are finely levelled and centered, the hardware setup is over and the software setup is to be started. The software setup of a total station differs from one make to another. One has to follow the user's manual of each instrument. The list below gives common important settings for most instruments, Most total stations memorize these settings, but it is better to check through the setup menu in order to avoid a false setting.

System : Choose appropriate existing interface for data output.

Angle measurements : Tilt correction / tilt compensator (2 axis)

Horizontal angle increments : At right angles (Clockwise).

Unit setting : Angle in degrees / min. / sec., distance in meters, temperature in °C and pressure in hPa.

EDM settings : Select IR laser, fine measuring mode, use RL with caution. So appropriate value for the prism constant (from the user's manual of the equipment).

Atmospheric parameters : Get ppm for the diagram from the manual of the equipment or let the total station calculate from hPa and degree centrigrade.

Commnunications : Set all parameters the same for a total station and data logger / PC. They are rate. data bits, parity, end mark and stop bits. Refer the manual for each device.

Total station initial setting (General setting required for all models)

The following are the steps for the initial setting of a total station:

1 Turn of the total station.

2 Release both horizontal and vertical locks.

3 Some total stations require rotating the telescope through 360° along the vertical and horizontal circles to initialize angles.

4 Adjust the telescope to best fit to the observer's eye. Using the inner ring of the eyepiece, make the image of the cross-hair sharp and clear.

5 Rotate the alidade until the Hz angle reading is equal to the azimuth to the back sight measured by the compass (for Sokkia models only). Push the HOLD key once. The Hz angle will not change until the next hold.

6 Aim at the very center of the prism at the back sight. For the coarse aiming, rotate the alidate and the telescope by hand using optical sight. Adjust focus using the outer ring of the eyepiece. When the prism comes into the sight and close to the cener, lock the horizontal and vertical drives. Then use dials to aim at the exact center of the prism.

7 For Sokkia models, push HOLD button again. The horizontal reading will now change according to the rotation of the telescope in the horizontal direction. For Leica models, input the azimuth of the back sight manually in the measurment setup window.

8 If a station ID and back sight ID are requirred, use a 2-digit or 3-digit serial number like 101, 102,.......for each reference point. Use a 4-digit number for unknown points.

9 Input station parameters like hi (height of the instrument), E0, N0, and H0 (easting, northing and RL of the point where the instrument is setup). Use 1000, 1000 and 1000 for E0, N0 and H0 to avoid negative figures. If the coordinates are known, manually input the data.

10 Input the traget height (hr.)

11 Check the pointing at the prism again.

12 Using the distance calculation key. make the back sight measurement. From the LCD display of the total station, not the horizontal angle, the vertical angle, slope distance, easting, northing and height, and record them in a field book with a sketch of the plan. Here the horizontal angle, vertical angle and the slope distance are the raw data.

13 Create a new job or open an existing job. A job is a block of data sets stored in the memory like a file. One can create a new job or appendix data to an existing job. A job name is used as an output file name in a new Lecia total station with. gsi extension

Precautions to be taken while using a total station

The following precautions need to be taken while using a total station:

1 Always carry a total station in a locked hard case even for a very short distance. Take the total station out of the hard case only for fixing it firmly on a tripod for taking observations.

2 Do not move or carry a tripod with the total station fixed on it. except for centering.

3 Use both bands to hold the total station handle.

4 Never release the handle before the total station is fixed with the tripod's fixing screw.

5 Set up the tripod as stable as possible.

6 Always keep the top of the tripod, the bottom and top of the tribrach and the bottom of the station clean and away from any shock and impact.

7 Take maximum care when the tribrach is removed from the total station.

8 Do not make the total station wet.

Cheracterstic and features of total station

Objectives : At the end of this lesson you shall be able to
- **define features of total station**
- **state the characterstics of total station**
- **advantages and disadvantages of total station.**

FEATURES OF TOTAL STATIONS

Total station are capable of measuring angles and distances simultaneously and combine an electronic theodolite with a distance measuring system and a microprocessor.

ANGLE MEASUREMENT

All the components of the electronic theodolite described in the previous lectures are found total stations.

The axis configuration is identical and comprises the vertical axis, the tilting axis and line of sight (or collimation). The other components include the tribrach with levelling footscrews, the keyboard with display and the telescope which is mounted on the standards and which rotates around the tilting axis.

Levelling is carried out in the same way as for a theodolite by adjusting to centralise a plate level or electronic bubble. The telescope can be transited and used in the face left (or face I) and face right (or face II) positions. Horizontal rotation of the total station about the vertical axis is controlled by a horizontal clamp and tangent screw and rotation of the telescope about the tilting axis.

The total station is used to measure angles in the same way as the electronic theodolite.

Distance measurement

All total station will measure a slope distance which the onboard computer uses, together with the zenith angle recorded by the line of sight to calculate the horizontal distance.

For distances taken to a prism or reflecting foil, the most accurate is precise measurement.

For phase shift system, a typical specification for this is a measurement time of about 1-2s, an accuracy of (2mm + 2ppm) and a range of

3-5km to a single prism.

Although all manufacturers quote ranges of several kilometres to a single prism.

For those construction projects where long distances are required to be measured, GPS methods are used in preferance to total stations. There is no standard difference at which the change from one to the other occurs, as this will depend on a number of factors, including the accuracy required and the site topography.

Rapid measurement reduces the measurement time to a prism to between 0.5 and 1's for both phase shift and pulsed systems, but the accuracy for both may degrade slightly.

Tracking measurements are take extensively when setting out or for machine control, since readings are updated very quickly and vary in response to movements of the prism which is usually pole-mounted. In this mode, the distance measurement is repeated automatically at intervals of less than 0.5s.

For reflector less measurements taken with a phase shift system, the range that can be obtained is about 100m, with a similar accuracy to that obtained when using a prism or foil.

Characterstics of total station

1 Angle units degree or radian
2 Distance units ft or m
3 Pressure unit mHg or mmHg
4 Temperature units âÂÂ °F or âÂÂ °C
5 Prism constant -30 or -40mm
6 Offset distances
7 Face 1 or Face 2 selection
8 Height of instrument (HI)
9 Height of reflector (HR)
10 Automatic point number incrementation
11 Point numbers and code numbers for occupied and sighted stations
12 Date and time settings

Capabiltites of a Total Station

- Monitors battery status, signal attenuation, horizontal and axes status, collimation factors
- computes coordinates
- Traverse closure and adjustment
- Topography reductions
- Remote object elevation
- Distance between remote points
- Inversing
- Resections
- Horizontal and vertical collimation corrections
- Setting out

- Vertical circle indexing
- Records, search and review
- On-board software
- Traansfer of data to the computer
- Transfer of computer files to date recorder

Field procedures for Total Station in topographic surveying

- A set routine should be established for a survey crew to follow
- Standard operating procedure should require that control points be measured and noted immediately on the data collector and/or in the field book after the instrument has been set up and levelled
- This ensures that the observation to controlling points are established before any outside influences have had an opportunity to degrade the setup
- In making observations for an extended period of time at a particular instrument location, Reserve the control points from time to time
- This ensures that any data observed between the control shot are good or that a problem has developed and appropriate action can be taken to remedy the situation
- As a minimum, require servey crews to observe both vertical and horizontal control points at the beginning of each instrument setup and again before the instrinstrument is picked up
- One of the major advantages of using a total station equipped with data collection is that some errors previously attributed to blunder can be minimized or eliminated.
- Even if the wrong reading is set on the horizontal circle on the field or the wrong elevation is used for the bench, the data itself may be precise
- To make the data accurate, many software packages will allow the data to be rotated and/or adjusted as it is processed.
- The only way to assure that these corrections and/or observations have been accurately processed is to compare the data to control points
- Without these observation in the recorded data, the orientation of the data will always be in question.
- The use of a total station with a data collection can be looked upon as two separate and distinct operations.

Following is the typical procedure for data collection in total station

- Set up and level instrument
- Turn on total station
- Create a file or open existing file
- Record Occupied station Name and instrument height
- Set Coordinate for Occupied Station
- Set backsight name and reflector height and observe the coordinate of the backsight (known) station and record the data
- Give name for foresight station and set reflector height
- Measure the foresight station and record the data
- For detailing, set detail point name and reflector height and start recording the data of different location.
- After completion of recording the data, Power off the machine and transfer the instrument to next station and procedure as above.

Total station consists of an electronic theodolite, an electronic distance measuring device (EDM) and a micro processor having a memory unit. By using this instrument it is possible to find out the coordinates of a reflector adjusting the cross hair of the instrument and at the same time measuring the vertical angles, and slope distances. A micro processor deals with the recording, readings, and the fundamental calculation of measurements.

The major advantages and disadvantages of total station are as following:

ADVANTAGES OF TOTAL STATION:

1 Quick setup of the instrument on the tripod by utilizing the laser plummet.

2 Programmed with on board area computation for computing the area of a field.

3 It supports local languages.

4 It shows the graphical view of land and plots.

5 No recording and writing errors.

6 It gives more accurate measurements than other conventional surveying instruments.

7 Data can be saved and transferred to a PC.

8 It has integrated database.

9 Computerization of old maps.

10 All in one and multitasking instrument, from surveying to GIS creation by using the appropriate software

11 Faster work, saves time, quick finishing off the job.

DISADVANTAGES OF TOTAL STATION:

1 The instrument is costlier than other conventional surveying instruments.

2 It might be troublesome for the surveyor to investigate and check the work when surveying.

3 Working with total station is not so easy, as more skilled surveyors are required to conduct a total station survey.

4 To check the survey work thoroughly it would be necessary to come back to the office and prepare the drawings by using the right software.

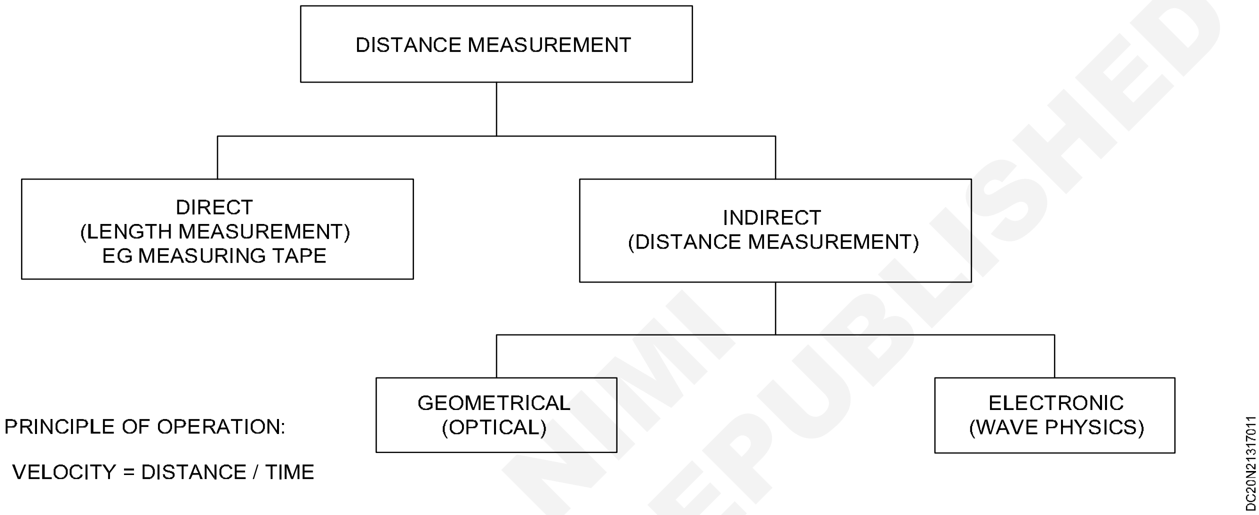
Principle of EDM - Working need setting and measurement

Objectives : At the end of this lesson you shall be able to
- **define EDM**
- **state the principle of EDM**
- **features of EDM.**

What is EDM ?

EDM is the electronic distance measuring device, measures from the instrument to its target. EDM sends out laser or inframed beam which is reflected back the unit and the unit used velocity measurements to calculate the distance traveled by the beam.

Fig 1



History

Theodolite & Tape
Stadia
EDM & Theodolite
EDM, Theodolite & Data Collector

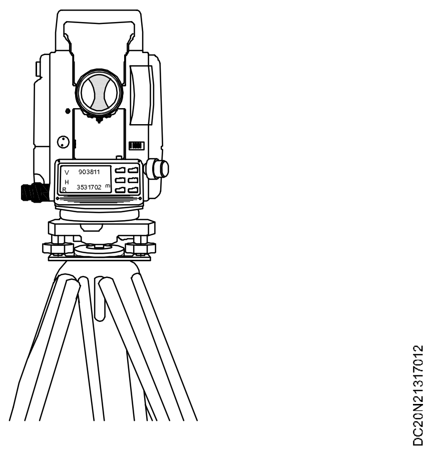
Prior to the total station, Theodolite with EDMs and data collectors were used to record number of points, and for measuring long distances. The systems were heavy, prone to failure, and many times the parts incompatible.

Prior to these systems, optical (stadia) and manual (tape) systems were used to measure distances.

History

- First introduced in the late 1950's
- At first they were complicated, large, heavy and suited primarily for long distances
- Current EDM's use either infrared (light waves) or microwaves (radio waves)
- Microwaves require transmitters/receivers at both ends
- Infrared use a transmitter at one end and a reflecting prism at the other and are generally used more frequently.

Fig 2



EDM Properties

- They come in long (10-20 km), medium (3-10 km), and short range (.5-3 km). Range limits up to 50 km
- They are typically mounted on top of a theodolite, but can be mounted directly to a tribrach.

Total station
=
<u>Theodolite with built in EDM</u>
±
<u>Microprocessor</u>
Principles of EDM

Gereral principles of EDM

Electromagnetic energy

Travels based on following relation

$$v = f\lambda \text{ so } \lambda = \frac{v}{f} \quad v = c/n$$

Instensity modulate EM energy to specfic frequency

Fig 3

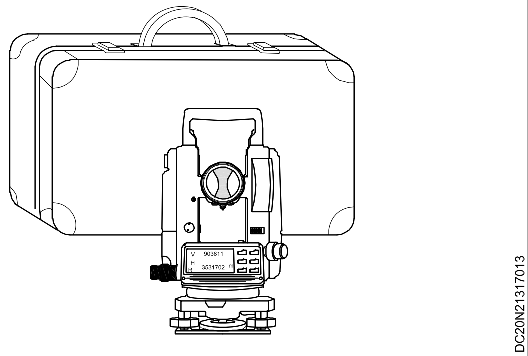


Fig 4

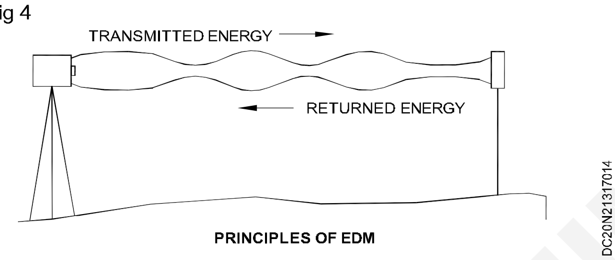
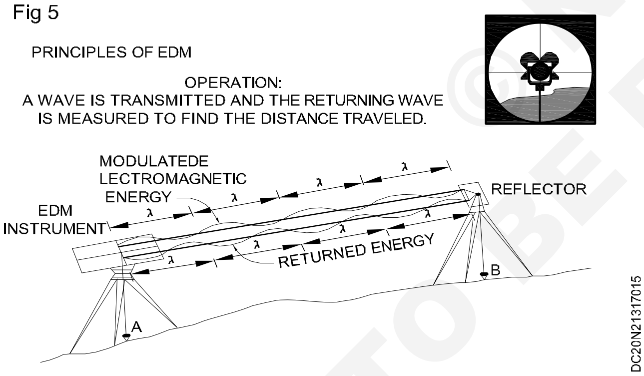


Fig 5



Principles of EDM

ADVANTAGE OF USING EDM

1 Precise measurement of distance

2 Capabale of measuring long distances

3 Electroless are single person operation

ELECTRONIC DISTANCE MEASUREMENT (EDM)

DISADVANTAGE OF USING EDM

1 Electronic = batterers

2 Accuracy affected by atmospheric conditions.

3 Can be expensive

USE OF EDM

a measuring distance

b setting distance

Different Wavelength Bands Used By EDM

Usally, EDM uses three different wavelength bands and their characteristics are:

Microwave Systems

Range up to 150 km

Wavelength 3 cm

Not limited to line of sight

Unaffected by visibility

Light Wave Systems

Range up to 5 km (for small machines)

Visible light, lasers

Distance reduced by visibility

Infrared Systems

Range up to 3 km

Limited to line of sight

Limited by rain, fog, other airbore particles

Total station :

tripod

theodolite

hammer

plumbob

peg

traverse

procedure

Full transcript

Things to remember in total station

- A total station is an electronic optical instrument widely used in modern surveying
- Total station instrument combine three basic components
- An EDM instrument, and electronic digital theodolite and a computer or microprocessor into one integral unit
- They digitally observe and record horizontal directions, vertical directions and slope distances
- These digital data observations can be adjusted and transformed to local X,Y, and Z coordinates using an internal or external microprocesor.
- Various atmosphere corrections, grid and geodetic correctoins, and elevation factors can be input and applied
- The total stations may internally perform and save the observation or these data may be download to an external data storage
- Angles can be electronically encoded to one are-second with a precision down to 0.5 arc-second
- Digital readouts eliminate the uncertainty associated with reading and interpolating scale and micrometer data
- The electronic angles - measurement system minimizes some of the horizontal and vertical angle errors that normally occur in conventional
- The modern versions of survey total station called robotic total station, let user control the instrument from a distance with the help of remote control.
- These instruments are also equipped with dual - axis compensator, which automatically correct both horizontal and vertical angles for any deviation in the plumb line.

Setting and measurements

Objectives : At the end of this lesson you shall be able to
- **define distance measuring**
- **state the principle of EDM**
- **state classification of EDM.**

Distances determined by calculating the number of wavelengths traveled.

$$L = \frac{n\lambda + \phi}{2}$$

Errors are generally small and insignificant for short distances. For longer distances they can be more important.

Errors can be accounted for manually, or by the EDM if it has the capability.

The principle of the measurement device in EDM, which is currently used in a total station and used along with electronic/optic theodolites, is that it calculates the distance by measuring the phase shift during the radiated electromagnetic wave (such as an infrared light or laser light or microwave) from the EDM's main unit, which returns by being reflected through the reflector

Velocity of light can be affected by:

Temperature

Atmospheric pressure

Water vapor content

- EDM characteristics
- Distance Range 750-1000 meters

Distance can be measured up to 1 km using a single prism under average atmospheric conditions. Short range EDM instruments can measure up to 1250 m using a single prism. Long range EDM instruments can be used for the measurement up to 15 km using 11prisms.

- Operating temperature between -20+50 degree centigrade.

Measuring Time

The measuring time required is 1.5 sec for short range measurements and up to 4 sce for long range measurements. Both accuracy and time are considerably reduced for tracking mode measurements.

