TRANSPORTATION ENGINEERING

INTRODUCTION

- The process of conveyance from one point to another is termed as **“TRANSPORTATION”.**
- Transportation has following effects over the socio- economic aspects of the life:

1. It helps in progress and advancement of the community.
2. Efficient transportation is essential for the economic prosperity and development of the country.
3. It helps in movement in emergency for defense of the country and to maintain better law and order.

MEDIUM OF TRANSPORTATION

Transportation can be achieved by any of the following mediums:

MAJOR MEDIUM	MINOR MEDIUM
• Land • Water • Air	• Pipeline • Conveyor belt • Elevator • Cable cars • Ropeway • Hyper loop

On the basis of the above media of transportation, following four major modes of transportation are used:

1. **Roadway/ Highway** for road transportation
2. **Railway** for rail transportation
3. **Waterway** for water transportation
4. **Airways** for air transportation

RAILWAYS

- It is the movement of multiple wagons or a train of wagons with steel wheels over two parallel steel rails, that offer comparatively lesser resistance.
- Hence, the cost of transportation by this method is approximately **one- sixth** of that by road transportation, but less flexible.
- Railways are considered as arteries of entire transportation system.


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A C CHAIR CAR

WATER TRANSPORTATION

- It offers minimum resistance to traction, hence it is the **cheapest** method amongst the all.
- But, the time required in this case is comparatively more.
- It is suitable for transportation of bulk goods of relatively low value.

AIR TRANSPORTATION

- It is the **fastest** method available for transportation.
- But, the cost involved in this method is also very high.
- It is suitable for transportation of high value goods for large distance.
- This method is affected by weather conditions.

ROADWAY/ HIGHWAY

- It is the most flexible mode of transportation amongst the all.
- But, it consumes petroleum product at highest rate and rate of emission of pollution is highest.
- Major road transportation is achieved by **highways and expressways.**
- Highways are special type of roads designed to allow high speed of vehicle.
- It is generally constructed on embankment as:

1. Better drainage facility
2. Safety in flood time
3. No lateral entry of public or animals

Eg- National Highways (NH) and State Highways (SH)

- Expressways are superior type of highways which are designed as a direct source of connectivity between two defined points.
- It is also known as **“freeway”.** It organizes the traffic in channelized way.


SKYLINE
ALL INDIA PERMIT

COMPARISON BETWEEN VARIOUS 20 YEAR ROAD DEVELOPMENT PLANS

	1st 20 YEAR PLAN	2nd 20 YEAR PLAN	3rd 20 YEAR PLAN
NAME	Nagpur	Bombay	Lucknow
DURATION	1943- 1963 (completed in 1961)	1961- 1981	1981- 2001
ROAD DENSITY	16 km/ 100 km^2	32 km/ 100 km^2	82 km/ 100 km^2
ROAD PATTERN	Star and grid	-	-
EXPRESS HIGHWAY	-	1600 km	20,000 km
CLASSIFICATION OF ROADS	NH, SH, MDR, ODR and VR	NH, SH, MDR, ODR and VR	1. Primary roads: EH and NH 2. Secondary roads: SH and MDR 3. Tertiary/ rural roads: VR, ODR

LENGTH OF THE ROAD AS PER 3rd 20 YEAR ROAD PLAN

1. Total length of road = max { (i) 4.74 × number of towns and villages; (ii) Road density × area }
2. Length of NH = $\frac{\text{Area (km}^2\text{)}}{50}$
3. Length of SH = max { (i) $\frac{\text{Area (km}^2\text{)}}{25}$; (ii) 62.5 × number of towns and villages – length of NH }
4. Length of MDH = max { (i) $\frac{\text{Area (km}^2\text{)}}{12.5}$; (ii) 90 × number of towns and villages }
5. Length of ODR and VR = Total – (ii) – (iii) – (iv)

CLASSIFICATION OF ROADS

Roads are classified as follows:

A. On the basis of duration of their use:

(i) All weather roads: paved and non- paved roads

(ii) Fair weather roads: surface and non- surface roads

B. On the basis of traffic volume

C. On the basis of load transported/ tonnage

D. On the basis of location and function

1. National Highway (NH): These are main highway running through length and width of country, connecting major ports, foreign highway, capitals of large states and large industrial area, tourist and places of strategic importance (defense).

2. **State Highway (SH):** These are arterial roads of states, connecting the national highways of adjacent state, district headquarters and important cities.
3. **Major District Roads (MDR):** They are important roads within a district, serving area of production, markets, etc.
4. **Other District Roads (ODR):** These are roads serving rural areas of production and providing them outlet to the market.
5. **Village Roads (VR):** These are roads connecting villages.

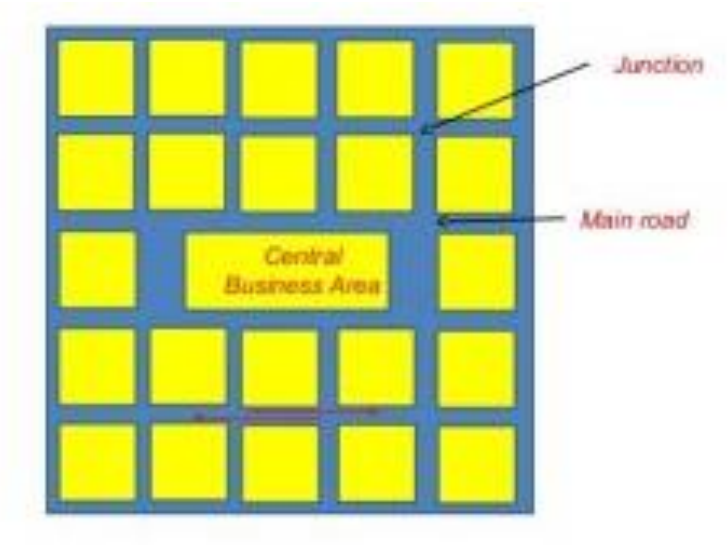
NOTE: Urban roads are also classified as follows:

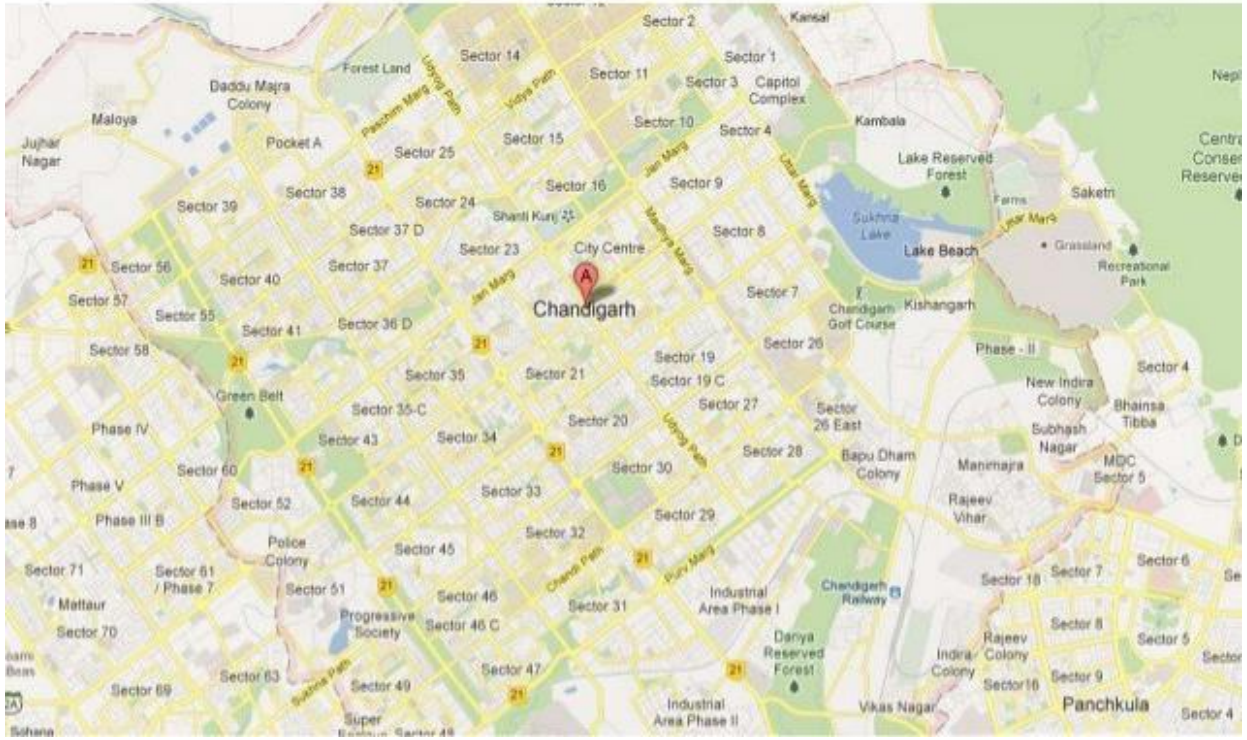
1. Arterial roads
2. Sub- arterial roads
3. Collector streets
4. Local streets

