UNIT 4

ROADS/HIGHWAY ENGINEERING

Basic Definition

A facility consisting of the means and equipment necessary for the movement of passengers or goods. At its most basic, the term “Transportation System” is used to refer to the equipment and logistics of transporting passengers and goods.

Importance of Transportation

The evolution and advancements in transportation facilities have been closely linked with the development of human beings throughout the history of the world. Role of Transportation Transportation plays a vital role in economic development of any region of any country, since every commodity produced, whether it may be agricultural or industrial products they need to be transported at various stages from production to distribution. At production stage for carrying raw materials and at distribution stage for transportation from farms and factories to marketing centers to retailers to consumers. Inadequate transportation facilities retard the process of socio-economic and cultural development. Development of transportation facilities in a country indicates its economic growth and progress in social development. The main objective of a good transportation system is to provide a safe, economical and efficient transportation facility for passengers and goods.

Economic Activity and Transport

These are the processes in which the products are utilized to satisfy human needs. Two important factors well known in economic activity are 1) Production or supply 2) Consumption for human needs or demands

Social Effects of Transportation

The progress of a nation depends on transportation facilities. The population usually settles along the transportation routes such as road sides, river shores and railway stations. However, in the present concept of road network planning the above said kind of ribbon development is discouraged for the sake of high speed travel and safety. Attempts are being made to decentralize the population away from main transportation routes. To avoid congestion on major cities, suburbs and satellite towns are being developed and are linked to the major cities with mass rapid transit system. The various social effects of transportation are a) Sectionalism and transportation b) Concentration of population in urban area c) Aspect of safety, law and order a) Sectionalism and Transportation 1) Improved transportation has important implication in reducing sectionalism within the country and also with other countries in the world 2) The living conditions and facilities of under developed colonies and tribes get improved since the distances are apparently reduced with reduction in travel time. 3) Frequent travel to the other parts of the country and outside the country tend to increase knowledge of the people by learning from other sections of society which results in improved trade and cultural exchanges. 4) International understanding for the better peace and order also improves with efficient network of transportation.

DIFFERENT MODES OF TRANSPORTATION

Transportation has developed along three basic modes of transport a) Land b) Water c) Air Land has given scope for development of transportation by road and rail transport. Water and air media have developed waterways and airways respectively. The roads or the highways not only include modern highway system but also includes the urban arterials, city streets, feeder roads and village roads catering for a wide variety of vehicles and pedestrians. Railways have been developed both for long distance travel and also urban travel. Waterways include transportation by oceans, rivers, canals and lakes for the movement of ships and boats. The airways help in faster transportation by aircrafts and carriers. Apart from these major modes of transportation, other modes include pipelines, elevators, belt conveyors, cable cars, aerial ropeways and monorails. Pipe lines are used for the transportation of water, other fluids and even solid particles The four major modes of transportation are: a) Roadways or highways for road transportation b) Railways for rail transportation c) Waterways for water transportation d) Airways for air transportation.

ROADWAYS

The transportation by road is the only mode which could give maximum service to one and all. Road transport mode has the maximum flexibility for travel with reference to choice of the route, direction, time and speed of travel. This is only mode which caters for the movement of passengers and goods independently right from the place of origin up to the destination of any trip along the route. The other three modes (railways; water ways; airways) have to depend on transportation by road for the service to and from their respective terminals. Therefore, the roadway essentially serves as a feeder network. It is possible to provide door to door service by road transport. Ultimately, road network is therefore needed not only to serve as feeder system for other modes of transportation and to supplement them, but also to provide independent facility for road travel by a well-planned network of roads throughout the country

Advantages:

1) Flexibility: It offers complete freedom to the road users. 2) It requires relatively smaller investments and cheaper in construction with respect to other modes. 3) It serves the whole community alike the other modes. 4) For short distance travel, it saves time. 5) The road network is used by various types of vehicles. Disadvantages: 1) Speed is related to accidents and more accidents results due to higher speed and is usually not suitable for long distance travel 2) Power required per tonne is more.

CLASSIFICATION OF ROADS

Types of Roads Basically, different types of roads can be classified into two categories namely,

a) **All-weather roads and**
b) **Fair-weather roads.**

All-weather roads: These roads are negotiable during all weather, except at major river crossings where interruption of traffic is permissible up to a certain limit extent, the road pavement should be negotiable during all weathers. Fair-weather roads: On these roads, the traffic may be interrupted during monsoon season at causeways where streams may overflow across the roads.

Based on location and Function:

1) Expressways: Expressways are the highest class roads in India. These are the highways with six to eight lane controlled access road network. Basically, expressways are of high quality consisting of modern features like access ramps, grade separation, lane dividers and elevated section.

2) National Highways (NH): The NH connects the capital cities of the states and the capital cities to the port. The roads connecting the neighboring countries are also called as NH. The NH are at least 2 lanes of traffic about 7.5m d wide. The NH are having concrete or bituminous surfacing.

3) State Highways (SH): SH are the main roads within the state and connect important towns and cities of state. The width of state highways is generally 7.5m.

4) Major District Roads (MDR): These roads connect the areas of production and markets with either a SH or railway. The MDR should have at least metaled single lane carriage way (i.e., 3.8m) wide. The roads carry mixed traffic.

5) Other District Roads (ODR): These roads connect the village to other village or the nearest district road, with ghat, river etc. these roads have a single lane and carry mixed traffic.

6) Village Roads (VR): these roads, like other district roads, connect the village or village or nearby district road. The roads carry mixed traffic.

Classification of Urban Roads

The road system within urban areas are classified as Urban Roads and will form a separate category of roads taken care by respective urban authorities.

a) Arterial roads
b) Sub-arterial roads
c) Collector Streets
d) Local Streets Arterial and Sub-arterial roads are primarily for through traffic on a continuous route, but 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

HIGHWAY ENGINEERING

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, favorable 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. This chapter gives an overview of pavement types, layers, and their functions, and pavement failures. Improper design of pavements leads to early failure of pavements affecting the riding quality.

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

i.Flexible Pavement- Bituminous road(Tar road in layman term)

ii. Rigid Pavement- Concrete roads

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).

Flexible Pavement

A pavement layer comprising a mixture of aggregates and bitumen, heated and mixed correctly and then laid and compacted on a bed of granular layer, is called flexible pavement.

The load transfer mechanism is depicted in fig 1.

Components of Flexible pavement

A typical cross-section of a flexible pavement consists of the following layers:

Sub-grade:

The sub-grade is the lowermost layer of the flexible pavement and usually consists of a compacted layer of natural soil. Its primary function is to bear all the imposed stresses from the upper layers. Acts as a foundation layer.

