DRAUGHTSMAN CIVIL

NSQF LEVEL - 5

2nd Year (Volume II of II)

TRADE THEORY

SECTOR: Constrution

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 Mentor Councils comprising various stakeholder's 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 2nd Year (Volume II of II) Trade Theory NSQF Level - 5 in Construction Sector under Semester Pattern.** The NSQF Level - 5 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 - 5 trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 5 the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these 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

RAJESH AGGARWAL
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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 the Federal Republic of Germany. The prime objective of this institute is to develop and provide instructional materials for various trades as per the prescribed syllabi (NSQF LEVEL - 5) 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.

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

NIMI is also grateful to everyone who has directly or indirectly helped in developing this Instructional Material.

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INTRODUCTION

Trade Theory

The manual of trade theory consists of theoretical information for the first semester course of the Draughtsman Civil under NSQF - Level 5. The contents are sequenced according to the practical exercise contained in the manual on trade practical. 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.

Module 1 - Road engineering

Module 2 - Bridge Engineering

Module 3 - Railway Engineering

Module 4 - Irrigation engineering

Module 5 - Estimating and costing

Module 6 - Total station

Module 7 - Global positioning system

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

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

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

Trade Practical

The trade practical manual is intended to be used in practical workshop /Hall. It consists of a series of practical exercises to be completed by the trainees during the second semester course of **Draughtsman Civil** under **NSQF Level - 5** Syllabus, which is supplemented and supported by instructions / informatics to assist in performing the exercises. These exercises are designed to ensure that all the skills in prescribed syllabus are covered.

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

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LEARNING/ ASSESSABLE OUTCOME

On completion of this book you shall be able to

- **Draw the cross sectional view of different types of roads showing component parts using CAD.**
- **Draw the details of different types of culverts using CAD.**
- **Prepare detailed drawing a bridge using CAD.**
- **Draw the typical cross section of rail sections, railway tracks in cutting and embankment using CAD.**
- **Prepare detailed drawing of typical cross sectins of Dam, barrages, weir and Cross drainageworks using CAD**
- **Draw the schematic diagram of different structures of Hydroelectric project using CAD.**
- **Prepare detailed estimate and cost analysis of different types of building and other structures using application software.**
- **Prepare rate analysis of different items of work.**
- **Problems on preparing preliminary/ Approximate estimates for building project.**
- **Prepare a map using Total station.**
- **Locate the station point using GPS and obtain a set of co - ordinates.**

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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 raod**
- **define highway engineering**
- **define necessity and characteristics of road.**

Transprtation 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 thebody. Similarly means of transpotation 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 sevice 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.

It is the only mode of transportation to provide door to door sevice.

Railways

Railways are steel tracks laid on the ground, over which the trains move. Railways have been developed both for long as well as for short distance and for urban travels. Transportation by railway system is advantages for longer distances.

Waterways

This mode of transportation include oceans rivers, canals and lakes for the movement of ships and boats. In this system ships and boats are used to transport men and materials. Transportation by this system is possible between the ports on the sea route or along the river or canals where ever inland navigation facilities are available. Though the speed of this system is the lowest among the four modes of transportation system, but it needs minimum energy to haul unit load through unit distance.

Airways

Air craft and helicopters use the air ways. Air system of transportation is the fastest and provides more comfort apart from saving time in transportation men and material, but is costliest among all the four systems mentioned above.

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 defence 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.

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9 They provide more employment opportunities to the people.

10 They help in providing National unity among people of different states.

Characteristics of road transport

1 It can be used by all types of vehicles including animal driven, cycle, and rickshaws.

2 It is the only mode of transport which can serve the remotest isolated villages in our country.

3 It should be free from being submerg during floods and thus should be available for safe movement of traffic at all times.

4 It offers flexibility of changes in direction of travel as per need, comfort and convenience.

5 It should be provided with easy gradient.

6 It requires small investment and maintenance cost as compared to railways airports, docks and harbours.

7 Road transport offers a complete freedom to raod used to transfer the vehicles from one lane to another or from one raod to another raod as per convenience and need of the user.

8 Road transport is cheaper and time saving in particular for short distance travel.

9 It should contain intelligently erected taffic signs and should make sufficient provisions for the safety of pedestrians and vehicles.

10 It should grant various amenities to raod users such as grass verges, sufficient lighting, watering and fuelling places at regular intervals, shady avenues, parking facilities in city areas, etc.

11 It should possess good alignment directness and visibility.

12 The curves along the raod should be properly designed and they should be free from blind corners.

13 The formation of road, either natural or prepared, should be stable enough to carry the foundation and traffic load.

14 The foundation depth should be adequate for effectively distributing traffic load over a suficient area of formation to keep the intensity of load within the safe permissible limits of the soil.

15 Theroad surface should be suitable for the general character of traffic and it shoudl possess characteristics such as

a economical in construction and maintenance costs,

b even and smooth, but hot slippery

c hard, durable with uniform wear

d neither dusty nor muddy and easy for cleaning and repairing

16 The surface of road should be impervious and impermeable to rain water

17 The width of raod should be sufficient and camber or cross fall of surface should be sufficient.

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 raods in Inida.**

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 requirments. They were aware of the fact that highways are the most important infrastructure needed for development.

History of road consturction

Roman roads

(Fig 1) 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.

The salient features of Roman roads are as follows.

i They were built straight without any gradient.

ii The soft soil from top was removed till the hard stratum was reached.

iii The total thickness of road section worked out as high as 750mm to 1200mm at some places.

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Fig 1 shows the typical cross-section of Roman raod. The construction procedure was caried out as follows:

i The trench having with equal to the width of carriage way required was dug in straight path by removing loose soil till hard surfaces was met with.

ii The bottom was covered by one or two layers of large foundation stones laid in lime mortar and having total thickness of about 100 mm to 200 mm. The edges of pavement were provided with vertical kerb stones.

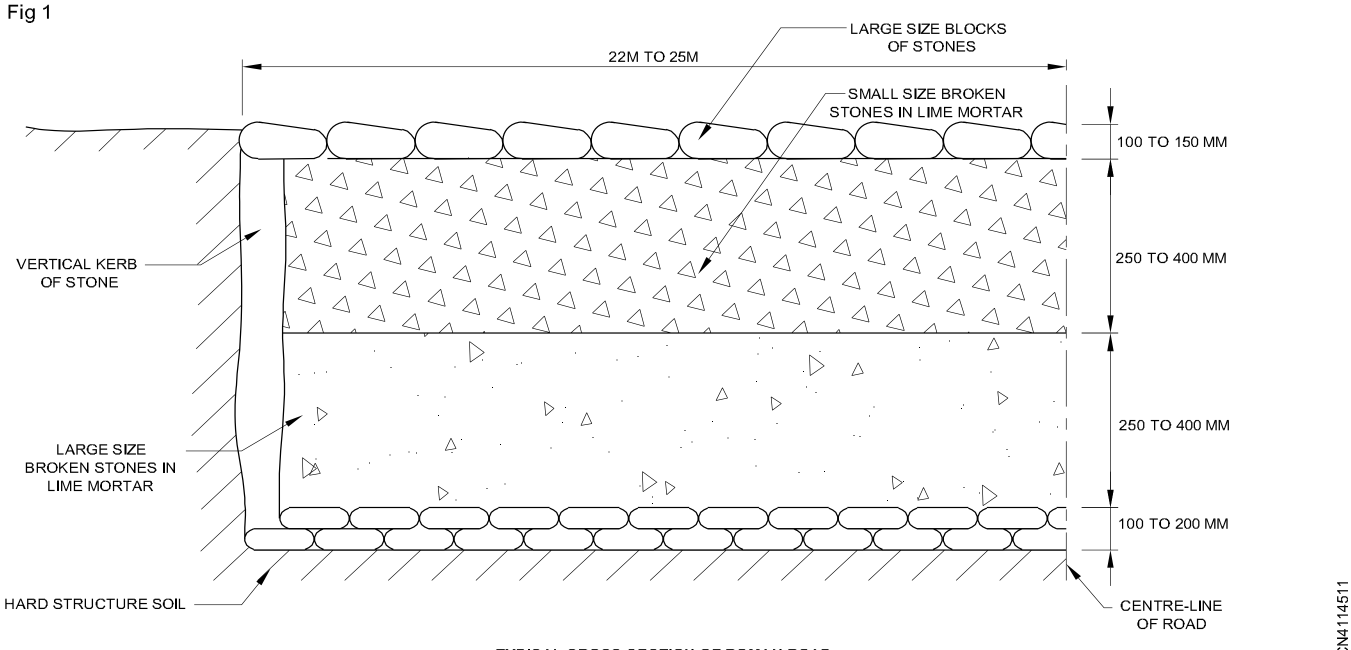
iii Above the bottom layer, another layer of thickness about 250mm to 400mm was placed and it consisted of large size broken stones mixed in lime mortar.

iv Over the second layer, another layer of thickness about 250mm to 400mm or more was placed and it consisted of small size broken stones mixed in lime mortar.

v Finally a wearing course in the form of large-sized blocks of stones of 100mm to 150mm thickness was provided at the top.

The Roamn techniques of road construction was found to be too costly and it did not gain popularity in other countries. As a matter of fact, there is no evidence showingn any remarkable progress made in road construction until the eighteenth century.

Fig 1



TYPICAL CROSS-SECTION OF ROMAN ROAD

Roads in France (Fig 2)

A Frebcg 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 1975 to 1785 and this method of read 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 wodern road construction technique. He also emphasised for due consideration of sub grade moisture condition and providion of camber at top to drain of the surface water.

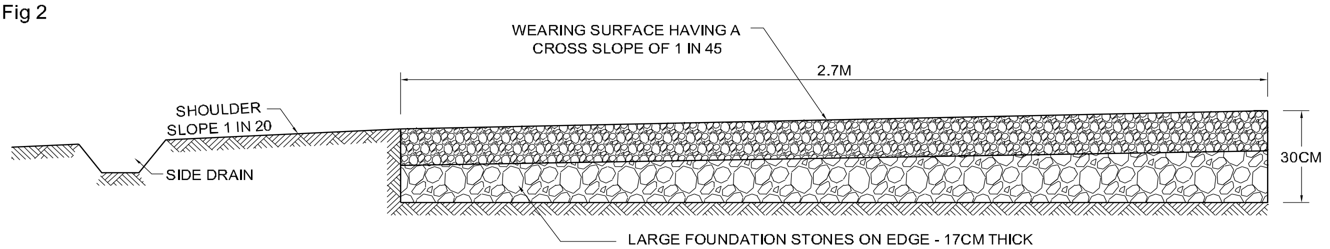
Construction Procedure

i The sub grade was prepared and a layer of large stones on edge was laid by hand. Generally the thickness of this layer was kept as 17cm. At the edges, the large stones were embedded edgewise to serve as submerged kerb stones.

ii Over this layer, another layer of smaller stones was laid and compacted thickness was kept at 8 cm.

iii The top wearing course was laid of smaller stones and its compacted thickness was made 5cm. For surface drainage a slope of 1 in 45 was provided.

Fig 2



TYPICAL CROSS-SECTION OF TRESAGUET'S CONSTRUCTION

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iv To provide lateral stability to raod, shoulders were also formed sloping. They were given a slope of 1 in 20 for proper drainage. This method was implemented in 1775.

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 or foads i n 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 varing the thickness of foundation stones.

Fig 3 shows the typical cross-section of telford's road construction. Following procedure was adopted

i The foundation was prepared for a road width of about 9m and it ws levelled.

ii Large-sized stones to 40mm and depth varying from 170mm to 220mm were then laid. The bigger stones were laid at the centre and stones with decreasing thickness were laid towardss the edges. Such an arrangement granted the necessary cross slope of the soil subgrade.

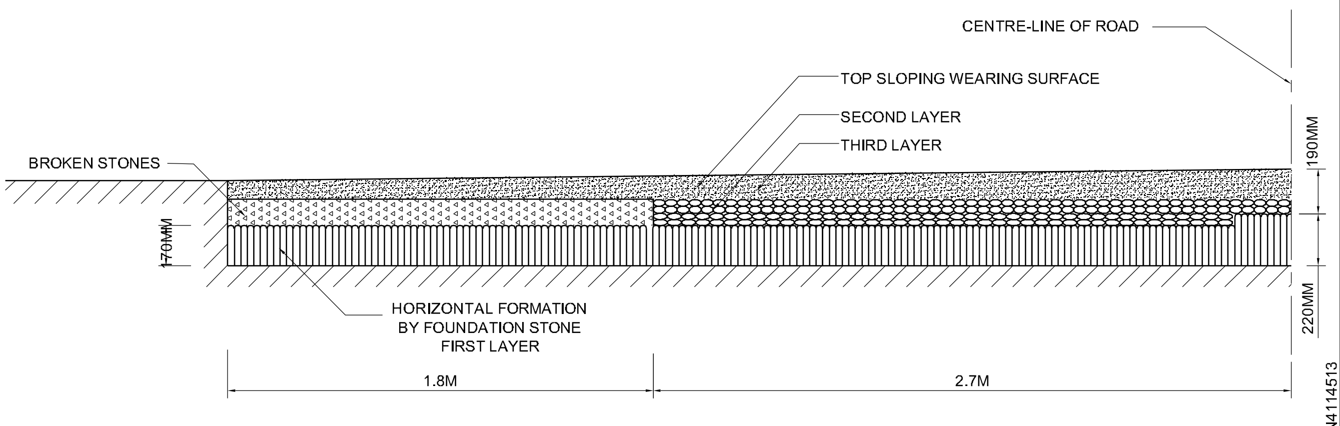
iii After filling the spaces between foundation stones by smaller stones and chippings and properly beating the surface, two layers of stones having compacted thickness of 100mm to 50mm respectively were laid in the central 5.4 m width of road. These layers were initially rammed and later on, they were allowed to be compacted by traffic and to be consolidated by rains.

iv The side portions were made up of only one layer of compacted broken stones of 150mm thickness and they were sometimes laid on lime mortar to serve the purpose of kerb stones.

v The formation top of the road was made of 40mm thick binding layer of gravel which was spread, watered and consolidated by traffic.

vi A cross slope of about1 in 45 as provided on the finished surface, to drain off the rain water leading to the side drain cross drain if needed were provided at an interval of about 90m.

Fig 3



TYPICAL CROSS-SECTION OF TELFORD'S ROAD CONSTUCTION

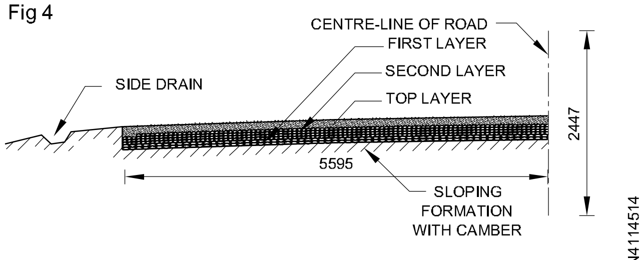
Macadam construction

John Macadam (1756-1836) an other Scottish engineer suggested a method of road construction in 1816 after studying the stone-road consturction 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.

Typical cross-section of Macadam's raod consturction

Fig 4 shows the typical cross-section of Macadam's road construction. Following procedure was adopted.

Fig 4



TYPICAL CROSS-SECTION OF MACADAM'S ROAD CONSTRUCTION

i The subgrade for a desired road width of 9m was prepared with a cross slope of 1 in 36.

ii The first layer of 100mm thickness of broken stones of strong variety and passing through 50mm size sieve was laid and compacted.

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iii The second layer of 100mm thickness of broken stones of strong variety and passing though 37.5mm size sieve was laid and compacted.

iv The top layer of 50mm thickness consisted of stones of size-less than 20mm and the layer ws compacted and finished wih a cross slop of 1 in 36.

Even now, in the new era of adopting latest technologies in the road construction, we follow the basic principle of macadam construction and such roads are known after the great engineer, John macadam.

Development of Roads in India.

The development of raods 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 inidcate 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 stae, he has compared the profile or cros-section of road with back of tortoise and it is thus clear that he knew the imprtance of upward convexity of top surface of road for drainage.

Chandra Gupta Maurya also formed a special communication department to look after raods and he managed to fix some pilars 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., therewas 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 rosds 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 raods. He constructed the longest road of his time connecting Lahore in Punhab 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 alos 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 represetative 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 developement.

Most of the recommendations made by the Jayakar Committee were accepted and implemented by the Central Government. A central raod 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.

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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 Inida. 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 raod development programmed in a planned manner. This conference prepared the firts 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 initated by the I.R.C and it was finalised in 1959 at a meeting of the Chief Engineers. The target of raod length achieved at the end of the second plan was nearly double than that of previous Nagpur plan and considerable improvement in road consturction 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 Develpment Project (NHDP) consisting seven phases to be executed during 2000 to 2010. This project covers upgradation, widening and strenghtening of National Highways, new BOT (Build, Operator and Transfer)and DBFO (Design, Build, Finance and Operate) projects, expressways, ring roads, flyovers, bypasses, etc.

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Technical Terms used in road engineering and Several Principles of Alignment

Objectives : At the end of this lesson you shall be able to
- **define raod and its advantages**
- **define the various terms used in raod engineering**
- **describe the vaious 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 activites 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, foood and clothing very quickly.

v They help in maintaining better law and order in the country

vi They hlep in providing effcient 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 defence 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 developement.

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 arboricultre.

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 raod. 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 raod. 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.

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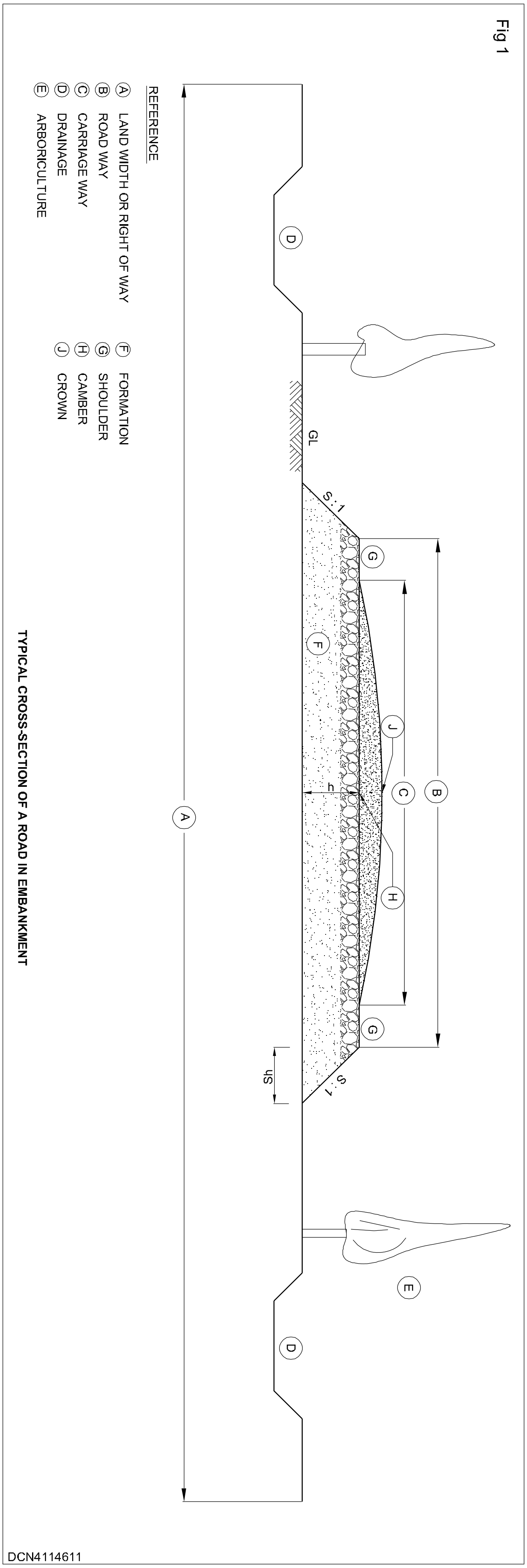

11 Acceleration lanes : An important roads lanes of sufficient width and length are provided to enable vehicles to accelerate to the design speed of the road after emerging out the intersection. Such lanes are called acceleration lanes.

12 crown(J) : The highest point of a cross section of a high way is called a crown.

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 option able 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 intermedite course of ashphalt mix between the base course and the wearing course is called binder course.

19 Ashphalt : It is defined as the mixture of refinery bitumen ad inert mineral matter. 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 raod : It is the main raod 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 raod is constructed which is called ring road.

25 Loop roads : These are alternative raods 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.

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27 **Bitumen :** It is a viscous mateiral 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 prodct is termed as bitumen.

28 **Capacity :** The maximum number of vehicles on a raod 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 raods. They allow water to flow across the raod surface during floods.

32 **Design speed:** The safe permissible speed on a given category of raod is called design speed.

33 **District road:** Road constructed with in the boudaries of the district connecting its vaious towns, industrial areas, thasil head quarter, high ways and railways etc are called district roads. They are comparatively less important.

34 **Drive way:** A road constructed to secure access from a road to a private property is called drive way.

35 **Earth roads:** The roads whose foundation as well as wearing course are made of soil available at the site are called earth roads.

36 **Earth work:** The preparation of the subgrade to the disired grade and camber is known as earth work for the road.

37 **Felling:** The process of removing stress is called felling

38 **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.

39 **Flexible pavements:** The pavements which reflect the deformation of subgrade and of subsequent layers on the top surface are called flexible pavements.

40 **Foot paths:** In the urban roads, separate space is provided for the use of pedistrians either in the midele or on edges of the road is called footpath. Generally footpaths are higher than the road by 15 to 25 cms.

41 **Fly over:** The road junction designed to divide the traffic to pass over or under each other is called fly over.

42 **Geometric design of high ways:** The design of road elements with wich the high way user is directly connected is called the geometric design of a high way

43 **Gradient:** The rate of rise or fall along the length of the road with respect to the horizontal length is called gradient.

44 **Head way:** The distance between successive vehicles moving in the same lane and measured from head to head at any instance is known as head way space.

45 **High way:** An important raod of a road system is called high way.

46 **Inter sections:** All road inter section which meet at about the same level allowing traffic manoeuvre like merging, diverting, crossing etc are called inter sections at grade.

47 **Joint filler:** The materrials used to fill the space between joints are called joint filler materials

48 **Lane width:** The width of carriage way is calledlane 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.

49 **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.

50 **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.

51 **Map cracking:** It is the defect in road pavement the cracking of bituminous srurfaces due to fatigue in an irregular fashion is called map cracking.

52 **Mastic asphalt:** A mixture of bitumen, fine aggregates and filler in suitable proortion which gives a void less and impermeable mass is called mastic asphalt.

53 **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.

54 **Native asphalt:** The asphalts which occur in pure or nearly pue state in nature is called native asphalt.

55 **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 defence purpose are called National high ways.

56 **Non skid coats:** To increase the skid resistance, a light coat of biumijous material and aggregate has to be applied on the existing surface. This coat is called non skid coat.

57 **Obligatory points:** these are the points which govern the alignment of the high ways.

58 **Over pass:** When the major high way is taken above general ground level by contsturcting a over bridge across an other high way then it is called a over pass.

59 **Patch repair:** Repair of localized damaged surface is called patch repair.

60 **Perception time**: Time required for a driver to realise the necessity of applying brakes to the vehicles, is called perception time.

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61 **Pot holes:** When the stone aggregate are lost from the base course of a pavement the holes formed are called pot holes.

62 **Prime coat:** A bituminous wearing surface placed upon a previously untreated c ompacted 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.

63 **Primer:** The adhesive material which penetrates into the capillary voids of the existing base and plug them is called primer.

64 **Revelling:** The removal of material from bases course of the pavement is called revelling.

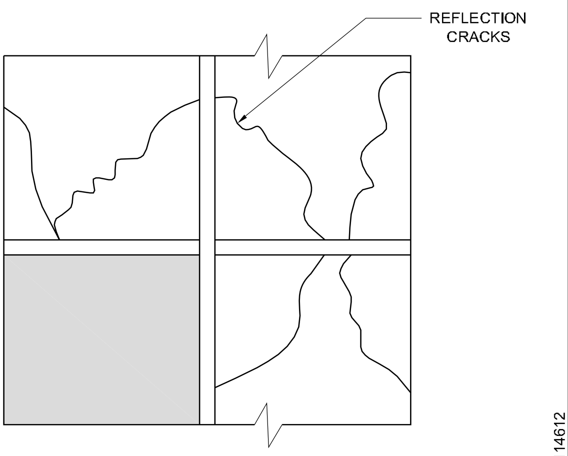
65 **Regression:** The changes in the strength of the sub grade are known as regression.

66 **Return wall:** Wall provided at right angles to the abutments to support earth fill at their back are called return walls.

67 **Reaction time:** The time taken from the instant the object is visible to the driver to the instant breakes are applied effectively is known as reaction time.

68 **Reflection cracks:** These cracks are developed in bituminous surfacing laid over existing cement concrete pavements (Fig 2).

Fig 2



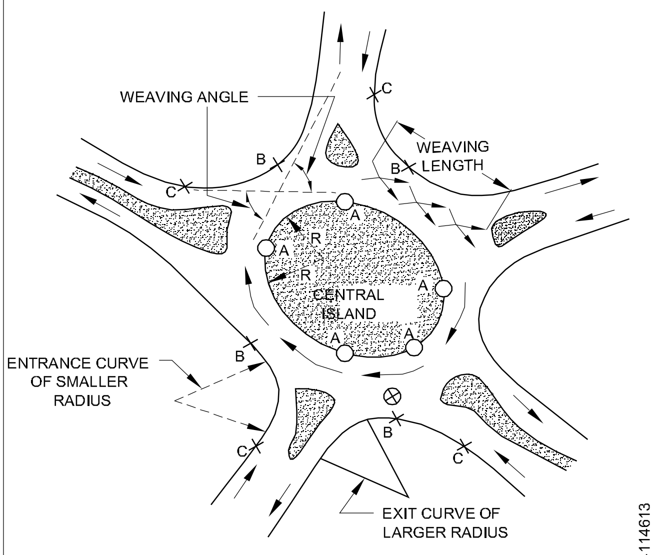
FORMATION OF REFLECTION CRACKS

69 **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.

70 **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 (Fig3).

71 **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.

Fig 3



ROTARY INTERSECTION

72 **Sand asphalt:** Base course or a surface formed from a mixture of sand, asphalt and cement with or without mineral filler is called sand asphalt.

73 **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 ingress of water.

74 **Sealer:** Compounds used to seal the joints are known as sealer.

75 **Set back or clearance distance:** The distance between the centre line of a horizontal curve to an obstruction on the inner side of the curve is called set back distance.

76 **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.

77 **Skid:** When wheels slide without revolving the phenomenon is called skidding.

78 **Slides:** The movement caused by finite shear failure is called slide.

79 **Slip:** If the wheel revolves more than the corresponding longitudinal movement along the road, then the phenomenon is called slip.

80 **Spalling of joint:** When the stone girt enters into the joint space reducing the effective width of the joint the fault developed is called spalling joint.

81 **Summit curves:** Curves whose convexity is upwards are called summit curves.

82 **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.

83 **Tar:** It is a viscous liquid obtained from the destructive distillation of coal or wood in the absence of air.

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84 **Trace cut:** A narrow track 0.6m to 1.2 m wide prepared along the alignment of a hill road to enable access to the road for inspection during location of the route is known as trace cut.

85 **Traffic:** All types of vehicles using road such as buses, trucks, carts, cycles etc. and pedestrians together form traffic.

86 **Transition curve:** Curve provided betwee 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.

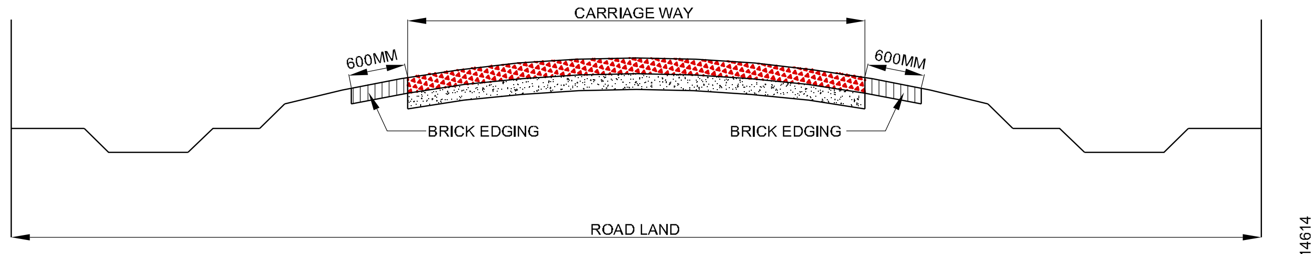
87 **Valley curves:** Curves with convexity downwards are called valley curves.

88 **Verticle curvese:** Curves provided at the intersection of different grades in the verticle alignment of a highway are called verticale curves those curves provide esasy change in grdients for fast moving vehicles.

89 **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.

90 **Brick edging:** For widening the main carriageway, the brick edging provides a cheap and effective method as shown in fig.4. The extra 600mm width of flat bricks or bricks on edge on either side of the carriageway provides additional travelling surface (Fig 4).

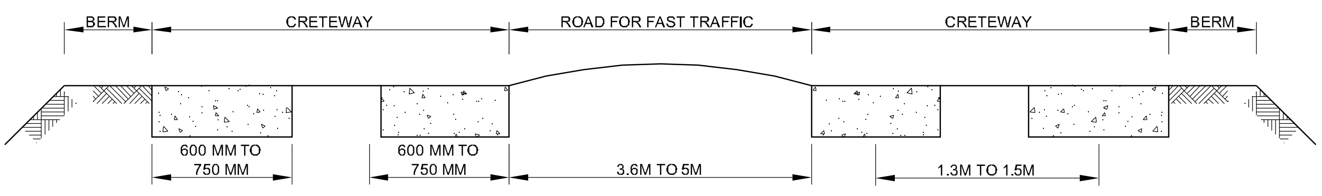
Fig 4



BRICK EDGING

91 **Creteways:** 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 raod is known as creteway and it is in the form of concrete slabs which may either be cast-in situ or precast. Fig 5 shows the section of road with creteways on the either side. The central portion of 3.6m to 5m width is used by fast moving traffic and the creteways on the sides are meant for slow moving iron-tyred bullock cart traffic. The nar row longitudinal stips of creteways are 600mm to 750 mm wide, 100 mm to 150 mm thick and 1.3 to 1.5m centre to centre apart.

Fig 5



SECTION OF ROAD WITH CRETEWAYS

92 **Kerbs:** To show the boundary between the road pavement and shoulder or footpath or islands, kerbs and provided as shown in Fig 6. For rural roads, the provision of submerged kerbs at pavement edges between the road pavement and shouloders will increase the lateral stability of the granular base course and flexible pavements.

The simplest form of traffic separator will be in the form of pavement markings. In case of important roads dividing islands or parkway strips may be provided to serve as traffic separators as shown in Fig 6.

As per the recommendations of the I.R.C. a minimum desirable width of 5m is necessary for medians of rural highways and it may be reduced to 3m where land is restricted.

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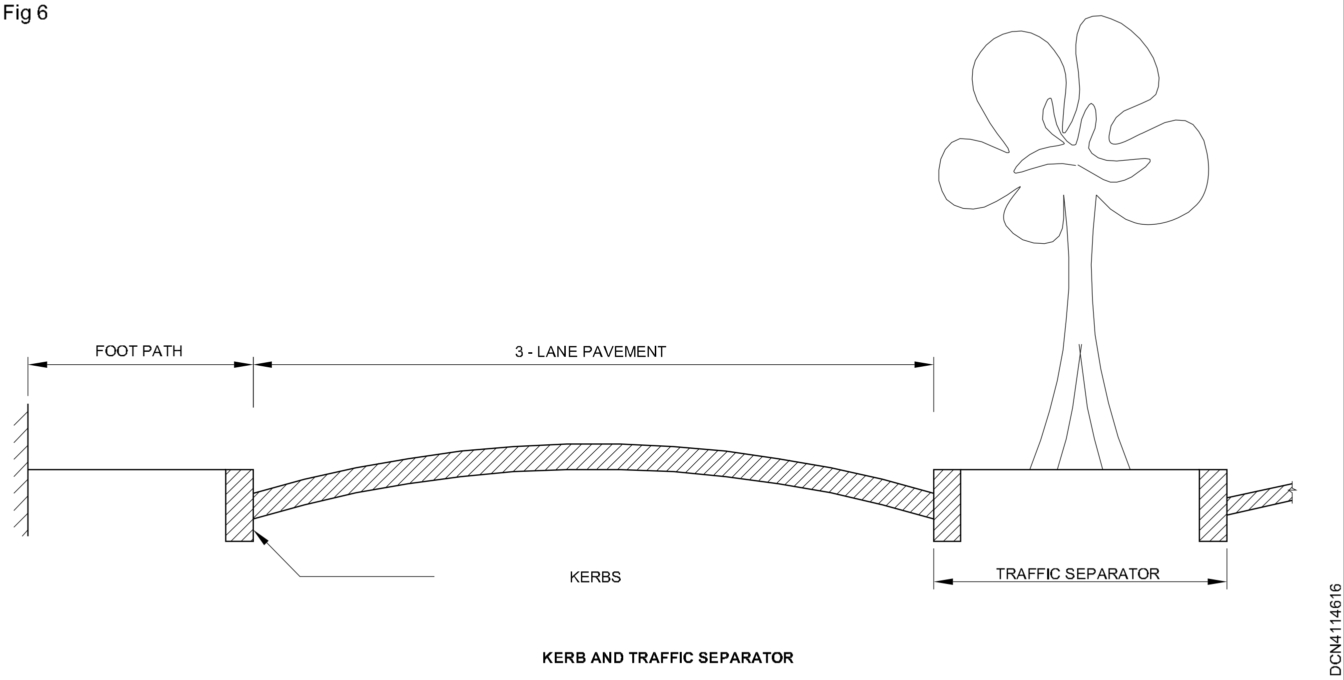
Fig 6



KERB AND TRAFFIC SEPARATOR

93 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 interesections

III To protect pedestrians

IV To segregate slow traffic and

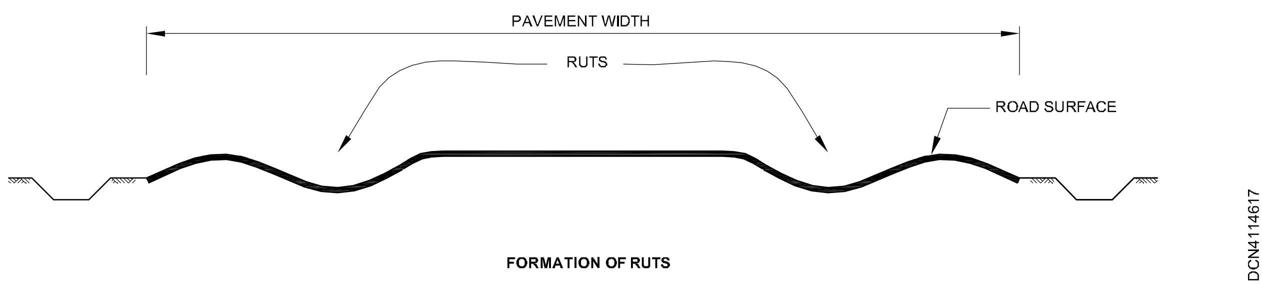
V To shadow the crossing and turning traffic

94 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 7)

95 Frost heaving: Depending upon the ground water and climatic conditions a localized heaving up of portion of pavement takes place due to the action of frost. The Fig 8 shows the failure of pavement due to frost heavy.

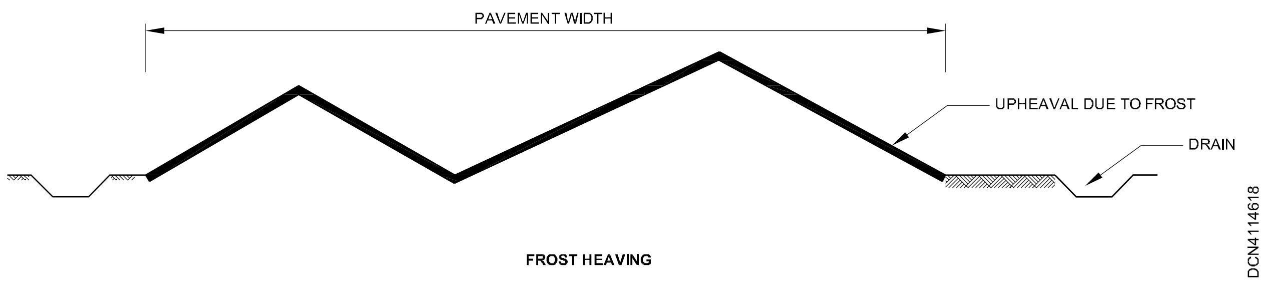
96 Traffic island: Traffic islands are raised areas constructed within the carriageway to provide physical channels to guide the vehicular traffic.

Fig 7



FORMATION OF RUTS

Fig 8



FROST HEAVING

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97 **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 prupose (Fig 9)

I Control of speed

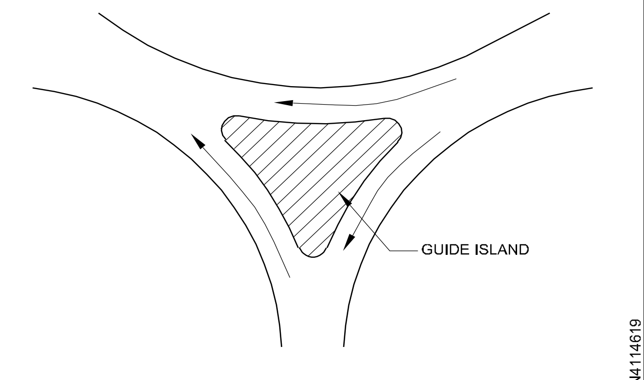
II Control of angle or conflict

III Separation of conflicts

IV Protection of traffic for vehicles leaving or crossing the main traffic system

V Protection of pedestrians

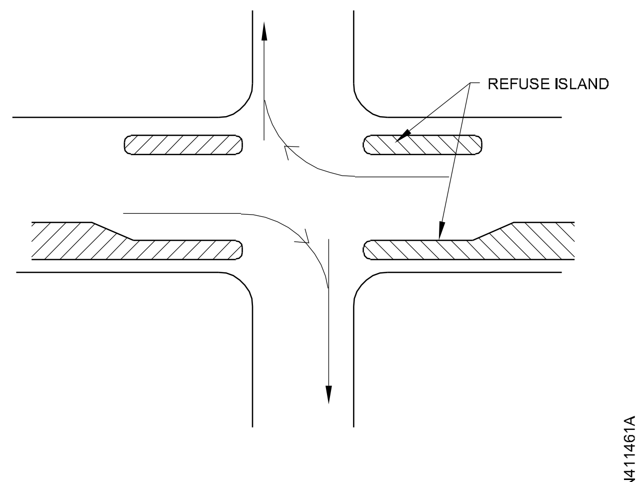
Fig 9



GUIDE ISLAND

98 **Refuse island:** An island providd 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 10).

Fig 10



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 suryers 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 maintanence 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.

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6 The alignment serves maximum population by connecting intermediate important towns and groupp 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 alnd 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

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 obtin information regarding the salient feature of the teritory

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 alterrnative routes found out by reconnaissance survey and to deltermine with the greater accuracy the cost of high way 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 surey along the route which has been found and fixed as the most economical route from the data of the preliminary suvey. It established the centre line of the actual highway to be laid and hene as so location survey is completed the construction work started.

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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 clasified as per the disired 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 Buituminous 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 catergories as follow:

1 National highwy (NH)

2 State highways (SH)

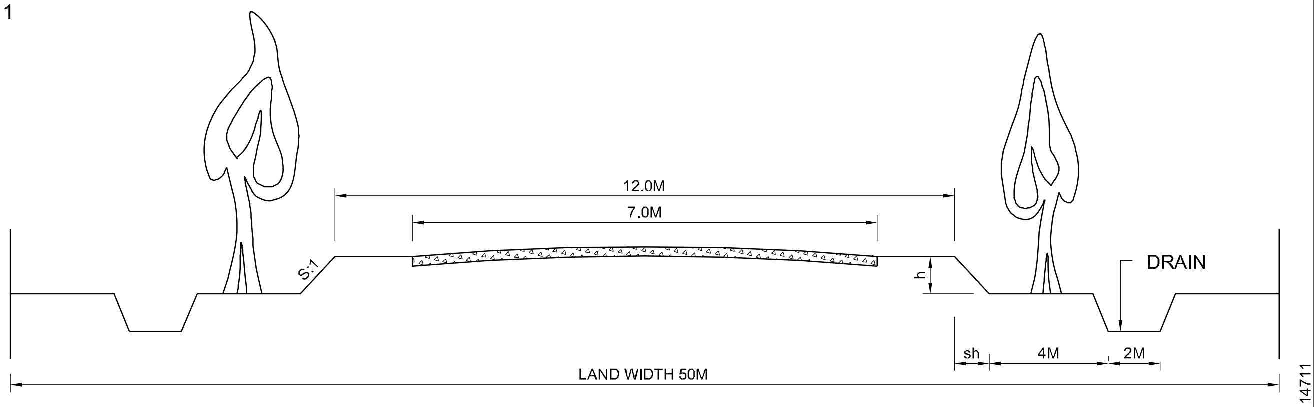
3 Major district roads (M.D.R)

4 Minor or other district roads (O.D.R)

5 Village roads (V.R)

1 National highways: These are the imprtant 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 nof 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 through out the year and they should be disigned to take traffic into the heart of the rural area. (Fig.4)

4 Other district roads (ODR): These raods are some what of lower specification as compared to major district roads. They are connected to major district roads and railwys. They are intended to serve the interior rural population of the district. (Figs 3&4)

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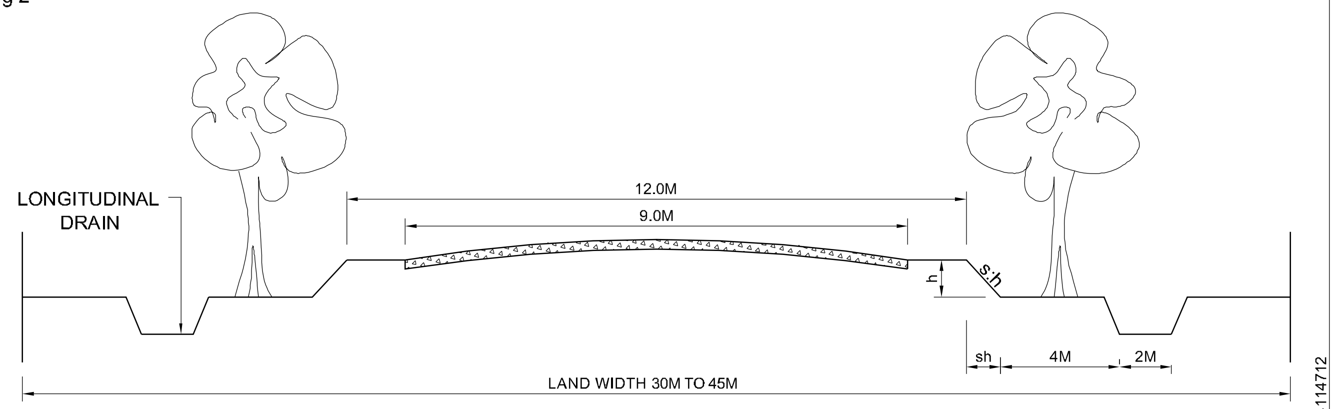
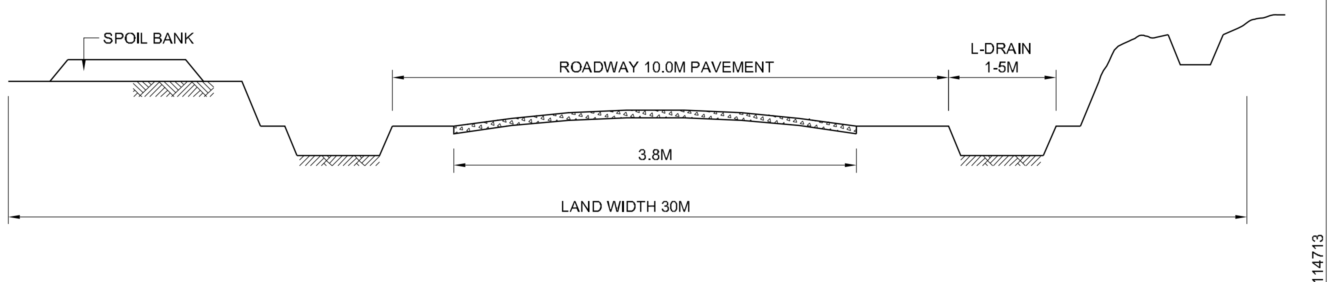
Fig 2



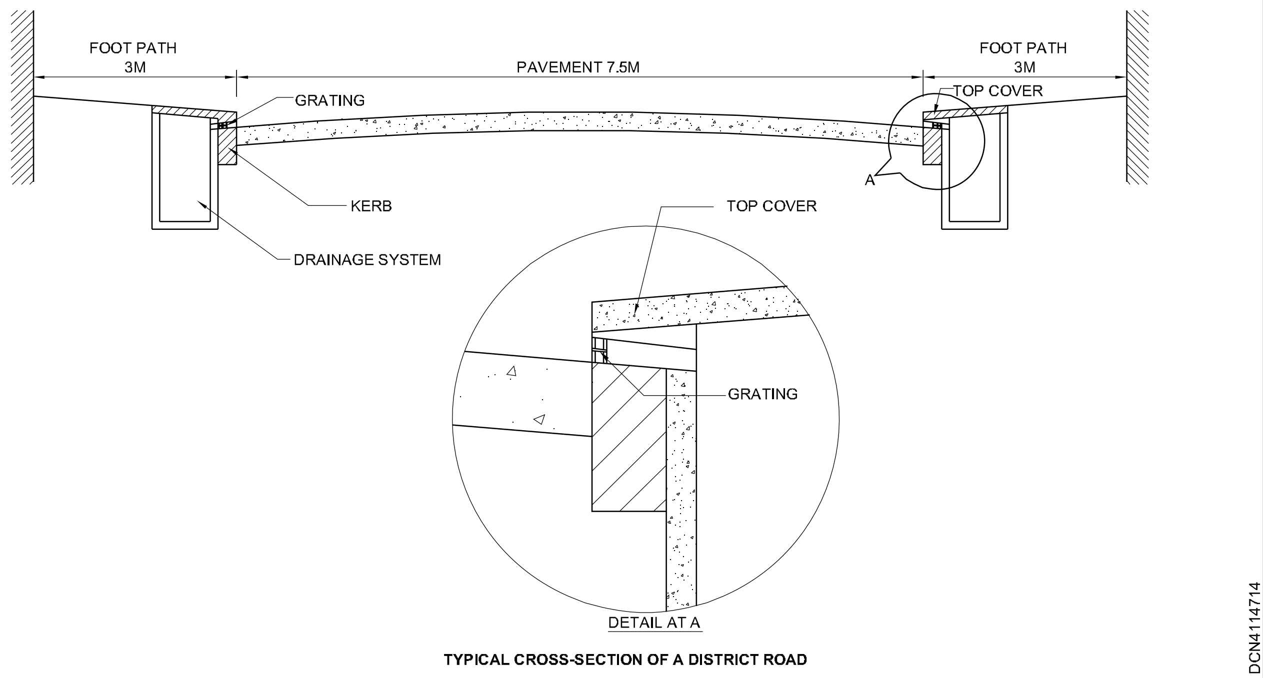
TYPICAL CROSS SECTION OF A STATE HIGHWAY

Fig 3



TYPICAL CROSS-SECTION OF A MAJOR DISTRICT ROADS

Fig 4



TYPICAL CROSS-SECTION OF A DISTRICT ROAD

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 unuseable. A metalled road, which passes near a village and is conneted by akachha road, is known as the village approach road. It is maintained by the village panchayat (Fig 5).

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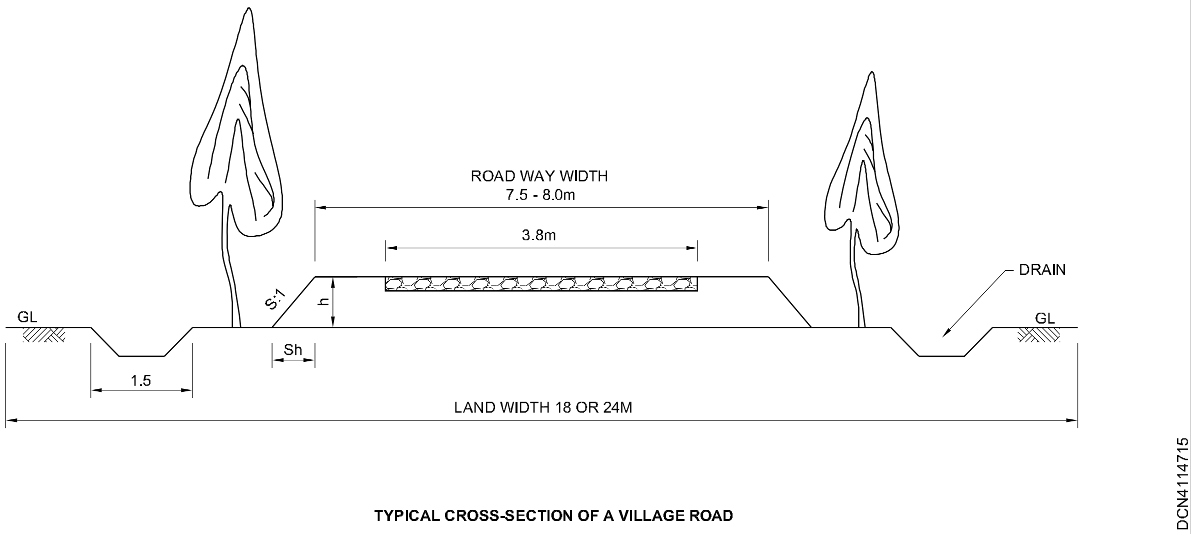
Recommemded Land width of different classes of roads (in metres)

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 defence point of view these roads are of much impotance. 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 ecpressways 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 imprtant 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 bny letter M. Similarly the letters T and P will indicate respectively that the traffic consists mostly of trucks and passenger vehicles.

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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 chracteristics, 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 imprtance

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 Clasification 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 sonnage 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 highw is transferred over to the government.

Following are some of the major BOT projects of India;

1 **Kundi Manesar 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 wxisting two lane road into four lane on NH 24.

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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 constructin 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 ncross sope 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 tow 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 raods.

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 raods 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 carrageway 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 paticles 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 sandostones, 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.

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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 page 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 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 leat 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 surfacemto become wavy and corrugated.

d Some quntity 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 sprinking of water should be done througha fine nose or nozzle.

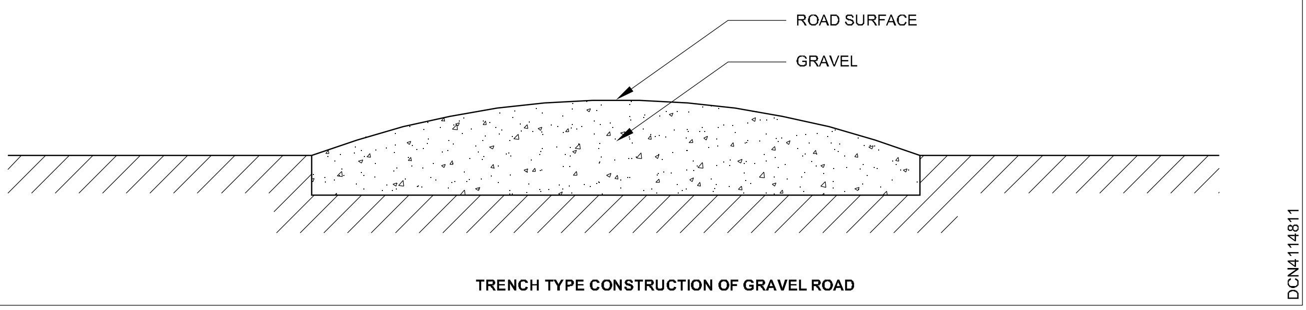
e The camber is checked at intervals and it is corrected, inecessary, with the help fo atmeplate or a camber board.

f The final rolling is carried out when the moisture content is at its optimum so that the completed surface which is formed is firm and unyielding.

g There are two types of construction for a gravel road, namely, trenchtype 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 otulet 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 trenchprevent lateral flow of water. However, the gravel will be confined in a better way in trench type construciton and hence, it is genrally adopted. When the gravel road is to be formed in more than two layers, it will be advantageous to combine both the methods. The bttom layers may be formed by the trench type construction and the top layer may be formed by the feather edge construction.

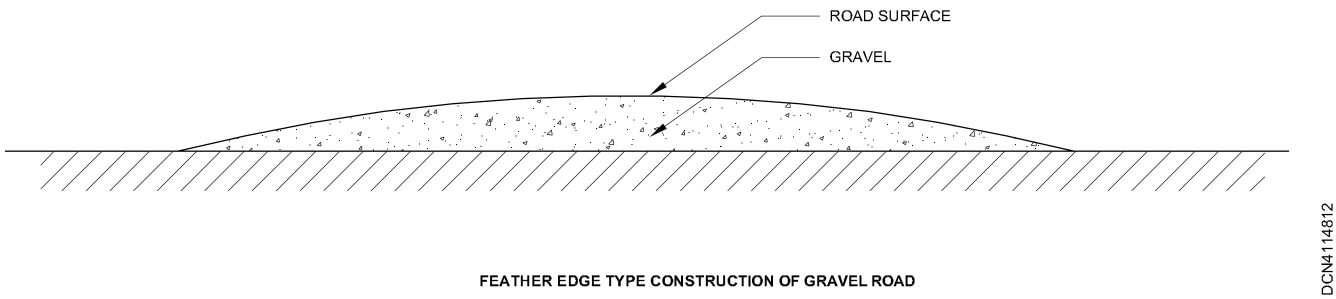
h A thin layer of sand of about 5 mm to 10 mm thickness is provided before eopening the road to traffic. The newly made surface should be watched carefully for several months and defects developed under traffic should be corrected immediately.

Fig 1



TRENCH TYPE CONSTRUCTION OF GRAVEL ROAD

Fig 2



FEATHER EDGE TYPE CONSTRUCTION OF GRAVEL ROAD

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Advantages of gravel roads

a A good gravel road is smooth, somewhat relsilient and pleasing in appearance.

b It is found that a well compacted gravel road gives good tranction and is not slippery when wet for moderate speeds.

c The capacity of gravel road may be taken as about 100 tonnes of pneumatic tyred 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 the design requiremements. Thesurface 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 thckness by smoothed wheel rollers. In W.B.M. roads generally camber is provided of the order 1 in 36 to 1 in 48.

Types of Macadam Road

Macadam roads may be classified into four groups as follows depending upon the method of binding action.

1 **Water bond macadam:** It is the layer of broken stone aggregates bound together by stone dust or screening and water applied during costruction, and compacted by heavy smoothed wheel rollers.

2 **Traffic bond 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 tow or more layers. The compacted thickness thickness of each layer may very from 2.5 to 5.0 cms.

3 **Bituminous macadam:** It is the compacted layer of clean crshed stone o reasonably uniform in size. Over this layer a second layer of crushed stone together with bitminous material heavily sprayed. Much of the bituminous mateirla 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 meterial is applied and a thin layer of still 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 carrageway, 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. Th 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.

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i There is formation of courrugations 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 brooming of each layer of screening should be carried out carefully.

f After the application of screening, the road surfaceis 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 th 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 skurfaces of roller. The process of rolling iscontinued till the slurry of binding mateiral 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 hungry spots or depression are found on the next day, they are filled up with screenings or binding material, as found necessary and after lighly 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.

Advantaes 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 particless. 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 dreainage 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 inwhich 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 apperance due to presence o bitumen.

Bitumen

It is a mixture of natral 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 ibtained by partial distillation of crude petroleum eithr 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 anexcellent binding material

iii It softens when heateds

Method of construciton

Surface dressing can be done on a new W.B.M. or an existing surface. If the surface ist o be given to a new W.B.M.road surface then in the construction process the bindage and blindage layers are omitted. In this case, the road metals are properly rolled after sprinkling water and the surface dressing is applied.

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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 dresing 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 reconditined as explained above. If the existing abse 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 chppings: 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 starte from the edge towards the centre longitudinally with overlapping not less than 1/2 of the wiedth or 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 wich 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 btuminous 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 vlaue for a given mix it becomes harmful to the good performance of the bituminous roads.

3 The viscosity of thebitumen-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 concerte road

It is modified method of construction used instead of bituminous road, for improving the quantity of road pavement.

Rubberised asphalt concrete (RAC) also known as asphalt rubber or just rubberzised 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 concretre 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 pavememnt. 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 pavememnts because of their rigidity. The cement concrete road provides a highly rigid surface and hence, for the succes of such roads, the following two conditions should be satisfied.

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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 distruibute 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 concrerte 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, shped 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 eaqual 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 preferaby by done in concrete mixer.

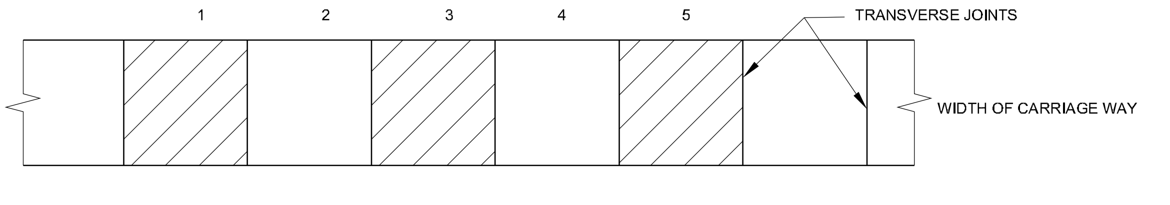
5 **Compactin and finishing:** After the concrete is placed in its position it should be brought in its proper position by a heavy screed or temper fitted with suitable handles the straight edging and refloating are continued until the entire surface is true to camber and grade.

6 **Belting brooming 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 brooming 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.

Fig 3



SINGLE LANE ROAD

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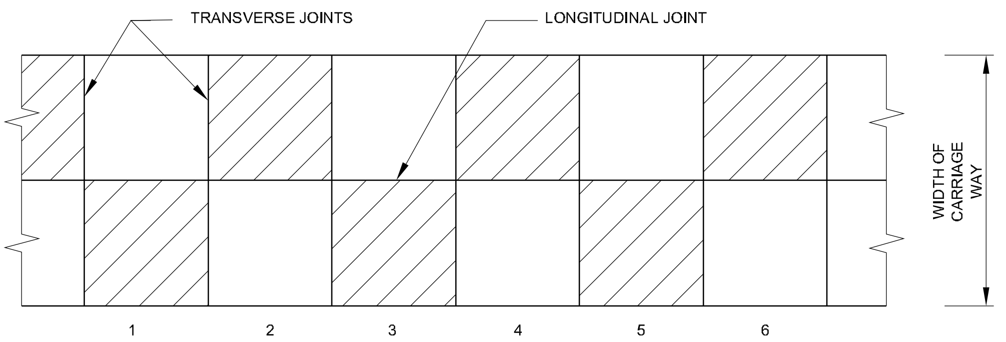
Fig 4



DOUBLE LANE ROAD

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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 suitble 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).

2 Continuous bay method: This is also knwon 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 consturction joint is provided where the new concrete meets the previously laid concrete.