TYPES OF ROAD PATTERN

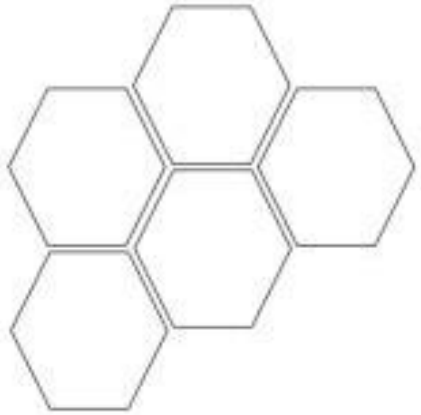
- The various types of road pattern may be classified as follows:

1. RECTANGULAR/ BLOCK PATTERN

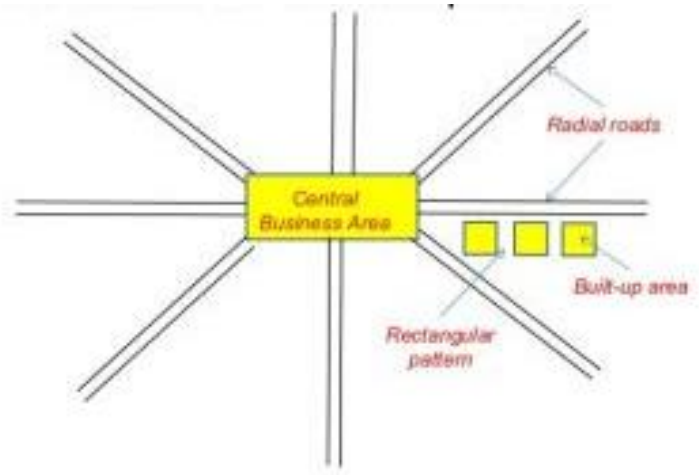




2. HEXAGONAL PATTERN

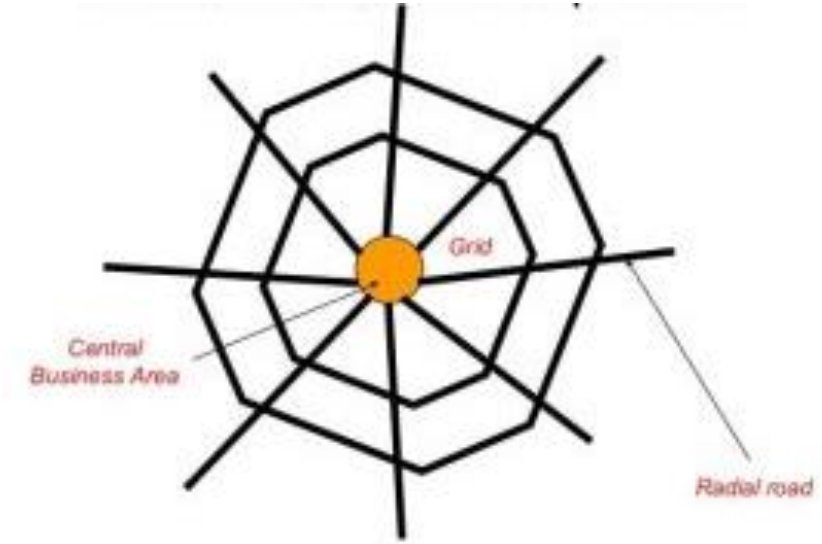


3. RADIAL OR STAR AND BLOCK PATTERN



4. RADIAL OR STAR AND CIRCULAR

5. RADIAL OR STAR AND GRID



HIGHWAY ELEMENTS

I. HIGHWAY CROSS- SECTION ELEMENTS

1. PAVEMENT SURFACE CHARACTERISTICS

- It depends upon pavement type, which in turn depends on availability of material, cost, composition of traffic, climatic conditions, method of construction, etc.
- Pavement surface characteristics include:

(i) Friction

(ii) Unevenness

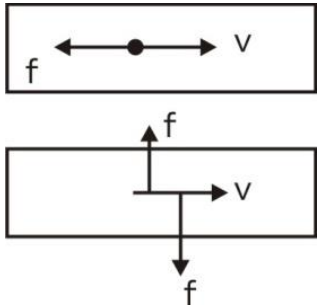
(iii) Reflection properties

(iv) Drainage of surface water

FRICTION/ SKID RESISTANCE

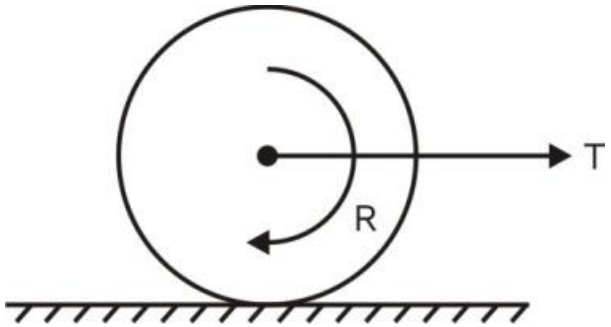
- It decides the operating speed and minimum distance required for stopping the vehicle.
- It is further classifies into two:

1. Longitudinal friction



2. Lateral or transverse friction

- Maximum friction is developed when brakes are applied upto complete extent.
- Friction also governs rotational and translational movement of the vehicle.
- **For uniform condition, Rotation = Translation**



Condition	Rotation	Translation	Impact
If longitudinal friction is more	No	Yes	Tyre burn
If longitudinal friction is less	Yes	No	No movement of vehicle (fuel burn)

NOTE: (i) When the path travelled along the road surface is more than the circumferential movement of wheels due to their rotation, it is termed as **"Skid".**

Translational motion > Rotational motion

For pure skid, Rotational motion = 0

For eg- When brakes are applied, rotation stops but skidding occurs

(ii) When the circumferential movement of wheels is more than the path travelled along the road surface, it is termed as **"Slip".**

Rotational motion > Translational motion

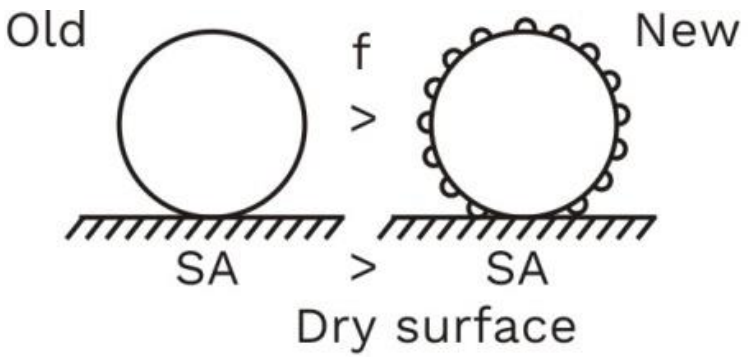
For pure slip, translational motion = 0

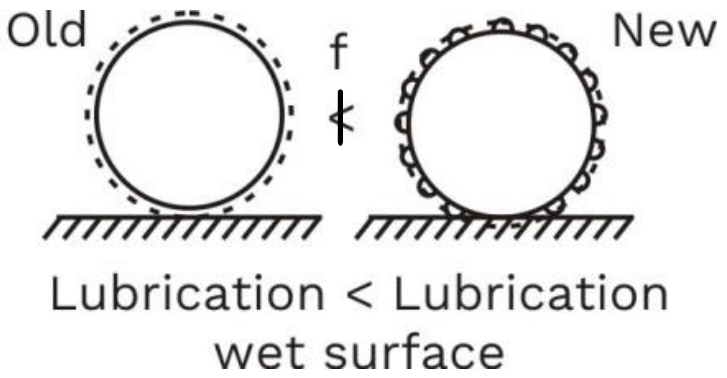
For eg- When wheels of vehicle are in mud, it rotates but do not move ahead.

Friction depend upon following factors:

1. Type of pavement surface (bitumen, concrete, earthwork)
2. Roughness of pavement (texture)
3. Condition of surface (dry or wet, rough or smooth)
4. Condition of tyre (new or old)
5. Speed of vehicle (high speed: less friction, low speed: more friction)
6. Extent of brake application (full or partial)
7. Temperature of tyre and pavement

NOTE: New tyre is more dependable in adverse conditions





- For the calculation of stopping sight distance, the **longitudinal friction co-efficient is taken to be (0.35- 0.40).**
- At f = 0.40, the retardation available is approximately 4m/s^2.
- **Lateral friction is taken as 0.15.**

UNEVENESS

- Presence of undulations on the pavement surface is called unevenness.