Slope Reduction

Manual or automatic in some models. The average of repeated measurements is available on some models.

Battery Capability

1500-5000 measurements depending on the power of the battery and the temperature.

Non-prism measurement

Non-prism measurements are available with same models They can measure up

They can measure up to 100-350m in case of non-prism measurements

(a) Microwave (b) Ifra-red

Signal alternation

Some average repeated measurements

EDM Accuracy

For short range EDM Instruments ±15mm+5ppm

For long EDM Instruments ± 3mmt

Distance is computed by (no. of wavelengths generated + partial wavelength)/2.

Standard or Random errors are described in the form of ± (Constant + parts per million).

- Constant is the accuracy of converting partial wavelength to a distance.
- ppm is a function of the accuracy of the length of each wavelength, and the number of wavelengths.

EDM Accuracy

Distance (ft)	Error (ft)	Linear Precision	PPM
10	0.0164	1:600	1670
25	0.0165	1:1,500	670
50	0.0166	1:3,000	330
100	0.0167	1:6,000	170
300	0.0173	1:17,000	60
500	0.0179	1:28,000	35
1000	0.0194	1:50,000	20
2000	0.0224	1:90,000	10
4000	0.0284	1:140,000	7
6000	0.0344	1:170,000	6

Table 1: EDM Error Tabulated Over Distance Where Error is ± (5 mm + 3 PPM)

Error & Accuracy

<u>Blunders:</u>

- **Incorrect 'met' settings**
- **Incorrect scale settings**
- **Prism constants ignored**
- **Incorrect recording settings**
  (e.g. horizontal vs. slope)

Typical accuracy ± 5 mm + 5ppm

Both the prism and EDM should be corrected for off-center characteristics.The prism/instrument constant (about 30 to 40 mm) can be measured by measure AC, AB, and

BC and then constant = AC-AB-BC

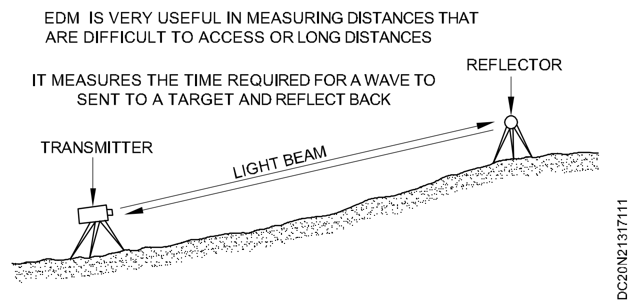
o--o------------------------------o

A B C

EDM Classifications

- Described by form of electromagnetic energy.
- First instruments were primarily microwave (1947)
- Present instruments are some form of light, i.e. laser or near-infrared lights.
- Described by range of operation.
- Generally microwave are 30 - 50 km range. (med)
- Developed in the eary 70's, and were used for control surveys.
- Light EDM's generally 3 - 5 km range. (short)
- Used in engineering and construction

Fig 1



Total Station Prism-Instrument error operation

Objectives : At the end of this lesson you shall be able to
- **explain Total Station Prisms**
- **describe sources of error in EDM**
- **EDM Instrument operation**
- **uses of EDM.**

Prisms

Fig 1

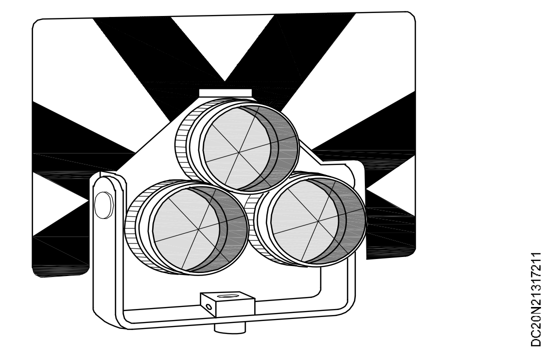
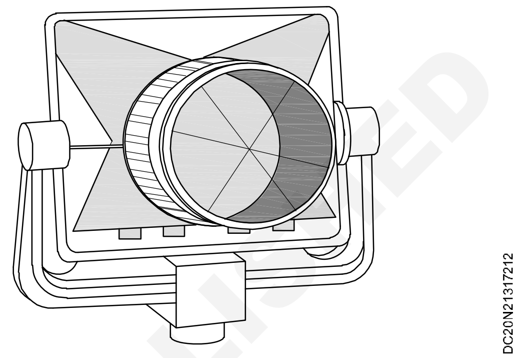


Fig 2



- Made form cube corners
- Have the property of reflecting rays back precisely in the same direction.
- They can be tribrach-mounted and centered with an optical plumment, or they can be attached
- To a range pole and held vertical on a point with the aid of a bulls-eye level.
- Prisms are used with electro-optical EDM instruments to reflect the transmitted signal
- A single reflector is a cube corner prism that has the characteristic to reflecting light rays precisely back to the emitting instrument
- The quality of the prism is determined by the flatness of the surface and the perpendicularity of the 90° surface

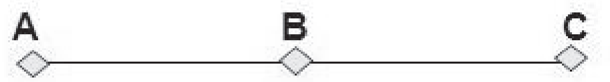
Source of Error in EDM:

Personal:
- Careless centering of instrument and/or reflector
- Faulty temperature and pressure measurements
- Incorrect input of T and P

Instrumental
- Instrument not calibrated
- Electrical centre
- Prism Constant (see next slide)

Natural
- Varying 'met' along line
- Turbulence in air

Determination of System Measuring Constant



1. **Measure AB, BC and AC**
2. **AC + K = (AB + K) + (BC + K)**
3. **K = AC- (AB + BC)**
4. **If electrical centre is calibrated, K represents the prism constant.**

Good Practice:

Never mix prism

types and brands on

same project!!!

Calibrate regularly !!!

Systematic

Errors/Instrumentation Error

- **Microwave**
- Atmospheric conditions
- Temperature
- Pressure
- Humidity - must have wet bulb and dry bulb temperature.
- **Multi-path**
- Reflected signals can give longer distances
- **Light** Atmospheric conditions
- Temperature
- Pressure
- **Prism offset**
- Point of measurement is generally behind the plumb line.
- Today usually standardized as 30mm

EDM instrument operation

1 Set up

- EDM instruments are inserted in to the tribrach
- Set over the point by means of the optical plummet
- Prisms are set over the remote station point
- The EDM turned on
- The height of the prism and the EDM should me measured

EDM instrument operation

2 Aim

- The EDM is aimed at the prism by using either the built in sighting devices on to EDM
- Telescope (yoke-mount EDMs) will have the optical line of sight a bit lower than the electronic signal
- When the cross hair is sight on target the electronic signal will be maximized at the center of the prism
- Set the electronic signal precisely on the prism center

EDM instrument operation

3 Measure

- The slope measurement is accomplished by simply pressing the measure button
- The displays are either liquid crystal (LCD) or light emitting diode (LED)
- The measurements is shown in two decimals of a foot or three decimals of a meter
- EDM with built in calculators can now be used to compute horizontal and vertical distance, coordinate, atmosphiric, curvature and prism constant corrections

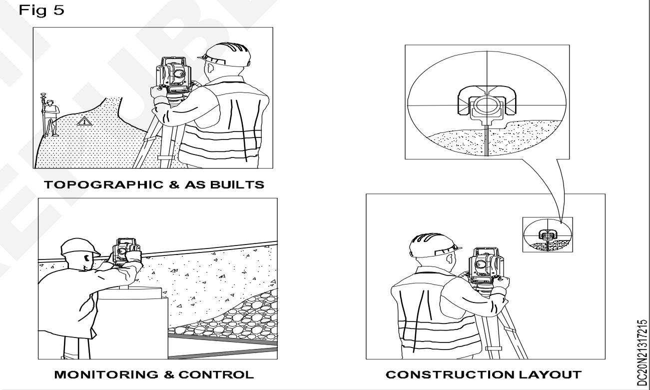
EDM instrument operation

4 Record

- The measured data can be recorded in the field note format
- Can be entered manually into electronic data collector
- The distance data must be accompanied by all relevant atmospheric and instrumental correction factors

Uses

Fig 5

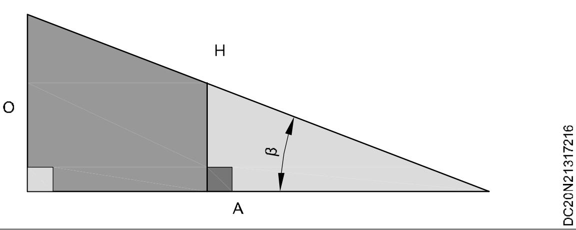


Uses

Total stations are ideal for collecting large numbers of points.

Plane Geometry

Fig 6



$$\text{Sin}\beta = \frac{O}{H} = \frac{xO}{xH}$$

$$\text{Cos}\beta = \frac{A}{H} = \frac{xA}{xH}$$

$$\text{Tan}\beta = \frac{O}{A} = \frac{xO}{xA}$$

They are commonly used for all aspects of modern surveying. Only when harsh conditions, exist or distances are short will a transit and tape be used.

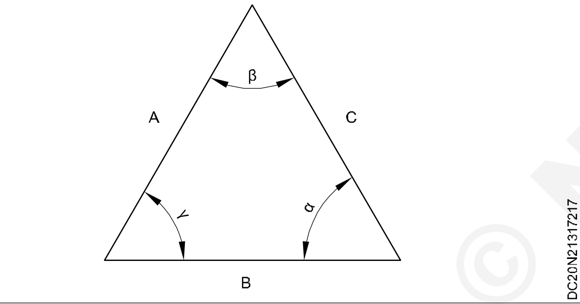
Problems

- Total stations are dependant on batteries and electronics. The LCD screen does not work well when it is cold.
- Battery life is also short, batteries and electronics both do not work well when wet.
- Total stations are typically heavier that a transit and tape
- Loss of data is an important consideration
- Plane geomentry vs spherical geometry

  Angles error x 1" with in 200 km^2 area

$$\frac{\text{Sin}\beta}{B} = \frac{\text{Sin}\alpha}{A} = \frac{\text{Sin}\gamma}{C}$$
$$C^2 = A^2 + B^2 - 2AB \times \text{Cos}\gamma$$

Fig 7



Distances error 0.009 mm pr km

Geometry of EDM Measurement

- Relatively simple if hi = HR
- More complicated when the EDM is on top of the theodolite and the prism is higher than the target

  (delta HR not equal to delta hi).

Plane Coordinates

Horizontal Coordinates

Vertical Coordinates

Trigonometry Levelling

Fig 8

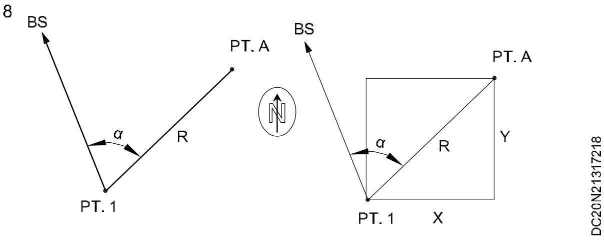


Fig 9

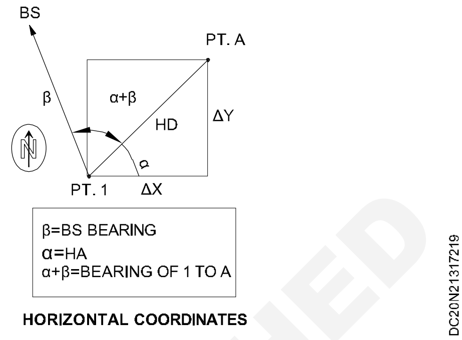


Fig 10

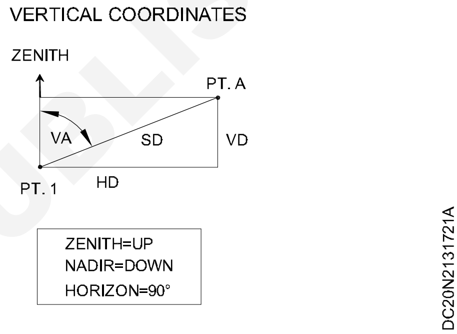
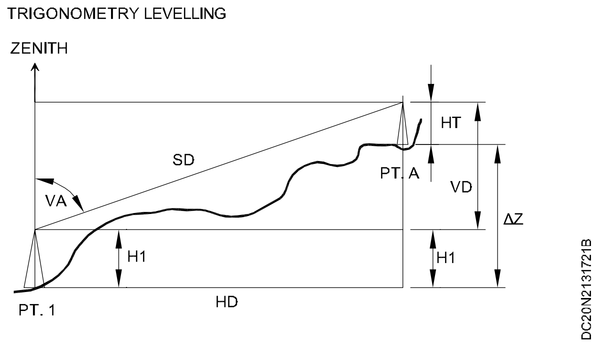


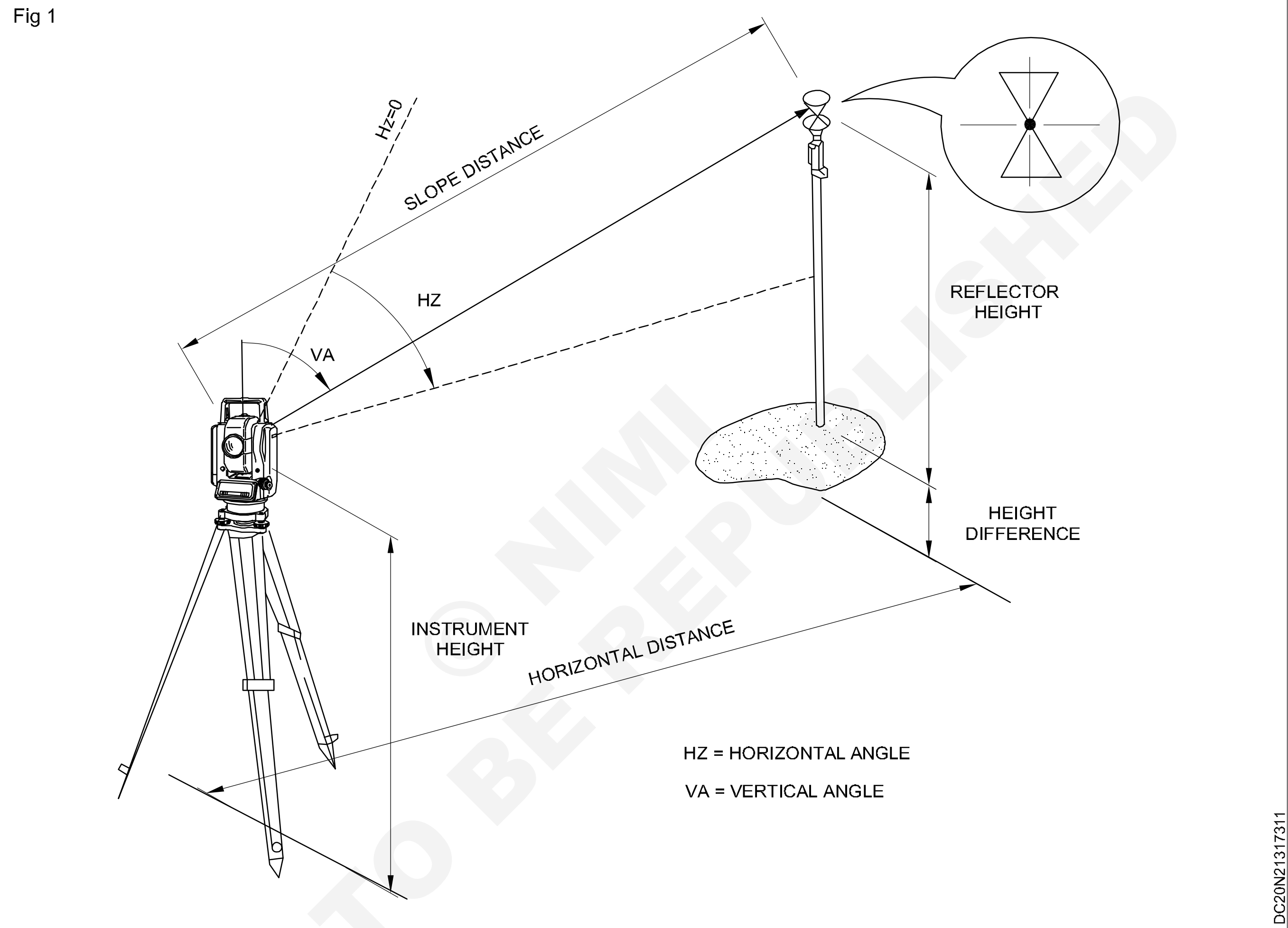
Fig 11



Electronic Display & Data recording

Objectives : At the end of this lesson you shall be able to
- **define Electronic Data recording**
- **explain Field Computers**
- **define Recording Modules**
- **that is internal memories.**

Fig 1



Electronic Data recording

The conventional method of recording surveys is overtaken by development in computer mapping and survey instrumentation which made electronic data recording and transfer essential.

The following are some methods of recording data electronically.

Data recoders:

These are dedicated to a particular instrument and can store and process surveying observations. These are also referred to as electronic field books. They use solid-state technology enabling them to store large amounts of data in a device of the size of a pocket calculator.

Field computers:

These are hand-held computers adapted to survey data collection. Comparing with a data logger, they offer a more flexible approach to data collection since they can be programmed for many forms of data entry.

Recording modules:

These are also called memory cards which take the form of plug-in cards onto which data is magnetically encoded by a total station. Data is transmitted to the memory card using a non-contact magnetic coupling system which eliminates the need to attach sockets or point to the card.

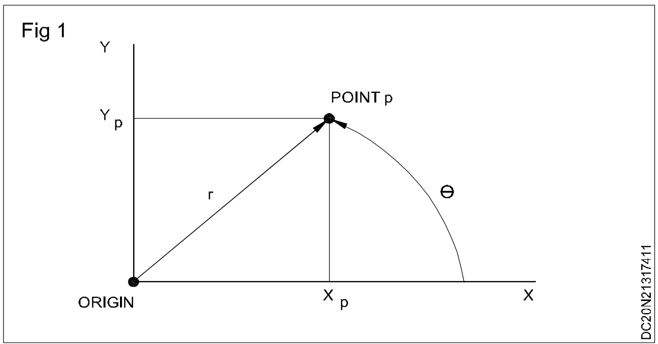
Internal memories:

A total station can be fitted with an internal memory capable of storing 900 to 10,000 points. This enables data to be collected without the need for a memory card or data recorder.