Sub-base Course: The sub-base course is the layer beneath the base course that provides additional structural support and boosts sub-surface drainage.It is usually an optional layer and may not be constructed if the base course comprises superior quality materials. Its thickness ranges from 100 mm to 300 mm.

Base Course:

Mainly, hard crushed aggregates are used in the construction of this layer.The base course is the backbone of flexible pavement.Its thickness ranges from 100 mm to 300 mm.

Binder Course:

The binder course is the intermediate layer between the surface course and the base course and duly transmits the wheel load from the surface to the base course.It is a bitumen-bound aggregate (nominal size) layer.This course is also called a **levelling course.**

Surface Course:

The surface course is the topmost layer of the flexible pavement and is generally the layer of the best quality as it has to withstand maximum stress and wear and tear.It is primarily designed to resist the imposed loads, prevent water ingress to the underlying layers, and ensure a skid-resistant riding surface

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 3. 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.

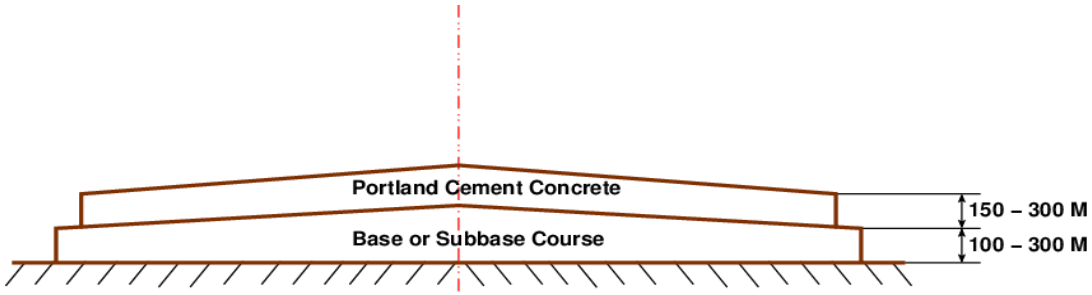


Figure 3: Typical Cross section of Rigid pavement

5.1 Types of Rigid Pavements

Rigid pavements can be classified into four types:

- Jointed plain concrete pavement (JPCP),
- Jointed reinforced concrete pavement (JRCP),
- Continuous reinforced concrete pavement (CRCP), and
- Pre-stressed concrete pavement (PCP).

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 has 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 are achieved by reinforcement.

MULTIMODAL TRANSPORT SYSTEM

CONCEPT

The concept of multi-modal transportation refers to a system that integrates multiple modes of transportation, such as trains, buses, automobiles, and bicycles, to provide more flexible, efficient, and convenient mobility options to passengers. The goal of multi-modal transportation is to create a seamless connection between different modes of transportation, allowing passengers to switch from one mode to another with minimal hassle. This can help reduce travel time, increase accessibility, and improve the overall transportation experience for passengers.

Multi-modal transportation systems also have environmental benefits, as they can help reduce emissions by encouraging people to shift from single-occupancy vehicles to more sustainable modes of transportation. Additionally, they can help reduce traffic congestion and promote urban development by making it easier for people to reach their destinations.

Overall, the concept of multi-modal transportation aims to create a more integrated, comprehensive, and user-friendly transportation network that meets the needs of a variety of travelers, whether they are commuting to work, running errands, or going on a trip.

Integrating multiple modes of transportation refers to the coordination and integration of various transportation options (e.g. buses, trains, bikes, ride-hailing services, etc.) into a seamless and efficient system. This involves the development of infrastructure, policies, and technology that allow for easy transfer between modes and provide an integrated experience for users.

Some key benefits of multi-modal transportation integration include:

1. Increased accessibility: By offering a variety of transportation options, users have more options to reach their destinations and can choose the most convenient and efficient mode for their needs.
2. Improved mobility: Integration can lead to reduced congestion and improved travel times, making it easier for people to get where they need to go.
3. Reduced emissions: Encouraging the use of low-carbon transportation options such as public transit, cycling, and walking can help to reduce greenhouse gas emissions and improve air quality.
4. Economic benefits: Multi-modal transportation can support local economic development by improving access to jobs, goods, and services and reducing transportation costs for individuals and businesses.
5. Improved public health: Encouraging the use of active transportation options such as walking and cycling can improve public health by increasing physical activity and reducing air pollution.

To achieve successful integration, it is important to consider the interplay between various transportation modes, as well as factors such as land use patterns, population density, and funding. It may also involve collaboration between various levels of government, transportation providers, and private sector organizations

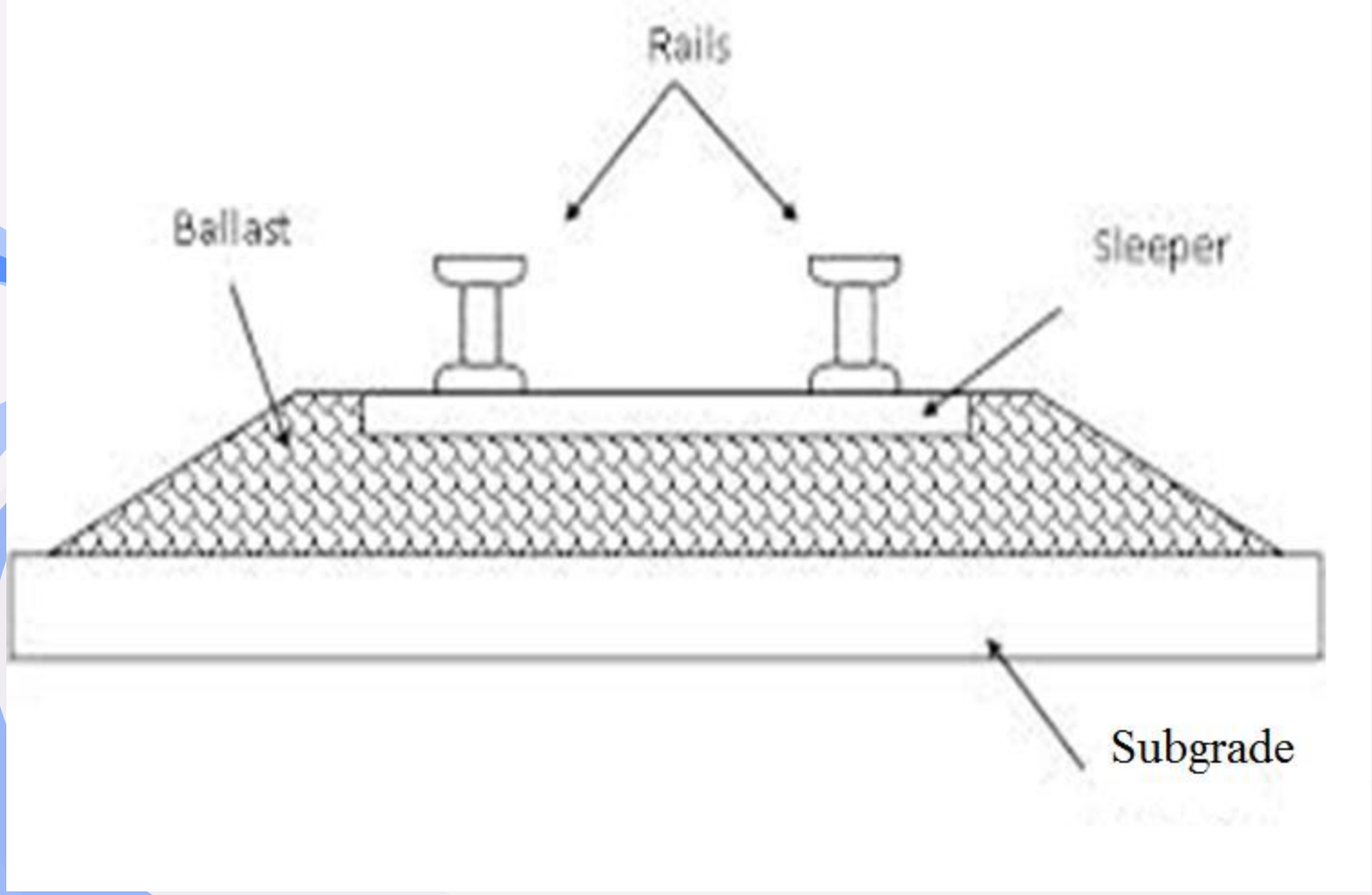
Integrating a multi-modal transport system involves several steps, which are as follows:

