UNIT- III

Transportation Engineering Importance of Transportation in Nation's economic Development -Types of Highway Pavements - Flexible Pavements and Rigid Pavements – Simple Differences. Basics of Harbour, Tunnel, Airport, and Railway Engineering.
Water Resources and Environmental Engineering: Introduction, Sources of water- Quality of water- Specifications- Introduction to Hydrology–Rainwater Harvesting-Water Storage and Conveyance Structures (Simple introduction to Dams and Reservoirs).

TRANSPORTATION ENGINEERING:

Introduction:
Transportation contributes to the economic, industrial, social and cultural development of any country. Transportation is vital for the economic development of any region since every commodity produced whether it is food, clothing, industrial products or medicine needs transport at all stages from production to distribution.

The inadequate transportation facilities retard the process of socio-economic development of the country. The adequacy of transportation system of a country indicates its economic and social development.

DIFFERENT MODES OF TRANSPORTATION:

1. Roadways or Highways
2. Railways
3. Waterways
4. Airways

Airways: The transportation by air is the fastest among the four modes. Air travel also provides more comfort apart from saving in transportation time for the passengers and the goods between the airports.

Waterways: Transportation by water is the slowest among the four modes; but this mode needs minimum energy to haul unit load through unit distance. The transportation by water is possible between the ports on the sea routes or along the rivers or canals where inland transportation facilities are available.

Railways: The transportation along the railway track could be advantageous by railways between the stations both for the passengers and goods, particularly for longer distances. The energy requirement to haul unit load through unit distance by the railway is only a fraction (one fourth to one sixth) of that required by road. Therefore, full advantage of this mode should be taken for the transportation of bulk goods along land where the railway facilities are available.

Roadways: The transportation by road is the only mode which could give maximum service to one and all. This mode has also the maximum flexibility for travel with reference to route, direction, time and speed of travel etc. through any mode of road vehicle.

It is possible to provide door to door service only by road transport. The other three modes viz., airways, waterways and railways have to depend on transportation by roads for the service to and from their respective terminals, airports, harbours or stations.

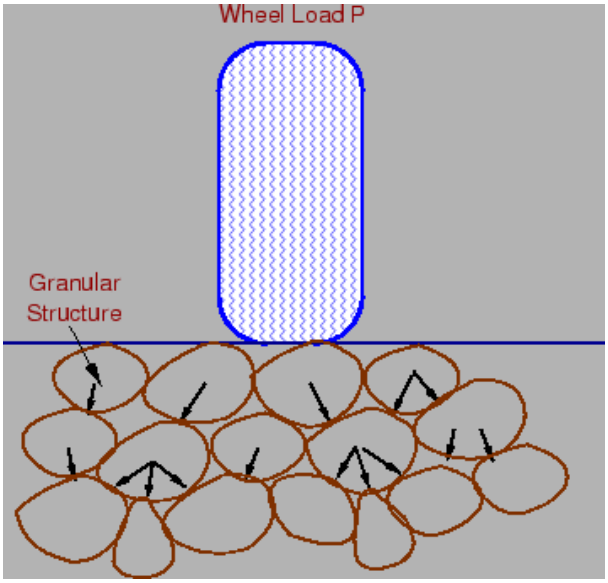
Pavement:
A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub-grade. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements.

Requirements of a pavement:

- An ideal pavement should meet the following requirements:
- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil,
- Structurally strong to withstand all types of stresses imposed upon it,
- Adequate coefficient of friction to prevent skidding of vehicles,
- Smooth surface to provide comfort to road users even at high speed,
- Produce least noise from moving vehicles,
- Dust proof surface so that traffic safety is not impaired by reducing visibility,
- Impervious surface, so that sub-grade soil is well protected, and
- Long design life with low maintenance cost.

Types of pavements:
The pavements can be classified based on the structural performance into two, flexible pavements and rigid pavements. In flexible pavements, wheel loads are transferred by grain-to-grain contact of the aggregate through the granular structure. The flexible pavement, having less flexural strength, acts like a flexible sheet (e.g. bituminous road). On the contrary, in rigid pavements, wheel loads are transferred to sub-grade soil by flexural strength of the pavement and the pavement acts like a rigid plate (e.g. cement concrete roads). In addition to these, composite pavements are also available. A thin layer of flexible pavement over rigid pavement is an ideal pavement with most desirable characteristics. However, such pavements are rarely used in new construction because of high cost and complex analysis required.

Flexible pavements:
Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure.



The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic, flexible pavements normally have many layers. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear. The lower layers will experience lesser magnitude of stress and low-quality material can be used. Flexible pavement layers reflect the deformation of the lower layers on to the surface layer (e.g., if there is any undulation in sub-grade then it will be transferred to the surface layer).

Typical layers of a flexible pavement:
Typical layers of a conventional flexible pavement include surface course, base course, sub-base course, compacted sub-grade, and natural sub-grade.

Wearing course or Surface course:
Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete (AC). The functions and requirements of this layer are:

- It provides characteristics such as friction, smoothness, drainage, etc. Also, it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade,
- It must be tough to resist the distortion under traffic and provide a smooth and skid-resistant riding surface,
- It must be water proof to protect the entire base and sub-grade from the weakening effect of water.

Base course:
The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

Sub-Base course:
The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage, and reduce the intrusion of fines from the

sub-grade in the pavement structure If the base course is open graded, then the sub-base course with more fines can serve as a filler between sub-grade and the base course A sub-base course is not always needed or used. For example, a pavement constructed over a high quality, stiff sub-grade may not need the additional features offered by a sub-base course. In such situations, sub-base course may not be provided.