Rectangular and Polar Co-ordinate System

Objectives : At the end of this lesson you shall be able to
- **illustrate Rectangular and polar coordinates.**

Rectangular and polar co-ordinates Fig 1



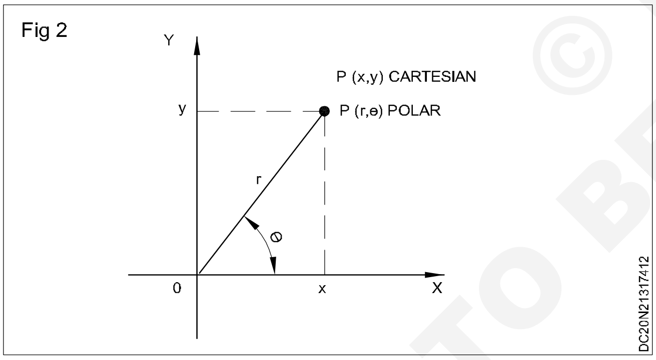
Point p can be located relative to the origin by Rectangular Coordinates (X_p, Y_p) or by Polar Coordinates

$$Xp = r\cos(\theta) \qquad r = \text{sqrt}\left(X_p^{\,2} + Y_p^{\,2}\right)$$

$$Yp = r\sin(\theta) \qquad \theta = \tan^{-1}\left(Y_p / X_p\right)$$

Converts from Polar to Cartesian coordinates.

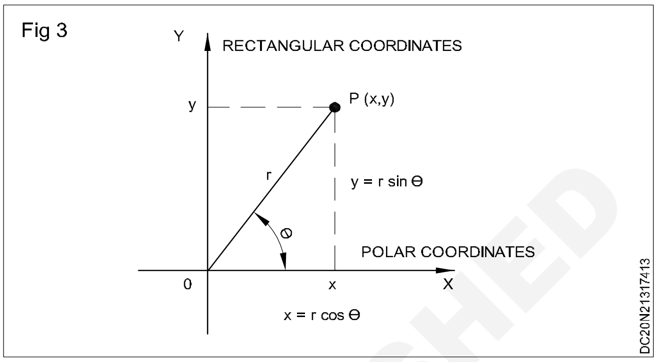
Transformation coordinates Fig 2



$\text{Polar}(r,\theta) \rightarrow \text{Cartesian}(x, y)$

$x = r\cos\theta c y = r\sin\theta$

Rectangular Coordinates Fig 3

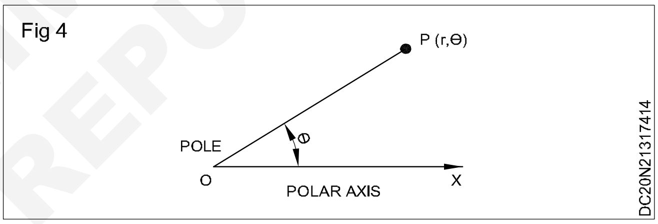


Polar Coordinate System

The **Pole**: point O

Polar Axis: ray from point O Fig 4

(along positive x-axis)



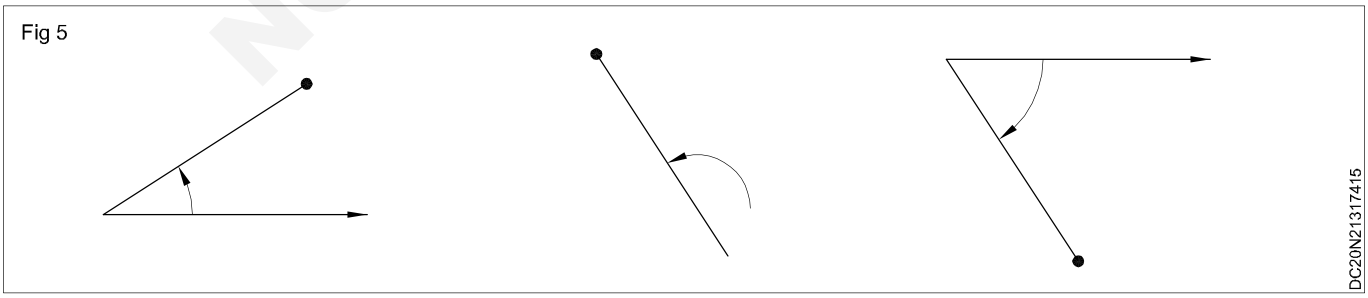
Polar Coordinates: (r, θ)

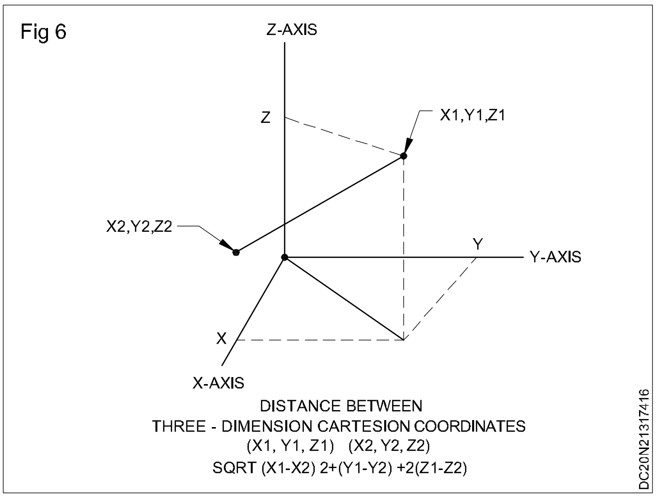
r: directed distance from O

θ : directed angle from polar axis

Plot the points with the given polar coordinates Fig 5

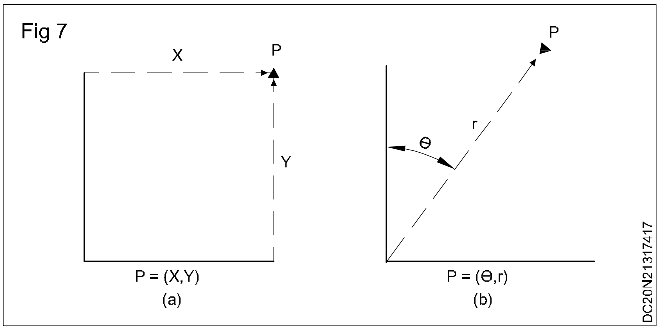
P $(2, \pi/3)$ Q $(-1, 3\pi/4)$ R $(3, -45°)$





Cartesian coordinates
Fig 7a

Polar coordinates
Fig 7b



Termmology of open and closed traverse

Objectives : At the end of this lesson you shall be able to
- **explain open and closed traverse in surveying**
- **explain the difference between close and open traverse.**

Open and Closed Traverses in Surveying

1 Background

A traverse is a form of control survey used in a wide variety of engineering and property surveys. Essentially, traverses are a series of established stations tied together by angle and distance. Angles are measured by theodolites or total stations; the distances can be measured by electronic distance measurement (EDM) instruments, sometimes by steel tapes. Traverses can be open, as in route surveys, or closed, as in closed geometic figures Figures 1 and 2).

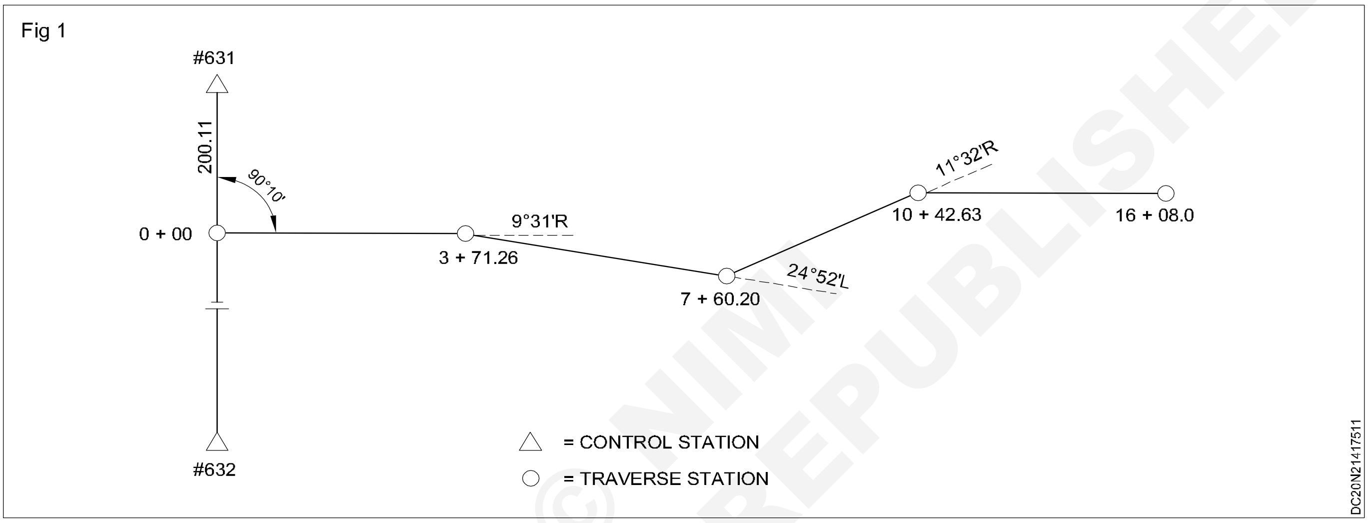
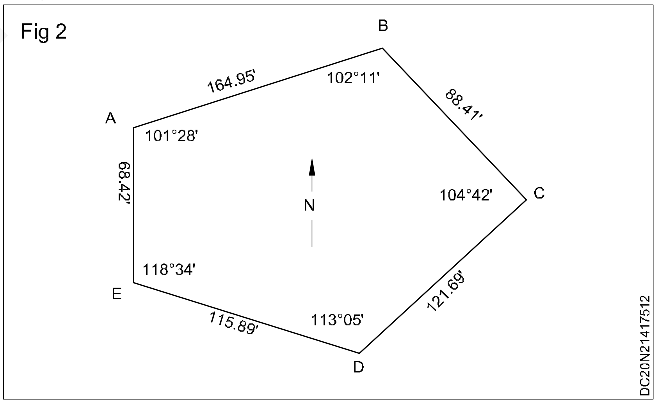


Figure 1: Open traverse

Traverse computations are used to do the following: balance field angles, compute latitudes and departures, compute traverse error, distribute the errors by balancing the latitudes and departures, adjust original distances and directions, compute coordinates of the traverse stations, and compute the area enclosed by a closed traverse. In modern practice, these computations are routinely performed on computers and/or on some total stations or their electronic field books/ data collectors. In this article. we will perform traverse computations manually (using calculators) to demonstrate and reinforce the mathematical concepts underlying each stage of these computations.

Figure 2: Closed traverse or loop traverse



In engineering work, traverses are used as control surveys

1 To locate topographic detail for the preparation of topographic plans and engineering design plan and profiles,

2 To lay out (locate) engineering works, and

3 For the processing and ordering of earthwork and other engineering quantities. Traverses can also help provide horizontal control for aerial surveys in the preparation of photogrammetric mapping.

1.1 **Open Traverse**

An open traverse (Figure 1) is particularly useful as a control for preliminary and construction surveys for highways, roads, pipelines, electricity transmission lines, and the like. These surveys may be from a few hundred feet (meters) to many miles (kilometers) in length. The distances are normally measured by using EDM (sometimes steel tapes). Each time the survey line changes direction, a deflection angle is measured with a theodolite or total station. Deflection angles are measured from the prolongation of the back line to the forward line (Figure 1); the angles are measured either to the right or to the left (L or R), and the direction (L or R) is shown in the field notes, along with the numerical values.

Field notes for open traverse

Angles are measured at least twice to eliminate mistake and to improve accuracy. The distance are shown in the form of stations (chainages), which are cumulative measurements referenced to the initial point of the survey, Open traverses may extend for long distances without the opportunity for checking the accuracy of the ongoing work. Thus, all survey measurements are repeated carefully at the time of the work, and every opportunity for checking for position and direction is utilized (adjacent property surveys and intersecting road and railroad rights-of-way are checked when practical.) Globlal positioning system (GPS) surveying techniques are also used to determine and verify traverse station positioning.

Many states and provinces have provided densely placed control monuments as an extension to their coordinate grid systems. It is now possible to tie in the initial and terminal survey stations of a route survey to corrdinate control monuments. Because the Y and X (and Z) coordinates of these monuments have been precisely determined, the route surveys changes from an open traverse to a closed traverse and is then subject to geometric verification and analysis. Of course, it is now also possible, using appropriate satellite-positioning techniques, to directly determine the easting, nothing, and elevation of all survey stations.

1.2 Closed Traverse

A closed traverse is one that either begins and ends at the same point or begins and ends at points whose position have been previously determined (as described above). In both cases, the angles can be closed geometrically, and the position closure can be determined mathematically. A closed traverse that begins and ends at the same point is called a loop traverse (Figure 2). In this case, the distances are measured from one station to the next and verified, using a steel tape or EDM instrument. The interior angle is measured at each station, and each angle is measured at least twice. In this survey, distances are booked simply as dimensions, not as stations or chainages.

Explain the difference between closed and open traverse. Comment on the advisability of using open traverses.

Answer: The difference between the two is that a closed traverse starts and ends on points with known location and an open traverse starts with a known point, but ends on a point with unknown location. An open traverse is usually not used since the error in location measurements cannot be computed. However, if an open traverse is used, measurements should be taken repeatedly.

What is the sum of the interior angles of a closed polygon traverse that has a) 6sides b) 8 sides and c) 12 sides?

Answer:

Sum of interior angles = (n-2)* 180°

a (6-2)* 180 = 720°

b (8-2)* 180 = 1080°

c (12-2)* 180 = 1800°

7 The interior angles in a five sided closed polygon traverse were measured and found to be: A = 139°10”11”, B = 126°17’43”, C = 94°28’30”, D = 71°04’59” and E =108°58’31”. Compute the angular misclosure. For what order and class is this survey?

Construction Draughtsman Civil - Global positioning systems | **Related Theory for Exercise 2.14.176**

Introduction of GPS System

Objectives : At the end of this lesson you shall be able to
- **explain EPS co-ordinate system**
- **describe geographic latitude and longitude**
- **GPS equipment.**

Introduction

Where am I? Where am I going? Where are you? What is the best way to get there? When will I get there? GPS technology can answer all these qustions. GPS satellite can show you exact position on the earth any time, in any weather, where you are! GPS technology has made an impact on navigation and positioning needs with the use of satellites and ground stations the ability to track aircrafts, cars, cell phones, boats and even individuals has become a reality.

System of satellites,computers, and receivers that is able to determine the latitude and longitude of a receiver on earth by claculating the time difference for signals from The Global Positioning System to reach the receiver. System (GPS) is a worldwide ratio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses the “Man-made stars” as reference points to calculate positions accurate to a matter of meters. In fact, with advanced forms of GPS you can make measurements to better than a cetimeter. In a sense it’s like giving every square meter on the planet a unique address. GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. And that makes the technology accessible economical. And that makes the technology accessible to virtually everyone. Navigation in three dimensions is the primary function of GPS. Navigation receivers are made for aircraft, ships, ground vehicles, and for hand carrying by individuals. Precise positioning is possible using GPS receivers at reference locations providing directions and relative positioning data for remote receivers. Surveying, geodetic control, and plate tectonic studies are examples. Time and frequency dissemination, based on the precise clocks on board the SVs and controlled by the monitor stations, is another use for GPS. Astronomical observatories, telecommunications facilities, and laboratory standards can be set to precise time signals or controlled to accurate frequencise by special pupose GPS receivers.

Definition

For thousands of years, navigators have looked to the sky for direction. Today, celestial navigation has simply switched from using natural objects to human-created satellites. A constellation of satellites, called the Global Positioning System, and hand-held receivers allow for very accurate navigation.

What is GPS?

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defence that continuously transmit coded information, which makes it possible to precisely identify locations on earth by measuring the distance from the satellites. The satellites transmit very low power specially coded radio signals that can be processed in a GPS receiver, enabling the receiver to compute positions, velocity and time thus allowing anyone with a GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock. The system was designed so that receivers did not require atomic clocks, and so could be made small and inexpensively.

The GPS system consists of three pieces. There are the satellites that transmit the position information, there are the ground stations that are used to control the satellites and update the infomation, and finally there is the receiver that you purchased. It is the receiver that collects data from the satellites and computes its location anywhere in the world based on information it gets from the satellites. There is a popular misconception to the satellites but this is not true, it only receives data.

After the second world war, it became obvious that we needed a solution to the problem of rapid and accurate absolute positioning. Over the next couple of decades, a number of projects and experiments were run. In the early1970’s, a bold experiment was proposed. A network of satellites, positioned thousands of miles above the earth, could provide rapid, accurate and absolute positioning anywhere. This vision became known as the Global Positioning System or GPS.

How accurate is GPS?

This is probably the most frequently asked posed question by new and potential GPS users. In practice, we have to trun this question around and ask, “How much accuracy do you need?” For example, for a hikere in the woods or a soldier in the field, a position within about 10 meters (30 feet) would usually be considered accurate enough. For a ship in coastal waters, accuracy on the order of about 5 meters (15 feet) is generally desirable. For geodetic land surveying, however, accuracy requirements are 1 centimeter (0.4 inches) or less. GPS can be used to achieve all these accuracies. For each required level of accuracy, receiver characteristics and the measurement techniques employed are different. Accuracy also depends on satellite configuration, nearby topography, distribution of buildings and trees, and even time to day.

Advantages of GPS

GPS has three advantages

i GPS may be used to identify or define the geographical co-ordinates associated with satellite imager. GPS is also used to reduce the distorsions and to improve the accuracy of these images positional. GPS receivers can be used to collect accurate geographical coordinates at these locations.

ii GPS can be used in the ground to get satellite images. When a particular satellite image has a region of unusual or unrecognised reflectivity the coordinates of that region can be loaded into GPS reciver.

iii GPS has developed into cost effective tool for updating GIS or computer aided design system. The GPS is an excellant device user can, generally see the sky and is able to get close to the objects to be mapped.

Setup and use of GPS equipment

GPS, or Global Positioning System, Devices are ubiquitous these days. They are on our phones, in our cars, and attached to many of our favorite apps. Today, We can use our GPS to get directions and find new places to eat and play, but learning how to use them can seem complicated thanks to the variety of different GPS styles. Luckily, all GPS devices are pretty simple to use.

Using simple GPS equipment

1 **Buy a smart phone or car GPS to get directions and your location:** The GPS market is flooded with different devices, option and features. Unless you plan or using your GPS in the wilderness or for research experiments, however, your smart phone or a car GPS can provide directions and your location quickly and easily. Most have touch screens and come with a rechargeable battery.

- **Smart phones:** Most smart phones come pre-loaded with a "Maps" or "Directions" app that uses GPS. If you do not have one, search and download an app, like Google Maps, from your app store to use for GPS.
- **GPS devices:** These are small, rectangular devices that specialize in driving directions and finding restaurants, airports, and other points of interest. Examples include Tom Tom, Garmin and Magellan etc.

2 **Open the "Map":** This is the basic screen for GPS. It shows a location, usually with your correct location at the centre, and all of the roads and major landmarks nearby.

3 **Click on "My Location":** Some GPS use touch screens, others have keypads, and some have scroll wheels and buttons. Click on the button labeled with a compass, navigational arrow, or crosshairs to show your current location.

- Your location is sometimes stored under the heading "Where am I?" "Favorite Locations" or "Current".
- iphone users can see their current location using the bulit-in Compass App. Make sure you "Allow Location Services" for the compass under "Settings" "Compass".