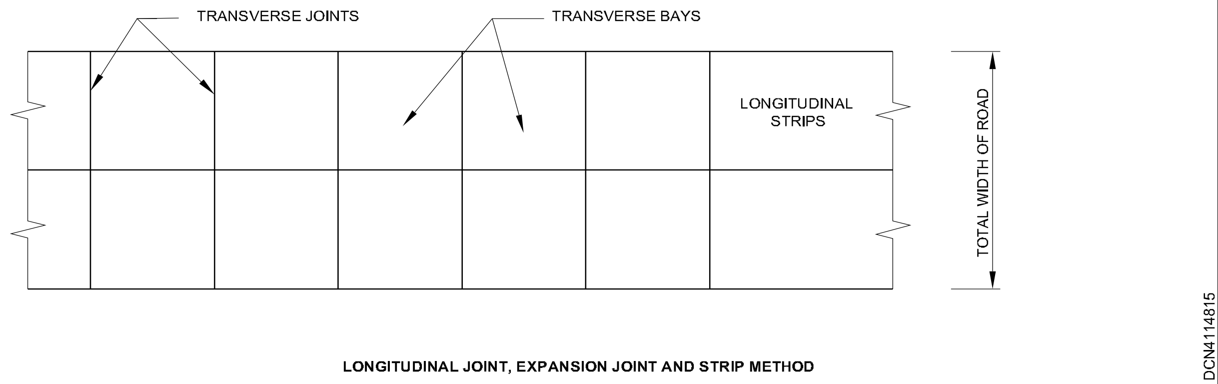
This method is suitable for raods having width not exceeding 4.5m and it is very simple in construction.

Howeve, it does not stand a high temperature varation 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 timeber formwork as shown in Fig 5. The joints are then suitably filled up with fillers like asphalt and finished so as to providefor the expansion of the concrete slab.

Fig 5



LONGITUDINAL JOINT, EXPANSION JOINT AND STRIP METHOD

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 themodern 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.

5 Tractive or rolling resistance is low.

6 It provides high night time visibility.

Disadvatages 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 metarial 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

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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 posses not slipppery surface

11 It should neither dusty nor muddy and easy for cleaning and repairing.

12 It should offer least resistance to traffic.

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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 anture of the terrain, cutrural fearues or other unavoidable reasons. Such cahnges in direction cannot be at sharp corners but have to be gradual which necessitates the introduction of curves in bteween 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.

Necesseity 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 excesive 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 horozontal curve is a curve in plant to provide change in direction to the centrall line of a road. The minimum radius of a horozontal curve depends on the permissible design speed for the road. The values of minimum radii for vaious 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

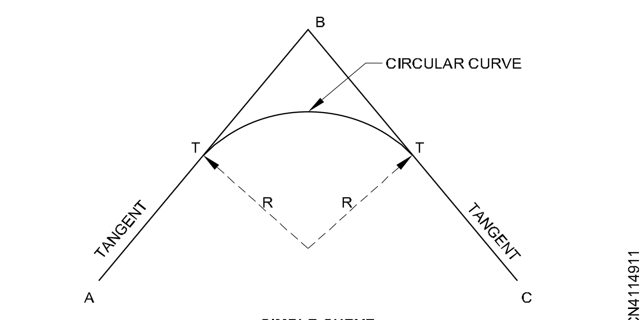
b Compound curve

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).

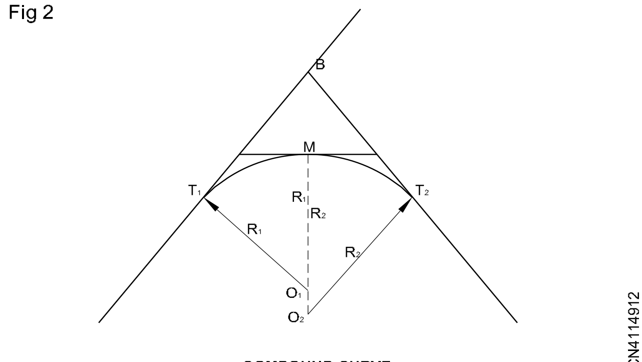
Fig 1



SIMPLE CURVE

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).

Fig 2



COMPOUND CURVE

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_1 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.

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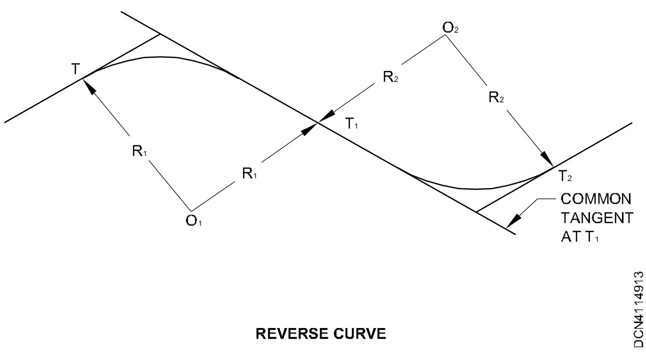
Objects of providing transition curve

a To provide gradual and easy transformation from straight to circular curve and from circular curve to the straight roads

Fig 3



REVERSE CURVE

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 apperance of the road.

Types of transtions curves (Fig 4)

The following types of transition curves are commonly adopted in horizontal aligment.

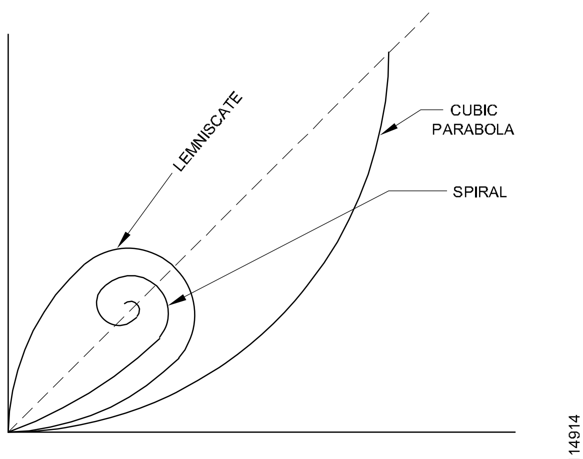
a Lemniscate

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.

Fig 4



TYPES OF TRANSITION CURVES

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

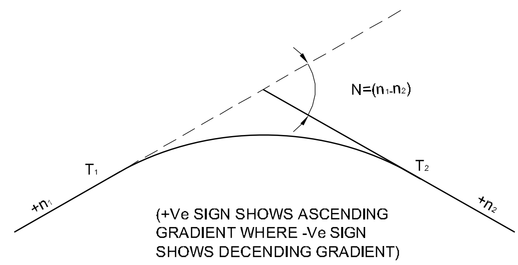
i a Summit curves

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 diatance and overtaing sight distance are considered separately (Fig.5).

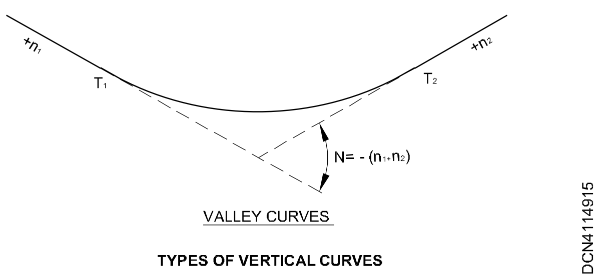
Valley curves: Valley curve are vertical curves having their convexity downward. This is also called sag curves. At the valley curves the centrifugal force acts downwards adding to the pressure on the suspensions in addition to the self weight of a vehicle moving on the curve. Hence the design of valley curve is governed by the allowable rate of change of centrifugal accelaration (Fig 6).

Fig 5



SUMMIT CURVES

Fig 6



VALLEY CURVES

TYPES OF VERTICAL CURVES

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 Forwrd tangent: The tangent IT_2 at T_2, the end point of the curve is called ‘forward tangent’. (Fig.7)

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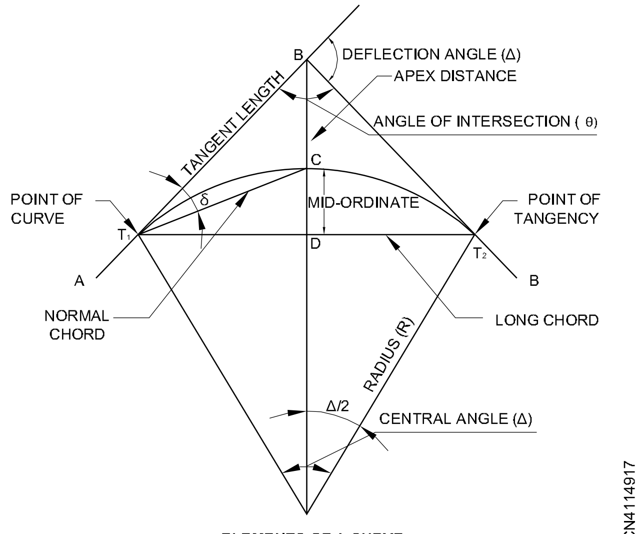
Fig 7



ELEMENTS OF A CURVE

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 tangecy, is called length of the curve.

11 **Long chord:** The chord joning the point of the commencement and point of tangency, is called long chord.

12 **Mid - ordinate:** The ordiante joning 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 distancee between the center curve ie apex to the point of intersection of simple circular curve.

Minimum radii of horzontal curves as per I.R.C

S No	Road classification	Minimum radii of horizontal curvers (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

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Geometrics of a circular curve (Fig 8)

To understand the geometrics of curves, the important proerties of a circle are discussed with reference to Fig 8

1 Length of tangents AT1 = AT2 = R tan $\frac{\theta}{2}$ where

θ is the

angle T_1OT_2 (central angle)

and R is the radius of the circle.

2 Long chord $T_1 T_2 = 2R\sin\frac{\theta}{2}$

3 The angle subtended by any chord at the centre of the circle is twice the angle between the chord and tangent.

ie $< AT_1B = \frac{1}{2} < T_1OB$

Proof : From Fig 8

Let $<AT_1 B = \delta$

Then $<BT_1 O=90° - \delta = < T1\ BO$, i.e Isoscel triangle of side 'R'

$\therefore$ Angle T_1OB subtended by the chord T_1B at the centre O

$= 180°-2(90° - \delta) = 2\delta$

or $< AT_1B = \frac{1}{2} <T_1OB$

4 The angle subtended by a chord at any point on the circumference is equal to the angle between the chord and the target, i.e.

$AT_1B = <T_1T_2B$ (From Fig 8)

Proof

From property No.3

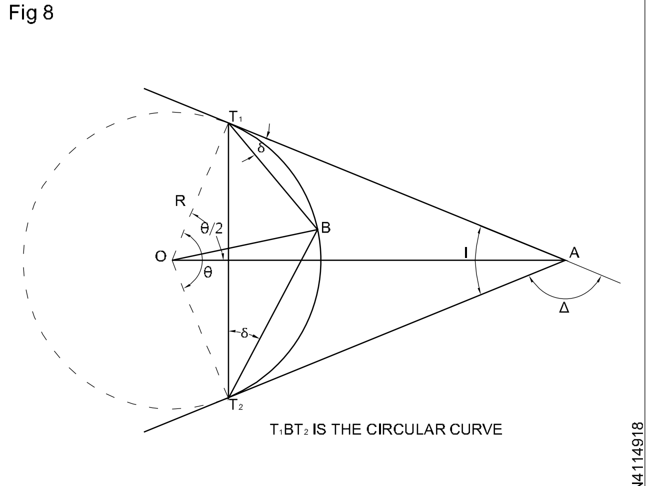
From the equadrilateral $T_1AT_2O_1$

$<OT_1B = <OT_2B=90°$ (Tangent and radius intersection)

$<T1\ \Delta\ T2 = 180$ - Deflection angle

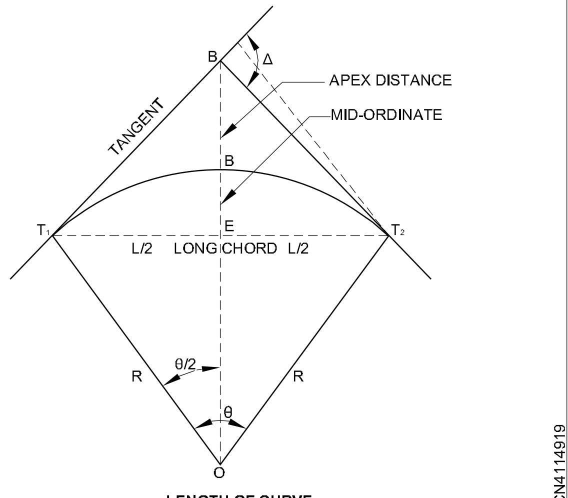
= 180° -   = (Inter Sector Angle)

Fig 8



GEOMETRICS OF A CIRCLE

Fig 9



LENGTH OF CURVE

Total included angle of a equadrilateral is 360°

ie (2n-4) x 90°

$\therefore <T_1 OT_2 + <T_1 AT_2B = 180°$

$T_1OT_2 = 180° - <T_1 AT_2 = 180° - (180°\quad)$

$<T_1 OT_2 =$

i.e., centre angle subtanted by the chord = total deflection angle.

Lengthe of curve (Fig 9)

Total circumference =2   R

So, arc length $T_1B\ T_2$ for an angle 'θ'

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$= \frac{2\pi R x \theta^{0}}{360^{0}}$

Length of curve $= \frac{\pi R \theta^{0}}{180^{0}} = \frac{\pi R \Delta^{0}}{180^{0}}$ (central angle $\theta°$

$=$ deflection angle Δ^{0}

$= R\ \Delta^{0}$ (When is in radian)

Mid ordinate

From $\Delta T_1 0E$

$BE = OB\text{-}OE = R\text{-}R \text{ Cos } \frac{\theta}{2} = R\left(1 - Cos \frac{\theta}{2}\right)$

Mid ordinate $0_0 R \left(1 - \text{Cos } \frac{\Delta}{2}\right)$

Apex distance = From ΔT_1OA

$\text{Sec } \frac{\theta}{2} = \frac{0A}{0T_1}, OA = OT_1 \text{Sec } \frac{\theta}{2}$

$(OB + AB) = OT_1 \text{ Sec } \frac{\theta}{2}$

$(R+AB) = R \text{ Sec } \frac{\theta}{2}$

$AB = R \text{ Sec } \frac{\theta}{2} \text{ -R } \left(\text{Sec } \frac{\theta}{2} - 1\right)$

Apex distance $= R \left(\text{Sec } \frac{\theta}{2} - 1\right)$

Mid-ordinate

As per linear method of cuve ranging.

From figure, consider the triangle OET.

$$OE = \sqrt{(OT_1)^2 - (T_1E)^2}$$

$$= \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

Now, BE = OB-OE

Mid-ordinate $R - = \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$

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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.**

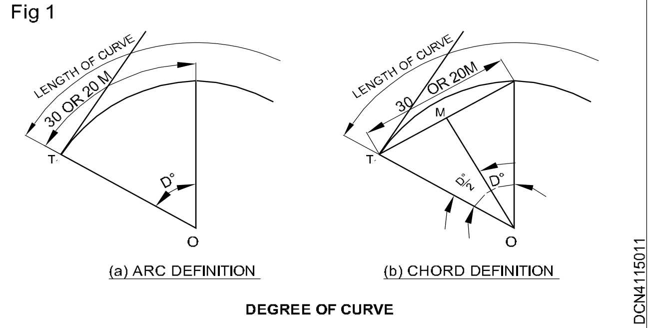
Designation

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 10 a,b. According to the chord definition, chord of 30 or 20 m lenth.

Fig 1



In highways, it is customary to use the arc definition whereas the chord definition is utilized in railways.

Relation between degree and radius of curve

Arc definition If R is the radius of a curve and D is its degree for a 30 m arc (Fig 1 a)

then,

R x D x (as per the lenght of curve)

or R =

$$orR = \frac{1718.9}{D} = \frac{1719}{D} \text{ .... (1)}$$

If ID is the degree of a curve for a 20 m arc, then

$$\text{R x D x } \frac{\pi}{180^0} = 20$$

or R =

$$\text{or R = } \frac{1145.9}{D} \approx \frac{1146}{D} \text{ .... (2)}$$

Chord definition for a30 m chord, from triangle T_1OM (Fig 1B)

$$Sin\frac{D}{2} = \frac{T_{1M}}{OT_1} = \frac{15}{R}$$

$$\text{R = } \frac{15}{Sin\frac{D}{2}} \text{ .... (3)}$$

Since D is very small, therefore, sin $\frac{D}{2} \approx \frac{D}{2}$

Hence,

$$R = \frac{15}{\left(\frac{D}{2}\right)\times\left(\frac{\pi}{180^0}\right)}$$

$$orR = \frac{15\times 2\times 180^0}{D\times\pi}$$

$$\text{or R = } \frac{1718.9}{D} \approx \frac{1719}{D} \text{ .... (4)}$$

Similary, for a 20m chord, from triangle T_1OM

$$\text{Sin } \frac{D}{2} = \frac{T_1M}{OT_1} = \frac{10}{R}$$

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$$R = \frac{10}{Sin\frac{D}{2}} \text{ .... (5)}$$

$$\text{Sin } \frac{D}{2} \approx \frac{D}{2},$$

Since D is very small, therefore, Sin Sin $\frac{D}{2} \approx \frac{D}{2}$,

Hence

$$R = \frac{15}{\left(\frac{D}{2}\right) \times \left(\frac{\Delta}{2} \frac{\pi}{180^0}\right)}$$

$$\text{or } R = \frac{10 \times 2 \times 180^0}{D \times \pi}$$

$$\text{or } R = \frac{1145.9}{D} = \frac{1146}{D}$$

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 1800. The telescope is then swung 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.

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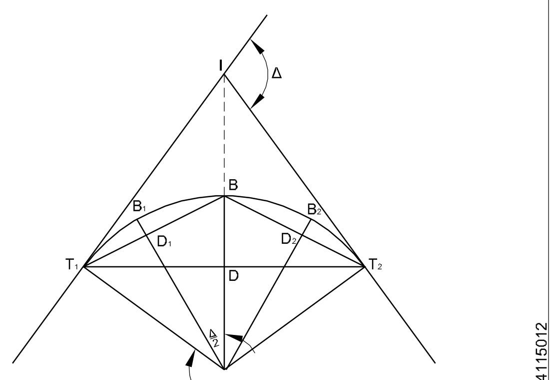
Setting out a simple circular curve

Linear method Successive bisection of arcs chords (Fig 2).

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

Fig 2



SUCCESSIVE BISECTION OF CHORDS

$$0_0 = R^2 - \left(\frac{L}{2}\right)^2 or R\left(1 - Cos\frac{\Delta}{2}\right)$$

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

$R\left(1 - Cos\frac{\Delta}{4}\right)$ 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 $R\left(1 - \cos\frac{\Delta}{2}\right)$ or $R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$

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.

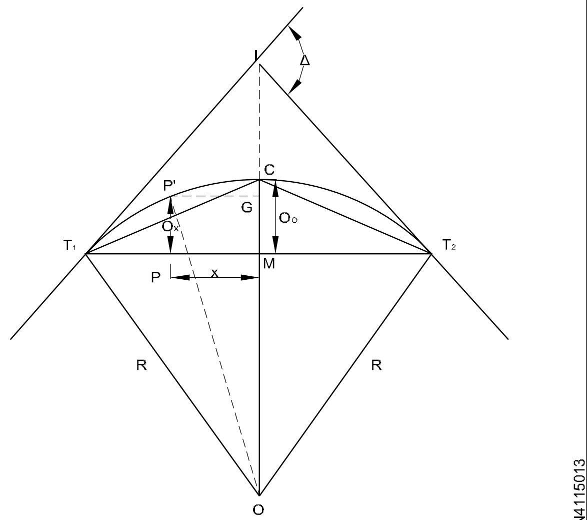
ii The length of $T_1B = T_2B = \sqrt{(T_1D)^2 + (BD)^2}$

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.

T_1T_1 is the long chord =L;

Fig 3



OFFSETS FROM THE LONG CHORD

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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

or $O_0 = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$

$OG = \sqrt{\left(R^2 - X^2\right)}$ and $OM = R - O_0$

The required offset

PP' = OG - OM The required

Hence , $PP' = \sqrt{\left(R^2 - X^2\right)} - \left(R - O_0\right)$

or $O_X = \sqrt{\left(R^2 - X^2\right)} - \left(R - O_0\right)$ (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

$= O_0 - \frac{X^2}{2R}$ .... 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.

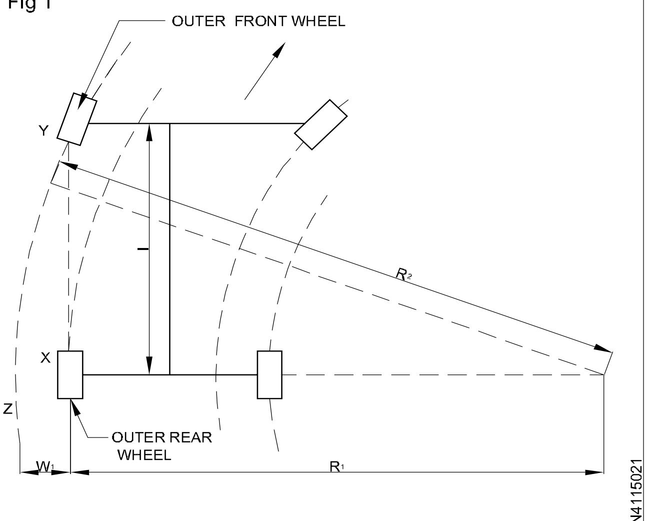
Widening of pavement on horizontal curves

Objectives : At the end of this lesson you shall be able to
- **express the need for widening of pavement in horizontal curves**
- **state the amount of widening.**

Widening of pavement on horizontal curves: A vehicle has a rigid wheel base and only the front or steering wheels can be turned. Thus on curved portion of a road, the steering wheels turn sideways so that the width of carriageway by a vehicle is more than the width of carriageway occupied by the vehicle on straight portion of the road. Hence, on horizontal curves, having radii less than about 300 meters.

It is the common practice to provide extra width of pavement. This is known as mechanical widening and it can be theoretically worked out as shown in Fig 1.

Fig 1



MECHANICAL WIDENING ON ROAD

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Mechanical widening on road

Let

R_1 = Radius of path traversed by the outer rear wheel in m.

R_2 = Radius of path traversed by the outer front wheel in m.

W_1 = Mechanical widening in m.

l = length of wheel base in m.

Then, $W_1 = OZ - OX = OY - OX = R_2 - R_1$

$\therefore R_1 = R_2 - W_1$

Also, from Δ OXY,

$OX^2 = OY^2 - XY^2$

$\therefore R^21 = R^22 - l^2$

$\therefore (R_2-W_1)2 = R_22 - l^2$ ($\therefore R_1 = R_2 - W_1$)

$\therefore R_22 - 2R_2W_1+W_12 = R_22 - l^2$

$\therefore l^2= W_1 (2R_2 - W_1)$

$\therefore W_1 =$

$$= \frac{l^2}{2R} \text{ approximately } ....$$

Where R is the mean radius of the curve. The above equation is meant for one vehicle negotiating a horizontal curve along one traffic lane. If the number of traffic lanes is n, the equation for mechanical widening on curves becomes,

$$W_1 = \frac{nl^2}{2R} \text{ ....}$$

For pavements with more than one lane, it also becomes necessary to provide additional widening, known as psychological widening, for the following three reasons.

i to allow the extra space for parking of vehicles which have stopped working.

ii to permit easy turning of vehicles at high speed, and

iii to provide sufficient clearance for overtaking and crossing of vehicles on curves.

The empirical formula given by the I.R.C. for this additional psychological widening is as follows.

$$W_2 = \frac{V}{9.5\sqrt{R}} \text{ ....}$$

Where W2 = psychological widening in m

V = design speed in km p.h.

Thus the total widening W required on a horizontal curve is given by the following equation.

$$W = W1 + W2 = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

Table shows the extra width recommended by the I.R.C. for single and two - lane pavements. For finding out the extra width on multi - lane roads, half the extra width of two - lane road is added for each additional lane of the multi - lane road.

Extra width of pavement on horizontal curves

S No	Radius of curve in m	Extra width in	
		Two - lane	Singlelane
1	Up to 20	1.5	0.9
2	21 to 40	1.5	0.6
3	41 to 60	1.2	0.6
4	61 to 100	0.9	Nill
5	101 to 300	0.6	Nill
6	Above 300	Nill	Nill

The extra widening is usually distributed in equal amount on inner and outer sides of the curve. But on sharp curves of hill roads having radius less than 50 m, the extra widening may be provided in full on the inside of the curve only. The widening should start at the beginning of the transition curve and is progressively increased at a uniform ratio so that the full widening is achieved at the end of the transition curve.

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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.

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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 ot 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 carriagewy insted of raising centre. The rate of camber usually designated by 1 in n which means that the transverse slope is in the ration 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 bitunminous 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.

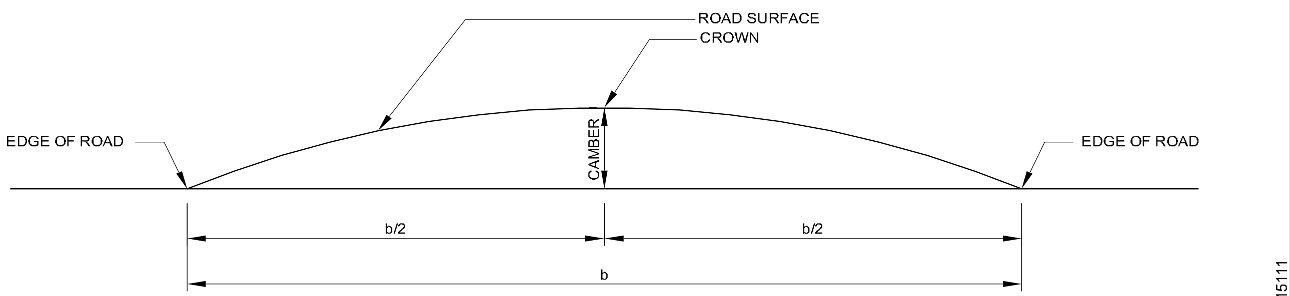
ii Problems of toppling over of highly laden bullock carts.

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.

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

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Shapes of camber:

Following are the three commonly adopted shapes of cambers for road surface.

i Parabolic camber

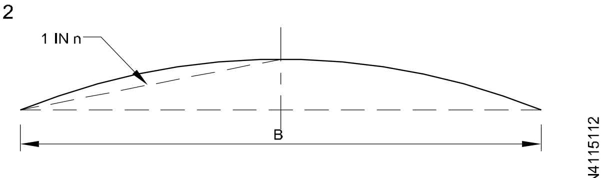
ii Straight line camber

iii Combined camber

i Parabolic camber

The road surface is given the shape of parabola or an ellipse as shown in fig. 2. This is also known as barrel camber and it consists of a continuous curve of either parabolic or elliptical shape. Such a shape of camber gives flat profile at the middle and steep profile towards the edges. This shape of camber is preferred by fast moving vehicles as they have to cross the crown line frequently during overtaking operations.

Fig 2

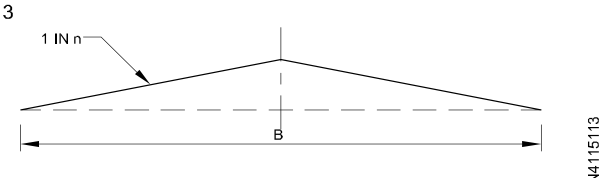


PARABOLIC CAMBER

ii Straight line camber

In this case, the crown is joined with edge of road in the form of a straight line as shown in fig.3. This shape of camber is known as sloped camber and it consists of two straight slopes joining at the centre. It is adopted when very flat camber, as in case of cement concrete pavements, is to be provided. It is found that steel tyred wheels of animal drawn vehicles can cause considerable damage to the road surface due to high stresses.

Fig 3

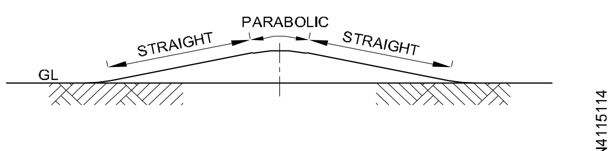


STRAIGHT LINE CAMBER

iii Combined camber

In this case, straight lines are provided near the edges and parabolic shape is given at the crown as shown in fig 4. It is also known as composite camber and it consists of two straight slopes with a parabolic curve in the centre. It is sometimes preferred as it combines the advantages of parabolic camber and straight line camber.

Fig 4



COMBINED CAMBER

Camber boards: For providing camber in the field, the templates or boards with desired shape giving the specified camber are prepared and they are used to check the lateral profile of the finished pavement during construction.

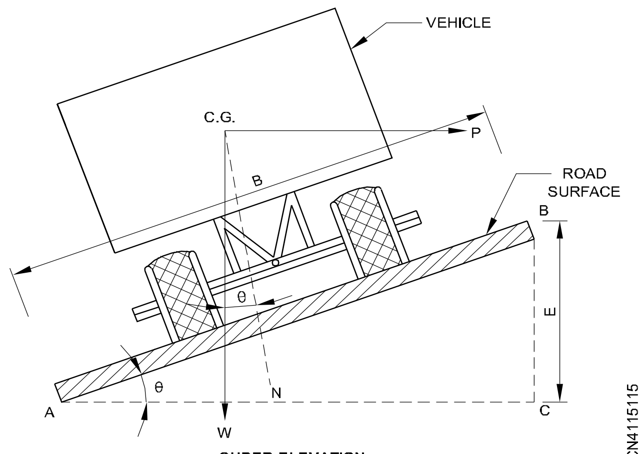
Super elevation: When a fast moving vehicles negotiates a horizontal curves the centrifugal force acts on the vehicle from inside towards the outside of the curve and hence the vehicles has a tendency to overturn and skid. In such situation the outer edge of the pavement is raised with respect to the inner edge.

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.

The super elevation is expressed as the ratio of the height of outer edge with respect to the horizontal width of the pavement from Fig 5.

Fig 5



SUPER-ELEVATION

Super elevation, $e = \frac{BC}{AC} \tan\theta$

In practice the value of q is so small, then tan q is equal to sin q

Then $e = \tan\theta = \text{Sine}\ \frac{BC}{AC} = \frac{E}{B}$

Total super elevated height of outer edge for a pavement width 'B' is equal 'eB'

E=eB

By analysis of super elevation, we get $e = \frac{V^2}{12TR}$

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(considering the co - efficient lateral friction as zero)

Where V = Speed of vehicle

R = Radius curve

Advantages of superelevation

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 6,7&8)

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 instance.

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 6.

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 7).

ii Passing sight distance or overtaking sight distance.

iii Sight distance at intersection(Fig 8).

iv Crossing sight distance.

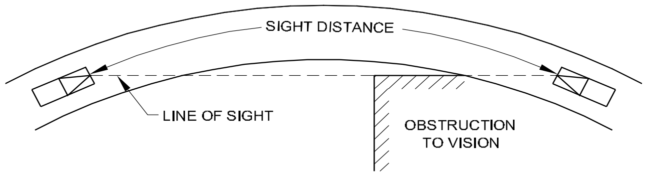
Apart from the above sight distances, the following sight distances are considered by the I.R.C in highway design.

v Intermediate sight distance

vi Head light sight distance.

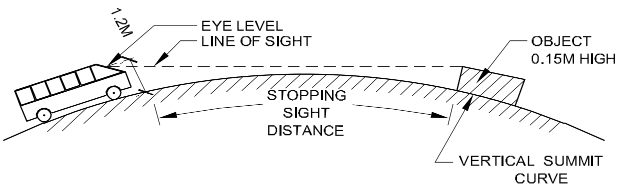
i Stopping sight distance: Stopping sight distance is the minimum sight distance available on a road to stop vehicle without collision. This is also sometimes called non - passing sight distance.

Fig 6



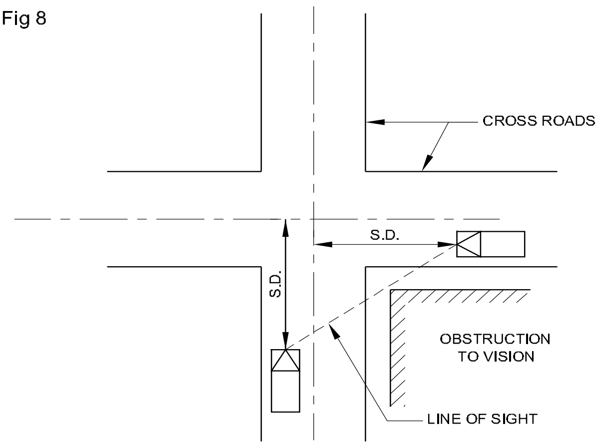
(a) SIGHT DISTANCE AT HORIZONTAL CURVE

Fig 7



(b) SIGHT DISTANCE AT VERTICAL SUMMIT CURVE

Fig 8



(c) SIGHT DISTANCES AT INTERSECTION

SIGHT DISTANCE AT DIFFERENT SITUATIONS

DCN4115116

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.

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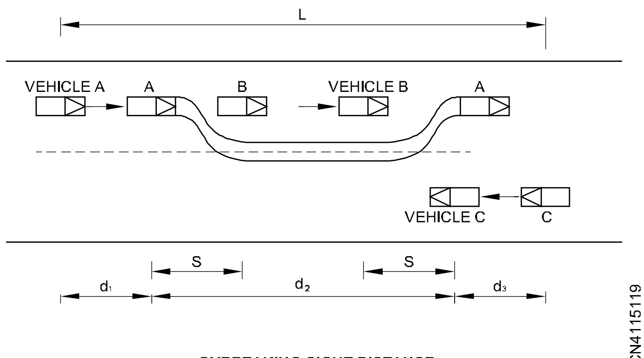
ii Overtaking sight distance: All the vehicle on a road do not move at the same speed and hence the problem of overtaking slow moving vehicle by fast moving vehicle is a common phenomena on all the roads.

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 9).

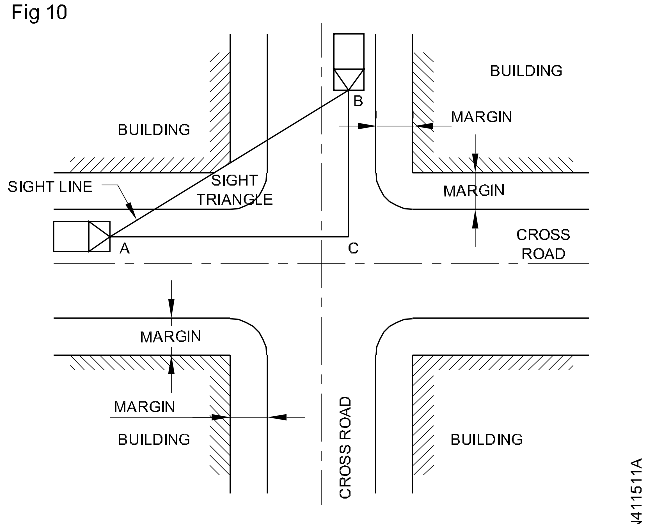
Fig 9



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 10 Thus the unobstructed sight triangle with two sides as equal to sight distance and one side as sight line will be formed.

Fig 10



SSD AT INTERSECTIONS

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.

Expressed as a percentage, i.e. $1 \times \frac{1}{100}$

In the above case gradient is 1 in 100 or 1 percent

Factors affecting road gradient: Following factors govern the road gradient.

i **Access to adjoining properties:** If access of adjoining properties is to be provided on road, it becomes necessary to consider the level of such properties while deciding the road gradient.

ii **Appearance:** Sometimes the road is provided with suitable gradient to grant attractive appearance to the road.

iii **Drainage:** The road gradient is mainly provided to dispose off rain water from road surface as quickly as possible. Hence, the higher the rainfall, the steeper will be the road gradient.

iv **Nature of traffic:** The road gradient is regulated by the nature of traffic. For instance, it should be as gentle as possible for slow moving animal driven traffic such as bullock carts, tongas, etc.

v **Obligatory points:** It becomes necessary to provide suitable road gradient at road intersections and connections of the road with bridge, canal, railway crossing, etc.

vi **Topography of country:** The amount of gradient to be provided is directly related to the nature of ground and topographical features of the country. For flat country, gentle road gradient will be provided and for hilly or mountainous areas, steep road gradient will be desirable to avoid unnecessary deep embankments or cuttings.

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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 tis 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)

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Road Drinage 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 const5ructed to provide cheap arrangement for collecting impurities of water (sullage and storm water).

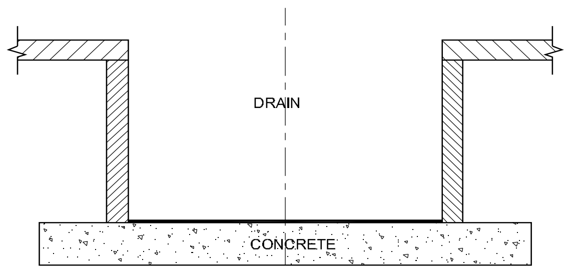
The following are the four shapes of surface drains are used in construction.

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

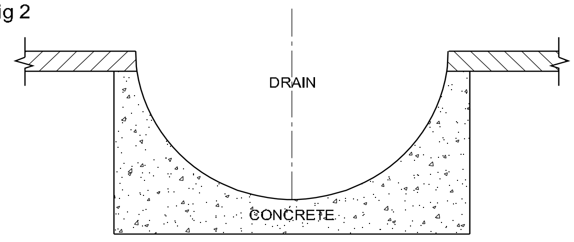


RECTANGULAR SURFACE DRAIN

2 Semicircular surface drains (Fig 2)

- 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.

Fig 2

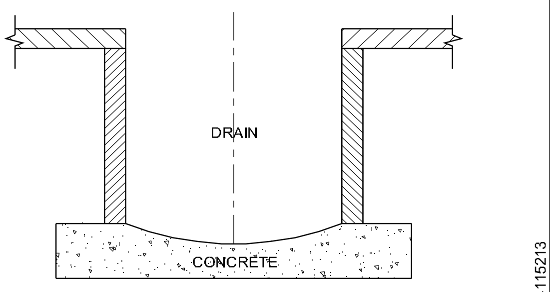


SEMI-CIRCULAR SURFACE DRAIN

3 'U' shaped surface drain (Fig 3)

- 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 are.

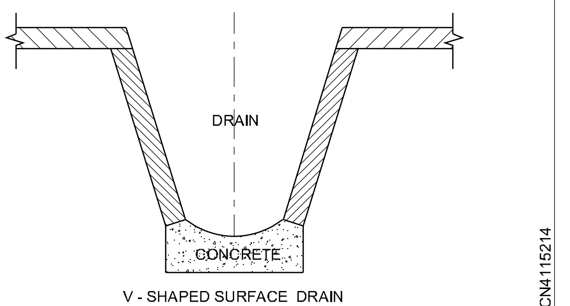
Fig 3



U - SHAPED SURFACE DRAIN

4 'V' shaped surface drains (Fig 4)

Fig 4



V - SHAPED SURFACE DRAIN

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- 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 thefluctuating 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.

Fig 5

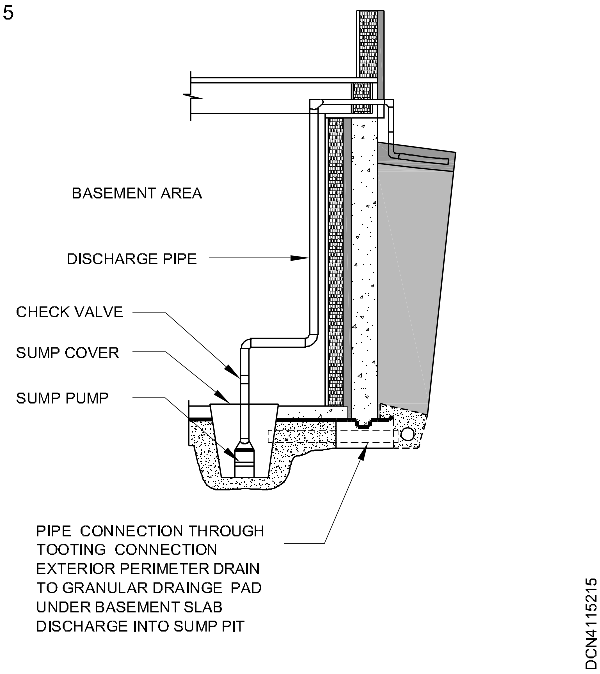


Fig 6

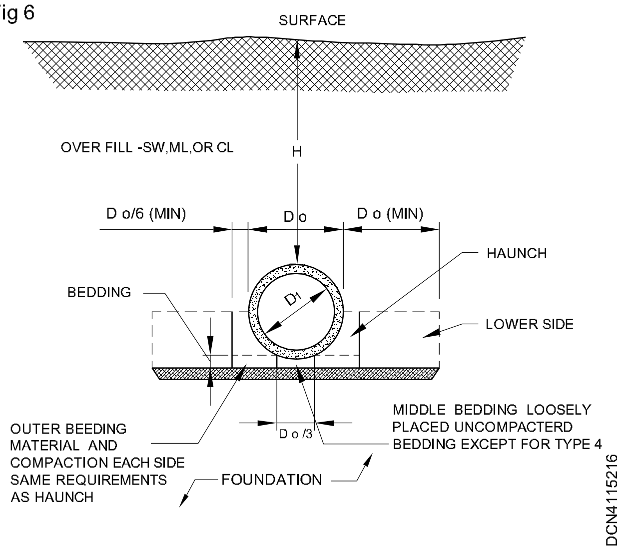


Fig 7

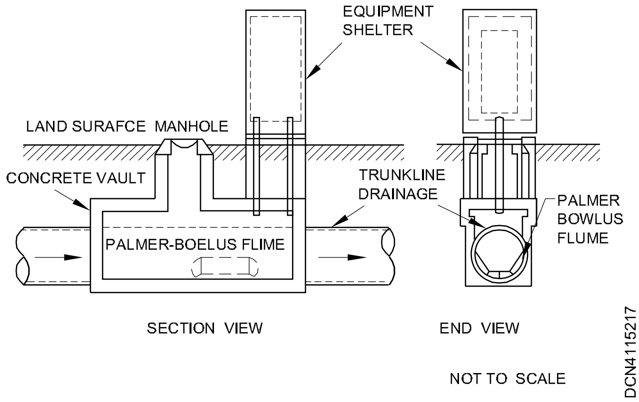


Fig 8

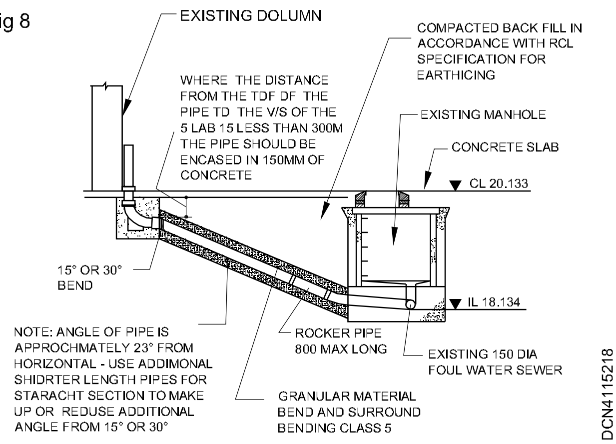
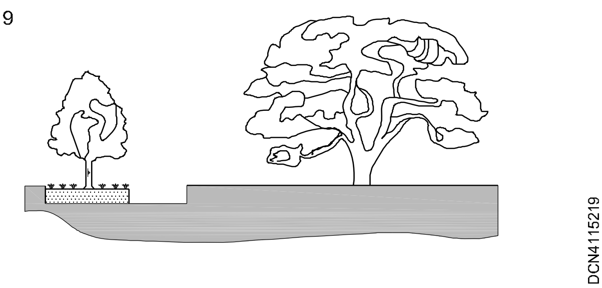


Fig 9



Different types of road side drain

Drain are the common drainage components of the road which intercept the surface water running off the carriageway, shoulder and side slopes flanking the road. The process of surface drainage involves the collection and then disposing of the surface water. The water from the pavement surface is immediately removed by providing camber and cross slope to the pavement. The camber and the slope are desinged according to the intensity of rainfall and type of pavement. To prevent infiltration of water, the road surface is made impervious as far as possible.

On the basic of the shape of the drain, it is classified as:

- Rectangular
- Trapezoidal
- Traiangular
- Semi-circular

The surface drainage may be divided into 3 categories:

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- **Drainage in rural/road highway**

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 sidesin embankments while drains are provided on boths ides 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 10

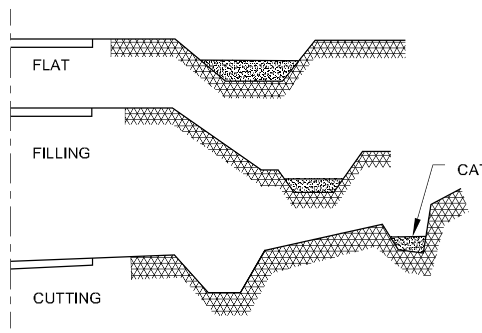


Fig 11

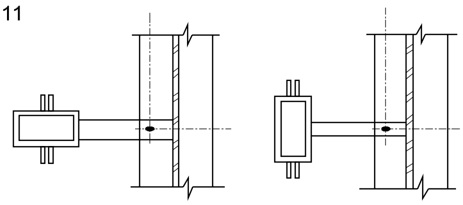
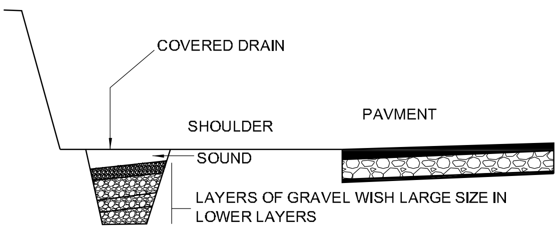


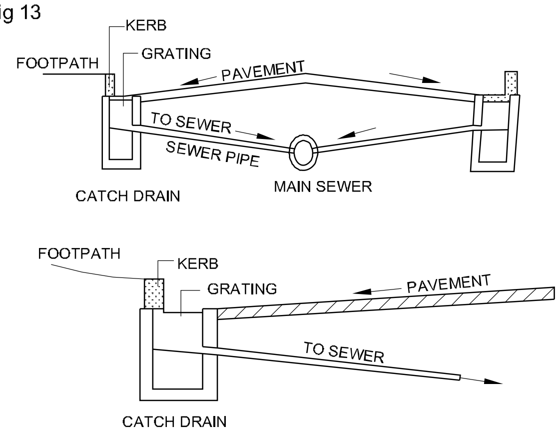
Fig 12



- **Drainage in urban roads**

In urban roads, underground longitudinal drains are provided due to the limitation ofland 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 impervous 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.

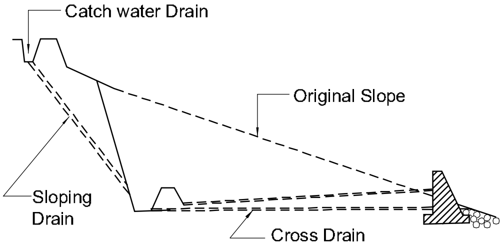
Fig 13



- **Drainage in hill roads**

In hill roads, there are complex drainage problems. Water flowing down the hill has to be efficiently intercepted and disposed of downhill side by constructin suitable cross drainage works. Catch water drains at the upper hill side, sloping drains andcross 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 or parking.

Fig 14



4.4.2 Cross drainage structures (Culverts and others)

Cross drainage structures are those structures which are provided whenever streams have to cross theroadway 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

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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 the of the culvert is always beneeath 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 borad 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, labors, 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. Deiversion structures can be used to divert the straam so that right angled one can be used instrad 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.

Flow in culverts

Three types of flow occur in culverts:

- **Free flow:** The flow satisfying the condition $H \leq 1.2\ h_b$ is termed as free flow. Where, H is the depth of head water and h_b is the height of culvert barrel. The culverts having such flow are called non-pressure culverts. Most of the culverts are designed to achieve this condition and has similar condition to flow over a weir.
- **Part full flow:** The flow satisfying the condition $H = (1.2\text{-}1.4)^*\ h_b$ is termed as part full flow. The head water depth at the inletpoint flow is full but has the free surface at the entire length of the barrel in this flow. This flow is very hard to achieve and is similar to the flow of orifice.
- **Full flow:** The flow satisfyint the condition H 1.4 h_b is termed as full flow. The culvert in such case will operate as a pipe and such conditions are met in flat or slightly rolling countries.

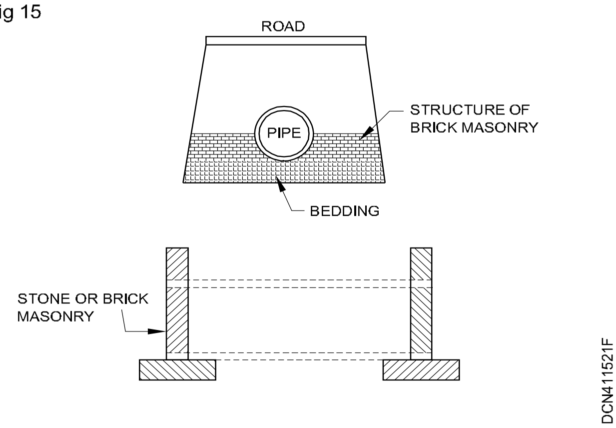
Types of culverts

There are four types of culvert:

- **Pipe culvert**

These culverts are suitable inlow discharge areas, low debris flow areas, and high embankment. There should be at least 50 cm cover of soil above the pipe so that load is transmitted in the pipe with small intensity without vibrations. The pipes are laid slightly inclined. The minimum diameter of the pipe is limited to 60 cm to facilitate cleaning and avoid blocking with the standard length of 2.5m jointed by collar or tongue groove. Single or double barrel precast concrete pipe culverts are generally used for small openings up to 2 m^2. Pipes may be made of stone ware, xconcrete, RCC, etc. with standard sizes of 0.5m, 0.75m, 1m, 1.25m and 2m in diameter. A bedding of 15 cm is applied below the pipe to increase the stability. For large areas, multiple pipes are used joined to each other by joints because the length of a single pipe islimited to 2.5m.

Fig 15



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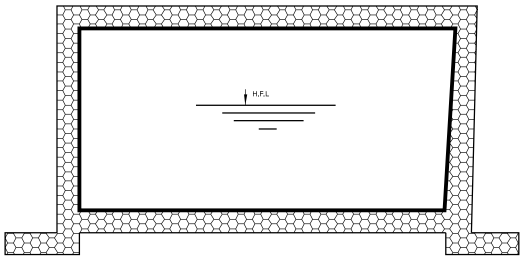
- **Box culvert**

These culverts are suitable in heavy debris flow areas. These are constructed when the nature of the soil below the fundation is not suitable for individual footing under piers and abutments. An RCC rigid frame box for square or rectangular opening span up to 3m is used as box culvert with minimum size passage of 60cm *60cm for easy cleaning of debris. These culverts have larger life spans, greater hydraulic efficientcy, superrior durability for worst environmental conditions and greater resistance to damage due to debris. The height of such culverts rarely exceeds 3m.

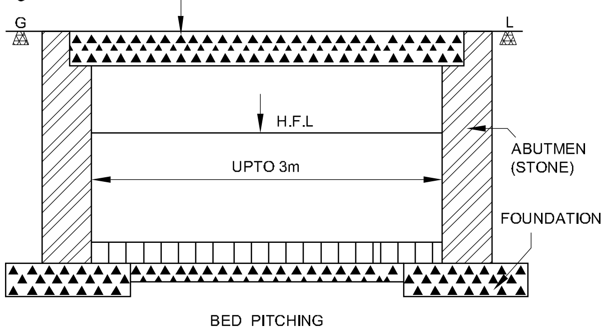
Fig 16



- **Slab culvert**

These culverts are suitable in high discharge areas and low debris flow areas. These structures consist of masonry abutments with the stone slab over them. These culverts are mostly used in those places where the stone is easily available but RCC slabs can be used instead of stone which can be designed as simply supported slabs with the span of about 3m. These culverts are used where the water opening is less than 15 m^2 and road corsses the waterway on a relatively high embankment. They should be located where the road crosses a valley, where there is a stream and the water course should not move. Free board of generally 0.5m is seen in this type of culvert thus, no pressure flow occurs in this culvert. This culvert is not very useful where the stream level is very low and where the stram level keeps fluctuating.

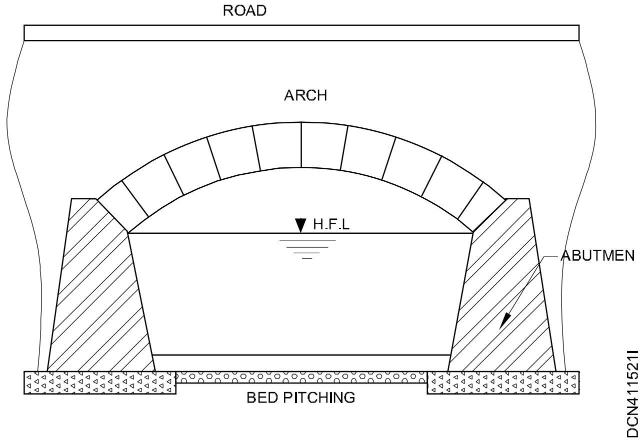
Fig 17



- **Arch culvert**

These culverts are suitable in high discharge areas and low debris flow areas. These culverts are constructed when high filling are involved and there is heavier loading on the culvert. The arches are built of brick masonry, stone masonry or plain cement concrete whose span is kept less than 3m.

Fig 18



The selection of culvert is done on the basis of availability of construction materials, labors and economic conditions.

A bridge is a structure constructed over water course to carry traffic over it. In NRS 2070, briudges are the structures having linear waterway span more than about 6m.

Types of bridges

Bridges can be clasified in various ways.

On the basis of construction materials

- Steel bridges
- Concrete bridges
- Timber bridges, etc.

On the basic of structural point of view

- Cantilever bridges
- Suspension bridges
- Moving bridges, etc.

On the basis of span length

- Minor bridge (up to 30m)
- Major bridge (above 30m)
- Long bridge (above 120m)

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On the basis of load carrying capacity

- Class 70 (Corresponding to class AA)
- Class 40 (Corresponding to class A)
- Class 30 (Corresponding to class B)
- Class 9
- Class 3
- Class 1

Parts of bridge

Bridge is divided into the following three parts structurally:

1 **Foundation:** Since bridges take very heavry loading upon them, the foundations should be carefully designed. If rocky strata are availabe for the abutments and piers at the location of bridge site it becomes very easy to construct bridge but if they are not available then well sinking may have to be done or caison type piers or abutments may have to be construced in the foundation site location.

2 **Substructure:** Substructure is portion of the bridge which lies between the decking and the foundation. The various components in the substructure are wing walls, piers, abutments, etc. The choice of the type of abutment is done according to the site condition concerning the soil classification which can be made of brick masonry, stone masonry, PCC or RCC.

3 **Superstructure:** Superstructure is the portion which lies above the decking and can be made of material like: timber, steel, RCC or pre-stressed cement concrete.

4.4.2.3 Causeway

Causeway is those cross drainage structures with or without openingbelow the road surface provided across a shallow drainage course at or about the bed level which allows floods/runoff to pass over it. They are constructed instead of culverts on less important roads where the maximum flow of depth does not exceed 1.5m which saves the construction cost. During the flood, the water flows over the road and traffic on both sides is stopped but as soon as the flood recedes, the traffic flow is resumed. It does not restrict the waterway and is constructed perpendicular to the flow direction. So, causeways may be underwater during heavy floods.

Bed slope of the causeway in estimating the span should not generally exceed (4-5) % in order to prevent the vehicles from skidding and overturning downstream. The depth of flow in most of the period of the year should not exceed 30cm.

There are two types of causeway:

1 **High level causeways:** The causeway which is provcided with vents below to pass regular flow under the road and flood across the road surface at any time is termed as high level causeways. It is constructed quite above the stream bed and is also termed as submersible bridge.

Fig 19

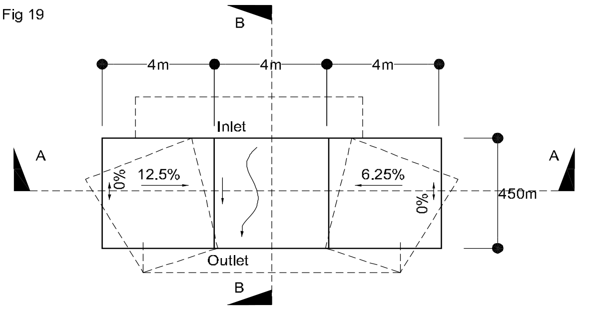
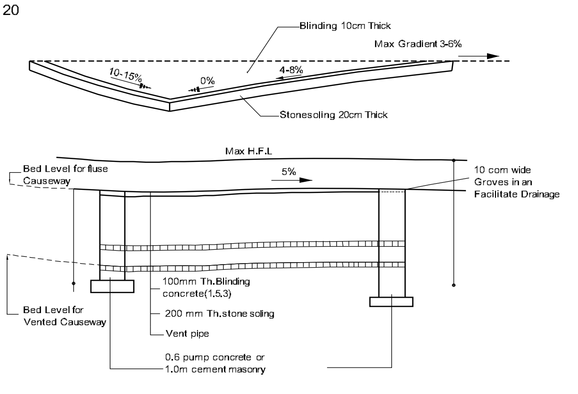


Fig 20

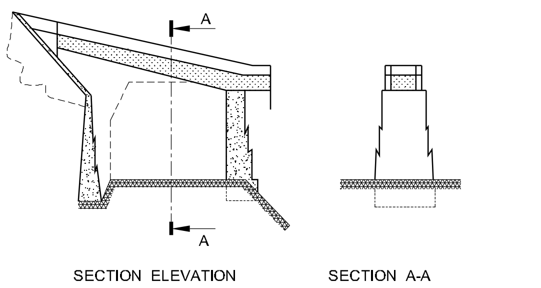


2 **Low level causeways:** The causeway which is constructed at the bed level of the stream which allows flood to pass over the road surface at any time is termed as low level causeway. It remains dry for most time and is also called flush causeway, Irish bridge of Ford in some literature.

Causeway

Aqueduct is an open or closed conduit sufficiently above the roadway to drain water across the road with the provision of pillar supports on either side of the road. These structures can bhe advantageously used in hill roads where culverts and siphons are not feasible due to frequent choking problem. Depending upon its form it can be designed as an open canal, culvert or pipe.

Fig 21



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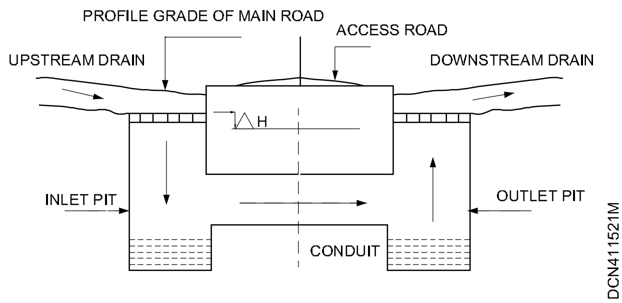
If the road has cutting exceeding 5m and if the water has to be drained or taken to the other side of the road, none of the cross drainage works becomje feasible except aqueduct. Inverted siphons can be used but it will be under high pressure which is not desirable.

Concrete Elevated Aqueduct

Inverted Siphon

The inverted siphon is a structure which lowers the invert level of the conduit to the desired level and both inlet and outlet pits are provided to receive flow from the drain and discharge water to the downstream drain respectively. These types of structures are widely used in the irrigation system. Its use as a cross drainage structure in highways is limited because the surface water generally carries debris and silt on a large scale due to which the inlet pit, conduit and outlet pits may be blocked. However, if the water does not carry silt and debris, it becomes an economical substitute to other drainage structures. It is generally provided when the provision of culvert and aqueduct is impossible. In the inverted siphon the head (H) should be such that it should overcome the frictional loss along with the entry and exit losses. The conduit must be made water tight.

Fig 22



Surface drainage system is most important in Highway engineering. A pavement without proper drainage facilities will not server for long time. The water or rainfall on road should be collected by side drains which carries the drain water to nearest stream or any water course.