Sub-grade:
The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed. It should be compacted to the desirable density, near the optimum moisture content.

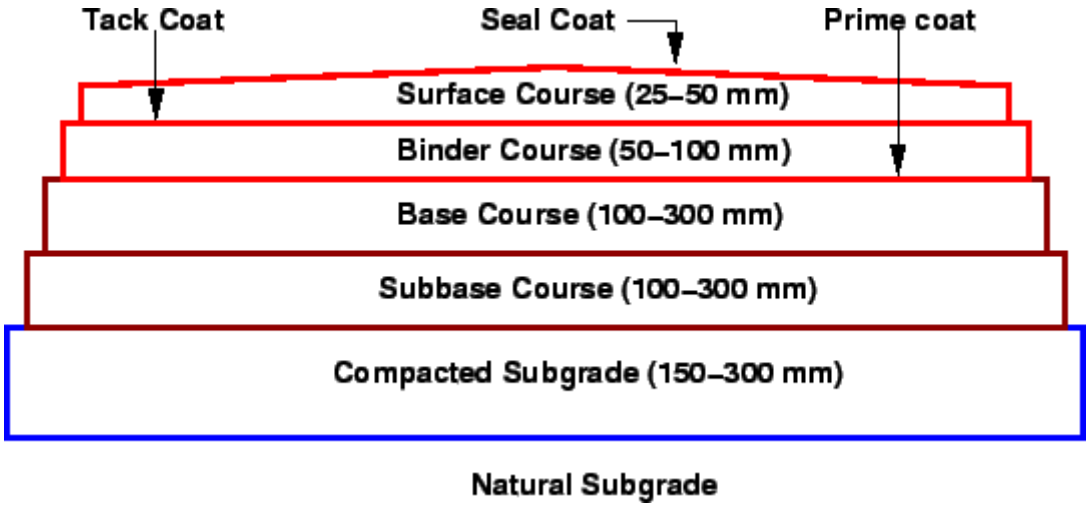


Figure: Typical cross section of a flexible pavement

Rigid pavements:
Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. A typical cross section of the rigid pavement is shown in Figure. Compared to flexible pavement, rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the sub-grade, this layer can be called as base or sub-base course.

A rigid pavement is constructed from cement concrete or reinforced concrete slabs. Grouted concrete roads are in the category of semi-rigid pavements. The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resists the loads from traffic. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil.

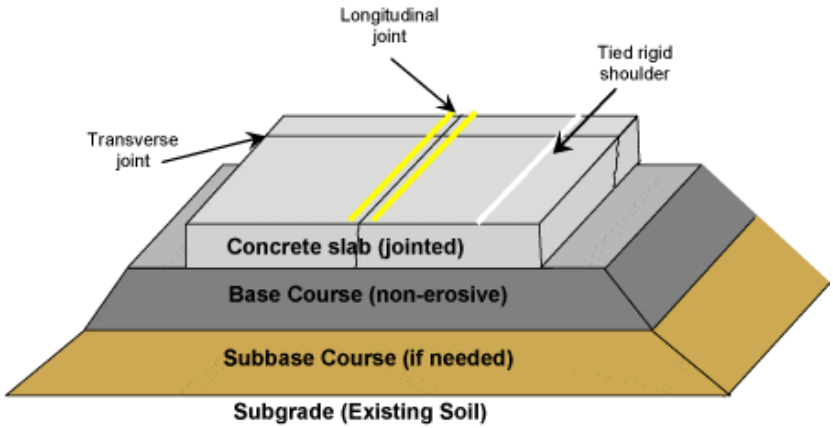


Fig: Rigid Pavement Cross-Section

Types of Rigid Pavements:

Rigid pavements can be classified into four types:

1. Jointed plain concrete pavement (JPCP),
2. Jointed reinforced concrete pavement (JRCP),
3. Continuous reinforced concrete pavement (CRCP).

Jointed Plain Concrete Pavement: are plain cement concrete pavements constructed with closely spaced contraction joints. Dowel bars or aggregate interlocks are normally used for load transfer across joints. They normally have a joint spacing of 5 to 10m.

Jointed Reinforced Concrete Pavement:

Although reinforcements do not improve the structural capacity significantly, they can drastically increase the joint spacing to 10 to 30m. Dowel bars are required for load transfer. Reinforcements help to keep the slab together even after cracks.

Continuous Reinforced Concrete Pavement:

Complete elimination of joints is achieved by reinforcement.

Difference between Flexible Pavements and Rigid Pavements:

S.No	Flexible Pavement	Rigid Pavement
1	It consists of a series of layers with the highest quality materials at or near the surface of pavement.	It consists of one layer Portland cement concrete slab or relatively high flexural strength.
2	It reflects the deformations of subgrade and subsequent layers on the surface.	It is able to bridge over localized failures and area of inadequate support.
3	Its stability depends upon the aggregate interlock, particle friction and cohesion.	Its structural strength is provided by the pavement slab itself by its beam action.
4	Pavement design is greatly influenced by the subgrade strength.	Flexural strength of concrete is a major factor for design.
5	It functions by a way of load distribution through the component layers.	It distributes load over a wide area of subgrade because of its rigidity and high modulus of elasticity.