4 **Choose your destination address:** Using the search bar found at the top of your GPS, type in the address you want to reach. Many touch screen GPS's let you choose a location by holding your finger on the location in the map.

- Some GPS's will prompt you with a button labeled "Get Directions". Choose this if there is no search bar to input an address.
- If you know the exact latitude and longitude of your trip, use these; they will give you the most accurate location possible.

5 **Follow the GPS instructions to get to your location:** The GPS will give you directions at every turn you need to take. Don't worry if you miss a turn- most GPS will auto-correct and give you a new route to get back on track.

- If you are struggling to keep up, check your GPS's setting and make the "Trun Warning Frequency" setting longer - giving you more time to hear the next direction.

Using GPS for research and exploration

1 **Learn to read latitude and longitude coordinates:** latitude and longitude are represented by numbers, known as degrees, which measures your distance from tow "zero lines" Longitude measures your distance East or West of the prime meridian, and latitude mesure your distance North or South of the equator. This is the most accurate system of measurement for your GPS.

- An examples (guess where it is), is 37° 26'46.9"N, 122°09' 57.0"W.
- Sometimes direction is noted by positive or negative numbers. North and East are considered positive. The previous example could be written as: 37° 26' 46.0",-122° 09" 57.0"
- If there is no notation, know that the latitude always comes first.

2 **Mark you current location as a waypoint:** Waypoint are saved in the GPS to be viewed later, allowing you to take notes, draw maps, and keep information on the landscape easily. On your GPS click "Save location","And to Favourites," or "Mark Waypoint".

- Complex scientific GPS systems often let you mark specific waypoints-artifacts, streams rock formations, etc.
- The more points you save into your GPS, the more accurate your map of the area when you get home.

3 **Set waypoints in advance if there are no addresses:** Plug in the longitude/latitude coordinates of water sources, compgrounds, or ranger stations under "Get Directions" or "Find Location" then save them by clicking "And to Favourites". You can now access it anytime.

- "Add to Favourites" might be labeled by a star or flag as well.
- Click "Saved Locations" or "Favourite Locations" to see your waypoints anytime. You can click on them to get directions from anywhere in the world.

4 **Plug your GPS into your computer to download the data:** Most complex GPS systems come with software that lets you save your data onto your computer. The program will import your waypoints and use them to make a map of the area you were in, complete with elevation data and any notes you made on your GPS.

- If you are mapping a specific area, make as many waypoints as you can for an accurte map. The more data the program has, the better the final product.

Troubleshooting your GPS

1 **Download the latest map updates if your directions are incorrect:** If you are using a phone this will heppen automatically, but some GPS devices need to be manually updated. This will give you the latest information, topography, and directions.

- Find the "About" button, usually located in "Settings."
- Scroll down to see Map Information. If this is more than 6 months old, you will need to update.
- Plug your GPS into an internet-enables computer using the cord that came with the unit.
- Perform an internet search for "your GPS + Map Update" follow the onscreen instructions.

2 **Know that GPS uses satellites to locate you:** There are over 25 satellites orbiting earth that receive signals from your GPS and use those signals to determine your latitude and longitude. Developed by the army, GPS can accurately tell your location anywhere in the world by several feet - as long as the signal can reach the satellites.

- Cell phone GPS uses cell towers and internet signals to find your location , so they won't work in the wilderness.

3 **Get into the open:** GPS needs a clear view of the sky to accurately communicate with the satelite's, so move away from overhangs or tall trees and head outside if you have issues. Generally, if you can see the sky, the GPS can as well.

- Tunnels, caves, and basements may all keep your GPS from communicating to satellites and working successffully.

4 **Initialize your GPS when yo buy it:** Most GPS devices are built in Asia, and are used to communicating with satellites over that area. Initializing your GPS acquaints it with your local area. To initialize a GPS, go to "Settings" and click "Initialize". Follow your GPS's manual if you have any problems finding the GPS's manual if you have any problems finding the setting, and know that this may take up to 20 minutes.

- Turn your GPS off and restart it if you are having problems.
- Make sure you have a clear view of the sky.
- You may need to reset your GPS the first time you buy it by clearing the memory. Refer to the manual for instructions.

5 **Use "Satellite Lock" before you head out:** This is especially useful when hiking. In the parking lot, find your GPS's satellite lock setting and have it get to work - it usually takes several minutes.

- Signs that you have a bad signal are changing directions, jittery locations, or error messages.

6 **Know that GP'S are not replacements for maps and compasses:** Because and GPS can run out of battery, lose signal, or break, you should never rely on it completely to get around. While useful, you need to be prepared in case you cannot use it for some reason.

Getting the most out of your GPS

1 **Find shops,restaurants, and events near you:** Most GPS devices can find much more than addresses these days. Try searching "Indian Food", "Post Offices", "Gas, "Rock climbing gyms", or whatever else you are interested in and see what pops up. This can be incredibly useful when you are in a new city, or if you just feel like finding the closest burrito shop.

- Apps and Internet enabled GPS (like those found on phones) will always have this feature.
- Many portable GPS devices have a section labeled "Nearby Loctions" of "Find Locations" that list businesses within a short radius of your current location.

2 **Have fun Geocaching:** Geocaching is when people hide objects in the world with GPS coordinates. It is a global community that prides itself on sharing and exploration, and can be a great way to see the outdoors. To Geocache, buy a GPS and sign up for one of the many internet-based services and forums.

3 **Track your workouts:** Most modern GPS devices and apps can be turned on while you run or bike, and store the information on your speed, elevation, and distance for later. You will need a specific app like NikeFit, MapMyRun, or AppleHealth to get the most out of this feature.

4 **Find a lost phone:** Because smart phones are constantly hooked up to a GPS, You can use them to find lost or stolen phones if you act quickly. Download a tracking app on for your phone and sync it with your computer to always keep tabs on your phone's location.

- Use "Find my iPhone", going to the Find my iPhone Website and inputting your Apple user name.

Satellite and Convensional Geodetic system

Objectives : At the end of this lesson you shall be able to
- **what is satellite System?**
- **define Geodetic System.**

The satellites of the Global Positioning System (GPS) offer an important new geodetic resource making possible a highly accurate portable radio geodetic system. A concept called SERIES (Satellite Emission Radio Interferometric Earth Surveying) makes use of GPS radio transissions without any satellite modifications. By employing the technique of very long baseline interferometry (VLBI) and its calibration methods, 0.5 to 3 cm three dimensional baseline accuracy can be achieved over distances of 2 to 200 km respectively, with only 2 hours of on- site data acquision. The use of quasar referenced ARIES Mobile VLBI to establish a sparse fundamental control grid will provide a basis for making SERIES GPS measurements traceable to the time-invariant quasar directions. Using four SERIES stations deployed at previously established ARIES sited, allows the GPS satellite apparent positions to be determined. These apparent positions then serve as calibrations for other SERIES stations at unknown locations to determine their positions in a manner traceable to the quasars. Because this proposed radio interferometric configuration accomplishes its signal detection by cross-correlation, there is no dependence upon knowledge of the GPS transmitted waveforms which might be encrypted. Since GPS radio signal strength are10^5 Stronger than quasar signals, a great reduction in telecommunications sophistication is possible which will result in an order of magnitude less cost for a SERIES GPS station compared to a quasar based mobile VLBI system. The virtually all-weather capability of SERIES offers cost-effective geodetic monitoring with applications to crustal dynamics and earthquake research.

Satellite Systems (GNSS) such as **Global Positioning System (GPS)**, cellular network infrastructure or on the integration ... **GPS** receivers **Convert** space vehicles (SV) signals into **position**, velocity, and time estimates. Currently some **geodetic** type receivers are available on the market tracking **GPS** and Glonass **satellites** ...

System (**GPS**) operation and application are the computational developments that have led to accurate user **positioning**. This information discusses some of these developments from a historical perspective. The developmental odyssey begins with the events leading to initial **GPS** operation. Early developments in **satellite**...

The Global Postioning System (GPS). ▫ A **satellite-** based ... In **geodesy**: shape and rotation of the Earth, terrestrial reference frame. In solid Earth ... **GPS positioning:** A simple principle. ▫ Principle of **GPS positioning:- Satellite** 1 sends a signal at time Ground receiver receives it signal at time t r. - The range ...

The effectiveness of global positioning system electronic navigation ...

Global Positioning System (**GPS**) is a worldwide radio-navigation system that consists of a constellation of twenty-four satellites located in six orbits, The position in the X, Y, and Z dimensions along with time are converted in the receiver to calculate geodetic latitude, longitude and height above the ellipsoid.

The **Global Positioning System (GPS),** originally Navstar GPS, is a space-based radio navigation system owned by the United State government and operated by the United States Air Force. It is a global navigation **satellite system** that provides geolocation and time information to a **GPS** receiver anywhere on or near the...

Satellites in orbit: 31
Orbital height: 20, 180 km (12,540 mi)
Total satellites: 33
Accuracy: 5 meters

World Geodetic System -

The **World Geodetic System (WGS)** is a standard for use in cartography, geodesy, and navigation including **GPS.** It comprises a standard coordinate **system** for the Earth, a standard spheroidal reference surface for raw altitude data, and a gravitational equipotential surface (the geoid) that defines the nominal sea level.

Global Positioning System Overview -

Global Positioning System (GPS) Overview. ... Four **GPS satellite** signals are used to compute positions in three dimensions and the time offset in the receiver clock.... Geodetic Coordinates. ECEF XYZ to **Geodetic** Coordinate Conversion. Geodetic to ECEF XYZ Coordinate Conversion; Latitude and longitude are usually ...

Is GPS accurate?

Certain atmospheric factors and other sources can affect the accuracy of GPS receivers. Garmin GPS receivers are typically accurate to within 10 meters. Accuracy is even better on the water. Some Garmin GPS receiver accuracy is improved with WAAS (Wide Area Augmentation System).

What does the accuracy of a GPS mean?

User Range Error (URE) vs. User **Accuracy.** To calculate its position, a **GPS** device measures its distance (range) form multiple **GPS** satellites. URE is a measure of ranging accuracy. User **accuracy** refers to how close the device's calculated position is from the truth, expressed as radius. Dec 5, 2017

What can affect the accuracy of a GPS?

Accuracy depends on a wide variety of **factors** coming together at a particular location and time. They include distortion of **GPS** signals as they travel through the ionospere and errors in the position (ephemeris data) transmitted by **GPS** satellites.

Why do GPS receivers need to receive signals from four satellites?

The **GPS receiver** also knows the exact position in the sky of the satellites, at the moment they sent their **signals**. So given the travel time of the **GPS signals** from three satellites and their exact position in the sky, the **GPS receiver** can determine your position in three dimensions - east, north and altitude.

What causes errors in GPS?

Multipath effects. **GPS** signals can also be affected by multipath issues, where the radio signals reflect off surrounding terrain; buildings, canyon walls, hard ground, etc. These delayed signals **cause** measurement **errors** that are different for each type of GPS signal due to its dependency on the wavelength.

Can GPS be used without internet?

The Maps app **requires** an **internet** connection to download the Map information and imagery as you move along. The **GPS** itself does not **require** an internet connection. The free Google Maps app can now download areas of interest in advance of needing them.

Can GPS be used to transmit data?

GPS receivers do not transmit any information they are built for receiving information. The encompassing device then uses said information depending on what the device was built for. 'Talking' to'the satellites' is not a necessary part of GPS functionality.

What kind of signal does a GPS use?

Each GPS satellite continuously broadcasts a navigation message at 50 bits per second on the microwave carrier frequency of approx 1600 MHz. FM radio, for comparison, is broadcast at between 87.5 and 108.0 MHz and Wi-Fi networks operate at around 5000 MHz and 2400 MHz More precisely, all satellites broadcast at 1575.42 ...

What is the accuracy of GPS devices?

The United State government currently claims 4 meter RMS (7.8 meter 95% Confidence Interval) horizontal accuracy for civilian (SPS) GPS. Vertical accuracy is worse. Mind you, that's the minimum. Some devices/ locations reliably (95% of the time or better) can get 3 meter accuracy.

Geodetic Coordinates

Roger Foster

Coordinate System Analysis Team (CSAT)

In order to discuss geodetic coordinates, we must first discuss the three axes. (See Figure 1) The Z-axis is the rotational axis of the ellipsoid. The X-axis lies in the equatorial plane and intersects the prime meridian. The Y-axis also lies in the equatorial plane and is 90 degrees from the X-axis. (Please note that all of the axes extend completely through the ellipsoid, but only half of each axis is shown for illustrative purposese.)

In the example in figure 1, we are determining the geodetic coordinates (longitude, latitude, and geodetic height) of a point on the earth surface near the border of Indian and Pakistan. The light green colored line is perpendicular to the ellipsoid at the example point and therefore, does not intersect the center of the ellipsoid. The darker green line is this projected onto the equatorial plane.

To measure the geodetic longitude, symbolized by the Greek letter lambda,λ,we would measure the angle from the X-axis (or the Prime Meridian) to the dark green line on the equatorial plane. The geodetic latitude, symbolized by the Greek letter phi, ϕ, would be the angle between the two green lines.

Figure 2 illustrates geodetic height, which is represented by a lower case letter "h". Consider a line drawn from a point on the earth's surface. The distance along that line from the earth's surface perpendicular to the ellipsoid surface. The distance along that line from the earth's surface to the ellipsoid is the geodetic height, also referred to as the "height above the ellipsoid" (HaE). It is important to note that geodetic height is not the same as height above Mean Sea Level, and is not the same as orthometric height (or height above the geoid). Geoids will be discussed in the next article.

Figure 1

Geodetic coordinates are commonly derived from Global Positioning System (GPS) receivers. A directive by the Joint Chiefs (CJCS 3900.01B) urges the adoption of geodetic coordinates, in particular, geodetic height, for use in weapon systems, targeting and all geospatial information for DoD.

Figure 2

Geoids and Vetical Datums

The next will discuss geoids and vertical datums.

Fig 1

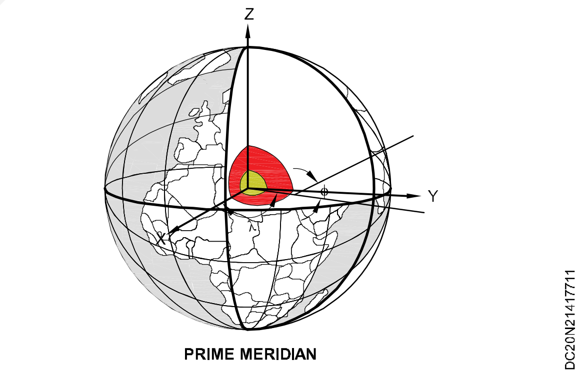
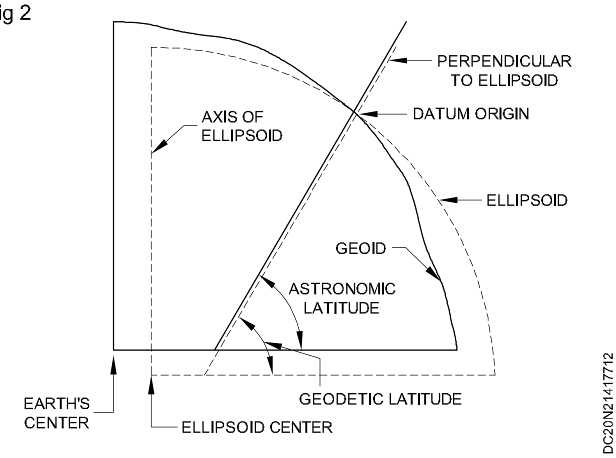


Fig 2



GPS co-ordinate system & components of the GPS system & Segments

Objectives : At the end of this lesson you shall be able to
- **explain GPS co-ordinate systems**
- **describe geographic latitude and longitude**
- **explain components of GPS system**
- **describe components of GPS receiver.**

Introduction

Satellites orbit around the earth or travel in the planet system of the sun. 1 They are generally observed from the earth. To describe the orbits of the statellites (positions and velocities), suitable coordinate and time systems have to be defined. Before starting a GPS surveys, decide which co-ordinate system to use.

History

In 1884, the United states hosted the Internation Meridian Conference and twenty-five nations attended. Twenty-two of them agreed to adopt the longitude of the Royal Observatory in Greenwich, England, as the zero-reference line. The Dominican Republic voted against the motion, while France and Brazil abstained. France adopted Greenwich Mean Time inplace of local determinations by the Paris Observatory in 1911.

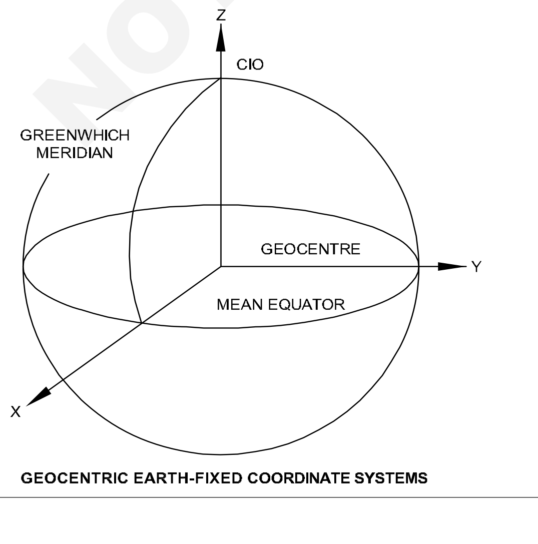
GPS Coordinate system

GPS measurements are referenced to the 1984 World Geodetic System reference ellipsoid, known as WGS84. However, for most survey tasks, results in terms of WGS84 have little value. It is better to display and store results in terms of a local coordinate system. Before you start a survey, choose a coordinate system. Depending on the requirements of the survey, you can choose to give the results in the national coordinate system, a local coordinate grid system, or as local geodetic coordinates.

Geographic coordinate system Fig 1

A geographic coordinate system is a coordinate system that enables every location on the earth to be specified by a set of numbers or letters, or symbols. The coordinates are often chosen such that one of the numbers represents vertical postion, and two or three of the numbers represent horizontal position. A common choice of coordinates is latitude, longitude and elevation.

Fig 1



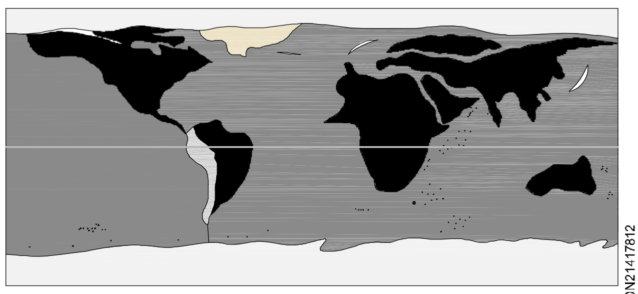
GEOCENTRIC EARTH-FIXED COORDINATE SYSTEMS

Geographic latitude and longitude Fig 2

The “latitude (abbrevation: lat.,φ, or phi) of a point on the Earth’s surface is the angle between the equatorial plane and the straight line that passes through that point and throught (or close to) the centre of the Earth. Lines joining points of the same latitude trace circles on the surface of the Earth called parallels, as they are parallel to the equator and to each other. The north pole is 90° N; the south pole is 90° S. The 0° parallel of latitude is designaed the equator, the fundamental plane of all geographic coordinate systems. The equator divides the globe into Northern and Southern Hemispheres.