So, prior to the construction of road, the designer should leave required space for providing proper drainage facilities as well as the pavement should also be constructed with minimum camber.

Design of Surface Drainage System for Highway

The desing of surface drainage system carried by two types of analysis:

- Hydrologic analysis
- Hydraulic analysis

Hydrologic Analysis of Drainage for Highway

Whenever there is a rainfall, some of the rain water infiltrated into the ground and stored as ground water and some of the portion may evaporate into the atmosphere. Other than these losses, the water left on the surface is called as run off.

The method of estimating the run off is called hydrologic analysis. To estimate the maximum quantity of water expected to reach the drainage system is the main objective of hydrologic analysis. For this, one need to know the factors affecting run off and they are

- Rate of rain fall
- Moisture condition
- Soil type
- Ground cover presence
- Topography

Other than the above factors, rain fall intenstiy, occurrence of storms in that area are to be studied from the old records. Hence, maximum run off can be estimated to build safe surface drainage system. The run off can be calculated by below formula

Where Q = run off (m^3/sec)

C = run off coefficient

i = intensity of rain fall (mm/sec)

A_d = area of drainage (m^2)

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Types of Surface	Coefficient of run off
Pervious soil surface	0.05 - 0.30
Soil covered with turf	0.30 - 0.55
Imprervious soil	0.40 - 0.65
Gravel & WBM roads	0.35 - 0.70
Bituminous & C.C roads	0.80 - 0.90

Run off coefficient "C" is the ratio of run off to the rate of rainfall. So, it is not same for all types of surfaces. It varies for different types of surfaces and its values for different surfaces are as follows:

If the drinage area contains differentsurfaces in it then run off coefficient is calculated as

$C= (A_1 C_1+A_2 C_2+A_3 C_3) / (A_1+A_2+A_3)$

Where C_1,C2,C3 are run off coefficients for differentsurfaces and A_1,A2,A3 are their respective areas.

In the next stage, Intensity of rainfall "i" is to be calculated. To find this, first we need to know the time taken by water to reach drainage inlet from the drainage area. This is called as **inlet time.**

Now we need to calculate the time required for water to travel from inlet of drainage to the outlet which is called as travel time This is calculated from the velocity allowed in the drainage line and generally it is kept at 0.3 - 1.5 m/sec.

After that both times (inlet time and travel time) are added which finally gives us the time of concentration. From this total duration, read the rain fall intensity from the below graph by assuming frequency of rainfall occurrence (say for 5 years, 10 years etc.)

Lastly area of drainage is calculated by studying on the topographical maps of that region. Hence, the design value of run off "O" is obtained finally.

Hydraulic Analysis of Highway Drains

Now come the second stage hydraulic analysis, in which the dimensions of drainage channels or culverts are designed based on "Q" obtained in the above stage of analysis. Now we have discharge which is designed run off "Q".

If we know the allowable velocity "V" in the channel, then the area of channel can be calculated from below formula:

$$Q = A.V$$

But the allowable velocity is not same for all types of channels. If the channel is lined, then the allowable velocity can be kept at normal. But if the channel is unlined it may cause severe damage to the channel in the form of silting or scouring.

So, the allowable velocity for different cases of unlined materials is as follows:

Soil type	Allowable velocity (m/sec)
Sand or silt	0.30 - 0.50
Loan	0.60 - 0.90
Clay	0.90 - 1.50
Gravel	1.20 - 1.50
Soil with grass	1.50 - 1.80

Now we can find out the area of channel in m^2. Next, the longitudinal slope of channel "S" is to be calculated by Manning's formula:

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Where V = Allowable velocity (m/sec)

N = Manning's roughness coefficient

R = Hydraulic radius (m)

S = Longitudinal slope of channel

In the above formula, we already know the "V" value. Hydraulic radius "R" is the ratio of area of the channel to its wetted perimeter. Now comes, the toughness coefficient which is again varies according to lining materila as follows:

Finally, longitudinal slope "S" is known and all the dimensions of drainage channel are known. Thus, the design of surface drainage system is complete. This method is mostly used for designing side drains of roads.

Read More:

Horizontal Transition Curves for Highwat and Its Calculation

Drains and Sewers Terms Definitions

Types of Plumbing and Drainage Systems in Building

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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**
- **explain IRC loading**
- **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, cnal, 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 enalble 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 extremem 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 linepassing 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 cuttingof river - bed is known as scour.

19 **Run off:** The portion of therain 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

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25 **Water cushion:** It is a pool of water constructed on the downstram side of the dam, chute drop or other spilway structure and acts as cushion to absorb the impact of falling water.

26 **Revetment:** This is made of stones or concrete blocks or mattresses, placed on thebottom 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.

IRC loading of bridges

A bridge is to be designed for the worst effects produced by various forces, loads and stresses which are acting on it simultaneously. The loads on the bridges are partially imposed by the vehicle andthe user and partly by nature. It was found necessary to lay the standards for the guidance of the engineers to design the bridge structure so that uniformity is maintained ind esigning the same.

The public roads and railways in India are managed and controlled by the government and hence, the bridges to be constructed for roads and railways are to be designed as per standards set up by tghe concerned authorities. For highway bridges, the standard specifications are contained in the Indian roads congress (I.R.C) bridge code and for railway bridges, the Indian raiway standard (I.R.S). Bridge rules are framed to accommodate the standard specifications. The bureau of Indian standards (BIS) has also framed specifications for certain types and conditions of bridge and they are to be followed,whenever applicable.

To facilitate easy working, the Indian roads congress has issued printed booklets containing drawingsfor slabs and beams for standard spans and also for piers and abutments of normal heights. Similarly, the research design and standards organisation (RDSO) of the Indian railway has evolved drawings for standard spans and also computer programmes for the design of piers and abutments. The detailed design is therefore carried out only inrespect of the bridges with long spans and having very deep waterways.

Choice of bridge type

There is no hard andfast rule for selecting a particular type of bridge in all cases. As a matter of fact, the various possible alternatives can be worked out and the ultimate choice should be made for that type of bridge which will give the maximum benefits and would involve favorable conditions for its construction. In general, the bridge should be aesthetically pleasing in appearance, strong enough to carry the traffic and other incidental loads, economical, etc. Some of the aspects which influence the choice to be made between different types of bridges are as follows.

1 **Approaches:** The formation level and length of approachs at bridge site will also have considerable influence on the choice of a particular type of bridge.

2 **Availability of funds:** If the fund available is not sufficient to put up a high level bridge, the small submersible bridge or causeway may be recommended instead of totally abandoning the project for lack of money.

3 **Climatic conditions:** If the environmetnal conditions are unsuitable or unfavorable, certaintypes of the bridges cannot be cosntructed. For instance, if the climatics conditions at bridge site are likely to accelerate the process of corrosion, the steel trusses cannot be adopted.

4 **Economy in construction:** If the river is wide, the economy in construction can be achieved by putting up a road - cum - rall bridge in two tiers instead of two separate bridges, namely highway bridge and railway bridge. It will result in the economy in construction.

5 **Foundations:** The soil conditions at bridge site may bring down the possible alternatives and under such circumstances, the choice of a particular type of bridge is to be made from such limited alternatives only.

6 **Navigational requirements:** If it is desired to have more vertical clearance for satisfying the navigational requirements of thecommunity or locality, certain types of bridges such as arch bridges, suspension bridges, etc. will only have to be selected.

7 **Specialized firm:** If the tender for long bridge is invited on cimpetitive basis withfreedom to submit the alternative designs by the tenderers, it is likely that the type of bridge to be selected finally willbe influenced by the specialization achieved by a particular firm for a certain type of bridge. Each shpecialized firm will try to convince about the adaptibility of its design for a particular bridge site.

8 **Type of traffic:** The choice of bridge type will also be governed by the nature of traffic. For instance, the steel trusses are preferable to the suspension bridges for railway traffic. Normally, the bridge forms part of an overall project like the construction of a new road or a new railway line. Hence, the traffic forecst is made for the project as such and it will help in determining the size of bridge i.e. the number of lanes or tracks to be provided. It should be seen that the type of bridge is such that the volume of traffic that will develop for a future period of say about 30 years is accommodated without any additional work or reconstruction of the bridge.

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.

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Fig 1

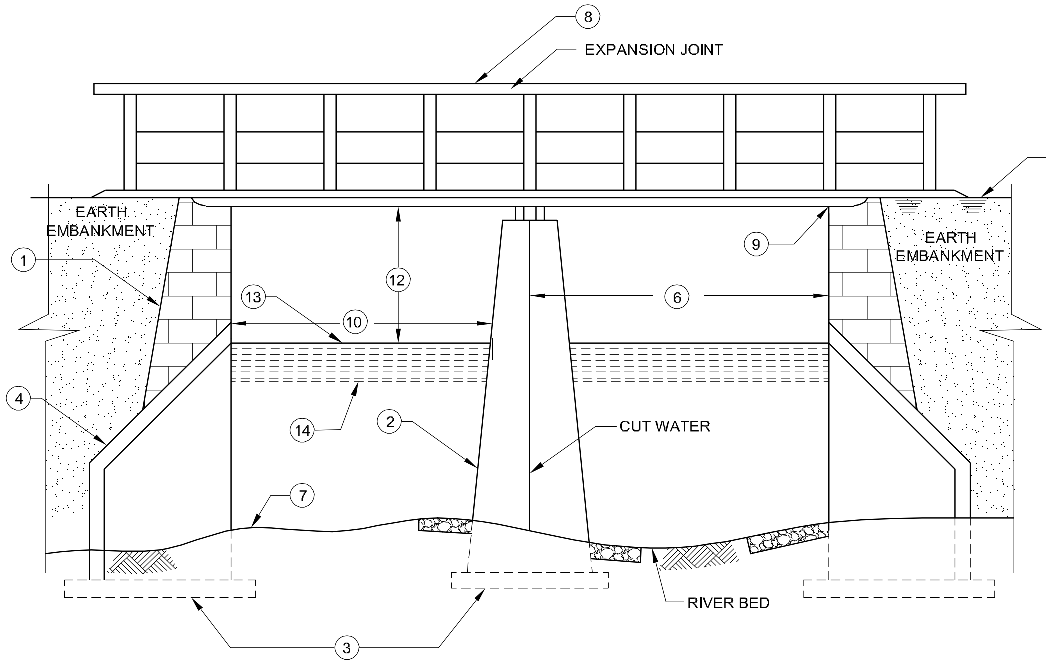
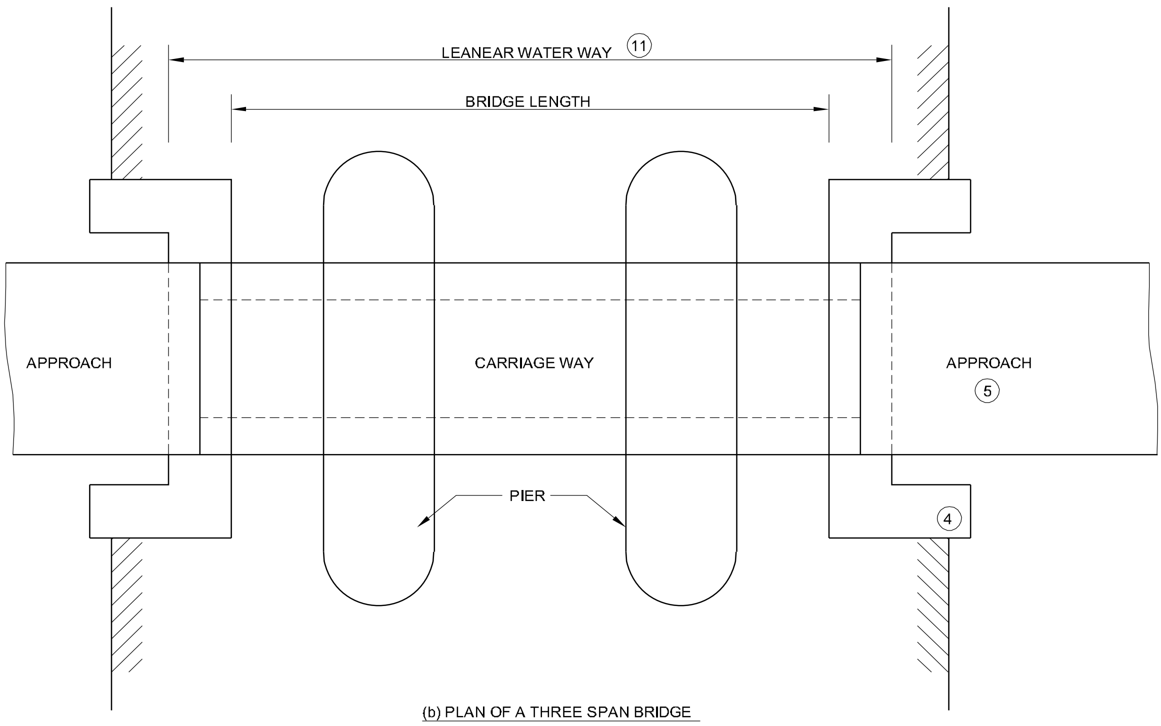


Fig 2

(a) ELEVATION OF TWO SPAN BRIDGE



(b) PLAN OF A THREE SPAN BRIDGE

NOTES

1. ABUTMENT
2. PIER
3. FOUNDATION
4. WING WALL
5. APPROACH
6. SPAN
7. APRON
8. RAILING
9. BEARING
10. CLEARANCE
11. LEANEAR WATERWAY
12. FREE BOARD
13. HIGHEST FLOOD LEVEL (HFL)
14. LOW WATER LEVEL (LWL)

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COMPONENT PARTS OF BRIDGES

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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.

3 At the site, the stream should be anrrow withwell defined and firm banks.

4 At site the river flow should be without whirls and cross currents.

5 At the site the 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 unavoidablethey 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 andnot up stream. facing up stream will cause heading up, pocket formation, and danger to the appraoches.

In reality ideal site never exists. Hence aleast objectionable site should be selected. Threfore to select such a site investigations for a number of probale 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

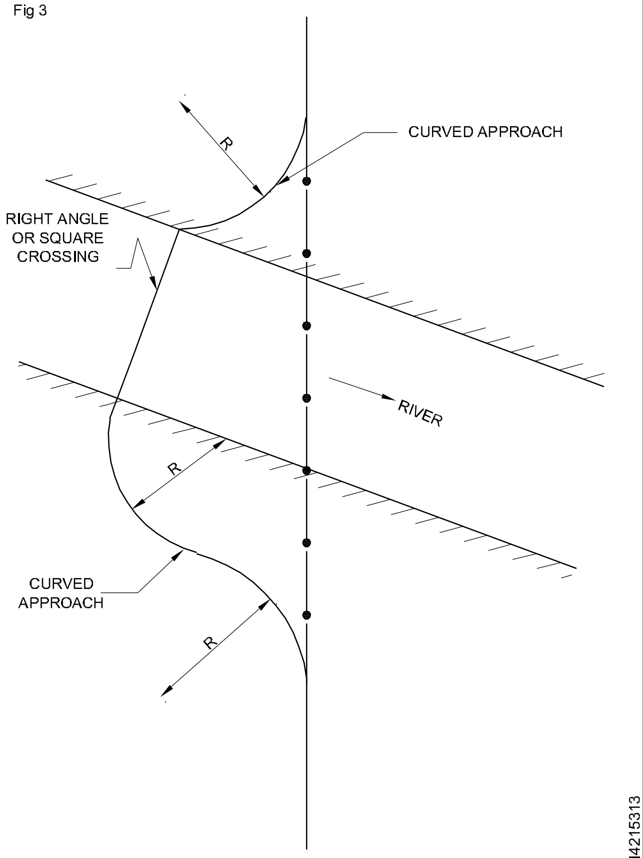
3 Effects of siting and scouring

4 Layout of approaches

5 River training works

1 Skew bridges: Alignment on curve in hilly areas, it is not possible to avoid thealignment of bridge on a curve. In such cases, it isnecssary 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.

Fig 3



LAYOUT OF APPROACHES

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 sustream 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 siliting 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 approches: 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 appraches is made with suitable curve radii so as to cause the least inconvenience to the traffic using such approaches.

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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 displacementin a system ofstationary 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. Thanalysis 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.

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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 uniformaly 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 descrioption 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 adersely affect its performance. This aspect requries 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 shouls also be seen than the differential settlement is so limited as not to cause any damage to the structure.

The term differential settelment 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 safisfactory, all three conditions should be simultaneously satisfied.

Types of founations

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 form 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 firction developed on the sides of piles. The piles are generally driven vertically or in near vertical position.

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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 sun through ground or water to exclude water and semi - fluid material during the process of excavation of foundations and which subsequently becomes an intergral part of the substrutre.

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 ajacent 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 caison 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 bepenetrated, 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 whicha re usually employed for the construction of a caisson are as follws.

1 Cast - iron

2 Reinforced cement concrete

3 Steel

4 Timber

1 Cast - iron: The cast - iron is suitable for caissonsof 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 ofa caisson in the early stages of development of a caisson. But this material is now practically not adopted mainly becasue 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 botton. 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 suerstructure, 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.

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Fig 1

- CAISSONS
  - BOX CAISSONS (OPEN AT TOP AND CLOSED AT BOTTOM)
  - WELLS (OPEN AT TOP AND BOTTOM)
    - SINGLE
    - MULTIPLE OR MONOLITHS
    - CYLINDERS
  - PNEUMATIC CAISSONS (CLOSED AT TOP AND OPEN AT BOTTOM)

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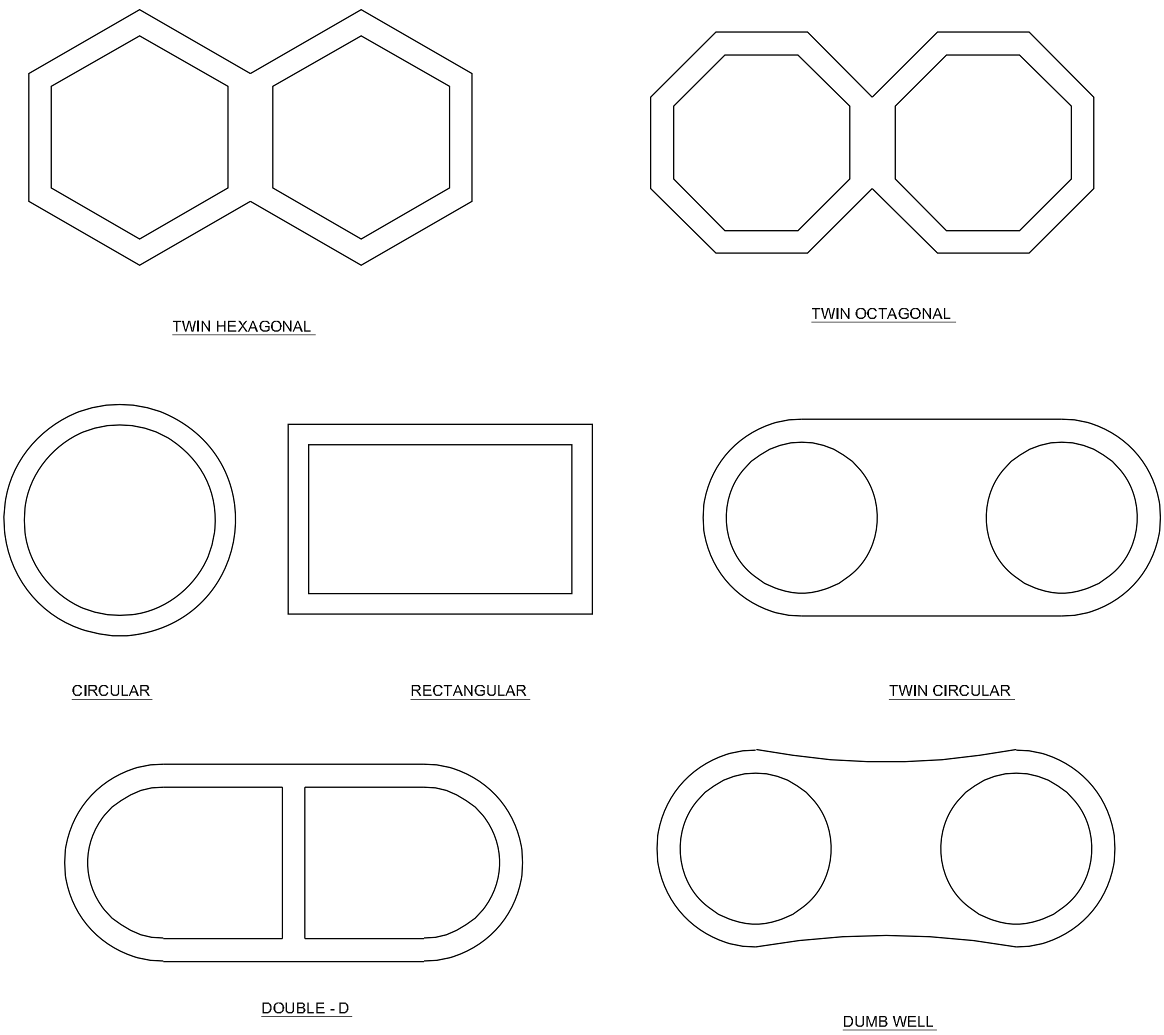
CHART SHOWING CLASSIFICATION OF CAISSONS

Fig 2



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SHAPES OF WELL

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The only drawback of a circular well is that it causes more obstruction to thewaterway 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 diemnsion 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 thenatureos soil through which the well has to pass. If the number of wells is two, it is known as a twin well andtwo wells may be combined to form andeliptical well in plan. If the number of wells is very large, a monolith is formed.

The well when to be sunk too deep becomes slender and it requires begger dimensions. It then beocmes 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 sied 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 resonably watertight. It may either rest on imprevious soil or may be extended to imprervious 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 watertightness is not desired in a cofferdam. It is not only impracticable but expensive too. The design and layot 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 os as to make estable 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 theconstruction of a cofferdam are earth, timer, 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 ocfferdams 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

Followingare 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, locks, etc.

iv To enclose a space for the removal of sunken vessles.

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

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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.

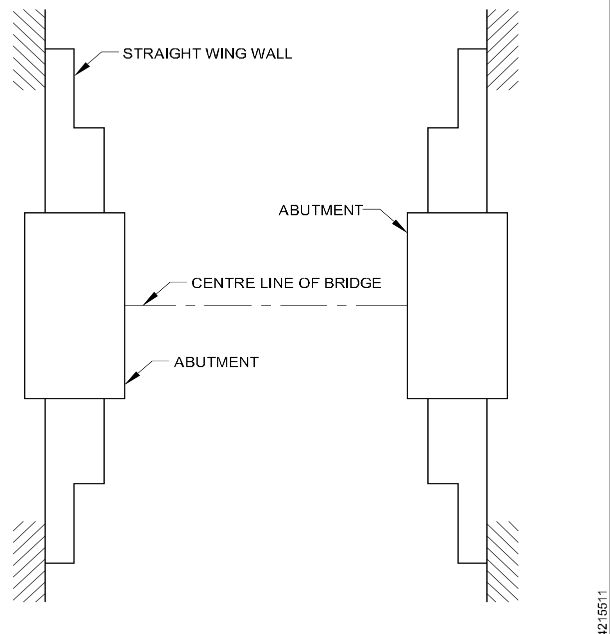
ii According to the type of superstructure.

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. Scuh 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.

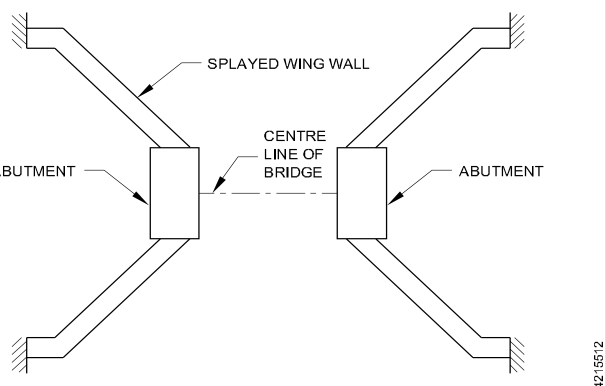
Fig 1



ABUTMENT WITH STRAIGHT WING WALL

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 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 bubject to erosion.

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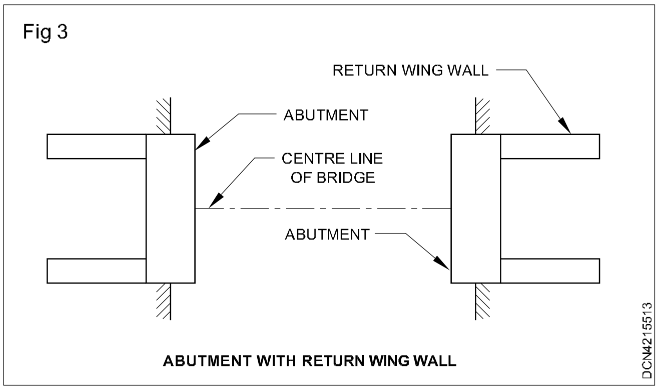


It is however not suitable for rivers or streams subjected to heavy floods as considerable portion of embankment outside the wing walls remains un protected from the scouring action of water and it will not be safe because there is a tendency for the flood water to damage the embankment.

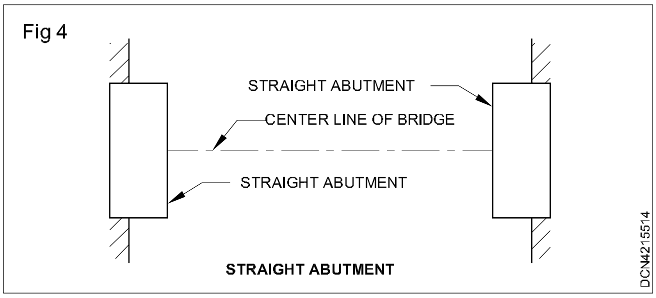
The abutments with wing walls suffer from the following drawbacks

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 negiligible waterway.



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.

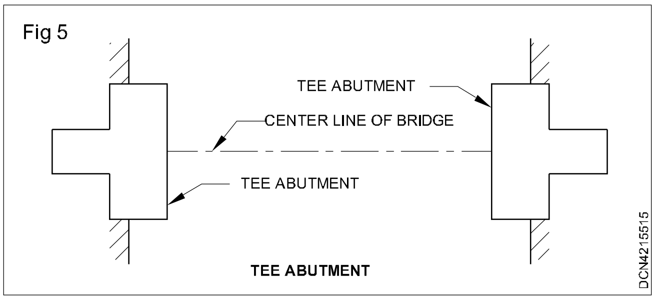
It is usually not recommended because of the following disadvantages

1 It does not protect the embankment of river.

2 It gives a rigid formation over its stem portion.

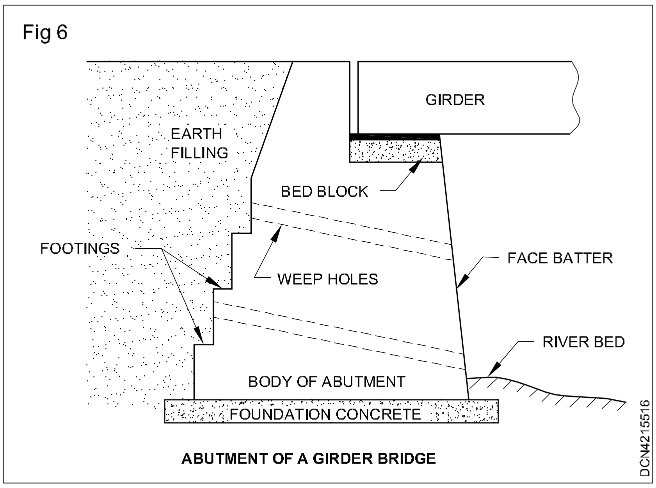
3 It is uneconomical.

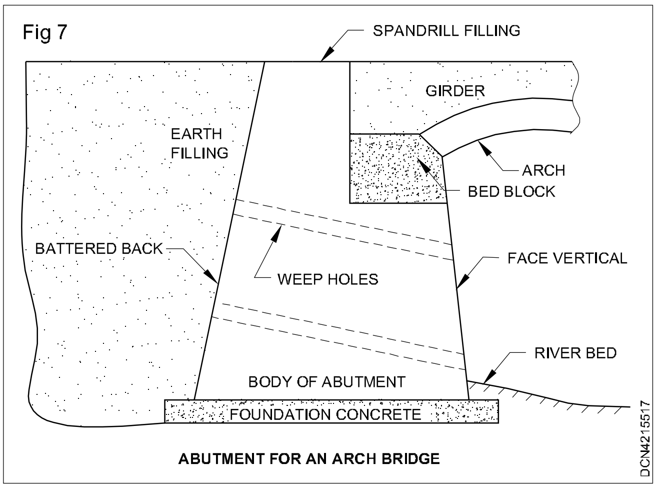
4 The quantity of masonry required for its construciton works out to be more in proportion to its function.



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 levle. 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.





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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

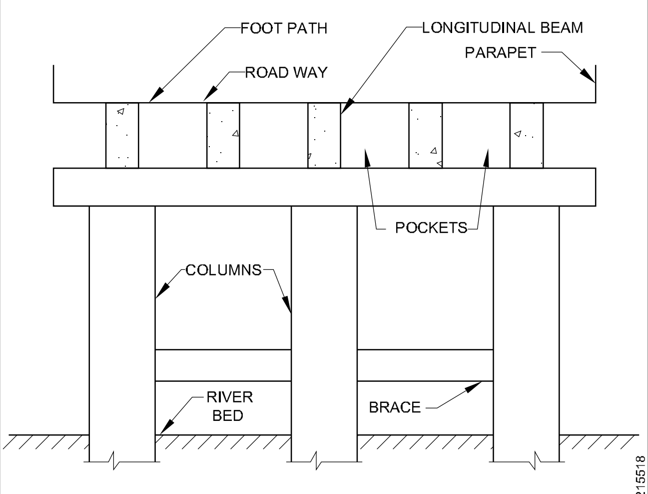
iv Pile bents

v Solid piers

vi Trestle bents

i Coumn bents: A column bent type of pier is adopted, if thelongitudinal beams or girders of the superstructure of bridge are closely spaced. The term bent is used to indicate a supporting frame consisting of vertical memebers and braces. The transverse beams are provided to support the longitudinal beams and two or more colums on a solid foundation are construced to support the transverse beams as shown in Fig 8.

Fig 8

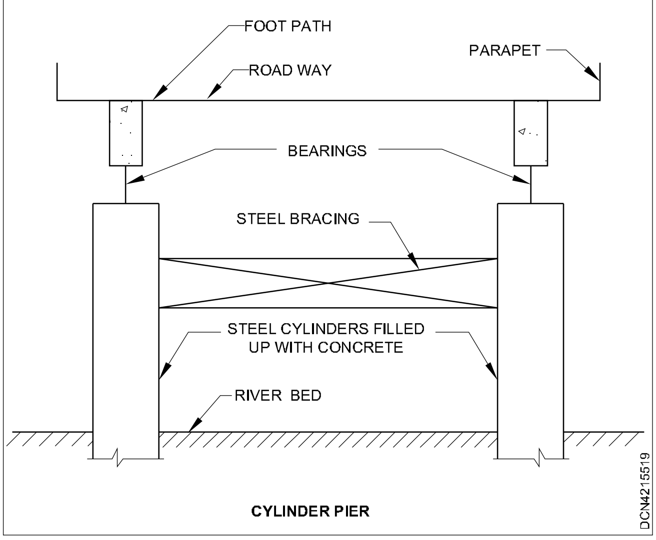


COLUMN BENTS

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 continous 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.

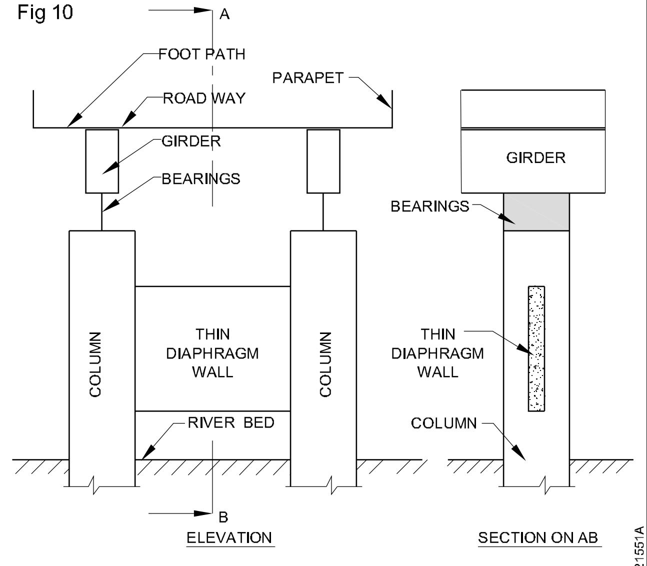
Fig 9



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 advantange 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 weidght as compared to the solid mass concrete piers.

d They are very much suitable when the well foundations are adopted.

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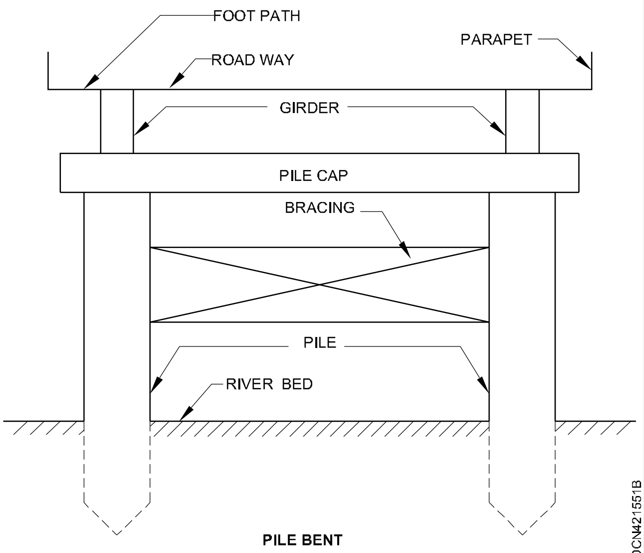
iv **Pile bents:** In case of pile bents, the girders of superstructure of bridge are supported on R.C.C. or steel piles. A pile cap is provided to connect piles at the top and they are suitably braced along their height as shown in Fig 11. The file bents are used for low piers over unstable or muddy ground.

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 reistance to the actions of floating bodies.

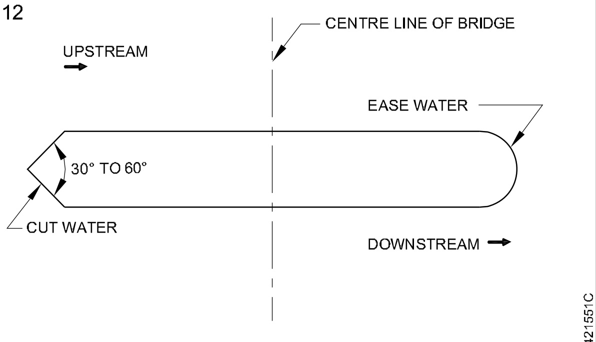
Fig 11



PILE BENT

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 traiangular 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.

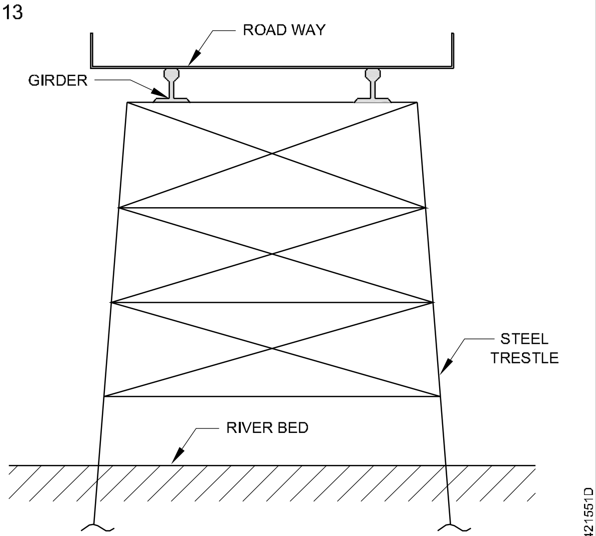
vi **Trestle bents:** A trestle is a framed pier and it consists of vertical, horizontal and diagonal members as shown in fig. 13 The trestle bents may be of steel or concretre, the former being very common. The trestle bents are useful for constructing piers for a bridge along a viaduct or incase of 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.

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.

Fig 13



TRESTLE BENT

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.

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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. Thge wing walls may also be curved, instead of being played. The splay or inclination is usually 45^o 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^o, as shown in fig 3 the wing walls are known as the return wing walls. Scuh wing walls are preferred to the splayed wing walls in case of very high embankments. When the return wing walls are asopted, 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 strnegth.

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.**

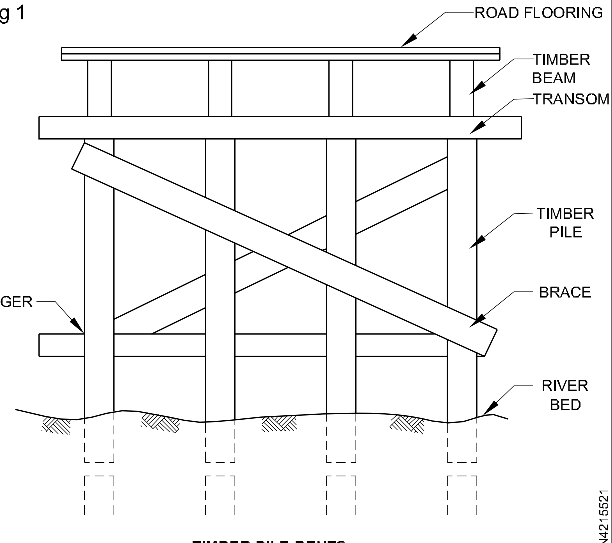
Classification of bridge

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.

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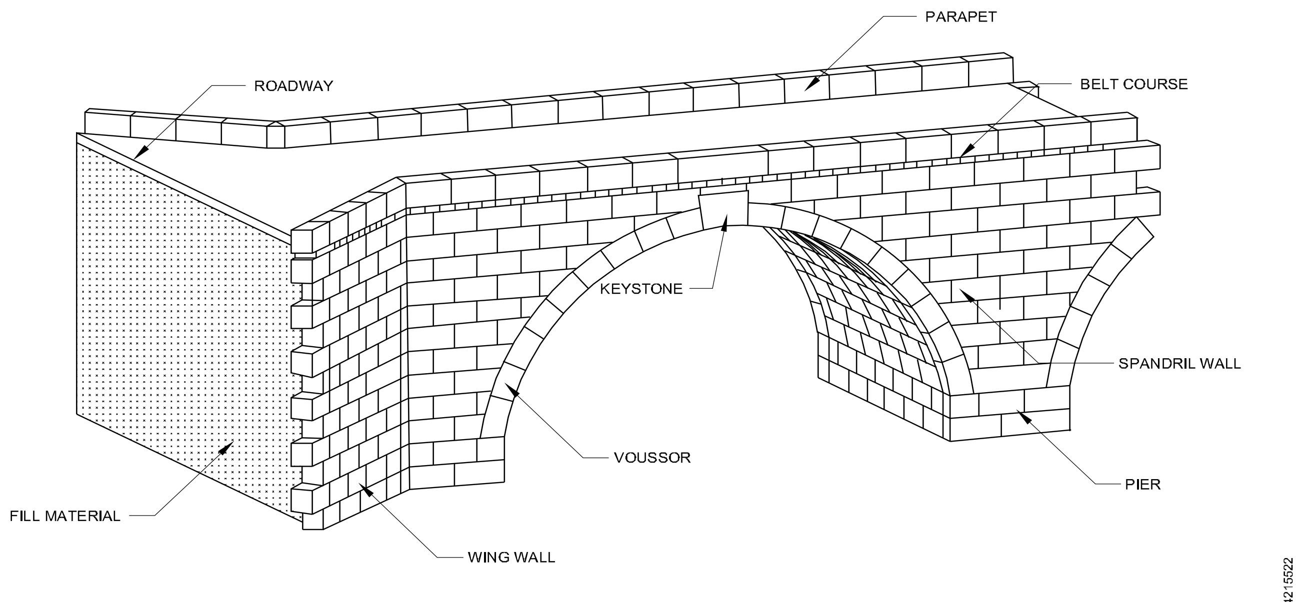
Fig 2



MASONRY 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

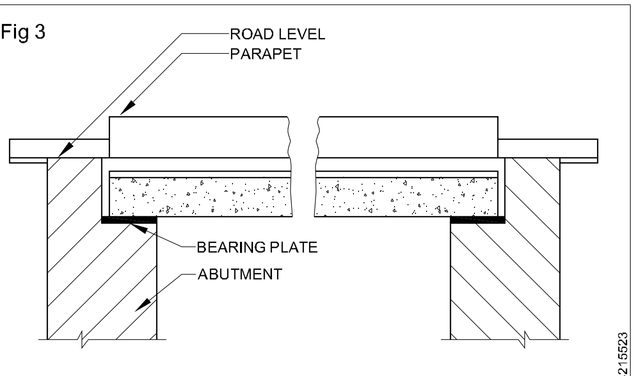
b Steel girder bridge

c Steel truss bridge

d Suspension bridge

a Steel trough plate bridge (Fig 3)

Fig 3



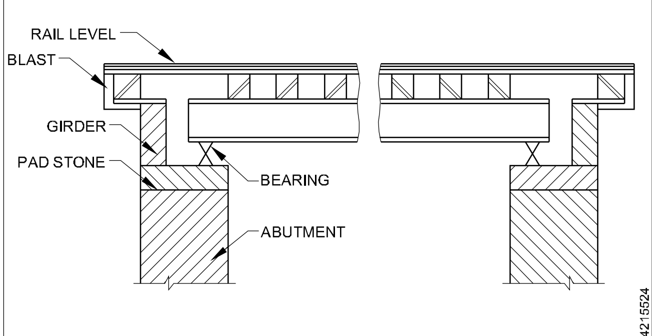
STEEL TROUGH-PLATE BRIDGE

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.

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.

Fig 4



STEEL GIRDER BRIDGE

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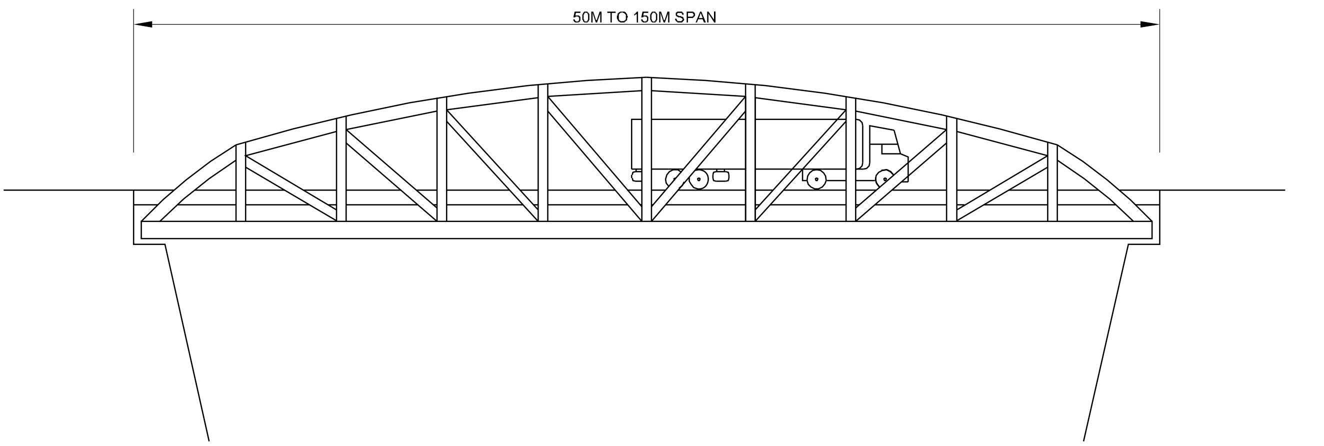
c Steel truss bridge (Fig 5)

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 memebers 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, warren, awe and nor limville. These trusses usually have a depth equal to 1/5 th of span.

Fig 5

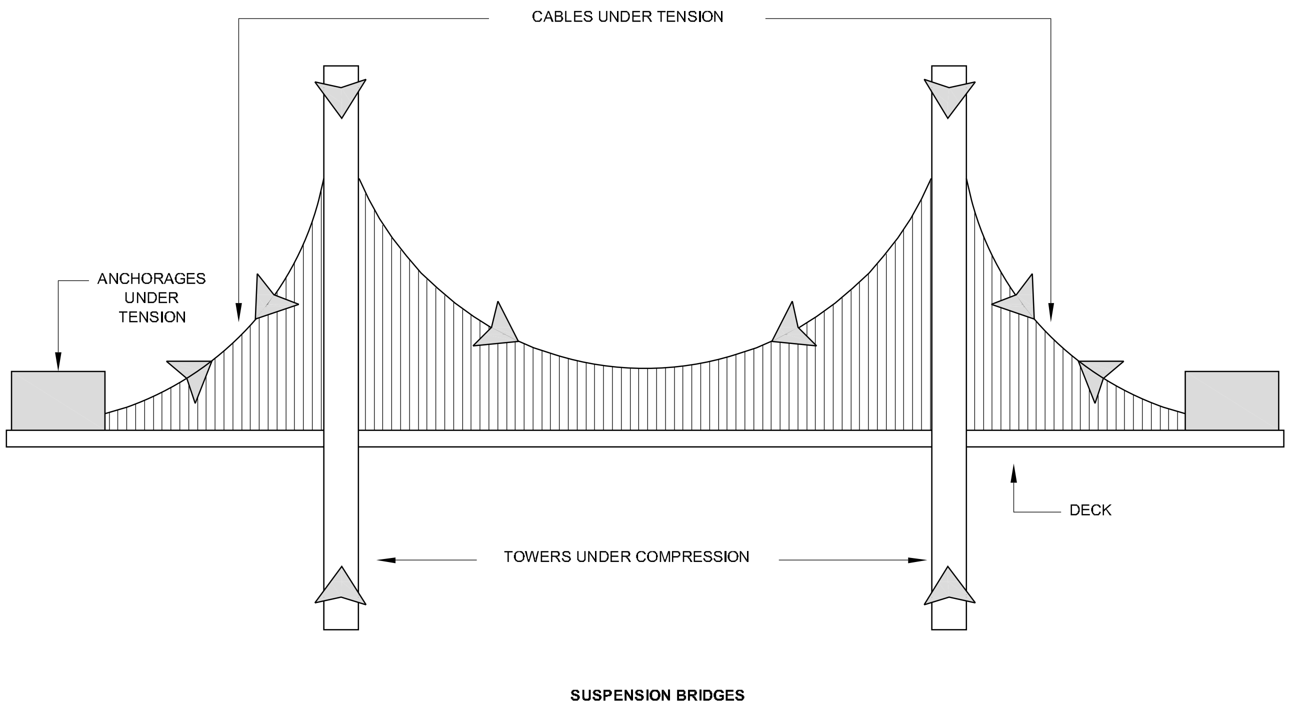


STEEL TRUSS BRIDGES

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

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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.

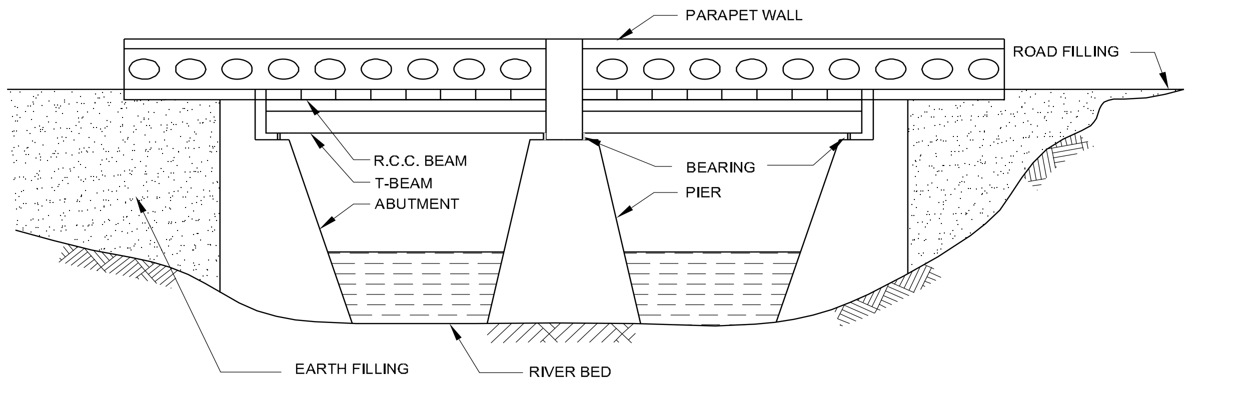
1 **R.C.C slab bridges**

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

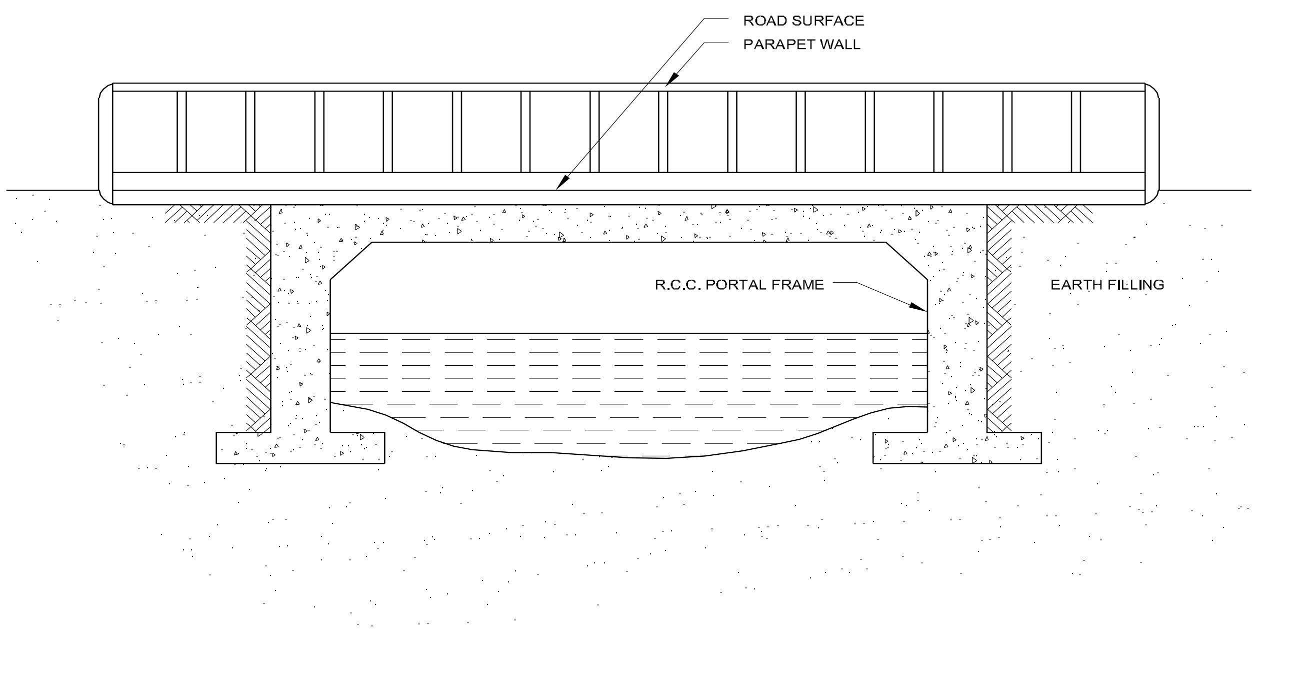


R.C.C. T-BEAM AND SLAB BRIDGE

R.C.C rigid frame bridge (Fig 8)

In this type of bride 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 bot suitable for spans below 10m and also for very long spans.

Fig 8



R.C.C. RIGID FRAME BRIDGE

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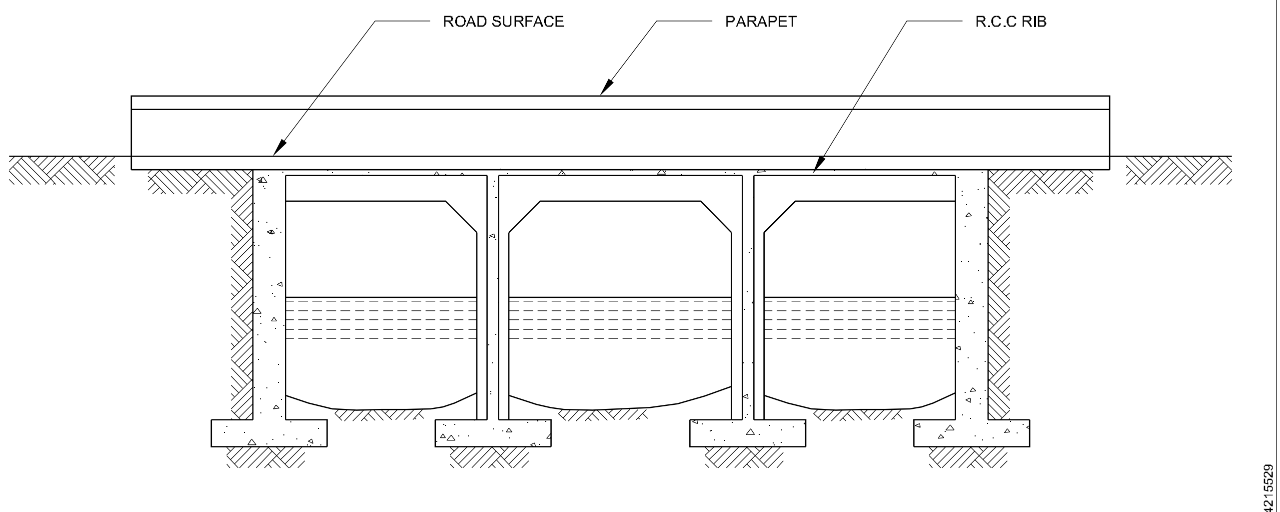
R.C.C multiple - span portal bridges (Fig 9)

This bridge should not have more than 16m span of each way. It essentially consists of continous 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

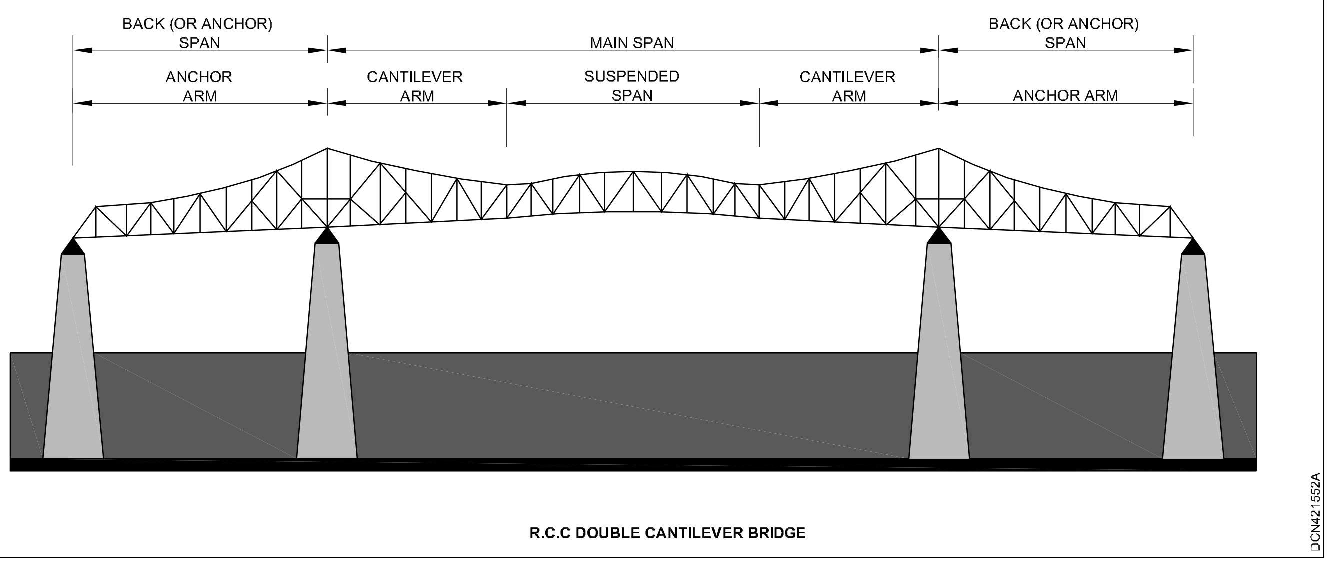


MULTIPLE SPAN PORTAL FRAME BRIDGE

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 vetical 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 cirumstances.

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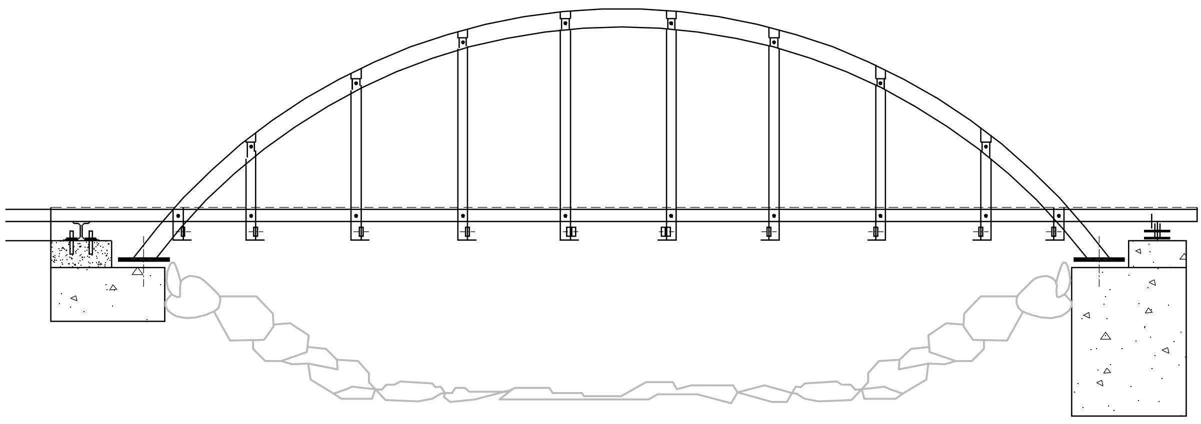
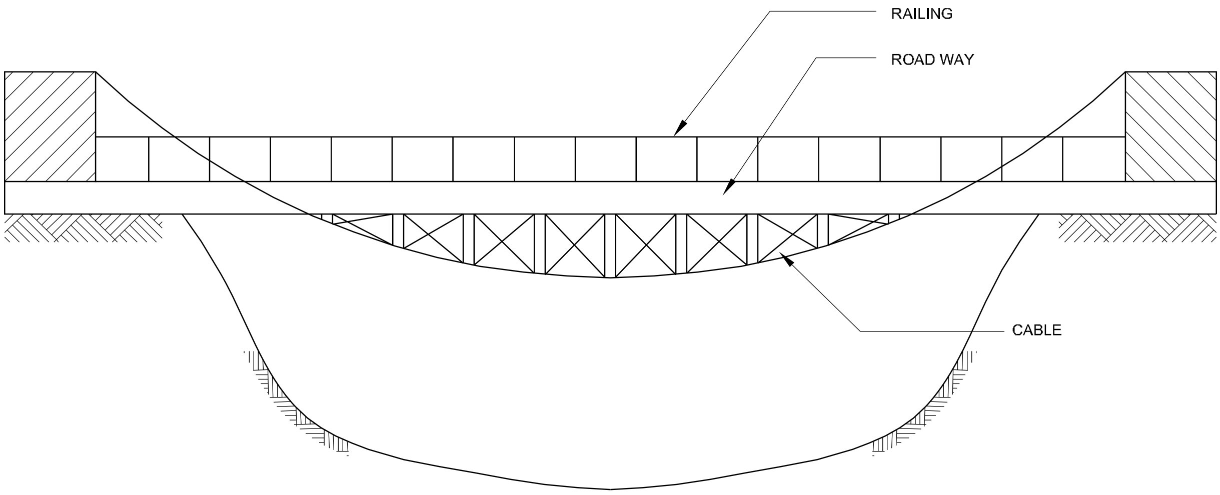
Fig 11



R.C.C. BOWSTRING GIRDER BRIDGE

Fig 12



R.C.C. BOW-STRING TYPE BRIDGE

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.