1. **Assessment of current transport system:** To integrate multi-modal transport, it is important to have an understanding of the current transport system. This includes identifying the strengths and weaknesses of each mode of transport, and the challenges they face.
2. **Identification of transport nodes:** Multi-modal transport requires the identification of key transport nodes, such as bus and train stations, airports, and ferry terminals. These nodes serve as hubs for different modes of transport, making it easier for passengers to switch between them.
3. **Development of a common ticketing system:** To integrate multi-modal transport, it is important to have a common ticketing system that allows passengers to use the same ticket for different modes of transport. This helps to simplify the process of switching between modes and reduces the time and effort required for ticket purchasing.
4. **Planning for intermodal connections:** To effectively integrate multi-modal transport, intermodal connections between different modes of transport need to be planned and developed. This includes the provision of pedestrian walkways, bike lanes, and park-and-ride facilities.
5. **Investment in public transport infrastructure**: Integration of multi-modal transport requires significant investment in public transport infrastructure, including the development of new transport nodes, upgrading existing ones, and the provision of new intermodal connections.
6. **Development of information and communication systems:** Effective integration of multi-modal transport requires the development of information and communication systems, such as real-time information displays and smartphone applications. These systems provide passengers with up-to-date information on transport schedules, delays, and service disruptions.
7. **Collaboration between different transport operators:** To effectively integrate multi-modal transport, it is important for different transport operators to collaborate and coordinate their services. This can be achieved through the development of agreements between operators, the sharing of information and resources, and the establishment of joint marketing and ticketing initiatives.
8. **User-friendly and accessible transport systems:** To ensure the success of a multi-modal transport system, it is important to make the transport system user-friendly and accessible for all users, including people with disabilities. This includes the provision of ramps, elevators, and accessible toilets, as well as clear signage and information displays.

RAILWAY ENGINEERING..

RAILWAY TRACK

- COMPONENT PARTS OF A RAILWAY TRACK



Section of Permanent Way

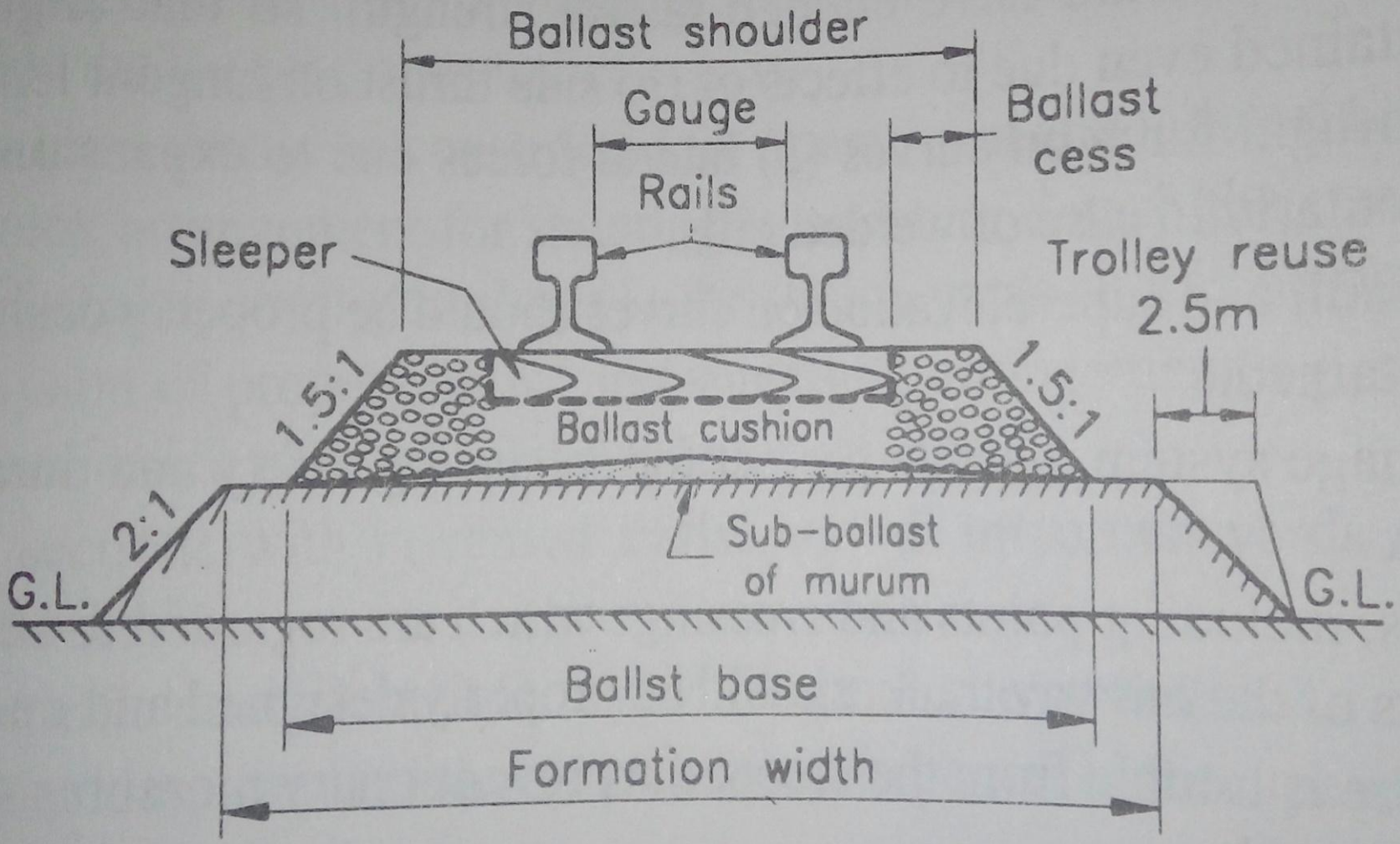


Fig. 3.1 Typical Cross-section of a Permanent Way on Embankment.