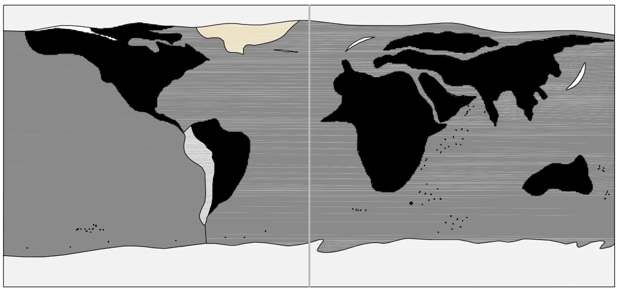
The “longitude” (abbreviation: Long., l, or lambda) of a point on the Earth’s surface is the angle east or west from a reference meridian to another meridian that passes through that point. All meridians are halves of great ellipses (often improperly called great circles), which converge at the north and south poles. The meridian of the British Royal Observatory in Greenwich, a little east of London, England, is the International Prime Meridian although some organizations - such as the French Institute Geographique National - continue to use other meridians for internal purposes. The Prime Meridian determines the proper Eastern and Western Hemisphers, although maps often divide these hemispheres further west in order to keep the Old World on a single side. The antipodal meridian of Greenwich is both 180° W and 180° E. This is not be conflated with the International Data line, which diverges from it in several places for political reasons including

Fig 2



GRAPHIC LATITUDE AND LONGITUDE - EQUATOR between far eastern Russia and the far western Aleutian Islands Fig 3.

Fig 3

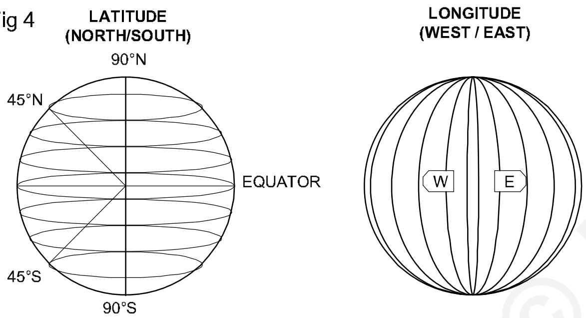


GRAPHIC LATITUDE AND LONGITUDE - PRIME MERIDIAN

DC20N21417813

The combination of these two components specifies the position of any location on the surface of the Earth, without consideration of altitude or depth. The grid thus formed by latitude and longitude is known as the "graticule". The zero/ zero point os this system is located in the Gulf of Guinea about 625 km (390 mi) south of Tema, Ghana Fig 4.

Fig 4



LONGITUDE LINES ARE PERPENDICULAR AND LATITUDE LINES ARE PARALLEL TO THE EQUATOR

GRAPHIC LATITUDE AND LONGITUDE

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Reading coordinates

To simplify map navigation, a system of coordinates is used. Coordinates divide the map into a grid and identiry a particular location by listing its relative position north/south and east / west. To choose a coordinate system, simply go to the Preferences screed. The most common coordinate systems used in GPS navigation are:

- **DMS (Degrees/Minutes/Seconds):** This is the standard way of listing latitude and longitude.

  Example: N47° 37' 12" W122° 19' 45".

  In this example, N47°37' 12" indicates that the north/ south position is 47 degrees, 37 minutes and 12 seconds north of the equator; while W122° 19' 45" places the east/west position at 122 degrees, 19 minutes and 45 seconds west of the Prime Meridian (at Greenwich, England)

- **DDM (Degree/Decimal/Minutes):** A decimal of DMS, DDM is used by geocachers and other GPS enthusiasts. These coordinates look like this:

  Example: N47° 37.216' W122° 19.75'.

  The north/south and east/west position remains unchanged. The difference is that the seconds part of the location is converted to a decimal by dividing the seconds by 60.

- **UTM (Universal Transverse Mercator):** This military deriver grid system is not tied to latitude and longitude. It divides the map into a square grid with the grid lines all 1,000 meters apart. Most topo maps have UTM grid lines printed on them. The system is metric-based and requires no conversion of minutes and seconds.

Example 10T 0550368 5274319.

Here, "10T" identifies the map zone, "0550368" is the east/ west or "easting" number, while "5274319" is the north/ south or "northing" number.

Your GPS receiver can automatically display whichever of these coordinate systems you select. It can also convert coordinates form one system to another. This is helpful if you're given coordinates for a location in one system (e.g.,UTM) but want to actually navigate in another (e.g.,DDM).

Components of the GPS system

There are 3 min components to the GPS system. These components are known as Segments, as follows Fig 5.

1 Space Segment - the satellites, also known as space vehicles of SVs

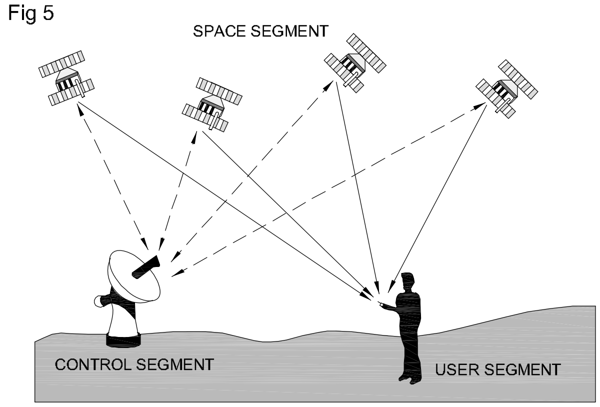
2 Control Segment - ground stations run by the DOD

3 User Segment - all users and their GPS receivers

Vocabulary / Definitations

GPS	:	Glopal Positioning System
Satellite	:	An object launched specifically to orbit
Receiver	:	A device that accepts (recives) incoming signals and converts them to a usable form.
Orbit	:	The path an object in space follows as it circles the Earth.
Trilateration	:	Postion determined by intersecting distances.
Triangulation	:	The location of an unknown point by the formation of a triangle.

Fig 5



SEGMENTS OF GPS SYSTEM

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Each segments is described in the following sections

1 Space segment Fig 6

The space segment consists of the GPS satellites. Much of the GPS literature refers to the satellites as “space vehicles” or simply, SV’s. The arrangement of GPS satellites in space is called their constellation. The minimum constellation to meet the objecives of the DOD is 24 operational satellites.

The orbit altitude was selected so that each satellite repeats the same track over any point on earth approximately once every 24 hours. One orbit takes a little less than 12 hours. There are six orbital planes, with nominally four stallites per orbital plane. The lanes are equially spaced 60 degrees apart inclined at about 55 degrees to the equator. The configuration was optimized to provide the best coverage between about 75 degrees north latitude and 75 degrees south latitude. This constellation provides the user with between five and eight satellites visible from most any point on earth at any time.

Fig 6

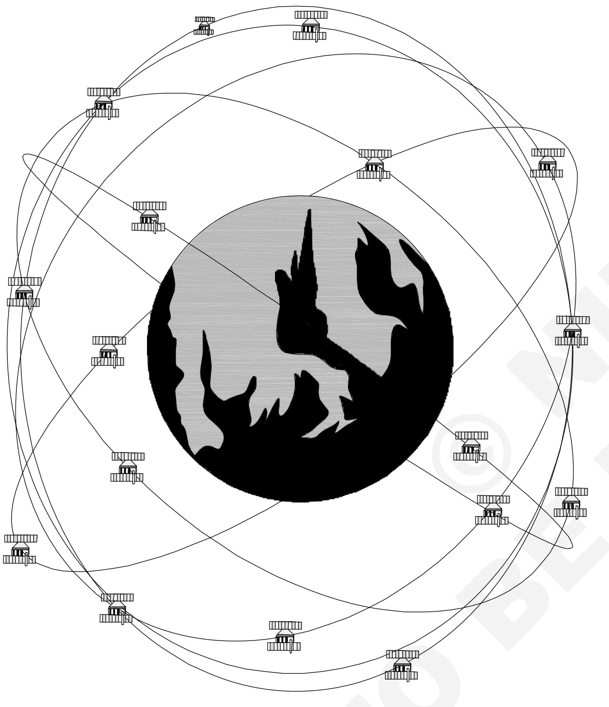
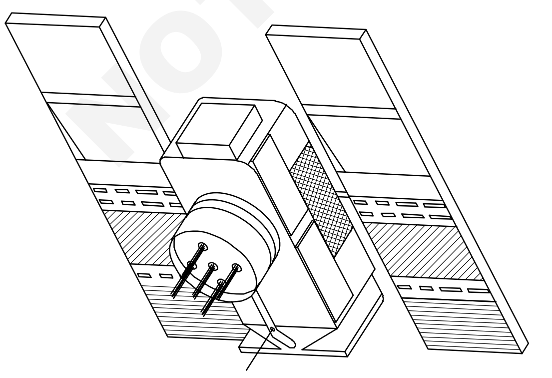


Fig 7



The satellite orbits are approximately 2,200 kilometers (12,000 miles) above the earth surface. The satellites travel at about 12,000 km/hour (7,000 miles per hour). Each satellite is solar powered with battery backup, and contains radio receivers and transmitters, one or more atomic clocks, small thrusters used for course corrections, special antennas, and, of course, computer equipment. The antennas on the satellites are designed to allow GPS signals to be received anywhere from the earth’s surface to about 5,00 km (3,000 miles) into space. This “service volume” not only meets all civilian needs, but also provides the military with satellite tracking and missile guidance capabilities.

The first GS satellite was deployed in February 1978. By 1994, a total of 24 operational satellites were inplace. Replacements and upgraded satellites have been launched on a regular basis. As of early 2001, a total of 43 satellites had been launched, and the operational constellation consists of 28 satellites. The number of satellites reported in various books, articles and internet resources varies considerably, reflecting the data that the work was prepared.

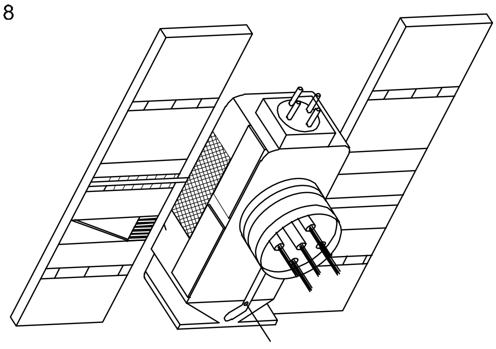
GPS satellites

Four classes (generatons): blocks I, II, IIA, IIR and IIF
Block I (Fig 8)

- 11 satellites launched between 1978 and 1985 on Atlas Frockets.
- Life expectancy = 4.5 years, actual mean life = 7.1 years.
- Signal entirely accessible to civilian users
- Last block I satellite died on February 28, 1994

Block II (Fig 9)

Fig 8



- Possiblility to degrade the signal for civilian users
- 1 satellite ~ 25million dollars
- Life expectancy = 10 years
- 5 m3, 2 tons, solar panels, boosters

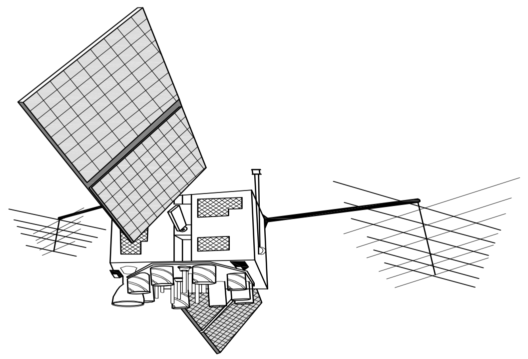
New launches on a regular basis

Monitored and controlled from the ground

2 Control segment

The control segment consists of a master control station in colorado springs, colorado with five monitor stations and three control up link stations located throughout the world. Monitor stations track all GPS satellites in view and collect ranging information from the satellite broadcasts. The monitor stations send information they collect from each of the satellite back to the master control

Fig 9



station which computes extremely precise statellite orbits. The information is then formated into updated navigation message for each satellite. The updated information is transmitted to each satellite the control up link stations which also transmit and receive satellite control and monitoring signals.

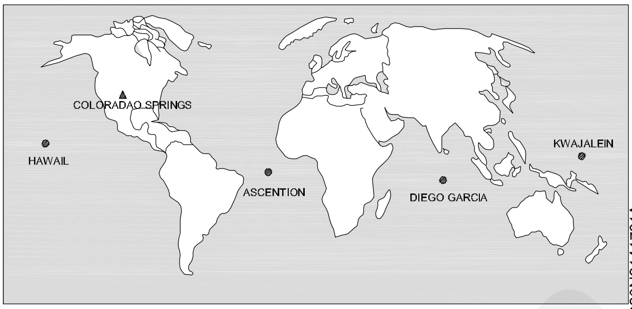
The monitor stations receive all satellite signals from which they determine the pseudo range to all visible satellites and transmit the ranged data along with local meteorological data via data link to the master control station. From these data the master control station precomputes satellite ephemerides and the behaviour of the satellite clocks and formulates the navigation data. The message data are transmitted to the ground antennas and up linked via S-band to the satellites in view. Because of the global distribution of the up load antennas at least three contacts per day can be realized between the control segment and each particular satellite.

The US Military operates the control segment. There are five control stations around the world, four unmanned stations near the equator and one Master Control Station in Colorado, as shown on the following Fig 10.

3 User segment

The user segment consists of all the users of the GPS signals. This includes both civilian and military users. It is important to note that GPS receivers do not send any signals back to the GPS satellites. Therefore, it is not possible to track the position of a receiver using GPS satellites. The satellites merely transmit their signals blindly throughout the service volume. In this way, the number of potential users at any one time is unlimited, and there is

Fig 10



LOCATION OF THE FOUR UNMANNED STATIONS (CIRCLES)

not interference between users.

As opposed to the space and control segments, which are maintained by the US government, the user segment is served by many commercial companies who manufacture and sell GPS receiver hardware, software and services. Anyone in the world can make and market GPS receiver equipment. There are no licences, user fees, or any other restrictions. Allowing the private sector to design and maufacture receiver equipment has resulted in a continual reduction in size.

Components of GPS receiver

The components of a GPS receiver are:

i Antennas with preamplifier

ii RF section with signal identification and signal processing

iii Microprocessor for receiver control data sampling, data processing.

iv Precision oscillator

v Power supply

vi User interface, command & display panel

Memory data storage

The antenna detects the electromagnetic waves arriving from the satellites converts the wave energy into electric current amplifies the signal strength and hand over to the signals over the receivers electronics. GPS signal structure requires that all GPS antennas must be circularly polarized. The antennas have to be very sensitive because of the rather weak satellite signal and the gain pattern must allow signal reception from all elevations and azimuths of the visible hemisphere.

GPS Segments

Objectives : At the end of this lesson you shall be able to
• **define GPS Segments.**

Fig 1

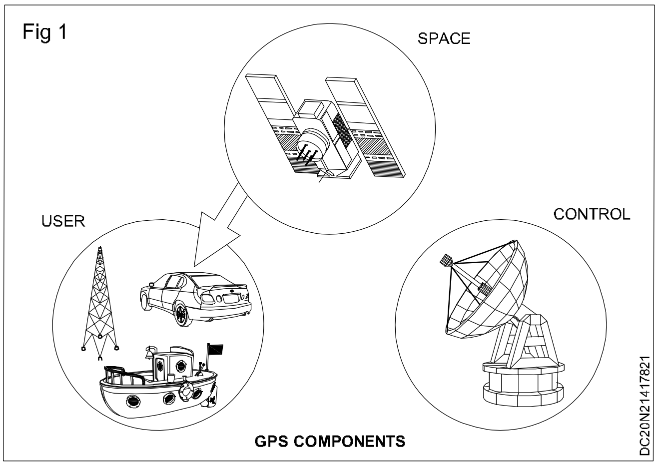
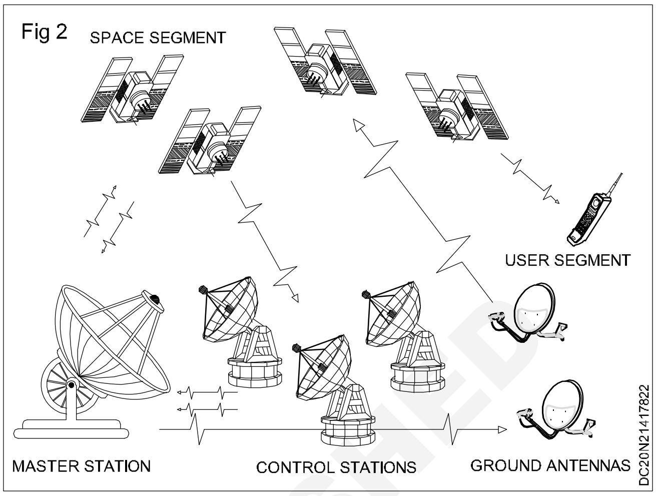


Fig 2



Various Segments:

For better understanding of GPS, we normally consider three major segments viz. space segment, control segment and User segment. Space segment deals with GPS satellites systems, control segment describes ground based time and orbit control prediction and in User segment various types of existing GPS receiver and its application is dealt (Fig.3).

Table 1 gives a brief account of the function and of various segments along with input and output information.

Table 1

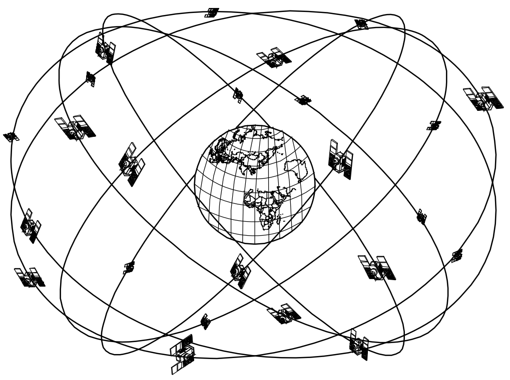
Segment	Input	Function	Output
Space	Navigation message	Generate and Transmit code and carrier phases and navigation message	P-Code C/A Code L1,L2 carrier Navigation message
Control	P-Code Observation Time manage space vehicles	Produce GPS time Predict ephemeris	Navigation message
User	Code observation Carrier phase observation Navigation	Navigation solution Surveying solution Message	Position velocity time

GLONASS (Global Navigation & Surveying System) a similar system to GPS is being developed by former Soviet Union and it is considered to be a valuable complementary system to GPS for future application.