- This unevenness results in:

1. Increased fatigue
2. Reduces speed
3. Increases fuel consumption
4. Increases wear and tear of vehicles
5. Increases chances of accidents

- The unevenness of pavement is measured with the help of equipment called “Bump Indicator” (BI) in terms of unevenness index, which is the vertical undulations of pavement surface recorded per unit length of road (in India, mm/km is used).
- The different values of unevenness index and the corresponding serviceability of road is as follows:

Unevenness index (mm/ km)	Type of road
< 1500	Good
1500 - 2500	Satisfactory
2500 - 3500	Bad
> 3500	Uncomfortable

BUMP INDICATOR

NOTE: 1. Internationally, the riding quality of pavement surface is quantified in terms of roughness and is expressed as **"International Roughness Index".**

2. It can also be related with unevenness index as follows:

$$\textbf{BI (mm/km)} = \textbf{(IRI)}^{1.12}\ \textbf{(m/km)}$$

Unevenness of the pavement depends on following factors

1. Improper compaction
2. Use of improper compaction methods
3. Use of inferior quality materials
4. Improper surface and sub- surface drainage
5. Poor maintenance of pavement surface

REFLECTIVE PROPERTIES

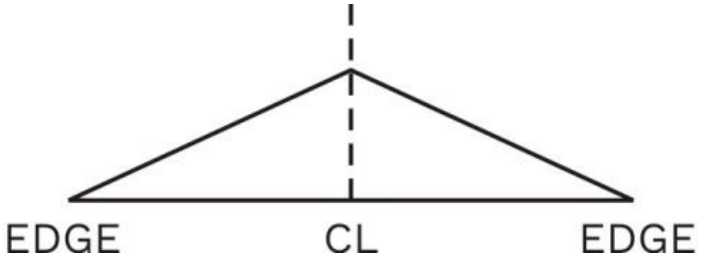
- Visibility over the pavement surface depends upon its color and light characteristics, the glare caused by the reflection of head light is high on wet pavement surface than dry pavement surface.
- Light colored pavement gives good visibility at night but produces more glare during sunlight. On the other hand, dark color pavement offers good visibility at day and poor at night.

2. CROSS- SLOPE/ CAMBER

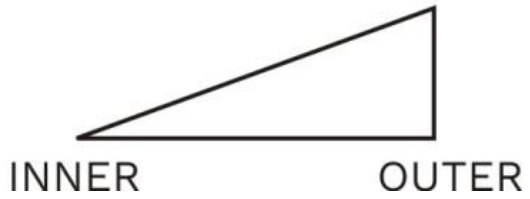
- It is the slope provided to the road surface in the transverse direction to drain the rain water from the road surface to avoid the following:

1. Stripping of bitumen from the aggregates in the presence of water.
2. Swelling and heaving of subgrade, in case water seeps into it.
3. To avoid the slipping of vehicle over the wet pavement.
4. To avoid the glare in wet pavement.

- On straight roads, it is provided by raising the centre of the carriageway w.r.t. the edges forming the crown on the highest point along the centre line.
- On horizontal curve, with super- elevation, the drainage is provided by lifting the outer edge.



STRAIGHT ROADS



HORIZONTAL CURVE

- It is represented by any of the following ways:

1. As % : for eg- cross- slope = 5%; $\tan\theta = 5/100$

2. As fraction: for eg- cross- slope = 1 in 20 or 1/20 or 0.05; $\tan\theta = 1/20$

1 in 20 means, 1V: 20H

- The value of cross- slope depends upon following factors:

1. Type of pavement surface
2. Amount of rainfall

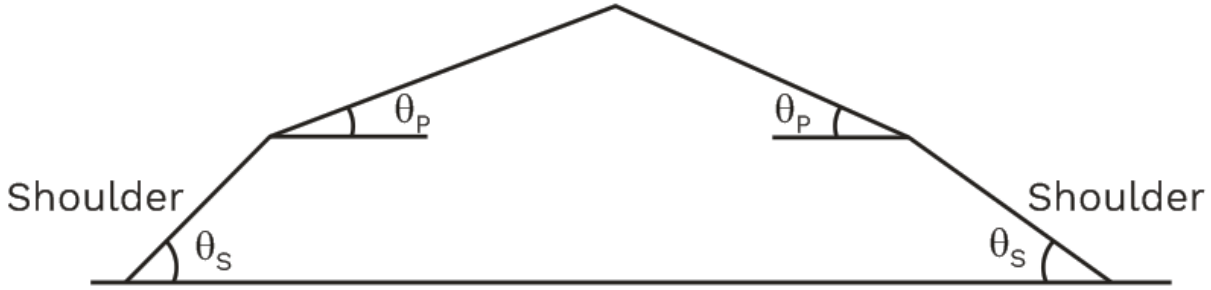
- Cross- slope provided would be comparatively increased if amount of rainfall is more and pavement surface is permeable.

Type of road surface	Range of cross- slope	
	Heavy rainfall	Light rainfall
Cement concrete and high type bituminous surface	2%	1.7%
Thin bituminous surface	2.5%	2%
WBM and gravel pavement	3%	2.5%
Earthern road	4%	3%

- The cross- slope of shoulder should be more than that of pavement, so as to avoid accumulation of water at junction of the two.

- Cross- slope of shoulder should be 0.5% more than cross- slope of adjoining pavement, having minimum value of 3% and maximum value of 5%.

$$5\% \leq CS_{shoulder} = (0.5\% + CS_{pavement}) \leq 3\%$$



- The cross- slope on expressways for carriageway and paved shoulder and edge strip with bituminous surface is 2.5% with rainfall exceeding 1000mm and 2% for places having rainfall less than 1000mm.
- If too steep cross- slope is provided, then:

1. Toppling of slow moving and over- loaded vehicles.
2. Tendency of most vehicles to travel along the centre line.
3. Uncomfortable side thrust and drag on the vehicle.

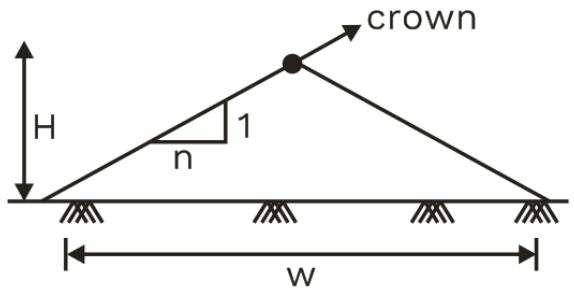
TYPES OF CROSS- SLOPE

Cross- slopes are of following types:

1. Straight line Camber:

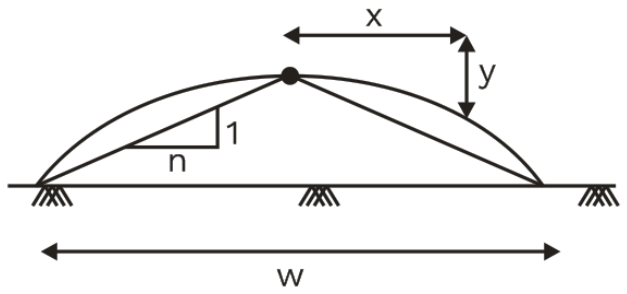
$$\frac{1}{n} = \frac{H}{w/2}$$

$$\mathbf{H = \frac{w}{2n}}$$



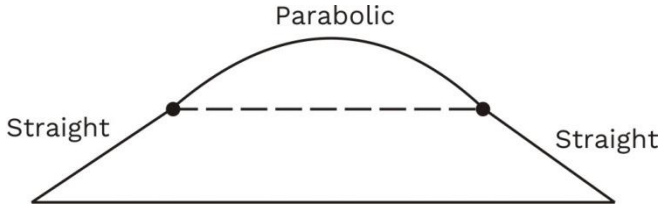
2. Parabolic Camber:

$$\mathbf{y = \frac{2x^2}{nw}}$$



3. Composite Camber:

Parabolic at top and straight at sides.



NOTE: For CC pavement, straight line camber is preferred as it is easier to lay.

3. WIDTH OF PAVEMENT/ CARRIAGEWAY

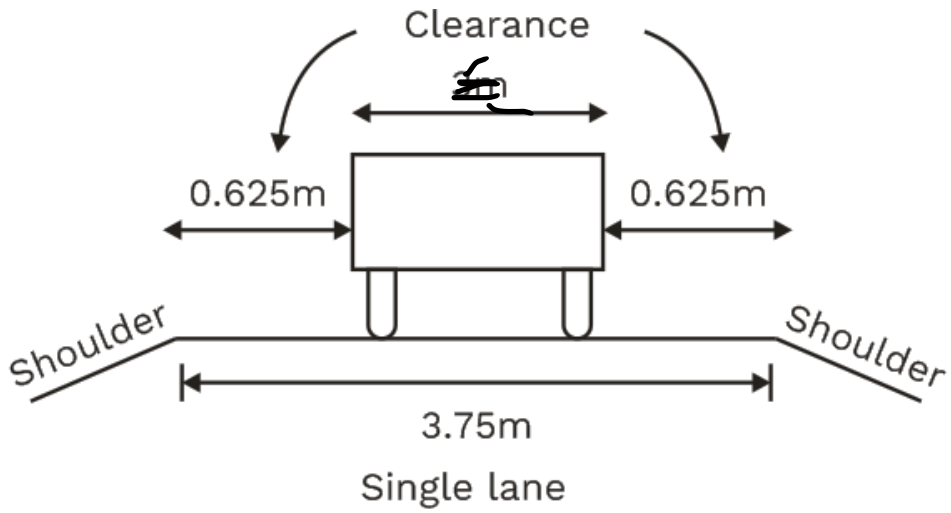
- Width of pavement depends upon width of traffic lane and number of lanes.
- The portion of carriageway width that is intended for one line of traffic movement is termed as **“traffic lane”.**
- Width of traffic lane is decided on the basis of type of vehicle moving it along with some clearance in both the sides.
- **Passenger car** is considered as standard vehicle to decide the width of carriageway.