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 birdge, 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.

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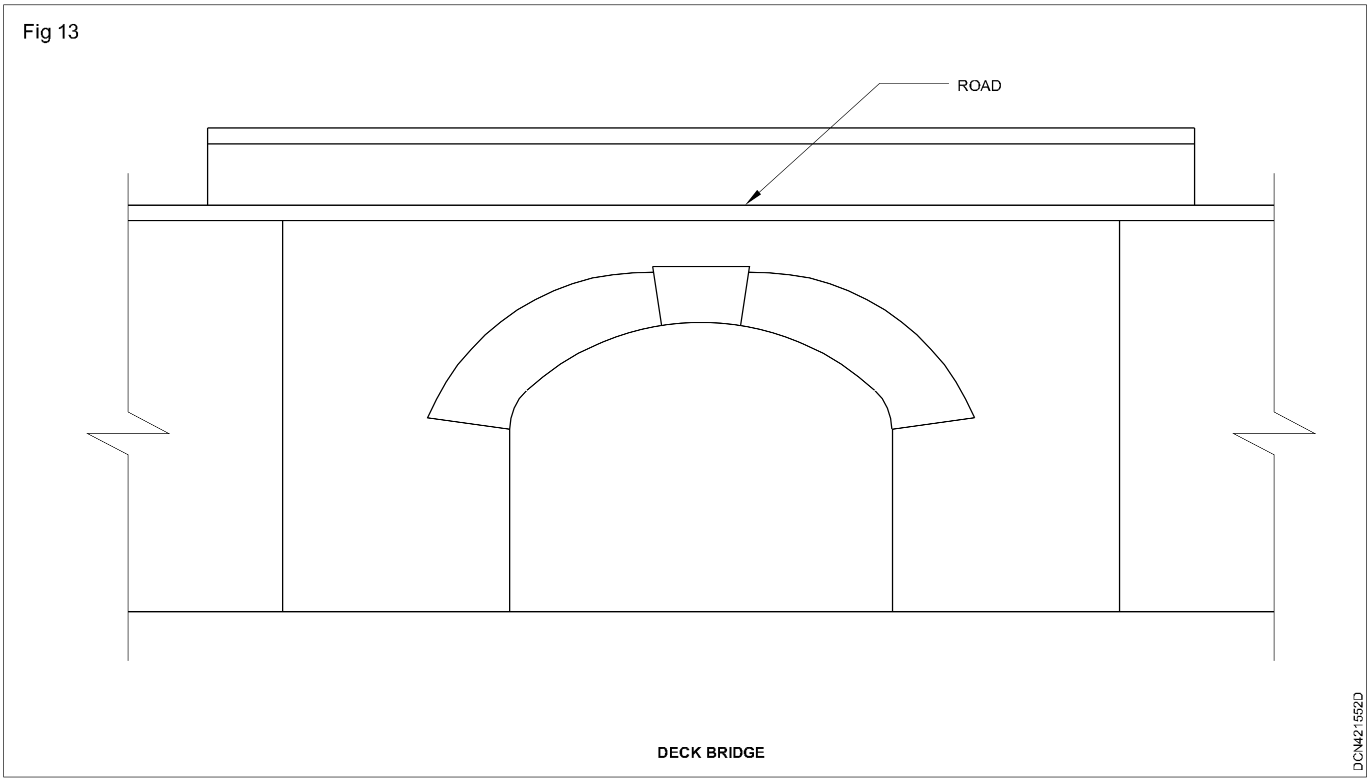
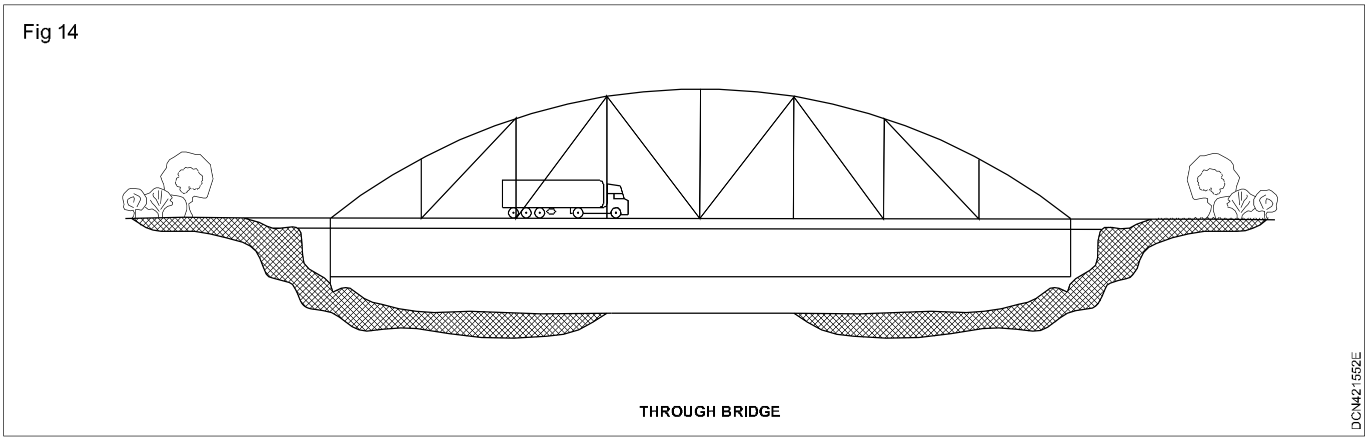


2 Through bridge (Fig 14)

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.

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 consturcted 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.

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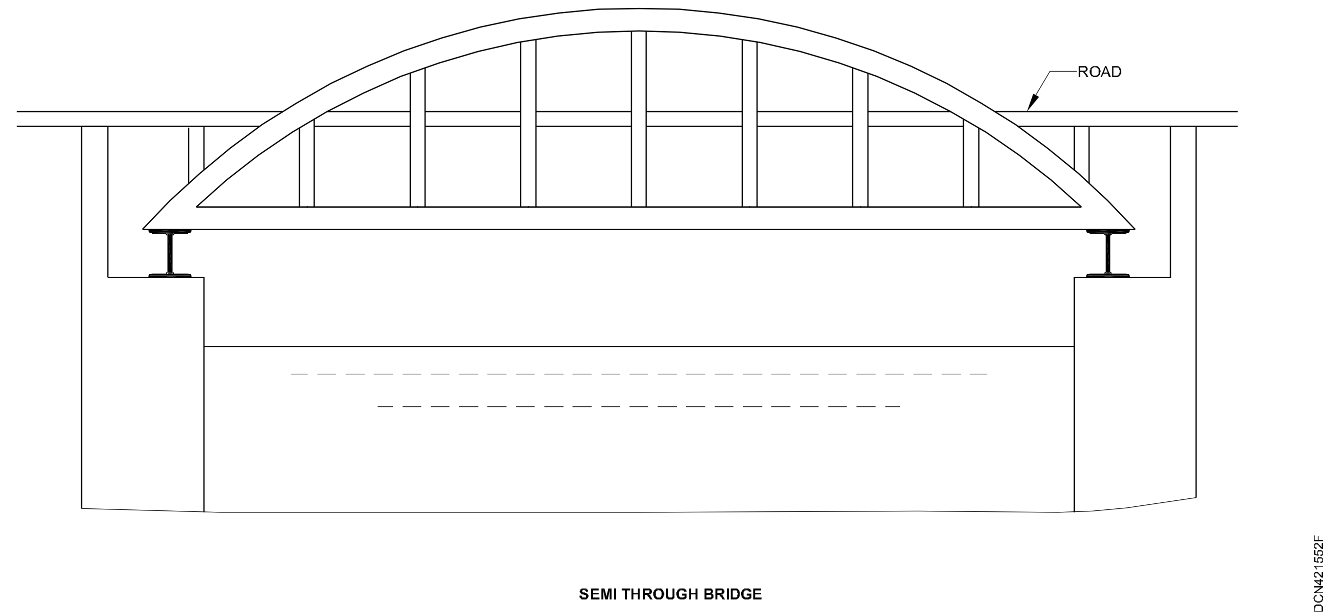
Fig 15



SEMI THROUGH BRIDGE

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 raiways, 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 amd more; or more than 110 m2.

The cross - drainage structures for the purpose of investigation are grouped into the following three categories iin 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

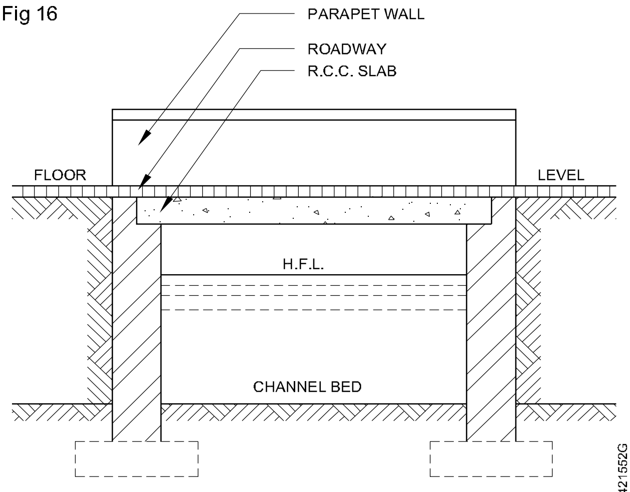
3 Box culverts

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

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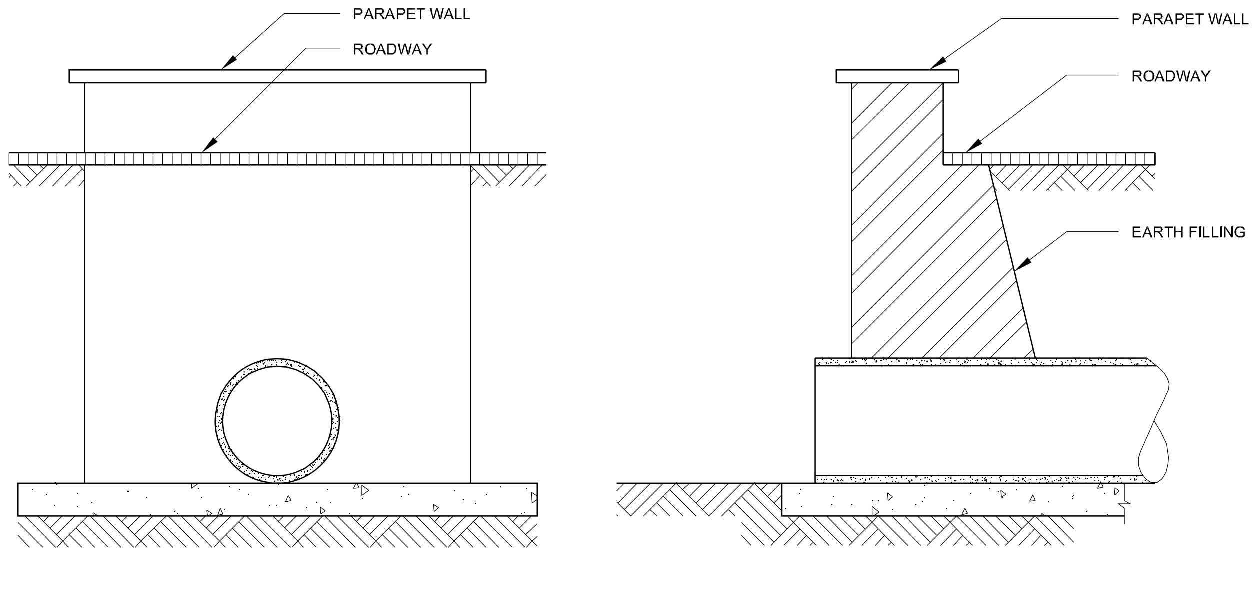
2 **Pipe culverts:** Pipe culverts are becoming more common due to easiness in construction. Hume pipes of various diameters are available. The kutch roads may be provided with pipe culverts, by simply laying the R.C.C. or Hume pipe in the position and filling the soil around it. (Fig. 17)

Fig 17



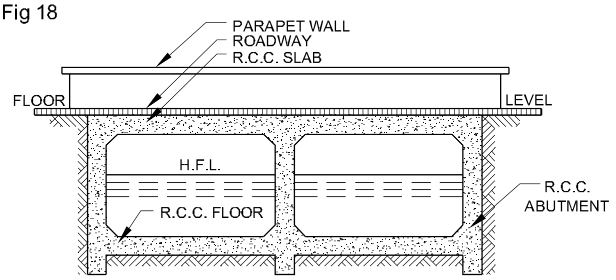
PIPE CULVERT

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)

These culverts mainly consist 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.

Fig 18



BOX CULVERT

4 Arch culverts (Fig. 19)

These culverts manily consist 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.

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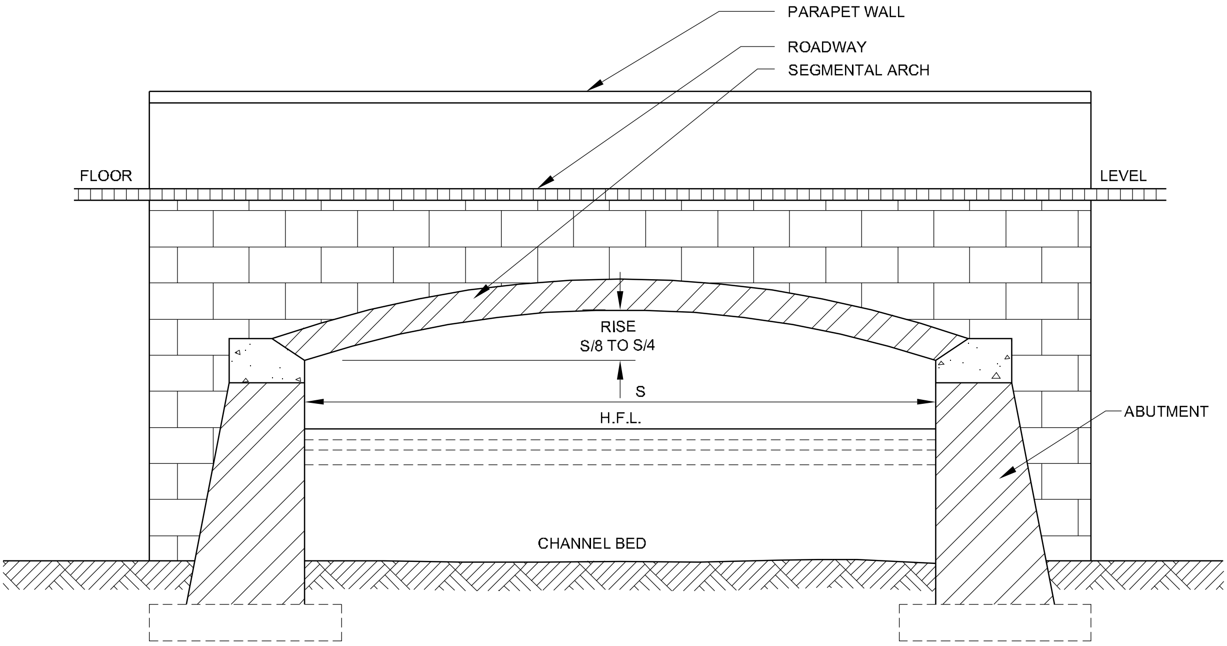
Fig 19



ARCH CULVERT

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 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)

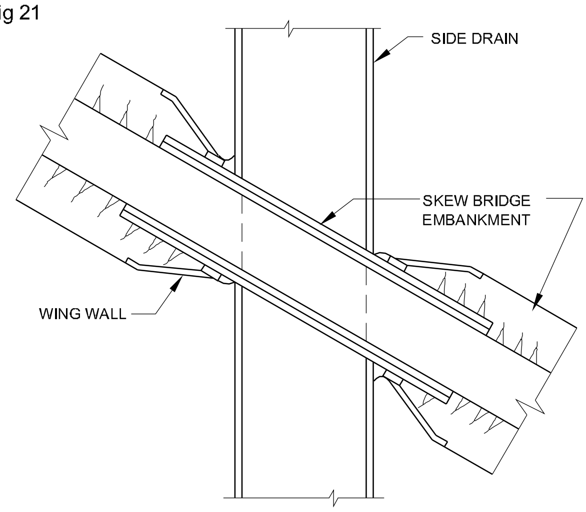
Classifiation

According to the level at highways and railways the bridges are classification as.

1 Over bridge

2 Under bridge

Fig 21



SKEW 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.

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ll 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/ recommedndations, 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 toher 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.

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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 Comustion Engines
- Noise Control
- Fire Prevention and Control
- Excavaion 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 constract when excavating and ocnstructing 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 sationn, 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 protable 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 applicalble 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.

Personla Protective Equipment: Employees entering underground working must wear, as a minimum, hardhats, appropriate eye protecttion, and foot protection. Employees entering wet areas must wear rubber footwear; underground type rain gear; 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

23.2.1 Evacuation Plan. Develop and post emergency evacuation plans, including provisions for rescue equipment, at the portal or shaft head. Instruct employees in the emergency procudures.

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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 traning 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.

a Provide at least two rescue crews of at least five men each for tunnel and shaft operations employing 25 or more employees at one time underground. One crew must be on the job site or within 1/2 hour travel time away from the portal. The other crew must be within 2 hours travel time.

b Organize and train at least one crew of at least five employees as a rescue crew, or, for smaller jobs, arrange in advance with a locally available rescue service. Locate the rescue crew or rescue service on the job site or within 1/2 hour travel time from the portal.

c Thoroughly instruct new crew members upon assignment to the rescue crew and conduct refresher training for the full crew at least every 6 months.

d Instruct and train rescue team members to perform resuce operations; use and care for oxygen breathing apparatus; and use firefighting equipment. Provide oxygen breathing apparatus unless, in the development of the emergency plan, analysis specifically indicates that the use of self-contained breathing apparatus is sufficient. Keep breathing aparatus in good condition and ready for use at all times. Maintain a sufficient supply of spare breathing apparantus, replacement parts, and regenerating material or air cylinders.

Emergency Lighting. Provide each employee and visitor entering underground workings with an MSHA approved protable 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, nonrecirculated, 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.

Ventilation System Design Requirements: Submit the system (s) design criteria, specifications, and appropriate drawings before acquiring or installing the system. Incorporate the following specific design features in all ventilation system.

a Mechanically induce all airflows. Do not provide required air quantities by natural ventilation methods.

b Construct primary ducts and fans of noncombustible metallic materials. You may use short, noncritical sections of expandable-type ducting in secondary system.

c Use class 1, division 1 electric motors, fans, drives, and auxiliary equipment, including wiring, starters, and constrols. Design install, and maintain the system in explosion-proof condition and make sure it is capable of operating in an explosive atmosphere.

d Ensure the noise levels of ventilation fans does not exceed 90 decibels when measured at the closest point of employee exposure.

e Ensure system airflows, secondary systems excepted, are reversible from a surface location. Incorporate a control system in the reversing feature so it is not necessary to rewire fans or electrical circuits to accomplish the reversing sequence.

f Design the primary ventilation systems to operate in the exhausting mode.

g Maintain primary duct system inlets within 3 duct diameter of the tunnel face or shaft bottom when operating in exhaust and within 10 duct diameters of the tunnel face or shaft bottom when operating on blow. In conventional drill and blast tunnels, you may need to install a supplemental ventilation system to maintain minimum ventilation rate to the tunnel face or shaft bottom during all protions of the excavation cycle. "Blow Joes" or similar-type recirculating devices do not meet this requirement.

h Heat or cool the ventilation air as necessary to ensure air temperatures at work sites are betwewn 40 ^{o}F and 100^{o}F.

i Design ventilation system capacities (cubic feet minute) to be the greater of:

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1 The total rate (cubic feet per minute) required for all MSHA-approved diesel engines operating underground.

2 The total rate (cubic feet per minute) required for all non MSHA-approved equipment. Non MSHA-approved diesel equipment must meet appropriate requirements in this section.

3 The total rate (cubic feet per minute) required to contorl airborne contaminanats or toxic and flammable gas or vapor within prescribed limits or values specified or referenced in this section and in the "Occupational Health" section.

4 The rate (cubic feet per minute) required to maintain a minimum air velocity of 100 feet per minute (feet per minute) over the gross bore area of all sections of the underground workings.

Air Volume Measurements. Develop and implement a procedure to maintain design airflows in all sections of underground workings. The procedure, as a minimum, must require the following:

a Determining airflows immediately after any system installation or modification that could significantly affect airflows (e.g., adding new fans, repairing fans, or changing duct arrangements).

b Continously monitoring airflows in primary ventilation systems with direct readout instruments containing low-air volume alarms.

c Determining airflows in congested tunnel areas (e.g., headings and near rapid excavation machines) by pitot tube traversing of the duct system supplying or exhausting air from the area. (Refer to American Conference Ventilation," for acceptable equipment and methods for air volume determinations.)

d Maintaining all data obtained by measurement, including the date, place, time, instrumentation, calculations, results, and the names of test personnel, on the surface and make it available for review.

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 continous sampling hydrogen sulfide indicator with alarm to monitor the affected work area if hydrogen sulfied levels exceed 10 parts per million (0.001 percent).

3 Take steps to increase ventilation to reduce the concentration if the concentration of hydrogen sulfied 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 ventilatiom 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."

Quantitative Sampling of Underground Environments
A competent person must conduct the quantitative sampling or underground environments. A competent person is one who through education, experience, and training can, using acceptable scientific instruments and methods, determine the quality of air in underground environments. Conduct quantiative smapling as follows:

a While excavaing the tunnel at least once each 4 hours and before reentry into the face area after each blast, test the environment in the face area: first for oxygen concentration and then for flammable gas or vapors, carbon monoxide, hydrogen sulfide, and nitrogen dioxide.

b At least once during each work shift change, test all working environments for oxygen concertration, flammable gas or vapors, carbon monoxide, nitrogen dioxide, hydrogen sulfide, and other applicable gases or vapors.

c Sample all working environments near dust-producing operations for applicable airborne particulates within 10 days after underground operations begin, and at 90-days intervals thereafter, or within 10 days following major changes in tunnel excavation methods or major modifications to ventilation systems. Within 10 days following the sampling date, furnish a full report of the sampling method and analysis and an evaluation of the environmental conditions to the affected employees.

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d Log and file environmental sampling data, indluding procedures, equipment, personal, dates, and results at a surface location and make it available for review.

In addition to quantitative sampling requrements, install specialized direct reading instruments to determine the concentration of flammable gases and vapors as follows:

a Equip all rapid excavation machines with a multisensor continuous flammable gas and vapor detector designed to shut down excavation operations when gas or vapor concentrations reach 10 percent of the lower explosive limit. Locate one sensor at the dust shield near the conveyor belt opening. Locate another sensor at the operator's station and a third sensor in the primary duct of the exhaust mode ventilation system.

b At least once during each work shift change, test all working environments for oxygen concentration, flammable gas or vapors, carbon monoxide, nitrogen dioxide, hydrogen sulfide, and other applicable gases or vapors.

c Sample all working environments near dust-producing operations for applicable airborne particulates within 10 days after underground operations begin, and at 90-day intervals thereafter, or within 10 days following major changes in tunnel excavation methods or major modifications to ventilation systems. Within 10 days following the smapling date, furnish a full report of the sampling method and analysis and an evaluation of the environmental conditions to the affected employees.

d Log and file environmental sampling data, including procedures, equipment, personnel, dates, and result at a surface location and make it available for review.

23.4.2 In addition to quantitative sampling requirements, install specialized direct reading instruments to deternine the concentration of flammable gases and vapors as follows:

a Equip all rapid excavation machines with a multisensor continuous flammable gas and vapor detector designed to shut down excavation operations when gas or vapor concentrations reach 10 percent of the lower explosive limit. Locate one sensor at the dust shield near the conveyor belt opening. Locate another sensor at the operator's station and a third sensor in the primary duct of the exhaust mode ventilation system.

b In conventional (drill and blast) operations, install an automatic multisensor continuous gas detector near the tunnel heading or shaft bottom. Equip the unit with visual and audio alarm components capable of alerting employees working at the heading or bottom that flammable gas or vapor concentrations have exceeded 10 percent of the lower explosive limit. Locate one sensor in the primary duct of an exhausting ventilation system and at least one more sensor in the general tunnel area within 30 feet of the face. Locate all sensors installed in the tunnel proper as near the crown as practical.

c Machine excavation operations, other than those described in paragraph

a above, require a similar detection system, a system with one sensro effectively placed to detect flammable gas and vapor concentrations near the cutter head.

23.4.3 Suspensions of Operations. Suspend all underground operation and remove all employees from underround workings whenever flammable gas or toxic gas or vapor concentrations exceed the acceptable levels set forth in this section on "Air Quality." Prohibit reentry, except for rescue operations, until authorized in writing by the contracting officer or representative, or office head. Do not provide written authorization until the following occurs:

a The employer has engaged the services of a PE experienced in gaseous tunneling or mining operations.

b The PE has, after onsite investigation and testing, developed a written detailed procedure for safely reentering the underground workings and resuming operations.

c The procedure complies with all requirements of these standard and the regulations of Federal and State entities having jurisdiction.

23.5 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.

23.5.1 Drilling: Equip rotary and percussion drills with water or chemical dust-control systems or other control systems.

23.5.2 Machine Excavation: Equip tunnel boring machines or other excavating machines with an effective dust-constrol system(s) before installation. Make sure the system can control the dust concentrations within the specified safe hygienic limits. Routinely maintain and test the system to ensure its effectiveness.

23.5.3 Muck Piles: Keep muck piles wet to reduce dust concentrations.

23.6 Requirements for Combustion Engines: Do not use internal combustion engines, other than approved diesel-powered equipment, underground. Provide written approavals or certifications before taking the equipment underground. Do not consider equipment approved until it meets one of the following provisions:

a The diesel-powered equipment has been approved or certified under the provisions of MSHA regulations 30 CFR Part 32 or Part 32 or Part 36 (formerly) schedules 24 and 31). When applicable, obtain a permit from the State entity having jurisdiction.

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b The employer certifies the diesel-powered equipment is equivalent to MSHA-approved equipment and meets the following requirements:

1 The engine's fuel injection system allows adjustments to the mecahnism controlling maximum fuel injection only by breaking a seal or by altering the design.

2 At maximum fuel air adjustment under normal operating conditions and within the rated output range of the engine, make sure the undiluted exhaust gas does not contain more than 2,500 parts per million carbon monoxide and no more than 2,000 parts per million oxide of nitrogen.

3 Dilute the exhaust gas with air before discharging it into the surrounding tunnel atmosphere. Ensure that the discharged mixture of exhaust gas and air doesn't contain more than 100 parts per million carbon nonoxide, 25 parts per million oxides of nitrogen, 10 parts per million aldehydes, and 2 milligrams per cubic meter of exhaust gas particulate emissions.

4 Cool engine exhaust to less than 160 °F before releasing it into the surrounding tunnel atmoshpere.

Ventilation Requirements. Ensure that ventilation (cubic feet per minute) incident to the use of diesel-powered equipment underground meets the requirements of this sections, including the following:

a The cumulative MSHA-approved ventilation rate for all diesel-powered equipment must be used for underground ventilation.

b For non-MSHA-approved equipment, a ventilation rate (cubic feet per minuite) adequate to dilute all gaseous exhaust contaminanats to below the prescribed limits or reduce the particulate emissions to below 1 milligram per cubic meter. In no case must the required ventilation rate be less than 150 cubic feet per minute multiplied by themanufacturer's rated horsepower of all engines when operating at maximum fuel/air ratio.

Maintenance and Testing: Inspect and maintain diesel equipment in accordance with the manufacturer's instructions. Design, operate, and maintain diesel equipment in conformance with MSHA 30 CFR Parts 36, 75.1909, and 1914. Maintain records of inspections and maintenance.

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.

Heating: Do not use liquified petroleum gas (LPG) and natural gas heaters underground.

Gasoline, Diesel and LPG: Do not permit gasoline or liquefied petroleum gases underground. Do not permit more than 1 day's supply of diesel oil underground. Do not pipe diesel fuel or combustible liquids from the surface to below ground.

Welding and Cutting: Comply with the section, "Hand Tools, Power Toos, Pressure Vessels,Compressors, and Welding," as well as this paragraph when welding and cutting underground. You may use acetylen and methyl acetylene propadiene stabilized gas underground for welding, cutting, and hot work. Do not permit underground more than the amount of fuel gas and oxygen necessary for work under progress for that shift. Before and continuously during welding or cutting, a competent person must determine that the atmosphere does not exceed the flammable gas, vapor, or oxygen limits.

Lubricants: Keep oil, grease, and diesel fuel stored underground in tightly sealed containers in fire-resistan areas at least 300 feet (91.44 meters) from explosive magazines and 100 feet (30.48 meters) from shaft statins, inclined passageways, and major electrical installations. Install in the storage area only electrical lighting systems that are approved for class I, division 2 locations.

Hydraulic Fluids: Use only fire-resistant hydraulic fluids approved by a recognized authority, such as Underwriters Laboratories, Inc., or Factory Mutual, in hydraulically actuated machinery and equipment, unless the equipment is protected by a fire protection system.

Belt Conveyors: Provide fire extingushers of at least 2-A:40-B:C units at the head and tail pulleys and at 300-foot intervals along the belt line. Install a device on the conveyor drive system that automatically disconnects power to the drive unit if the converyor stalls.

Portal Structures: Erect fire-resistive structures within 100 feet of a tunnel portal or shaft etrance. Place flammable material storage areas at least 200 feet away from the portal or shaft entrance. Do not permit combustible or flammable material within 100 feet of the portal or shaft entrance, main fan installation, or in a location where, in case of a spil or leak, the material will flow into the portal area.

Fire-Suppression Systems for Diesel-Powered Equipments: Equip all diesel- powered equipment operated underground with all of the following:

a A minimum of one 2--A:40-B:C dry chemical fire extinguisher that is accessible from ground level.

b Factory Mutual or other nationally recognized independent testing laboratory must specifically approve a dry chemical, pre-engineered, fixed-nozzle-type fire-suppression system for the respective service and the potential hazard. The design, installation, operation, and maintenance of the system must be in accordance

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with the testing laboratory's recommendation. The system, where applicable, must conform to National Fire Protection Association Standard No. 17, "Dry Chemical Extinguishing System," and the requirements of the authority having jurisdiction. Manual system actuators must be accessible from ground level and within reach of the operator when seated in the operating position.

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. Protec employees engaged in these activities from dislodements by location, ground support, or other equivalent menas.

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. Aslo provide safe access to the deck and cover the decks with solid, nonslip decking. When moving jumbos, do not permit rders 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 thedrill 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 materilas and equipment to the top decks of jumbos more than 4 feet high.

i **Airhose:** Secure all airhose 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.

23.9.2 Mechanical Excavation

a **Mechanical Hazards:** Sound an audible warning before excavating or conveying machinery. Equip excavating machines with dead-man controls. Provide adequate guarding where workers are exposed to moving parts or to hydrauliic lines operating at temperatures greater than 160 ^{o}F.

b **Lockout:** In addition to requirements found in thesection, "Hazardous Energy Control Program," provide a means to lock out all power sources from the mechanical excavating equipment. Where employees may need to work between theface and teh cutter head tunnel-boring machines, provide the employees with a positive mechanical block to prevent movement of the cutter head and a provision to clock out the power.

c **Examination:** Thoroughly examine the heading before starting excavation equipment.

Requirements for Ground Support

Tunnel Portals: Keep rock faces above and adjacent to protal areas throughtly 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 protals. 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 gopod condition. A completent 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 themw ith 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.

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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.

a **Locomotives:** In addition to ensuring that locomotives meet the requirements of this section, equip them with: (1) a braking system, capable of stopping and holding a loaded train on any secton of track; (2) headlights, a bacup light, an audible warning device, a continuous revolving flashing amber light that is visible in all driections; (3) seats for the operator and all passengers; (4) adequate platform and handholds for the train crew; (5) rerailers and jacks; (6) dead-man controlds; and (7) falling object protection in accordance with the latest revision of 29 CFR 1926, Subpart S, "Tunnels and Shafts, Caissons, Caissons, Cofferdams, and Compressed Air."

b **Man-Haul Units:** (1) Totally enclose man-haul units, ecept for doors, small windows, and ventilation openings; (2) equip man-haul units with seats for all passengers, adequate access devices, and safety chains in addition to safety coupling devices; (3) use man-haul units only to transport personnel, their personal equipment, and small secured tools. Man-haul trips must consist of an engine and man-haul car(s) only. Pull man-haul cars when occupied. Personnel who are incidentally transported between shift changes may sit on locomotive seats or in specially equipped, empty muck cars that have adequate headroom. Engines must pull muck cars carrying personnel, and muck cars must be equipped with safety chains.

c **Haulage Cars:** Equip mine dump cars with automatic safety couplings. Equip cradle or bottom dump cars with a positive-locking device to prevent accidental dumping. Provide and use tiedown chains or bumper blocks to prevent overturning of cars dumped by hand.

d **Tracks:** Install and maintain rails in a manner that prevent shifting or excessive settlement. Anchor rails to prevent unsafe separation, and gauge them during laying operations and regularly while in use. Provide berms, bumpers, blocks, safetly hooks, or equivalent means to prevent overtravel or overturning at dumping areas.

e **Operations:** Load and secure materials to be hauled to prevent sliding or dislodgement. Carry only small hand tools, lunch pails, or similar light items on top of locomotivers, provided that the top of the locomotive is designed or modified to retain them while traveling. Chock, block, or set the brakes on parked equipment to prevent inadvertent movement.

Nonrail-Type Haulage Systems: Nonrail-type haulage systems must comply with the following applicable requirements:

a Rubber-tired or crawler equipment and operations must comply with applicable requiremnets of this section and the section, "Mobile and Stationary Mechanized Equipment."

b Conveyor systems equipment and operation must conform with applicable requirements of this section and the setion, "Hoisting Equipment, Piledrivers, and Conveyors."

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.

Access: Provede all shafts with pretected manway designed to permit safe entrance to an exit from the shaft bottom. Hoisting systems designed, installed, operated, and maintained as set forth in this section may transport personnel.

Guards: Protect the shaft opening with totally enclosed perimeter guarding that is high as a standard gurardrail. Slope the ground adjacent to the top of the shaft collar away from the shaft to prevent liquids from entering and construct an effective barrier to prevent mobile equipment from accidentally entring the shaft.

Hoisting Systems: Do not use cranes, derricks, or similar equipment as the primary hoisting system to raise or lower personnel. Only use cranes, derricks, or similar equipment meeting the requirements of this section for an emergency hoisting system. Do not use cranes to raise or lower muck or concrete buckets or similar devices to remove excavated material or to place concrete, except in shafts less than 75 feet (22.86 meters) deep. You may use cranes to raise and lower construction materials or equipment that cannot be safely handled by the hoisting system. Cranes must conform with applicable provisions of the "Hoisting Equipment, Piledrivers, and Converyors" section and all of the following requipments:

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- Equip primary and secondary hoisting lines with planetary or worm gears, torque convertors, automatic braking systems, or other equipvalent systems that prevent the load lines from being placed in a free wheeling or neutral position controlled only by a manual brake or dogs (hooked or U-shaped device used for gripping or holding heavy devices).

- Equip hoisting lines with: (1) an anti-two-blocking device or a two block damage prevention feature; and (2) a lilmit switch to prevent overtravel at the bottom of the shaft. Keep at least two full wraps or wire rope on the drum at all times.

- A competent person must inspect the crane at the beginning of each shift and each time it is set up at the work site. Give the crane a full cycle operational test lift before initial use at the shaft site and each time it is reset at the site.

a **General Requirements of the Primary Hoisting System:** Install a stationary hoisting system meeting the requirements of this subsection and applicable provisions of the "Hoisting Equipement, Piledrivers, and Conveyors" section, and ANSI A 10.22, "Safety Reqirements for Rope-Guided and and Non-Guided Workmen's Hoists," at all shaft sinking operationary hoisting systems. Follow the more deep. A PE must design all stationary hoisting systems. Follow the more stringent standard if there are conflicts between these and referenced standards.

b **Specific Requirements of the Primary Hoisting System:** The stationalry hoisting system must meet applicable ANSI satndards, the requirements of the State having hurisdiction, and the following specific requirements:

1 **Personnel Hoisting:** You may use the primary hoisting system to hoist personnel in attached cages or manskips that meet the requirements of referenced ANSI standards or in buckets suspended beneath crossheads operating on rail or rope guides, provided: (1) the sides of the bucket are steel and at least 4 feet high, and at least 1/16 inch thick; (2) you use emergency chains, slings, or double clevis pins between the lower end of the hoisting rope and the bucket to prevent the byucket from falling in the event of ring bolt or clevis pin failure; (3) you provide a bonnet that covers the top to protect it from falling rock or other objects; (4) the bonnet is the equivalent of two steel plates 3/16 inch thick, sloping toward each side and arranged to permit safe egress from the bucket; (5) the speed of the personnel platform does not exceed 200 feet per minute; and (6) governor controls set for 200 feet per minute are installed in the control system and used during personnel hoisting.

2 **Hoist Motors:** Design the hoist motor so that the load powers up and down through the gears. There must be no fricion gearing or clutch mechanism by which the motor or other power source can be disconnected from the hoist drum. When the control is brought to the remain the stopped position.

3 **Hoist Controls:** Design the hoist control to return to the "stop" position when the operator removes his/her hand from the control lever. Whenever the control lever is in the stop position, the brakes must automatically apply and the power must cut off. All hoist controls and the emergency power cutoff must be within reach from a single operating position.4.

4 **Guides:** Equip shafts more than 75 feet (22.86 meters) deep with guide rails or guide cables to prevent the cage or bucket from swaying. When sinking shafts more than 75 feet (22.86 meters) deep, keep the guide rails or cables as close as possible to the bottom of the shaft. Maintain rail guides within one rail length of the bottom. Provide a safe means of access from the bottom landing to the bottom of the shaft. When sinking shafts less than 75 feet (22.86 meters) deep, guide cages, skips, and buckets that may swing, bump, or snag against shaft sides or other structural protrusions by fenders, rails, ropes, or a combination of those means. Guide cages, skips, and buckets in all completed shafts by ropes or rails for the full length of their travel.

5 **Broken-Rope Safety:** Equip cages, skips, or buckets operating on guides or guide cables in shafts more than 75 feet (22.86 meters) deep with a broken-rope safety device, or equivalent, that will stop and hold a weight that is 150 percent of rated capacity in the event of a hoisting cable failure.

6 **Limit Stops:** Equip hoists with approved-type limit switches that will automatically stop the cage or bucket at the limits of travel.

7 **Communications:** Provide hoist operators with a closed-circuit communicatons system to each landing station. Locate a speadker microphone so that the operator can communicate with individual landing stations during the hoist.

8 **Performance Inspections and Tests:** Following installation and before use, at 6-month intervals thereafter, and after modification or repair of the critical components, inspect each hoist and load test it under the direction of the PE or a qualified person certified by the PE to conduct such inspections and tests. Maintain a comprehensive report detailing the required inspections and test procedures and results. The PE, or his or her designee, must sign and maintain the report. Include a broken rope drop test to verify that safety clamps function properly and that the guide ropes/rails, their supports, and the bucket/cage are able to withstand the imposed load.

(**Note:** ANSI A10.5, "Safety Requirements for Material Hoists, "under "Standards for Material Handling, Storage, and Disposal, "detaills one method for conduting such tests.)

Further, performance test the hoist with a test load of 125 percent through all limits of travel to ensure satisfactory operation of limit switches, speed indicators, braking systems, and controls.

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9 **Periodic Inspection and Tests:** A competent person must visually check all hoisting machinery equipment, anbchorages, and hoisting rope at the beginning of each shift and during hoist use, as necessary. A competent person must check each safety device at least weekly during hoist use to ensure suitable operation and safe condition. Periodic inspections and test must conform to the PE's recommendations.

c **Overhead protection:** Do not hoist or lower material or tools while personnel are working at the bottom of a shaft unless a barrier of adequate strength is installed to protect the personnel from falling objects or material. Do not lower any load, cagte, skip, or bucket directly to the bottom of a shaft when personnel are working there. All such equipment must stop at least 15 feet above the bottom of the shaft and remain there until the signal person at the bottom of the shaft gives the signal to lower.

Suspended or Movable Work Platforms: Design, inspect, and test suspended or movable work platforms in accordance with applicable provisions of this section and the section, "Hoisting Equipment, Piledrivers, and Conveyors." The term "platform" in this subsection is synonymous with the terms skip or cage, in referenced subparagraphs, subsections, or standards.

Small-Diameter Shafts. Provide small-diameter shafts, such as manholes, well, or test pits that employees must enter, with a steel casing, concrete pipe, timber cribbing, or other support adequate to train surrounding earth.

Inspection. Following a blast, check the walls, ladders, supports, blocking, and wedges to determine if they have loosened. If they are loose or unsafe, make repairs before continuing work in the shaft.

Requirements for Tunnelimg 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 shielld. Do not permit emplyoees 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 Suuprt: A PE must design support systems for tunnels exacavated 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.

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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 thengauges 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 laterla 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 locomitive 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

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

New railway zone

To increase the efficiency of the railways, the ministry of railways has set up six new raiway zones.

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

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Classification of Indian railways

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.

a Trunk routes

b Main lines

c Brance 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 consist 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.

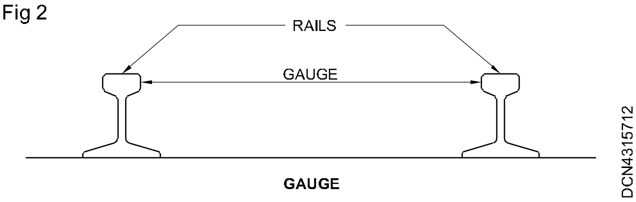
Group E

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 he 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.

Fig 2



GAUGE

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 propspects 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.

Name of gauge	Gauge in metre
Broad gauge	1.676 m.
Metre gauge	1.00 m.
Narrow gauge	0.762 or 0.61 m.

Advantanges 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.

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

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Fig 3

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".

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.

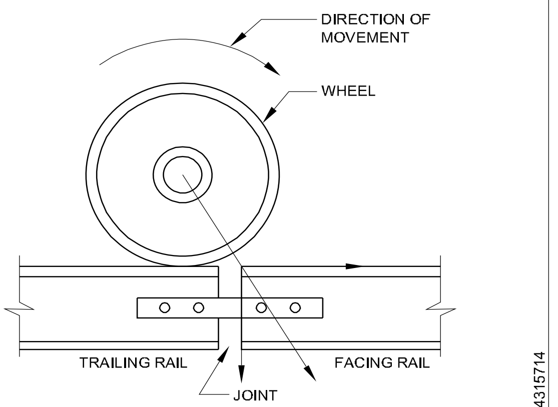
5 **Bull - headed rail:** The rail having similar head and bottom shapes is known of bull - headed rail. It is used with rail chairs.

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.

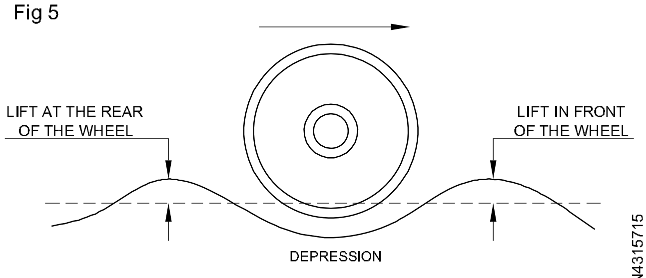
8 **Creep of rails** (Figs 4&5) **Rail creep:** Longitudinal movement of rails in a track in the direction of motion is called rail creep. It varies from negligible length to few centimetres. The rail may either move with respect to sleepers or sleepers may move along with rails.

Fig 4



PERCUSSION THEORY OF CREEP

Fig 5



WAVE THEORY OF CREEP

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 formaion 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

  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 expectedintensity 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.

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vi Defective creep anchors should be replaced when onseved 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.

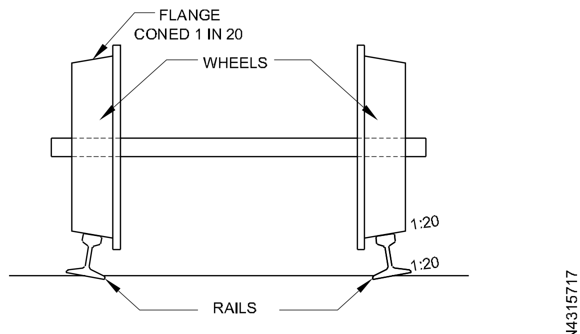
18 **Terminal station:** This is the last station of the routes at which the track terminates.

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.

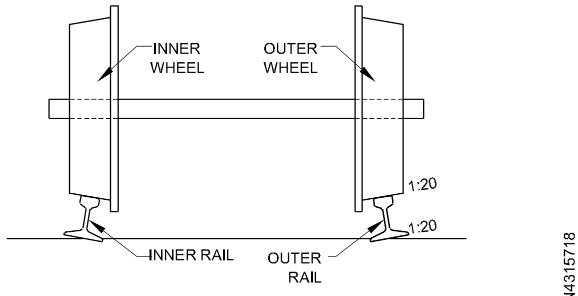
21 **Coning of wheels:** The outer rims of the railway wheel are coned at slope at a slope of 1 in 20, to prevent the rubbing of the wheel flanges with the side of the top flanges of the rails. Provision of this slope of 1 in 20 to the wheel rims prevents the lateral movement of the axle with its wheels 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.

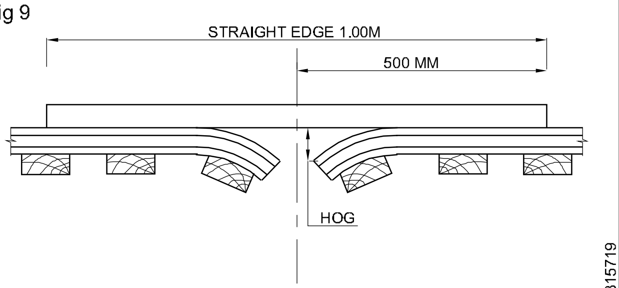
23 **Wear of rails:** The flow of rails metal due to abnormally heavy load is called wear of rails.

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 theinner sides of the main rails at the level crossing and other crosings 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 direcion. A hogged rail end in the track is ascertained by unfishing 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

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27 Wear of rails: The moving of a numbe of wheels of the vehicles causes what is known a sthe wear of rails. Depending upon its location, the wear of rails can be classified as follows.

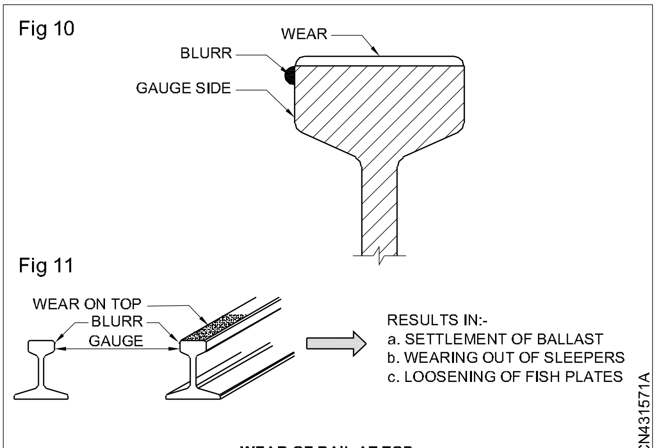
1 Wear pf rails on top or head of rail.

2 Wear of rails at ends of rails.

3 Wear of rail onthe 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.



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.

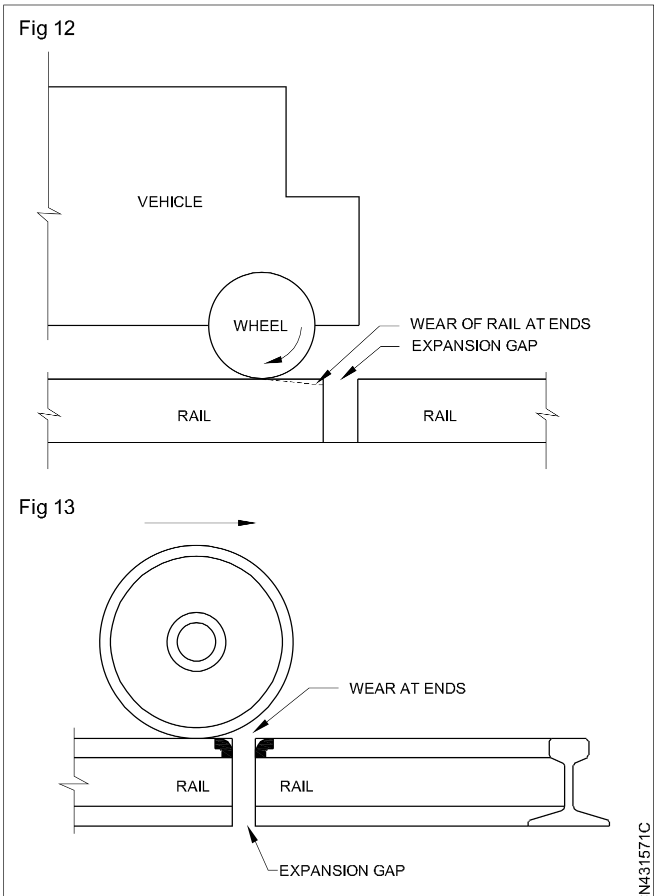
iii The impact of heavy loads causes top of rail to wear.

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 gto take a jump and during this jump, they impart a blow to the ends of the rails as shown in figs 12 &13.



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 settement of ballast at these points.

Wear of rail on the sides of the had 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 galnges 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.

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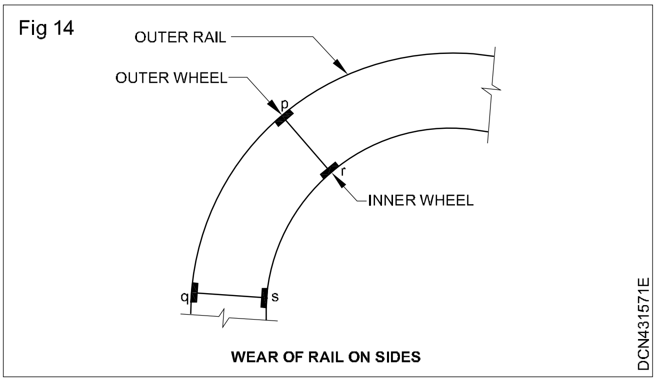

But due to rigid connections between two wheels, they cover the same distance and hence the inner wheel slips over the inner rail, resulting in the wear of inner side of head of inner rail.

28 Bending of rails: It is themethod of bending of bending the rails section according to the curves required. (Fig 15).

Fig 15

29 Welding of rails: Welding is requried 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 conponents of points and crossing. The following methods are used for welding.

They are

1 Electric are welding

2 Oxy - acetylene welding

3 Chemical or thermite welding

4 Flash butt welding.

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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.

Functon 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 wheeels.

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

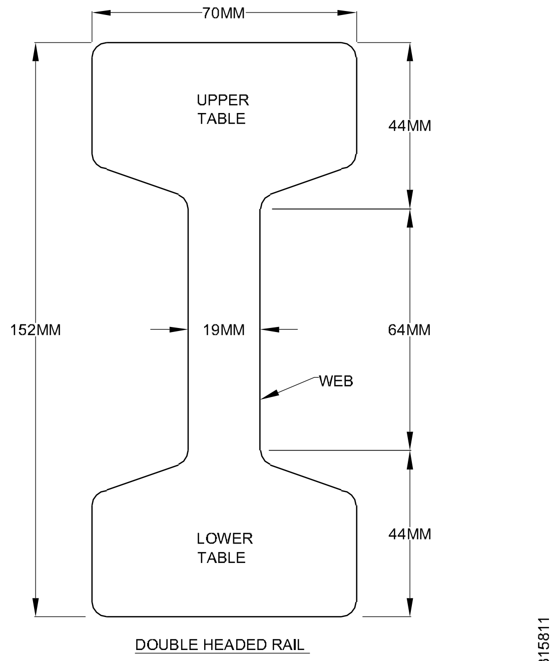
ii Bull headed rail

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



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 lenght 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.

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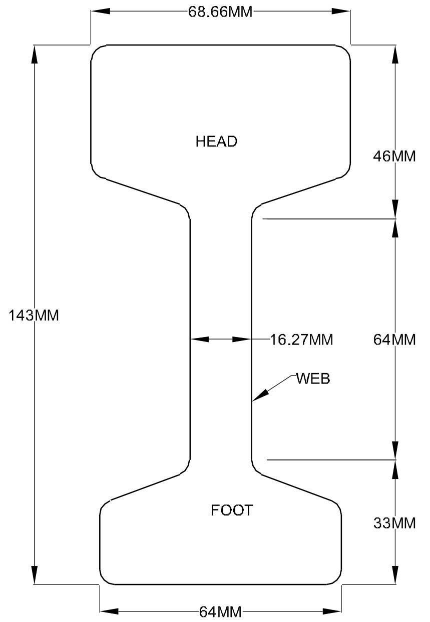
Fig 2

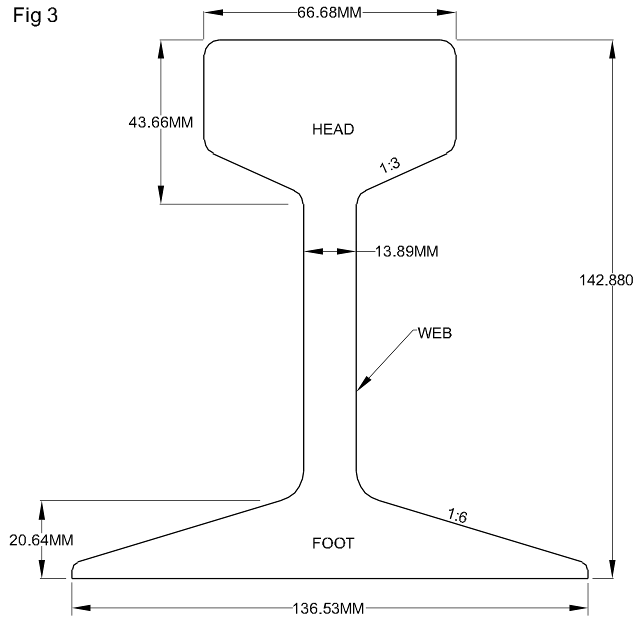


BULL HEADED RAIL

TYPER OF RAILS

DCN4315812

Fig 3



FLAT FOOTED RAIL

TYPES OF RAILS

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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

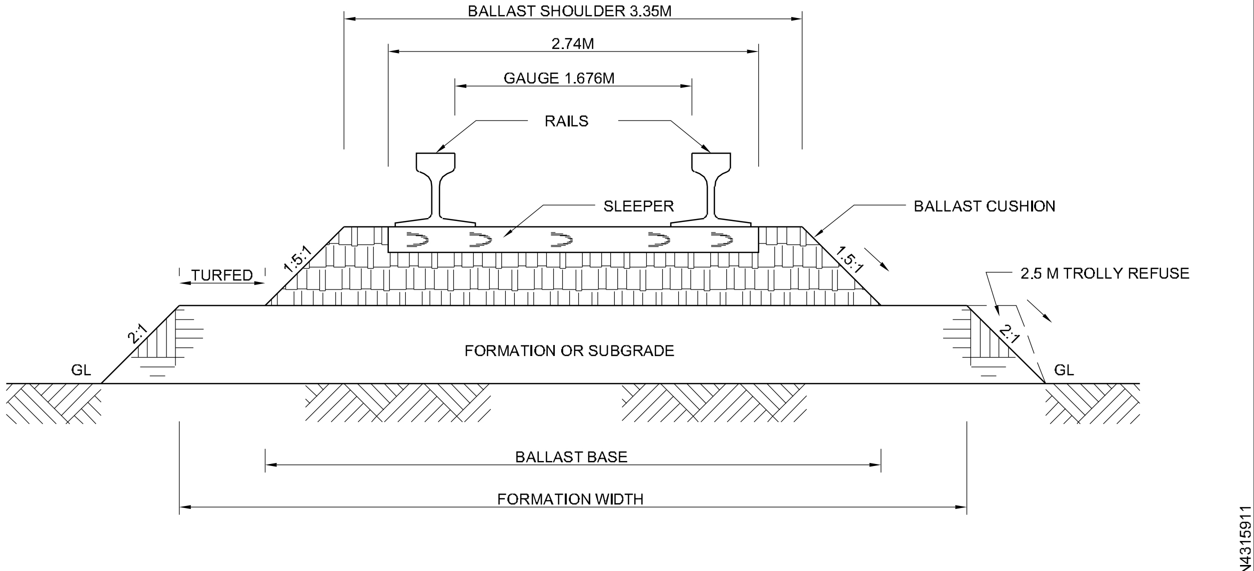
iii Sleepers

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 tain 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

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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 with 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 rail 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 raiway board has recommended the following dimensions of borad gauge.

a Minimum distace, centre to centre of track = 4. 725 m.

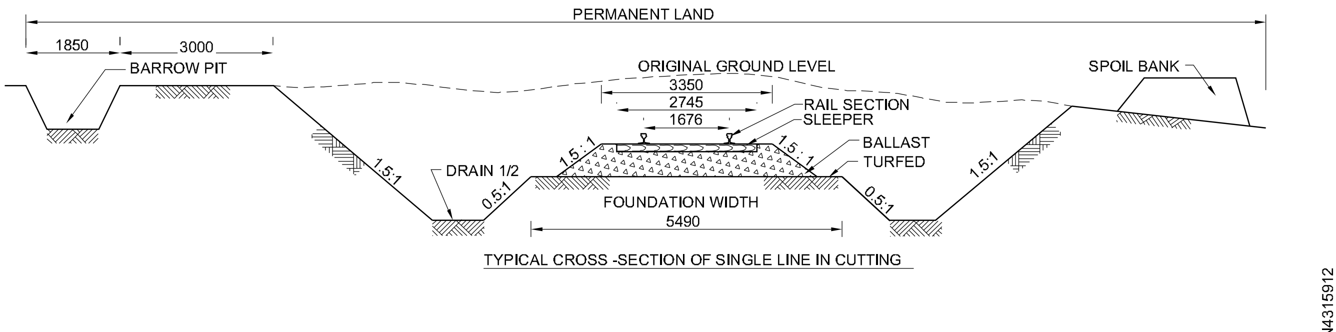
b Minimum formation width in embankment (single line) = 6.10 m (Fig 3).

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 4).

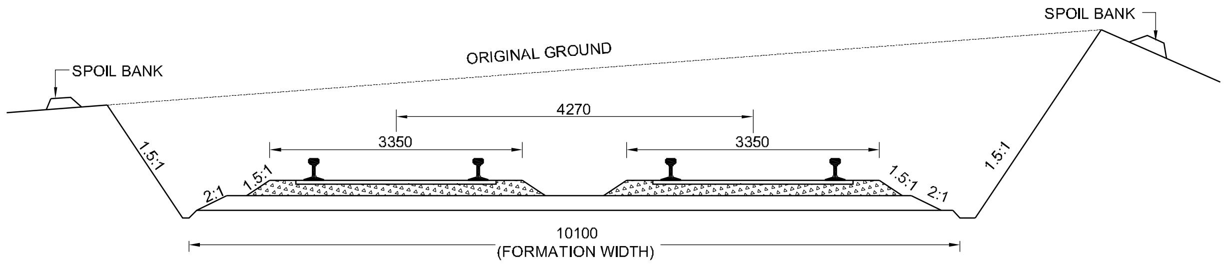
e Minimum formaion width in cutting (double line) = 10.058 m (Fig 5).