Space segment:

Space segment will consist 21 GPS satellite with an addition of 3 active spares. These satellites are placed in almost six circular orbits with an inclination of 55 degree. Orbital height of these satellites is about 20,200 km corresponding to about 26,600 km

Fig 3



GPS NOMINAL CONSTELLATION
24 SATELLITES IN 6 ORBITAL PLANES
4 SATELLITES IN EACH PLANE
20,200 KM ALTITUDES, 55 DEGREE INCLINATION

DC20N21417823

Fig 4

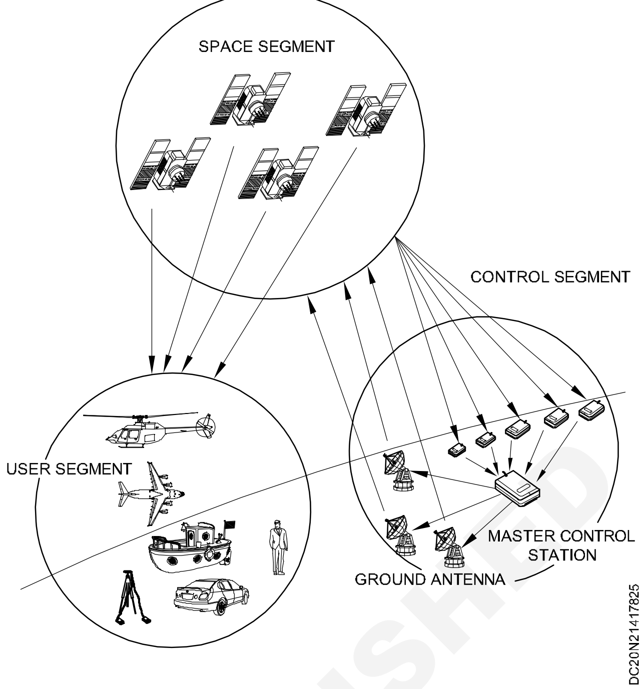
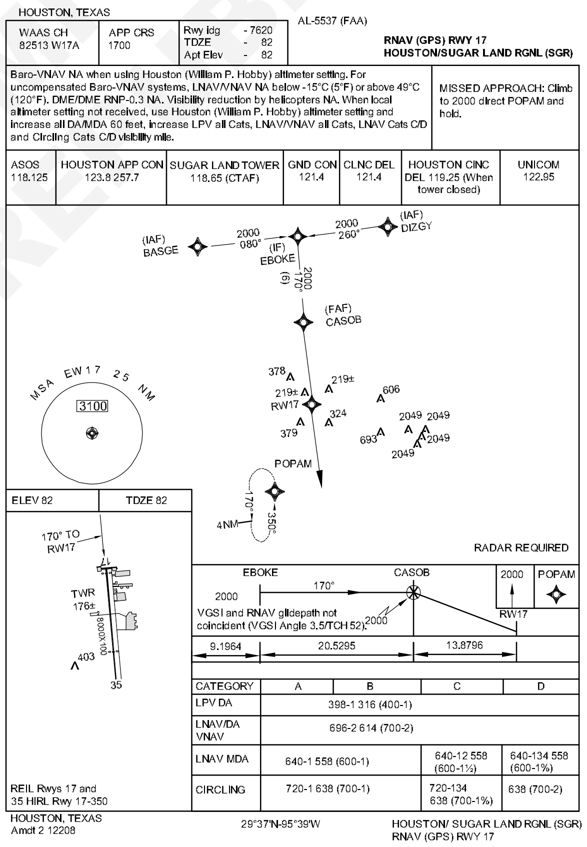


Fig 5



Let's Fly - The Initial Segment

- GPS loaded and activated - Note you can review the approch in the GPS (Garmin press FPL key)
  - If approach is not activated before 2 nm of MAWP, approach mode will not become active timely.
- Radios tuned to Approach/ Tower
- Confirm CDI is set for GPS (not VLOC) !
- Reduce power to approach setting
- Cross over IAF at 2,000 feet - segment should
- Trun magenta
- Turn to track towards IF either (80 / 260 degrees)
- Be sure to turn the OBS ring with each directional change to match the couse as a reminder, although it won't impact the CDI indication
- Before IF begin turn inbound on 170° based on
- Turn anticipation
- Intermediate segment should become active magenta

3 Segments of GPS Fig 4

The Control Segment: This part consists of 5 worldwide

unmanned base-stations that monitor the satellites to track their exact position in space, and to make sure that they are operating correctly. The stations constantly monitor the orbits of the satellites and use very precise radar to check altitude, position and speed.

T**he Space Segment:** This part consists of satellites, manufactured by Rockwell International, which are launched into space by rockets, from Cape Canaveral, Florida. They are about the size of a car, and weight about 19,000lbs. Each satellite is in orbit above the earth at an altitude of 11,000 nautical miles (12,660 miles), and Fig 4

Takes 12 hours to orbit one time

The User Segment: This part consists of user receivers which are hand-held or, can be place in a vehicle. All GPS receivers have an almanac programmed into their computer, which tells them where each satellite is at any given moment Fig 5.

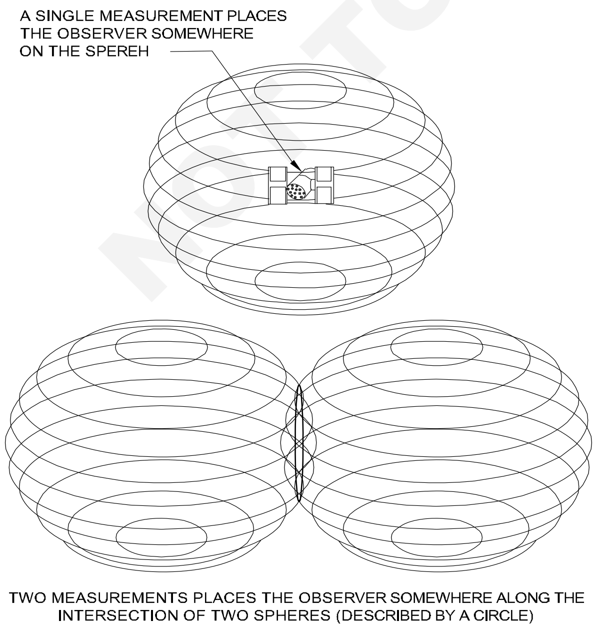
Principle of operation of GPS & surveying with GPS

Objectives : At the end of this lesson you shall be able to
- **state principle of operation of GPS**
- **describe role of transit in GPS development**
- **explain surveying with GPS**
- **determine observation techniques of GPS**
- **describe realtime GPS survey**
- **state time measurement and timing.**

Technical description (principle of operation of GPS)

The principle behind GPS is the measurement of distance (or “range”) between the receiver and the satellites. The satellites also tell us exactly where they are in their orbits above the Earth. It works something like this - If we know our exact distance from a satellite in space, we know we are some where on the surface of an imaginary sphere with radius equal to the distance to the satellite radius. By measuring its distance from a second satellite, the receiver knows it is also somewhere on the surface of a second sphere with radius equal to its distance from the second satellite. Therefore, the receiver must be somewhere along a circle which is formed from the intersection of the two spheres. Measurement from a thrid satellite introduces a thrid sphere. Now there are only two points which are consistent with being at the intersection of all three spheres. One of these is usually impossible, and the GPS receivers have mathematical methods of eliminating the impossible location Measurement from a fourth satellite now resolves the ambiguity as to which of the two points is the location of the receiver. The fourth satellite point also helps eliminate certain errors in the measured distance due to uncertainities in the GPS receiver’s timing as well.

Fig 1

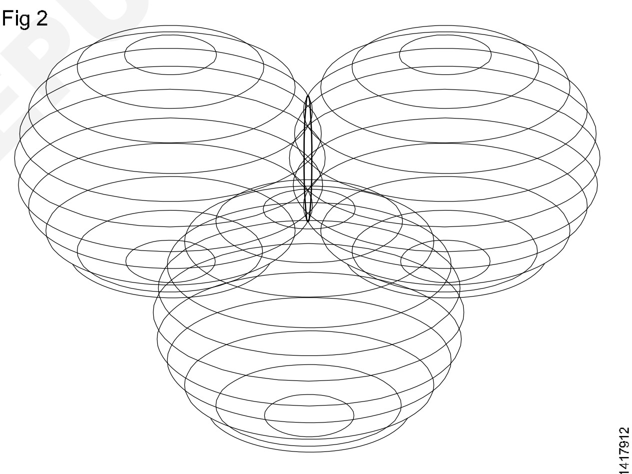


TWO MEASUREMENTS PLACES THE OBSERVER SOMEWHERE ALONG THE INTERSECTION OF TWO SPHERES (DESCRIBED BY A CIRCLE)

Here’s how GPS works in five logical steps

- The basis of GPS is “triangulation” from satellites.
- To “triangulate”, a GPS receiver measures distance using the travel time of radio signals.
- To measure travel time, GPS needs very accurate timing, which it receives with some tricks.
- Along with distance, you need to know exactly where the satellites are in spacce. High orbits and careful monitoring are the secret.
- Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

Fig 2

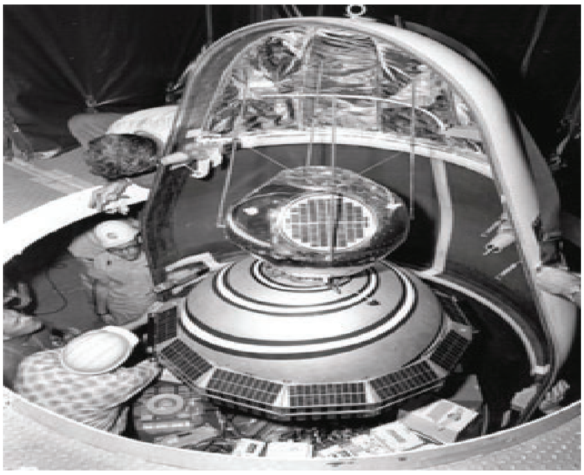


THREE MEASUREMEMTNS PLACES THE OBSERVER AT THE INTERSECTION OF THREE SPHERES (ONE OF TWO POSSIBLE POINTS)

Role of transit in GPS development

The transit system, also known as NAVSAT or NNSS (for Navy Satellite System), was the first satellite navigation system to be used operationally. The system was primarily used by the US Navy to provide accurate location information to its Polaris basllistic missile submarines, and it was also used as a navigation system by the Navy’s surface ships, as well as for hydrographic survey and geodetic surverying. Transit provide continuous navigation satellite series from 1964, initially for Polaris submarines and later for civilian use as well.

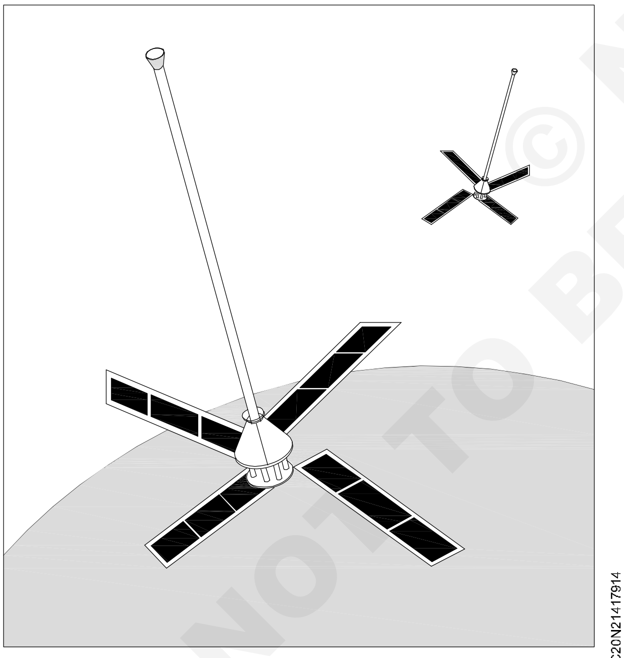
Fig 3



History

Development of the transit system began in 1958, and a prototype satellite, **Transit 1A**, was launched in september 1959. That satellite failed to reach orbit. A second satellite, **Transit B**, was successfully launched on April 13, 1960, by a Thor-Ablestar rocket. The first successful tests of the system were made in 1960, and the system entered Naval service in 1964.

Fig 4



The transit system was made obsolete by the Global Positioning System(GPS), and ceased navigation service in 1996. Improvements in electronics allowed the GPS system to effectively take several fixes at once, greatly reducing the complexity of deducting a position. The GPS system uses many more satellites than were used with transit, allowing the system to be used continuously, while transit provided a fix only every hour or more.

Surveying with GPS

Initially developed for military use, GPS is now part of everyday life; used in moblie phones, in-car navigation and search and rescue equipment to mention just a few. But there is a wide variety of equipment and techniques that can be used for surveying.

GPS was rapidly adapted for surverying, as it can give a position (Latitude, Longitude and Height) directly, without the need to measure angles and distances between intermediate points. Survey control could now be established almost anywhere and it was only necessary to have a clear view of the sky so the signal from the GPS satellites could be received clearly.

The first GPS instrument to be used for control surveying was the Micrometer V-1000. This instrument has the capability of determining a point's precise co-ordinates without relying on any of the special codes broadcast by the GPS satellites and is therefore often referred to as a codless receiver. For the past year, the TI 4100 GPS instrument has also been used for precise control surveys.

Advantages of GPS surveys

- Three dimensional
- Site intervisibility not needed
- Weather independent
- Day or night operation
- Common reference system
- Rapid data processing with quality control
- High precision
- Less labour intensive/ cost effective
- Very few skilled personnel needed

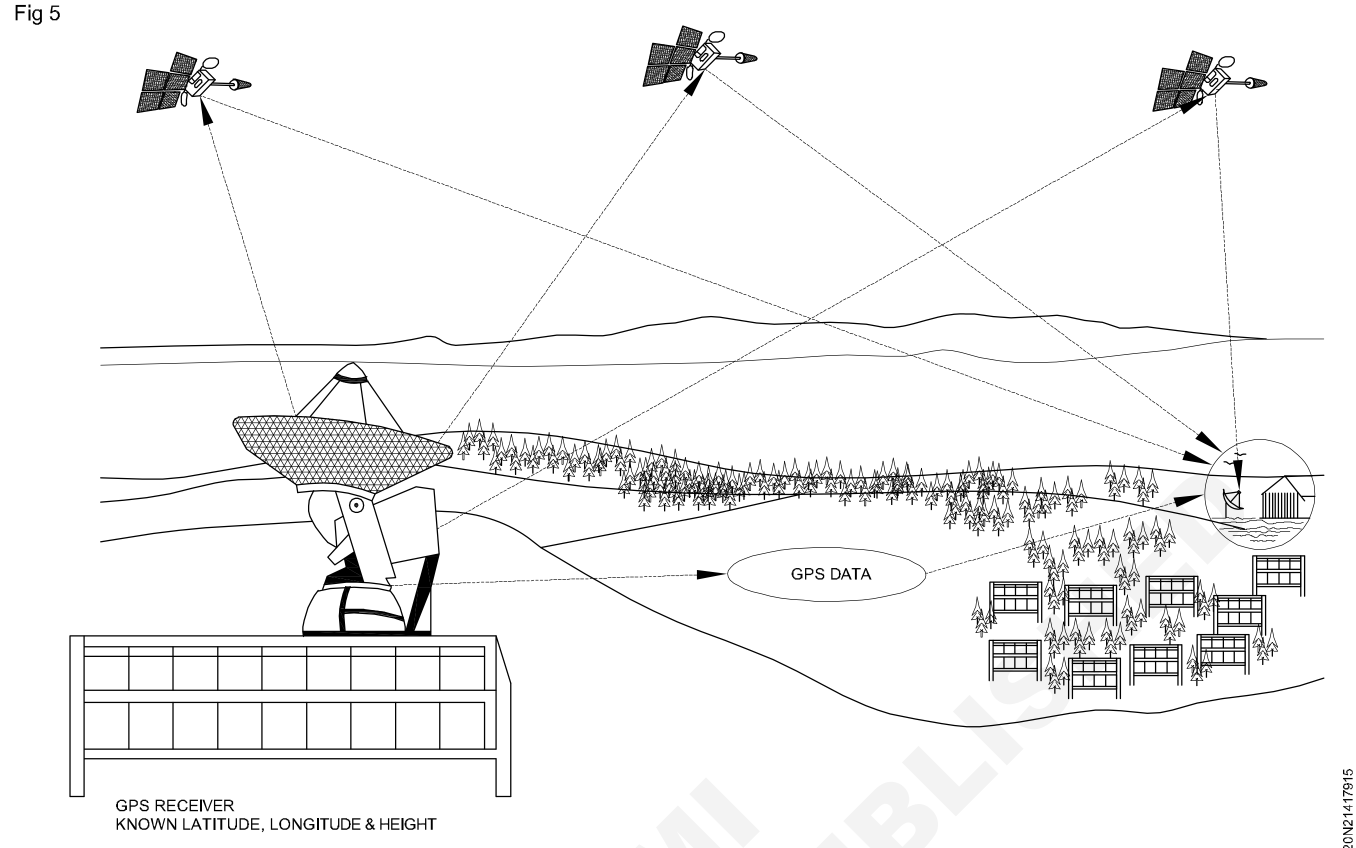
GPS observation techniques and methods of GPS surveying Fig 5

Because the X,Y,Z coordinates of each satellite are known (by computation), the coordinates of a ground point can be determined by measuring the ranges to at least three satellites. In practice, the ranges to a minimum of four satellites are measured because of the measruing techniques used. When only one receiver is used to range to the satellites, a single or point position is determined. This is why the use of a single receiver is called point positioning. The accuracy of point positioning with GPS averages ±10 meters, depending on a number of factors.

Most surveyors are interested in a second technique called differential positioning or translocation. When this method is used, one satellite receiver is placed over a point whole position is known while a second received is placced over a point whole coordinates are to be determined. The determined to centimeter accuracy (plus 2 ppm of the distance between points) when sufficient data are observed.

Both the point positioning and translocation methods involve measuring the ranges to a number of satellites over a series of intervals from 2 seconds to several minutes. The point's coordinates or difference in coordinates are

Fig 5



GPS SURVERYING

then computed by standard resection techniques.

For projects requireing geodetic accuracy, National Geodetic Survey (NGS) must be contacted or NSRS database must be accessed to determine points available in the project area before the project begins.

Real time kinematic GPS surverys (Fig 6)

Real time kinematic (RTK) refers to a stop-gas method where the coordinates of points are available in real time using a techique called differential GPS or DGPS.

The DGPS technique is based on using at least two GPS recivers. One receiver is located at a fixed position which has been accurately located using traditional land surverying techniques. This receiver is known as the base station, and also contains a computer. The remaining receivers are roving, and are used for the surveying or navigation activity.

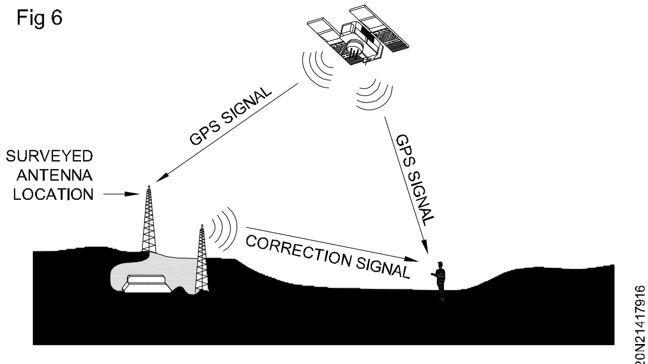
The base station takes GPS readings continuously and calculates its "position" based on the GPS data. The computer then compares the receiver position based on the GPS data to the actual receiver location based on the accurate land survey. The difference between the GPS calculated "position" and the real position of the receiver is the error in the GPS for that particular reading. Each reading is also time-stamped, so we know for what time of day the errors are valid.