- A permanent way is the combination of rails, fitted on sleepers and resting on ballast and subgrade.
- The following are the component parts of a permanent way:

  a) Formation of sub-grade. b) Ballast. c) Sleepers. d) Rail. e) Fixtures and fastenings.

5 Major Cross Sectional Elements of a Railway Track

1. Right of Way

The area of land acquired and reserved for construction and development of railway track along its alignment is called right of way or permanent land. The width of the right of way is called permanent land width.

2. Formation

The prepared and finished surface of earthwork(**in embankment** or **in cutting**) on which a railway track is laid is called the formation of subgrade. Formation serves the following functions.

1. It provides a firm foundation bed to the track.
2. It provides a smooth and graded surface to the track.
3. It provides effective drainage of the track.

3. Formation width

- The top width of a railway embankment or bottom width of formation of cutting excluding the side drain is called formation width. The formation width of a railway track depends upon its gauge, number of tracks to be laid and space required between them.

4. Side Slopes

- The slopes given to the sides of the earthwork of a track in cutting or embankment for stability are called side slopes. Side slopes should be such that the earthwork becomes stable ever adverse climatic conditions.
- It depends upon various factors such as the nature of the soil, climatic conditions, method of drainage, and method of protection of side slope from erosion, height of embankment and depth of cutting. Usually, 2:1 side slope for track embankment and 1:1 side slopes for cutting is recommended.

5. Side Drains

- The drains provided on either side of railway tracks are known as **side drains**. Side drains are generally trapezoidal in section with 1.8 m top width and 0.9 m bottom width of a track embankment. In case of track in cutting, the top width of the side drain is usually kept as 1.22 m.

Requirements of Permanent Way

1. The gauge should be correct and uniform
2. The rail should be at a proper level. In the straight track, two rails must be at the same level. On curves, the outer rail should have proper superelevation
3. The alignment should be correct.
4. The **gradient** should be uniform. Any change of gradient should be followed by a smooth vertical curve.
5. The tractive resistance of the track should be minimum.

The track should possess sufficient elasticity.

7. The track should be sufficiently strong against lateral forces.

8. The radius and **superelevation** on curves should be properly designed and maintained.

9. The drainage system of the track should be perfect.

10. It should be free from excessive rail joints. All joints including points and crossing should be properly designed and maintained.

11. All the components of track should fully satisfy the requirements for which they have been provided.

12. There should be adequate provision for easy renewals and repairs of any portion of the track.

13. The track structure should be strong.

14. The initial cost of construction, as well as the maintenance cost of the track, should be as minimum as possible

RAIL GAUGE

The clear horizontal distance between the inner faces of the two rails forming a track is known as a **Railway Gauge.**

Dimension of gauges

1. Broad Gauge(BG) 1676mm

2. Standard Gauge(SG) 1435mm

3. Meter Gauge(MG) 1000mm

4. Narrow Gauge(NG) 762mm

5. Light Gauge 610mm

RAILS

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RAILS

- The rolled steel sections laid end to end in two parallel lines over sleepers to form a railway track as known as **rails**
- Made up of high carbon steel to withstand wear and tear
- Flat footed rails are mostly used in railway track

FUNCTIONS OF RAILS

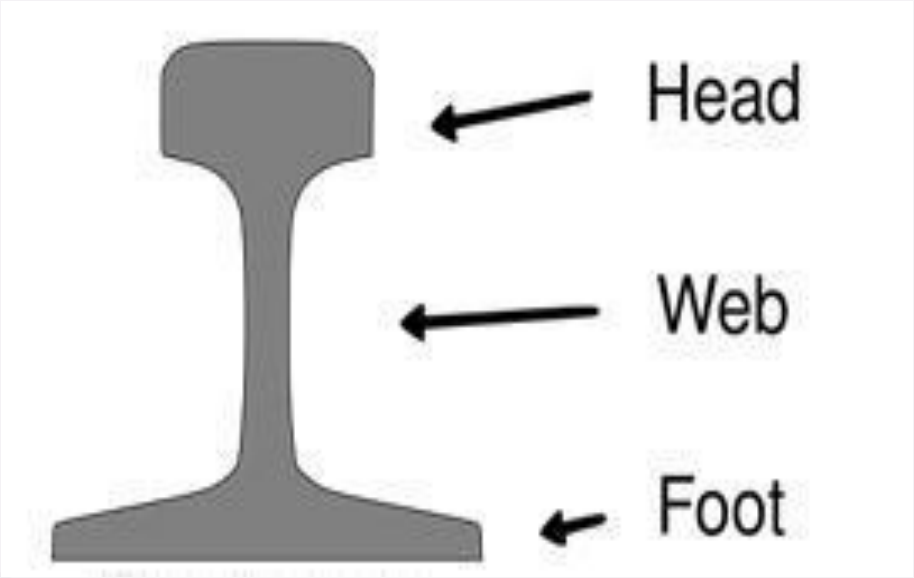
- Rails provide hard, smooth and unchanging surface for passage of heavy moving loads with minimum friction between steel rail and steel wheel

- Rails bear the stresses developed due to heavy vertical loads, lateral and braking forces and thermal stresses

- The rail material used is such that it gives minimum wear to avoid replacement charges and failure due to wear

- Rails transmit the loads to sleepers and consequently reduce pressure on ballast and formation below

REQUIREMENTS OF RAILS



- Rails should be designed for optimum nominal weight to provide for the most efficient distribution of metal in its various components

REQUIREMENTS (cntd..)

- The vertical stiffness should be high enough to transmit load to sleepers. The height of the rail should be adequate
- Rails should be capable of withstanding lateral forces. Large width of head and foot provides the rail with high lateral stiffness
- The depth of head of rail should be sufficient to allow for adequate margin of vertical wear. The wearing surface should be hard
- The web of rails should be sufficiently thick to bear the load coming to it and should provide adequate flexural rigidity in horizontal plane

REQUIREMENTS (cntd..)