Fig 2



TYPICAL CROSS-SECTION OF SINGLE LINE IN CUTTING

Fig 3



TYPICAL CROSS-SECTION OF DOUBLE LINE IN CUTTING

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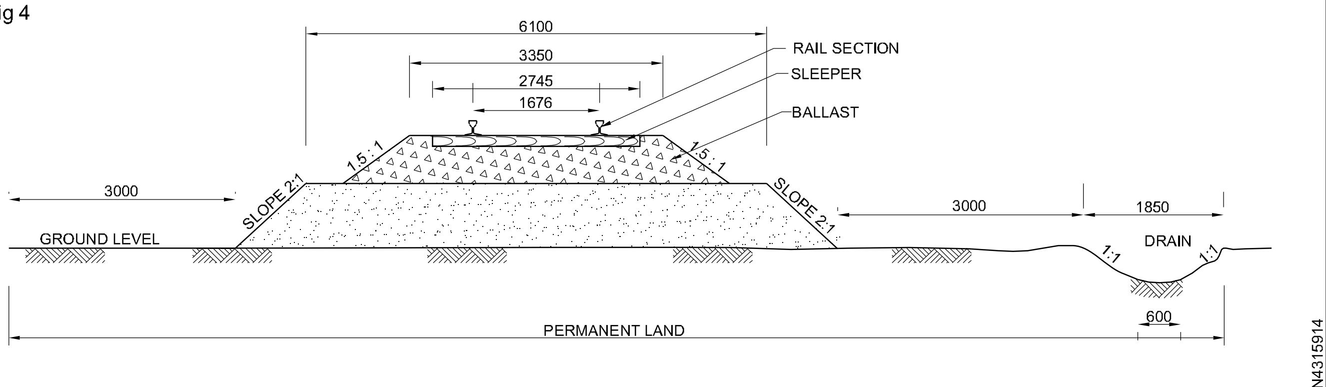
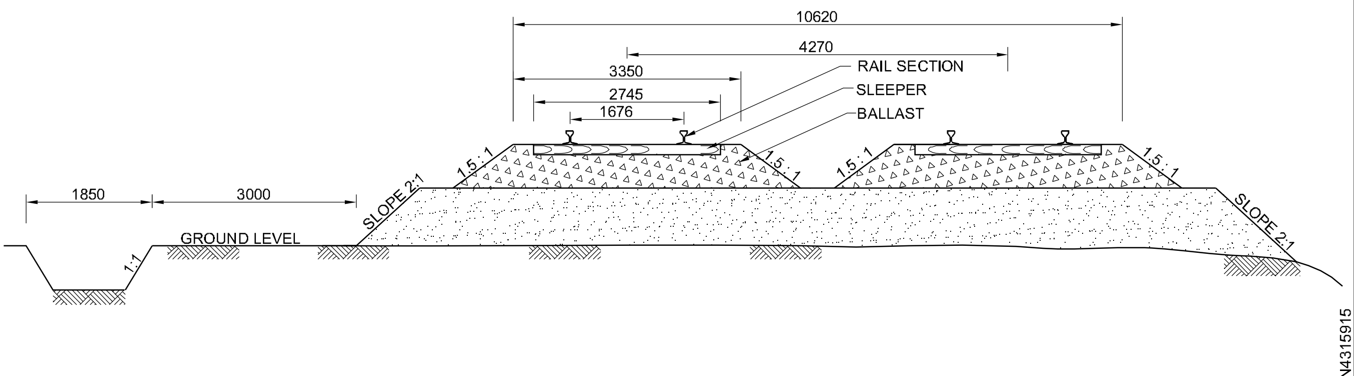
Fig 4



TYPICAL CROSS-SECTION OF SINGLE LINE IN EMBANKMENT

Fig 5



TYPICAL CROSS-SECTION OF DOUBLE LINE IN EMBANKMENT

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.

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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

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 seviceable 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 loacations like points and crossings, bridges, ash-pits, etc.

7 They permit track-circuiting because they are good insulators.

8 The damages during derailmetne is less when these sleepers are used.

9 They can be used on yiedling formation bacause 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 whiteants, vermins, rail cutting, warping cracking etc.

6 They require special treatment for fire protecion

7 They possess less scrap value

2 Steel Sleepers: The steel sleepers are extensively used on the Indian railways, with excellent results.

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.

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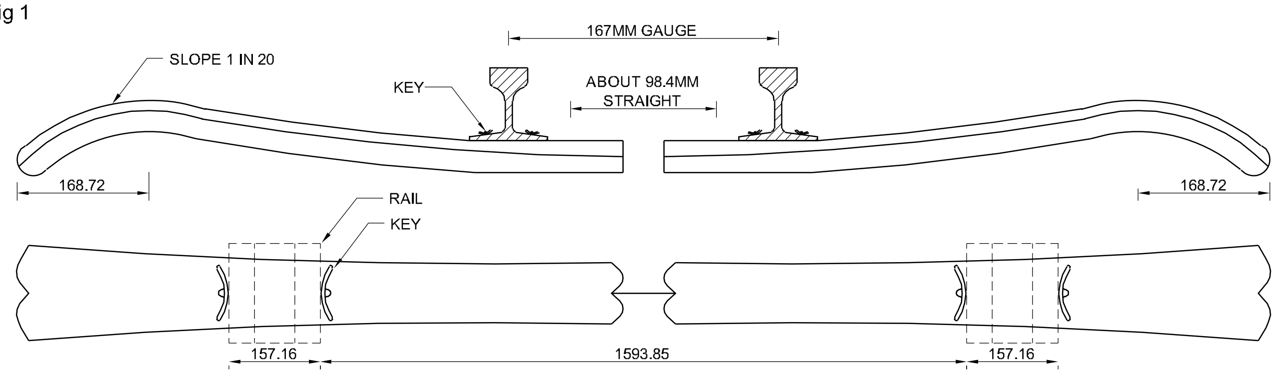
Fig 1



STEEL SLEEPER

Types of cast iron sleepers

a Pot sleepers

Pot sleepers are in the form of two bowls placed under each rail and commected 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.

Fig 2

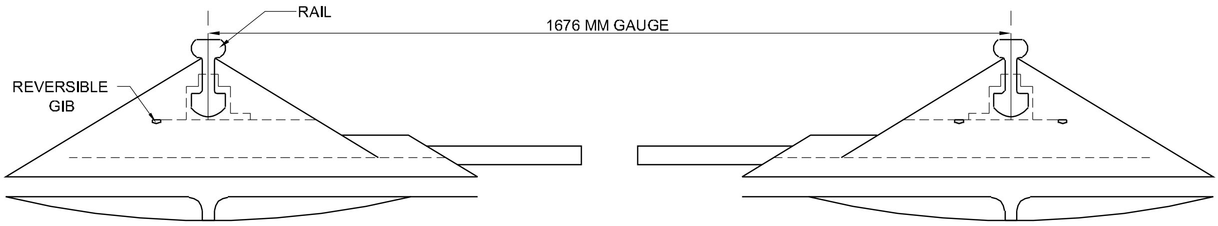
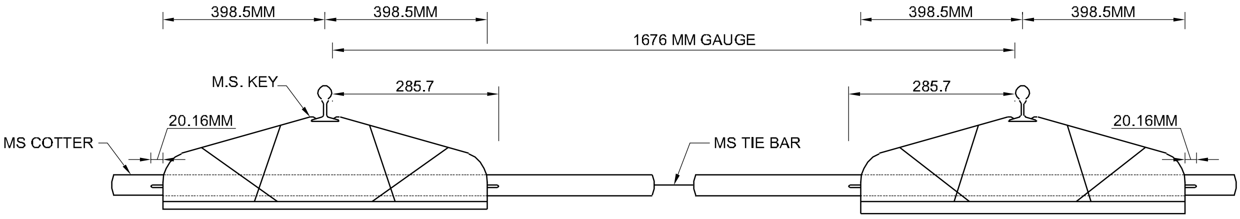


PLATE SLEEPER

c C.S.T. - Sleeper(Central Standard Trial-9) (Fig 3)

This sleeper is a combination of pot, plate and box sleepers.

Fig 3

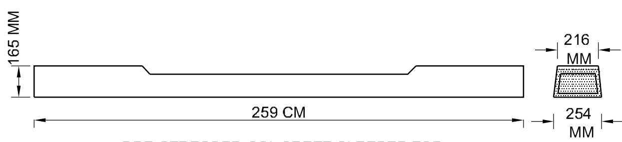


C.S.T. - 9 SLEEPER

Reinforced concrete sleepers (Fig. 4)

There are two types of RCC slseepers. 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

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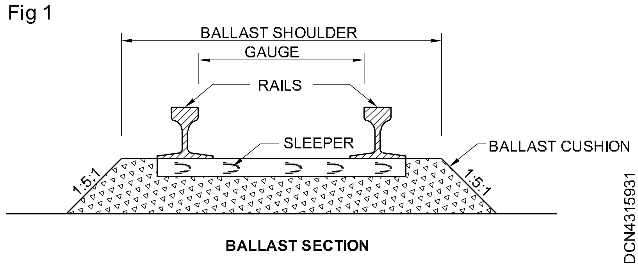
Ballast

Objectives : At the end of this lesson you shall be able to
- **define the ballast**
- **state the functions of ballast**
- **state the chracteristics 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.

Fig 1



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.

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 prorous 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 Earth ballast

ix Slab

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 fo 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.

ix Slag: It is waste product obtained from the blast furnaces and is widely used in foreign countries

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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

Minimum depth of ballast (Fig 2)

Depth of ballast section may be calculated by the formula D= (s-b)/2

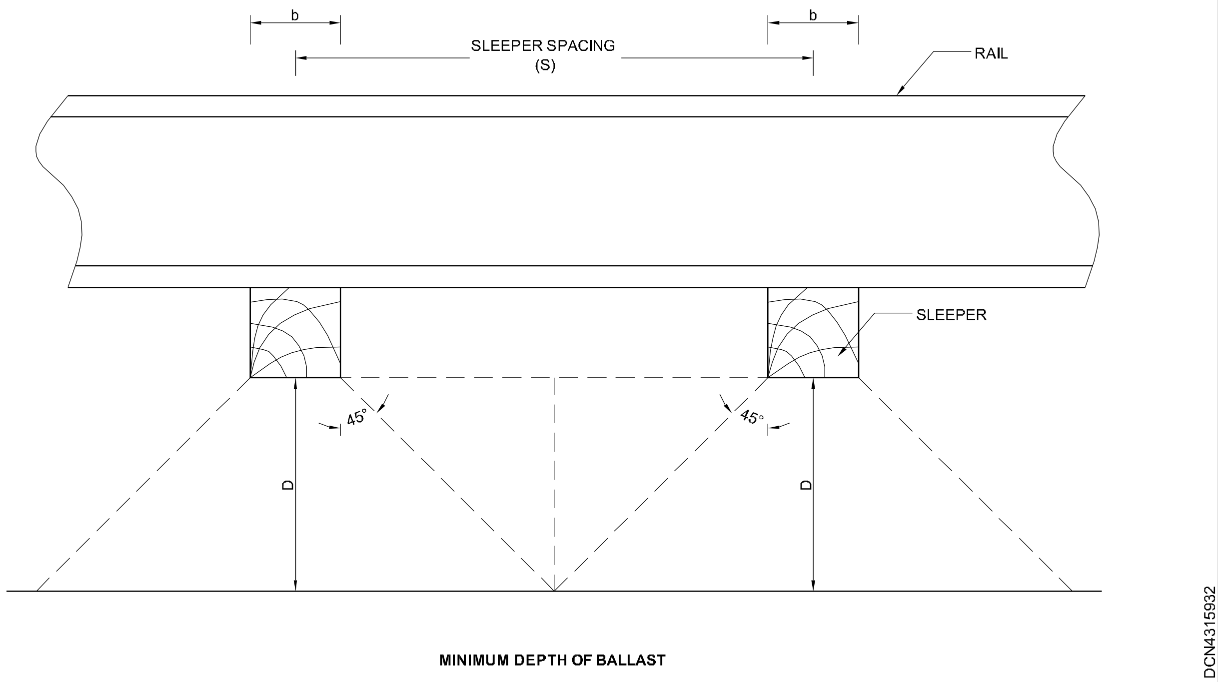
Where D = Depth of ballast

s = sleeper spacing

b = width of sleeper

$$\text{Depth of ballast} = \frac{\text{Spacing of sleeper} - \text{width of sleeper}}{2}$$

Fig 2



MINIMUM DEPTH OF BALLAST

Example

Let the track is laid on wooden sleepers of 25cm width and sleeper spacing 65cm

Solution

Depth of sleeper

$$D = \frac{s-b}{2}$$

$$= \frac{65-25}{2}$$

$$= \frac{40}{2}$$

$$= 20\text{cm}$$

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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 (Fig 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 rial. For joining the rial, 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.

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

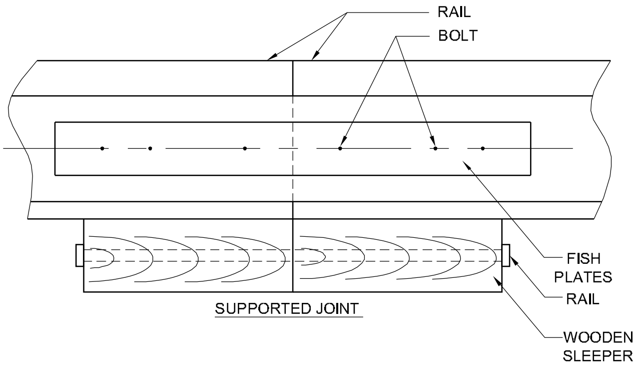
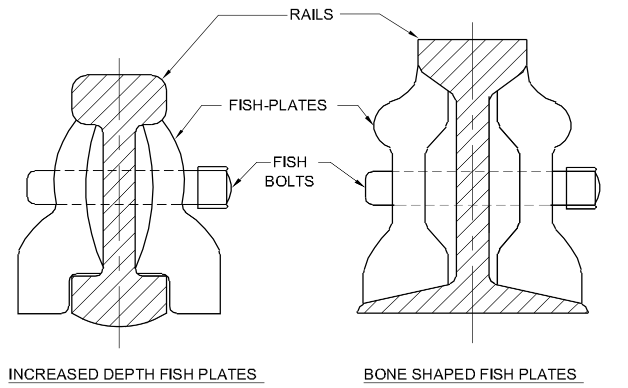


Fig 2



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FISH - PLATES

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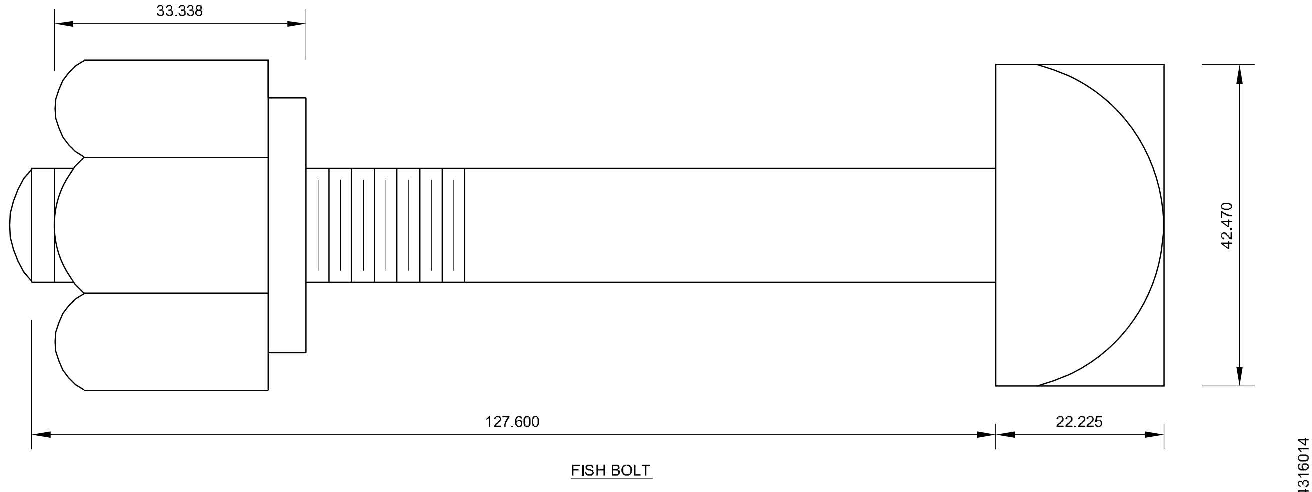
Fig 4



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 id driven.

Fig 5

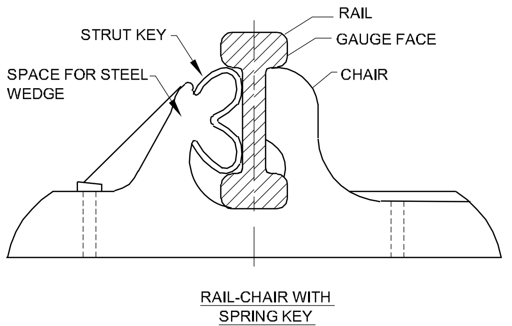
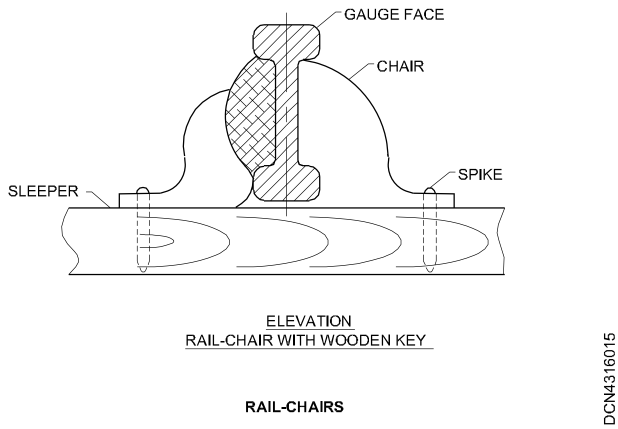


Fig 6



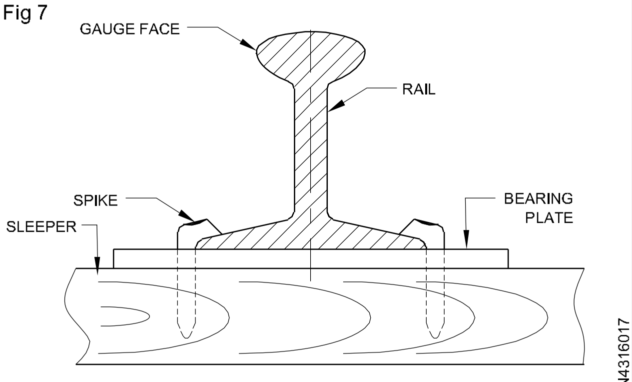
RAIL-CHAIRS

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 sosft 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.

They distribute the pressure over a wider area and prevent the crushing of sleepers by preventing the rubbing aciton on th rails.

Fig 7



BEARING PLATES

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)

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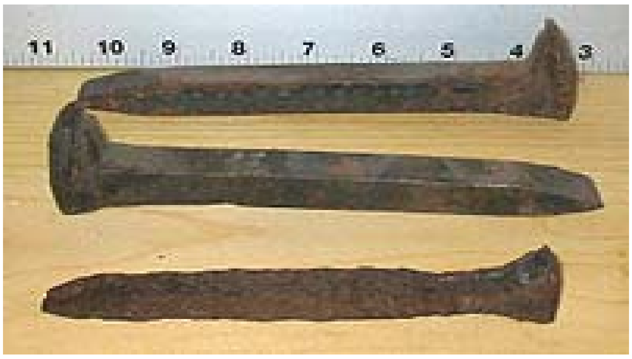
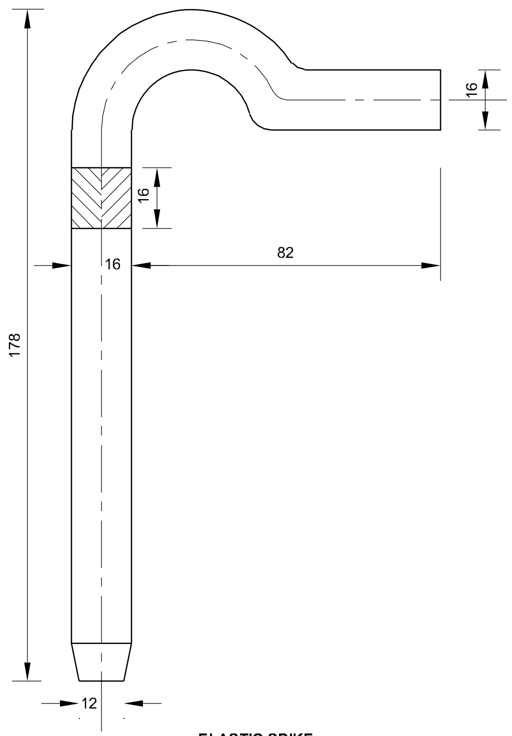


Elastic spike: These are the special types of fastenings used for holding rails to the sleepers firmly at a constant pressure without affecting the track structure for sufficient time. These are suitable for high speed track. These spikes are not used in Indian railways (Fig 9).

Fig 9



ELASTIC SPIKE

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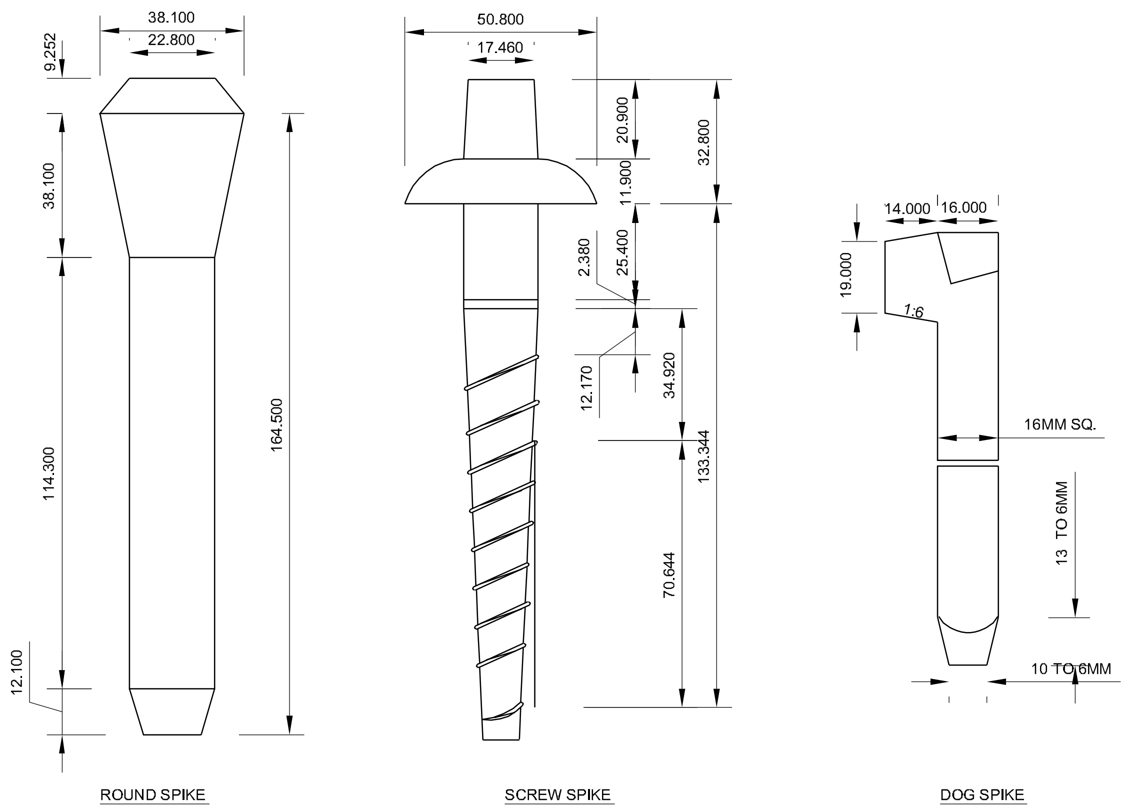
Fig 8



COMMON RAIL SPIKES

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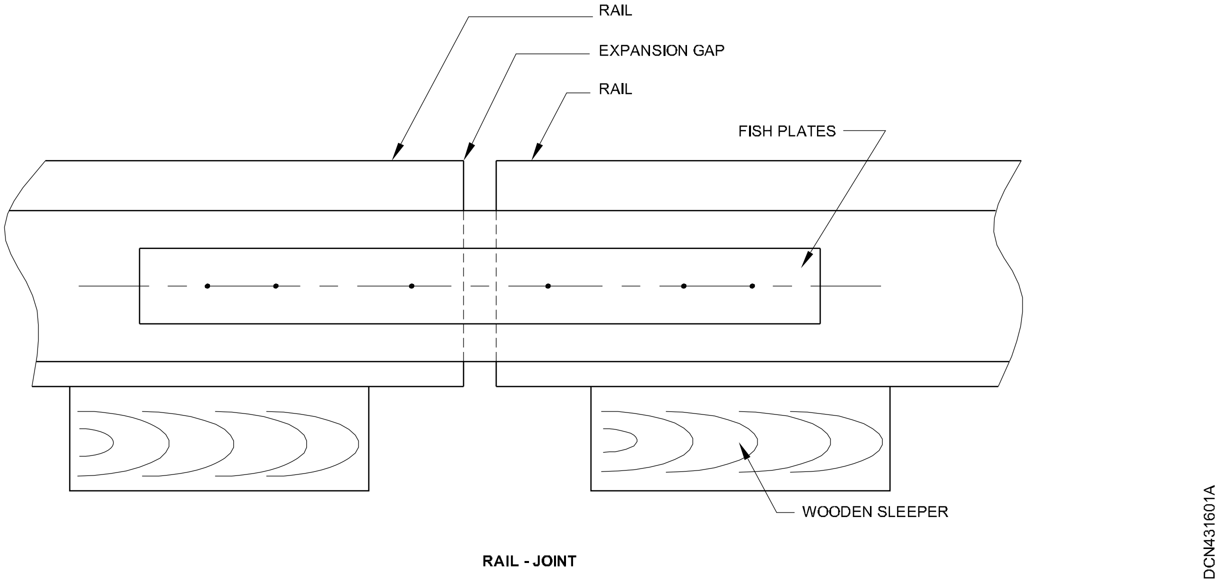
Rail joint: It is impossible to construct track without rail joint. Rails are manufactured in suitable length and are jointed together after laying. The rails can be jointed together with the help of fish plate and bolts or welding. Between two rails 1.5 to 3mm gap is provided. generally for giving more strength, sleepers near rail joint are placed closer together (Fig 10).

Fig 10

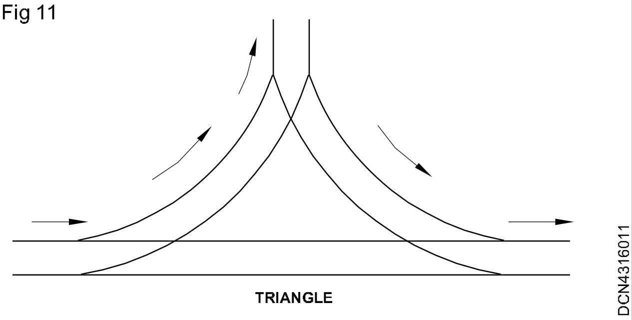


RAIL - JOINT

Trun 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 automoatically changes.

Fig 11



TRIANGLE

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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

Thecauses of rail creep can be broadly classified into two categories

1 Major Causes of Creep

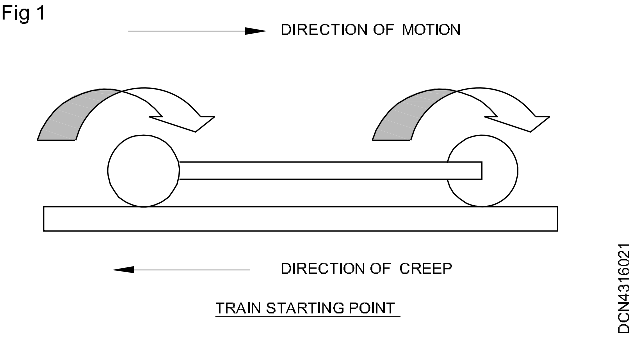
2 Minor Causes of Creep

Major Causes of Creep

Major causes of creep also known as principal causes of creep. Follows are the major causes of creep in rail

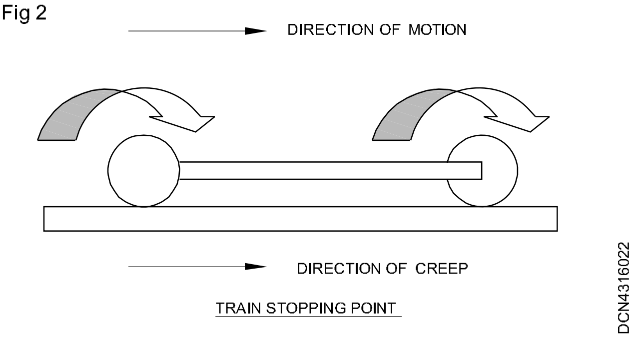
1 Creep may be developed due to forces that come into operation when the train is starting or stopping by application of brakes. Increase so starting the wheels pushes the rail backward and hence the direction of creep is in backward direction.

Fig 1



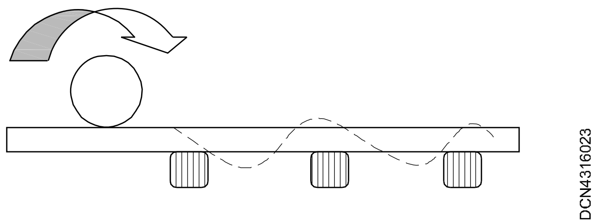
When brakes are applied then the wheels of the vehicles push the rails in forward direction and hence the creep is in forward direction.

Fig 2



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.

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. **Read More**

Results and Cnsequence 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. **Read More**

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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 **Read More**

Tags rails way engineerings

Fig 24

Railway Sleepers Density

Fig 25

Railway Sleepers - Types of Sleepers

Fig 26

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 vaious sections. The ancors when driven in rail feet, grip the rail firmly and when set aganist sleepers resists longitudinal movement of Rails Caused by passing trains.

Railway Sleepers Definition, Characteristcs, Treatment

Fig 27

Screw Spike/Coach Screw

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

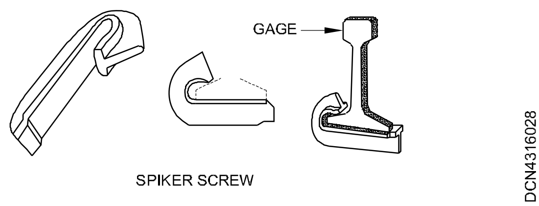
Washers

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.

Fuctions

- 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.

Fig 8



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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 tensity of irrigation**
- **difine 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 tothe 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 tosome 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, reducced 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 lilke 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 scarctiy of water for the crops. Thus, famine and scarcity donditions are created. In his bid tocontrol 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 gennerally, termed, as irrigation. Irrigation may, therefore, be difined 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 diversiy 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 bectares 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 facillities 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.

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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 togeher of two or more crops in the same field. If the weather canditions 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 facililties are lacking, and especially during Crash programmes in under-developed countties. But if the irrigation is assured, mixed cropping can be eliminated or ruduced.

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 mxied 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 eaach other, reducing the purity of each other. But, when regaular and permanent water suply 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 desinged for irrigation alone. Canal falls can be used for ever generation. Ganga and Sarda canals, consturced 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 diffuculty. It also provides water for swimming, bathing, cattle drinking, etc.

7 **Facilities of communications:** Irrigation channels are generally provided with embankents 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 soild as fertilizer. Sometimes, upto 50% of the nitretes 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 cary the polluted water out into the ocean, is still a amtter 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.

Functions of irrigation water

The functions of soil moisture in plant growth are very important. Water and nuterients are the two most important requirements of the crop. Following are the main functions of irrigation water.

i It acts as a solvent for the nutrients. Water forms the solution of the nutrients, and this solution is absorbed by the roots. Thus, water acts as the nutrient carrier.

ii The irrigation water supplies moisture which is essential for the life of bacteria, which is required for the plant growth.

iii Irrigation water supplies moisture which is essential for the chemical action within the plant leading to its growth.

iv Some salts present in solid react to produce nourishing food products only in the presence of water.

v Water cools the soil and the atmosphere, and thus makes more favourable environment for healthy plant growth.

vi Irrigation water, with controlled supplies, washes out or dilutes salts in the soil.

vii It reduces the hazard of soil piping.

viii It softens the tillage pans.

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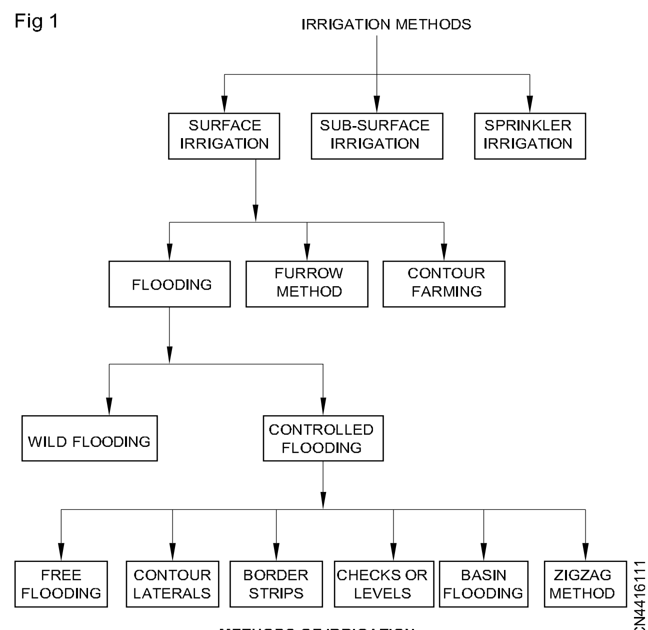
Method of irrigation

Classification of irrigation: Irrigation may broadly be classified into



METHODS OF IRRIGATION

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 druing 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 practised in India.

ii **Flood irrigation:** This kind of irrigation, is sometimes called a unundation irrigation. In this method or irrigation, soil is kept submerged and through saturation of the land. The moisture soaked by the soil, when occasionlly suuplented 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 suface. The underground water nourishes the plant roots by capilarity. It may be divided intothe 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 throught the sub-soil, it may irrigate crops, sown on lower lands, by capilarity. 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 effrot, 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 artficial 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 favourable 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

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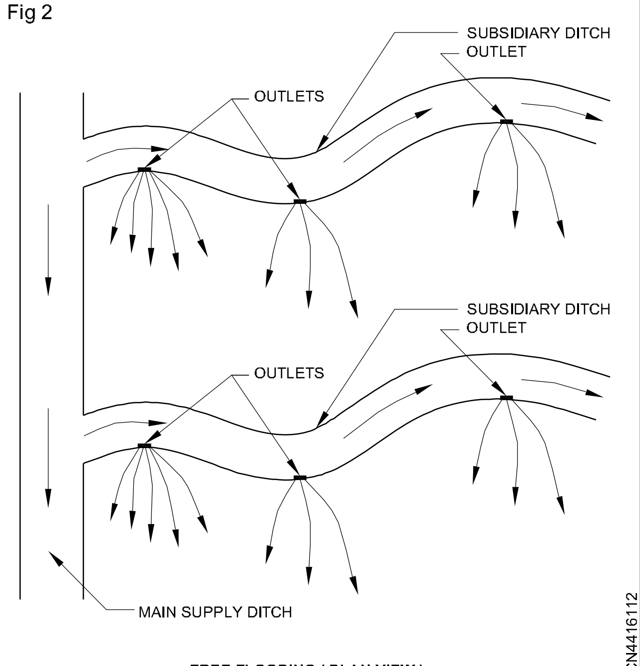
Fig 2



FREE FLOODING (PLAN VIEW)

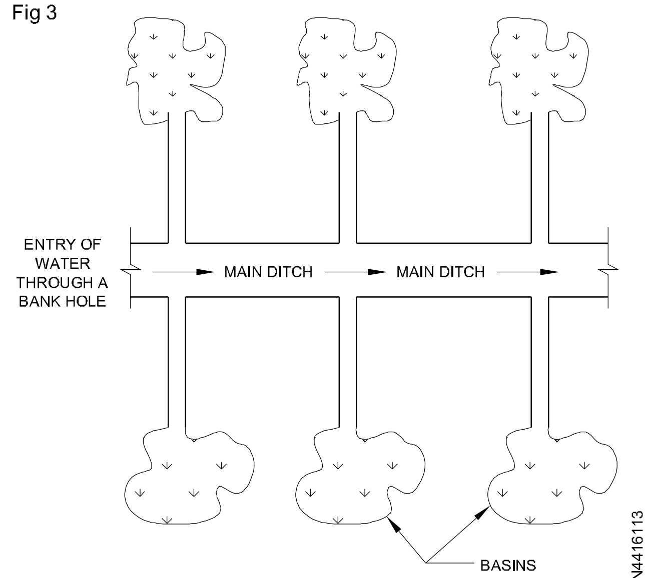
These methods are briefly discussed below:

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 subsidianary.

ii Border flooding/Border strip method: In the broder stripo 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.

Fig 3



BASIN FLOODING

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 oof check flooding adpated to rochads. 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 inplace or ditches.

v Furrow irrigation: Furrows are narrow field ditches, excavated between rows of plants and carry irrigation water through them. Hence only on-fifth to one half of theland surfaces is wetter 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 spary 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, becasue it ful fils 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.

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Advantages of drip irrigation system

i **Less requirement of irrigation water:** The evaporation and percolation losses, commonly associated with surface irrigation method are reduced.

ii **Water supply at optimum level:** An optimum water level, equal to the field capacity can always be maintained, by the water flow controls available in this method. Soil is maintained in most congenial form.

iii **Water logging avoided:** Because of check over deep percolation losses, the changes of water logging are all together removed.

iv **High yield:** Because of proper contorl over the factors governing soil-water-crop relationships, higher yield is obtained.

v **Cultivation of cash crops:** The method is specially suited to cash crops such as vegetables, cotton, tobacco and orchard products.

vi **No over-irrigation:** In surface methods of water application, over-irrigation is sometimes done to provide sufficient moisture at deficient area. This is avoided in this method since water is supplied to the root zone directly for each crop.

vii **Variation in application rate:** It is possible vary the application rate, throughtout the crop period. When the crop is infant, application rates can be easily increased.

viii **Weed contorl:** The nuisance of weeds commonly associated with surface application methods, is avoided. This will, in turn, result in increase in crop prouduction, and saving in farm application.

ix **Increase in net irrigation area:** In surface application, a lot of area is wasted in the construction of field channels etc. As water is carried through small diamter pipes, there is considerable saving land.

x **Nutrients preservation:** Soil nutriends are preserved becasue of reduction in deep percolation losses. Moreover, feeding of water enriched with fertilizers results inproper maintenance and preservation of nutrients of optimum level.

xi **Effective pest control:** Insect and pest combating chemical can be directly conducted into the root zone.

xii **Reduced labour cost:** The labour cost, otherwise associated with the maintenance of field channels, furrows etc. is reduced.

xiii **No soil erosion:** The problems of surface soil erosion, associated with surface application methods, are practically absent in this method.

xiv **Suitability of saline soils:** The saline, alkaline or brakish soils otherwise unsuitable, can be utilized by cultivation by the drip irrigation method.

xv **Maintenance of high surface temperature:** In surface application method, soil temperature is lowered because of water spread over the entire area. However, in this method, entire soil surface is not wetted. Hence high soil temperature is maintained which will be useful in hastening the ripening or maturity of the crop.

xvi **Suitable for any topography:** No land levelling is required, and is suitable even for sloping and undulating terrain.

Disadvantages of drip Irrigation System

i **High initial cost:** The initial cost of various components such as pumping unit, filter units, pipelines, nozzles etc. is very high.

ii **Danger of blockade of nozzles:** The nozzle holes are very small in size (0.5 to 1 mm dia). Hence they are very frequently clooged, if the water has high degree of total dissolved salts which cannot be removed by filtration.

iii **Change in spacing of nozzles:** This is due to the change in the crops may result in frequent replacement of the trickle lines.

iv **Shallow root depth of the crops:** This is especially for fruit trees etc. may result in instability of the crop or tree which may topple during high winds.

9 Technical terms in irrigation

i **Hygroscopic water:** When an oven-dried sample is kept open in the atmosphere, it absorbs some emount 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 1 st 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 ration.

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

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between the area of crop irrigated and the quantity of irrigation water required during th entire period of the growth of the crop.

Delta: It is the total depth of water in centimetere required by a crop during the entire 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 hectres/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 consideered 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 ares is thus the total area lying between drainage boundaries which can be commanded or irrgated by a canal system".

b Culturable Commanded Area (C.C.A): The gross commanded area also contains unfertile barren lan, 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 Incutivated 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 dangeer of water logging.

e intensity or irrigation: The entire culturable commanded area, is not proposed to be irrigated at one time me reason 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, wich 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 seasonlly 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.

f Time factor: It is the ratio of the number of the days the canal has actually to run, to the base period in days. Water requirement of the channel (i.e. its capacity) should be divided by the time factor, so as to obtain the design capacity, since this factor is less than 1.

g Capacity factor: It is the ratio of the mean supply discharge to the full capacity discharge.

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 sceince 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.

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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 isohyetals 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.

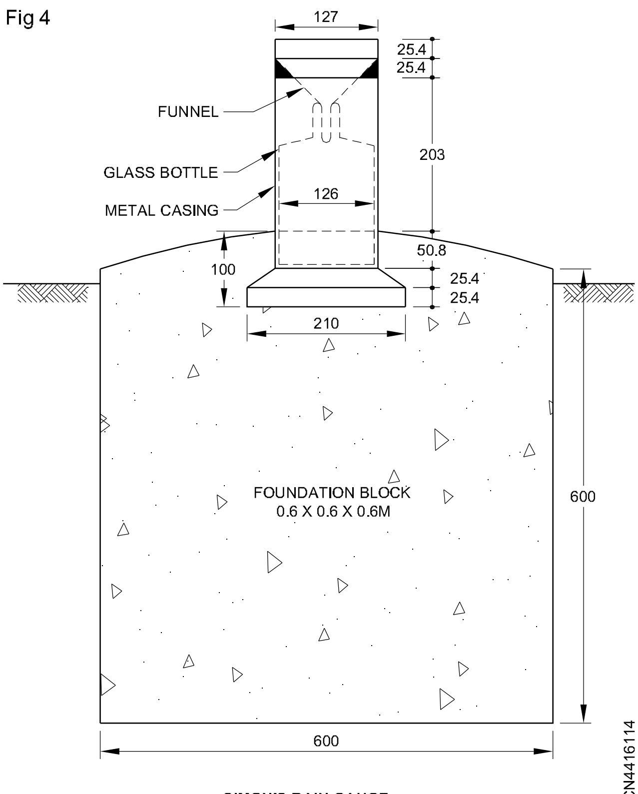
There are two types of rain gauges.

a Non-recording or non-automatic rain gauge

b Recordi g 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).

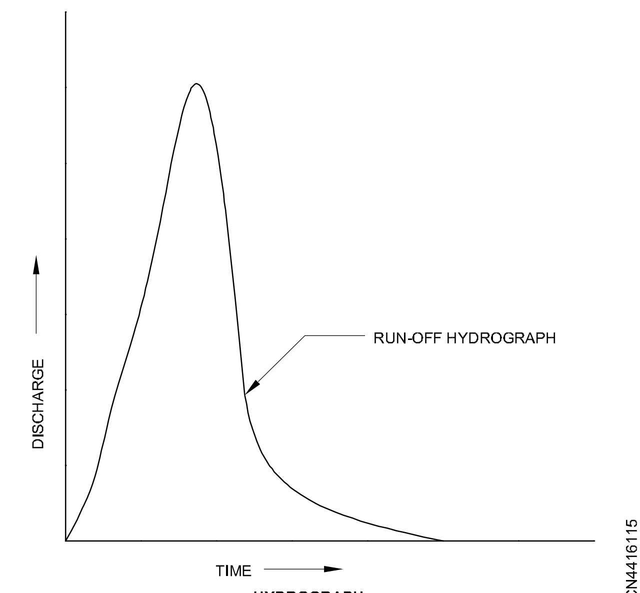
Fig 4



SIMON'S RAIN GAUGE

xvi Hydrograph: Hydrograph is defined as a graph showing discharge, velocity or other feature of flowing water with respect to time. Discharge or velocity etc. is plotted as ordinate and time is plotted as abscissa. Thus a discharge hydrograph shows the discharge of a river (at a particular site) as ordinate against the duration of this discharge as abscissa. The time period for discharge hydrograph may be hour, day, week, month, etc. Discharge hydrogrph is commonly known as flood hydrograph or runoff hydrograph (Fig 5) for a particular storm falling on the catchment area which lies on the stream side of the river-site under consideration. Such a stream on the catchment causes the above said discharge (or flood flow) at this site of the river. Thus, the flood hydrograph has reference to a particular river-site.

Fig 5



HYDROGRAPH

xviii 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.

xix 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 lwoer 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.

There are two types of catchments in general i.e. (i) pan shaped catchment (ii) fern leaf catchments, (Fig 6) pan shaped catchments give greater runoff because tributaries are nearly the same size, and therefore time of flow is nearly the same and is smaller, whereas in fern leaf catchments, the time of concentration is more since the discharge is distributed over a long period, as is evident from the figures.

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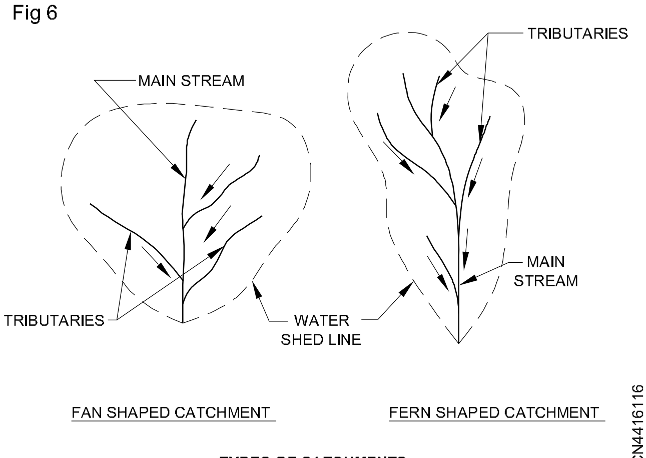
Fig 6



TYPES OF CATCHMENTS

xx 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.

Maximum rate of runoff: The intensity of rainfall on catchment varies from time to time and hence, the rate at which the water begins to flow down from catchment also varies from time to time. The maximum rate at which the water comes down from a catchment is called its maximum rate of runoff. This occurs when all the factors producing it are simultaneously at their maximum effect.

The rain may fall either on the whole basin or on small part of it. For small drainage basins, the peak flows are generally the result of intense rains falling over small areas. On the other hand for large drainage basins, the peak flows are the result of storms of lesser intensity but covering large areas.

The runoff from basin is thus very much dependent upon the rainfall distribution. The rainfall distribution is generally expressed by the distribution coefficient. The distribution coefficient for a given storm can be obtained by dividing the maximum rainfall at any point in the ebasin by the mean rainfall on the basin. Thus, if the distribution coefficient is more, it means that, rain is less uniformly distributed; and hence for a given total rainfall and for other conditions remaining the same, the greater the distribution coefficient,the greater will be the peak runoff. Moreover, even for the same distribution coefficient the runoff may be more for the storm falling on the lower parts of the basin (near the outlet) and will be less for the storms falling on the upper parts of the basin (near the head waters).

In the design of hydraulic structures, sometimes the total volume rate, the resultant runoff from the surface would finally reach a rate equal to the rate of rainfall. In the beginning, start reaching the outlet from the entire area, and in that case, the runoff would become equal to the rainfall rate. The time required to reach this equalibrium condition is knwon as the time of concentration (Tc). For small impervious areas, we may assume that it a rain persists at a uniform rate for a period at least as long as Tc, the peak rate of runoff will be equal to the rate of rainfall.

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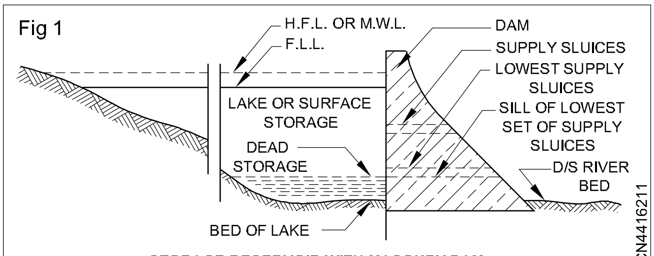
Reservior and Types of Reservior and Dams

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 typesm of dam**
- **define spillway.**

Definition: Dam is a fairly inpervious 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 lesses 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 bease, 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 raod, 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 thsoe 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 o 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 sesason) 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.

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Fig 2

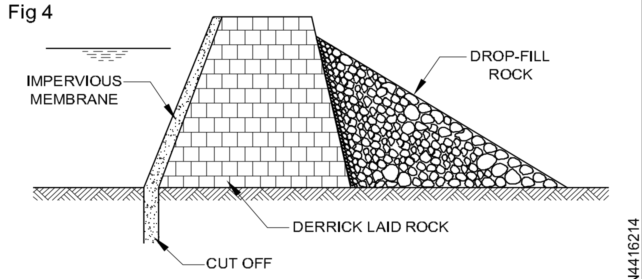
ii Diversion dam Fig 3: The purpose of a diversion dam is essentially different. While a storage dam stores water as its upstream for future use, a diversion dam simply rasies water level slightly in the river and thus provides head for carrying or derting water into ditches, canals, or other conveyance 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 wers 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 3

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.**

Soemtimes, detention dams are constructed across tributaries carrying large silt and sedimet. In such case it is known as **debris dam.**

Fig 4



ROCKFILL DAM

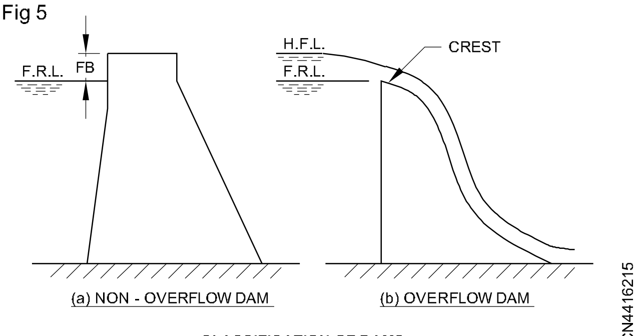
2 Classification according to hydraulic design

According to hydraulic design dams may be classified as follow:

i Non-overflow dam

ii Over flow dam

Fig 5



CLASSIFICATION OF DAMS

i Non-overflow dam: A non-overflow dam is the one in 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, rockfillm 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 rthe 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 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 (spilway) 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 cconcrete dam

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c Concrete buttress dam

d Steel dam

e Timber dam

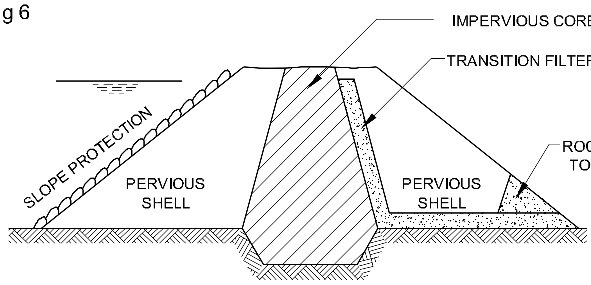
ii **Non-rigid dams:** Non-rigid dams are those which are constructed of non-rigid materials such as earth and/ or rockfill. The common types of non-rigid daks are:

a Earth dams

b Rockfill dams

c Combined earth and rockfill dams

Fig 6



EARTH DAM

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.

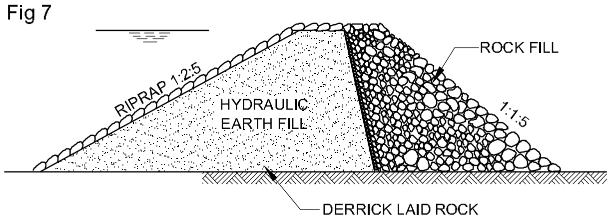
Arch dams: An arch damis a dam curved in plan and carries manor parts of its water load horizontally to the abutment by arch acton.

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.

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.

Fig 7



COMBINED EARTH AND ROCKFILL DAM

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.

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.

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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 surveyingat 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.

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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 match-difference between notches an weirs flow**
- **difference between OR IFICE and mouth PIECE flow.**

- What is a Barrage:

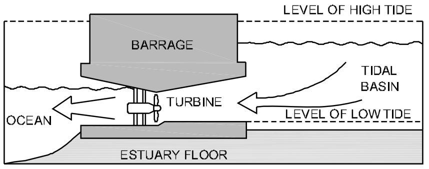
A Barrage is a barrier with low crest provided with series of Gates across the river to regular water surface level and pattern of flow upstream and other purpose distinguished from a weir in that it is gated over its entire lingth and way or may not have a raised sill.

- An artificial Structure F 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 bareage 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.

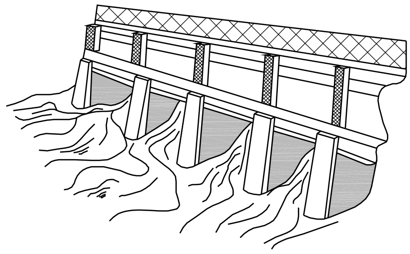
Fig 1



Fuction of a Barrage

- Function of a Barrage is similar to a weir.
- There is no solid obstruction across river (darrs and weirs have a solid obstruction across the river).
- 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

Fig 2

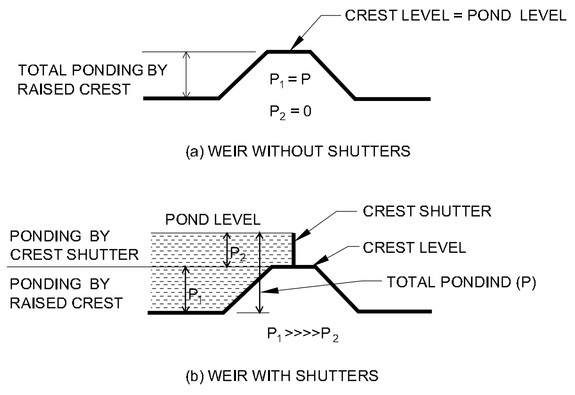


Qadirabad-Balloki Link is an extension of Rasul-Qadirabad Link by which the water is transferred to the Ravi river.

Weir:

If major part or the entire ponding of water is achieved by a raised crest and a smaller part or nikk part of it is ahcieved by the shutters, then this barrier is known as weir.

Fig 3



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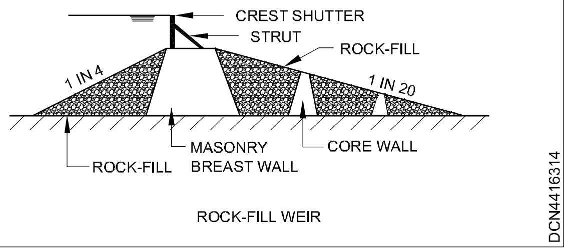
Dry store stopping weir

Fig 4



ROCK-FILL WEIR

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.

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 is more	Silting may be controlled by judicial operation of gates
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.

NOTCH:

- A notch may be defined as an opening provided in oneside of a tank or a reservoir, with upstream liquid levle below the top edge of the opening.
- A notch may have only the bottom edge and sides.
- The bottom edge of north over which the liquid is flow known as

Sill or crest.

- The sheet of liquid flowing over a notch is known as **nappe** or **vein.**
- A notch is usually made of a metallic plate.
- A notch is used to measure discharge of a small stream or canal.

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Difference between NOTCHES ans weirs flow

NOTCHES FLOW	WEIRS FLOW
A notch may be defined as an opening in one side of a tank or a reservoir, like a large orifice, with the upstream liquid level below the flowing of the fluid is called notches flow.	A structure, used to dam up a stream or river, over which the water flows, is called a weir and the flow is called weirs flow.
can be found in narrow sections of rivers or in the lower ranges of the dams	In areas near dams one can see the use of V-shaped, rectangular notches
the notch of a small size	the weir is of a bigger one.
a notch is usually made in a plate	a weirs is made of masonry or concrerte.

DIFFERENCE BETWEEN ORIFICE AND MOTHPIECE FLOW

ORIFICE FLOW	MOUTHPIECE FLOW
Fluid is flowing through the samll opening of any cross section on the side or at the bottom of the tank.	Fluid is flowing through a short length of a pipe which is two or three times its diameter in length, fitted in a tank containing the fluid which is called mouthpiece.
An orifice is a small aperture through which the fluid passes. The liquid from a tank is usually discharged through a small orifice at its side.	Thsi discharge through an orifice is increased by fitting a short length of pipe to the outside known as mouthpiece.
Since the dimension of the orifice is to small so, flow through orifice is very small.	Dimension of mouthpiece is comparatively bigger than orifice. so, flow through mouthpiece is quiet large

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Storage and diversion head mark 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 contivated land for this, sufficient quantity of water way 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 imprevious 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

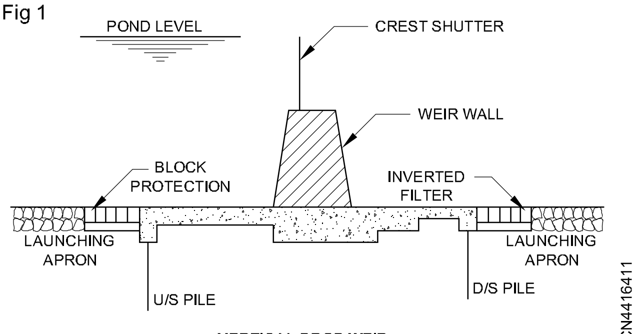
Storage works are constructed to server many purposes, which include.

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.

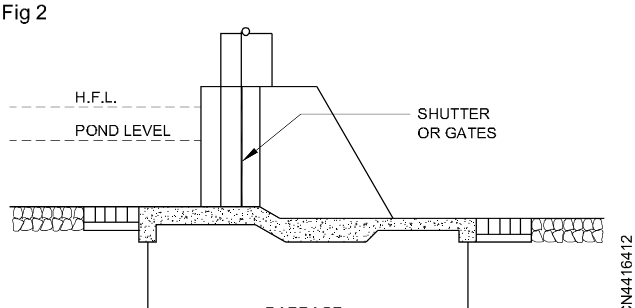
Barrage: The function of a barrage is similar to that of weir, but the heading up of water is effected by the gates alone (Fig 2). No solid obstruction is put across the river. The crest level in the barrage is kept at a low levert. During the floods, the gates are raised to clear off the high flood 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



VERTICAL DROP WEIR

Fig 2



BARRAGE

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 ka 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

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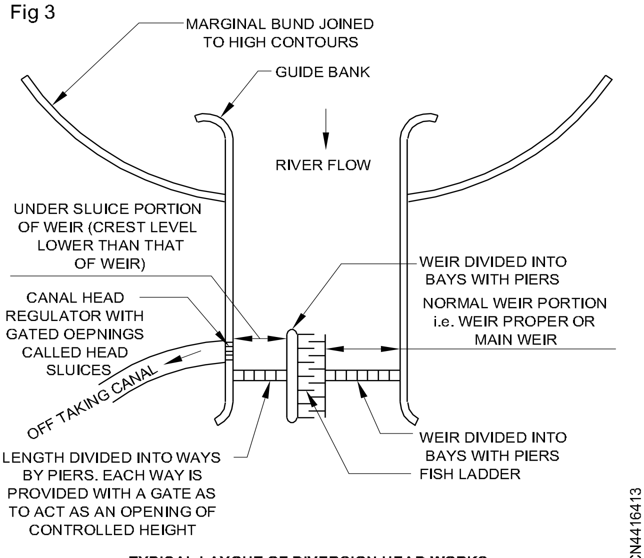
6 Canal Head Regulator

7 Weir's ancillary works, such as shutters, gates etc.

8 Silt Regulation Works.

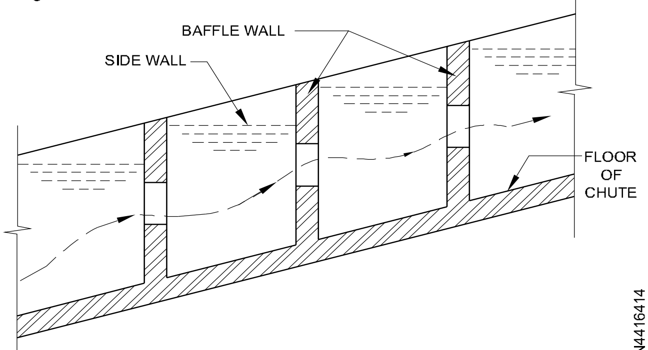
Fig 3



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 secotion 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 cutlets 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.