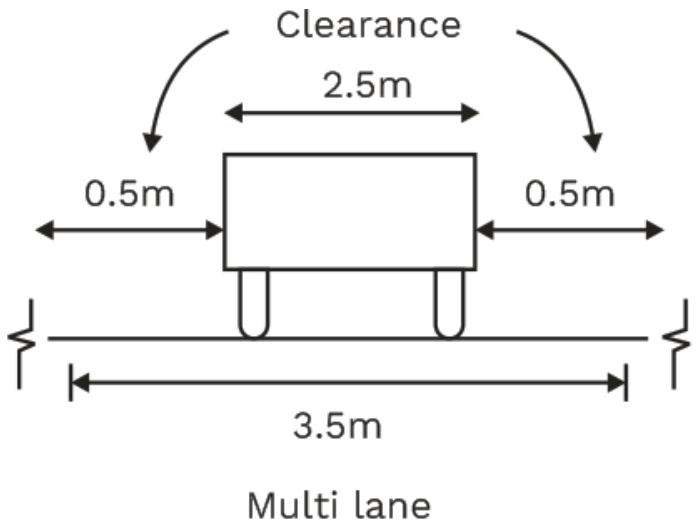
NOTE: Width of passenger car = 2.44 ≈ 2.5m

- For rural highway, if pavement has two or more lanes (multi- lanes), width of single lane = 3.5m.
- The number of lanes to be provided depends upon traffic volume.

The width of the carriageway for different conditions are as follows:

Type of road	Width of carriageway
1. Single lane road	3.75 m
2. Two lane road without raised kerbs	7 m
3. Two lane road with raised kerbs	7.5 m
4. Intermediate carriageway	5.5 m
5. multi- lane pavement	3.5 m per lane





4. MEDIANS/ TRAFFIC SEPARATOR

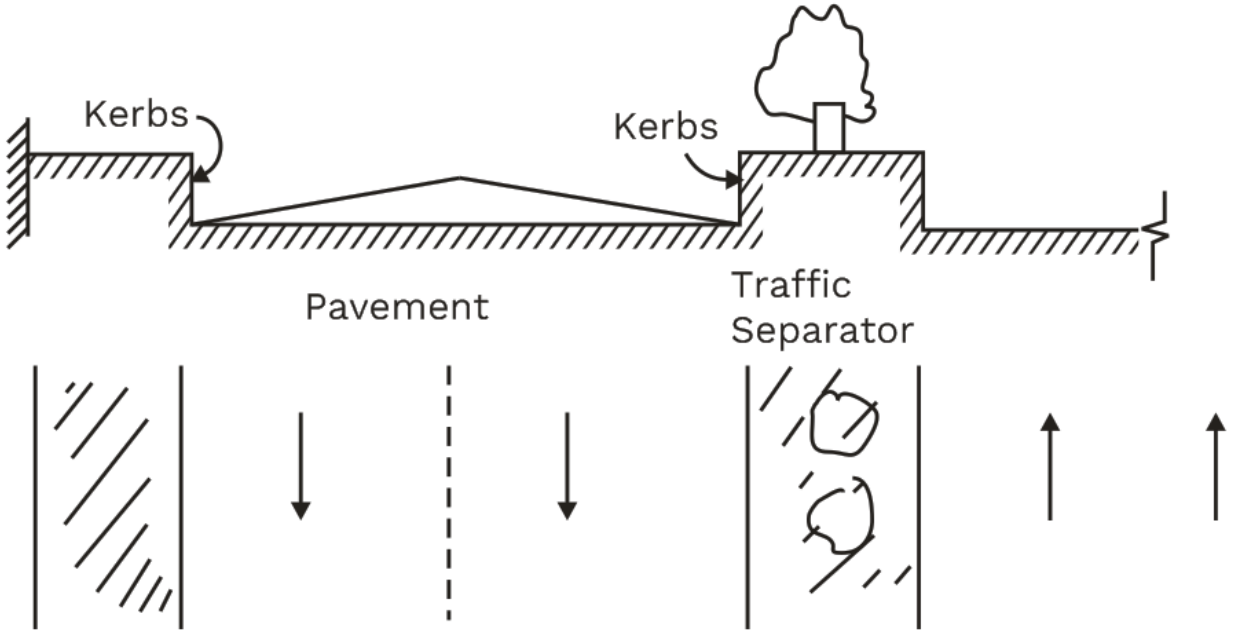
- In highway with divided carriageway or pavement, a median is provided between two sets of traffic lanes intended to divide the traffic moving in opposite directions.
- The main function of median is to prevent head- on collision between vehicles moving in opposite direction.
- It also serves following other functions:

1. To channelize traffic into streams.
2. To protect the pedestrians.
3. It can be used to reduce the glare of the head light of opposite moving vehicle by providing green cover on it.
4. To segregate the slow traffic.


Divider

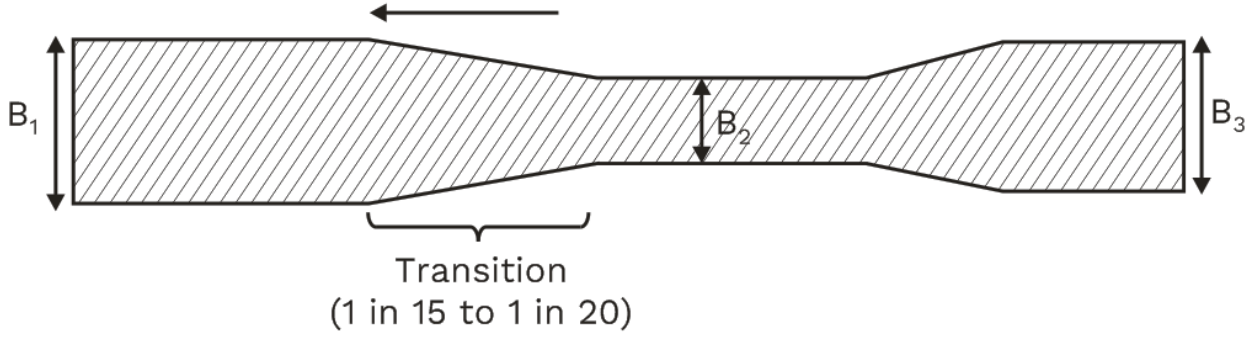
- Medians can be provided in following forms:

1. As pavement marking
2. As physical divider (mechanical separator)



- Desirable width of median is **(8-14)m.**
- It includes the provision for future expansion of roads.
- In order to reduce the glare of headlight of opposite vehicle, a minimum of 6m width is required.

- IRC recommends minimum width of 5m for median, that can be reduced to 3m where land is restricted.
- On bridges, width required for median is in the range of (1.2- 1.5)m.
- The median should be normally of uniform width throughout the length of the pavement or carriageway, but where its width is changed a transition of 1 in 15 to 1 in 20 must be provided.



- In urban areas, minimum width of median to be provided is 1.2m and desirable width is 1.5m
- For expressways, minimum width to be provided is 12m and desirable width is 15.5m.

5. KERB

- Kerb indicates the boundary between the pavement and median or foot path or island or shoulder.
- Kerbs are mainly divided in following three categories:

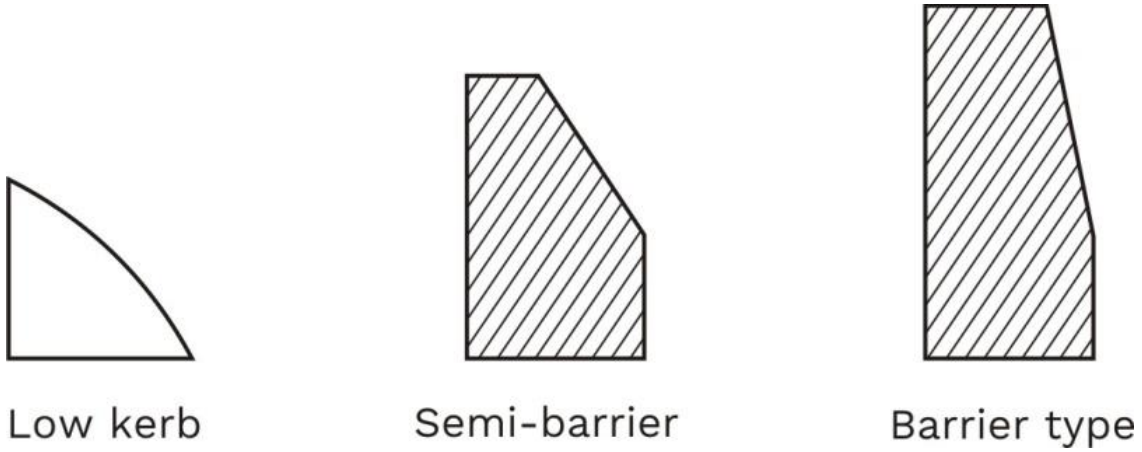
A. Low kerb: It is of height 100mm (10cm) above the pavement surface (edge) with a slope to enable the vehicle to climb the kerb at slow speed.