- Foot should be wide enough so that the rails are stable against overturning especially on curves

- Bottom of the head and top of foot should be so as to enable the fish plates to transmit the vertical load efficiently from the head to the foot at rail joint

- The centre of gravity of rail section must lie approximately at mid height so that maximum tensile and compressive stresses are equal

REQUIREMENTS (cntd..)

- Tensile strength of rail shouldn't be less than 72 kg/m^2
- To bring down the contact stresses to minimum level, the contact area between the rail and wheel should be as large as possible

Ballast

- Ballast is the granular material placed and packed below and around the sleepers to transfer load from sleepers to the formation. Ballast in railway track performs the following function:

- It provides a suitable foundation for the sleepers.
- It transfers and distributes loads from the sleepers over a larger area of the foundation.
- It holds the sleepers in the correct position and prevents their lateral and longitudinal movement due to dynamic loads.
- It helps in maintaining the correct levels and alignment of a track.
- It acts as an elastic medium and thereby increases the elasticity of the track.
- It protects the top surface of the formation.
- It improves the drainage facility of the track.

Size of Ballast

- The **size of the ballast** used in railway track varies from **1.9 cm to 5.1 cm**. The stone of size larger than 5.1 cm is not preferable due to poor interlocking property.
- The **best-recommended ballast** is that which contains stones ranging in size from 1.9 cm to 5.1 cm.

The **size of the ballast** mainly depends upon the type of sleeper used and the location of the rail track. The following sizes of ballast are used in Indian Railway:

Types of Sleepers and Section	Size of ballast
1. Wooden Sleepers	51 mm
2. Steel Sleeper	38 mm
3. For Point and Crossing	25.4 mm

What Is Tunnel?

- An Underground Passage For The Transport Of Passengers, Water, Sewage, Minerals, Gas Etc.
- A tunnel is relatively long and narrow; the length is often much greater than twice the diameter, although similar shorter excavations can be constructed, such as cross passages between tunnels

Necessity/Advantages of a Tunnel

- **(a) A tunnel may be required to eliminate the need for a long and circuitous route for reaching the other side of a hill, as it would considerably reduce the length of the railway line and may also prove to be economical.**
- **(b) It may be economical to provide a tunnel instead of a cutting, particularly in a rocky terrain. Depending upon various factors, a rough calculation would indicate that for a small stretch of land the cost of constructing a tunnel is equal to the cost of a cutting in a rocky terrain.**
- **(c) In hills with soft rocks, a tunnel is cheaper than a cutting.**
- **(d) In metropolitan towns and other large cities, tunnels are constructed to accommodate underground railway systems in order to provide a rapid and unobstructed means of transport.**
- **(e) A tunnel constructed under a river bed may sometimes prove to be more economical and convenient than a bridge.**
- **(f) In the case of aerial warfare transportation through tunnels provides better safety and security to rail users compared to a bridge or deep cutting.**
- **(g) The maintenance cost of a tunnel is considerably lower than that of a bridge or deep cutting. However, the construction of tunnels is also disadvantageous in certain ways, as enumerated here. (a) The construction of a tunnel is costly as it requires special construction machinery and equipment.**
- **(b) The construction of a tunnel involves the use of sophisticated technology and requires experienced and skilled staff.**
- **(c) It is a time-consuming process.**

Classification of Tunnel

1) Classification of Tunnels According To Alignment
2) Classification of Tunnels According To Shape
3) Classification of Tunnels According To Type of Materials

Classification Of Tunnels According To Alignment

A) Spiral Tunnels:-

- Spiral Tunnel Provided To Increase The Length Of The Tunnel To Avoid Steep Slops In Narrow Valleys.
- Tunnels Provided In Narrow Valley In The Form Of Loops In The Interior Of Mountain So As To Increase Length Of Tunnel To Avoid Steep Slopes.

Spiral Tunnel

B) Off-Spur Tunnels

Off Spur Tunnels Are Constructed To Short-Cut Minor Obstacles Is Very High Projections On The Way, Which Can Not Be Followed With Permitted Curves.

C) Saddle Tunnels

Saddle Tunnels Constructed In Valley Along Natural Slope, This Tunnels Mainly Used For Transportation Purpose. Or Tunnels Constructed In The Valley Along The Natural Slope Till Slope Does Not Exceed Ruling Gradient

D) Slope Tunnels

- Tunnel Constructed In Steep Hills For Economic And Safe Operations Of Roads And Railways Non As Sloping Tunnels, This Type Of Tunnel Also Used For Transportation Purpose Mainly

Classification of Tunnels According To Shape

- Rectangular shape
- Circular Shape
- Elliptical Shape
- Horseshoe Shape

Circular shape

- This Type Of Tunnels Strong In Order To Resistance To External Pressure Caused By Water, Soil and Ground.
- Circular Shape Tunnels Not Suitable For Railways, And Highway Transportation Mainly Used For Sewage Lines.

Rectangular shape

Rectangular Tunnels Suitable For Hard Rock Sites And Mainly Uses For Pedestrian Passage, But This Type Of Tunnels Are Costly.

Horse Shoe Tunnels

- Horse Shoe Tunnels Can With Stand Internal And External Pressures, Having Semi-Circular Rood With arch Sides, Commonly Uses For Railway And Roadways.

Elliptical Tunnels

- Elliptical shape tunnels have the advantages for the transportation of sewer. The smaller cross section at the bottom maintains the flow at the required self cleaning velocity. However, due to the difficulty in construction, circular shape ones are more commo

Classification of Tunnels According To Type Of Materials

Tunnels In Hard Rock

Tunneling Through Hard Rock Almost Always Involves Blasting.

Tunnels In Soft Ground

- A Tunnel Built In Soft Ground Such As Clay, Silt, Sand, Gravel, Or Mud Requires Specialized Techniques Compared To Hard Rock.

HARBORS’ AND PORTS

DEFINITION

Harbour: It is partly enclosed area which provides safe and suitable accommodation for supplies, refueling, repair, loading and unloading cargo

DEFINITION

- A port is a harbour or area that can provide shelter to numerous boats and vessels (transferring people or cargo) and allow constant or periodic shipment transactions.
- In layman's language, a port is a place to facilitate the loading as well as unloading of vessels. Technically speaking, it is a convergence point between freight circulation domains.
- **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 Harbour

- It should be connected with roadway and railway.
- Surrounding land should be fertile and densely populated.
- Ship channels must have sufficient depth for draft or vessel.
- Breakwaters must be provided to protect against destructive wave action.
- The bottom should furnished secure anchorage to hold ships against the wind force.
- Numbers of quay, piers and wharfs should be sufficient for loading and unloading cargo.
- It should have facilities like fuel, repair and etc. for ships.
- Harbour area should be sufficiently large.