6	Construction cost is less and maintenance cost is less	Construction cost is less and maintenance cost is less
7	Flexible pavements have design period is 15-35 years.	Rigid pavements have design period is 35-50 years

CLASSIFICATION OF ROADS:

Roads are classified in to two types:

1) Urban Roads 2) Rural Roads

Urban Roads:

1) Arterial roads
2) Sub-arterial roads
3) Collector streets and
4) Local streets

Arterials and sub arterials are streets primarily for through traffic on a continuous route, but the sub-arterials have a lower level of traffic mobility than the arterials.

Collector streets provide access to arterial streets and they collect and distribute traffic from and to local streets which provide access to abutting property.

Rural Roads: Rural roads are classified as following

1) Express Highways
2) National Highways
3) State Highways
4) District Roads
5) Village Roads

Express Highways: Express highways are separate class of highways with superior facilities and design standards and are meant as through routes having very high volume of traffic. These high ways should permit only fast-moving vehicles.

National Highways: are main highways running through the length and breadth of India, connecting major ports, foreign highways, capitals of large states and large industrial and tourist centres including roads required for strategic movements for the defence of India.

State Highways: are arterial roads of a state, connecting up with the national highways of adjacent states, district head quarters and important cities within the state and serving as the main arteries for traffic to and from district roads.

District Roads: are important roads within a district serving areas of production and markets and connecting those with each other or with the main highways of a district.

Village Roads: are roads connecting villages or groups of villages with each other to the nearest road of a higher category.

HARBOUR ENGINEERING:

HARBOUR:
It is partly enclosed area which provides safe and suitable accommodation for supplies, refuelling, and repair, loading and unloading cargo.

Site selection for a harbour:
The guiding factors which playa great role in choice of site for a harbour is as follows,
➢ Availability of cheap land and construction materials
➢ Transport and communication facilities
➢ Natural protection from winds and waves
➢ Industrial development of the locality
➢ Sea-bed, subsoil and foundation conditions
➢ Availability of electrical energy and fresh water
➢ Favourable marine conditions
➢ Defence and strategic aspects

Requirements of good harbour:
➢ This channel which may either be natural or artificial must have sufficient depth for the draft the vessels visiting the harbour
➢ The bottom should furnish secured anchorage to hold the ships against the force of high action.
➢ The land masses or breakwaters must be provided to protect against the destructive wave action.
➢ The harbour entrance should be wide enough to permit ready passage for shipping and at the same time, it should be narrow enough to restrict the transmission of excessive amounts of wave energy during storm.

Classification of harbour:
1. Classification depending upon the protection needed
2. Classification depending upon the utility
3. Classification depending upon the location

Classification based on the protection needed
i. Natural Harbour:
Harbour protected by storms and waves by natural land contours, rocky out crops, or island that is called Natural Contour. Example - Kandla port, Cochin port & Mumbai Harbour

ii. Semi - Natural Harbour:
A semi – natural harbour is protected on the sides by the contours of land and requires manmade protection only to the entrance. Example - Mandvi, Veraval & Visakhapatnam port
iii. Artificial Harbour:
An artificial harbour is one which is manmade and protected from storms and waves by engineering works. Example - Chennai Harbour

Classification based on utility:

i) Commercial Harbour:

It is a harbour in which docks are provided with necessary facilities for loading and unloading of cargo. Example - Chennai Harbour

ii) Refuge Harbour:

These are used as a heaven for ships in a storm or it may be part of a commercial harbour. Example - Chennai Harbour and Visakhapatnam Harbour

iii) Military Harbour:

It is a naval base for the purpose of accommodating naval ships or vessels and it serves as a supply depot. Example -Mumbai Harbour & Cochin Harbour

iv) Fishing Harbour:

These HARBOURs have facilities for departure and arrival of fishing ships. They have also necessary arrangement to catch fish.

Classification based on location:

i. Ocean Harbour
ii. River Harbour
iii. Canal Harbour
iv. Lake Harbour

PORTS:

A port is a harbour where marine terminal facilities are provided. A port is a place which regularly provides accommodation for the transfer of cargo and passengers to and from the ships.

Port = Harbour + Storage Facility + Communication Facility + Other Terminal Facility

From above, It can be stated that a port includes a harbour i.e. every port is a harbour

Requirements of good port:

➢ It should be centrally situated for the hinterland. Foe a port, the hinterland is that part of the country behind which it can served with economy and efficiency by the port

➢ It should get good tonnage

➢ It should have good communication with the rest of the country through rail and highways so that the commodities can be transported to and from the port easily and quickly

➢ The hinterland should be fertile with a good density of population

➢ It should be advanced in culture, trade and industry

➢ It should be place of defence and for resisting the sea-borne invasion

➢ It should be capable of easy, smooth and economic development

➢ It should afford shelter to all ships and at all seasons of the year

➢ It should provide the maximum facilities to all the visiting ships including the servicing of ships

Facilities at major port:

➢ Protection facilities
➢ Dredging facilities
➢ Entrance facilities
➢ Guiding facilities
➢ Locking facilities
➢ Turning facilities
➢ Docking facilities
➢ Loading and unloading facilities
➢ Storage facilities
➢ Repairing facilities
➢ Administrative facilities
➢ Offshore terminal facilities
➢ Quarantine inspection facilities

CLASSIFICATION OF PORTS:

Ocean Port - This is a port intended for large ocean-going ships.
River Port - River port is located on the banks of the river inside the land.
Entry Port - This is location where foreign citizens and goods are cleared through custom house.
Free Port - This is an isolated and enclosed area within which goods may be landed, stored, mixed, repacked, manufactured and reshipped without payment of duties.