- It is also termed as “Mountable Kerb” which encourages the traffic to remain in the through traffic lanes yet allows the driver to enter the shoulder area at slow speed.

B. Semi- barrier type kerb: It is provided on the periphery of the roadway where the pedestrian traffic is high. This type of kerb is of height of about 150mm above the pavement edge with slope of 1:1 on top 75mm.

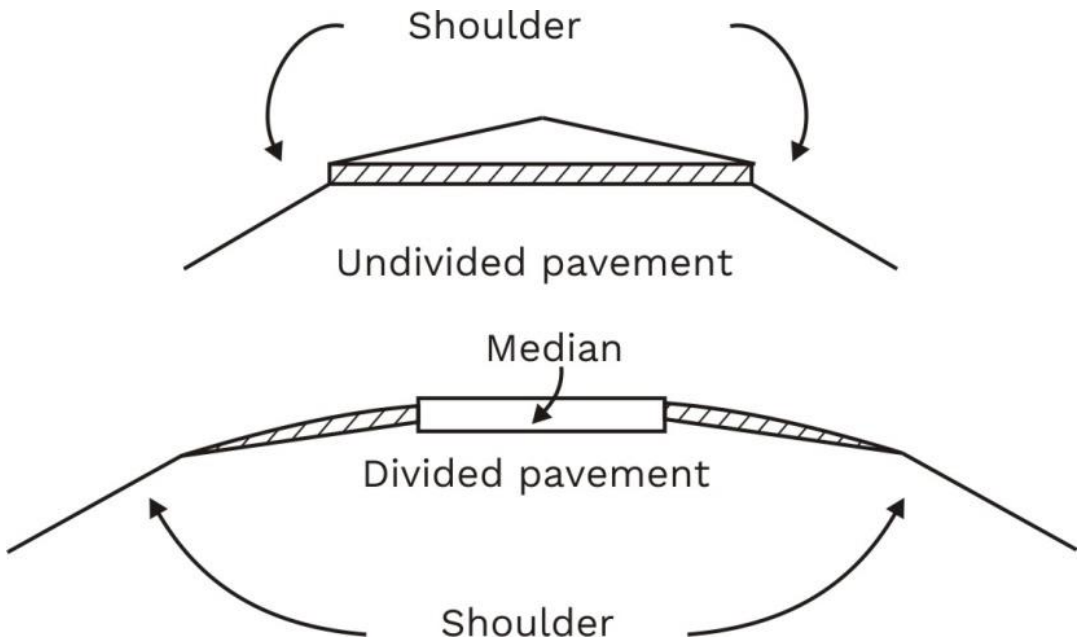
- This kerb prevents encroachment by parking vehicles, but in case of emergency, it is possible to drive over this kerb with difficulty.

C. Barrier type kerb: It is provided in built- up areas adjacent to footpaths with considerable pedestrian traffic. Height is 20cm (200mm) above the pavement edge of step slope of 1V: 0.25H.



6. SHOULDER

- Shoulders are provided on both sides of the pavement, all along the road in the case of undivided carriageway and on outer edge of divided carriageways.
- The earthern shoulder should have sufficient strength to carry the vehicular load in case of emergency.
- The minimum shoulder width as per IRC is 2.5m.




Shoulder
Shoulder

FUNCTIONS OF SHOULDER

Shoulder serves the following functions:

1. It imparts structural stability to the pavement.
2. It increases the capacity and operating speed of pavement.
3. In emergency, it can be sued as mode of movement.
4. It can also act as a service lane for the vehicles that are disabled.
5. The surface of the shoulder may be rougher than the traffic lanes, so as to discourage the vehicle to fly over it.
6. The color of the shoulder should be different from that of pavement, so as to differentiate between the two.

7. ROAD MARGINS

The various elements included in the road margins are guard rails, foot path, drive way, cycle track, parking lane, lay- bays, front edge, road and embankment slope.

(i) **Guard rail:** These are provided at the edge of the shoulder when the road is constructed running of the embankment, especially when the height of fill is more than 3m.

(ii) **Foot path/ Side walk:** In order to provide safe facility to the pedestrian to walk along the roadway, footpath/ side walk is provided in urban areas, where the pedestrian traffic is comparatively more.

- Its minimum width required is 1.5m and desirable width is 2m.
- It is provided with cross- slope of 2.5 – 3% and has comparatively smoother surface than pavement.



(iii) Drive ways: It connects the highway with local commercial establishment like service station, fuel station, restaurant, etc.

(iv) Cycle track: These are provided in urban areas for the safe movement of cycle traffic.

- The minimum width required is 2m for cycle track and it can be increased by 1m for each additional cycle way.

(v) Parking lanes: These are provided on urban roads to allow kerb parking.

- As far as possible, only parallel parking should be allowed as it is safer for moving vehicles and space required would also be less.
- For parallel parking, the minimum width is 3m.

(vi) Bus bays: It may be provided by pushing back the kerb to avoid the conflict with the moving traffic and must be located atleast 75m away from intersection.

- It is used for safe loading and unloading of passengers.

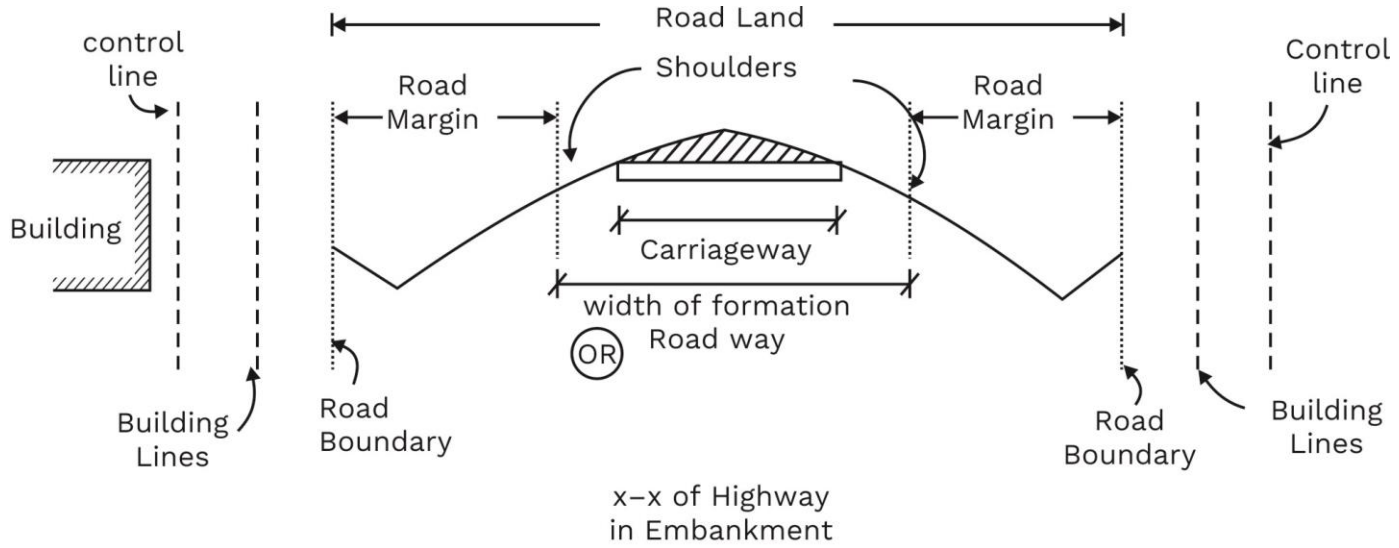
(vii) Lay byes: These are provided near public convenience to avoid the conflict with running traffic. Minimum width is 3m.

(viii) Frontage roads: These are provided to give access to the property along the highway to control the access to the expressway.

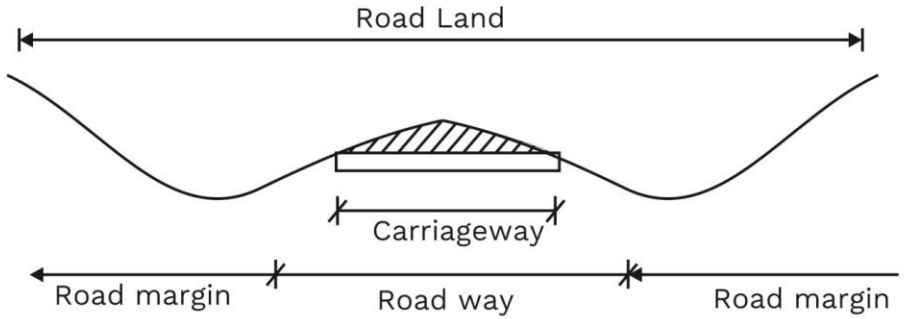
(ix) Embankment slope: If pavement is constructed over embankment, slopes are also provided along it, of magnitude 1:3.