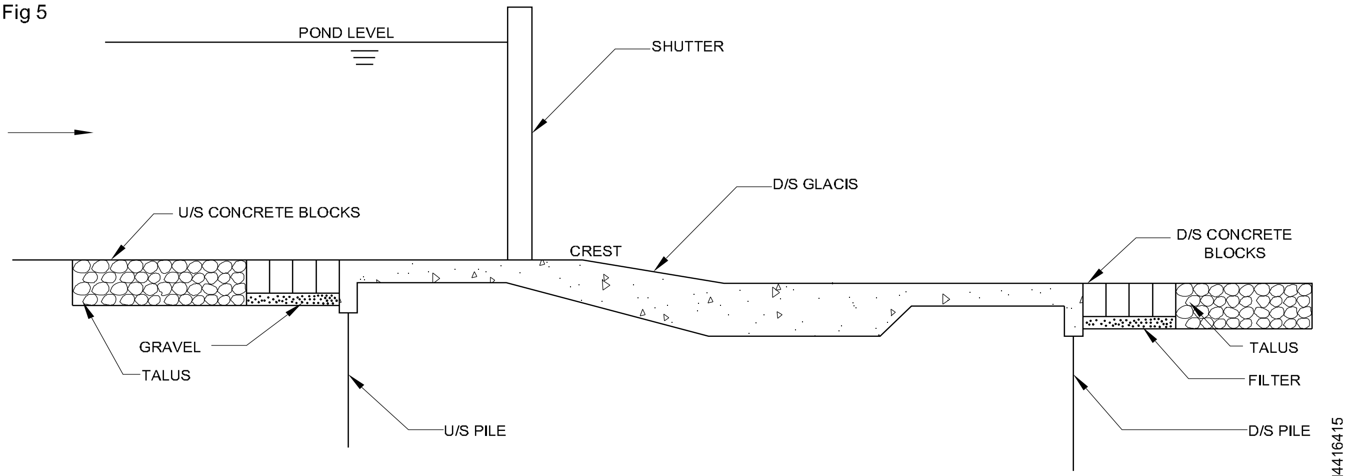
3 They can be used to pass small floods to the downstram, without dropping the shutters of the main weri.

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 lwering the upstream high flood level because the discharge intensity over the sluice portion is greater than that in the weri portion.

6 The creat 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

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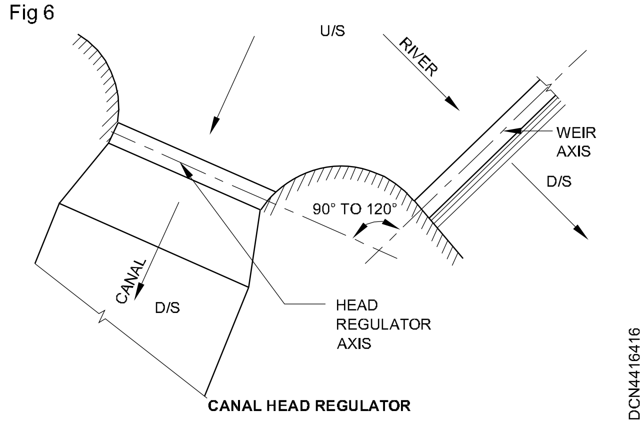
Canal head regulator Fig 6

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 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).

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 (or rip rap). 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 suchthat 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.

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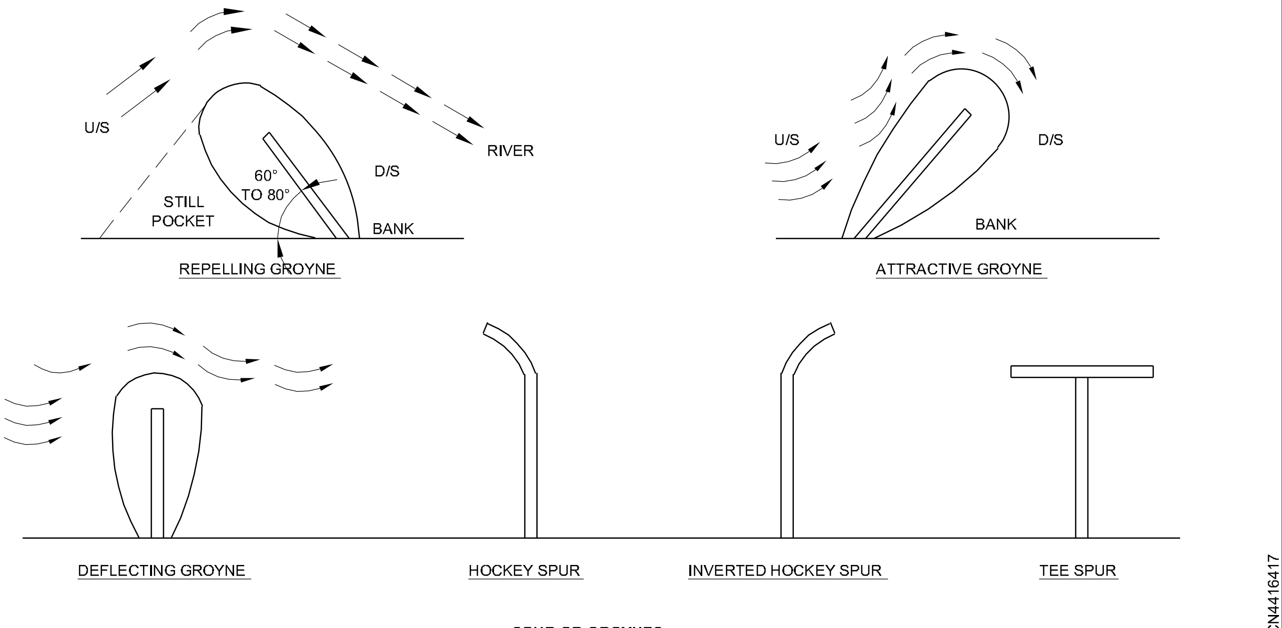
Fig 7



SPUR OR GROYNES

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

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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 corsses 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 drinage 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 shifting the alignment. However, the suitablty of the site for the consturction of the strutue 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.

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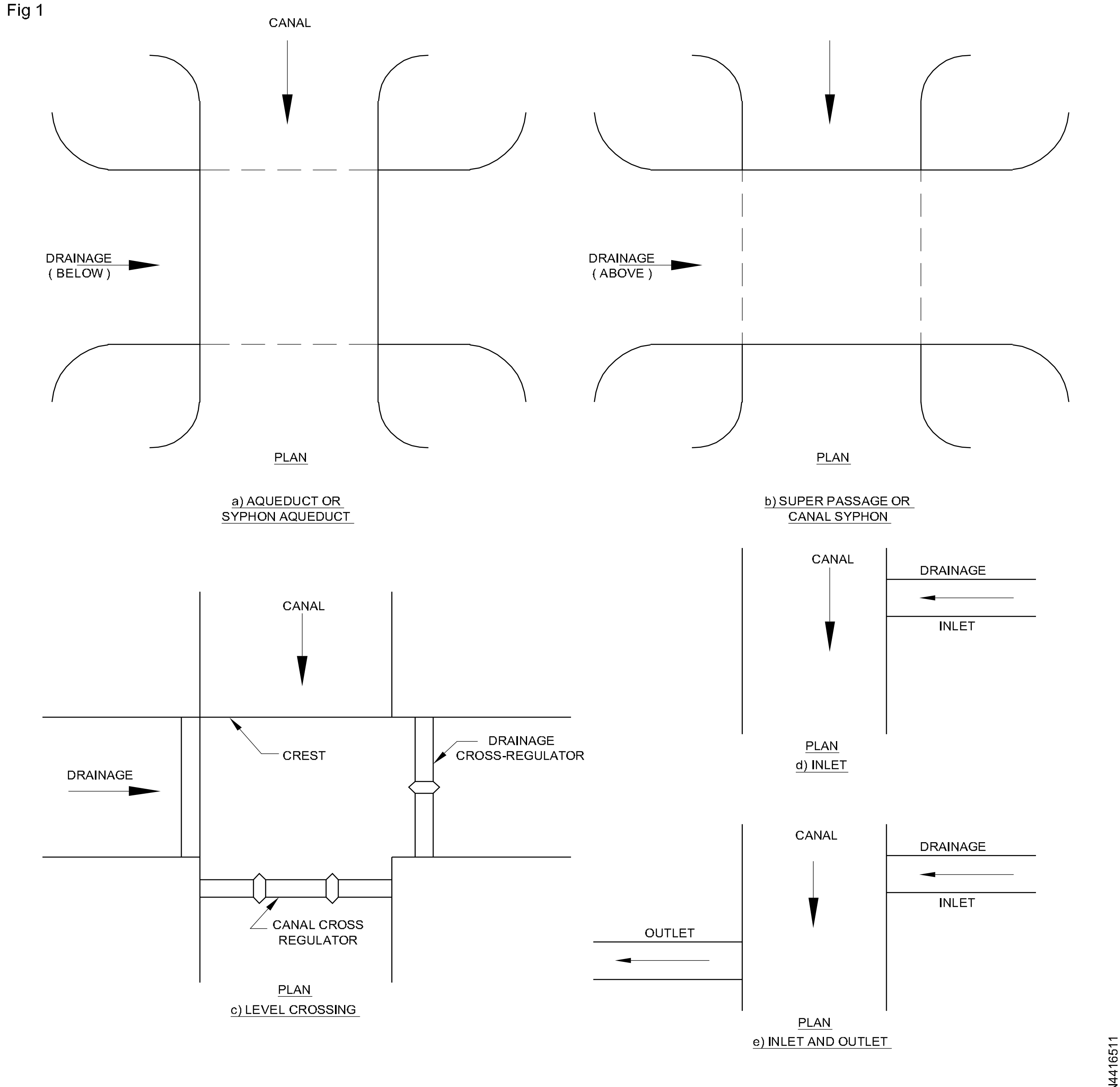
Fig 1



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 etween the piper 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 lia: 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 whent he 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.

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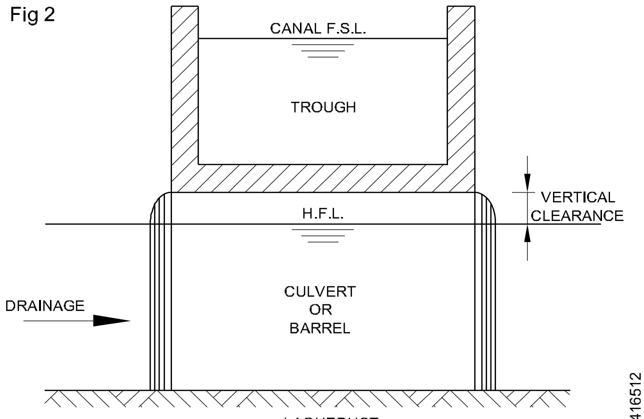
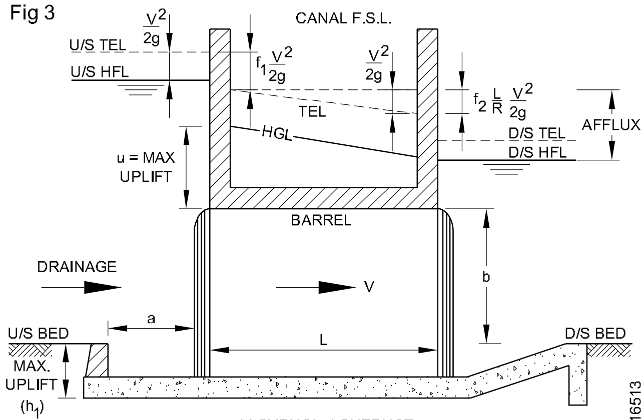
Fig 2



a) AQUEDUCT

CANAL OVER THE DRAINAGE

Fig 3



b) SYPHON AQUEDUCT

CANAL OVER THE DRAINAGE

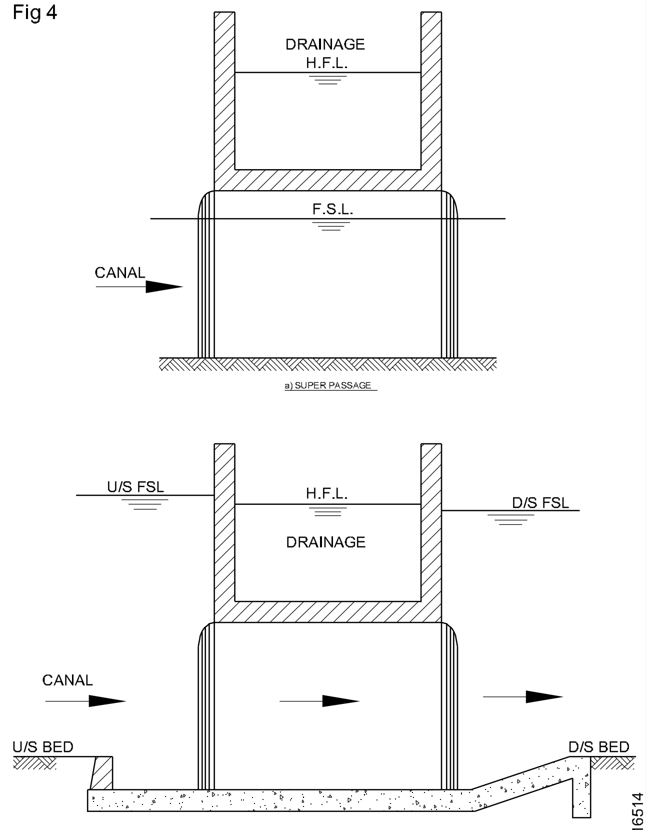
3 Canal at the same level as the drainage

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 tha 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.

Fig 4



b) CANAL SYPHON

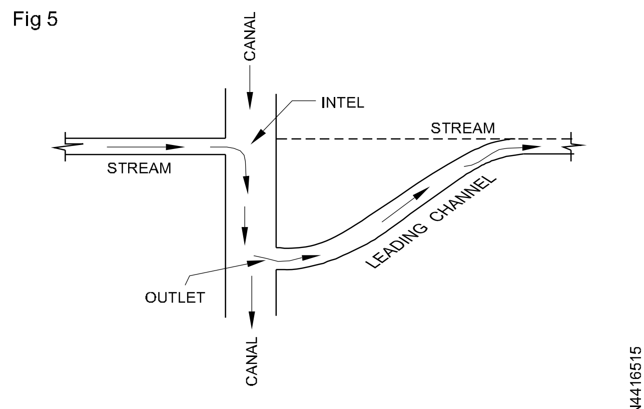
CANAL BELOW THE DRAINAGE

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 distabce 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.

Fig 5



INTEL AND OUTLET

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3 Selection of suitable type of cross-drinage work

The following factors should be considered while selecting the most suitable type the cross-drainage work.

1 **Relative levels and discharge**s: The relative levels and dishcarges of the canal and of the drainage mainly affect type of cross-drainage work required. The following are the broad outlines.

i If the canal bed level is sufficiently above the H.F.L. of the drainage, an aqueduct is selected.

ii If the F.S.L. of the canal is sufficiently below the bed level of the drainage, a super passage is provided.

iii If the canal bed level is only slightly below the H.F.L. of the drainage, and the drainage is small, a siphon aqueduct is provided. If necessary, the drainage bed is depressed below the canal.

iv If the F.S.L. of the canal is slightly above the bed level of the drainage and the canal is of small size, a canal siphon is provided.

v If the canal bed and the drainage bed are almost at the same level, a level crossing is provided when the discharge in the drainage is large, and an inlet-outlet structure is provided when the duscharge in the drainages

However, as explained later, the relative levels of the canal and the drinage can be altered to some extent by changing the canal alignment to have another crossing. In that case, the most suitable type of the cross-drainage work will be selected depending upon the levels at the changed crossing.

2 **Performance:** As far as possible, the structure having an open channel flow should be preferred to the structure having a pipe flow. Therefore an aqueduct should be preferred to a siphon aqueduct. Likewise, a super passage should be preferred to a canal siphon.

In the case of a siphon aqueduct and a canal diphon, silting problems usually occur at the crossing. Moreover, in the case of a canal siphon, there is considerable loss of command due to loss of head in the canal.

3 **Provision of road:** a aqueduct is better than a super passage because in the former, a road bridge can easily be provided along with the canal trogh at a small extra cost, whereas in the letter, a separate road bridge is required.

4 **Size of drainage:** When the drainage is of small size, a siphon aqueduct will be preferred to an aqueduct as the latter involves high banks and long approaches. However , if the large size, an aquaduct is preferred.

5 **Cost of earthwork:** The type of cross-drainage work which does not involve a large quantity of earthwork of the canal should be preferred.

6 **Foundation:** The type of cross-drainage work should be selected depending upon the foundation available at the site of work.

7 **Material of construction:** Suitable types of material of consturction in sufficient quantity should be availabe near the site for the type of cross-drainage work selected. Moreover, the soil in sufficient quantity should be available for constructing the canal banks if the structure requires long and high equal.

8 **Cost of construction:** The cost of construction of cross-drainage work should not be excessive.

9 **Permissible loss of head:** Sometimes, the type of cross-drainage in selected considering permissible loss of head. For e.g. if the head loss cannot be permitted in a canal at the site of cross-drainage a canal siphon is ruled out.

10 **Sub-soil water table:** If the soil water table is high the type of cross-drainage which requires excessive excavation should be avoided, as it would involve dewatering problems.

Types of Cross Drainage Works

- **Type I (Irrigation canal passes over the drainage)**
- (a) Aqueduct
- (b) Siphon Aqueduct
- **Type II (Drainage passes over the irrigation canal)**
- (a) Super passage
- (b) Siphon super passage
- **Type III (Drainage and canal intersection each other of the same level)**
- (a) Level crossing
- (b) Inlet and outlet

Types of Cross Drainage Works

- **Type-II Drainage Passes Over the irrigation Canal.**
- **Super Passage Fig 6**
- The hydraulic structure in which the drainage is taken over the irrigation canal is known as super passage. The structure is suitable when the bed level of drainage is above the fullsupply level of the canal. The water of the canal passes clearly below the drainage.

Siphon Super Passage

- The hydraulic structure in which the drainage is taken over the irrigation canal, but the canalwater passes belowthe drainage undersiphonic action is known as siphon superpassage. This structure is suitable when the bed level of drainage is below the full supply level of the canal.

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Fig 6

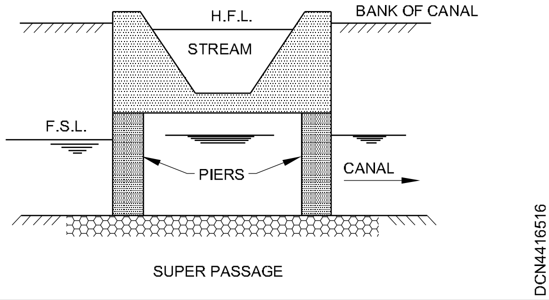
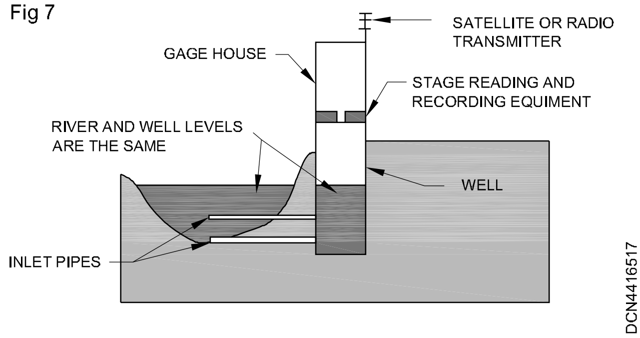


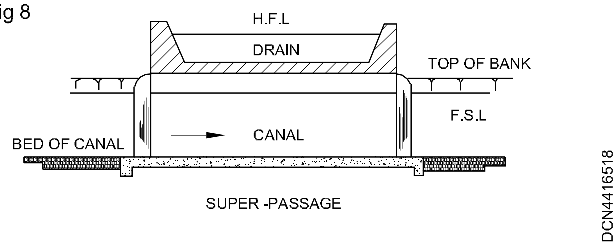
Fig 7



Inlet and out let

- Inlet is provided in the canal to admit drain water into it.
- It is provided in following situations
- Drain water is less in magnitude
- Drain water is free from heavy silt
- The drainage bed level is lower than F.S.I

Fig 8



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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 precribed 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

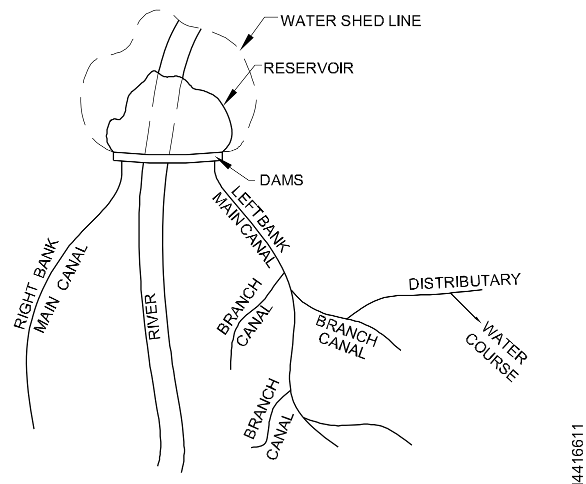
2 Branch canal

3 Major distributary

4 Minor distributary

5 Water course

Fig 1



CANALS

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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, thecanal 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

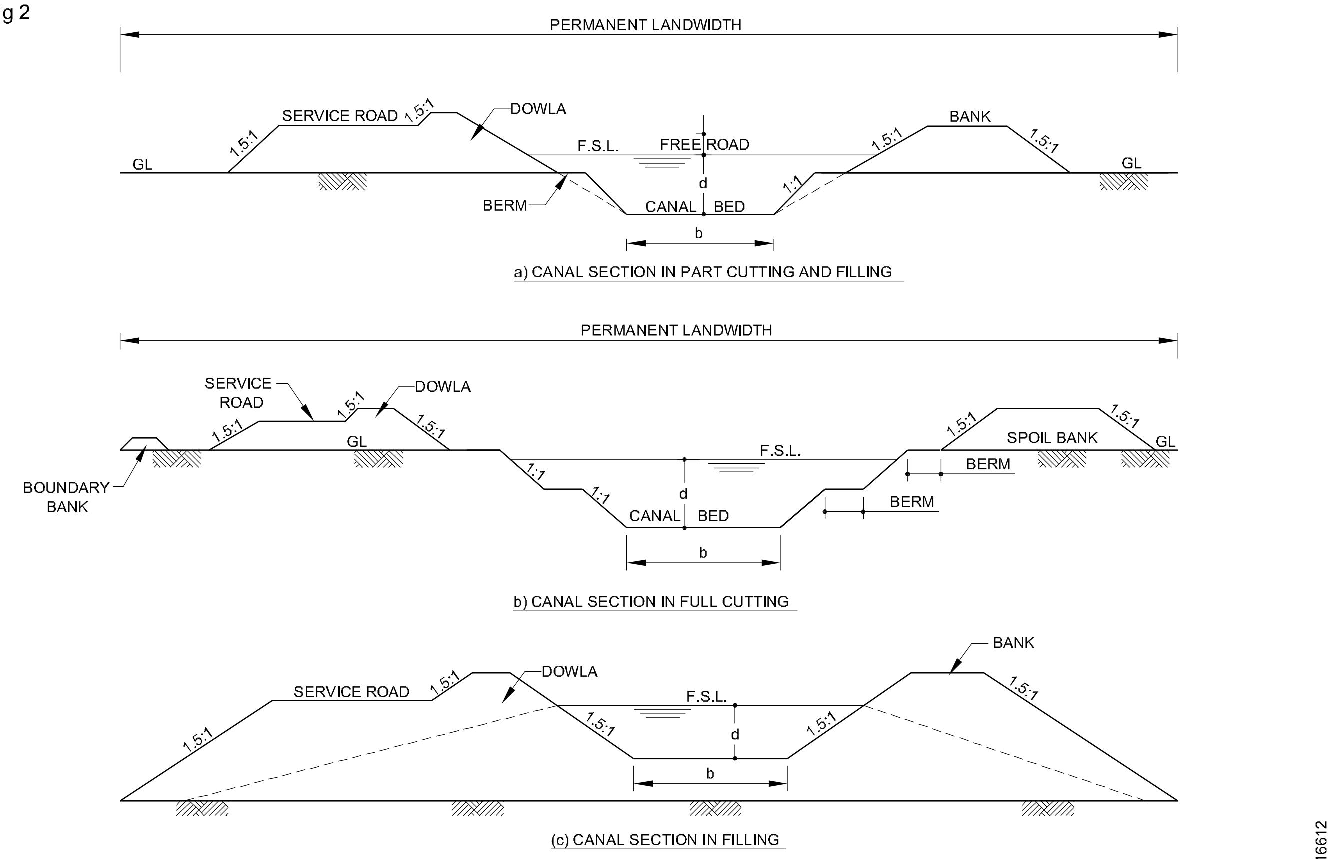
The channel section in these three conditions are shown in Fig 2. When the ground level is above the top of the bank, the canal is said to be in cutting. Similarly, when the ground level is below the bed level of canal, it is said to be in filling. A canal is in partial cutting or filling when the ground level is in between bed level and top of bank.

A canal can have a dowla 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 dowla section on the other side. Usually the left bank of canal has a dowla 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

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e Classification based on canal alignment

According to the alignment, a canal may be classified as under:

1 Contour canal or

2 Watershed canal or Ridge canal.

3 Side slope canal.

The characteristic features of these canals are discussed below:

1 Contour canal

A channel aligned nearly paralled to the contours of the country is called a contour canal.

When the canal takes off from a river in a hilly area, it is not possible to align the canal on the watershed as the watershed on the top of the hill may be very high and the areas which need irrigation are concentrated in the valley. The canal is then aligned roughly parallel to the contours of the area. The contour chosen for the alignment

should be so placed as to include all culturable area of the valley on one side of the canal.

The contour channel can irrigate only on one side. As the gound level on the other side is quite high, there is no necessity of a bank on this side. Hence, a contour canal is sometimes constructed with one bank only, and is known as a single bank canal. However, when both the banks are provided, it is known as a double bank canal.

2 Ridge canal

A ridge canal or a watershed canal is aligned along a watershed and runs for most of its length on a watershed. When a channel is on the watershed, it can command areas on both banks and so a large area can be brought under cultivation. Also, no drainage can intersect a watershed and, hence, the necessity of constructing cross drainage works are obviated.

3 Side slope canal

It is a channel aligned roughly at right angles to the contours of the country and is neither on the watershed nor in the valley. Such a channel would be roughly parallel to the natural drainage of the country and, hence, it does not intercept any cross-drainage. However, it has very steep bed slope, since the direction of the steepest slope of the ground is at right angles to the contours of the country.

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 theparent 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 resons:

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.

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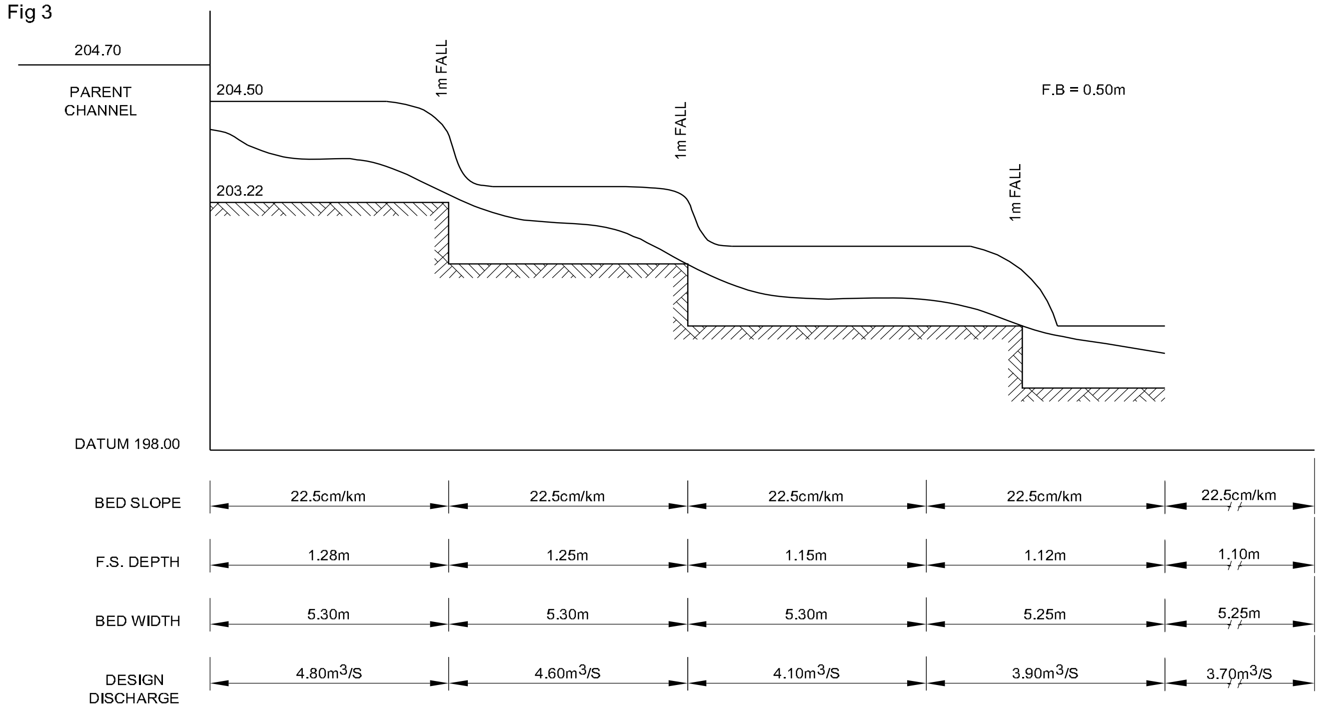
Fig 3



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

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LONGITUDINAL SECTION OF A CHANNEL

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.

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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.

Cross-section of an unlined channel

Unlined irrigation channels may be broadly classified on the basis of cross-section as follows:

1 Channel in cutting (Fig 4a)

2 Channel in filling (Fig 4b)

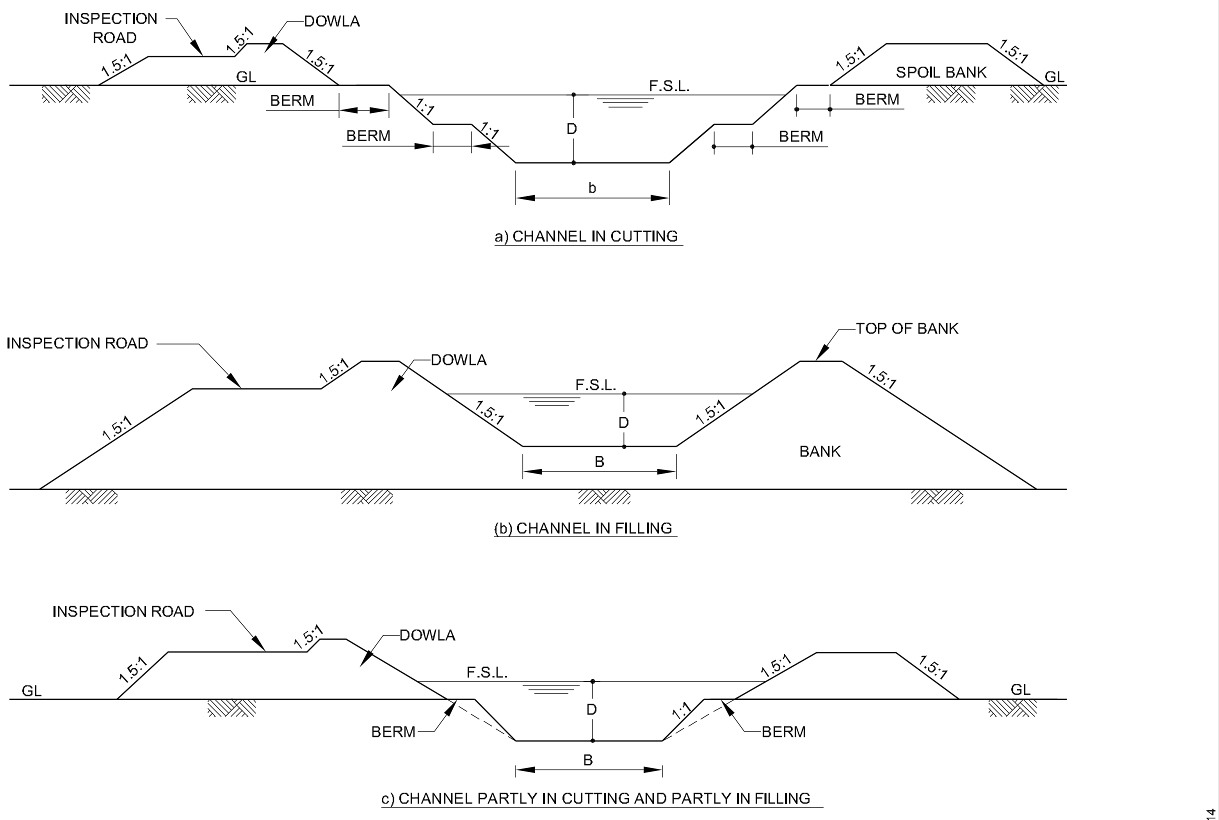
3 Channel in partial cutting and partial filling (Fig 4c)

1 Channel in cutting Fig 4a: A channel is said to be in cutting when the ground level is above the F.S.L. of the channel shows the cross-section of a channel in cutting. the side slopes of the channel should be such that they are stable for the type of material. However, a comparatively more steep side slope can be provided for the channel incutting as compared to that in the filling because the soil in the natural condition in cutting is more compact than that in the filling.

In an average loam soil, the side slope is usually kept 1:1 in cutting. For other types of soils, the typical side slopes are given in the below table 1.

2 Channel in filling Fig 4b: A channel is said to be in filling when the ground level is below the bed level of the channel. As already mentioned, the side slopes for the channel in filling are generally flatter than those in cutting for the same soil. In an average loam soil, the side slopes in filling are usually kept 1.5:1. For other types of soils, the side slopes are usually adopted as per the table 1.

Fig 4



UNLINED IRRIGATION CHANNELS

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Table 1 - Side slopes

S.No.	Type of material	Side slope in cutting (horizontal to vertical)	Side slope in filling (horizontal to vertical)
1	Hard rock	0.125:1 to1.25:1	-
2	Soft rock	0.25: to 0.5:1	-
3	Hard clay or morrum	0.75:1 to 1.0:1	1.5:1
4	Soft clay, alluvial soil	1:1	15:1 to 2:1
5	Sandy loam	1:5:1	2:1
6	Light sand	2:1	2:1 to 3:1

Canal regulation works

Objectives: At the end of this lesson you shall be able to
- **express the importants of canal regulations works**
- **explain the alignment of the off-taking channel**
- **define canal fall.**

1 Introduction

The structures (or masonry works) constructed on a canal to control and to regulate discharge, velocity, depth, etc. are known as canal regulation works. these structures are required for proper and efficient functioning of an irrigation canal system. The water which enters the main canal through a head regulator installed at the canal headworks is distributed into different branches and distributaries. To distribute the water effectively, the discharge is regulated in these smaller channels.

The distributary head regulator is constructed at the head of a distributary (or a branch canal) to control and to regulate the flow of water into the distributary. Thus a distributary head regulator provides a necessary link between the parent channel and the offtaking channel.

A cross-regulator is generally constructed across the parent channel at the downstream of the off-take point of the offtaking channel for raising up the water level in the parent channel when its discharge is less than the full supply discharge. Cross regulators are also constructed for various other purposes.

A canal fall is a structure constructed on a channel to effect a sudden change in the bed level of the channel. Canal falls are required on a channel when the slope of a natural ground along the alignment of a channel is steeper than the bed slope of the channel. If a fall is not provided, the channel will go in excessive filling, which is not desirable.

The offtaking channel should take its proportionate share of sediments of the parent channel. Various silt-excluding devices are provided at the distributary head regulator. The aim of all such devices is to separate the bottom layers of wate charged with the concentrated sediment load from the top layers and to draw top layers of clear water into the offtaking channel without causing any disturbance.

2 Alignment of the off-taking channel

A channel taking off from another large channel (called parent channel) should be properly aligned with respect to the parent channel. the alignment should be such that the off-taking channel is able to draw its supply without any undersirable effect. The following types of alignment are commonly adopted in practice.

1 The best alignment of the offtaking channel is when it makes zero angle with the parent channel initially and then separates out gradually along a transition curve. The transition curve should be properly designed to avoid accumulation of silt in the form of a silt jetty and to ensure equitable distribution of silt.

2 If the transition curves are not provided, the alignment shown in Fig may be adopted. In this case, the offtaking channel as well as the parent channel on downstream make an angle with the parent channel on upstream of the offtake point.

3 If it is essential to keep the parent channel straight, the edge of the channel rather than the centre line should be considered while deciding the angle of offtake. An angle of 60º to 80º is generally quite suitable. However, for large and important works, the model studies should be conducted to determine the most suitable angle.

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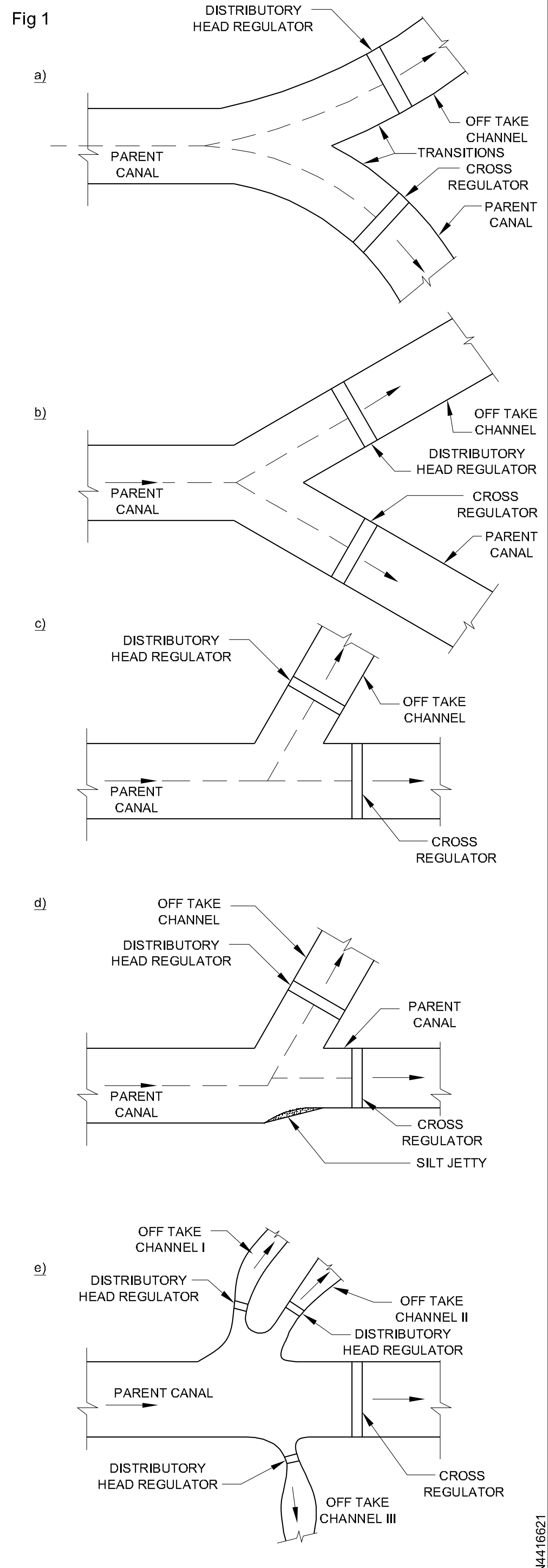

ALIGNMENT OF THE OFF-TAKING CHANNEL

The Fig.1 shows an unbalanced offtake, which should be avoided as far as possible. This usually results in the formation of a silt jetty. Moreover, the deviated current of water scours the bed along the deviated line to make up the loss to silt due to jetty formation.

4 When a number of channels offtake from one parent channel, the alignment shown in the below Fig is generally adopted. In this case, the offtaking channels are generally flumed to accommodate all the offtakes in the normal width of the parent channel. In this case, only one cross-regulator serves the purpose of a number of cross-regulators which would have been required if separate off-take points were provided for different offtaking channels.

3 Regulators

Functions of regulators

The regulators are required on a channel to regulate and control the supply of water. The functions of the distributary head regulator and the cross-regulators are summarised below:

Function of a distributary head regulator: A distributary head regulator serves the following main purposes (Ref Fig 1 a to e.

1 It regulates the supply of water from the parent channel to the offtaking channel.

2 It controls the entry of silt into the offtaking channel.

3 It can serve as a meter for the measurement of discharge.

4 It is used for shutting off the supply into the offtaking channel when water is not needed, or when the offtaking channel is required to be closed for repairs or maintenance.

Functions of a cross-regulator Fig 1 a to e

1 The main function of a cross regulator is to raise the water level in the parent channel on the upstream so that the offtaking channel can take its full supply even when the water level in the parent channel is lover than F.S.L.

2 It is also used to close the supply in the parent channel on its downstream. The supply in that case is usually directed to other channels. If an escape is also provided in conjunction with a corss-regulator, the water can be diverted to the escape channel.

3 There is usually a bridge on the cross-regulator, which provides a means of communication.

4 It helps absorb fluctuations in the various sections of the canal system and thus prevents breaches in the tail reaches.

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5 In can be used to control discharge at an outfall of a canal into aother canal or a lake.

6 It can be very easily combined with a canal fall; in which case, it helps to control the water surface slope for bringing the canal to a regime slope and to a balanced depth.

7 It can be used to control the drawdown when the subsoil water levels are high to ensure safety of canal lining.

8 Cross regulators are useful for effective regulation of the entire canal system. In a good canal system, a large number of cross-regulators are usually provided.

4 Canal falls

A canal fall (or a fall) is a structure constructed on a channel to lower down the water level and the bed level of the channel. The canal fall is also known as a canal drop. Becuase of the drop of the water level at the fall, the potential energy of the water is converted into the kinetic energy, which may damage the d/s portion of the canal

by scouring action. The canal fall is, therefore, designed to dissipate the surplus energy possessed by the water falling over the structure. Thus the canal fall consists of a combination of a water-lowering structure and an energy-dissipating device.

The canal falls are required when the natural slope of the ground along the channel alignment is steeper than the bed slope of the channel. The difference in slopes of ground and canal is adjusted by providing falls in the bed of the channel at suitable points. The exact location of a fall depends upon a number of factors. The following factors should be considered while deciding the location of the fall.

1 The site for the fall in the case of main canals and branches, from which no direct irrigation is done, is usually selected from the consideration of economy of earthwork. As far as possible, the canal should be kept in the balanced depth of cutting. If the fall is not provided, the canal would go in excessive filling, which is not desirable from the consideration of the economy of earthwork and the maintenance of the canal.

2 The site for the fall in the case of distributaries, from which direct irrigation is done, is usually decided in such a way that the command is not sacrificed in the proccess of lowering of the water level.

A fall is usually provided at a point where the F.S.L. of the canal outstrips the ground level but before the channel bed comes into the filling. Sometimes, the F.S.L. may remain below the ground level for a distance of 1/2 to 1.0 km d/s of the fall. This will however not result in any decrease of command because upto that distance, the area can be irrigated by a water course from an outlet provided on the u/s of the fall at a high level.

3 For locating the fall, it is first necessary to fix the F.S.L. required at the head of all offtake channels and outlets and mark them on the L-section of the canal on which the fall is to be located. The F.S.L. of the canal is then marked so that it covers all the commanded points and allows for a minimum working head of about 0.3 m for the regulators of the offtaking channels and 0.15 m for all outlets. The falls are then located at the points wherever actual F.S.L. of the canal is much greater than the F.S.L. required.

4 The location of a fall may also be decided from the consideration of the possibility of combining it with a cross-regulator, a road bridge or any other masonry work to effect economy and to have better regulation.

5 Relative economy should be considered while deciding the number of falls and the drop in each fall. In a given reach, if the drop of each fall is increased, the number of falls is decreased and vice versa. Generally, the provision of a large number of small falls results in economy of earthwork bu the cost of fall structures is incresed. On the other hand, the provision of a small number of large falls results in extra cost of earthwork, but the cost of fall structures is decreased. The combination which gives the minimum overall cost, subject to the condition that the command is not reduced, should be selected.

6 Sometimes it may be necessary to provide fewer falls of large drops to enable hydropower generation at these falls.

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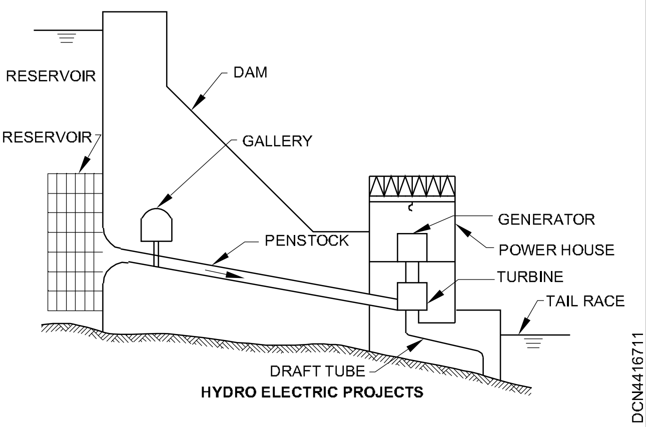
Hydro electric projects and Turbines

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.

Hydrpower 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 onpractical 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 (Fig1a). 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.

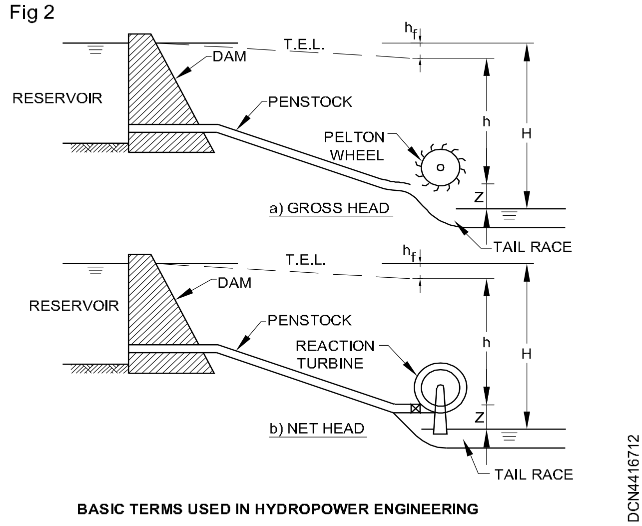
2 **Net head (h):** The net head (or effective head) is the head available for the turbine. it is equal to the difference of total head at the point of entry and at the point of exit of the turbine Fig 2b.

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.

Fig 2



BASIC TERMS USED IN HYDROPOWER ENGINEERING

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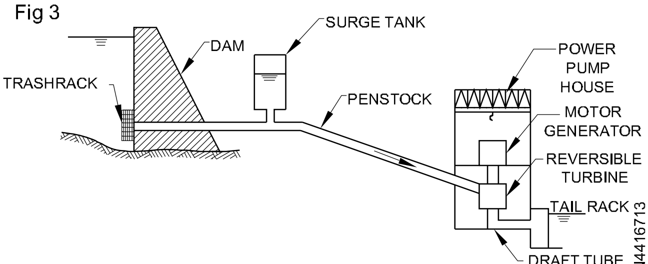
For most of the schemes at the Optimum conditions, the overall efficiency of the scheme is usually beteween 60 to 70 percent.

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, whcih 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 whicb 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.

Comparison of hydropower and thermal power

Hydropower is developed by coupling a generator to a water turbine, whereas thermal power is produced by coupling a generator to a steam turbine. Water turbine are run by hydraulic energy whereas the steam turbines are run by fuels such as coal, oil or natural gas.

In addition to hydropower and thermal power, other sources of power are nuclear energy, wind energy, solar energy, geo-thermal energy, tidal energy, etc. However, these sources are not major sources because they are still in the developing stage and the amount of power produced in not significant.

Hydropower has the following advantages and disadvantages over thermal power:

a Advantages

1 Water is a perpetual source of energy; whereas fuel used for thermal plants is limited in supply.

2 Water is neither consumed nor converted into something else after generation of hydropower from it. It can be reused for various other purposes. The fuel in a thermal plant is consumed and converted into flyash which has very little use.

3 The running cost of a hydropower plant is very small as compared to that of a thermal plant.

4 A hydropower plant can be put on or shut off in a few minutes, whereas a thernmal plant requires a couple of hours or even days.

5 The system reliability of a hydroelectric plant is much greater than that of thermal plant.

6 The life expactancy of a hydropower plant is 50 years or more; while that of a thermal plant, it is usally less than 30 years.

7 The hydropower generators give a very high efficiency over a considerable range of load.

8 Hydropower plant do not cause air pollution.

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9 Hydropower development schemes can be planned to provide ancillary benefits, such as irrigation, flood control, water supply, etc.

10 The cost of power production in a hydroelectric plant per kWh is usually less than that in a thermal plant.

b Disadvantages

1 The initial cost of a hydroelectric plant is usually more than that of a thermal plant.

2 A hydroelectric plant requires construction of dams, which takes a lot of time. Therefore, the gestation period of a hydropower plant is long, about 10 to 15 years.

3 The development of hydropower depends upon the supply of water. The discharge in the river is extremely variable because it depens upon the hydrological conditions, The firm power of a hydroelectric power plant is therefore much less than that in a thermal plant.

4 The reservoirs on the upstream of the dam constructed for hydropower may submerge a large area and may distrub the ecological balance.

5 A hydropower plant is usually located at a place in a hilly region far off from the load center.

What is a turbine machine?

A **turbine** is a **machine** that transforms rotational energy from a fluid that is picked up by a rotor system into usable work or energy. **Turbines** achieve this either through mechanical gearing or electromanetic induction to produce electricity.

What are the differnet types of turbines?

There are 3 main types of **impulse turbine** in use: the Pelton, the **Turgo,** and the**Crossflow** turbine. The two main types of reaction turbine are the **propeller turbine**(with Kaplan variant) and the **Francis turbine.** The reverse **Archimedes Screw** and the overshot **waterwheel** are both **gravity turbines.**

What is a power turbine?

The gas **turbine** is the engine at the heart of the **power** plant that produces electrical energy.

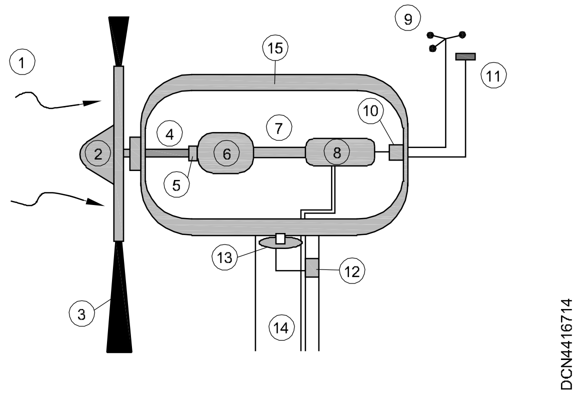
What is the Francis turbine?

The **Francis turbine** is a type of water **turbine** that was developed by James B. **Francis** in Lowell, Massachusetts. It is an inward-flow reaction **turbine** that combines radial and axial flow concepts. **Francis turbines** are the most common water **turbine**in use today.

How a Wind Turbine Works

Learning **how a wind turbine works** is easy as long as you first make sure to know how a turbine generator works.

Fig 4



The diagram of the wind turbine above is a side view of a horizontal axis wind turbine with the turbine blades on the left. Most modern wind turbines are built with a horizontal-axis similar to the one sen in the figure.

The figure is also a common up-wind turbine, meaning that the for the turbine to perform effectively, the nose and blades of the turbines should be facing the wind.

To learn more about how wind turbines work, one can start by looking at the diagram above and study each component of a wind turbine.

Step-by-step look at each piece of a wind turbine from diagram above:

1 Notice from the figure that the **wind direction** is blowing to the right and the nose of the wind turbine faces the wind.

2 The **nose** of the wind turbine is constructed with an aerodynamic design and faces the wind.

3 The **blades** of the wind turbine are attached to the nose and the rotor and begin to spin in ample wind speed.

4 The **main turbine shaft** is what connects the spinning blades to the inner workings of the machine. The turbine shaft spins with blades and is the mechanism that transfer the rotational/mechanical energy of the blades towards the electrical generator.

5 A **brake** is installed to prevent mechanical failure from high wind and high rotational speeds. It can also stop the turbine when it is unneeded.

6 The **gearbox** is used to increase the rotational speed of the turbine shaft. The gearbox works like the gears on a bicycle, as the gears change, the rotational speeds will change too. Then, it transfers the rotational energy into the high-speed turbine shaft and into the generation.

7 The **high-speed turbine shaft** connects the gear box and the generator. It's high rotation speeds are what spin the turbine generator.

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8 The **turbine generator** is the most essential part of how a wind turbine works. The turbine generator is what converts the mechanical energy from the wind into electrical energy using the rotating force that is transferred from the gears and turbine shaft.

9 The **anemometer** is a device that measure wind speeds. They are usually installed to instruct the collector to stop or start the turbine in certine wind speed conditions.

10 The **controller** is installed in case the wind speeds reach an undesired speed, the anemometer can instruct the controller to use the brake and stop the rotating blades. The controller is also used to help start spinning the blades and rotor in low wind speed.

11 The **wind vane** is an instrument that measures the direction of the wind. The wind vane is important for up-wind trubines that need to be facing the wind in order to operate properly.

12 The **yaw drive** in the mechanism that receives data from the wind vane and instructs the wind turbine to rotate to be facing the wind.

13 The **yaw motor** is the device that physically rotates the turbine to be facing the wind or as instructed by the yae drive.

14 The **turbine tower** contains wiring so the wiring so the generator can send electricity into a transformer or a battery which will eventually distribute usable electric power. The tower is also a crucial structural support system that holds the turbine high in the air where wind speeds are more desirable.

15 How a wind trubine works well outside, and during intense wind speeds is because all of the components are built at the top of the turbine are usually made out of cylindrical steel and can either be supported by guy tensions or stand alone using a lattice standing base.

Again, this diagram shows an example of an up-wind, horizontal axis wind turbine that may be made of steel and thoughtful analysis and strategy to find desirable locations with ample wind speeds. potentially stand several stories tall. How a wind trubine works not only invloves great engineering, it also requires

How Much Energy do Wind Turbines Produces?

In 1914, German physicists Albert Betz discovered that no wind turbine could physically capture more that 59.3% of the kinetic energy of the wind. A simple way to explain that if a wind turbine ever captured 100% of the wind, there would be no wind passing through the other side of the wind turbine blades. If there is no wind passing the other side, then according to the physical law of wind movement, there would be no room for any more wind to pass through the front of the wind turbine, rendering the wind turbine useless.

So, to calculate wind powet output or the amount of wind electricity that is expected to be produced from a wind turbine you will need a short list of depended variables:

(Cp) -Turbine efficiency coefficient, maximum of 0.593

(ρ) - Air Density, measured in pounds/cubic foot

(A) - Area of rotor blade, measured in square feet

(V) - Wind Speed, miles/hour

(k) - k is a constant that equals 0.000133, this converts the answer into kilowatts

(p) - Power output, the independent variable we wish to calculate, in kilowatts

With the above variables, the equation to calculate the wind electrical output of a wind turbine is:

P = k * Cp * (1/2) * ρ * A * (V^3)

Note the relationship of each variable from the equation and how it relates to how a wind turbine works. The area swept by the trubine blades, the air density, and the wind speed. The overall design of the wind turbine is also crucial for how efficiently the blades can capture the wind.

Smaller wind turbines used for boats, caravans, or smaller machines generally produce around 250 watts to 100 kilowatts of wind electricity. Some of the biggest winf turbines in the world produce around 7 megawatts of eletricity.

It is important to remember that wind speed is not constant, so the theoretical output of electircity that a wind turbine can produce is a maximum potential of energy output that is rarely reached. The actual energy produced from a wind turbine, when stated in a ratio with the theoretical expectations of the wind turbine is called the capacity factor.

A 10 kilowatts wind turbine in an area with about 12 mph wind speed would produce about 10 kilowatt-hours of wind electricity a year, which is around the amount the amount need to supply electricity to an average household.

A 5 megawatt wind trubine could produce around 15 million kilowatts hours of wind electricity in one year, which could provide power to over 1,000 households.

Conclusion: A wind turbine only when the wind is blowing, and understanding how a wind turbine works means understanding the aerodynamics of the wind and blades, while also knowing how a turbine generator creates electricity. At its most fundamental roots, a wind turbine works by allowing wind to roate a turbine generator.

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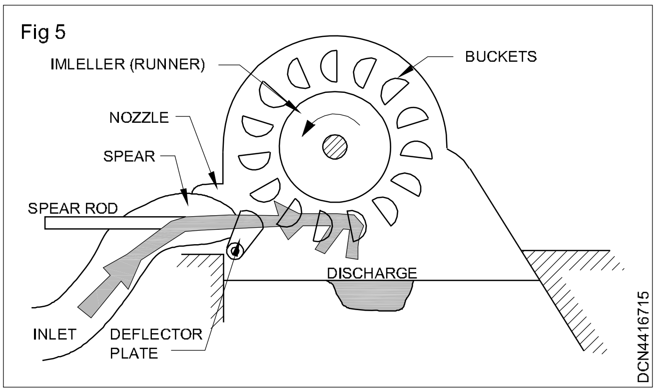

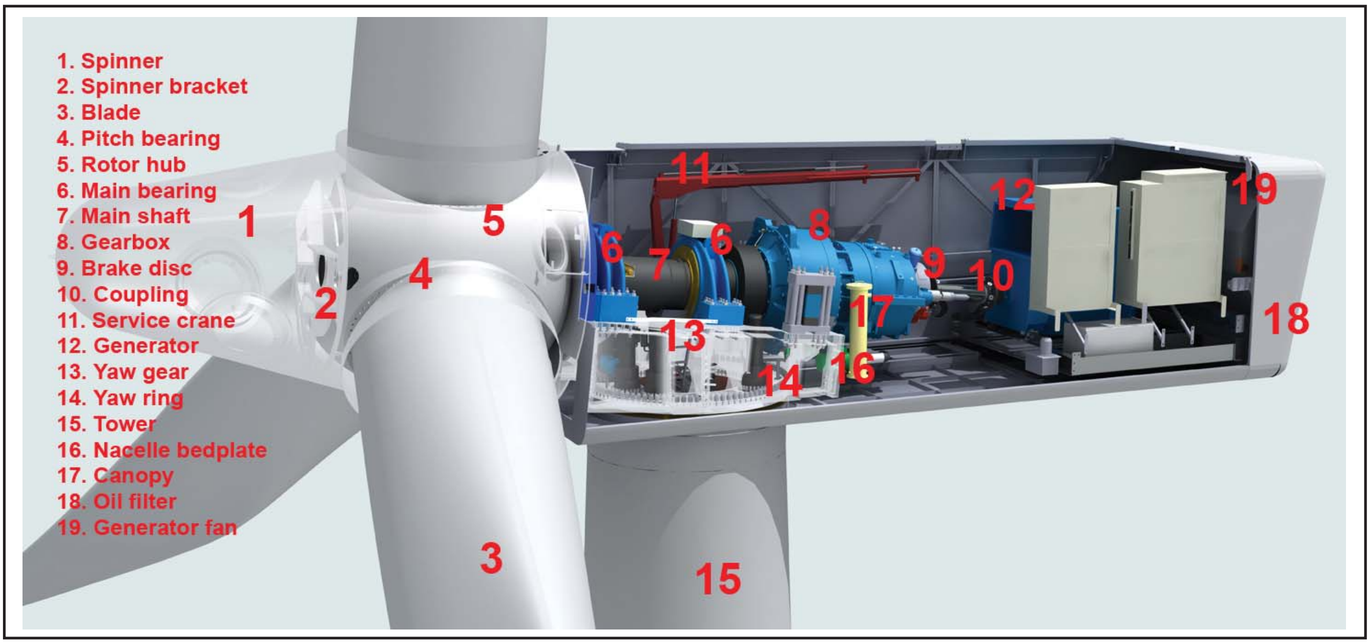

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Estimation - Purpose - Technical Terms - Datas And Classification

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. Apporoximate 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, estamlishment, 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 nessary 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 fo all works.