DOCKS:

Docks are enclosed areas for berthing the ships to keep them afloat at a uniform level to facilitate loading and unloading cargo. A dock is a marine structure for berthing of vessels for loading and unloading cargo and passengers.
Docks are necessary for discharging of the cargo as ships require a number of days for discharging cargo, during which period they need a uniform water level. If ship is subjected to a vertical movement by the tides, great inconvenience will be felt in lifting the cargo from the ship and special arrangement will be needed for lifting the cargo.

Classification of docks:

Docks can be classified into following two categories:

➢ Wet docks.
➢ Dry docks.

WET DOCKS - Docks required for berthing of ships or vessels to facilitate the loading and unloading of passengers and cargo are called wet docks. These are also known as harbour docks.

DRY DOCKS - The docks used for repairs of ships are known as dry docks.

Classification of Dry docks:
Dry docks are classified in the following five categories:

- ➢ Graving or dry docks.
- ➢ Floating dry dock.
- ➢ Marine railway dock.
- ➢ Ship lifts dry docks.
- ➢ Slip ways.

Dry or graving dock - A dry dock is also known as graving dock. It is long excavated chamber, having side walls, a semi-circular end wall and a floor. The open end of the chamber is provided with a gate and acts as the entrance to the dock.

Floating dry dock - It may be defined as a floating vessel, which can lift ship out of water and retain it above water by means of its own buoyancy. It is a hollow structure made of steel or R.C.C consisting of two walls and a floor with the ends open. To receive a vessel or ship for repair, the structure or floating dock is sunk to the required depth by filling water known as ballasting in its interior chambers and the vessel is then floated into position and berthed. The dock is raised bodily with the berthed vessel by a ballasting the chambers by pumping out the water. The earliest floating dry docks resembled the shape of ships

Marine railway dock - The marine railway or slip dock or slip way is an inclined railway extending from the shore well into the water as the off there. This railway track is used to draw out a ship needing repair out of the water.

Lift dry dock - This is a constructed platform capable of being lowered into and raised from water. Lowering and rising is achieved by means of hydraulic power applied through cylinders supporting the ends of cross girders carrying the platform.

Ship lifts - As the name suggests, in the ship lift, the ships are lifted bodily out of water. The ship lifts may be electric, hydraulic or pneumatic. These lifts are used for launching as well as for dry docking the ships. Their main advantage is the ease in adaptability to transfer system enabling multiple garaging of ships.

Slipways - This technique is used for repairs as well as for building of vessels. In its simplest form a slip way consists of an inclined path of timber or stone lay on a firm ground. On this inclined path a series of rails are fixed. The rails run up from a sufficient depth of water to the required height above the high-water level to a point at which the longest vessel to accommodate is completely out of range of tide. The lower end of slip is tidal and open to water.

AIRPORT ENGINEERING:

COMPONENTS OF AIRPORT:

The main components of airport are

1. Landing Area of Airport

It is the airport components used for landing and take-off operations of an aircraft. Landing Area includes Runways and taxiways.

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Landing area includes,

a. Runways

b. Taxiways

Runways:

It is the most important part of an airport in the form of paved, long and narrow rectangular strip which actually used for landing and take-off operations. It has turfed (grassy) shoulders on both sides. The width of runway and area of shoulders is called the landing strip.

The runway is located in the center of landing strip. The length of landing strip is somewhat larger than the runway strip in order to accommodate the stop way to stop the aircraft in case of abandoned take-off. The length and width of runway should be sufficient to accommodate the aircraft which is likely to be served by it. The length of runway should be sufficient to accelerate the aircraft to the point of take-off and should be enough such that the aircraft clearing the threshold of runway by 15m should be brought to stop with in the 60% of available runway length.

Taxiways:

Taxiway is the paved way rigid or flexible which connects runway with loading apron or service and maintenance hangers or with another runway. They are used for the movement of aircraft on the airfields for various purposes such as exit or landing, exit for take-off etc. The speed of aircraft on taxiway is less than that during taking off or landing speed.

The taxiway should be laid on such a manner to provide the shortest possible path and to prevent the interference of landed aircraft taxiing towards loading apron and the taxiing aircraft running towards the runway. The intersection of runway and taxiway should be given proper attention because during turning operation, this part comes under intense loading. It is also provided with a shoulder of 7.5m width paved with bituminous surfacing. The taxiway should be visible from a distance of 300m to a pilot at 3m height from the ground.

2. Terminal Area:

The transition of passengers and goods from ground to air takes place in the terminal area. Various methods are used to accommodate and transfer the public and its goods arriving either by ground or by air. The degree of development in the terminal area depends up on volume of airport, operations, type of air traffic using airport, number of passengers and the airport employees to be served and the manner in which they are served and accommodated. Terminal area consists of the following parts Terminal building, Apron, Automobile Parking Area, Hangers.

Hangars: Hangars are buildings in which airplanes are repaired or serviced. Most airlines have their own hangars, in which they can park many jets at the same time. Most hangars are far away from terminals and runways so that they do not interfere with airport traffic.

RAILWAY ENGINEERING:

COMPONENTS OF A RAILWAY TRACK (OR) PERMANENT WAY

1) Rails
2) Sleepers
3) Ballast

RAILS:

Rails are the I-section members of a track laid in two parallel lines to provide a level surface for the movement of trains.

Function of Rails:

➢ To provide a continuous and level surface for the movement of trains.
➢ To serve as a lateral guide for the wheels.
➢ To transmit the load to a large area of the formation through sleepers and ballast.
➢ To bear the stresses developed due to vertical loads transmitted to them.