NOTE: 1. ROADWAY/ WIDTH OF FORMATION

It is the sum of width of pavement or carriageway including separator and the shoulder. Roadway width is the top width of highway embankment or bottom width of highway cutting excluding the side ways.



x–x of Highway in Embankment



x–x of Highway cutting

Width of roadway of various class of roads are as follows:

Type of roads	Roadway width (m)	
	Plain and rolling terrain	Mountaineous and steep terrain
NH and SH		
(a) Single lane	12	6.25
(b) Two lane	12	8.8
MDR		
(a) Single lane	9	4.75
(b) Two lane	9	-
ODR		
(a) Single lane	7.5	4.75
(b) Two lane	9	-
Village roads	7.5	4

NOTE: 2. ROADLAND/ LAND WIDTH/ RIGHT OF WAY

- It is the area of the road, along its alignment keeping in view its future expansion also.
- Construction of a particular type of building is only permitted with sufficient setback from the road boundary upto control line.
- Width of land for different roads in rural areas are as follows:

Road Classification	**Plain and Rolling**		**Mountaneous**	
	Open	Built area	Open	Built area
Expressway	90m	-	60m	-
NH and SH	45m	30m	24m	20m
MDR	25m	20m	18m	15m
ODR	15m	15m	15m	12m
VR	12m	10m	9m	9m

RAILS & RAIL JOINTS

Rails :

- These are steel girders used for carrying the axle load (train load) and transfer it to the subgrade through sleeper and ballast.

  Rail convert the moving wheel load of train into point load, which acts on the sleepers.

  Since it has to resist high wear & tear, it is made of high carbon steel.

  In India, its manufacturing is done by 'open hearth / duplex process.'

NOTE :

- Steel is manufactured by two processes :

(i) Triplex Process :

- It has three main production facilities
  - (a) Acid Bessemer Converter
  - (b) Basic Open Hearth Furnace
  - (c) Acidic Open Hearth Furnace

  It is outdated.

  ↳ 1950's में बन्द हो गया था।

(ii) Duplex Process : (or, Open Hearth Process)

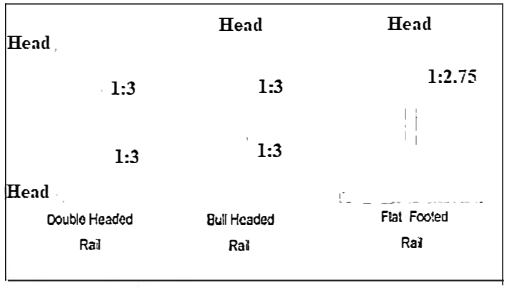
- It consists of blowing hot metal & scrap in the Acid Bessemer Converter and finally refining them in Basic Open Hearth
- Here, scrap is also utilized.
- Used in today's time

Types of Rails :

(1) Double Headed Rails (DH Rails)

(2) Bull Headed Rails (BH Rails)

(3) Flat Footed Rails (FF Rails)
OR, Vignales Rails



(1) Double Headed Rails

- These rails were used in beginning.

  The idea behind providing two heads was, if one head will worn out, the rail can be inverted and re-used.

  But in lower part due to indentations, smooth running surface was not obtained.

(2) Bull Headed Rails :

- In these rails, head was made a little thicker and stronger than ~~former~~ lower

(3) Flat Footed Rail / Vignole's Rail :

Here, bearing plate / flat plate is used at bottom.

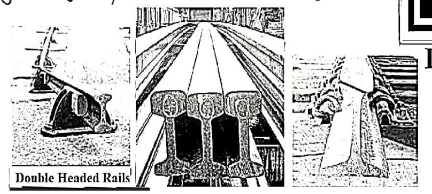
These rails are designated by weight of rail per unit length

52 kg/m or 52 MR

60 kg/m or 60 MR

52 MR $V \leq 130$ kmph

60 MR $V \leq 160$ kmph



Flat footed rails are more stronger, stiffer, easy to lay, cheaper and easy to maintain in comparison to double head / bull headed rails.

Requirement of Rails :

These must be capable of withstanding the lateral forces.
(Hence, width of head and foot is increased.)

To allow for vertical wear of 10 mm on its head.

↳ अगर 10 mm से ज्यादा wear & tear हो रही है तो उस rail को change करना पड़ेगा

Minimum tensile strength is 72 kg/m².

Must pass weight / tup test.

↳ इसमें 1.5 m की rail लेते हैं और इसके ऊपर 1000 kg (1 tonne) का weight (tup) fall कराया जाता है, 7.2 m की height से। ऐसा करने से concerned rail fail नहीं होनी चाहिए।

Lec-1 (20:35)

NOTE: **Breathing Length :**

- It is the minimum length of welded rail on both ends of track required such that portion of rail b/w it does not undergo expansion or contraction.

Que : Theoretical length of LWR beyond which central portion of 52 kg/m rail would not be subjected to any longitudinal movement due to 35°c temp. increase, if : $A_s = 66.15\ cm^2$

$\alpha = 11.5 \times 10^{-6}$

$E_s = 21 \times 10^6\ kg/cm^2$

$S = 60\ cm$

$f_{s_1} = 300\ kg$

$\Delta t = 35°c$

Sol : Force developed in rail, $F_s = \alpha \Delta t\ E_s\ A_s$

$= 11.5 \times 10^{-6} \times 35 \times 21 \times 10^6 \times 66.15$

$= 55\,9132.8\ kg$

No. of sleepers reqd, $n = \frac{F_s}{f_{s_1}} = \frac{559132.8}{300} = 1864$

$S = 60\ cm$

Breathing length reqd $= 2(n-1)S = 2(1864-1) \times 60 \times 10^{-2} \times 10^{-3}\ km$

$= 2.235\ km$

SLEEPERS

SLEEPERS :

- These are members which support the rails and are laid rail.
- They are provided to :
  - (a) To hold the rail to correct gauge
  - (b) To allow adzing of rails
  - (c) To act as elastic medium
  - (d) To provide longitudinal and lateral stability.
  - (e) To distribute load from rail to ballast

Classification of Sleepers :

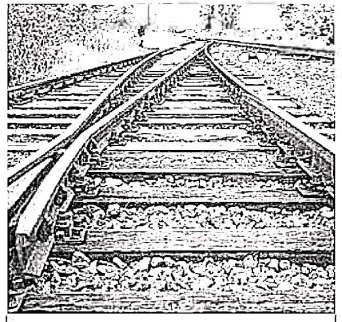
(1) Wooden Sleepers

(2) Metal Sleepers
  - (i) Cast Iron
  - (ii) Steel

(3) Concrete Sleepers
  - (i) RCC – 2.6 m x 250mm x 250 mm
  - (ii) PSC – 2.6 m x 250 mm x 125 mm

(1) Timber/Wooden Sleepers :

- These are regarded as best sleepers as it has low initial cost, low maintenance cost, easy to lay, pack, lift and maintain.
- Sal and teak is commonly used for sleepers.
- These are easily subjected to wear & tear, decay, attack of white ants.
- Their life is short, 12-15 years.
- It can be increased by creosoting.



Timber/Wooden Sleepers

Composite Sleeper Index (CSI) :

- It measures the mechanical strength of timber, derived from its composite properties of strength and hardness.

$$CSI = \frac{S + 10H}{20}$$

S = Strength at 12% moisture content

H = Hardness at 12% moisture content

Lec-6 (46:25)

(2) Metal Sleepers :

- Metal sleepers are in the form of inverted channel with corners bent or folded.

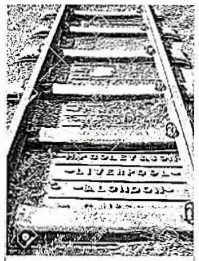
Cast Iron Sleepers :

- Life of cast iron sleepers is comparatively more (35–50 years).
- Cast iron sleepers can be used for any type of ballast.
- Maintenance cost of cast iron sleepers is comparatively less and scrap value is more, initial cost is high because of more no. of fasteners.
- Cast iron sleepers do not provide elastic bed b/w rails and ballast.

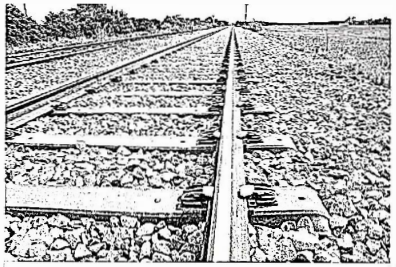
Steel Sleepers :

- Steel sleepers are light weight, so handling is comparatively easy.
- Fasteners reqd. in steel sleepers are comparatively less.
- Maintenance is comparatively easy than cast iron sleepers but it has rusting prblm.

☆ Metal sleepers cannot be used for track circuiting bcoz of short-circuit problem.



Cast Iron Sleepers



Steel Sleepers

Concrete Sleepers

(3) Concrete Sleepers :

- No decay (as in timber sleepers)
- Track circuiting can be done easily.
- It provides elastic bed b/w rails and ballast.
- Since it has high modulus of elasticity, it is able to resist high stresses.
- No scrap value for concrete.
- Its weight is 2–4 times more than timber sleepers, so transportation becomes difficult.

SLEEPER DENSITY :

- No. of sleepers per rail length is termed as sleeper
- In India, sleeper density is represented as 'M + x'.

  where, M : is rail length

  x : is number which varies b/w 3–7

- For BG, it is 'M + 5'

Que: Using sleeper density M+5, find out the number of sleepers required for construction of a railway track 1280 m long (BG track).