Besides the buildingm, structurres 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.

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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 dawn 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, corriodos, 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 pilnth 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.

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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, mezzaninies, barsaties, 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 ino 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 adjecents 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, corrdors, 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 Barsaties

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 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.

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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-charget 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 amout of work-charged estamblishment 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 techical 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. Om receipt of the tenders the rates and amounts are compared and decision about entrusting the work is finalised.

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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, elevaion and sectional elevaions 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 inpreparing 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 seperately, 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.

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.

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
	7 Extention and Improvement Estimate

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 seperately 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 an d 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 ofbuilding, 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

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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 beetween 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, elevaion, 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%

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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 particulars	Quantity	Unit	Rate	Amount

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 furtheer 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 absract 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 maintan 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.

6 **Extension and improvement estimate:** When some changes and extensions are required to be made in the old work, the cost of whcih 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.

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Rules measurement of Techniques

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 tothe 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 desribed 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 separatley 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 separatley and the heights shall be described

a From foundation to plinth level.

b From plinth level to first flor level.

c From first floor level to second floor level and so on.

The parapet shall be measured with the corresponding items fo the storey next below

	Particulars of materials and works	Dimensions metric system
1	Bricks, stone blocks, etc.	All dimensions cm.
2	Files, 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.

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Unit of measurements in metric system

The principle for dimensions and measurements is to use milimetre (mm) for minute dimensions, centrimetre (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 kandkar, 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 cu. 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. chujja, 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.

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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 partion 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)	meetre	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 chujjas, 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.
8	Ballies (Diameter specified0	metre	per m.

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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 (Manimum 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	metere	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 (G.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 oer 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.

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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.

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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 kn 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 panes or cleaning	no.	per no.
20	Renewing of glass panes	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, Tunner, 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 iteem	Same as for different iteam

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S. No	Particulars of Items	Unitsof Measurement in MKS	Unitsof payment in MKS
33	Desmantling 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 flat0	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, etec. (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

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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 brreadth 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 foundationmay 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.

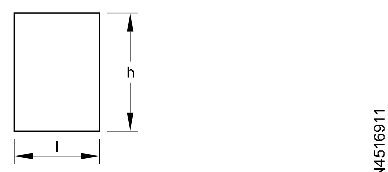
Bearings of floor and roof slabs are made in the following wall masonry.

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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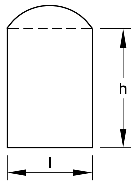
Doors and windows with small segmental arches (Fig 2)

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.

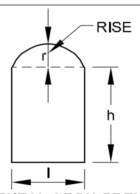
$$\text{The area of segmental portion} = \frac{2}{3}lr + \frac{r^3}{2l}$$

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)

$$\text{The total deduction will be} = \left[(l+h)+\left(\frac{2}{3}\text{xlxr}\right)\right]\text{x}$$

$$[\text{Thickness of wall}]$$

Fig 3



SEGMENTAL ARCH OPENINGS

Semi-circular arch openings (Fig 4)

The area of semi-circular portion = $\frac{1}{2}\pi r^2$

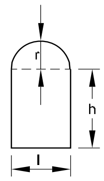
But for the deducation, the area of the semi-circular portion is obtained approximately by ¾ of span x rise, (¾ x l x r).

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



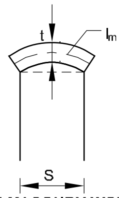
SEMI-CIRCULAR ARCH OPENINGS

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



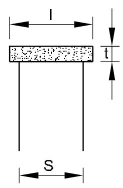
ARCH MASONRY WORK

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 th 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.

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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 contct 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 inone 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 cu. c. 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, raffers, 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.

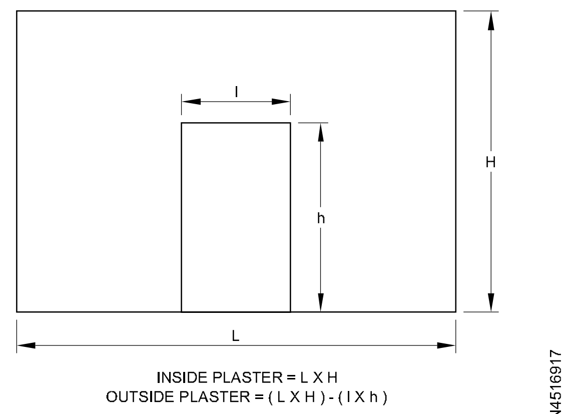
For deduction of arch opening the same principle as for masonry work is followed. Plastering of ceiling usually of 12 mm. thick computed in sq. m. under a separate head as this work is done with richer mortar. For R.C.C. work usually no plastering is allowed but for fair finish a thin plaster of rich 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, cor-belling, coping, etc. are measured and paid for in running metre for the complete work.

Fig 7



PLASTERING

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.

$= \frac{\pi d^2}{4} \times ht.\,cu.m$ for round pillars, d is the dia.

$= a^2 \times$ ht. cu.m for square pillars, a is the side.

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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, burgahs, 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	Pannelled, 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.

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v Venetian	___	3 times one surface area, for both sides.
vi Iron bars, grills in windows	___	1 time the are of 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.

$$\begin{aligned}\begin{pmatrix}\text{Long wall length}\\ \text{out} - \text{to} - \text{out}\end{pmatrix} &= (\text{Centre to centre length})\\ &\quad + (\text{half breadth on one side})\\ &\quad + (\text{half breadth on the other side})\\ &= (\text{Centre to centre length}) + (\text{One breadth})\end{aligned}$$

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.

$$\begin{aligned}\begin{pmatrix}\text{Short wall length}\\ \text{in} - \text{to} - \text{in}\end{pmatrix} &= (\text{Centre to centre length})\\ &\quad - (\text{one breadth})\end{aligned}$$

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.

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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, octogonal, 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.

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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

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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

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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)

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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 1:7:20, 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:

$$\text{Cement(C)} = \frac{1.54xC}{(C+S+A)} \text{cu. m.}$$

$$\text{Sand (S)} = \frac{1.54 \text{ x } S}{(C+S+A)} \text{cu. m.}$$

$$\text{Aggregates (A)} = \frac{1.54 \text{ x } A}{(C+S+A)} \text{ cu.m}$$

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

$$\text{Quantity of Cement} = \frac{1.54 \text{ x } C}{(C+S+A)}$$

$$= \frac{1.54 \text{ x } 1}{7} = 0.22 \text{ cu. m. or } 6.4 \text{ bags}$$

$$\text{Quantity of Sand} = \frac{1.54 \text{ x } S}{C+S+A)}$$

$$= \frac{1.54 \text{ x } 2}{7} = 0.44 \text{ cu. m.}$$

$$\text{Quantity of Aggregate} = \frac{1.54 \text{ x } A}{(C+S+A)}$$

$$= \frac{1.54 \text{ x } 4}{7} = 0.88 \text{ cu. m.}$$

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.

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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

$$\therefore \text{Cement required} = \frac{0.30\text{x}1}{(1+5)}$$

$$= 0.05\text{cu.m or } 1.5 \text{ bags}$$

$$\text{Sand required} = \frac{0.30\text{x}1}{(1+5)} = 0.25 \text{ cu.m}$$

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.

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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.

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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.)	Corse aggregate (Stone) (cu.m.)	Quantity of concrete mixed with water (cu.m.)
1 : 2 : 4	21	42	84	100
1 : 2 : 5	17.2	34.40	86	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.

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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.

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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.

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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

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	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 of the property 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 caitalized 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

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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

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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

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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 pained 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

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specifications are written to express the requirements clearly n a concise form avoiding repetition and embiguity.

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, insttead 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 reauired, 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

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.

$$A = \frac{d}{2}\left[0_1 + 0_n + 2\left(0_2 + 0_3 + 0_4 + \ldots\ldots + 0_{n-1}\right)\right]$$

$$A = \frac{\text{dist.bet.ordinate}}{2}\left[\begin{array}{l}(\text{first ordinate} + \text{last ordinate}) + \\ 2(\text{sum of other ordinates})\end{array}\right]$$

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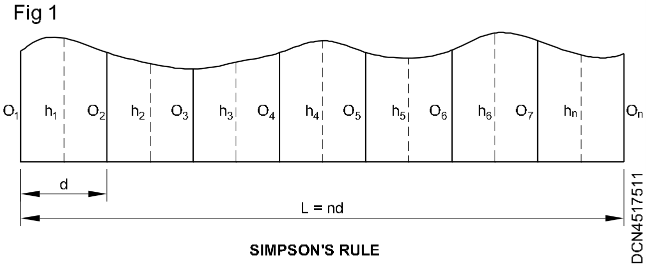
Simpson's rule

$$A = \frac{d}{3}\left[\begin{array}{l} 0_1 + 0_n + 4\left(0_2 + 0_4 + \ldots\ldots + 0_{n-2}\right) + \\ 2\left(0_3 + 0_5 + \ldots\ldots 0_{n-1}\right) \end{array}\right]$$

$$A = \frac{\text{Common dist. (d)}}{3}\left[\begin{array}{l} (\text{first ordinate} + \text{last ordinate}) + \\ 4(\text{sum of even ordinates}) + \\ 2(\text{sum of odd ordinates}) \end{array}\right]$$

Fig 1



SIMPSON'S RULE

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 irrigular 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

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

$$\Delta_1 = \frac{d}{3}\left[O_1 + O_n + 4(O_2 + O_4 \ldots\ldots) + 2(O_3 + O_5 + \ldots\ldots)\right]$$

$$= \frac{5}{3}\left[2.5 + 6.10 + 4(3.80 + 5.20) + 2(4.60)\right]$$

$$= 89.67\,m^2$$

$$\Delta_2 = \frac{10}{3}\left[(6.10 + 5.8) + (4 \times 4.70) + (2 \times 0)\right] = 102.33\,m^2$$

$$\Delta_3 = \frac{20}{3}\left[(5.8 + 2.20) + (4 \times 3.90) + (2 \times 0)\right] = 157.3\,m^2$$

$$\text{Total area} = \Delta_1 + \Delta_2 + \Delta_3 =$$

$$89.67 + 102.33 + 157.3 = 349.30\,m^2$$

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Computation of volumes

The computation of volumes of various quantities from the measurements done in the field is required in the measurements done in the field is required in 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 os 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 adn S:1 (horizontal:vertical) the side slope then,

Area of mid section = Area of rectangular portion + Area of two triangular portion.

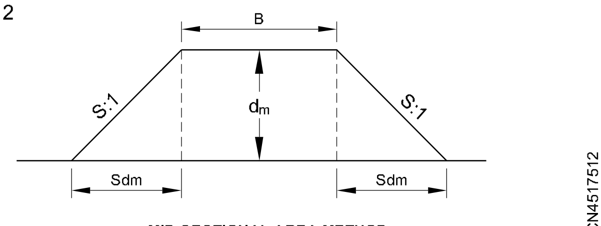
$$= Bd_m + \tfrac{1}{2} sd_m^2 + \tfrac{1}{2} sd_m^2$$

$$= Bd_m + sd_m^2$$

$$\therefore \text{Quantity of earth work } = \left(Bd_m + sd_m^2\right) xL$$

General, Q=(Bd+sd2)xL, where d stands for mean height or depth.

Fig 2



MID-SECTIONAL AREA METHOD

The quantities of earthwork may be calculated in a tabular form as below

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

Area of side sloping surface

The area of sides which may require turfing or pitching, may be found by multiplying the mean sloping breadth oby 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 $= 2L_1 \text{ x d} \sqrt{s^2 + 1}$

This also may be calculated in a tabular form

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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 $2L_1 \times d\sqrt{s^2+1}$

This table may be added to previous table or may be worked out separately, d being mean depth or beight

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.

The mean sectional area $A = \frac{A_1 + A_2}{2}$

Quantity $Q = \frac{A_1 + A_2}{2} \times \text{Length}$

The quantities of earth work may be calculated in a tabular form as given below:

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 $(bd + sd^2) \times L$	
							Embankment	Cutting

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

Fig 3

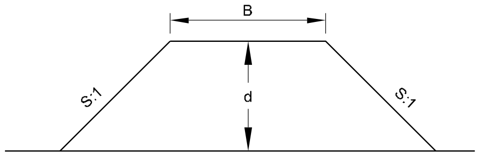


Fig 4

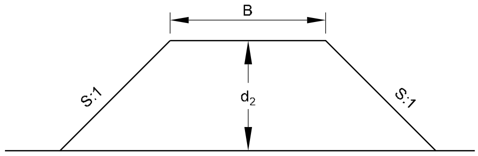
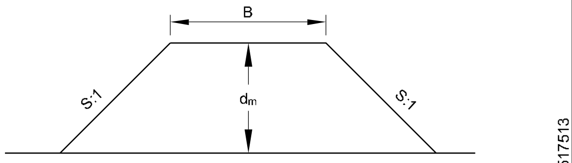


Fig 5



PRISMOIDAL FORMULA METHOD

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$$A_2 = Bd_2 + Sd_2^2$$

Cross section at middle

$$d_m = \frac{d_1 + d_2}{2}$$

$$A_m = Bd_m + Sd_m^2$$

$$A_m = B\frac{d_1 + d_2}{2} + S\left(\frac{d_1 + d_2}{2}\right)^2$$

$$\text{Quantity} = \frac{L}{6}\left(A_1 + A_2 + 4A_m\right)$$

$$= \frac{L}{6}\left[\left(Bd_1 + Sd_1^2\right) + \left(Bd_2 + Sd_2^2\right) + 4\left\{B\left(\frac{d_1 + d_2}{2}\right) + S\left(\frac{d_1 + d_2}{2}\right)^2\right\}\right]$$

$$= \frac{L}{6}\left[\left(Bd_1 + Bd_2 + 4\frac{Bd_1}{2} + 4\frac{Bd_2}{2} + Sd_1^2 + Sd_2^2 + 4S\frac{d_1^2 + d_2^2 + 2d_1d_2}{4}\right)\right]$$

$$= \frac{L}{6}\left[\left(3Bd_1 + 3Bd_2\right) + 2Sd_1^2 + 2Sd_2^2 + 2d_1d_2\right]$$

$$= \frac{BL}{6}\left(d_1 + d_2\right) + \frac{2LS}{3}\left(d_1^2 + d_2^2 + d_1d_2\right)$$

$$= \frac{BL}{2}\left(d_1 + d_2\right) + \frac{LS}{3}\left(d_1^2 + d_2^2 + d_1d_2\right)$$

$$= \left[B\left(\frac{d_1 + d_2}{2}\right) + S\left(\frac{d_1^2 + d_2^2 + 2d_1d_2}{3}\right)\right] x L$$

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 Prisosidal 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 prismodial 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 primosidal 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 shold be calculated by prismoidal formulae.

To calculate the volume of earthwork from contour plan, for filling a depression or pond and for cutting ahillock, 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.

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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.

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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 anglogue 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

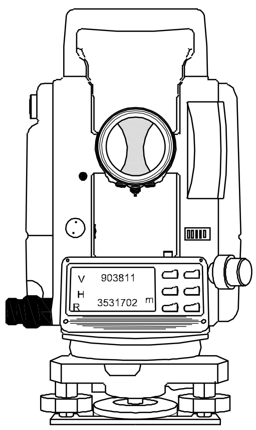

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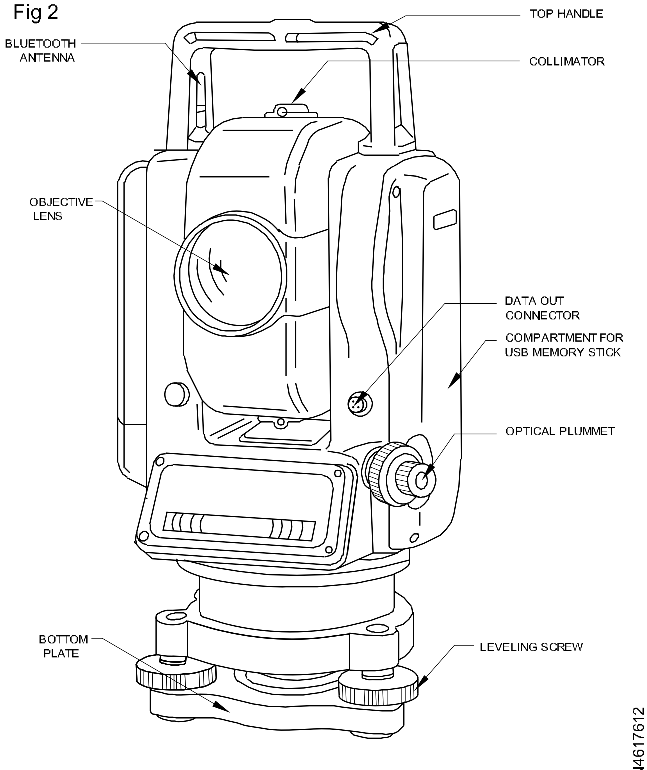
Fig 2



TOTAL STATION - INSTRUMENT COMPONENTS

Features of total station

1 The theodolite is offering a complete product family. It is easy fot 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.

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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 levelld

by operating levelling screws.

Within a small range instrument is capable of adjusting itself to the level positon. Then vertical and horizontal reference directions ared indexed using onboard 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 withpoint 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.

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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 advdantagges 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 qick 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 nots. 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 personnel 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 elevtronically was the slope distances.

Semi-automatic total stations

The user had to manually read the horizontal circle for these instruments, but the vertical circule 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

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 istances to about 3 millimeters or 1/1000th of a foot..

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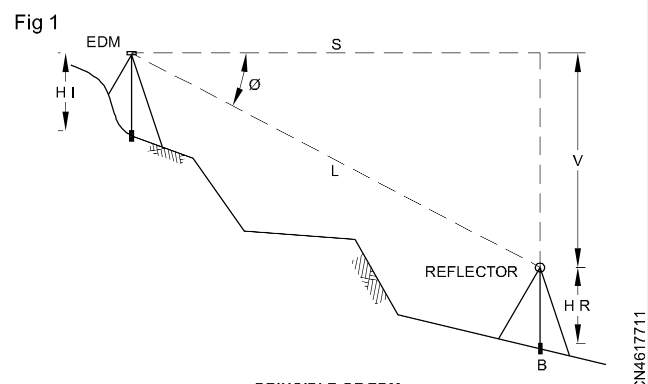
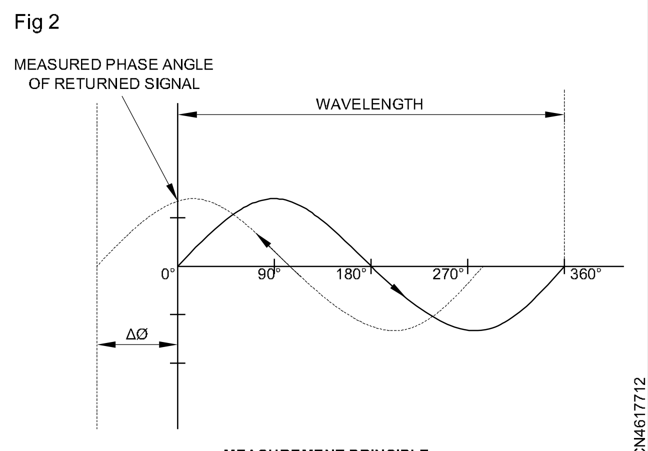


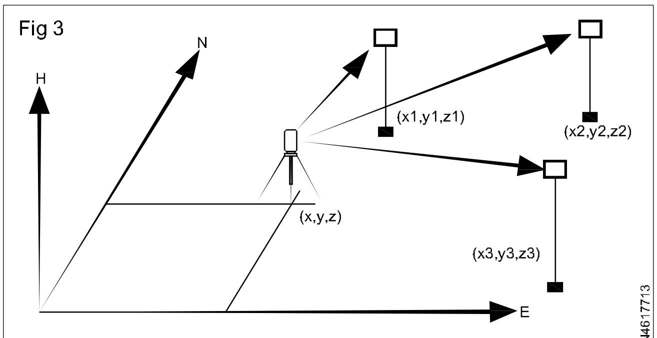
PRINCIPLE OF EDM



MEASUREMENT PRINCIPLE

Basics of total station

- Angles and distances are measured from the total station to points under survey, and the coordinates (X,Y, and Z or nothing, easting and elevation) of surveyed points relative to the total station position are calculated using trigonometry and triangulation.
- 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 withing withing 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.
- Total Station - requires lines line of sight obsrvations and must be set up over a known point or with line of sight 2 or more points with known location.



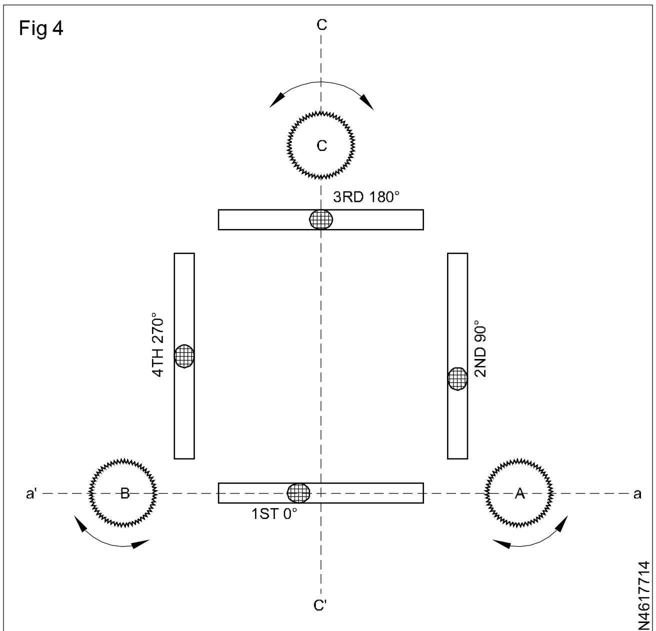
3D COORDINATES

From the above figure

- 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



FINE LEVELLING PROCEDURE

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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 Prism

   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, meaory card, etc.)

5 Survey tools

   a Stakes, nails, paint, marker

   b Hammer

   c Thermoeter, barometer / altimerer

   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 pf 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 stetady, and put down the stake at the centre using the plummet.

5 To occupy an existing station above a refrence 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.

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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.

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.

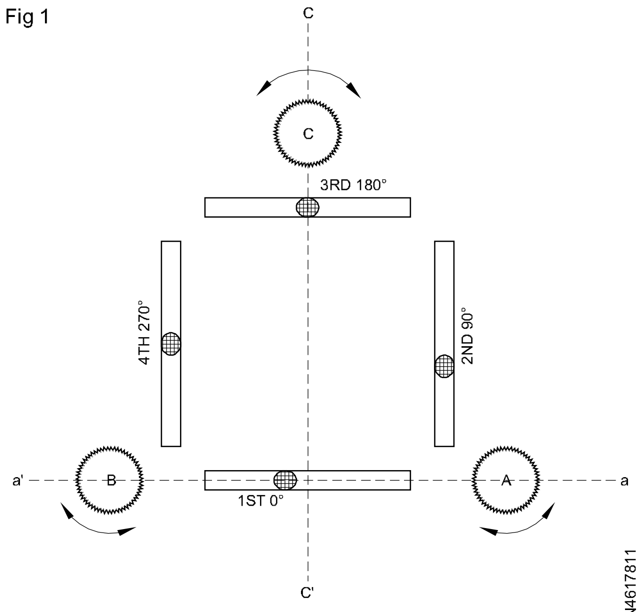
f Turn the foot screws A and B in the opposite direction, the same amount to eliminate half the centering error.

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).

Fig 1



FINE LEVELLING PROCEDURE

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 offseet 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 Tightem 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 triped. 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 trubrach 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.

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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 tru 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, thehardware 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 initalize 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 thenext 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 clos 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 creat a new job or append 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 statio:

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.

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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 carre when the tribrach is removed from the total station.

8 Do not make the total station wet.

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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 dis advantages 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 tribatch 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 shifr sysrem, the range that can be obtained is about 100m, with a similar accuracy to that ontained when using a prism or foil.

Characterstics of total station

1 Angle units degree or gon
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

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- 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 leveled
- 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, reonserve 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 heinght
- 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.

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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 usning the right software.

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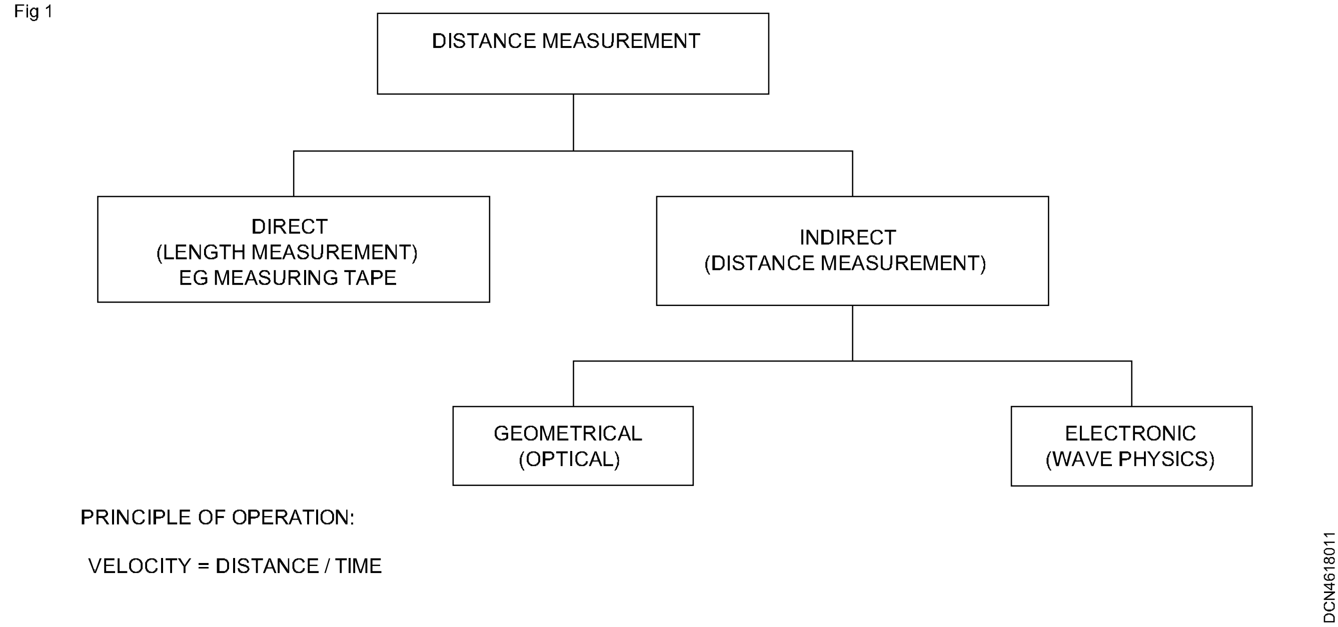
Principle of EDM - Working need setting and measurement

Objectives : At the end of this lesson you shall be able to
- **defene EDM**
- **state the prenciple of EDM**
- **features of EDM.**

What is EDM ?

EDM is the electronic distance measuring device, measures from the instrument to its target. EEDM sends out laser or inframed beam which is roflected back the unit and the unit used velocity measurements to calculate the distance traveled by the beam.

Fig 1



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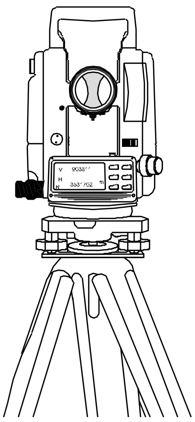
History

Theeodolite & 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.

Fig 2



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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.

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>

Fig 3

Fig 4

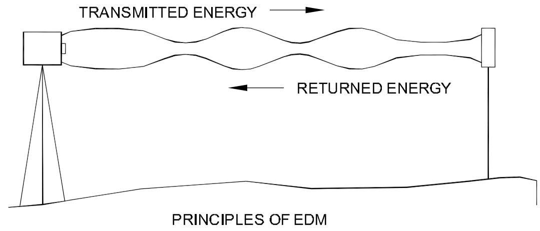

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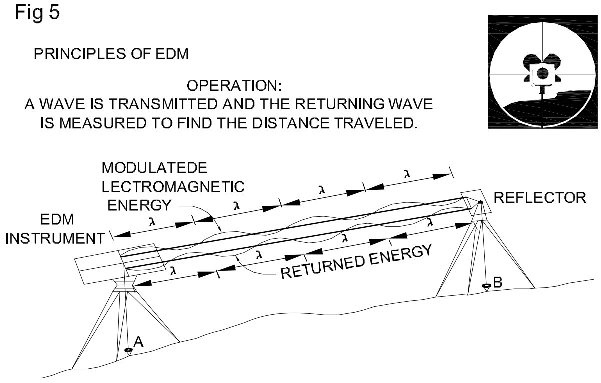
Fig 5



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Principles of EDM

Gereral principles of EDM

Electromagnetic energy

Travels based on following relation

$$v = f\lambda \text{ so } \lambda = \frac{v}{f} \qquad v = c/n$$

Instensity modulate EM energy to specfic frequency

Principles of EDM

ADVANTAGE OF USING EDM

1 Precise measurement of distance
2 Capabale of measuring long distances
3 Relectroless are single person operation

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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, amd elevation factors can be input and applied
- The total stations may internally perform and save the observation or these data may be download to anexternal 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.

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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.

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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

Blunders:

- **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

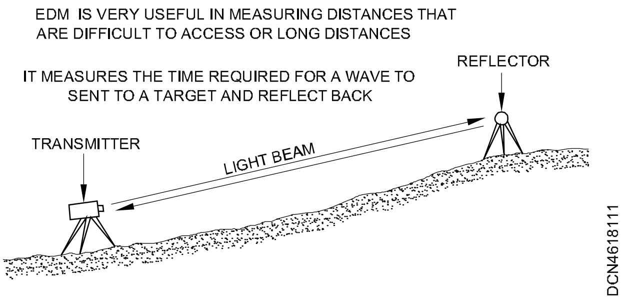
o---o----------------------------o

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



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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

- 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 plummet, 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

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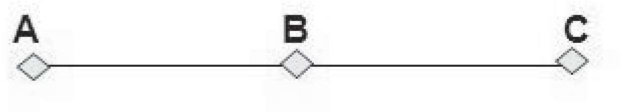
Determination of System Measuring Constant



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 ard 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 te 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, curveture 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

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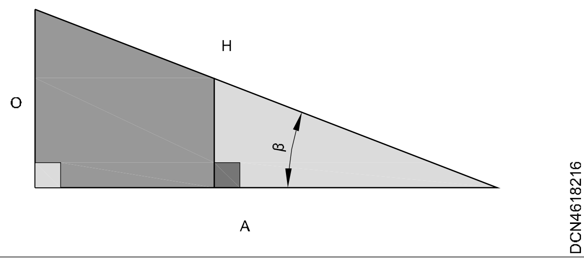
Uses

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

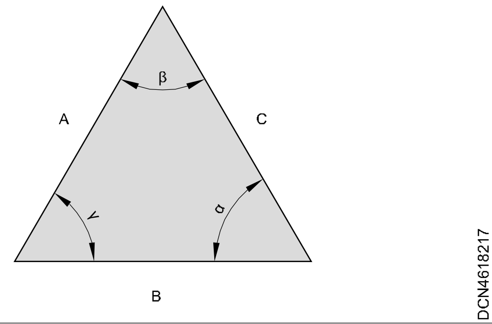
- Total stations are dependant on batteries and electrinics. The LCD screen does not work well when it is cold.
- Battery life is also short, batteries and electronics both do not work well when wet.
- Total stations are typically heavier that a transit and tape
- Loss of data is an important consideration
- 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

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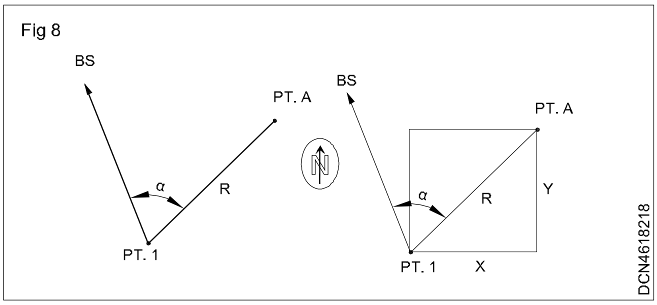

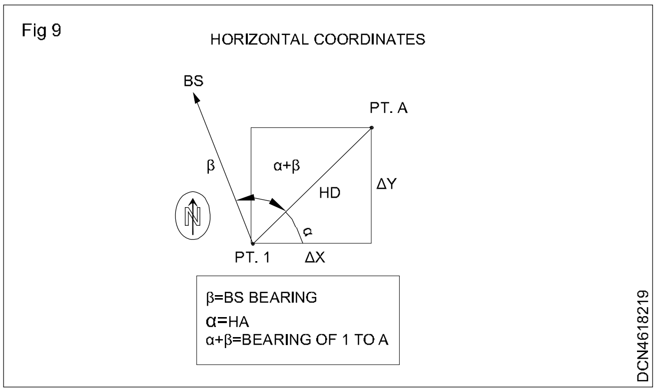

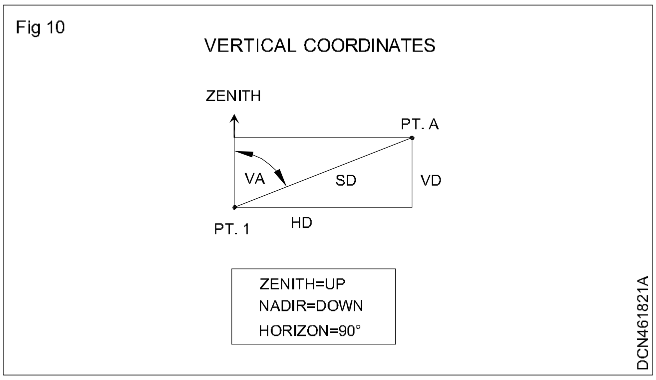

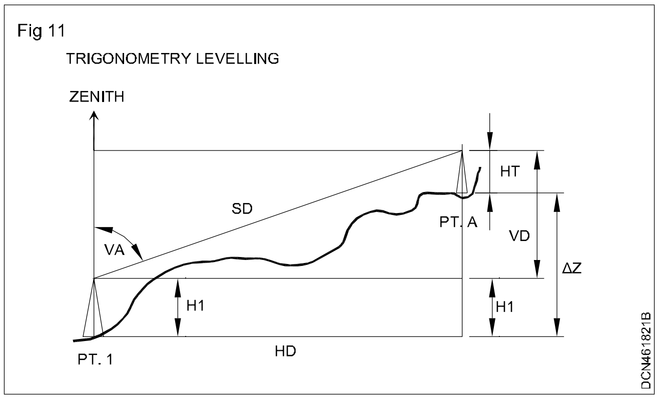

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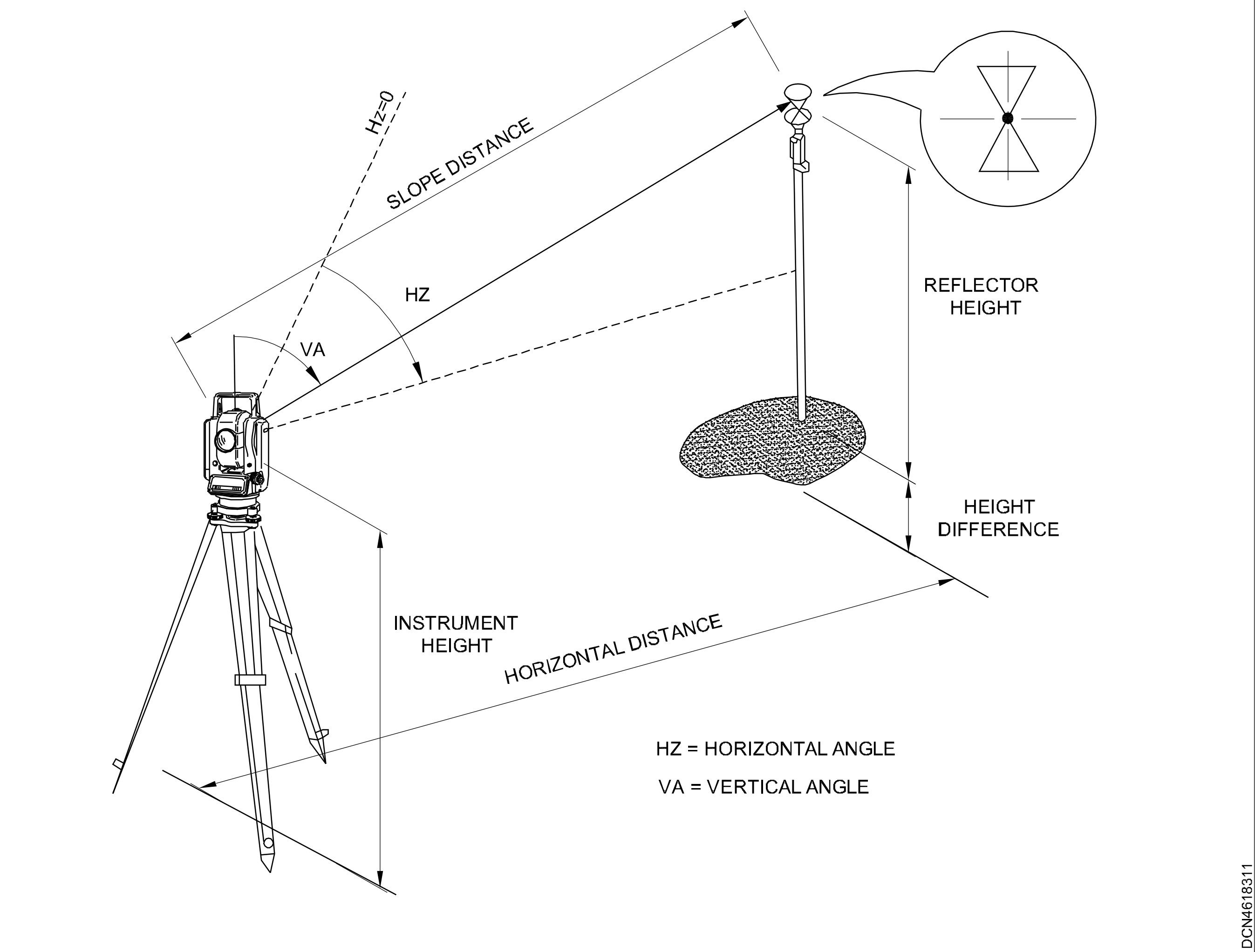
Electronic Display & Data recording

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.

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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 enty.

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.

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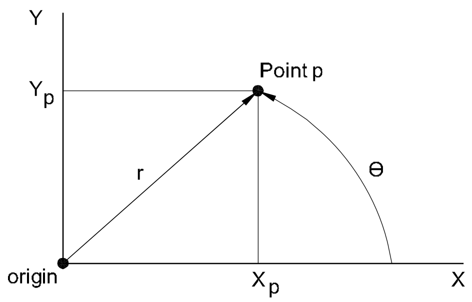
Rectangular and Polar Co-ordinate System

Objectives : At the end of this lesson you shall be able to
- **illustrate Rectangular and polar coordinates.**

Rectangular and polar co-ordinates Fig 1

Fig 1



Point p can be located relative to the origin by Rectangular Coordinates (X_p,Y_p) or by Polar Coordinates

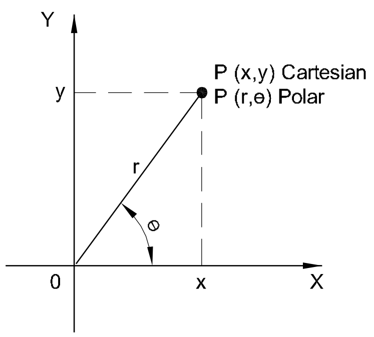
$$Xp = r\cos(\theta) \qquad r = \text{sqrt}\left(X_p{}^2 + Y_p{}^2\right)$$

$$Yp = r\sin(\theta) \qquad \theta = \tan^{-1}\left(Y_p / X_p\right)$$

Converts from Polar to Cartesian coordinates.

Transformation coordinates Fig 2

Fig 2

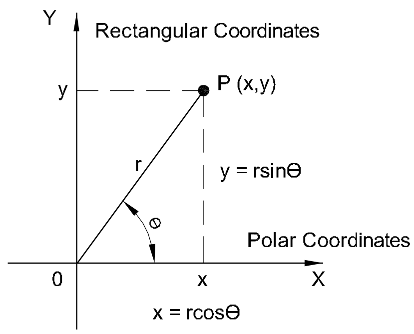


$$\text{Polar}(r,\theta) \rightarrow \text{Cartesian}(x, y)$$

$$x = r\cos\theta c y = r\sin\theta$$

Rectangular Coordinates Fig 3

Fig 3



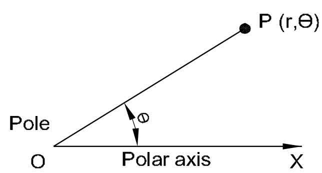
Polar Coordinate System

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

Fig 4



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Plot the points with the given polar coordinates Fig 5

P $\left(2, \pi/3\right)$ Q $\left(-1, 3\pi/4\right)$ R $\left(3, -45°\right)$

Fig 5

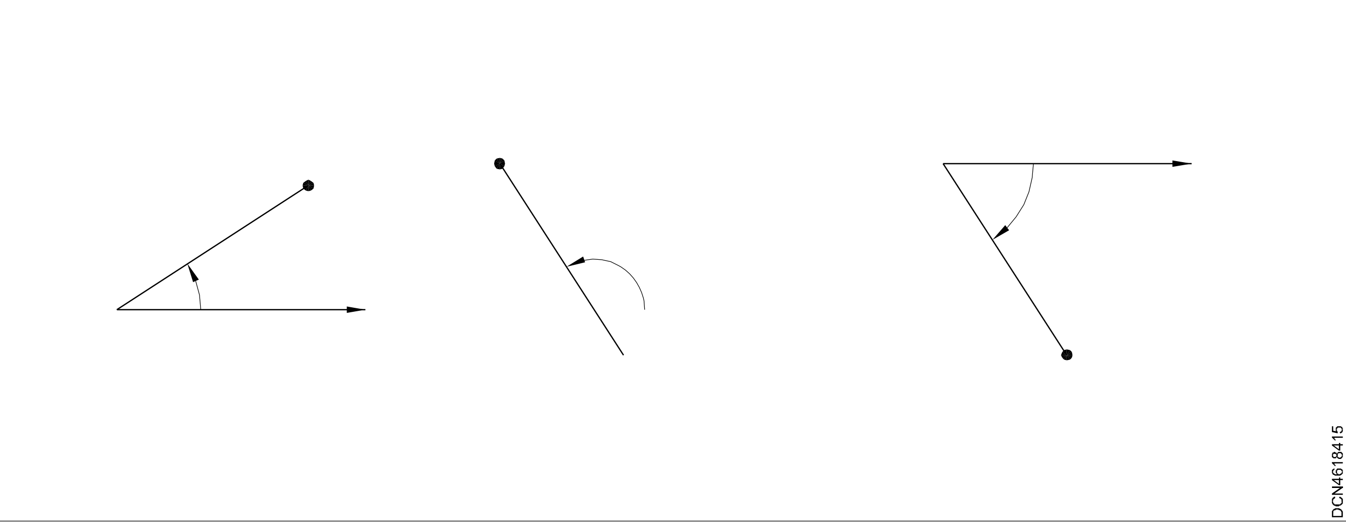
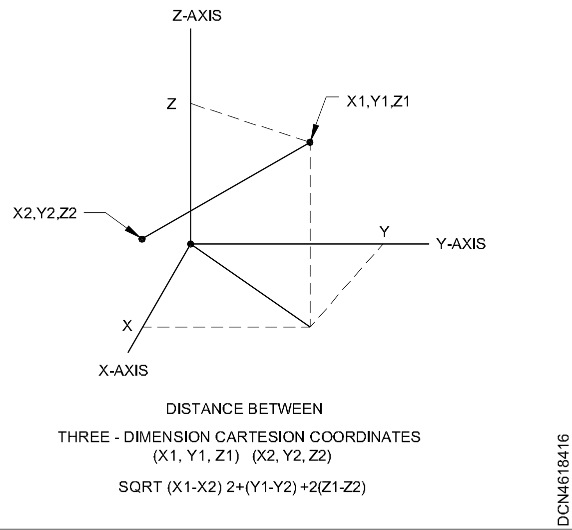


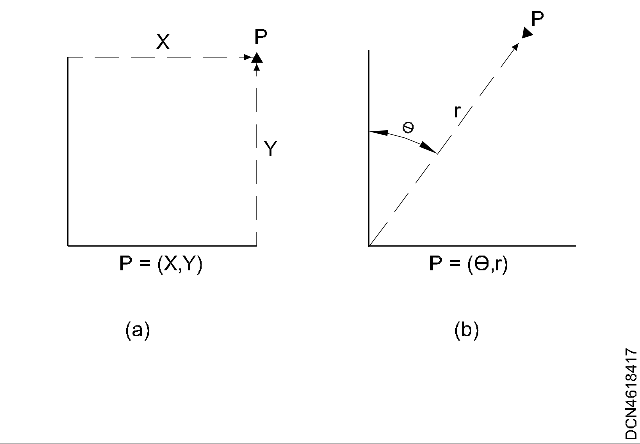
Fig 6



Cartesian coordinates Fig 7a

Polar coordinates Fig 7b

Fig 7



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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).

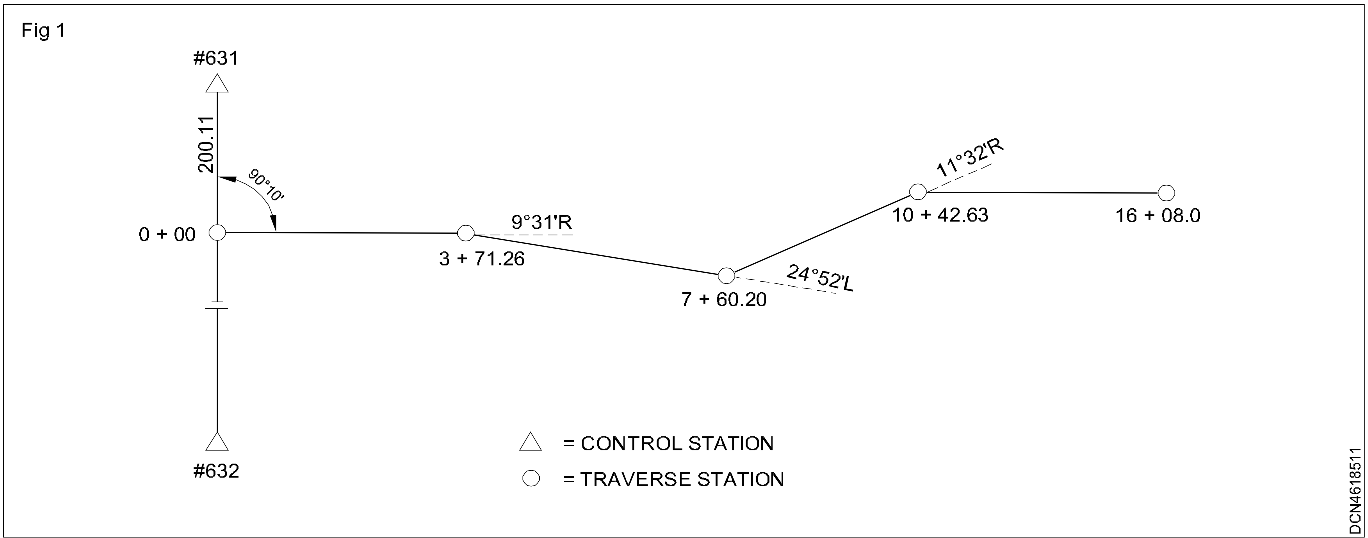

Figure 1: Open traverse

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.

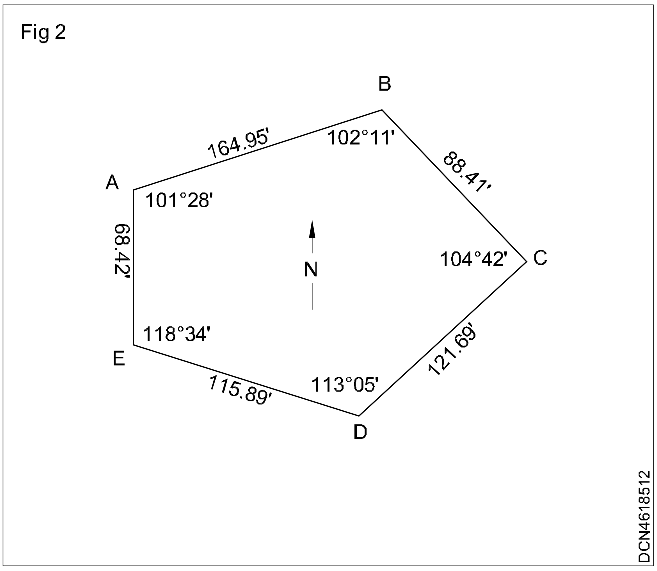

Figure 2: Closed traverse or lop traverse

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.

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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.

Figure 3: 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, 0 + 00. See Figure 3 for typical field notes for a route 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. Figure 4 illustrates typical field notes for a loop traverse survey. In this of 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 travers 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?

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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 longtitude**
- **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 hasbecome 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 thes “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 tovirtually 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 provideing 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 anouther use for GPS. Astronomical observatories, telecommunications facilities, and laboratory standards can be set toprecise time signals or controlled to accurate frequencise by special pupose GPS receivers.

Definition

For thousands of yers, 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 receiveres 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 tocontrol 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 iformation 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, postioned 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 questionposed 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 accuacies. For each required level of accuracy, receiver characteristics and the measurement techniques

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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 current 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 themost 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”.

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- 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 y our 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, andevents 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 Interneet 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.

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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.

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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-invarint 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 accu- rate 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 sysem 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, an. ... 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 radionavigationsystem 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 ...

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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 **Accuacy**. 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.

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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.

Fig 1

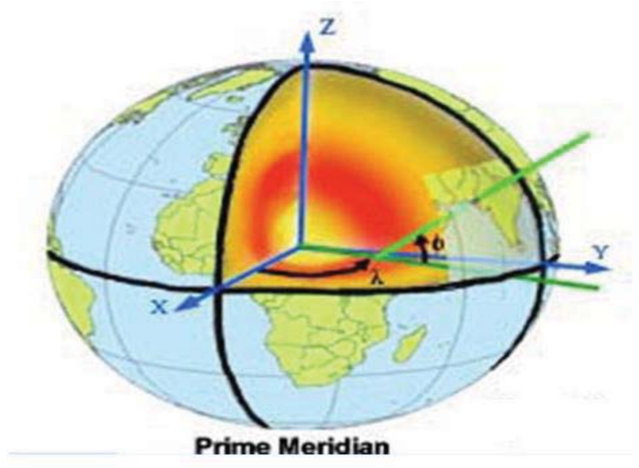
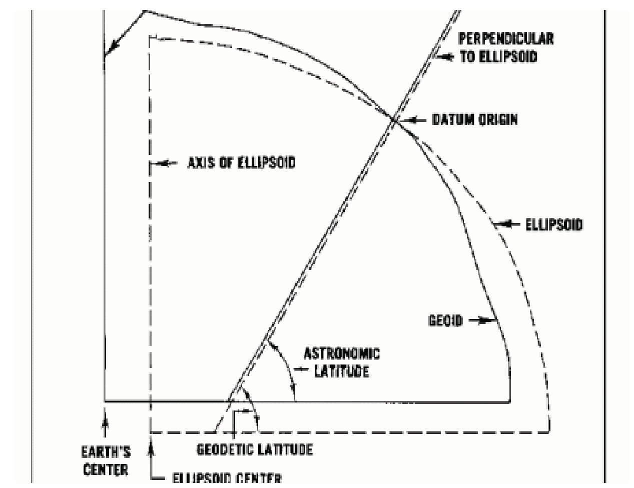


Figure 2

Geoids and Vetical Datums

The next will discuss geoids and vertical datums.

Fig 2



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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

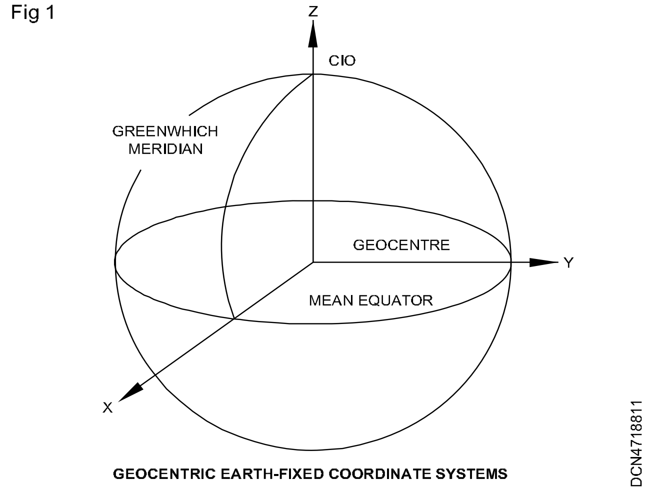
In 1884, the United states hosted the Internation Meridian Conference and twenty-five nations attended. Twenty-two of them agreed to adopt the longitude of the Royal Observatory in Greenwich, England, as the zero-reference line. The Dominican Republic voted against the motion, while France and Brazil 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

Fig 1



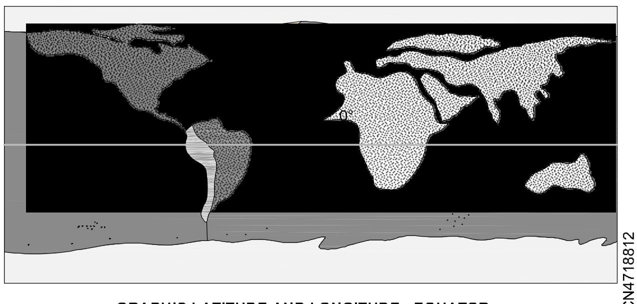
GEOCENTRIC EARTH-FIXED COORDINATE SYSTEMS

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 verticalpostion, and two or three of the numbers represent horizontal position. A common choice of coordinates is latitude, longitude and elevation.

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.

Fig 2



GRAPHIC LATITUDE AND LONGITUDE - EQUATOR

The "longitude" (abbreviation: Long., I, 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 orgnizations - such as the French Institut Geographique National - continue to use other meridians for internal purposes. The Prime Meridian determines the prper 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

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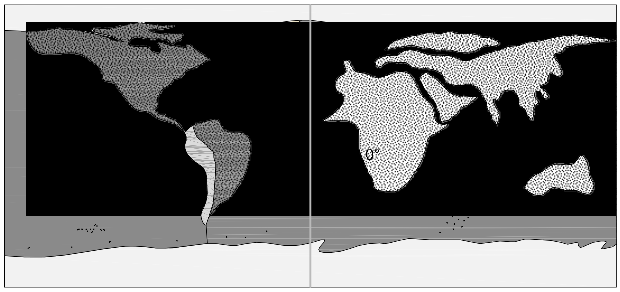
International Data line, which diverges from it in several places for political reasons including between far eastern Russia and the far western Aleutian Islands Fig 3.

Fig 3

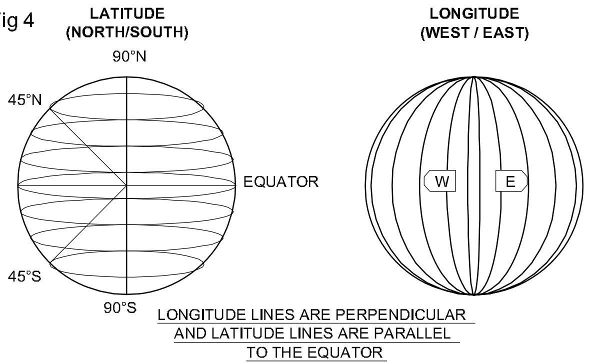


GRAPHIC LATITUDE AND LONGITUDE - PRIME MERIDIAN

DCN4718813

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



GRAPHIC LATITUDE AND LONGITUDE

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Reading coordinates

To simplify map navigation, a system of coordinates is used. Coordinates diveide the map into a grid and identiry a particular locationa 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 latitue 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 reciver 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

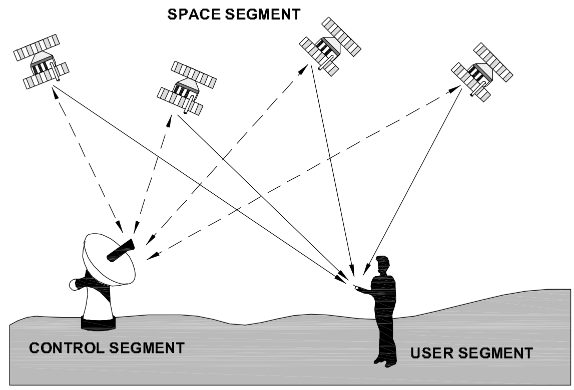
2 Control Segment - ground stations run by the DOD

3 User Segment - all users and their GPS receivers

Vocabulary / Definitations

GPS	:	Golbal 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.

Fig 5



SEGMENTS OF GPS SYSTEM

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Trilateration : Postion determined by intersecting distances.

Triangulation : The location of an unknown point by the formation of a triangle.

Each segments is described in the following sections

1 Space segment Fig 6

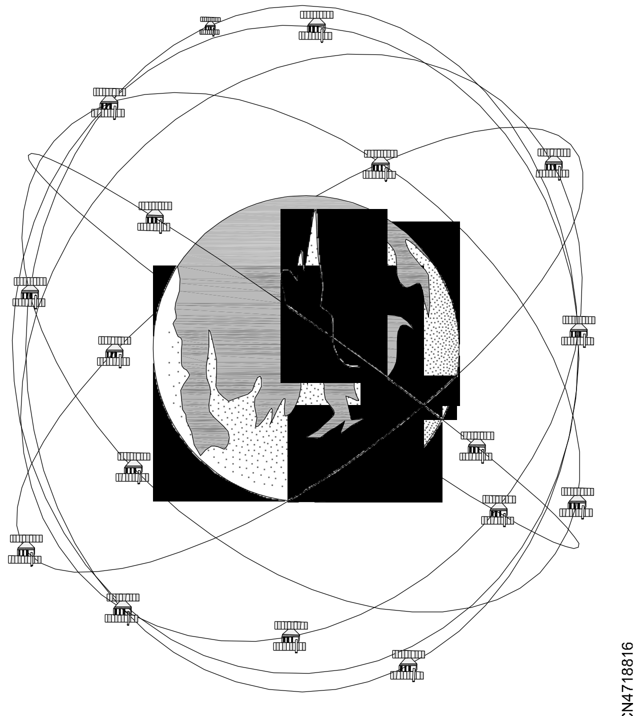
The space segment consists of the GPS staellites. Much of the GPS literature reers to the satellites as “space vehicles” or simply, SV’s. The arrangement of GPS satellites in space is called their constellation. The minimum constellation to meet the objecives of the DOD is 24 operational satellites.