Classification in Ports

- **Inland Ports**
- **Fishing Ports**
- **Warm water Ports**
- **Dry Ports**
- **Sea Ports**

Types of Ports

Inland Ports

- Inland ports are built on smaller water bodies such as rivers or lakes. They can either be for cargo purposes or passengers or both. Conventionally Inland Ports are constructed or naturally maintained ports at the coastline of small waterways like lakes, rivers or estuaries and are also rarely seen at sea coasts.
- Some of these inland ports can have access to the sea with the help of a canal system. As such, ports are built on inland waterways. They usually behave like normal seaports but cannot allow deep draft ship traffic

Fishing Ports

- Fishing ports are mainly related to the commercial sphere as they participate in fishing. Fishing activities can also be treated as a mode of recreation. The existence of a fishing port entirely relies upon the availability of fish in that region of the ocean. A fishing port can be an inland port or a seaport.

Warm Water Ports

- These are the ports in which the water is maintained at warmer temperatures. The biggest advantage where a warm water port is concerned is that the water does not freeze during the frosty winters. Therefore, it is free to operate all year round without a temporary shutdown during the freezing time. Such ports help to a great extent to boost the economy of the nation.

Dry Ports

- As the name suggests, a dry port is **a port that is away from the sea.** It is more inland and connected to a seaport with either a paved road or railway. Dry ports are terminals where cargo brought over on ships is transshipped
- These are specifically employed for the transhipment of cargo to inland destinations. It is a trans-shipment port connected to a seaport and manages intermittent billing and coordination between importers and exporters.


DRY PORT

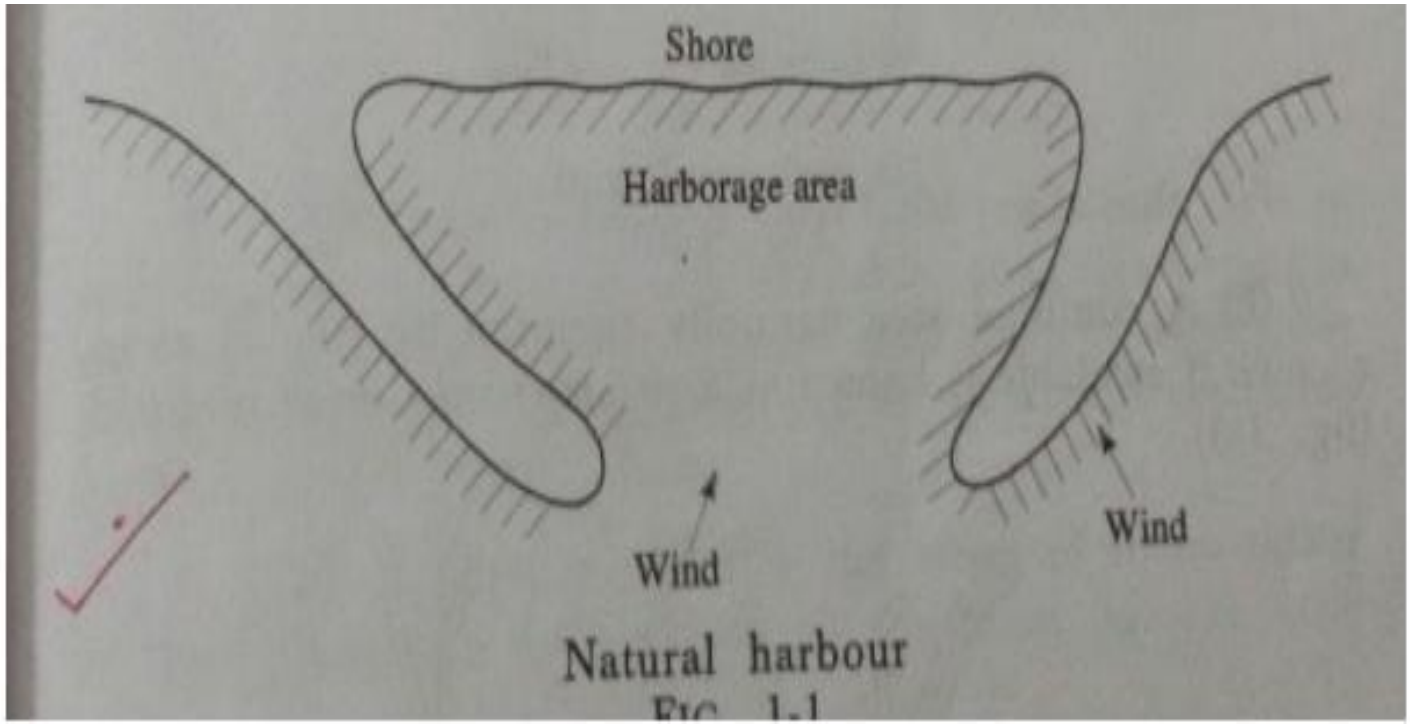
Sea Ports

- Seaports are the most common types of ports worldwide used for commercial shipping activities. These ports are built on a sea location and enable the accommodation of small and large vessels.