Sol: No. of rails in 1280 m = $\frac{1280}{12.8}$ = 100 rails

No. of sleepers per rail length = M + 5

= 12.8 + 5

= 17.8 ≃ 18

Total no. of sleepers = 18 x 100 = 1800

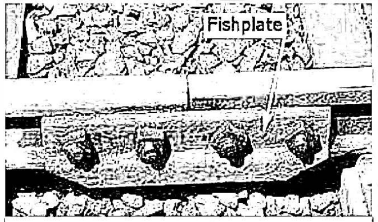
TRACK FASTENERS

TRACK FASTENERS

(i) Fish Plate
(ii) Spikes
(iii) Chair
(iv) Bolts
(v) Key
(vi) Bearing Plate

(i) Fish Plate :

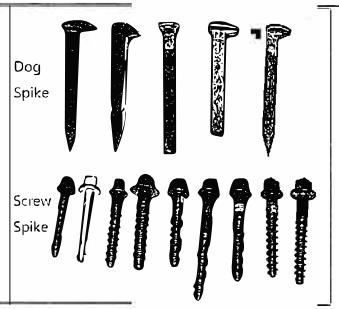
It is used at rail joints in order to maintain continuity of rail joints and permit thermal expansion and contraction.

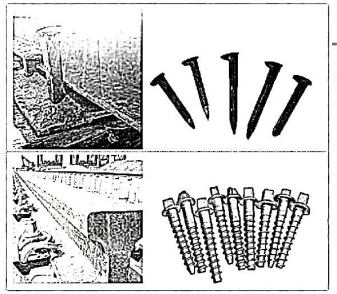


Fish Plate

(ii) Spikes

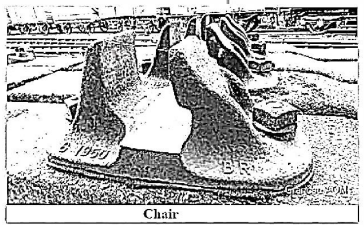
It is used to hold rails on wooden sleepers.
For holding flat footed rails on wooden sleeper, dog spikes are used.
Screw spikes have double holding power than dog spike.





(iii) Chair :

— Chairs are used to support bull headed rails on the sleepers.

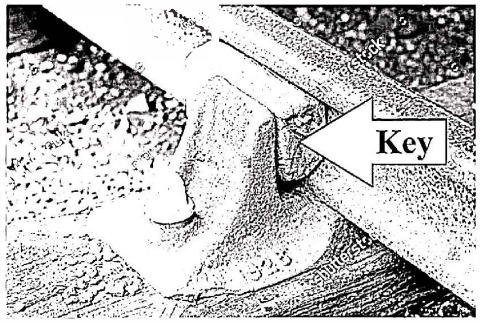

Chair

(iv) Bolts :

— These are used to connect rails with either sleepers or chair or bearing plate.

(v) Key :

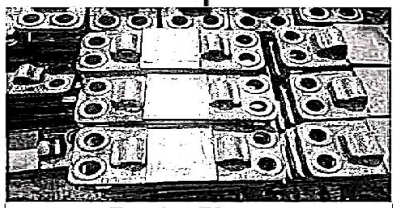
— These are small tapered piece of timber coated with steel that fix rails to chairs on sleepers.

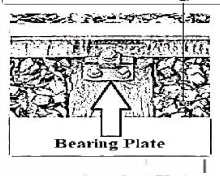


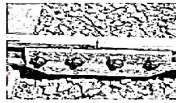
(vi) Bearing Plate :

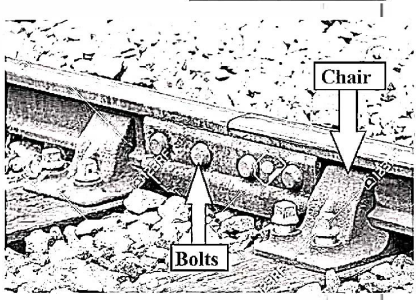
These are rectangular plates of either mild steel or cast iron, and are used below flat footed rails to distribute the load on a larger area of timber sleepers

— These are not used in concrete or metal sleepers.


Bearing Plates







BALLAST & SUBGRADE

BALLAST :

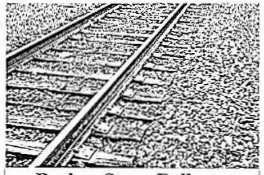
- It is the granular material usually made of broken stones or kankar/gravel/sand etc. which is placed below the sleeper and is used to transmit the load from sleeper to subgrade.

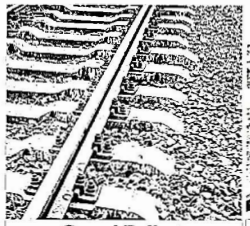
Functions of Ballast :

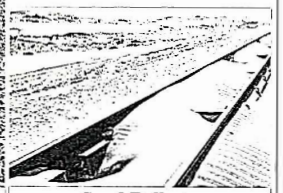
(a) Load transfer
(b) Drainage
(c) Superelevation on curves
(d) imparts elasticity to track
(e) imparts longitudinal and lateral stability to sleepers.
(f) absorbs shocks and vibration
(g) helps in controlling vegetation

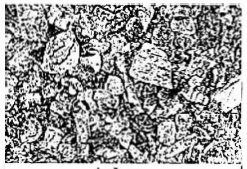
Types of Ballast :

(a) Broken stones
(b) Gravel
(c) Sand
(d) Ashes
(e) Brick
(f) Blast furnace slag.

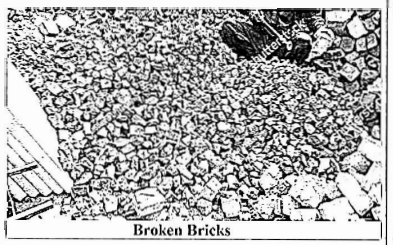

Broken Stone Ballast


Gravel Ballast


Sand Ballast


Ashes


Blast Furnace Slag


Broken Bricks

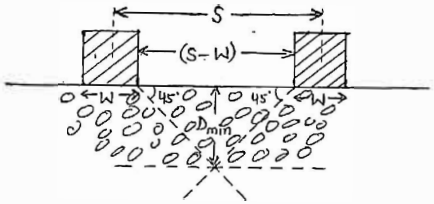
- Broken stone is the best material for ballast. Igneous rocks such as granite, quartz etc. are used for broken stone. It is provided in almost every track. Size of broken stones varies from 1.9 cm to 5.08 cm.
- River pebbles or gravels are used in gravel ballast. Since these are smooth, they don't provide proper interlocking.
- Sand in sand ballast provides good drainage and there is no vegetation. Track made of sand ballast is silent, i.e, does not produce noise. But, during vibrations, sand is removed off. And, sand also drains off in the situation of flood.
- Ash ballast also offers good drainage but it is very soft, so it breaks very easily when train runs over it. Also, It becomes slippery during rainy season. Hence, it is avoided.
- Broken bricks can also be used as ballast.
- Blast furnace slag is the residue left after the extraction of metal.

Specification of Ballast :

- Size : 1.9 cm – 5.1 cm
  - ↳ Interlocking comes out to be good for this size.
- For different types of sleeper, size of ballast used is :

  for wooden sleepers = 5.1 cm
  for steel sleepers = 3.8 cm
  in case of crossings = 2.64 cm
  for concrete sleepers = 4.5 cm

- The depth of the ballast layer affects bearing capacity and distribution of load on subgrade.
- Greater the depth of ballast, greater will be load bearing capacity.
- Load distribution below the sleepers is assumed to be 45° to the vertical, so minimum depth is given as :



$$\tan 45^\circ = \frac{D_{min}}{\frac{S-W}{2}}$$

$$1 = \frac{D_{min}}{\frac{S-W}{2}}$$

$$\boxed{D_{min} = \frac{S-W}{2}}$$

— The quantity of ballast (stone) required per meter length is :

for BG : 1.036 m^3

for MG : 0.71 m^3

for NG : 0.5 m^3

SUBGRADE :

— It is naturally occuring soil which is prepared to receive ballast, sleepers, rails for construction of railway track.

— Subgrade must have :

(a) stability

(b) good drainage

(c) property to prevent punchering of ballast into it.

(d) ability to bear the transmitted load.

Que : If the spacing of the sleeper is 1.2 m and width of sleeper is 30 cm. Find the minimum depth of ballast cushion.

$$D_{min} = \frac{S-W}{2} = \frac{1.2-0.3}{2} = 0.45\,m = 45\,cm.$$

Airport Design

Airports are classified by 2 organisations
(i) ICAO (International Civil Aviation Org^n)
(ii) FAA (Federal Aviation Agency)

Safety
Economical
Uniformity

ICAO classifies airport into 2 categories
(i) Based on basic runway length requirement
A → longest runway
E → Shortest runway
(ii) Based on equivalent single wheel load of the aircraft.

Runway length Requirement will be more if landing & take-off operations are performed along the wind direction.

Wind parameters (direction, duration & intensity) are graphically represented by a diagram called Wind Rose Diagram.