Track Gauge:

As per Indian Railways, it is the clear minimum distance between the running faces of two rails

- **Broad Gauge (B.G.) 1.676 m**
- **Meter Gauge (M.G.) 1.000 m**
- **Narrow gauge (N.G.) 0.762 m**

SLEEPERS:

Sleepers are the transverse ties laid to support the rails.

Function of Sleepers

➢ To hold the rails in their correct gauge and alignment
➢ To give a firm and even support to the rails
➢ To transfer the load evenly from the rails to a wider area.
➢ To provide the longitudinal and lateral stability to the permanent way.
➢ To act as a elastic medium between the rails and the ballast to absorb the vibrations caused by wheel loads

Types of Sleepers:

- Timber/wooden sleepers
- Steel sleepers
- Cast Iron Sleepers
- Concrete Sleepers

BALLAST:
Layer of broken stones, gravel, moorum or any other granular material placed and packed below and around sleepers.

Functions of Ballast:
➢ Provides a level and hard bed for the sleepers to rest on.
➢ Holds the sleepers in position.
➢ Transfers and distributes load from the sleepers to a large area of the formation.
➢ Provides effective drainage of the track.
➢ Provides elasticity and resilience to the track for proper riding comfort.

TUNNEL ENGINEERING

Def: A tunnel may be defined as an **underground passage connecting two places** on the surface. It is constructed with a view of achieving a definite purpose such as:

i) **Maintaining route of rail or road traffic** in a difficult terrain on the surface or under an extensive water body such as river or sea.
ii) **Conveyance of water** for drinking water supply or for power generation or even for navigation.
iii) **Drainage** of city waste; and for creation of underground parking places.
iv) As a **defence** requirement.

Tunnels are admittedly far costly and hazardous to construct compared to surface connections but they do offer distinct and definite long-term advantages such as:

- Flexibility in choosing the shortest route to connect different places with added advantages of saving in terms of time and fuel.
- Greater safety and security as controlling and monitoring the road or railway traffic through tunnels are comparatively easier.
- Safety from pollution and crime risks as well which are inherent features of a good sub-surface transport system.

SITUATIONS FOR TUNNELS:

Tunnels become desirable and economical solutions on long-term basis in many specific situations some of which are as follows:

a) **A high mountainous terrain:** In long distance travels in many countries, there are areas where the rail or road traffic will have to climb great heights to cross over to the other side. Such a route would require long, zig-zag and winding tracks or roads with steep grades, full of difficult curves and open to vagaries of weather such as frequent slides and slope failure during heavy rains and snow avalanches and so on. In such a situation, a tunnel connecting the two desired locations at lower elevations on either side of the mountain or the hill is an ideal, very convenient, all weather and ultimately cost-effective solution.

b) **A busy metropolitan area:** Many old cities of the world have grown to the status of metropolis with passage of time due to heavy urbanisation. Space in such areas is not available for improving traffic networks which become so essential for communication from one place to another with in the city. Destroying the old construction to lay new traffic lanes is often impossible due to compensation demands and social set up reasons. In such cases, **underground pathways** are the only viable solutions. These tunnels, often called **subways or metros.**

c) **An Intervening Extensive Water body:** It often happens that a large water body such as a big river or lake lies between two places that must be connected in the interest of the people living on either side. In such cases, the choice may be between a very large and long bridge (over surface connection) or a tunnel (subsurface connection).

d) **Hydroelectric Power Generation:** In many parts of the world, power generation is through **water-fed turbines** or hydroelectric power stations. In such cases, the source of water is located at quite a distance from the place where a power-generating station should be located. This necessitates transportation of water from the source (river or lake) to the power generation plant. When this distance is more than a couple of kilometres, then the choice is between a feeder canal or a water-tunnel, called in this case a "hydro-power tunnel".

e) **Other situations:** where tunnelling is often warranted and adopted include:
   - **i)** **Conveyance of water** for drinking water supply from the main source to the water supply reservoir adjacent to the water-distribution centre.
   - **ii)** **Transport of the Municipal waste,** the sewage, to destinations outside the city- the sewage tunnels
   - **iii)** **Creating parking places** below the surface, providing underground passages for the pedestrian traffic to cross the busiest points of traffic etc.
   - **iv)** **Creating underground storage capacity** for strategic equipment and armament for defence use in sensitive areas.

CLASSIFICATION OF TUNNELS:

Tunnels are commonly classified on the basis of **intended use** as follows:

1. **Traffic Tunnels:** These tunnels are constructed for providing a continuity to a particular type of traffic in difficult situations and consist of major group of tunnelling activity. These are further divided into following sub-types:
   a) **Railway tunnels:** excavated exclusively for serving railway traffic through all types of terrain
   b) **Highway tunnels:** Located at specific points, mostly in hilly terrains.
   c) **Subways or Metros:** Which are traffic paths of metros that have been made by excavation through the ground rather than by cut and cover method; mostly used for terrain traffic.
   d) **Pedestrian tunnels:** Which are small, local level underground passages excavated at congestion points to provide a way to pedestrian traffic without disturbing the overflowing heavy traffic of all the types.

2. **Hydropower tunnels:** These are constructed for a definite purpose of conveying water in sufficient volume and manner to a power generating plant from a distant source such as reservoir or river or a lake. These are of two types:
   a) **Gravity Tunnels:** where water is conveyed from the source to a point above the power generating plant essentially under the influence of gravity.
   b) **Pressure Tunnels:** Where water is made to move under a head for some distance or is made to impinge upon the turbine at a predetermined head.