SEA PORTS IN INDIA

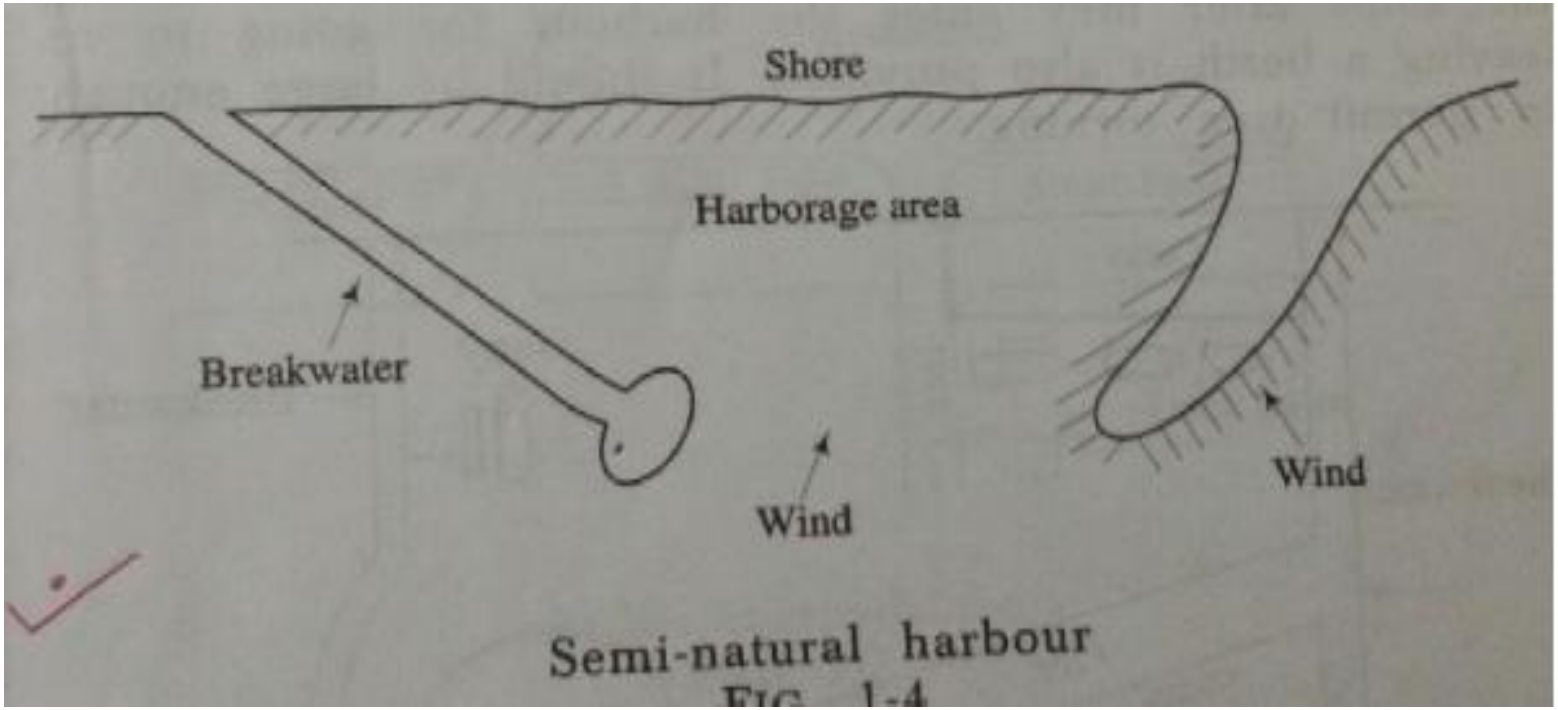
Types of Harbors

- Natural Harbour: Harbour protected by storms and waves by natural land contours, rocky out crops, or island that is called Natural Contour. (Eg. Kandla port, Cochin port & Mumbai Harbour)



Semi - Natural harbour

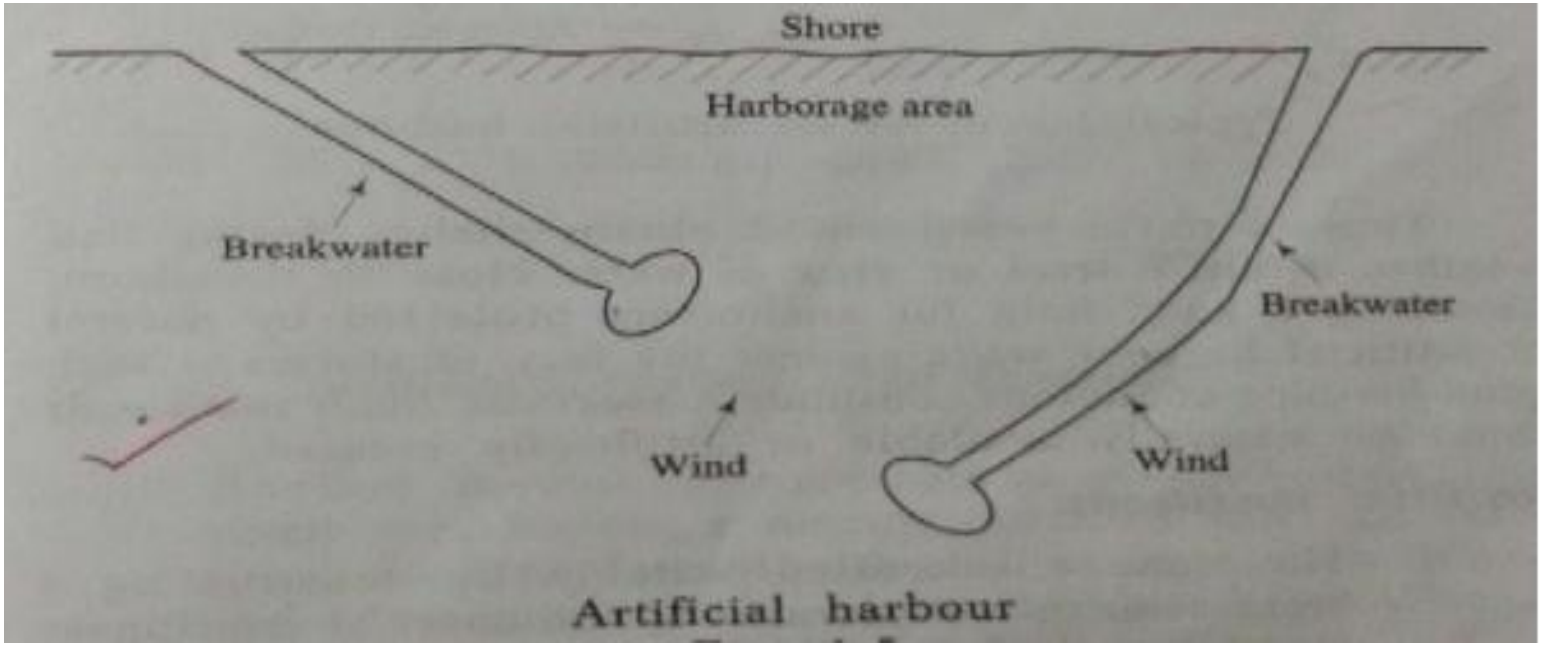
A semi – natural harbour is protected on the sides by the contours of land and requires manmade protection only to the entrance. (Eg. Mandvi, veraval & visakhapatnam port)