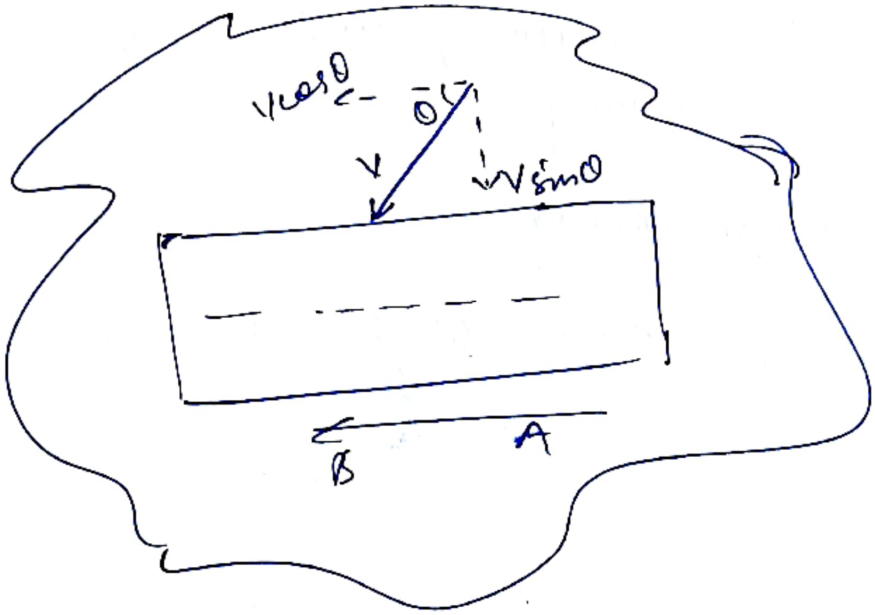
Wind parameters should be collected for a period of atleast 5 yrs.

The normal component of the wind is called as Cross-wind component ($V \sin\theta$). & it may interrupt safe landing & take-off of the aircraft. wt ↑ → stability ↑ →

For the smaller size of the aircraft, max^m permissible value of the X-wind component is 15 km/hr & for bigger size of aircraft, max^m permissible value is 25 km/hr.

This X-wind component may interrupt safe landing & take-off of the aircraft.

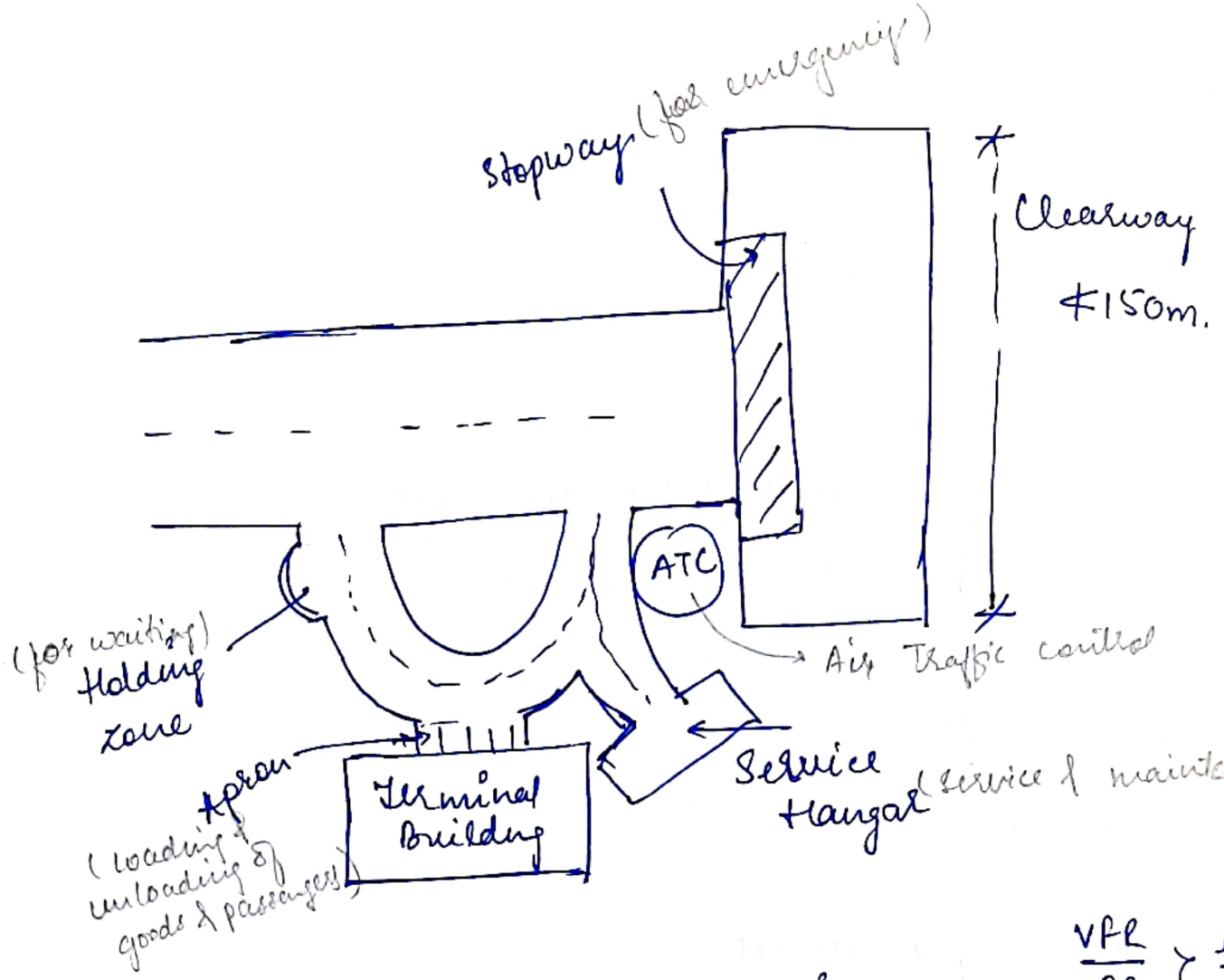
The %age of time during which, in a year the cross-wind component remains within the permissible limit is called as Wind Coverage.



Basic Runway Length Requirement

- Airport altitude is at sea level.
- Std. atmospheric temp^r is 15°C.
- Runway is levelled in the longitudinal direc^n
- Aircraft is loaded through its full-loading capacity.
- Speed of wind should be 0. for the runway.

Airport Layout



$\frac{VFR}{IFR} > 1$

Aircraft movements will be more in case of Visual Flight Rules (VFR) as compared to Instrumental Flight Rules (IFR)

Harbour

Harbours provide safe anchorage to ships in cond^{n} of bad weather.

Ports are used for loading & unloading of passengers, cargo, etc.

~~Dock~~ { every port is a harbour, but the reverse is not true.

Docks which are used for ships to facilitate loading & unloading of passengers & cargo are known as wet docks.

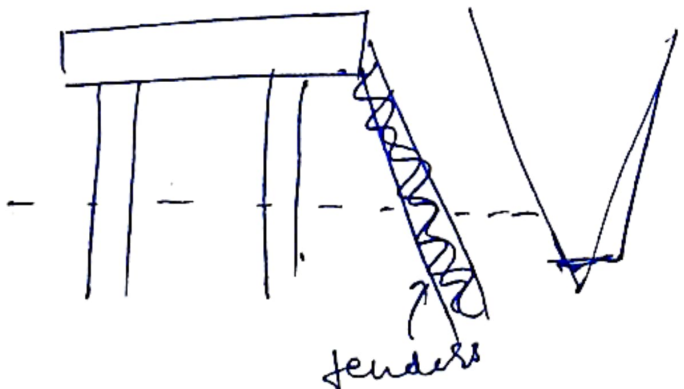
Docks which are used for maintenance of ships are known as dry docks.

Wharf

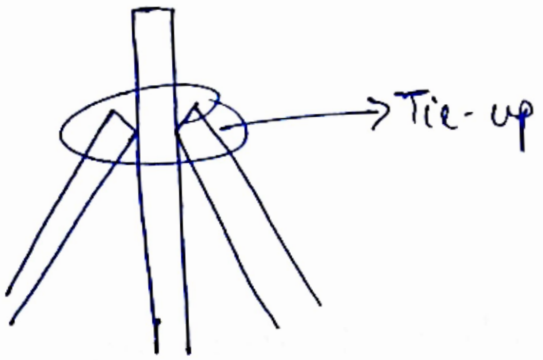
It is a type of ~~raised~~ fixed platform usually on pile foundation where ships are docked & unloaded.

Fenders

Dockwall receives large amount of impact & to avoid this, cushions are provided permanently with dockwalls & these are known as fenders.



Dolphin pile foundat^{n} is provided to tie up ships



Litteral Drift

Sea waves are generated by prevailing winds & they move lighter particles of sand in suspension & this suspended sand is carried in a zig-zag manner & deposit^{n} of this sand is known as litteral drift.

Excavat^{n} below the water surface is known as dredging

Navigational Aid

Any device which is used to help travellers in navigat^{n}.

eg. - Buoys & lighthouses.