Water Resources and Environmental Engineering:

Sources of Water:
Water is the main constituent of the earth surface. Water occurs in liquid, solid(ice) and gas (water vapour). There are mainly two sources of water, surface source water and subsurface source water.

1.Surface sources of water:

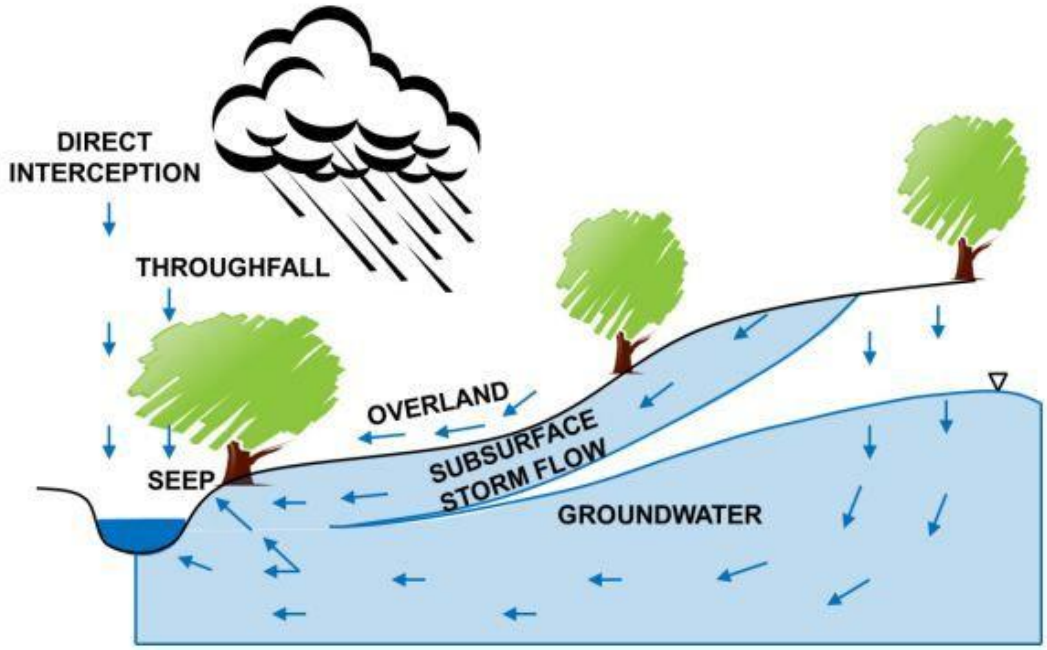
Storage reservoirs:
Storage reservoirs are the main sources of water for a city or town. Because storage reservoirs always have sufficient amount of water available during the summer and as well as in winter season. The capacity of the storage tank is determined by several methods. Read more in Water Supply System.

Lakes:
The lake water is pure compared to all other sources. The fresh water comes from the rock or surrounding area always drive under the filtration of soil. So impurities in lakes water will be less. Lake water has algae, weeds and other vegetables. It is one of the main surface sources of water.

Rivers or streams:
The main use of the river is navigation between land. The river water is pure at mountains, but when it approaches plain area, it will deteriorate due to the wastes from town or municipal areas. The river water flows and it reaches the sea. The main source of water to the wells is from runoff.

Oceans:
Ocean is the largest source of water in the earth. They cannot be used drinking or construction purpose due to high salinity of the water. The normal salt content for drinking purpose is 2 percent, but the salt content in seawater exceeds 3 percentage. So sea water damage human kidney system.

Precipitation:
Precipitation is rain. Precipitation is also other pure water sources to the earth.



2.Sub Surface sources of water:

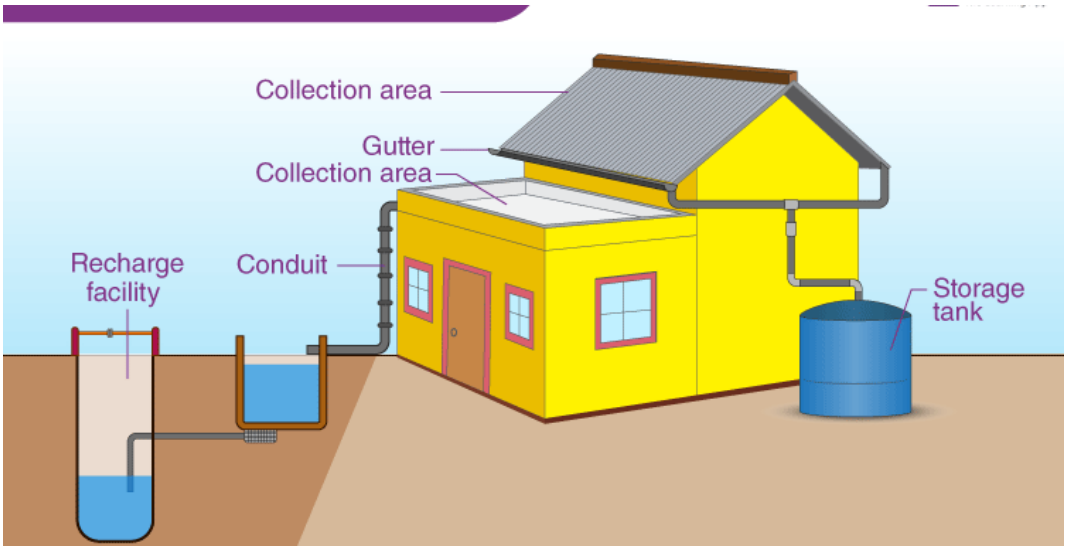
Infiltration galleries:
A horizontal tunnel usually rectangular in cross section. Infiltration galleries have permeable boundaries so that water can be filtrate into them.