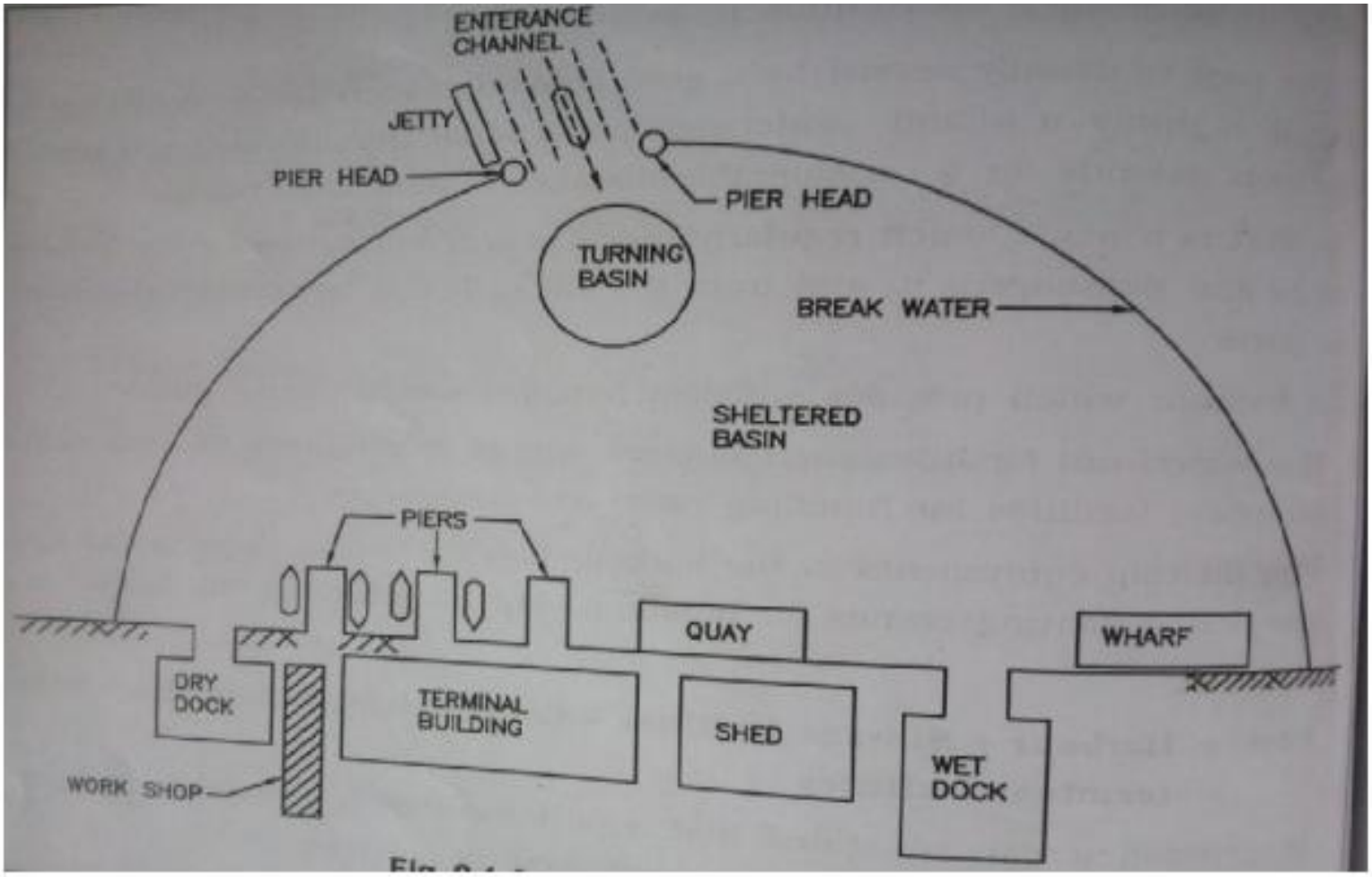
Semi-natural harbour

Artificial Harbour

An artificial harbour is one which is manmade and protected from storms and waves by engineering works. (Eg. Chennai Harbour)



Components of Harbors



Ludington Harbor, Michigan

Dry dock

Wet dock

Airport engineering

Introduction

- Fastest mode
- Speed more than 300 kmph
- Modern speed-
  3 x speed of sound

- Advantages

  - No artificial track
  - Time saving
  - emergency

- Disadvantages

  - Flight rules
  - Operating expense
  - Safety
  - Weather cond.

International Civil aviation organization (ICAO)

- Set up on April 4, 1947
- Head quarters in Canada
- 151 Sovereign state are members
- Objective are safe growth, new aircraft design and development of airways

International Airport Transport Association (IATA)

- More than 100 members
- To promote interest of civil aviation
- Provides forum for industry views

Air Transport In India

- First flight by Frenchmen Henry carrying mail from Allahabad to Naini in 1911
- Regular service Karachi to Delhi on December 30, 1929
- Internal service by Tata on Oct. 15, 1932 which later changed as Air India Limited.
- Govt. established Air India International limited in 1948
- Air trp corp. bill was passed in 1953 and two corporation were established for domestic and international service each as "Indian Airlines Corporation" & Air India International Corporation resp.

Present Status

- In India there are :

1. More than 335 domestic airport
2. More than 20 International airport

Airport Authorities of India (AAI)

- The Airport Authority of India is the body that manages both the International Airports in India as well as the Domestic Airports in India.
- Airports Authority of India (AAI) manages a total of 137 Airports, which includes 103 Domestic Airports, 24 International Airports, and 10 Customs Airports. AAI is responsible for creating, maintaining, upgrading, and managing civil aviation infrastructure in India and works under the Ministry of Civil Aviation.

Classification of Airport in India

INTERNATIONAL AIRPORT

An **international airport** is an airport with customs and border control facilities enabling passengers to travel between countries around the world. International airports are usually larger than domestic airports and they must feature longer runways and have facilities to accommodate the heavier aircraft such as the Boeing 747 commonly used for international and intercontinental travel. International airports often also host domestic flights, which often help feed both passengers and cargo into international ones (and vice versa).

Domestic Airport

- A **domestic airport** is an airport that handles only domestic flights within the same country. Domestic airports do not have customs and immigration facilities and so cannot handle flights to or from a foreign airport.

Custom Airports

- These airports have custom and immigration facilities for limited international operations by national carriers and for foreign tourist and cargo charter flights. These include Gaya, Patna, Madurai, Pune, Bagdogra, Chandigarh and Visakhapatnam

Civil enclaves in Defence airports

- A **joint-use airport** is an aerodrome that is used for both military aviation and civil aviation. They typically contain facilities of both a civil airport and a military air base.

Airport Classification as per ICAO

ICAO AIRPORT CLASSIFICATION

Airport type	Basic runway length (m)		Width of runway pavement (m)	Maximum longitudinal grade (%)
	Maximum	Minimum		
A	over 2100	2100	45	1.5
B	2099	1500	45	1.5
C	1499	900	30	1.5
D	899	750	22.5	2.0
E	749	600	18	2.0

TABLE 1-5
ICAO AIRPORT CLASSIFICATION

Code No.	Single isolated wheel load (kg)	Tyre pressure (kg/cm^2)
1	45000	8.5
2	34000	7.0
3	27000	7.0
4	20000	7.0
5	13000	6.0
6	7000	5.0
7	2000	2.5

have basic runway width

Airport Site Selection

- Meteorological and Atmospheric condition
- Avail. Of land for expansion
- Availabilities of Utilities
- Development of Surrounding areas
- Economy of construction
- Ground accessibility
- Presence of other airport
- Regional Plan
- Soil Characteristics
- Surrounding obstruction
- Topography