The orbit altitude wa 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.

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 entennas, 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.

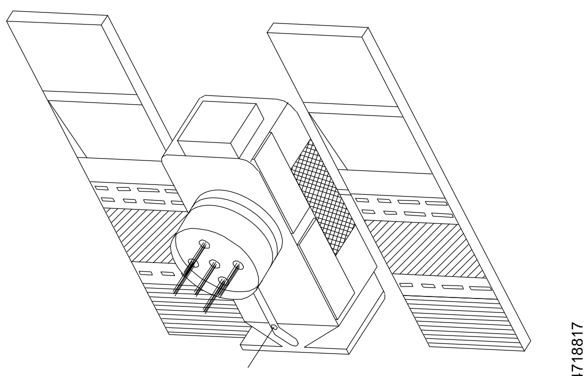
The first GS satellite was deployed in February 1978. By 1994, a total of 24 operational satellites were inplace. Replacements and upgraded satellites have been launched on a regular basis. As of early 2001, a total of 43 satellites had been launched, and the operational constellation consists of 28 satellites. The number of satellites reported in various books, articles and internet resources varies considerably, reflecting the data that the work was prepared.

Fig 6



SEGMENT

Fig 7

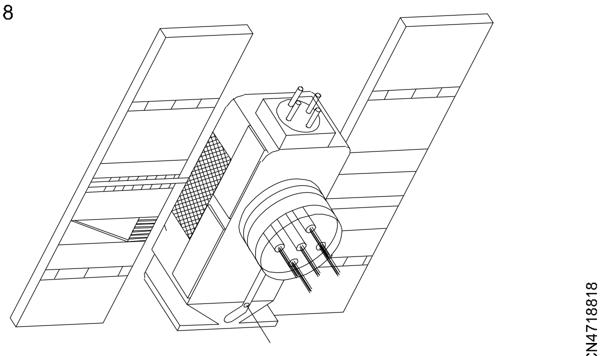


TYPICAL GPS SATELLITE

GPS satellites

Four classes (generatons): blocks I, II, IIA, IIR and IIF Block I (Fig.8)

Fig 8



BLOCK I SATELLITE

- 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

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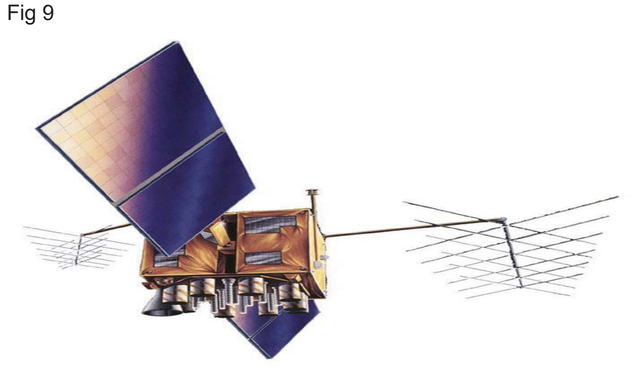
Block II (Fig.9)

- 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

Fig 9



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 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.

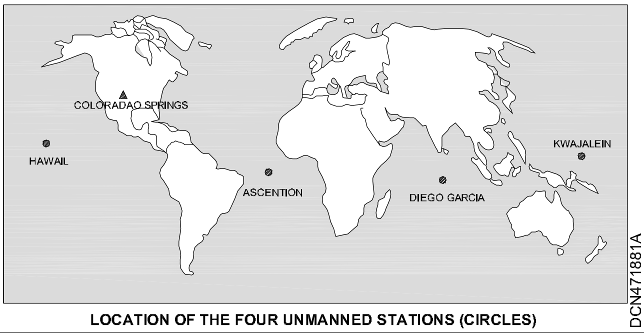
The monitor stations recive all satellite signals from which they determine the pseudo range to all visible satellites and transmit the ranged data along with local meteorological data via data link to the master control station. From these data the master control station precomputes satellite ephemerides 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

Fig 10



LOCATION OF THE FOUR UNMANNED STATIONS (CIRCLES)

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 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 reciver 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 signa 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.

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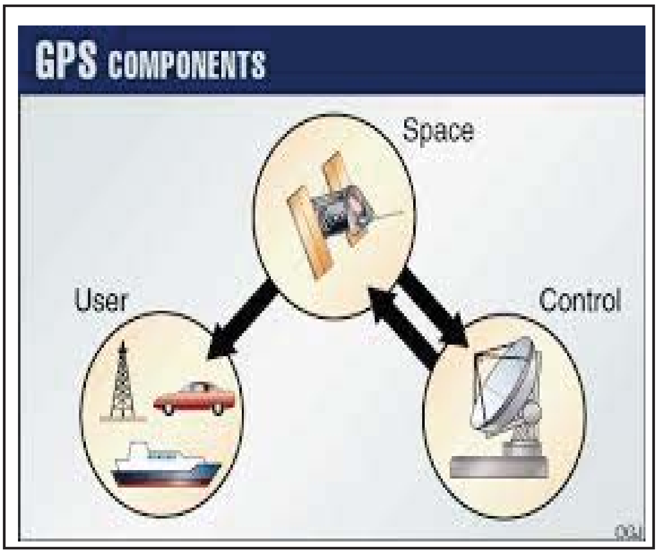
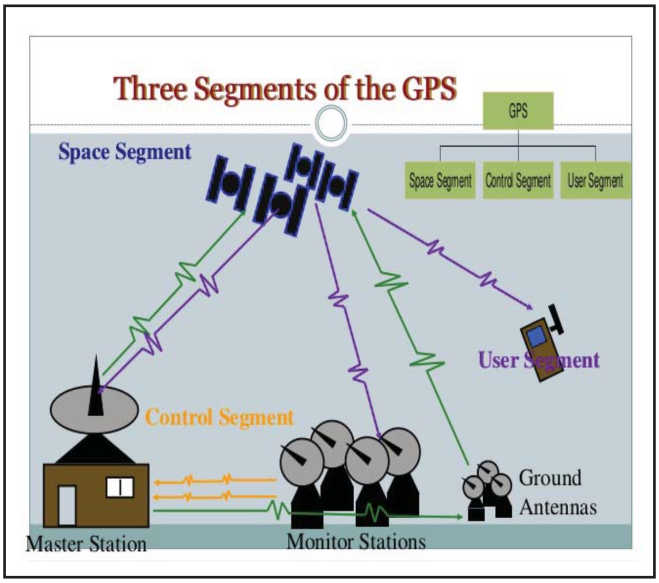
GPS Segments

Objectives : At the end of this lesson you shall be able to
- **define GPS Segments.**





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

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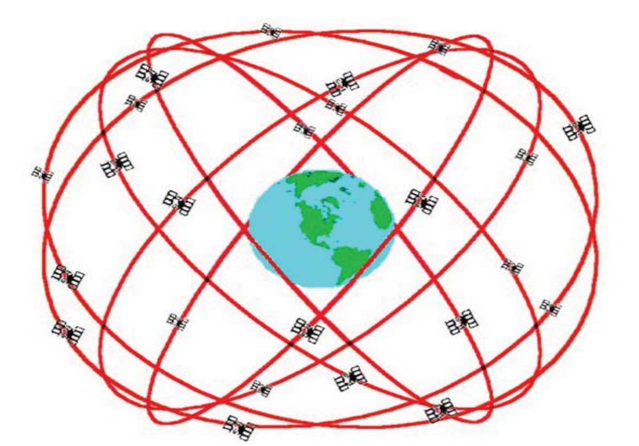
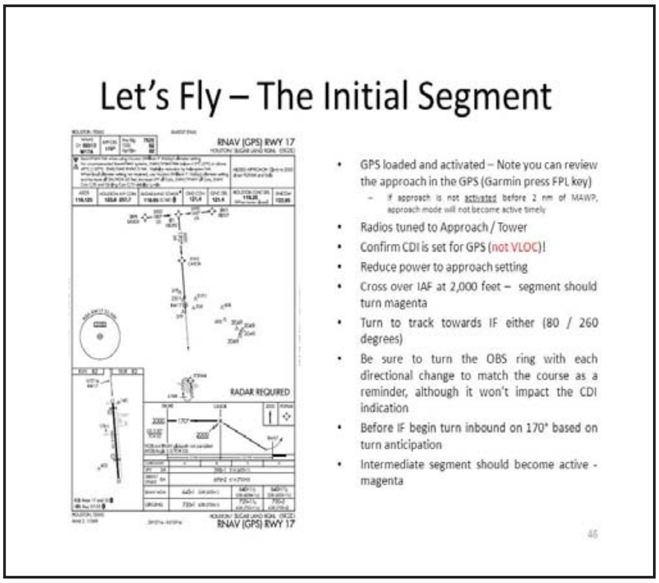


GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

Let's Fly - The Initial Segment

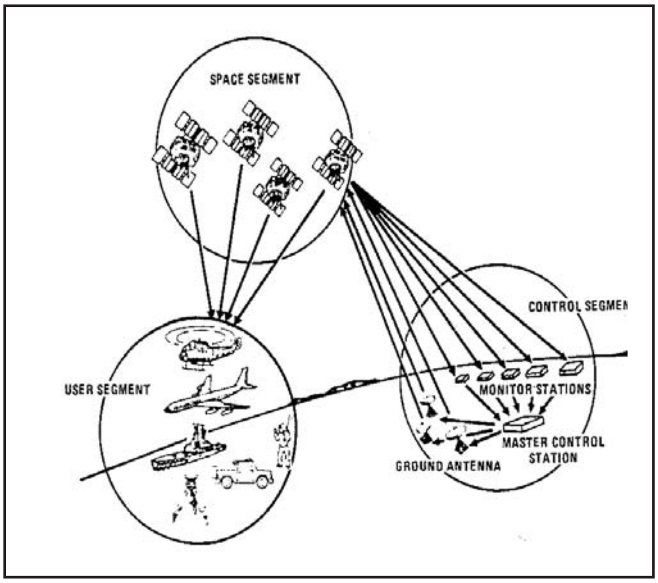
- GPS loaded and activated - Note you can review the approch in the GPS (Garmin press FPL key)
  - If approach is not activated before 2 nm of MAWP, approach mode will not become active timely.
- Radios tuned to Approach/ Tower
- Confirm CDI is set for GPS (not VLOC) !
- Reduce power to approach setting
- 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.



The 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 4.

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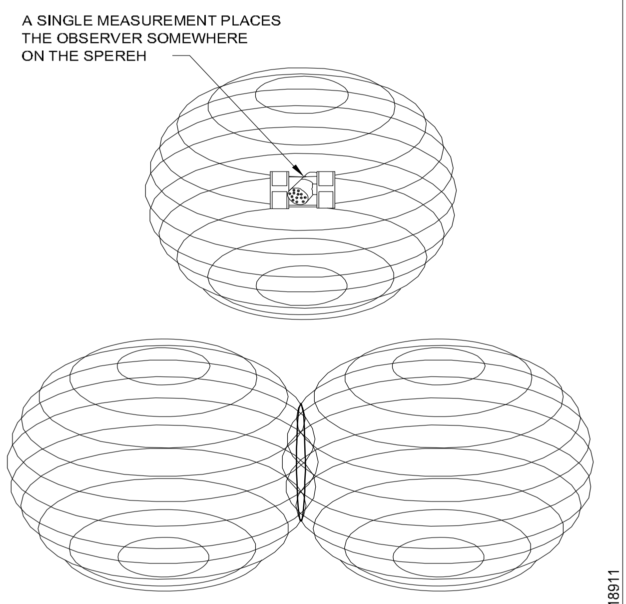
Principle of operation of GPS & surveying with GPS

Objectives : At the end of this lesson you shall be able to
- **state principle of operation of GPS**
- **describe role of transit in GPS developmen**
- **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

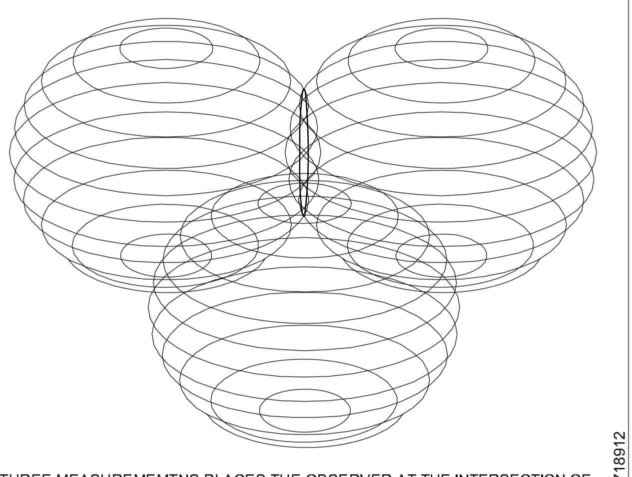


TWO MEASUREMENTS PLACES THE OBSERVER SOMEWHERE ALONG THE INTERSECTION OF TWO SPHERES (DESCRIBED BY A CIRCLE)

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 serice from 1964, initially for Polaris submarines and later for civilian use as well.

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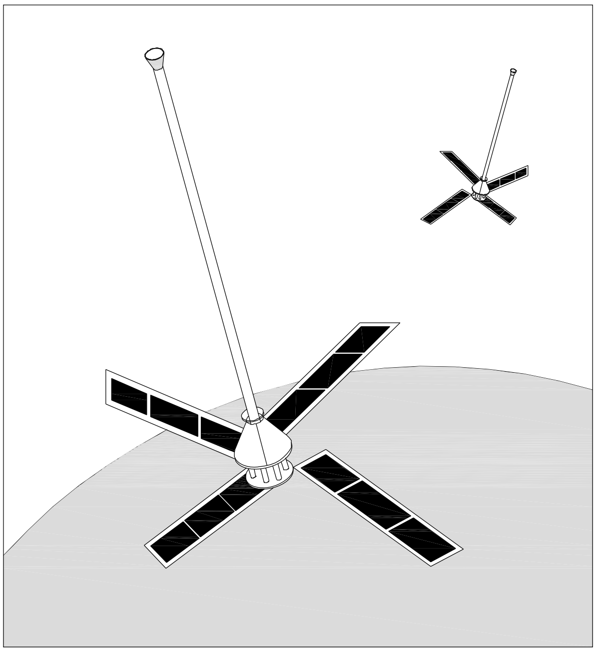
Fig 3

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 Macrometer 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,Zcoordinates of each satellite are known (by computation), the coordinates of a ground point can be determined by measuring the ranges to at leat three satellites. In practice, the ranges to a minimum of four satellites are meaured 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.

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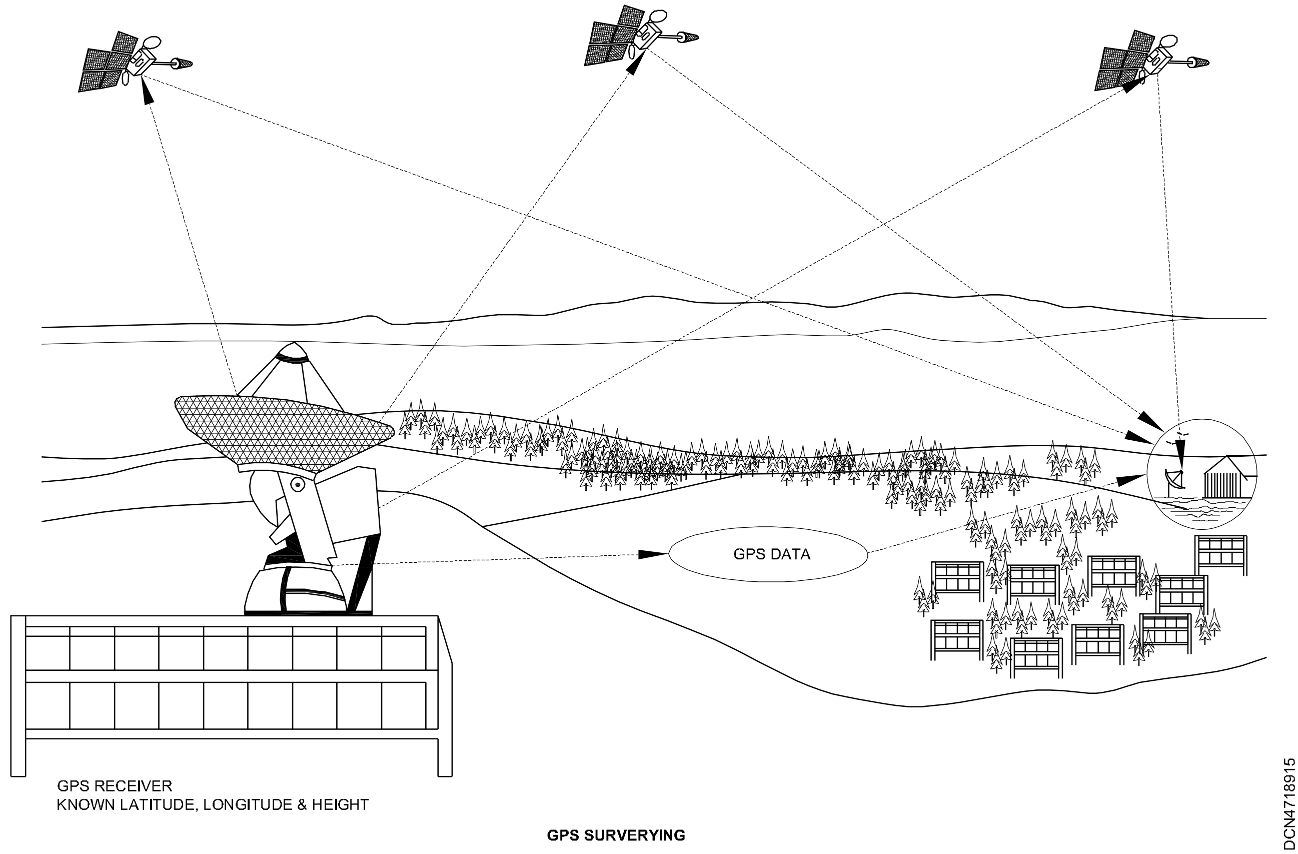
Fig 5



GPS SURVERYING

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 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.

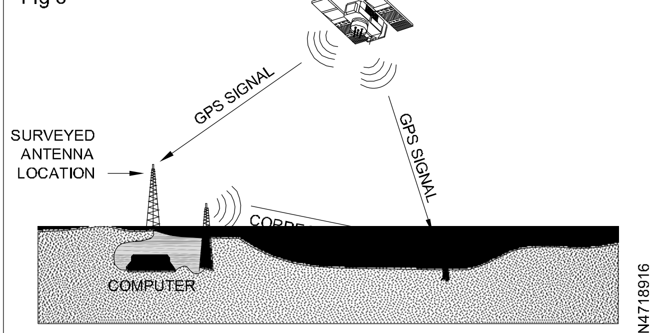
Real time kinematic GPS surverys

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.

Fig 6



REAL-TIME DGPS CONFIGURATION

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.

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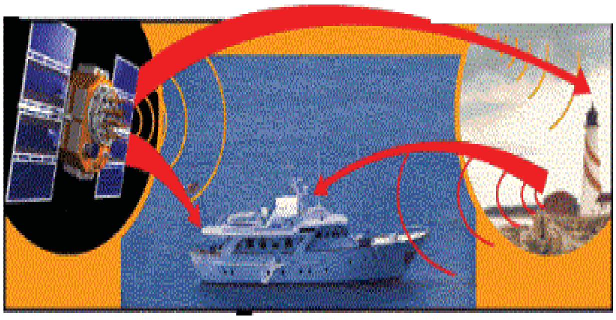
The following figure illustrates the Real-times DGPS configuration. Note that only one satellite is shown. In reality, the base station must receive signals from all the satellites visible to the roving reciver.

Fig 7



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 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.

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.

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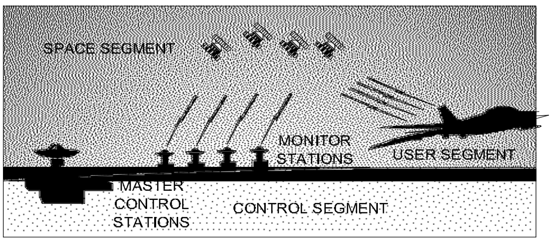
Principle of operation of GPS & positioning system

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

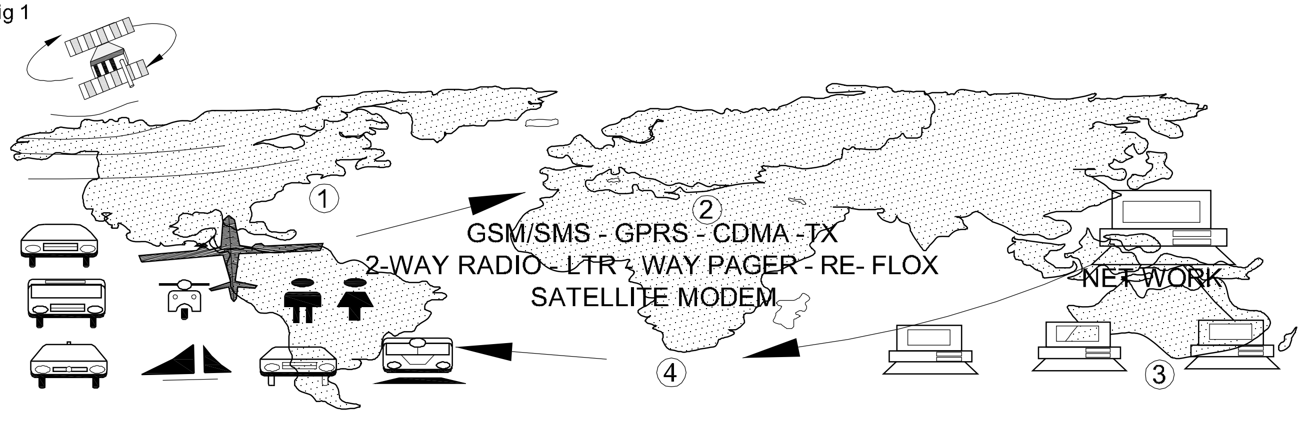
The Master Control Station receives the monitoring station tracking and ground antenna telemetry information and computes the current and predicted satellite clock offsests and satellite positions. It then converts this data to the navigation data formats described later. These rather complex satellite 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 developemtn 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 astationary receiver of a tracking 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

Fig 1



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

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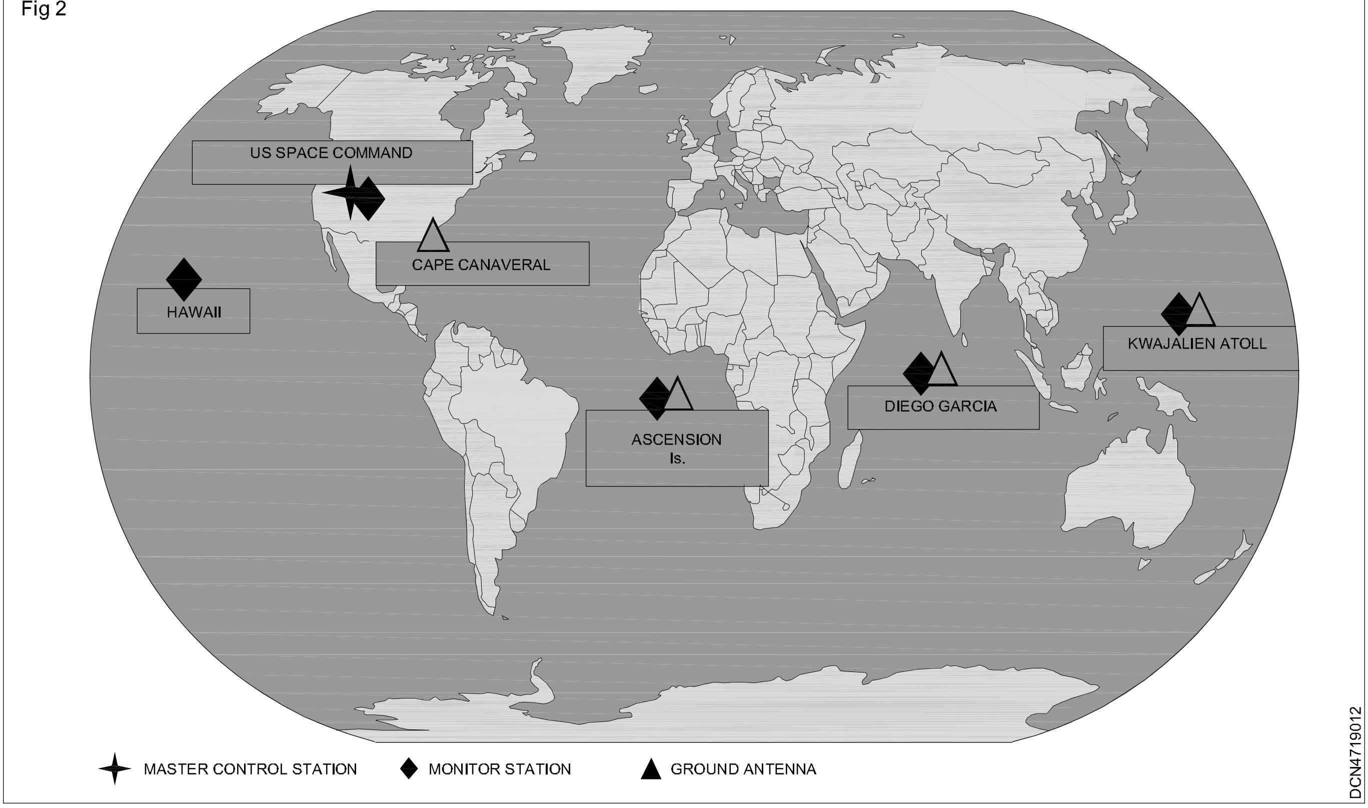
Fig 2

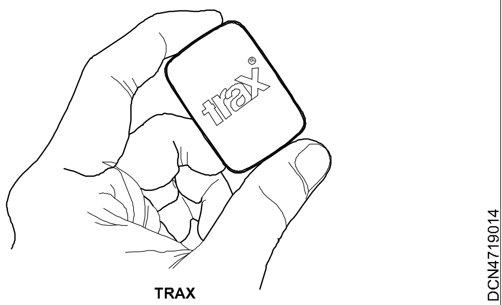


system consists of a GPS receiver inside the vehicle and a communications link between the vehicle and the control Center as well as pc-based tracking software for dispatch. The communication system is usually a cellular network similar to the one used by your cell phone.

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 ave crept into the market without you realising it. Here is a list of the top personal tracking devices.

Fig 4



TRAX

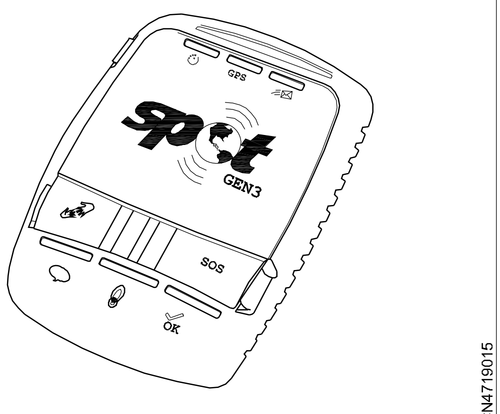
1 Tax (Fig.4)

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 ou 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.

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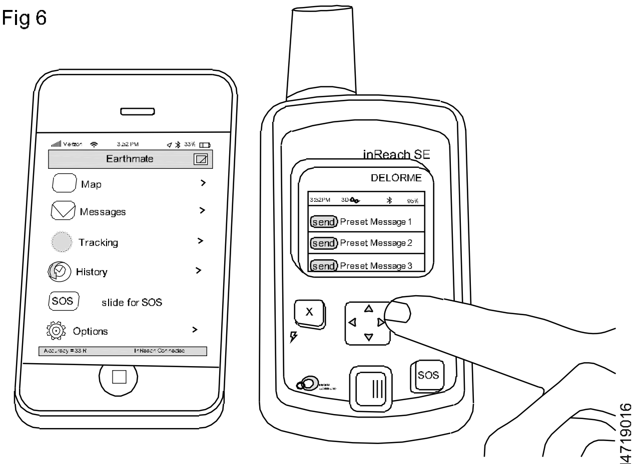
Fig 6



DELORME INREACH SE

DCN4719016

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 onw 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

DCN4719017

5 Real-Time Correction of Multiple Receivers Inverse DGPS

Suppose you are interested in accuatelly 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 reauires 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 publis 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.

Fig 8

MARINE GPS RECEIVER

DCN4719018

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 has led to widespread private and commercial use. An exlample 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.

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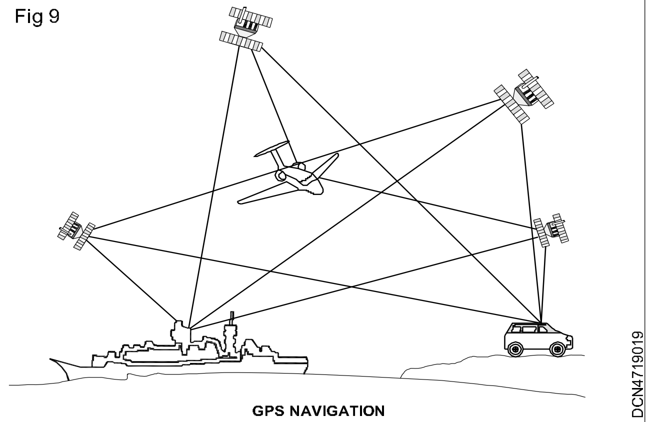
GPS for visually impaired: The projects of the navigation system using GPS for the visually impaired have been conducted quite a few times. GPS was introduced in the late 80's and since then there have been several research projects such as MoBIC, Drishti, and Brunel Navigation System for the Blind, 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 ratee 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.

Fig 9



GPS NAVIGATION

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

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.

On our nation's waterways, GPS is being used for recrreational 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 minimal 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.

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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 beig used within specifications, helps manage maintenance scheduling and minimizes theft.

Fig 10

ONE OF JAPAN'S GPS RECEIVERS

DC47041A

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Remote sensing

Objectives : At the end of this lesson you shall be able to
- **explain remote sensing**
- **distinguish between GPS, GIS and CAD.**

Introduction

Geographic Information System (GIS) are a new and blossoming concept, and conitnue to grow in complexity and utility thanks in large part to the preceeding and conitnual development of Remote Sensing. Remote Sensing plays a large role in the enhancement of any GIS, and in most cases, allows data to become much more relatable and useful for anyone. A GIS receives much of the data for its built-in layers from Remote Sensing platforms such as satellitesm radars and airplanes. Passive sensors contribute to imagery and data for land after mapping, change detection, snow monitoring, thermal changes and terrain modeling. Active sensors contribute heavily to data for extremely accurate terrain models known as Digital Elevation Models(DEMs). These large quantities of data can be goe-referenced and integrated into one large GIS, allowing a user to access a powerful amount of information at one time with relative ease. And as remote sensing technology continues to increase in resolution and power, the data base will enlarge and increase the potential power of users of a Geographic Information System.

Remote sensing

The term remote sensing is defined as the study of something without making actual contact of study. It can be precisely defined as the science and art of acquiring information about a material object by making measurements at a distance from without coming into a physical contact with the help of the electro magnetic energy it radiates.

Whatever working definition we use to describe remote sensing, the concept is that it involves making observations remotely or with physical contact with the object. The remote nature these technoligies allow us to make observations, take measurements produced images of phenomena that are beyond the limits of our own senses and capabilities.

Remote sensing tools can be used to study things on all scales ranging from the smaller within the atom to the universe as a whole. While remote sensing tools are often associated with researchers and scientists who conduct scientific inquiry.

The common man also pracitices natural remote sensing in his day to day life in one form of the other.

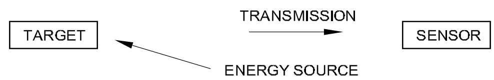
Component parts of a remote sensing system

There are four basic components of a remote sensing include a target an energy source, a transmission path and a sesnsor

Fig 1a

COMPONENT PARTS OF A REMOTE SENSING SYSTEM

Fig 1b



COMPONENT PARTS OF A REMOTE SENSING SYSTEM

The target is the object or material that is being studied. The components in the system measure and record information about the target without actually coming into physical contact. There must also be an energy source which illuminates or provides electromagnetic energy and will act as a medium for transmitting information from the target to the sensor. The sensor remote device that will collect and record the electromagnetic radiation.

Once the energy has been recorded, the resulting set of data must be transmitted to a remote where the data are processed into usable format which is most often as an image. The image interpreted in order to extract information about the target. This interpretation can be done electronically with the aid of computers and image processing software.

Weather satellite imaging of the earth is a familiar example of a remote sensing system. Such system is the earth's surface, which gives off energy in the form of infrared radiation energy.

Two types of remote sensing"

Aerial photography (Fig 2)

Aerial photographs are acquired with the help of specially designed cameras which are mounted on the aircraft. Theses aircrafts fly over the ground and record the photographs of the area. Aerial photography analyses have played major roles in discovery of many oil and mineral deposits around the world. Phototrammetry is defined as the art, science, technology of obtaining reliable information about physical objects through processes of recording, measuring and interpreting photo images. It is a technique of producing 3-dimensional coordinates from two-dimentional photographs.

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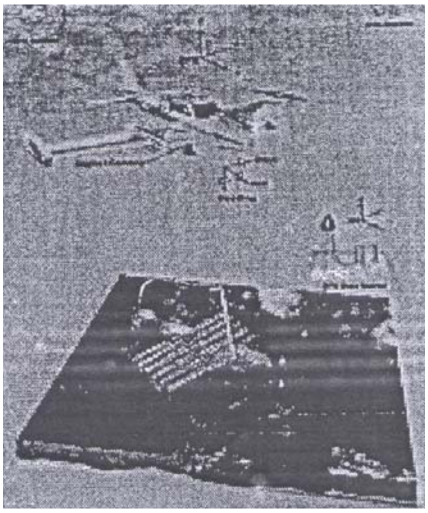
Fig 2



AERIAL PHOTOGRAPHY

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Satellite remote sensing (Fig 3)

In case of satellite remote sensing, sensors are mounted on the satellites which record the reflectance value from various objects and form a digital image. The satellites revolve around the earth at several hundred kilometres from the earth's surface.

Fig 3

SATELLITE REMOTE SENSING

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Comparison of GPS with GIS & CAD

As a start, GPS (completely known as Global Postioning System) is one of the ways to precisely pinpoint specific location in almost any place on the planet. Simply, it is a network of satellites that determines specific coordinates on earth. This network usually operates by the transmission of certain radio signals from the said satellites into the GPS receivers on the planet using the process known as trilateration. Using the US government's advanced tracking satellite technologies, the GPS system can also locate coordinates with the combination of multiple GPS satellites, receivers and oftentimes a processing circuit for data.

This techonology was first developed for the purpose of the US military, but little did they know that this invention could one day revolutionize how people look for what they are trying to find. The GPS has now been used in practical day to day applications and makes life easier. At present, this system is being used universally to navigatem to map an area and even to survey a specific geographical location.

On the other hand, GIS is frequently confused with GPS because it is a more generic acronym (Geographic Information System) used to describe a more complex mapping technology that is connected to a particular database. Because it's generic, it is a broader therm than the GPS in its technical sense. Thus, GIS is a computer program or application that is utilized to view and handle data about geographic locations and spatial correlation among others. It simply gives the user a framework to obtain information.

Overall, the difference between a GPS and a GIS can be summed up:

1 The GPS (Global Positioning System) is a network that localtes certain places here on earth whereas the GIS (Geographic Information System) is a computer program that process data linked to certain places or locations.

2 The GIS is more generic framework compared to the specific GPS network.

Examples of GPS and GIS

Global Positioning System (GPS) (Fig 4)

An agricultural producer may use a handheld GPS receiver to determine the latitude and longitude coordinates of a water source next to a field or vineyard.

Fig 4

GPS

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Global Information System (GIS) (Fig 5)

Following a chemical spill, maps obtained from a GIS system can reveal environmentally-sensitive areas that should be protected during response and recovery phases.

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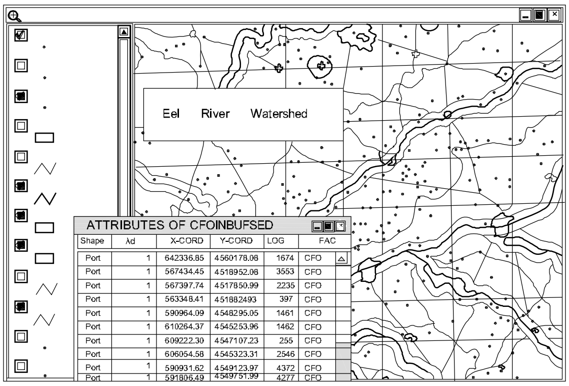
Fig 5



GLOBAL INFORMATION SYSTEM

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With GIS software, information from a GPS unit may be combined with data such as:

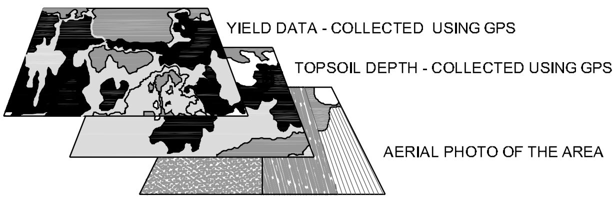
1 USGS topographical maps
2 Digital elevation model
3 Critical infrastructure maps
4 Aerial photography
5 Crop land use
6 Census maps

“Layered” maps can be generated by the GIS software.

Example of map “Layers” (Fig 6)

A GIS database creates “layers” with many pieces of information visualized for the same area.

Fig 6



EXAMPLES OF GPS AND GIS

DCN4719116

CAD and GIS

The difference between CAD and GIS systems is becoming blurred with the internal attributes and database linkages enhancing CAD;s capabilities.

1 GIS data normally covers a large geographic area, where CAD data are normally much smaller areas.
2 GIS data is normally displayed at smaller scales than CAD data.
3 GIS data is often captured with less accuracy than CAD data.
4 GIS data normally include attribute information, where CAD data historically haven’t. But this is changing and Information Modelling is becoming an important part of “Data Mortality” as discussed by Greg Bentley during the BeInspired conference.

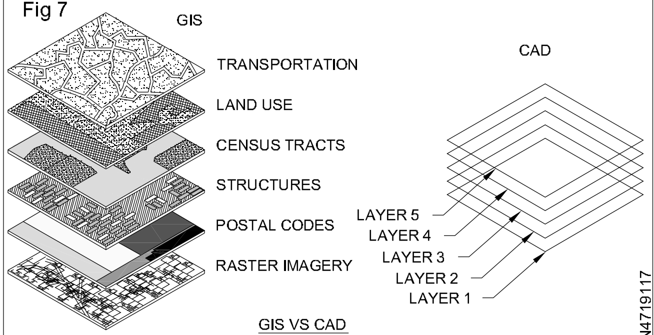
But what happens when you combine GIS and CAD requirements within one solution. Basically you get highly spartially accurate data with attribute information, and from what I seen this is where the CAD software vendors are heading with their Information Modelling products.

GIS is a database program, and CAD is a graphics program. With CAD, it’s the lines that are important, i.e. the drawing is the information. With GIS, the lines are just a representative of the data behind it.

Data layer examples (Fig 7)

GIS vs. CAD

Fig 7



DATA LAYER EXAMPLES

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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, imagepattern recognition, DSP, neural network architecture, microcomputer, ADSP 2189, Analog Devices, character recognition system, error probability

Data Acquisition Systems

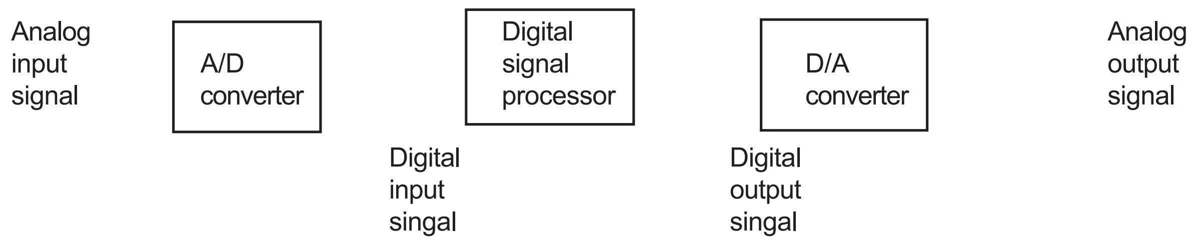
- Data Acquisition (DAQ)

  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.

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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.

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

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 todata 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 hadware redesign, testingm 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 ten to spoil analog signals.
- Reduced cost
- Flexibility in response to design changes
- Noise immunity
- Easy to control and manipulate

Digital transmission system

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Why to Apply Digital Transmission?

Advantages of Digital Communication Over Analog Modulation:

- There are many advantages of using Digital Communication over analog Communication. Some of them are listed as below: The digital communication has mostly common structure of encoding a signal so devices used are mostly similar.
- The Digital Communication's main advantage is that it provides us added security to our information signal.
- The digital Communication system has more immunity to noise and external interference.
- Digital information can be saved and retrieved when necessary while it is not possible in analog.
- Digital Communication is cheaper than Analog Communication.
- The configuring process of digital communication system is simple as compared to analog communication system. Although, they are complex.
- In Digital Communication System, the error correction and detection techniques can be implemented easily.

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).

The observation equation for the difference between two signals collected with a single

receiver has the following form, derived from (2):

Rssig^{1}sig^2,r=Rssig^1,r=c(Bsig^2,r-Bssig^2-Bsig^1,r+Bssig1)+Mssig1sig2,r+Rsig1sig2,rs-Rsig1,rs=c(Bsig2s-Bsig1,r+Bsig1s)+1fsig1fsig2,rs+Msig1sig2,rs+Rsig1sig2 (5)

This difference is sometimes referred to as the geometry-free linear combination, as all geometric terms are canceled out. These include the geometric range, the clock errors, and the tropospheric delay. The term Bsig2,r-Bssig2-Bsig1,r+Bssig2,r-Bsig2s-Bsig1,r+Bsig1 s refers to the combined receiver and satellite DCB. The DCB term might be separated into receiver-specific and one satellite-specific DCB term,

DCbssig1sig2,r=DCBsig1sig2,r-DCBssig1sig2DCBsig1sig2,rs=DCBsig1sig2,r-DCBsig1sig2s (6)

where

DCBsig1sig2,r-Bsig1,rDCBsig1sig2,r=Bsig2,r-Bsig1,r (7)

and

DCBssig1sig2=Bssig2-Bssig1DCBsig1sig2s=Bsig2s-Bsig1s (8)

In (5), fsig1fsig1 and fsig2fsig2 might be equal. In that case, even the ionosphere and multipath terms

cancel out and only the bias terms remain. Otherwise, both the ionospheric and multipath influences have to be accounted for beside the DCBs.

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As the ionosphere is a dispersive medium for all frequencies used by current GNSS carriers, GNSS signals modulated onto carrier waves of different frequency will be delayed by a different amount of time at the moment of reception in the GNSS receiver. DCBs are thereby of significant importance when we want to relate the TEC along the signal path in the atmosphere with a geometry-free linear combination of code observations from different carriers, as the DCB delay adds to the ionospheric delay in the measurements. Separation of these two terms is therefore necessary in order to estimate TEC from GNSS measurements. This is a technique which is used for instance in GNSS-based ionospheric modeling (Jensen et al. 2007).

GPS system time correction parameters transmitted in the broadcast navigation message are given with respect to the ionosphere-free linear combination of the P-code signals on L1 and L2 (IS-GPS-200H 2013). This is achieved by the satellite clock corrections terms in the broadcast navigation message (Tetewsky 2009). Consequently, single frequency users of P-code on L1 and L2 have to correct their measurments with the T parameter supplied in the broadcast navigation message. This value corresponds to the differential delay induced in the satellite at the time of transmission of the P-code signals. The GPS Interface Specification documents IS-GPS-200H (2013) states that TGD=11-f2L1f2L2(tL1P-tL2P)TGD=11-fL12fL22(tL1P-tL2P) (9)

Replacing t_{LIP} - t_{L2P}in (9) by - $DCB_{P1P2}^{GPS,s}$, using the same sign convention as earlier, the relation between the T_{GD} parameter and the satellite DCB can be expressed as D C B G P S , s P I P 2 = (f 2 L 1 f 2 L 2 - 1)TGD+CDCBP1P2GPS,s=(fL12fL22-1)TGD+c (10)

The constant C has been added to the expression above due to the fact that only the total DCB, DCBssigsig2,rDCBsig1sig2,rs, is estimable from GNSS observations alone. The satellite and the receiver part of the total DCB can in practice only be separated if an additional constraint is added. This constraint is usually chosen to be either a mean value constraint, where the maean certain receiver is set to a certain value known beforehand (Montenbruck and Hauschild 2014). This will give the effect of a constant offset depending on the chosen

constraint in the estimation process. For a user relying on the C/A-code on L1 instead of the P-code, only the most modern GPS satellites, which includes the Block IIR-M, Block IIF and subsequent satellite blocks, transmit a C/A-code correction parameter called Inter-Signal Correction (ISC) in the newly implemented civil navigation (CNAV) message (IS-GPS-200H 2013).

As was suggested in the previous section, the receiver originating code biases are sometimes also dependent on the transmitting satellite. This is the case when the transmitted signals are distorted at the satellite payload (Edgar et al. 1999; Lestarquit et al. 2012). As the receiver

biases of both signals are constituents of the DCB, this effect of satellite dependence will also show up on the receiver DCB under the conditions mentioned above.

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.

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Table 1

GNSS Hardware biases

Bias type	Origin	Absolute/relative	Symbol used	Temporal variation	PPP user	Relative user
Receiver Phase bias	Recei Ver HW	Absolute	$b_{f,r}^{sys}$	Long term	Eliminate	Eliminate (CDMA) Calibrate/ Eliminate (FDMA)
Satellite phase bias	Satellite HW	Absolute	b_{f}^{s}	Long term	-	Eliminate
Satellite phase bias	Satellite HW		-	Short term	Correction	-
Intersystem bias (ISB) phase	Receiver HW	Relative	bsys1sys2f,r1r2bf, r1r2sys1sys2	Long term	Estimate	TC: Estimate/Calibrate LC: Eliminate
Bias type	**Origin**	**Absolute/relative**	**Symbol used**	**Temporal variation**	**PPP user**	**Relative user**
GLONASS inter-frequency bias (IFB) phase	Receiver	Relative	bCGLOr112+fs. bVGOr1r2bcr1r2 GLO+kfs.bvr1r2GLO	Long term	Estimate/ Calibrate	Calibrate/ Eliminate
Receive SS bias	Recei HW	Absolute ver	$B_{sig,r}^{sys}$	Long	Elimin term	Eliminate ate (CDMA) Calibrate (FDMA)
Satellite code bias	Satellite HW	Absolute	B_{sig}^{sys}	Long term	-	Eliminate
Differential Code bias (DCB)	Satellite and receiver HW	Relative	DCBssig1sig2,rDCB sig1sig2,rs f	Long term	Calibrate	Calibrate
Intersystem bias (ISB) code	Receiver HW	Relative	-	Long term	Estimte	TC: Estimate/Calibrate LC: Eliminate

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GLONASS inter-frequency bias (IFB) code bias	Recei HW	Relative ver	-	Long	Calibra term	Calibrate te

a In single constellation positioning

b The form of the satellite phase bias correction depends on the PPP model and

c TC Tight combining

d LC Loose combining

e In a float solution, they can be merged with the phase ambiguities

f Total satellite-receiver DCB

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 termsm 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 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.

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The notation (.)sys,ssig/f,r(.)sig/f,rsys,s is henceforth used for a term associated with a signal sig 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:

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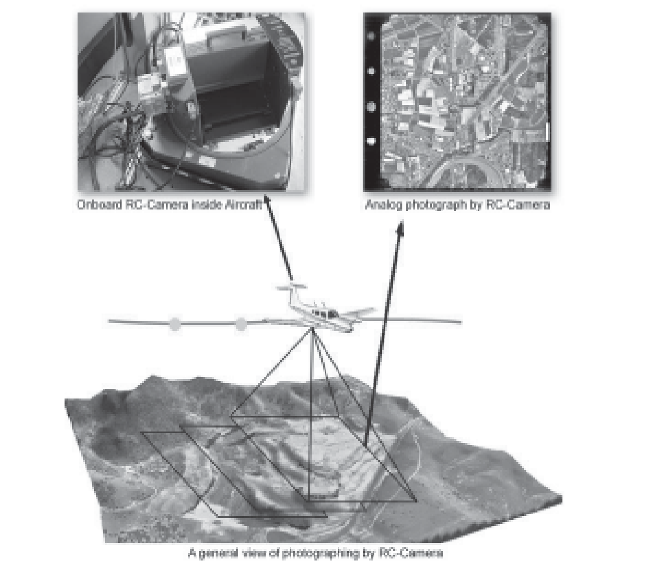
Photo grammetry & Ariel photograps

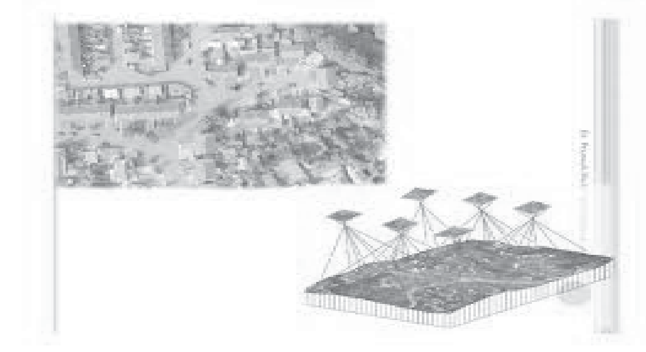
Objectives : At the end of this lesson you shall be able to
- **describe phogrammetry**
- **explain Ariel photographs.**

INTRODUCTION

- Photogrammetric surveying or photogrammetry is the branch of surveying in which maps are prepared from photo-graphs taken from ground or air stations.
- With an advancement of the photogrammetric techniques, photographs are also being used for the interpretation of geology, classification of soils and crops,etc.
- Is the science of making measurements from photographs, especially for recovering the exact positions of surface points.
- Used to recover the motion path ways of designated eference points located on any moving object, on its components and in the immediately adjacent environment.
- Photorgrammetry may employ high-speed imaging and remote sensing in order to detect, measure and record complex 2-D and 3-D motion fields.



A general view of photographing by RC-Camera



INTRODUCTION

- Photogrammetry is the practice of determining thegeometric properties of bojects from photographic images.
- Is the making of precise measurements from photographs; the making of maps from photographs, especially from aerial surveying.
- The science of using aerial photagraphy and other remote sensing imagery to obtain measurement of natural and man-made features on the earth.
- In this method, object are measured without being touched.

Definition

- Process of making surveys and maps using photographs.
- The science of deducing the physical dimensions of objects from measurements on images (usually photographs) of the objects.
- The making of maps by photography from the air using reference points of known level and position which can be identified on the photographs.
- A series of techniques for measuring position and altitude from aerial photographs or images.
- Is the Art, Science and Technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring and interpreting photographic images.

Broadly Photogrammetry Requires:

- Planing & taking the photographs
- Procesing the photographs
- Measuring the photographs & Reducing the measurement to produce end results.

Field Application of Photogrammetry:

- Used to conduct topographical survey or engineering surveys.
- Suitable for mountainous and hilly terain with little vegetation.
- Used for geolgical mapping which includes identification of land forms, rock type & rock strictures.

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- Used for projects demanding higher accuracy, since it provides accurate measurements.
- Used in urban and regional planning applications.
- Used mostly in Planning/designing in transport planning, brige, pipeline, hydropower, urban planning, security and strategic planning, disaster management, natural resources management, city models, conservation of archaeological sites etc.

Impotance/application of photogrammetry

- Its applications include satellite tracking of the relative positioning alterations in all Earth environments (e.g. tectonic motions etc.),
- The quantitative results of photogrammetry are used to guide and match the results of computational models of the natural systems, thus helping to invalidate or confirm new theories, to design novel vehicles or new methods for predicting or/and controlling the consequences of earthquakes, tusnamis, any other weather types.
- Photogrammetry also helps for the solving of triangulation, trilateration and multidimensional scaling.
- In the simplest example, the distance between two points that lie on a plane parallel to the photographic image plane can be determined by measuring their distance on the image, if the scale (s) of the image is known.

Importance/application of photogrammetry

- Used in different fields, such as topographic mapping architecture, engineering, manufacturing, quality control, police investigation, and geology, as well as by archaelogists to quickly produce plans of large or complex sites and by meteorologists.

Advantage

- Covers large area
- Less time consuming/fast
- Can 'reach' inaccessible and restricted area
- Cheap/cost effective for large area and in a long run
- Easy to interpret, understand

Davantage

- Complex system, highly trained human resource needed
- Costly at the time of installation/initiation
- Heavy and sophisticated equipments needed
- Lengthy administrative procedure for getting permission to fly
- Weather dependent

PRINCIPLE OF PHOTOGRAMMETRY

- Principle of photogrammetric survey in its simplest form is very similar to that of the plane table survey.
- Only difference is that the most of the work which in plane table survey is executed in the field, is done in office.
- The principal point of each photograph is used as ad fixed station and rays are drawn to get points of intersections very similar to those used in plane table.
- Is suitable for topographical or engineering surveys and also for those projects demanding higher accuracy.
- It is unsuitable for dense forest and flat-sands due to the difficulty of identifying points upon the pair of photographs.

TYPES OF PHOTOGRAMMETRY / PHOTOGRAPHS

- The photographs used in photogrammetry may be broadly classified into two types depending upon the camera position at the time of photography.

The types are-

- Terrestrial Photographs
- Aerial Photographs

Terrestrial Photographs

Photographs taken from camera station at a fixed position on or near the ground is known as Terrestrial Photographs.

The photographs are taken by means of a phototheodolite which is combination of a camera and a theodolite.

Based on the principle that "if the directions of same objects photographed from two extremities of measuredbase are known, their position can be located by the intersection of two rays to the same object.

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TERRESTRIAL PHOTOGRAPHS

- Photographs are taken from elevated ground stations.
- Method is very similar that the camera is in stationary position.
- Camera used in this method is called photo-theodolite as it will require the same features as theodolite.
- It is much cheaper and can be carried out by individual surveying firms also.

TERRESTRIAL PHOTOGRAPHS

- Difference between this and plane tabling is that more details are at once obtained from the photographs and their subsequent plotting etc. is done by the office while in plane tabling all the detailing is done in the field itself.
- Fig A and B are the two stations at the ends of base AB.
- Arrow indicate the directions of horizontal pointing (in plan) of thecamera.
- For each pair of pictures taken from the two ends, the camera axis is kept parallel to each other.
- From economy and speed point of view, minimum number of photographs should be used to cover the whole area and to achieve this it is essential to select the best positions of the camera stations.
- Study of the area should be done from the existing maps, and a ground reconnaissance should be made. Selection of actual stations depends upon the size and ruggedness of the area.
- These photographs provides the front view of elevation & are generally used for the survey of structure & Architectural Monuments.

AERIAL PHOTOGRAPHS

- Photographs taken from a Aerial camera mounted on a aerial vechicle
- Used for various purpose, mainly information extraction on the ground surface
- Aerial photographs are obtained from the aerial cameras mounted on aerial vehicle(aeroplane for the purpose of photography)
- Used for various purpose, mainly information extraction on the ground surface
- Photographs are taken from camera station in the air with the axis of camera vertical or nearly vertical.
- Is the branch of photogrammetry where the photographs are taken from air station.
- This is the best mapping procedure yet developed for large
- objects and are useful for military intelligence.
- For this, aerial camera is used which are fixed on flying aircraft.

AERIAL PHOTOGRAPHS

According to the direction of the camera axis at the time of exposure aerial photographs may be classified into:

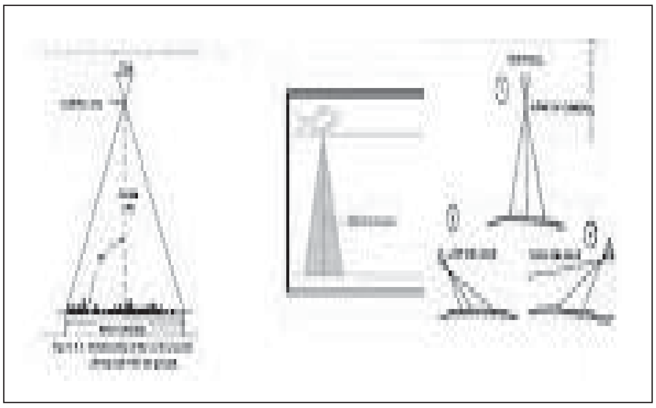
- **Vertical photographs**
- **Oblique photographs**

Vertical photographs

These photographs are taken from the air with the axis of the camera vertical or nearly vertical.

A truly vertical Photograph closely resembles a map.

These are utilized for the compilation of topographic and engineering surveys on various scales.



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BASIC TERMS USED IN PHOTOGRAMMETRY

Tilted Photograph:

- An aerial photograph taken with a camera having it's optical axis tilted usually less than 3° from the vertical is known as tilted photograph.

Exposure (or air) station (o):

- The exact position of the front nodal point of the lens in the air at the instant of exposure.

Flying height (H): (2009)

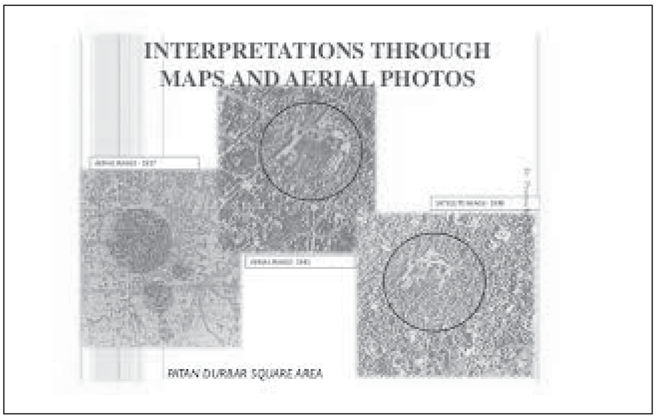
- The elevation of the air station above the mean sea level is known as flying height of the aircraft.

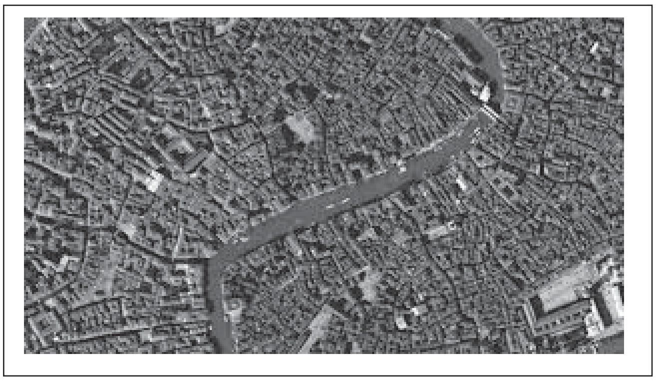
Nadir Point (Plumb Point) : (2009)

- The point where a plumb line dropped from the front nodal point strikes the photograph

Camera Axis : (2006)

- It is the line passing through the centre of the camera lens perpendicular both to the camera plate (negative) and the picture plane (photography).





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