Infiltration wells:
It is shallow well-constructed in series along the bank of the river. The surface water flowing through the river flow towards the well-constructed in the bank of the river.

These wells contain only pure water. Because during their movement from the river to infiltration wills, the water purification takes place by filtration of soil.

Well:
Well is the main sub surface sources of water for houses. Usually, they are rounded shape and usually having a depth more 8 meters. The main sources of water to the wells are from infiltration of water through the soil. Two types of wells are there
Open wells-They have large diameter and low yield
Tube wells-They have small diameter, long pipe sunk into the ground intercepting one or more water-bearing strata.

Rainwater Harvesting:
Rainwater harvesting is the simple process or technology used to conserve rainwater by collecting, storing, conveying and purifying of rainwater that runs off from rooftops, parks, roads, open grounds, etc. for later use.



Different methods of rainwater harvesting:

The different methods of rainwater harvesting include:

Rooftop rainwater harvesting – The rooftop becomes the catchments, and the rainwater from the building and houses are collected. The components of the rooftop rainwater harvesting are:

- First, flush.
- Transportation.
- Catchment.
- Filter.

Surface runoff harvesting – It is the system that collects rainwater, which flows away as surface runoff. The runoff rainwater is caught and used to recharge aquifers by adopting appropriate techniques.

Rainwater harvesting systems consists of the following components:

Catchment- Used to collect and store the captured rainwater.
Conveyance system – It is used to transport the harvested water from the catchment to the recharge zone.
Flush- It is used to flush out the first spell of rain.
Filter – Used for filtering the collected rainwater and removing pollutants.
Tanks and the recharge structures: Used to store the filtered water which is ready to use.

The process of rainwater harvesting involves the collection and the storage of rainwater with the help of artificially designed systems that run off naturally or man-made catchment areas like- the rooftop, compounds, rock surface, hill slopes, artificially repaired impervious or semi-pervious land surface.

Importance of rainwater harvesting:

Rainwater harvesting is a sustainable process that helps in preserving water for future needs. Water scarcity is a major concern in today's scenario. The process of rainwater harvesting is a good way to conserve water.

Advantages of rainwater harvesting:

The advantages of rainwater harvesting are:

- It is cost-effective.
- Conserves water.
- A source of water for landscape irrigation.
- It is a simple method and easy to practice.
- It reduces soil erosion and pollution of water bodies due to fertilisers and pesticides.

Water quality is the physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to drinking water, safety of human contact and for the health of ecosystems.

Environmental water quality:
Environmental water quality, also called ambient water quality, relates to water bodies such as lakes, rivers, and oceans. Water quality standards vary significantly due to different environmental conditions, ecosystems, and intended human uses. Toxic substances and high populations of certain microorganisms can present a health hazard for non-drinking purposes such as irrigation, swimming, fishing, rafting, boating, and industrial uses. These conditions may also affect wildlife which use the water for drinking or as a habitat. Modern water quality laws general specify protection of fisheries and recreational use and require as a minimum, retention of current quality standards.

WATER QUALITY PARAMETERS AND DRINKING WATER STANDARDS

SL. NO.	PARAMETERS	UNITS	DRINKING WATER IS: 10500 - 1991	
			DESIRABLE	MAXIMUM
1.	Colour	Hazen units	5	25
2.	Odour	-	Unobjectionable	-
3.	Taste	-	Agreeable	-
4.	Turbidity	NTU	5	10
5.	pH value	-	6.5 to 8.5	No relaxation
6.	Total hardness (as $CaCO_3$)	mg/l	300	600
7.	Iron	mg/l	0.3	1.0
8.	Chlorides	mg/l	250	1000
9.	Residual, free Chlorine	mg/l	0.2	-
10.	Dissolved Solids	mg/l	500	2000
11.	Calcium	mg/l	75	200
12.	Copper	mg/l	0.05	1.5
13.	Manganese	mg/l	0.1	0.3
14.	Sulphate	mg/l	200	400
15.	Nitrate	mg/l	50	No relaxation
16.	Fluoride	mg/l	1.0	1.5
17.	Phenolic compounds	mg/l	0.001	0.002
18.	Mercury	mg/l	0.001	No relaxation
19.	Cadmium	mg/l	0.01	No relaxation
20.	Selenium	mg/l	0.01	No relaxation
21.	Arsenic	mg/l	0.05	No relaxation
22.	Cyanide	mg/l	0.05	No relaxation
23.	Lead	mg/l	0.05	No relaxation
24.	Zinc	mg/l	5	15
25.	Anionic detergents	mg/l	0.2	1.0
26.	Chromium	mg/l	0.05	No relaxation
27.	Polynuclear aromatic Hydrocarbons	mg/l	-	-
28.	Mineral oil	mg/l	0.01	0.03
29.	Pesticides	mg/l	Absent	0.001
30.	Radioactive materials (a) Alpha emitters (b) Beta emitters	Bq/l Pci/l	- -	0.1 0.037
31.	Alkalinity	mg/l	200	600
32.	Aluminlum	mg/l	0.03	0.2
33.	Boron	mg/l	1	5

Dams:

Dam Meaning- A dam is a structure that is constructed across a river or natural stream to collect water in a reservoir. Upstream side refers to the side of the barrier where water collects, and the downstream side refers to the opposite side. Dams are primarily constructed to generate electricity through the use of water. Hydroelectricity is the name given to this type of electricity. Dam-created reservoirs not only prevent flooding but also offer water for purposes such as agriculture, human consumption, industrial use, aquaculture, and navigation.