If accurate project coordinates are needed, an accurate transformation needs to be done by including a sufficient number of points whose coordinates are known in both systems. This method is called Static Surveying, is used for surveying project that requires high accuracy.

The following figure illustrates the Real-times DGPS configuration. Note that only one satellite is shown. In reality, the base station must receive signals from all the satellites visible to the roving reciver.

For the highest accuracy in a local area, setting up a base station and using DGPS is the best approach. However, the US Government realized the benefit or setting

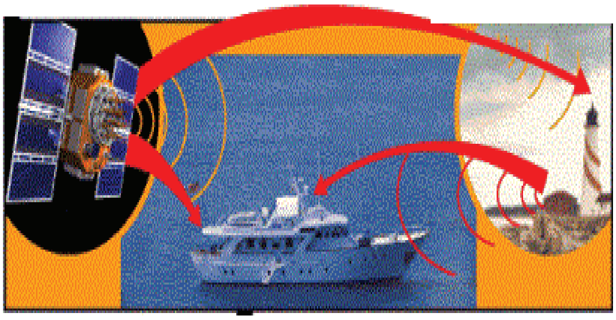
Fig 6



REAL-TIME DGPS CONFIGURATION

up permanent DGPS base stations and raios transmitters, especially along coastal areas and around airports. The installation of permanent DGPS base stations and making the correction signals available for free or by subscription is known as GPS Augmentation. Three augmentation systems. Beacon, WAAS and LAAS have been developed by the US Government.

Fig 7



Time measurement and timing in GPS

We live in a four-dimensional world and the fourth dimension is time. Without an accurate estimate of time, finding position as it is understood today is not possible. The GPS delivers time, time interval and frequency they where in the world with precision and accuracy more than adequate for many applications.

With GPS timing, precision of billionths of a second is now possible. A billionth of a second is called a nanosecond (ns). Such precision has opened up all kinds of opportunities.

There are several types of GPS receivers used in time and frequency metrology. The cost, size, and design of a GPS timing receiver varies significantly from model to model, but most share several common features. Most receivers use the C/A code broadcast on the L1 frequency as their time and frequency reference. Most can simultaneously track from 8 to 12 satellites, and can provide time and frequency signals derived from an average of all satellites in view. Most provide time-of-day and data information in a computer readable format.

At the hear of GPS is the timing accuracy available from atomic clocks. Albert Einstein gave us the relationship between space and time - the four dimensions of relativity. These four dimensions may be through of as latitude, longitude, altitude and time, or in shorthand x, y, x and t. GPS is the first engineering implementation of relativity and would not work without it. Fortunately, an understanding of relativity is not necessary to gain an understanding of how GPS works. The relativistic terms are accounted for in the design of the satellite clocks and in the receivers that properly process the data.

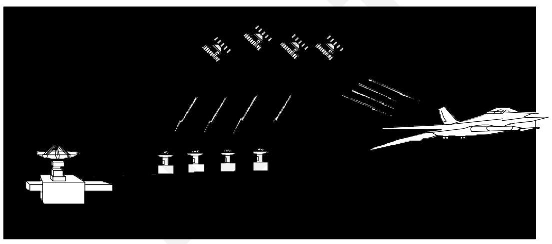
Principle of operation of GPS & positioning system

Objectives : At the end of this lesson you shall be able to
- **explain ground support equipment**
- **enumerate best personal GPS tracking devices**
- **describe differential GPS**
- **explain application of GPS.**

Ground support equipment and signals (Figs 1&2)

The signals the GPS receivers get from the satellites are converted into position, velocity and time estimates. Conceptually the process is one of measuring the time a signal from a given satellite takes to reach the receiver. Since the travel speed of the signal, which is the same as that of light is known, the distance of the receiver from the satellite can be computed.

Fig 1



GROUND SUPPORT EQUIPMENT & SIGNALS

DC20N21417921

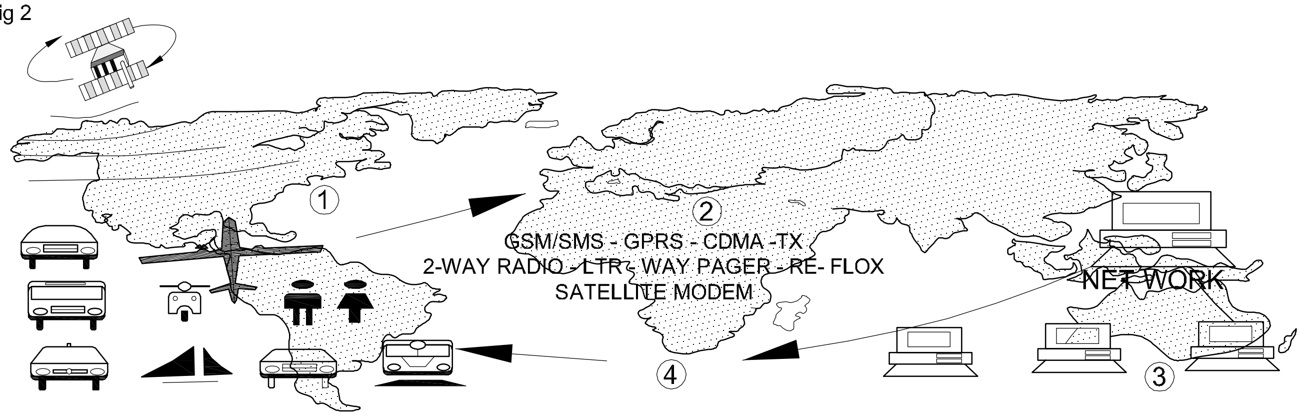
The Master Control Station receives the monitoring station tracking and ground antenna telemetry information and computes the current and predicted satellite clock offsets and satellite positions. It then converts this data to the navigation data formats described later. These rather complex satellite orbit/time filter estimating algorithms must also model the satellite solar radiation pressure, atmosheric drag on the satellite, Sun/Moon gravitational effects, including solid Earth and ocean tides, and Earth's geopotential model. Improved GPS satellite-to-satellite cross-link ranging data may also be used in the future.

The navigation data are uploaded from several 10-m S-band ground antenna upload stations.

Tracking (Fig.3)

GPS tracking means to trace something or someone with the Global Positioning System. The below diagram illustrates the basic AVL System. It shows the GPS signal arriving from satellite to vehicle. The vehicle location is communicated to the PC (Control Centre) via wireless network. But for thousand of years Homosapiens has had the opportunity to observe the movement and general habits of members of his own species as well as of wildlife, particularly by following their tracks. It was a hard and particular unsafe affair. Hence the developement of satellite tracking by the Argos consortium was a quantum leap in the human tracking business. Since 1994 the Global Positioning System has been available for civilian use at no cost. Nowadays GPS makes it available to everyone to track nearly everything. Objects as well as persons can be tracked if they are fitted out with a GPS receiver estimating the respective location. The GPS location data is stored on board of the GPS receiver. Modern GPS tracking systems are able to send such GPS position data from the object directly to a receiveing station. A receiving station can be a stationary receiver of a tracking

Fig 2

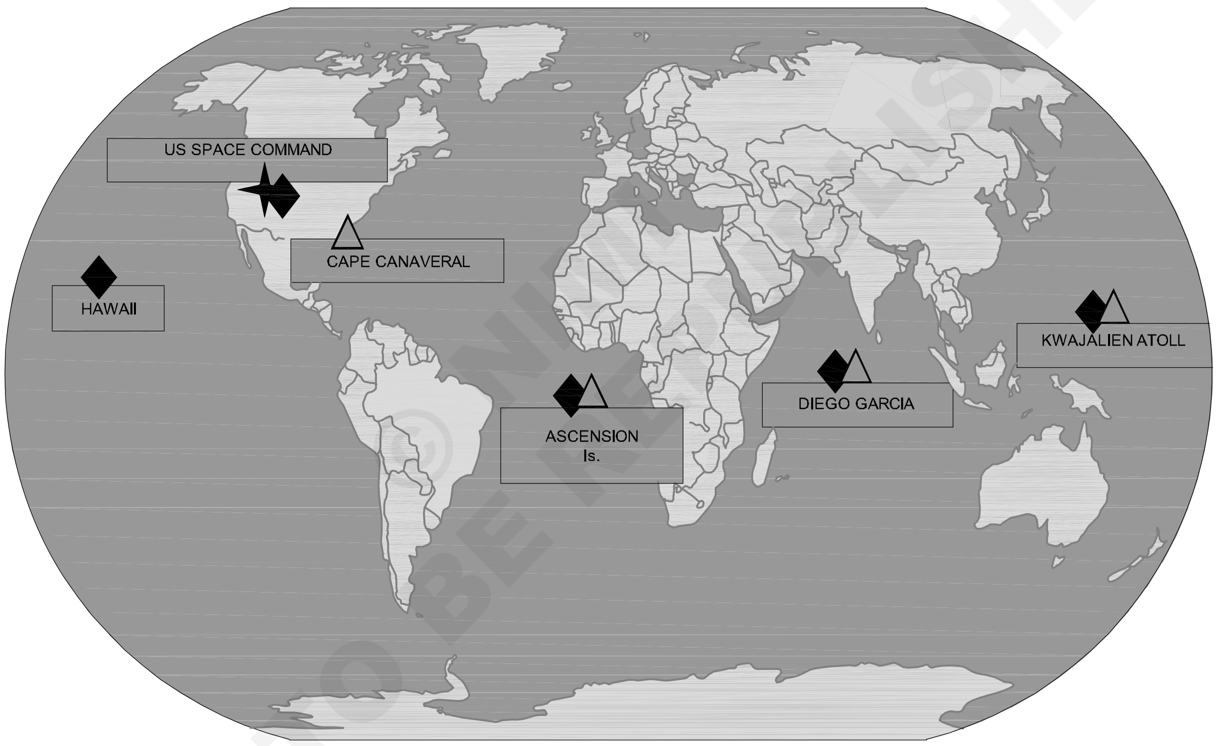


1. GPS RECEIVERS IN EACH MOBILE ASSET RECEIVE SIGNALS FROM A NETWORK OF OVERHEAD SATELLITES.
2. TRANSMIT THE DATA TO THE COMMUNICATIONS CENTER VIA DIFFERENT NETWORKS.
3. THE CONTROL CENTER RECEIVE AND PROCESS THIS DATA AND SHOWS REAL-TIME PINPOINT INFORMATION OVER MAPS.
4. THE CONTROL CENTER IS ABLE TO SEND COMMANDS TO TEACH UNIT (TRIGGER ALARMS, STOP ENGINES, CHANGE DIRECTION, PERSONAL MESSAGES, ETC.)

TRACKING

DC20N21417923

Fig 2



MASTER CONTROL STATION   MONITOR STATION   GROUND ANTENNA

DC20N21417922

service company (in case of car tracking f.ex.) or provider of a mobile phone company, or just a PC. Nowadays the GPS location data can be also received by samll mobile gadgets like laptops, handsets etc. The AVL tracking system consists of a GPS receiver inside the vehicle and a communications link between the vehicle and the control Center as well as pc-based tracking software for dispatch. The communication system is usually a cellular network similar to the one used by your cell phone.

Best personal GPS tracking devices

GPS trackers are getting thinner, cheaper and more useful for security and outdoor activity than every before. Infact, several excellent models may Have crept into the market without you realising it. Here is a list of the top personal tracking devices.

Fig 4

TRAX

DC20N21417924

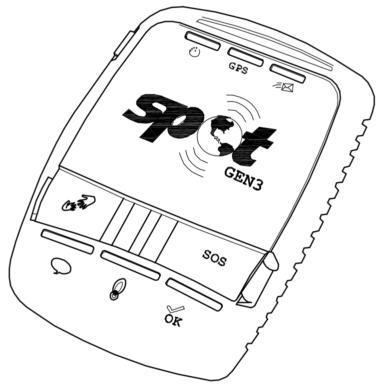
1 Trax (Fig.4)

Trax stand out by being highly consumer-oriented in its approach to GPS tracking devices. The company offers one Trax package that includes two different clips (albeit only one tracker), one for clothing and one for a collar indicating the company's two different approaches for kids and dogs.

2 Spot Gen3 (Fig.5)

Spot Gen3 takes a different approach to GPS tracking by using a personal GPA tracking device that's much more than just a tracking chip. This larger tracker comes without a screen (to be evenmore durable, it seems) but does have several buttons for different commands. It can track exactly where you are, record where you; have been, allow to check in at specific places, and even send specific pre-planned messeages or SOS signals.

Fig 5

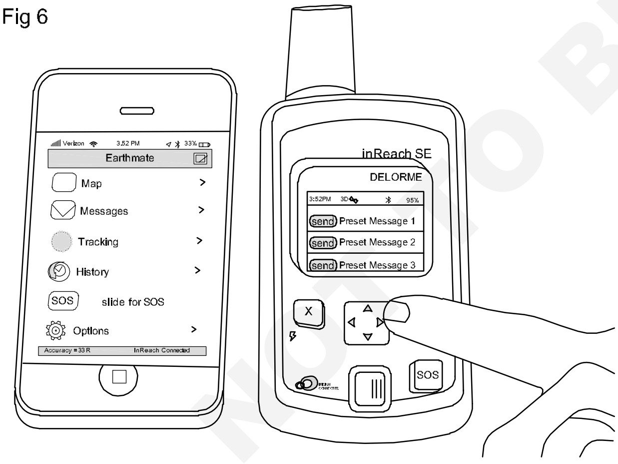


SPOT GEN 3

3 DeLorme InReach SE (Fig.6)

DeLorme InReach SE is an excellent modern GPS tracker if you want something more social than the Spot Gen3. This device has a tiny screen and basic direction buttons you can use to tap out a text message no matter where you are or what mountain you just scaled. It also has SOS capabilities, extensive.

Fig 6



DELORME INREACH SE

4 Pocket Finder (Fig.7)

Pocket Finder is something of a supermarket in the personal tracking devices world, with options for people, pets and vehicles, each with its own characteristics. The personal GPS locator is designed for kids, teens, seniors, and anyone else who wants them. The know-like shape is a little odd compared to other offerings, but all the functionality is still present, complete with an app that overlays maps with the locations of multiple people. Geofencing also gives you important updates on location. If you aren't quite sure what features you want in a tracker, PocketFinder's models make a good starting place for your research.

Fig 7

POCKETFINDER

5 Real-Time Correction of Multiple Receivers Inverse DGPS

Suppose you are interested in accuately tacking where a number of vehicles are and how fast they are moving using GPS in real-time, and you want to monitor all of them from a central location (for example, for a fleet of delivery or service trucks). Each vehicle would need a GOS receiver. That would tell the vehicle where it is, but not you. Therefore, each vehicle must transmit its own positional information, usually by radio, back to the home office. For accurate location and speed determination, you decide to use Differential GPS. To equip each vehicle with DGPS capability requires more equipment and is expensive. The better approach is to have one DGPS station at the home office, and use this single correction factor for all the data coming back from the vehicles. This tehcnique is called Inverse DGPS.

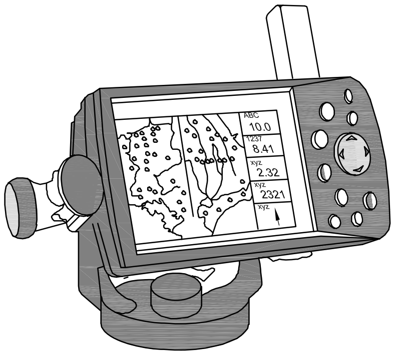
Inverse DGPS is applicable whenever there are multiple moblie receivers and the receivers themselves don't need differential GPS accuracy. This approach can be used for accurately tracking vehicles, weather balloons, semi atonomous robots, or even real-time surveying of pre defined points. Several companies offer inverse DGPS for publie bus systems and even school buses, so that central dispatch always knows the status of the transportation system.

Applications of GPS

GPS in marine system (Fig.8): Marine GOS receivers feature waterproof casings, marine chart plotter maps, and even fishing tables and celestial schedules. Most can also store highway map information, so you can use your marine GPS to get you to the marina and then out to the fish.

GPS for private and commercial use: The GPS system is free for everyone to use, all that is needed is a GPS receiver, which costs about $90 and up (March 2005). This

Fig 8



MARINE GPS RECEIVER

has led to widespread private and commercial use. An has lid to widespread private and commercial use an example of private use is the popular activity Geocaching where a GPS unit is used to search for objects hidden in nature by traveling to the GPS coordinates. Commercial use can be land measurement, navigation and road construction.

GPS on air planes: Most airline companies allow private use of ordinary GPS units on their flights, except during landing and take-off, line all other electronic devices. The unit does not transmit radio signals like moblie phones, it can only receive. Note, however, that some airline companies might disallow it for security reasons, such as unwillingness to let ordinary passengers track the flight route.

GPS for visually impaired: The projects of the navigation system using GPS for the visually impaired have been conducted quite a few times. GPS was introduced in the late 80's and since then there have been several research projects such as MoBIC, Drishti, and Brunel Navigation System for the Blind, NOPPA, Braille Note GPS and Trekker.

MoBIC: MoBIC means Mobility of Blind and Elderly people Interacting with Computers, which was carried out from 1994 to 1996 supported by the Commission of the European Union. It was developing a route planning system, which is designed to allow a blind person access to information from many souces such as bus and train timetables as well as electronic maps of the locality. The planning system helps blind people to study and plan their routes in advance, indoors.

GPS applications in agriculture

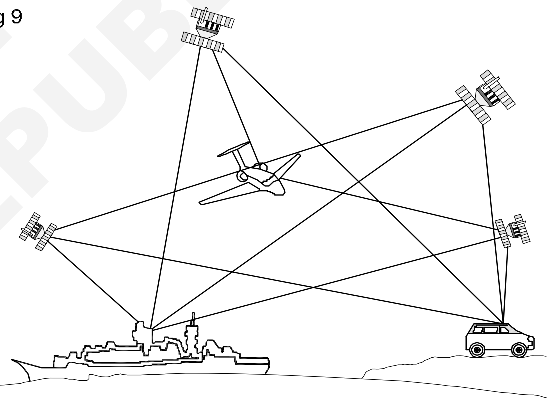
More and more producers today are using precision farming techniques that can help increase profits and protect the environment. Precision, or site-specific farming involves applying fertilizer, pesticides and other inputs only where they are needed. GPS-guided equipment is often used for variable rate application of fertilizer (based on soil tests) or pesticides (based on pest survey). GPS can also be used to develop the initial reference maps upon which variable rate applications are based. A GPS system on a combine with a yield monitor can be used to develop an on-the-go yield map or can be used to map weed locations from the combine when harvesting. Mounted in an airplane, GPS can be used to guide aerial spraying operations.