Purposes of Dams-

- Supply of Water
- Irrigation Purpose
- Flood prevention
- Production of hydroelectric energy
- Water quality improvement
- Sediment retention and control
- Contain and store waste (tailings) from mines
- Inland navigation
- Fish Farming

Classification Based on Materials of Construction:
Different types of dams based on the type of material they are constructed of are as follows:-

Earth Fill Dams:
An earth fill dam is constructed of the earth (or soil) that has been compacted in layers, with the most impervious materials used to create the core and more permeable materials used on the upstream and downstream sides.

Rock Fill Dams:
Large boulders and rock fragments are used to construct a rock fill dam. To lessen seepage through the dam, an impervious membrane is positioned on the rockfill on the upstream side

Concrete Dams:
Concrete Dams are dams that are either constructed of plain concrete cement or reinforced concrete cement. Concrete dams can be gravity dams, buttress dams, arch dams or any other form of a dam constructed by the use of concrete.

Masonry Dams:
Masonry dams are dams made primarily of stone and brick that is occasionally mortared together. They can be gravity or arch-gravity type. The Nagarjuna Sagar Dam in Telangana, India, is the largest masonry dam in the world.

Steel Dams:
A steel dam consists of a steel framework and an upstream steel skin plate. There are two main categories of steel dams: cantilever-type steel dams and direct strutted steel dams.

Timber Dams:
In timber dams, the main load-bearing structural components are made of wood, primarily coniferous species like pine and fir. Timer dams generally have sluices and they are made for small heads such as 2-4 metres or rarely 4-8 metres. Based on the apron design, the timber dams are categorised into piles, cribs, pile-cribs and buttressed dams.

RESERVOIR:

A reservoir is a natural lake or a man-made outdoor storage space where water is collected and stored in a limited quantity for later use. Reservoirs are an integral part of many water supply systems worldwide, which play an important role in supplying water to domestic, industrial, and agricultural demands.

Purpose Of Reservoir:
Sometimes weather fluctuations cause the natural flow of streams and rivers to change over time. The excess water flow and valley floods can vary according to short flow or drought. The main purpose of water storage or reservoirs is to store the excess water during periods of higher flow.

This way, floods can be controlled, and the stored water can be released gradually for longer periods. This stored water can be used for domestic, industrial, and agricultural purposes.

Types of Reservoirs:

The types of reservoirs are as follows:

1. Valley-dammed reservoir or Storage reservoir
2. Flood control reservoirs
3. Service reservoirs or Distribution reservoir

1. Valley Dammed Reservoir:

Valley-dammed reservoirs are formed in valleys in the middle of the mountains. There is often an existing lake or water, and the sides of the mountain are used as reservoir walls to hold water. A dam or artificial tank wall is built at the narrowest point to hold water.

Before constructing Valley-dammed reservoirs, the water flow or river must be diverted. The dam construction process involves laying the foundations for the dam, and then the concrete cladding is laid and the construction of the dam can proceed.

The construction of the dam usually takes many years, but when it is finished, valley ponds and a large water source can be used to serve the purpose of irrigation, hydropower generation, domestic and industrial water supply.

2. Flood Control Reservoir:
This type of reservoir, also known as a flood mitigation reservoir, is built to store the floodwater from a high flow water stream to reduce flooding in protected areas or populated areas.

The entire stream entering the water storage is discharged until the outflow reaches the safe capacity of the lower channel. The excess inflow is stored in the reservoir, and the stored water is gradually resealed to create a storage capacity for the next flood. There are two types of flood control reservoirs:

Storage Reservoir
Retarding Reservoir

i) Storage Reservoir:

A reservoir where gates and valves are installed at its spillways and sluice outlets is known as a storage reservoir. This reservoir requires a manual operation to open and close the gate, which gives complete control over the amount of water discharged.

ii) Retarding Reservoir: A reservoir that has ungated outlets and the flow is uncontrolled is known as retarding reservoir or retarding basin. The retarding reservoir has some advantages over the storage reservoir, such as no necessity of installing gates at sluiceways and spillway crests.

During maximum floods, the water present in the land is submerged temporarily and driven out in a few days after the flood is controlled or minimized.

3. Distribution Reservoir or Service Reservoir

Distribution Reservoir connected to the main water supply channels(pipelines). The main purpose of this type of reservoir is to serve or supply water to consumers according to changing demands or requirements of the local population.

It also serves as local storage in the event of an emergency. Here the water is stored in the reservoir by pumping at a specific rate, and later, this stored water can be used or supplied at a rate higher than the inflow rate during high demands.

The main advantage of this type of reservoir is it can store water during the demand period and supply water during the demand period. Distribution reservoirs mainly depend on the population's demand for water at a particular period.

Multi-purpose Reservoirs:

As the name suggests, these reservoirs are built to store and supply the water to meet more than one purpose; hence they are known as Multipurpose Reservoirs.

For Example, multi-purpose reservoirs are designed for irrigation, flood control, power generation, etc. In India, Bhakra Dam and Nagarjun Sagar Dam are examples of important multi-purpose projects that serve more than two purposes.