GPS can be used to locate weed, insect or diseases infestations and monitor their spread. It can also be used to navigate back to previously mapped infestations to apply controls. A field map can be created using GPS to record the coordinates of field borders, fence lines, canals, pipelines, and point locations such as wells, buildings, and landscape features. The resulting field map might be the first layer a producer would develop for an onfarm GIS (Geigraphic Information System). Additional layers showing crop damage from hail or drought, and riparian areas or wetlands could be mapped using GPS. Ranchers could use GPS to develop rangeland utilization maps and to navigate back to previously mapped areas of monitoring sites.

GPS navigation: Land, Sea and Air (Fig 9)

GPS is being used for emergency response (fire, ambulance, police), search and rescue, fleet management (trucking, deliver vehicles, and public transportation) and for automobile guidance systems. Recreational uses of GPS include navigation while hunting, or skining. GPS is even used on golf courses to track golf carts, and to let players know how far it is to the centre of the greens.

Fig 9



GPS NAVIGATION

On our nation's waterways, GPS is being used for recreational sailing and fishing and for commercial shipping fleet management. Assisted steering, risk assessment and hazard warning systems for marine navigation are being developed using GPS.

In the air, GPS is being used for en-route navigation (helicoper, airplane, hot-air balloon), aircraft landing, and air-collision avoidance systems.

GPS Applications: Mapping and Surveying

GPS applications in natural resource management include inventory and mapping of soils, vegetation types, threatened and endangered species, lake and stream boundaries and wildlife habitat. GPS has been used to aid in damage assessment after natural disasters such as fires, floods and earthquakes. GPS has also been used to map archoeological sites and for infrastructure (streets, highways and utilites) mapping, management, and planning for future growth. Engineers use GPS for surveying when building roads, bridges and other structures.

Public Health and safety - Earthquake Prediction

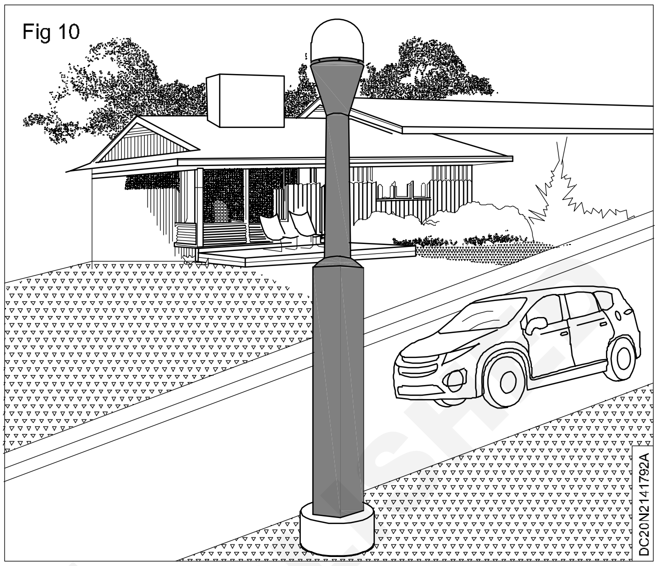
The occurrence of slight movements and tilting of the earth's surface often precedes moderate to large earthquakes. Historically, scientists have deployed measurement equipment only in limited areas, due mainly to cost, access, and manpower requirements. To overcome these disadvantages, the Geographical Survey Institute of Japan has deployed a permanent network of 1,000 GPS receivers across the country.

Engineering and construction - equipment control and monitoring

In addition to the improvement in the speed and efficiency of precision surveying, a number of other GPS applications have been developed in engineering and construction. For example, GPS equipped earth moving equipment can now excavate and grade complex foundations with minimum operator interference. GPS technology not only guides the path of the equipment, but can also be used to automatically control the height of blades or scrapers. This capability results in significant cost savings and efficiencies, since periodic manual surveying is not required.

The construction rental industry is also using GPS to monitor, in real-time, the location of equipment and details such as hours worked, engine revolutions, oil pressure and other ciritical parameters. This allows owners to ensure that their equipment is being used within specifications, helps manage maintenance scheduling and minimizes.

Fig 10



GPS Signal Code - an Biases

Objectives : At the end of this lesson you shall be able to
- **introduction to digital signal**
- **explain Data Acquisition systems**
- **describe signal processing**
- **explain code an Biases**

Abstract:

This paper evaluates the possibility of using a digital signal processor (DSP) in order to implement an image patten recognition system based on a neural network architecture. The paper presents a brief introduction to neural network architectures and how such architectures can be used in pattern recognition; it presents the implementation of the neural network using a very powerful DSP microcomputer (eg, ADSP 2189 from Analog Devices), illustrates the main results for a character recognition system (execution time and error probability), and presents some conclusions.

I Introduction

Usual digital signal processing is based on the algorithms, changing data through sequential procedures, which need parameters to operate. The parameters provide a benchmark to judge the data. The proper choose of parameters is very important (perhaps more than the algorithm itself). The neural networks will use very simple algorithms, but many highly optimized parameters.

- **IEEE Keywords**

Digital signals processing, Pattern recognition, Neural

networks, Signal processing algorithms, Microcomputers, Images recoginition, Digital signal processors, Error probability, Image databases, Pixel.

- **INSPEC: Controlled Indexing**

Character recognition, image recognition, digital signal processing chips, neural net architecture, error statistics

- **INSPEC: NON-Controlled Indexing**

Executuion time, digital signal processing system, image pattern recognition, DSP, neural network architecture, microcomputer, ADSP 2189, Analog Devices, character recognition system, error probability

Data Acquisition Systems

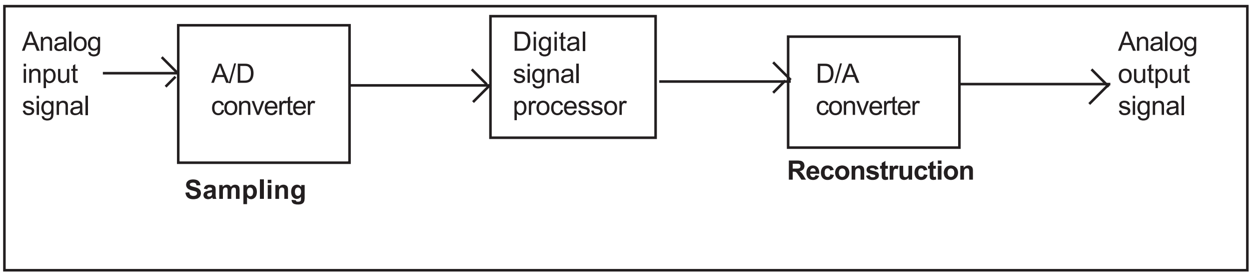
- Data Acquisition (DAQ)

  Process of getting digital equivalent of analog signals **(the measure of real world physical quantities)** into computer **for further processing**

- Data loggers

  Records measurements **of physical quantities** with time stamp

- Basic Functions of DAQ Systems - Analog Input
- **Conversion of** analog signal to digital data and
- Transfer **of converted data** to computing platform using standard interface



Block diagram of a digital signal processing system.

Converting Analog into Digital

Computationally

- The analog voltage can now be compared with the digitally generated voltage in the comparator.
- Through a technique called binary search, the digitally generated voltage is adjusted in steps until it is equal (within tolerances) to the analog voltage.
- When the two are equal, the digital value of the voltage is the outcome.

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After reading this chapter, you should be able to:

- Distinguish between data and signals, and cite the advantages of digital data and signals over analog data and signals.
- Identify the three basic components of a signal.
- Discuss the bandwidth of a signal and how it relates to data transfer speed.
- Identify signal strength and attenuation, and how they are related.

Data communications and Computer Network: A Business User's Approach, Sixth Edition

What is Digital Signal Processing?

Digital: operating by the use of discrete signals to

represent data in the form of numbers

Singal: a parameter (electrical quantity or effect) that can be varied in such a way as to convey information

Processing: a series operations performed according to programmed instructions.

changing or analysing information which is measured as discrete sequences of numbers

Advantages of Digital over Analog Signal Processing Why still do it?

- Digital system can be simply reprogrammed for other applications/ported to different hardware / duplicated

  (Reconfiguring analog system means hardware redesign, testing verification)
- DSP provides better control of accuracy requirements

  (Analog system depends on strict components tolerance, response may drift with temperature)
- Digital signals can be easily stored without deterioration

  (Analog signals are not easily trasportable and often can't be processed off-line)
- More sophisticated singal processing algorithms can be implemented

  (Difficult to perform precise mathematical operations in analog form)

A DSP System

In practice, a DSP system does not use idealized A/D or D/A models.

Anti-aliasing Filter: ensures that analog input signal does not contain frequency components higher than half of the

sampling frequency (to obey the sampling theorem). **this process is irreversible**

2 **Sample and Hold:** Hold a sample analog value for a short time while the A/D converts and interprets the value as a digital.

3 **A/D:** converts a sampled data signal value into a digital number, in part, through quantization of the amplitude.

4 **D/A:** converts a digital signal into a \staircase"-like signal.

5 **Reconstruction Filter:** converts a \staircase"-like signal into an analog signal through low pass filtering similar to the type used for anti-aliasing.

Advantages of Digital Signals

- The main advantange of digital signals over analog signals is that the precise signal level of the digital signals is not vital.
- This means that digital signals are fairly immune to the imperfections of real electronic system which to spoil analog signals.
- Reduced cost

- Flexibility in response to design changes
- Noise immunity
- Easy to control and manipulate

Digital transmission system

Satellite dependency of receiver originating biases

One of the earliest examples of the phenomenon that different receivers got different range errors tracking the same satellite appeared in 1993, when a signal anomaly of GPS Block II space vehicle number (SVN) 19 gave large differential positioning errors (Edgar et al.1999). Depending on the correlator spacing adopted in the receiver design, signal deformations on L1 originating from the SVN 19 hardware gave rise to different internal delays in the receivers, resulting in a differential positioning error of several meters when the reference and the rover receiver used different correlator spacing in their discriminatiors. Recent findings by Lestarquit et al. (2012) showed delay differences as large as 0.7 m between using a 0.1 and

0.05 chip discriminator when analyzing disrortions on the C/A-code transmitted from GPS Block IIA PRN-32, corresponding to SVN 23. It was also shown that different satellites, Which exhibit different kinds of distortions on their signals, produced different delays for a given correlator spacing. It was described by Simsky and Sleewaegen (2004) that this effect would be reinforced on some receiver brands when the multipath-mitigation setting was turned on. Since some multipath-mitigation algorithms use the form of the measured correlation peak to detect multipath, these distrotions on the received signals would incorrectly be interpreted as multipath by the receiver, which would produce an addition to the pseudorange error in the receiver.

However, even if the phenomenon mentioned above is present on all satellite systems using CDMA, its effect is comparatively small in relation to the code interchannel delays induced in the receiver hardware during GLONASS tracking. This effect is similar to the GLONASS phase IFB, and it will be discussed later on. In the following sections, we will focus on various code biases that are of importance in TEC estimation and multi-GNSS positioning.

Differential code biases

The differential code bias (DCB) is a time delay between two GNSS signals transmitted by a single satellite, and it consists of both delays induced in the receiver hardware at reception and in satellite hardware at tranmission. The DCB arise due to the use of different carrier frequencies, and due to differences between the structures of the signals. These delays thereby also exist between different types of signals using the same carrier frequency, as the C/A-code and P-code on GPS L1 (Gao et al. 2001).

Code biases

As Eq. (2) suggests, the code bias can be separated into one term that refers to the bias that originates from the receiver hanrdware, $B_{sig,r}^{sys}$, and one term that refers to the bias that originates from the satellite hardware, B_{sig}^{s}. In this representation, only the satellite term of the equation is assumed to be satellite dependent, while the receiver term is assumed to be constant for all satellites for a given GNSS signal and constellation. However,as will be explained later, this assumption of the receiver originating term being totally independent of the tracked satellite is not true in general, even for GNSS systems employing CDMA.

It was shown by Hegarty et al. (2004) that the receiver hardware delays depend on how signal tracking is employed in the receiver. Depending on the design of the delay-locked loop (DLL), signals that were using the same type of modulation showed different delays. Tracking of signals on the same carrier frequency with different types of modulation also showed delay differences of several nanoseconds. Consequently, receivers of different models, which are built with different architectures, will induce different hardware delays into the signal tracking process.

Moreover, signals from different GNSSs, which use different types of modulation, will show different delays in the receiver hardware, even if they are modulated on the same carrier frequency. This applies for instance in combined GPS and Galileo tracking where the same carrier frequencies are used for L1/E1 and L5/E5, but different modulation schemes are applied. Here, a receiver-specific intersystem bias will appear between the pseudorange observables from GPS and Galileo satellites, even though the signals are modulated on carrier waves of the same frequency.

Introduction

Today, Global Navigation Satellite System (GNSSs) are used for a multitude of applications around the world, and there is a general quest for better positioning accuracy and reliability, as well as faster position acquisition from both user groups and the GNSS research community. Combining observations from multiple GNSSs in one positioning process and/or using multiple frequencies from one or more GNSSs is important step toward reaching these goals (Gleason and Gebre-Egziabher 2009). Accounting for all error sources in the positioning process, including hardware biases, is a prerequisite for accurate results.

GNSS hardware biases occur because of imperfections and/or physical limitations in GNSS hardware. The biases are a result of small delays between events that ideally should be simultaneous in the transmission of the signal from a satellite or in the reception of the signal in a GNSS receiver. Consequently, these biases will also be present in the GNSS code and phase measurements. Moreover, hardware-induced biases differ between different signals, e.g., P1 and P2, and between different carrier waves, e.g., L1 and L2. Hardware-induced biases will cause degradation in the accuracy of the positioning solution if not handled properly. This is especially important in high-accuracy positioning with multiple GNSSs (Odijk and Teunissen2012; Paziewski and Wielgosz 2014; Tegedor et al. 2014), in Precise Point Positioning (PPP) for the resolution of the integer ambiguities (Teunissen and Khodabandeh 2014), and when using GNSS observations for estimation of the Total Electron Content (TEC) in the ionosphere (Jensen et al. 2007; Lanyi and Roth 1988; Sardon and Zarraoa 1997).

The topic of GNSS hardware biases has received a great deal of attention in recent years. The introduction of GLONASS besides GPS in precise positioning requires knowledge of biases in the receiver hardware that tend to be specific to the receiver model (Leick et al. 1998; Raby and Daly 1993; Wanninger and Wallstab-Freitag 2007). The emergence of new GNSSs, such as the European Galilew (OS-SIS-ICD-1.2 2015) and the Chinese BeiDou

(BDS-SIS-ICD-2.0 2013), further increases the need of understanding about GNSS hardware solution, as well as a reduction in the solution convergence time. The International GNSS Service (IGS) (Dow et al. 2009) arranged bias workshops in 2012 and 2015 to address this issue. In addition, a new data format with the purpose to store and exchange bias information has been developed recently. The format is called SINEX BIAS, and it is based on the Solution (Software/technique) INdependent EXchange Format (SINEX). It supports storage of code and phase biases specific to a particular GNSS, satellite, receiver, or satellite-receiver combination (Schare 2016).

As it turns out, code and phase biases are difficult to estimate in their undifferenced form, as they are highly correlated with other terms e.g., clock errors. Thus, only differences between biases are possible to estimate directly from code and phase observations. However, very often, it is sufficient to know only the differences between certain biases, as common offsets to the absolute biases might be absorbed by other terms (e.g., the receiver clock error) in the positioning process and thereby not influencing the calculated positions. Bias differences can be formed in various ways, relevant for different applications. Here, a review is performed of various phase and code bias differences, and a special emphasis is given to biases
δ that have relevance for precise postioning. The term bias will be used exclusively for delays that are induced either in the satellite or in the receiver hardware.

Theoretical description of various biases

The observation equations have the following form for the code and phase observables, respectively

(Hoffman-Wellenhof et al. 2008). They are slightly modified to also include the receiver and satellite phase and code biases.

The notation (.)sys,ssig/f,r(.)sig/f,rsys,s is henceforth used for a term associated with a signal or carrier wave frequency f, recorded by a receiver r, and which is transmitted by satellites, belonging to a GNSS system. Absence of either of these notations means that the term which the equation appears. Here the term "signal" depicts a ranging code modulated on a particular carrier frequency.

In (1) and (2), the terms are defined in the following way: P true geometrical distance between receiver r and satellite s, δ, receiver clock error, satellite clock error, $B_{sig,r}^{sys}$ receiver harware code bias for signal sig, B_{sig}^{s} satellite hardware code bias for signal sig, b_f^{sys} receiver

Hardware phase bias for carrier wave frequency f, b_f^{s} satellite hardware phase bias for carrier wave frequency f, ^{sys} time offset fore the system time of GNSS system sys with respect to a chosen reference, T tropospheric delay, I ionospheric delay, M code multipath, mphase multipath, λ_f wavelength of the carrier wave with frequency f, N phase ambiguity term, ε_ϕ phase noise, and ε_R code noise.

In (1) and (2), some error sources have been omitted for the sake of brevity. These error sources include antenna phase centre variations, earth tides, ocean loading, and for phase observations also the phase windup effect. The time dependence of the terms has been omitted for the same reason. In addition, extra care has to be taken with the receiver clock error as the observation time tags also depend on this error. It can be corrected with an additional term ρsrδrρrsδr , ρsrρrs where is the time derivative of the geometrical distance between receiver r and satellite s.

It is here assumed that the receiver hardwave delays are the same for satellites belonging to the same constellation and broadcasting the same signal. As will be shown, this assumption holds true most often for GNSSs using code division multiple access (CDMA) to distinguish between signals transmitted by different satellites. It is, however, not true for GLONASS biases, as GLONASS employs frequency division multiple access (FDMA) instead of CDMA. A consequence of FDMA is that the receiver hardware bias will vary depending on the satellite tracked, as the channels for different carrier wave frequencies will cause different delays in the receiver. These GLONASS-related biases apply both for phase and code measurements, and they will be discussed later.

Table 1 gives a summary of the biases that will be treated in the following sections. GNSS hardware biases appear both in the receiver and in the satellite hardware, and this is reflected in the second column in Table 1. For completeness, the absolute biases as given in (1) and (2) are also included in the table even though these biases are not estimable directly from GNSS observations; thus, the third column indicates whether the bias is an absolute value or a relative value (most often the product of combinations of observations). A bias will here also be defined as relative if it is biased by other error sources. The fourth column refers to the symbols used for the biases in this paper, and the fifth column lists the temporal variation of the biases. In general, GNSS hardware biases have been shown to be stable over time, and this is reflected for most of the biases estimated for practical applications. However, in some cases, the estimated bias might contain residues from other error sources that will affect its long-term stability. The last two columns list how the biases are normally treated on the user side in the positoning process. Here, we distinguish between four different ways of dealing with biases on the user side: