3rd Semester, Civil Engineering

Transportation Engineering (Th-2)

UNIT 1- OVERVIEW OF HIGHWAY ENGINEERING

UNIT-2- GEOMETRIC DESIGN OF HIGHWAY

UNIT-3-CONSTRUCTION OF ROAD PAVEMENTS

UNIT-4-BASICS OF RAILWAY ENGINEERING

UNIT-5-TRACK GEOMETRICS, CONSTRUCTION AND MAINTENANCE

UNIT 1

OVERVIEW OF HIGHWAY ENGINEERING

Overview of Highway Engineering

2 Mark Questions

1. Define Highway Engineering.

ANSWER: Highway Engineering is a branch of Civil Engineering that deals with the planning, design, construction, operation, and maintenance of roads and highways to ensure safe and efficient transportation of people and goods.

2. What is the importance of transportation in a nation's development?

ANSWER: Transportation facilitates trade, improves accessibility to resources, boosts industrial growth, and enhances the overall economic and social development of a nation.

3. List the different modes of transportation.

ANSWER: The different modes of transportation are land (road and railway), water (waterways), and air (airways).

4. Mention any two merits of road transport.

ANSWER: Road transport provides door-to-door service and offers flexibility in route and timing compared to other modes of transport.

5. Mention any two demerits of road transport.

ANSWER: Road transport is slower over long distances and more affected by traffic congestion and weather conditions.

6. What are the main characteristics of roads in India?

ANSWER: Indian roads are classified into National Highways, State Highways, District Roads, and Village Roads, connecting rural and urban areas efficiently.

7. What do you mean by road alignment?

ANSWER: Road alignment is the position or layout of the centreline of a road, determined both horizontally and vertically to ensure smooth traffic movement.

8. List two factors affecting road alignment.

ANSWER: Topography, traffic, drainage, and economic factors affect the selection of road alignment.

9. What is the scope of Highway Engineering?

ANSWER: Highway Engineering covers road planning, geometric design, pavement design, materials testing, and traffic engineering.

10. Define classification of roads.

ANSWER: Roads are classified based on function, traffic volume, and location, such as National Highways, State Highways, and Village Roads.

5 Mark Questions

1. Explain the role of transportation in national development.

ANSWER

Transportation is crucial for national development as it facilitates economic growth by connecting markets, enabling trade, and creating jobs, while also fostering social development by improving access to services like education and healthcare, and promoting regional integration. By linking people, goods, and services, transportation systems drive economic activity, support industries, and help create a more unified and accessible country.

Economic development

- **Facilitates trade and commerce**: Efficient transportation systems allow for the movement of raw materials to factories and finished goods to consumers, reducing costs and increasing profitability.
- **Encourages investment**: Good transport infrastructure attracts domestic and foreign investment, leading to more business and economic clusters.
- **Creates jobs**: The transport sector provides employment in areas like construction, management, operations, and logistics, with a significant "cascading effect" on other industries.
- **Boosts productivity**: Reduced travel times and lower costs for moving goods and people make the workforce more productive and the economy more competitive.

Social and regional development

- **Improves access to services**: Transportation provides access to essential services like education, healthcare, and employment for people in both urban and rural areas.
- **Promotes social integration**: It connects different regions of a country, fostering social interaction and a sense of national unity by allowing for greater mobility.

- **Develops rural areas**: Transportation links rural communities to urban markets, helping them sell products and get inputs for agriculture, which reduces migration to cities and promotes balanced development.

2. **Discuss the scope and importance of roads in India.**

ANSWER

Roads are critically important in India for their role in the economy and social development, providing the primary means for moving 64.5% of goods and 90% of passenger traffic. Their scope is vast, connecting rural and urban areas, linking all other forms of transport (rail, air, and sea), and reaching remote locations, which facilitates trade, access to services like health and education, and improves overall connectivity. The importance lies in their low construction and maintenance costs, flexibility, and ability to provide direct, door-to-door service, making them a vital component of India's infrastructure.

Scope of roads in India

- **Extensive network**: India has the second-largest road network in the world, which is constantly expanding and improving.
- **Connects all areas**: Roads connect cities, towns, and villages, providing crucial links to rural and remote areas, including hilly and border regions.
- **Integrates other transport modes**: Roads provide the essential feeder service to link railways, airports, and seaports, making the entire transportation network function.
- **Supports various activities**: The network supports a wide range of activities, from agricultural production and industrial transport to everyday passenger movement and emergency services.
- **Diverse users**: The network is used by a vast array of users, from modern vehicles to animal-drawn carts and pedestrians.

Importance of roads in India

- **Economic engine**: Roads are vital for economic growth, facilitating trade and commerce, and are essential to the national supply chain.
- **Rural development**: They are fundamental to the economic and social upliftment of rural areas by connecting them to markets, schools, healthcare, and other facilities.
- **Social development**: They enable access to education and healthcare, and improve social connectivity between different communities.

- **Cost-effectiveness and efficiency**: Road construction and maintenance are relatively inexpensive, and road transport is often cheaper for short distances, especially when considering door-to-door service, which minimizes loading and unloading costs.
- **Flexibility and accessibility**: Roads offer a more flexible and adaptable mode of transport than railways, allowing for direct routing and services to be stopped at any point.
- **Accessibility to difficult terrain**: Roads can be built in hilly and remote areas where other modes of transport are not feasible.
- **Support for perishable goods**: They are crucial for transporting perishable items like fruits and vegetables quickly and efficiently.

3. **Explain different modes of transportation and their merits and demerits.**

ANSWER

The main modes of transportation are **road, rail, air, and water**, each with its own pros and cons. **Road transport** is flexible and direct but can be slow and risky, while **rail transport** is economical for bulk, long-distance cargo but lacks flexibility. **Air transport** is the fastest but most expensive, whereas **water transport** is the cheapest for bulk goods but the slowest. Other modes like pipelines are used for specific goods like liquids and gases.

1. **Road transport**

- **Merits:** Highly flexible and door-to-door service is possible, making it ideal for short distances and deliveries. It is also generally faster for short-haul transport.
- **Demerits:** Limited capacity compared to rail or water, high risk of accidents, and contributes to pollution and traffic congestion.

2. **Rail transport**

- **Merits:** Very economical for transporting large quantities of goods over long distances, reliable, and has a lower environmental impact per ton-mile compared to road transport.
- **Demerits:** Less flexible as it is restricted to railway tracks, requires high capital investment for infrastructure, and can be slow due to the need for intermodal connections.

3. **Air transport**

- **Merits:** The fastest mode of transport, ideal for time-sensitive and long-distance travel of people and high-value cargo.
- **Demerits:** The most expensive mode, with high fuel costs and limited cargo capacity. It also requires significant infrastructure like airports.

4. Water transport

- **Merits:** The most cost-effective method for moving large volumes of heavy, non-perishable goods over long distances, especially internationally.
- **Demerits:** Very slow and limited to waterways, making it an impractical choice for urgent or short-distance transport.

4. **Write short notes on classification of roads.**

ANSWER

Roads can be classified in several ways, including by their location, function, construction material, and traffic volume. A prominent classification system in India is based on administrative function, as outlined in the Nagpur Road Plan.

Classification by location and function

This system, primarily used for planning and administration, categorizes roads based on their role in connecting different areas.

- **Expressways:** These are high-speed, access-controlled highways designed for heavy traffic and fast, uninterrupted travel. Entry and exit points are limited to minimize congestion and avoid at-grade intersections.
- **National Highways (NH):** Main roads that connect state capitals, major cities, ports, and important industrial and tourist centres. They run across the length and breadth of the country and are maintained by the central government.
- **State Highways (SH):** Arterial roads within a state that link district headquarters and important towns. They also connect to National Highways and highways of neighbouring states and are maintained by state governments.
- **Major District Roads (MDR):** Important roads within a district that connect areas of production and markets with the State and National Highways. They serve as primary conduits for district-level traffic.
- **Other District Roads (ODR):** Roads that serve rural areas by providing access to market centres and other important roads like MDRs and SHs. They provide connectivity within the district but handle less traffic than MDRs.
- **Village Roads (VR):** These roads connect villages to each other and to the nearest higher-category road. They are the most basic roads in the network and are crucial for rural accessibility.

- **Border Roads:** Strategic roads built and maintained by the Border Roads Organisation (BRO) to provide connectivity in remote and border areas of the country.

Classification by construction material

Roads can also be grouped by the materials used for their surface, which affects their durability, cost, and maintenance needs.

- **Earthen roads:** These are the cheapest to construct, using available soil. They are suitable for light traffic and often used as temporary roads. They are, however, susceptible to damage during the monsoon season.
- **Gravel roads:** More durable than earthen roads, these have a paved surface made of compacted gravel and earth.
- **Bituminous roads:** Also known as flexible pavements, these are widely used and offer a smooth surface. They are made with asphalt and are relatively low-cost. Their thickness depends on the underlying soil.
- **Concrete roads:** These are rigid pavements made with cement concrete. They are more expensive but are more durable, require less maintenance, and are suitable for high-traffic areas.
- **Water Bound Macadam (WBM) roads:** These roads are constructed with crushed stone aggregate, which is spread and rolled with water. They are superior to earthen and gravel roads but have a rough surface.

5.Discuss the factors affecting road alignment.

ANSWER: Factors affecting road alignment include topography, obligatory points (fixed locations like towns or river crossings), traffic needs, geometric design standards, drainage and environmental concerns, and economic considerations. These factors must be balanced to create a route that is safe, efficient, and cost-effective.

Topographical factors

- Terrain: The general lay of the land, such as plains, hills, or mountains, dictates the possible routes.

- Soil conditions: Soil stability is crucial. Unstable or soft soil may require special stabilization or a different alignment to avoid high construction and maintenance costs.

- Drainage and floods: Alignments should avoid low-lying, flood-prone areas. This can sometimes make the road longer but significantly reduces future maintenance costs and risks.

Obligatory points

- Points the road must pass through: These are fixed points like cities, villages, or bridges that the road is intended to connect to.
- Points the road must avoid: These are locations that must be bypassed, such as religious sites, historical monuments, national parks, or areas with expensive land.

Traffic and geometric factors

- Traffic volume and type: The number and type of vehicles (cars, trucks, etc.) influence the required width, curvature, and load capacity.
- Origin and destination: The intended start and end points of the road help determine the most direct and efficient path.
- Gradient and curves: The steepness of the slope and the sharpness of curves must be designed to ensure vehicle safety and comfort, following established standards.
- Sight distance: The alignment must provide an adequate sight distance for drivers to react and stop safely.

Environmental and social factors

- Land use: The road must consider existing land use, such as agricultural fields, forests, and wildlife sanctuaries.
- Environmental impact: Concerns such as noise pollution, air quality, and the impact on wildlife habitats must be addressed.
- Utilities: Underground and overhead utilities (like power lines and pipelines) must be identified and avoided or relocated.

Economic factors

- Construction costs: The alignment should aim to minimize earthwork (cutting and filling) and the need for costly structures like bridges.
- Maintenance costs: A well-chosen alignment will have lower long-term maintenance costs.
- Future expansion: The alignment should ideally consider possibilities for future widening or upgrades.

10 Mark Questions

1. **Describe in detail the role of transportation in the development of a nation.**

ANSWER

Transportation is vital for national development by connecting regions, moving goods and people, and fostering economic growth. It facilitates trade, creates jobs in various sectors, improves access to education and healthcare, and supports rural development by linking remote areas to urban centres. Efficient transportation systems lower costs for businesses, attract investment, increase market access, and enhance the overall quality of life.

Economic development

- **Facilitates trade and commerce:** Transportation connects supply and demand centres, enabling the efficient movement of raw materials and finished products, which is essential for both domestic and international trade.
- **Creates employment:** The construction, maintenance, and operation of transportation systems create numerous jobs directly. Additionally, transportation's support for industries leads to job creation in logistics, distribution, and manufacturing.
- **Lowers costs and increases efficiency:** Efficient transport systems reduce the time and cost of moving goods, which improves a business's competitiveness and profitability. It also helps stabilize prices by moving commodities from surplus to deficit areas.
- **Attracts investment:** Good transportation infrastructure makes a region more attractive for new investments and business development, fostering economic clusters and further growth.
- **Increases market access:** By connecting businesses to new markets and consumers to a wider array of goods, transportation stimulates demand and economic activity.

Social development

- **Improves accessibility:** Transportation provides access to essential services such as healthcare, education, and government facilities, especially for people in rural or remote areas.
- **Supports rural development:** By linking rural areas to urban centres, transportation supports the spread of economic activity and helps reduce regional disparities.
- **Promotes social integration:** The movement of people for social or economic reasons fosters greater interaction and integration between different regions of a nation.

Infrastructure and innovation

- **Acts as a catalyst for infrastructure:** The development of transportation networks spurs the creation of other related infrastructure and services, like logistics and warehousing.
- **Enables exchange of knowledge:** Transportation helps connect different regions, facilitating the exchange of ideas, knowledge, and innovation, which is crucial for long-term growth.
- **Contributes to national income:** The transportation sector is a significant contributor to a nation's GDP and a vital indicator of its overall development level. Well-developed transport networks are often a sign of a higher level of development.

2**. Explain the general classification of roads and the factors affecting road alignment.**

Roads are generally classified by location, function, and surface type, such as national highways, state highways, and local or village roads. Factors affecting road alignment include obligatory points (required locations like bridges), traffic volume and type, geometric design principles like gradient and curves, economic considerations such as construction costs, and governmental policies.

Classification of roads

- **By location and function**: This is a primary classification system based on the road's role in connecting different areas.
    1. **National Highways**: Connect major cities and the country's length and breadth, sometimes connecting to neighbouring countries.
    2. **State Highways**: Link major towns and cities within a state.
    3. **District Roads**: Serve to connect areas within a district.
    4. **Rural/Village Roads**: Provide access to smaller communities and villages.
- **By pavement surface**: This classification is based on the material used for the road's surface.
    1. **Paved Roads**: Have a hard pavement course, such as water-bound macadam (WBM), bituminous macadam (BM), or concrete.
    2. **Unpaved Roads**: Do not have a hard course layer and can be made of earth or gravel.
- **By traffic-related criteria**: This involves classifying roads by their weather resistance and design for traffic.
    1. **All-weather roads**: Roads that can be used in all types of weather.
    2. **Fair-weather roads**: Roads that are only usable during fair weather conditions.

Factors affecting road alignment

- **Obligatory points**: Specific locations the road must pass through or avoid.
    1. **Must-pass points**: Examples include bridges, railway crossings, and mountain passes.
    2. **Must-avoid points**: Examples include national parks, marshy land, religious sites, and expensive structures.
- **Traffic requirements**: The volume and type of vehicles determine design needs.
    1. High traffic volume requires wider lanes and straighter paths.
    2. The alignment must accommodate different vehicle types, such as trucks and cars.
- **Geometric design**: The road's physical layout specifications must be met.
    1. **Gradient**: The steepness of the road.
    2. **Curvature**: The radius of horizontal curves.
    3. **Sight distance**: The length of the road ahead that is visible to the driver.
- **Economic factors**: The cost of construction, operation, and maintenance must be minimized.
    1. The alignment should balance cutting and filling to reduce costs.
    2. Avoiding areas that require extensive and expensive construction techniques is desirable.
- **Governmental policies**: Regulations and government plans can influence the final alignment.

UNIT 2

GEOMETRIC DESIGN OF HIGHWAY

Geometric Design of Highway

2 Marks Questions

1. Define camber and state its types (as per IRC)

Answer: Camber is the slope provided to the road surface in the transverse direction to drain off rainwater.

Types:

- Straight line Camber
- Parabolic Camber
- Combination of straight and parabolic camber.

2. Define kerb and its types (as per IRC).

Answer: A kerb is a boundary between the carriageway and the shoulder or footpath. It provides lateral confinement to the pavement and improves road safety.

Types of Kerb:

- Mountable kerb.
- Semi-barrier kerb.
- Barrier kerb.
- Submerged kerb.

3. What is the right of way?

Answer: Right of way is the total land area acquired for the construction of the road, including shoulders, slopes, and the drainage system.

4. Define design speed and factors affecting design speed.

Answer: Design speed is the maximum safe speed at which vehicles can travel on a road under favourable conditions.

Factors affecting Gradient:

- Class of road (NH, SH, MDR, ODR, VR)
- Terrain (Plain, Rolling, Mountainous, Steep)

5. What is stopping sight distance (SSD) and write down the formula.

Answer: Stopping Sight Distance (SSD) is the length of road visible ahead to the driver from a specified height above the carriage way at any instance of time to stop the vehicle safely before collision.

SSD = Lag distance + Braking distance = $v.t + v^2/2gf$

Where, v = velocity of vehicle, t = reaction time, f = longitudinal friction factor, g= acceleration due to gravity.

6. Write down PIEV theory.

Answer: According to this theory, the total reaction time of the driver is split into four parts viz. time taken by driver for:

- ***Perception***: The time it takes for a driver to see a hazard and for the signal to be transmitted from the eyes to the brain.
- ***Intellection*****:** The time required for the brain to process the situation, analyse it, and make a decision on what action to take.
- ***Emotion***: Time lost in fear, anger, etc.
- ***Volition***: The time required for the final action.

7. Define super elevation.

Answer: Super elevation is the transverse inclination provided to the road surface at curves to counteract the effect of centrifugal force and reduce the tendency of the vehicle to overturn.

8. Write down the width of the carriageway.

- **Single lane**
- **Two lanes without kerb**

Answer: Width of carriageway: Single Lane: 3.75m, Two lane without kerb: 7.00m

9. Define transition curves and objectives of transition curves.

Answer: Transition curve is the curve provided between a straight and a circular so that the radius changes gradually from infinity to radius(R) and vice versa.

Objectives:

- To gradually introduce centrifugal force between the straight and circular.
- To avoid a sudden jerk
- To gradually introduce super elevation and extra widening.
- Aesthetic appearance.

10. Write down the difference between Formation width and formation level.

Answer: Formation width is the horizontal measurement of the top of the earthwork (including pavement, shoulders, and separators), while formation level is the vertical elevation of that finished surface, which is the prepared ground for laying the sub-base.

5 MARKS QUESTIONS:

1. What is Gradient? Explain different types of gradients used in highway design and state the maximum and minimum values as per IRC recommendations.

Answer:

A gradient (or grade) is the longitudinal slope provided to the road surface along its alignment for effective movement of vehicles.

It is expressed as a ratio (1 in n) or percentage (%), e.g. 1 in 50 (or 2%) means 1 m rise or fall in 50 m of horizontal distance.

Types of Gradients (as per IRC: 73-1980)

1. Ruling Gradient

Definition: The gradient which is normally adopted in the design of roads.

Purpose: It provides the best balance between construction cost and vehicle operation.

IRC Recommended Values: 1 in 30 (plain & rolling)
1 in 20 (mountainous)
1 in 15 (steep)

2. Limiting Gradient

Definition: The maximum gradient that can be permitted where topography or other constraints make ruling gradient impractical.

3. Exceptional Gradient

Definition: A steeper gradient than the limiting one, allowed only for short stretches (not exceeding 100 m).

4. Minimum Gradient

Definition: The least gradient required for proper drainage of the road surface, especially in urban or flat areas.

Typical Value:

For surface drainage: Minimum 0.5% (1 in 200) is recommended by IRC.

This ensures no water stagnation on the pavement.

IRC Recommendations:

S.No.	Type of Terrain	Gradient		
		Ruling	Limiting or Max	Exceptional
1.	Plain or Rolling	1 in 30 (3.3%)	1 in 20 (5%)	1 in 15 (6.7%)
2.	Mountainous and steep Terrain with	1 in 20 (5%)	1 in 16.7 (6%)	1 in 14.3 (7%)
3.	Elevation more than 3000 m. Steep terrain up to 3000 m height	1 in 16.7 (6%)	1 in 14.3 (7%)	1 in 12.7 (8%)

2. Explain the necessity and types of curves used in highways. Distinguish between horizontal and vertical curves with neat sketches.

Answer:

Necessity of curves:

- Comfortable ride & reduced passenger discomfort.
- Necessary when obstacles are encountered.
- Land use optimization- Minimize the need for extensive work or land acquisition.
- Enhance the visual appeal of roads.
- For safety- slowing down of vehicles & preventing accidents.

Types of Curves

Highway curves are classified into two main categories:

1. Horizontal Curves

2. Vertical Curves

1. Horizontal Curves: These curves are provided in plan to change the direction or alignment of the road.

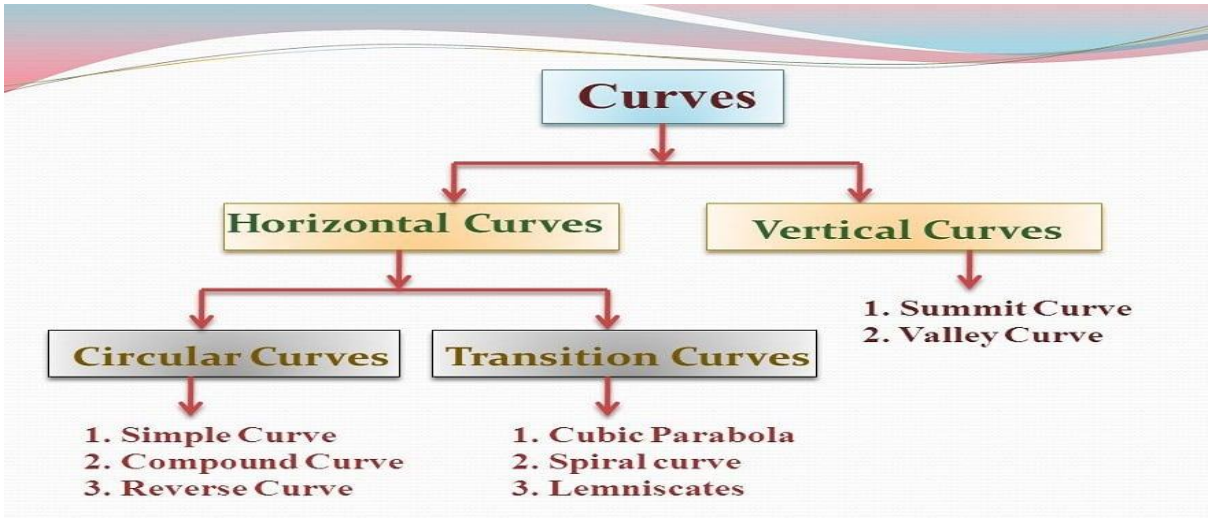
Types:

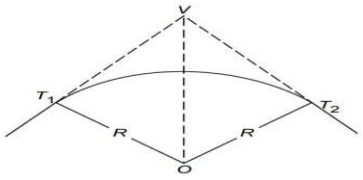
- Simple Curve: Single circular arc connecting two tangents.
- Compound Curve: Two or more simple curves of different radii turning in the same direction.
- Reverse Curve: Two simple curves of opposite direction with a common tangent.
- Transition Curve: A curve with varying radius (spiral) introduced between a straight and a circular curve for smooth vehicle movement.

2. Vertical Curves: Vertical curves are provided in longitudinal profile to connect two different gradients smoothly.

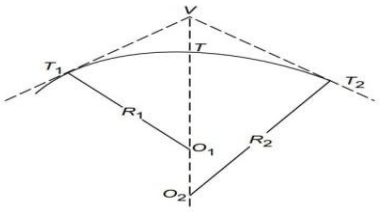
Types:

- Summit (Crest) Curve: Provided when an ascending gradient meets a descending gradient.
- Valley (Sag) Curve: Provided when a descending gradient meets an ascending gradient.

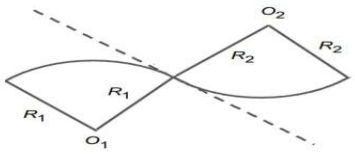




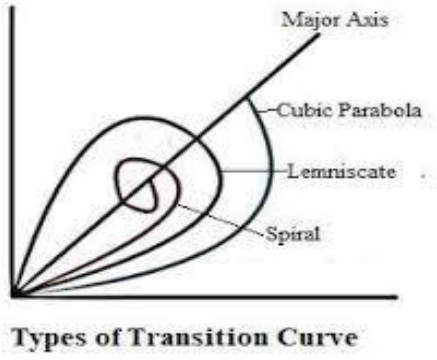
Simple Circular Curve



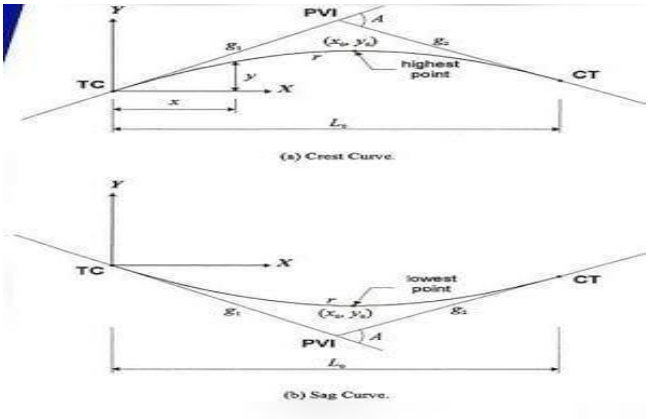
Compound Curve



Reverse Curve



Types of Transition Curve



3. What is super-elevation? Why super-elevation is provided to the road pavement. Estimate the super-elevation required at a horizontal curve of radius 300 m for a design speed of 80 kmph. Assume coefficient of lateral friction as 0.15.

Answer:

Super-elevation (e) is the difference in elevation between the outer and inner edge of a curved pavement; it is provided by banking the pavement so that component of normal reaction helps to counteract centrifugal force on vehicles navigating the curve.

- It reduces tendency of vehicle to skid outwards and increases comfort and safety at curves.

Design formula (equilibrium of forces):

$e + f = v^2 / (g * R)$

Where, e = super-elevation (m/m), f = coefficient of lateral friction, v (m/s), g = 9.81 m/s^2, R = radius (m).

Rearrange: $e = v^2/(g*R) - f$

Speed: 80 km/h = 22.2222 m/s (convert kmph to m/s)

Compute $v^2/(gR) = 22.2222^2/ (9.81 * 300.0) = 0.16780$

Super-elevation required $e = v^2/(gR) - f = 0.16780 - 0.15 = 0.01780$

- $e \approx 0.0178$ (i.e. 1.78 %).

4. Draw the standard cross-section of a National Highway in embankment and cutting as per IRC specifications.

Answer:

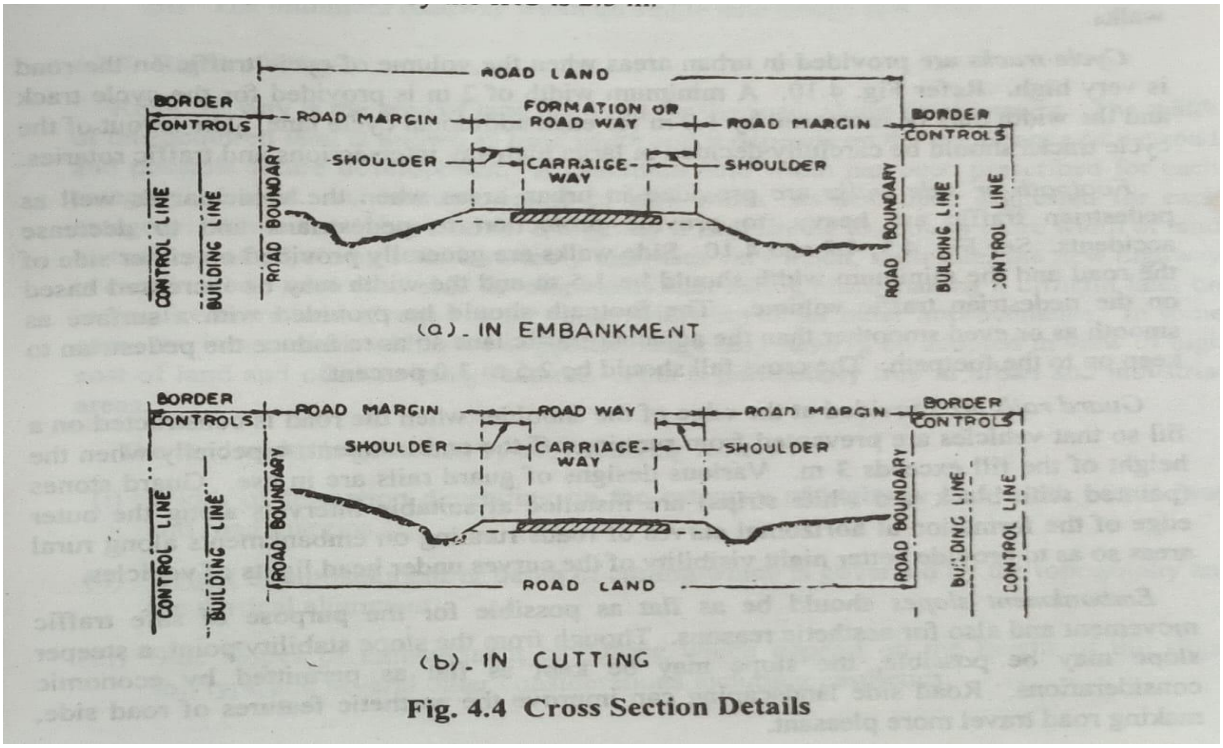


Fig. 4.4 Cross Section Details

5. Define Camber. State its purpose and explain different types of camber recommended by the IRC for various surface types.

Answer:

Definition of Camber: Camber is the transverse slope or cross slope provided to the surface of a road, usually with the highest point at the center and sloping downwards towards the edges.

Purpose of Camber:

1. Drainage of Rainwater:

To prevent the accumulation of rainwater on the road surface by enabling quick drainage towards the edges.

2. Protection of Pavement:

To prevent water infiltration into pavement layers and subgrade, which could weaken the road structure.

3. Safety and Comfort:

To reduce the risk of skidding by preventing water film formation on the surface.

4. Maintenance:

To enhance the durability and reduce maintenance costs of the road.

Types of Camber:

Depending on the shape of the cross slope, camber can be of the following types:

1. Straight Line Camber (Two Straight Slopes): Consists of two straight surfaces meeting at the crown.

Simple to construct but not very smooth in appearance.

2. Parabolic Camber: Surface follows a parabolic curve. Ensures uniform slope near the center and edges, providing smoother riding quality and better drainage.

3. Combination Camber (Straight + Parabolic): Combines straight slope near the crown and parabolic near the edges. Offers both ease of construction and smooth drainage.

IRC RECOMMENDATION:

Type of pavement	Camber	
	Heavy Rainfall	Light Rainfall
CC or thick bituminous	2%	1.7%
Thin bituminous	2.5%	2%
Gravel or WBM roads	3%	2.5%
Earthenware or kuchha road	4%	3%

10 MARKS QUESTIONS:

1. Calculate the safe stopping sight distance on a level road for design speed of 96 kmph for:

i) Two-way traffic on a two-lane road

ii) Two-way traffic on a single-lane road

Assume coefficient of friction (f) as 0.37, reaction time of the driver as 2.5 sec.

Solution:

Stopping Sight Distance (SSD) = Lag Distance + Braking Distance

Lag distance = v x t

Breaking Distance = $v^2 / (2 g f)$ ($g = 9.81 m/s^2$)

Convert speed: v (m/s) = (speed km/h) * 1000 / 3600

Speed: 96 km/h = 26.6667 m/s

Lag Distance= v x t = 26.6667 x 2.5 = 66.667 m

Braking Distance = $v^2 / (2gf) = 26.6667^2 / (2x9.81x0.37)$ = 97.957 m

SSD = 66.667 + 97.957 = 164.624 m

i) Two-way traffic on a two-lane road = SSD = 164.6243m (≈ 165m).

ii) Two-way traffic on a single-lane road = 2SSD = 2 x 164.64 = 329.28m (≈ 329 m).

2. Calculate the extra widening required for a pavement of width 7.0m on a horizontal curve of radius 250m if the longest wheel base of vehicle expected on the roads is 7.0m. Design speed is 70kmph. Compare the value obtained with IRC recommendations. Find the total width on curve.

Solution:

Extra widening required $W_e = W_m + W_{ps}$

$= nl^2/2R + V/9.5\sqrt{R}$

Hence, n= 2 (two lanes for pavement width of 7.0m)

l = 7.0m, R = 250m, V = 70kmph

$W_e = 2x7^2/2x250 + 70/9.5\sqrt{250} = 0.196 + 0.466 = 0.662m$

The IRC recommends extra widening of *0.6m* when the radius of the curve is 101 to 300m

Total pavement width on curve = $W + W_e = 7.0 + 0.6 = 7.6m$

UNIT 3

CONSTRUCTION OF ROAD PAVEMENTS

Construction of road pavements

Two marks questions with answers.

1. Write short notes on Prime Coat

Answer: A prime coat is a low-viscosity bituminous material applied to a granular base before laying a bituminous layer. It helps in binding the loose particles on the surface and provides a temporary waterproofing layer. The prime coat also promotes adhesion between the granular base and the subsequent bituminous layer, ensuring better bonding and reducing slippage.

2. Write two applications of Seal Coat.

Answer:

- **To waterproof the surface:** It seals the surface against the entry of moisture and prevents oxidation of the underlying bituminous layers.
- **To improve skid resistance:** Seal coat provides a new wearing surface, restoring texture and friction to worn pavements.

3. What is Emulsion? List different types of Emulsion

Answer: Emulsion is a mixture of bitumen and water, stabilized by an emulsifying agent. It is used in road construction where heating of bitumen is not feasible.

Types of Bitumen Emulsion:

- Rapid Setting (RS) Emulsion
- Medium Setting (MS) Emulsion
- Slow Setting (SS) Emulsion
- **Compare Tar and Bitumen.**

Answer:

Property	**Tar**	**Bitumen**
Source	Obtained by destructive distillation of coal or wood	Derived from petroleum refining process
Temperature Susceptibility	More temperature susceptible	Less temperature susceptible
Smell	Has a strong, unpleasant odour	Comparatively odour-less

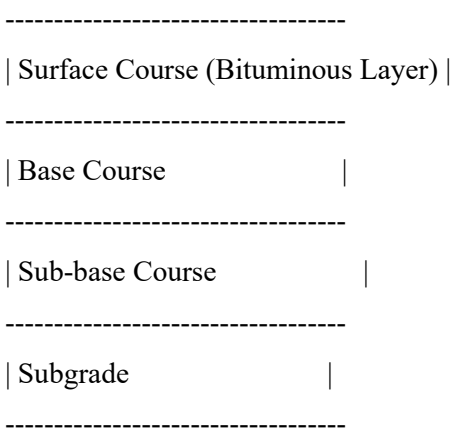
Property	Tar	Bitumen
Durability	Less durable	More durable and stable
Use	Rarely used due to carcinogenic nature	Widely used in road construction

5. What are the various types of pavements? Draw a sketch of flexible pavement cross section.

Answer: Types of Pavements:

1. **Flexible Pavement**
2. **Rigid Pavement**

Flexible Pavement Cross Section:



6. What are the various tests carried out on Bitumen.

Answer:

1. Penetration Test
2. Ductility Test
3. Softening Point Test
4. Flash and Fire Point Test
5. Viscosity Test
6. Specific Gravity Test
7. Float Test
8. Loss on Heating Test

7. **Write the difference between Alternate and Continuous Bay Method of Cement Concrete Road**

Answer:

Feature	**Alternate Bay Method**	**Continuous Bay Method**
Construction	Bays are laid alternately, leaving gaps between slabs	Bays are laid continuously without gaps
Curing	Easy and convenient	Requires careful curing and joint provision
Time	Takes more time due to gaps	Faster since continuous work
Joint Provision	Transverse joints after each bay	Expansion and contraction joints at regular intervals

8. What are the uses of Joint Filler and Sealer.

Answer:

- **Joint Filler:** Used to fill the space between adjacent concrete slabs to allow for expansion and contraction.
- **Joint Sealer:** Used to seal the joints and prevent the entry of water, dirt, and other materials into the joints.

9.What is Tie Bar and Dowel Bar.

Answer:

- **Tie Bar:** A deformed steel bar placed across longitudinal joints to prevent separation of adjacent slabs but not to allow movement.
- **Dowel Bar:** A smooth steel bar placed across transverse joints to transfer load between slabs while allowing horizontal movement due to expansion and contraction.

10. What is Abrasion? Which apparatus is used for Abrasion Test.

Answer: Abrasion is the process of wearing down the surface of aggregates or pavements due to mechanical action such as traffic.
Apparatus used: Los Angeles (L.A.) Abrasion Testing Machine.

Five numbers of five-mark questions with answers.

1. Construction Steps for Water Bound Macadam (WBM) Road.
Answer: Water Bound Macadam (WBM) road is a type of road where crushed aggregates are mechanically interlocked with the help of rolling and bonded together with filler material and water.
Construction Steps:

- **Preparation of Subgrade:**
  The subgrade is prepared and compacted to the required camber and gradient.
- **Preparation of Sub-base (if required):**
  A granular sub-base may be laid and compacted.
- **Spreading of Coarse Aggregates:**
  Coarse aggregates are spread uniformly to the specified thickness and camber.
- **Dry Rolling:**
  Initial rolling is done with a roller (6–10 tons) to seat the aggregates.
- **Application of Screening:**
  Stone screenings are applied to fill the voids in the coarse aggregates.
- **Sprinkling of Water and Wet Rolling:**
  Water is sprinkled and rolling continued until the voids are completely filled.
- **Application of Binding Material:**
  Binding material (like moorum or stone dust) is spread and the surface is rolled again with water sprinkling.
- **Curing:**
  The surface is allowed to set and dry for 24–48 hours before opening to traffic or applying the next layer.

2.Difference between Flexible Pavement and Rigid Pavement.
Answer:

Aspect	Flexible Pavement	Rigid Pavement
Composition	Made of bituminous materials	Made of cement concrete
Load Transfer	Load distributed through layer action	Load transferred by slab action

Aspect	Flexible Pavement	Rigid Pavement
Flexibility	Flexible and can adjust to minor settlements	Rigid and may crack due to settlement
Initial Cost	Low	High
Maintenance	Frequent maintenance required	Low maintenance
Life Span	10–15 years	30–40 years
Joints	No expansion joints required	Requires expansion and contraction joints
Example	Bituminous roads	Concrete roads

3. Desirable Properties of Aggregates for Pavement Construction

Answer: Aggregates play a vital role in pavement strength and durability. They should possess the following desirable properties:

- **Strength:** To resist crushing under heavy traffic loads.
- **Hardness:** To withstand abrasion and wear due to traffic.
- **Toughness:** To resist impact loads caused by moving vehicles.
- **Durability:** To resist weathering and disintegration.
- **Shape:** Angular aggregates provide better interlocking than rounded ones.
- **Adhesion with Bitumen:** Should form a good bond with bituminous binder.
- **Cleanliness:** Should be free from dust, clay, and organic impurities.
- **Water Absorption:** Should have low water absorption to prevent stripping of bitumen.

4. Desirable Properties of Bitumen and Tests on Bitumen

Answer: Desirable Properties:

- **Adhesion:** Should bind well with aggregates.
- **Cohesion:** Should resist deformation under traffic loads.
- **Durability:** Should withstand weathering and oxidation.
- **Temperature Susceptibility:** Should not become too soft in summer or too brittle in winter.
- **Workability:** Should be easy to mix and lay at construction temperatures.
- **Waterproofing Quality:** Should provide an impermeable layer.

Tests Carried Out on Bitumen:

- **Penetration Test** – Determines hardness.
- **Softening Point Test** – Indicates temperature susceptibility.
- **Ductility Test** – Measures the ability to stretch without breaking.
- **Viscosity Test** – Determines flow characteristics.

- **Flash and Fire Point Test** – Determines temperature safety limits.
- **Specific Gravity Test** – Indicates bitumen density.
- **Loss on Heating Test** – Measures volatility and aging.
- **Float Test** – Measures consistency and quality.

5. WBM and WMM Roads: Merits and Demerits.

Answer:

Feature	**WBM (Water Bound Macadam)**	**WMM (Wet Mix Macadam)**
Full Form	Water Bound Macadam	Wet Mix Macadam
Binder	Water used as binding agent	Water used for mixing, but mechanical mixing ensures uniformity
Mixing Method	Aggregates mixed manually or on road	Aggregates and screenings mixed in a plant
Compaction	Compacted by roller with water sprinkling	Compacted by vibratory roller
Construction Speed	Slow	Fast
Strength	Moderate	Higher than WBM
Surface Quality	Rough surface	Smooth and dense surface
Durability	Less durable	More durable and stable
Cost	Less expensive	Slightly more expensive but long-lasting
Use	Low-traffic roads or base course	Heavily trafficked roads and high-quality base course

Two numbers of 10-mark questions with answer.

1.What is CBR and explain the test procedure. How the results of the test obtained and interpreted the load and penetration reading.

Answer: The California Bearing Ratio (CBR) is a penetration test used to evaluate the mechanical strength and load-bearing capacity of subgrade soil, sub-base, and base course materials for flexible pavement design. Expressed as a percentage, the CBR is the ratio of the load required to cause a specified penetration in the tested material to the load required for the same penetration in a standard crushed stone material.

2. Test procedure (as per IS 2720, Part 16)

The test can be performed on remoulded or undisturbed soil specimens, typically under soaked conditions to simulate the worst-case moisture scenario.

Specimen preparation

1. **Sieving**: The soil sample is passed through a 20 mm sieve. Oversized particles are replaced with an equal weight of material passing the 20 mm sieve but retained on the 4.75 mm sieve.
2. **Compaction**: The soil is mixed with water, typically at its Optimum Moisture Content (OMC), and compacted into a standard cylindrical mould (150 mm diameter, 175 mm height).
    1. **Dynamic Compaction**: The soil is compacted in multiple layers (3 layers for light compaction, 5 layers for heavy compaction) using a standard rammer.
    2. **Static Compaction**: A static load is applied to achieve the desired density.

- **Soaking (if required)**: For soaked CBR tests, the compacted specimen is immersed in water for 96 hours (4 days). During this period, a surcharge load is placed on the specimen to simulate the weight of the overlying pavement layers. The amount of swelling is measured.

Penetration test

- The specimen (soaked and drained, if applicable) is placed under a loading machine, and a 50 mm diameter penetration plunger is cantered on the sample.
- A seating load is applied to ensure firm contact between the plunger and the soil.
- A surcharge weight, representative of the future pavement structure, is placed on the specimen.
- The plunger is made to penetrate the soil at a constant rate of 1.25 mm per minute.
- Load readings are recorded at specified penetration depths (e.g., 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0, and 12.5 mm).

Obtaining and interpreting the test results Load-penetration curve

- The recorded load readings are plotted against the corresponding penetration depths to create a load-penetration curve.
- **Correction for concave curves**: If the initial portion of the curve is concave upward due to surface irregularities, a correction is necessary. A tangent is drawn to the steepest part of the

curve, and the new, corrected origin is taken as the point where the tangent intersects the penetration axis.

Calculation of CBR value

The CBR value is calculated at two specific penetration depths: 2.5 mm and 5.0 mm.

- **Determine corrected loads**: Using the corrected load-penetration curve, find the load (P_T) at 2.5 mm penetration and the load at 5.0 mm penetration.
- **Divide by standard load**: The CBR is calculated using the following formula, comparing the test load (P_T) to the standard load (P_S)

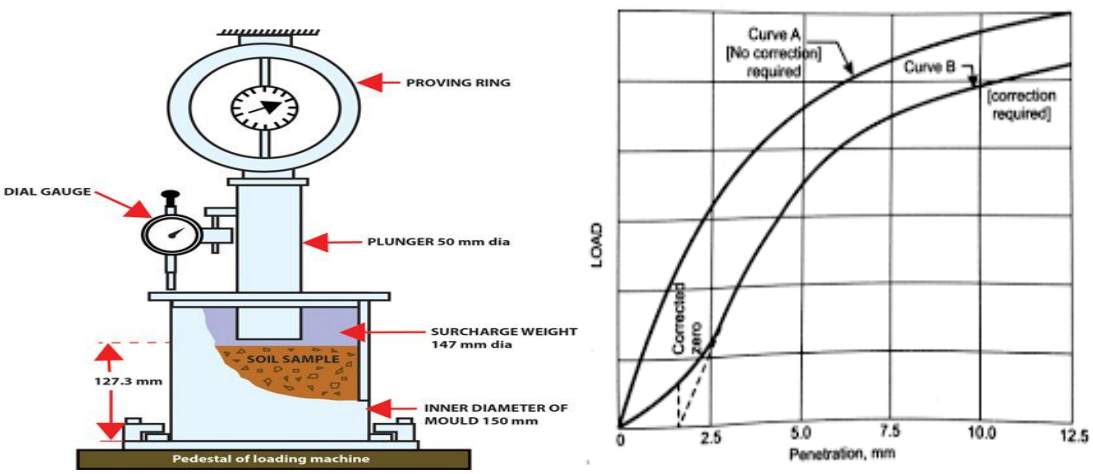
$$CBR(\%)=(P_T/P_S)\times 100$$

- **Standard loads for 100% CBR**:

1. At 2.5 mm penetration: $P_S = 1370$ kg
2. At 5.0 mm penetration: $P_S = 2055$ kg

Interpretation of CBR results

- **Select the design CBR**: Calculate two CBR values: one for 2.5 mm and one for 5.0 mm penetration.
- **Comparison**: Typically, the CBR value at 2.5 mm is higher and is adopted for design purposes.
- **Re-test**: If the CBR value at 5.0 mm penetration is higher than that at 2.5 mm, the test should be repeated. If the results are consistent, the 5.0 mm CBR value is used for design.



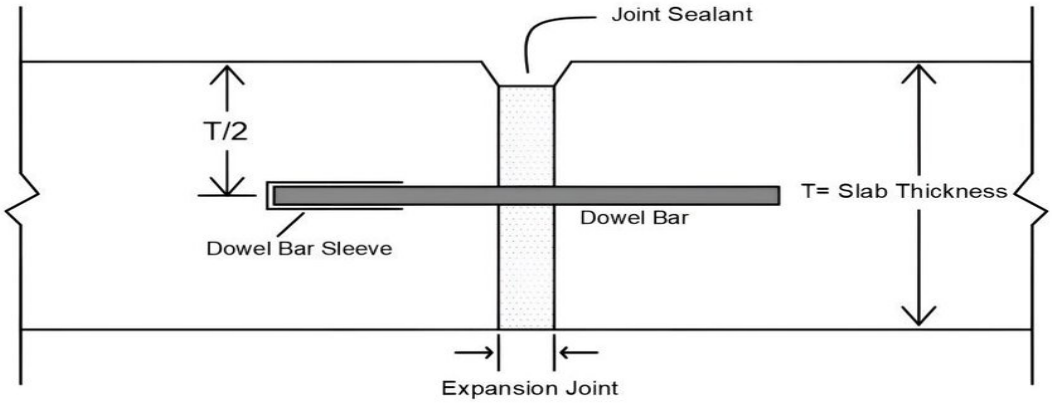
2.Discuss the objective of the following types of joints: Draw neat sketches.

1. **Expansion joints**
2. **Contraction joints**
3. **Warping joints**
4. **Construction joints**
5. **Longitudinal joints**

Answer: Objective of Joints

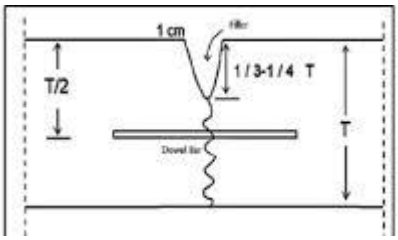
a) Expansion joints

The primary objective of expansion joints is to accommodate the volumetric expansion and contraction of concrete caused by temperature and moisture changes. They are designed to relieve compressive stresses that would otherwise cause the pavement to buckle or crack, especially in long structures and at the interface of a slab with other rigid structures like bridges or walls. These joints are typically filled with a compressible material to allow movement while preventing debris from entering the gap.



b) Contraction joints

The main purpose of contraction joints is to control cracking caused by the natural shrinkage of concrete as it cures and dries. A contraction joint is a weakened plane, often a groove, that is sawed or formed into the slab. This weak point guides any tensile stresses and forces the inevitable crack to form in a straight, controlled line at the joint, rather than in a random, irregular pattern across the slab.



c) Warping joints

Warping joints, also known as hinged joints, are designed to relieve stresses caused by the warping effect. This warping occurs when there is a difference in temperature or moisture between the top and bottom surfaces of a concrete slab, causing the edges to curl upwards or downwards. These joints are typically provided along the longitudinal direction of the pavement to maintain the structural integrity of the concrete under these conditions.

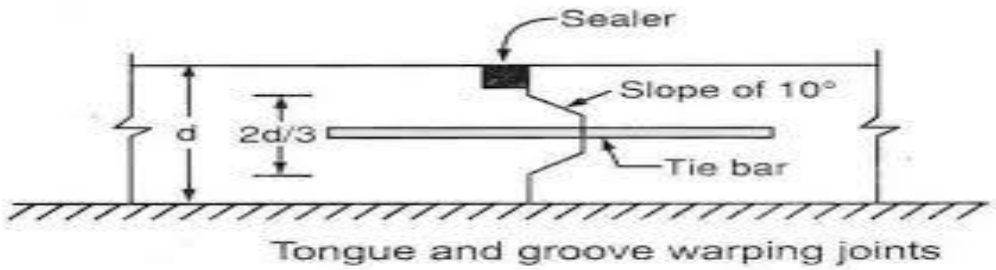
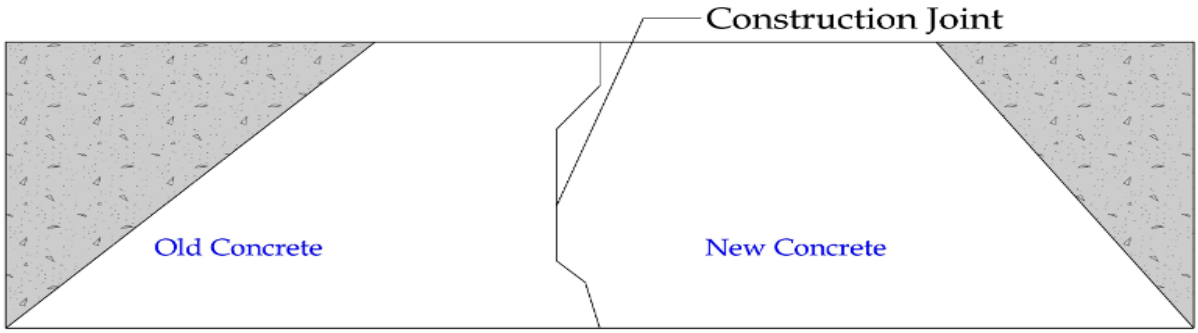


Figure (4)

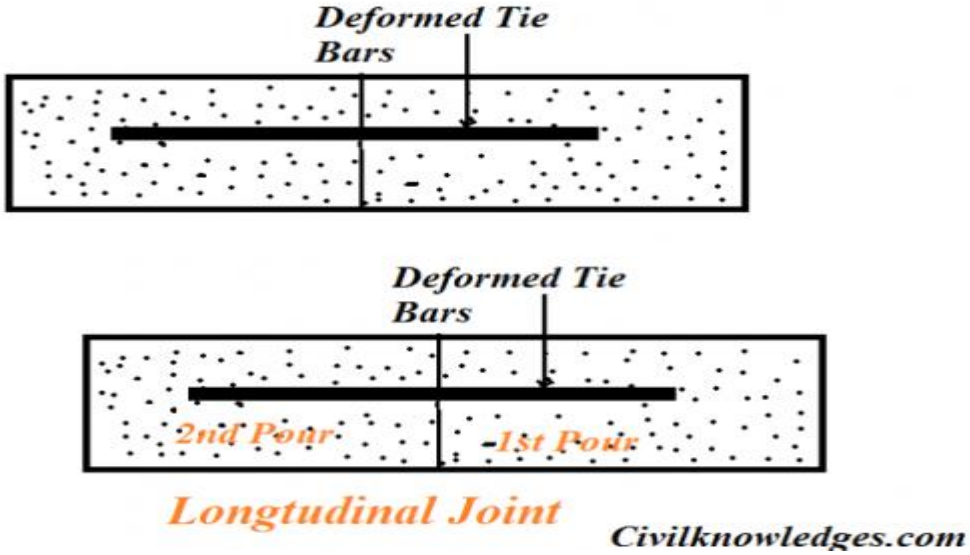
d) Construction joints

Construction joints are used when there is a planned or unplanned interruption in the concrete pouring process. They mark the point where fresh concrete is placed next to concrete that has already hardened, ensuring a proper bond between the two sections. While they facilitate the construction process, they can also be designed to permit movement or load transfer between the adjacent slabs, often incorporating dowel bars or keyways for this purpose.



e) Longitudinal joints

Longitudinal joints are provided parallel to the centreline of the pavement, separating adjacent traffic lanes. Their primary objectives are to relieve warping stresses and to prevent differential settlement between the slabs. They also help to reduce the width of the pavement section being poured, making it more manageable for construction. These joints often use tie bars to hold the two slabs together and prevent them from separating.


Deformed Tie Bars
Deformed Tie Bars
2nd Pour
1st Pour
Longtudinal Joint
Civilknowledges.com

UNIT 4

BASICS OF RAILWAY ENGINEERING

BASICS OF RAILWAY ENGINEERING

2 Mark Questions (With Answers)

1. What are the zones of Indian Railways?

Answer: There are 18 zones in Indian Railways such as Northern, Southern, Eastern, Western, Central, South Central, North Eastern, etc.

2. Define 'Permanent Way'.

Answer: Permanent Way is the combination of rails, sleepers, ballast, and subgrade over which trains move.

3. What is a rail joint?

Answer: A rail joint is a connection between two rail ends using fish plates and bolts.

4. Name the requirements of a good rail joint.

Answer: It should maintain correct alignment, allow free expansion, and provide smooth passage of wheels.

5. What are the functions of sleepers?

Answer: Sleepers hold the rails in position, maintain gauge, and distribute the load to the ballast.

6. Define creep of rail.

Answer: Creep of rail is the longitudinal movement of rails in the direction of traffic due to repeated loads.

7. Write any two functions of ballast.

Answer: It provides stability to the track and facilitates drainage.

8. What are fish plates and where are they used?

Answer: Fish plates are metal plates used to join the ends of two rails at a joint.

9. Mention any two types of rail gauges used in India.

Answer: Broad Gauge (1.676 m) and Meter Gauge (1.000 m).

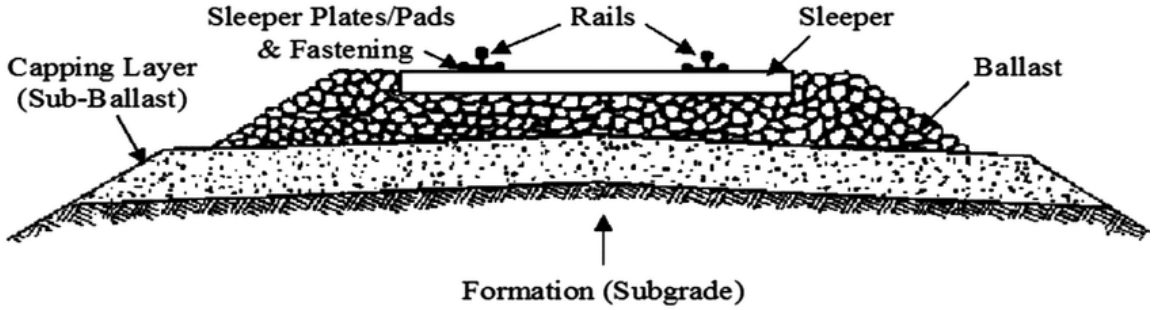
10. State the ideal requirements of a permanent way.

Answer: It should be strong, durable, smooth, and economical to maintain.

5 Mark Questions (With Answers)

1. **Explain the ideal requirements and components of a permanent way with a neat sketch.**

Answer: A permanent way should provide a smooth, strong, and stable surface for trains. Its components include rails, sleepers, ballast, and subgrade. Rails guide trains, sleepers maintain gauge, ballast distributes loads and provides drainage, and subgrade supports the entire structure.



2. **Describe the types of sleepers used in Indian Railways and their functions.**

Answer: Wooden Sleepers

- Wooden Sleepers are typically 2600 mm long, 254 mm broad, and 127 mm thick in cross-section.
- Wooden Sleepers are treated with preservatives after being seasoned (drying for up to 12 months to remove the juice/sap) for the preservation of timber. Creosote is an oil that is typically applied to or sprayed on the surfaces of wooden sleepers.
- These sleepers are either made of soft wood or hardwood.

Steel Sleepers

- Steel Sleepers can be used when wooden or concrete sleepers cannot be adopted.
- In heavier curves that are prone to gauge widening, steel sleepers are extensively used.
- The signal control system may face issues due to steel sleepers.
- Furthermore, these sleepers are also prone to fatigue cracking issues.

Cast Iron Sleepers

- Cast iron sleepers are used extensively worldwide, but particularly in Indian railways.
- They come in two varieties: **pot sleepers** and **plate-shaped cast iron sleepers.**

- Curves sharper than 4 degrees are not ideal for pot type sleepers.
- In Indian railways, **CST 9 type sleepers** are extensively adopted.

3. **Explain the causes and prevention of creep of rails.**

Answers: Causes of rail creep

- **Wave action:** As wheels roll over the rails, they create a slight depression. This depression moves forward with the wheel, and the rail behind it pushes forward, creating a wave-like motion.
- **Percussion or impact at joints:** When a wheel hits the end of a jointed rail, the impact pushes the trailing rail forward.
- **Starting and stopping:** The forces involved in a train's acceleration, deceleration, and braking cause the rails to move forward.

Prevention of rail creep

- **Install rail anchors:** These are devices that securely fasten the rail to the sleepers, increasing the resistance to creep.
- **Perform regular maintenance:**
    1. **Pull back the rails:** Periodically pull the rails back to their original position to relieve the accumulated stress.
    2. **Tighten fasteners:** Ensure all bolts and clips are tight to maintain a secure connection between the rails and sleepers.

4. **Describe the functions and types of ballast used in railway tracks.**

Answer: **Functions of ballast**

- **Load distribution:** Spreads the weight of trains from the sleepers across a wider area of the track bed.
- **Drainage:** Allows water to drain away from the tracks, preventing waterlogging and erosion.
- **Stability:** Prevents the sleepers and rails from shifting horizontally and vertically, keeping the tracks aligned.

- **Vibration and noise absorption:** Absorbs vibrations from moving trains, reducing noise and wear on the track.

Types of ballast

- **Crushed stone:** The most common type, typically made from igneous rocks like granite, quartzite, or basalt. It offers excellent strength, durability, and drainage.
- **Gravel:** Can be used, especially bank-run (unwashed) gravel for less-intensive lines. Washed gravel provides better drainage than unwashed gravel.
- **Sand:** Used in areas with very low traffic or for specific applications like with cast iron pots. It has good drainage properties but can be blown away by the wind.
- **Slag:** A byproduct of the steelmaking process that can be used as ballast.
-

5. **Discuss the various rail fixtures and fastenings used in railway engineering.**

Answer: **Rail joiners**

- **Fish Plates:** These are steel plates that connect two rail ends, maintaining continuity and allowing for thermal expansion and contraction. They are held in place by fish bolts.
- **Bolts:** Fish bolts connect fish plates to rails at joints. Other bolts, like fang bolts, are used to fix chairs to sleepers.

Fasteners for sleepers

Spikes: Large nails used to fasten rails to wooden sleepers.

1. **Dog Spikes:** A common type, hammered into wooden sleepers to secure rails.
2. **Screw Spikes:** Offer greater holding power than dog spikes, especially in steel sleepers, due to their helical threads.

Chairs: Cast iron fixtures used to hold double-headed or bull-headed rails in place on timber or steel sleepers. They have a rail seat and two jaws

10 Mark Questions (With Answers)

1. **Explain in detail the components of a permanent way with neat sketches.**

Answer: The railway track or permanent way is a component of railway lines that consists of pairs of rails typically laid on sleepers or ties embedded in ballast and intended to carry ordinary trains. The term "permanent way" refers to the fact that in the early days of railway construction, contractors would

frequently lay a temporary track to transport soil and materials around the site. Once this work was substantially completed, the temporary track was removed, and the permanent way was installed.

Rails in a permanent way are permanently joined either by welding or by using fish plates and are fastened to sleepers using various types of fasteners. Sleepers are properly positioned and packed. Ballast is placed on a prepared subgrade known as a formation.

Requirements of an Ideal Permanent Way

An ideal permanent way is essential for the safe and efficient movement of passengers and freight. The following are the requirements of an ideal permanent way:

- A uniform and correct gauge are necessary.
- The level of both the rails should be the same on a horizontal track.
- At the curved locations, superelevation in a permanent way must be provided properly by raising the outer rail of the track.
- The design of the permanent way should be done in such a way that the load is uniformly distributed between two rails.
- The track should possess the required elasticity and lateral strength.
- All joints, points and crossings should be properly designed in a permanent way.
- The drainage system must be properly installed.
- Scope for maintenance and renewables must be provided.

2. **Describe in detail the different types of sleepers, their advantages and disadvantages.**

Answer: Railway sleepers constitute an important component of the railway track. These maintain proper gauge and also facilitate the transfer of point load from the wheel loads to the uniformly distributed load to the ballast. The sleepers rest on the ballast and are also referred as Ties.

Functions of Railway Sleepers

The main functions of sleepers in railway track are:

- These keep the rails firmly in place also maintain a uniform gauge.
- These facilitate the transfer of wheel loads to the ballast.
- Rail sleepers lessen the vibrations emanating from the rails.

- These provide lateral and longitudinal stability

Wooden Sleepers

- Wooden Sleepers are typically 2600 mm long, 254 mm broad, and 127 mm thick in cross-section.
- Wooden Sleepers are treated with preservatives after being seasoned (drying for up to 12 months to remove the juice/sap) for the preservation of timber. Creosote is an oil that is typically applied to or sprayed on the surfaces of wooden sleepers.
- These sleepers are either made of soft wood or hardwood.
- Due to the easy availability of wood, these sleepers are extensively used.

Benefits of Wooden Sleepers

- Wooden sleepers are less expensive than other types of sleepers.
- They are lightweight, making them portable and simple to handle during installation.
- On wooden sleepers, fasteners may be fitted with ease. The rails are adequately protected since they are effective insulators.
- Wooden sleepers can be used to maintain the rail gauge effectively.
- They are appropriate for all kind of rail sections.
- These possess sufficient elasticity which allows them to absorb vibrations and shocks. In fact, wooden sleeper have the best track elasticity among all the types of sleepers.

Disadvantages of Wooden Sleepers

- Wooden sleepers are easily vulnerable to pest and weather attacks.
- They are prone to fire.
- With wooden sleepers, maintaining a uniform gauge can be a challenging task.
- The scrap value of wooden sleepers is less.
- They can only last for a period of **12 to 15 years**.

2. Steel Sleepers

- Steel Sleepers can be used when wooden or concrete sleepers cannot be adopted.
- In heavier curves that are prone to gauge widening, steel sleepers are extensively used.
- The signal control system may face issues due to steel sleepers.
- Furthermore, these sleepers are also prone to fatigue cracking issues.

- Steel and concrete sleepers are now often used on railroads due to a shortage of wood and other economic concerns.

Advantages of Steel Sleepers

- Steel sleepers are durable and resilient.
- They have a span of **35 years.**
- Less damage sustained in these sleepers during handling and transportation.
- They are resistant to attack of vermin and fire.
- Steel sleepers have a high scrap value.

Disadvantages of Steel Sleepers

- It as susceptible to corrosion.
- Cannot be used for track circuiting.
- It can only be used with the rails for which it was designed.
- Throughout the service of Steel Sleepers, cracks appear at the rail seats.
- higher number of fittings are needed overall in steel sleepers

3. **Explain in detail the types of rail joints, their requirements, and maintenance practices.**

- Answer: **Suspended joint:** The most common type of rail joint, where the rail ends are suspended between two sleepers. The ends cantilever slightly and rely on the support of the fishplates and bolts to carry the load, distributing it across two sleepers.
- **Supported joint:** In this type, the rail ends are placed directly over a single joint sleeper. While this provides strong vertical support, it can result in a hard ride and increased wear on both the rail ends and the sleeper, making it less common today.
- **Bridge joint:** Similar to a suspended joint, but with a flat or corrugated plate bridging the two joint sleepers to provide additional support and strength. This is not used on all railway systems.

4. **Discuss in detail the functions and types of ballast used in railways with neat sketches.**

Answer: Ballast is a granular material which is placed and packed below and around the railway sleepers. Different types of ballast materials used are broken stone, sand, gravel, moorum, brickbats

etc. The main purpose of ballast is to transmit the load from sleepers to the formation (consolidated track bed) and to provide drainage facilities to the track.

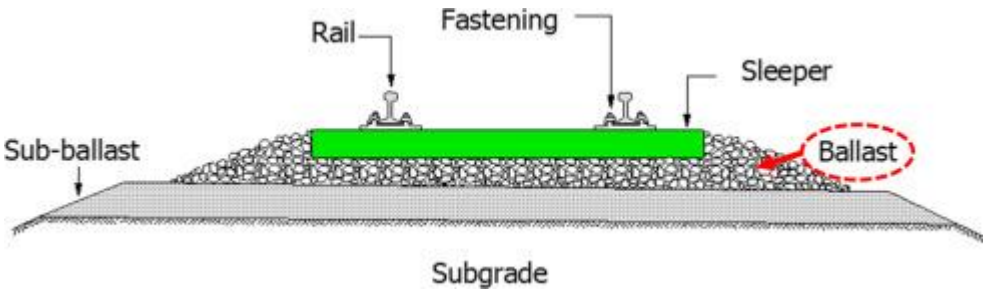
The size of ballast refers to the range of particle sizes of the material used. It is often specified by the maximum and minimum dimensions of the particles.

- Coarse ballast: Typically, larger particles, such as 20-40mm or 40-60mm.
- Fine ballast: Smaller particles, such as 5-20mm.

Functions of Ballast

The functions of ballast are as follows:

- It provides levelled bed or support for the railway sleepers.
- It transfers the load from sleepers to subgrade and distributes the load uniformly on subgrade.
- It holds the sleepers in a firm position while the trains pass by.
- It prevents the longitudinal and lateral movement of sleepers.
- It offers good drainage to the track



5. **Explain the creep of rails in detail with its causes, effects, and methods of prevention.**

Answer: **Creep of Rail** is defined as a longitudinal movement of rail with respect to sleeper. Rail have the tendency to gradually move in the direction of dominant traffic. The creep of rail is common to all railway tracks and its value varies from almost nothing in some cases to about 130 mm/ month in creep.

There is wide variation in the amount of ***creep of rail.*** The principal causes which are responsible for the development of creep of rail are discussed below.

Causes of Creep of Rail

1. Acceleration or Starting of Train:

At the time of acceleration, Wheel gives lateral thrust which causes creep of rail.

2. Deaccelerating or Stopping of Train:

If sudden stopping of train takes place, braking effect tends to push the rail forward and thus causes creep in forward direction.

3. Wave action or Wave Theory:

As train is passing under the rolls the portion under the rolling wheels is compressed and depressed slightly due to wheel loads. As more the wheel moves this depression also moves and the portion which is under depression previously comes back to its original position.

4. Percussion Theory:

This type of creep of rail occurs due to impact of load. In this type, when the wheels of rail pass over the joint, the trailing rails gets depressed down and the wheels gives impact to the facing of rail.

Effect of creep.

- The results of creep are of very serious nature and hence great care should be taken to detect and repair the creep.
- The suspended joints start becoming supported joints and rail ends get battered.
- The sleepers move out of their position and hence the rail gauge is disturbed and also the rail level. This result in bad running of train.
- Due to creep the position of point and crossing will be disturbed and it will be difficult to maintain a correct gauge and alignment.
- The interlocking mechanism of the signal are disturbed due to creep.
- Rail joints get opened out resulting in bolt holes getting elongated and premature fracture of fish plate and bolts.

Measurement of Creep.

Creep posts should be erected every kilometre on either side of the track and the position of joints should be marked on one-of the posts. The measurement of creep should be taken frequently at an interval of about 3 months in a prescribed register to he maintained by the P.W.T. Creep in excess of 150 mm (6 inches) should not be permitted on standard track and at one location not more than six consecutive rails should be found jammed in single rail track. In approaches of points & crossings, there should be no creep.

Adjustment of Creep:

When the creep becomes excessive (more than 6 inches) causing maintenance problems, the same should he adjusted by pulling back. The work is carried out under the protection of engineering signals after necessary caution order is given. A careful survey should be carried out of the expansion gaps and of the present position of rail joints.

The total creep proposed to be adjusted, the correct expansion gaps to be provided and the length of track to be tackled in one operation, should be decided in advance. The fish plates at one end are loosened and those at the other end are removed. Sleeper fittings i.e. spikes or keys, are loosened removed. The rails are then pulled back one by one with the help of a rope attached to the hook. Pulling back should be regulated in such a way that the rail joints remain central on the joint sleepers. Pulling back rail by rail is a slow process and can be done only for short isolated lengths. About 40 to 50 men per kilometre are normally required for adjusting the creep.

UNIT – 5

TRACK GEOMETRICS, CONSTRUCTION AND MAINTENANCE

TRACK GEOMETRICS, CONSTRUCTION AND MAINTENANCE

Two marks questions with answer

1.What is alignment of a railway track? Why proper alignment is required in railways?

Answer:

Alignment is the position of the centreline of the railway track on the ground, both in horizontal and vertical planes.

Proper alignment ensures safety, economy in construction, smooth running of trains, and reduced maintenance costs.

2.Differentiate between permanent land and temporary land.

Answer:

Permanent Land	**Temporary Land**
Land permanently acquired for track, side drains, and maintenance.	Land acquired temporarily during construction.
Used for long-term railway operation.	Released after construction is completed.

3.Define super elevation. Write down the formula for calculating super elevation.

Answer:

Super elevation (or cant) is the raising of the outer rail above the inner rail on a curve to counteract the centrifugal force on trains.

Formula, $e = \frac{Gv^2}{127R}$

Where:

e = super elevation (mm)

G = gauge (mm)

v = speed (km/h)

R = radius of curve (m)

4.Define coning of wheels and state its purpose.

Answer:

Coning of wheels is the slight taper on the tread of railway wheels, which is shaped like a cone with a slope of about 1:20. Its main purpose is to enable the train to navigate curves smoothly by allowing the wheels to cover different distances on the inner and outer rails.

Purpose:

- Ensures smooth running on curves.
- Reduces wear on wheel flanges and rails.
- Maintains proper contact between wheel and rail.

5.What is raiway crossing? How many types of crossing are used in railway.

Answer:

Crossing is a device used where two rails cross each other to allow the passage of wheel flanges. Generally, four types of crossing are used in railway. Thes are

- Acute angle (V) crossing
- Obtuse angle crossing
- Square crossing
- Diamond crossing

6.What are the duties of Permanent Way Inspector (PWI)?

Answer:

A Permanent Way Inspector (PWI) is responsible for the safety and maintenance of railway tracks within their jurisdiction, ensuring they are in a satisfactory and safe condition for train operations. This includes performing regular track inspections, coordinating and supervising track maintenance and repairs, identifying and addressing defects, and responding to track-related emergencies. They also oversee materials and tools, ensure compliance with regulations, manage track patrolling during adverse conditions, and maintain records.

7.Why track maintenance is necessary?

Answer:

Track maintenance is necessary for:

- Ensure safe and smooth train movement.
- Reduce wear of track components.
- Prevent accidents and track failures.
- Maintain correct alignment and level.

8.State the functions of a marshalling yard.

Answer:

The functions of a marshalling yard are to receive, sort, reform, and dispatch trains; load, unload, and store goods; and perform maintenance on railway vehicles. It is a central hub for sorting wagons and cars from incoming trains, grouping them by destination, and creating new trains to be sent out.

9.Write down the purposes of a railway station.

Answer:

the purposes of a railway station are:

- For transport and logistics
- For control and regulate train movements
- For provide operational and maintenance facilities
- For railway operations
- For passengers and public services
- For the local community and economy

10.What is station yard?

Answer:

A station yard, or rail yard, is a complex network of parallel tracks within a railway station used for storing, sorting, and servicing locomotives and rail vehicles. The movement of trains within a yard is governed by specific rules and signals and is not authorized by the standard timetable.

Five marks questions with answer

1.Write short notes on components of a standard railway track cross section with neat sketch.

Answer:

A standard railway track is composed of several key components that work together to provide a stable and smooth surface for trains. The cross-section can be divided into two main parts: the superstructure and the subgrade.

Components of a standard railway track

Superstructure

The superstructure includes all the components above the formation level.

- **Rails:** These are steel girders laid end-to-end in two parallel lines to form the track. Their functions are to:
    1. Provide a smooth and level surface for the wheels to roll on.
    2. Bear the heavy stresses from moving loads, braking, and temperature variations.
    3. Transmit the load from the wheels to the sleepers.
- **Fastenings:** These are devices used to fix the rails securely to the sleepers. They prevent lateral and longitudinal movement of the rails and maintain the correct track gauge. Examples include:
    1. **Fish plates and fish bolts:** Used to join the ends of two rails together.
    2. **Spikes, clips, and screws:** Used to fix the rails to the sleepers.
    3. **Bearing plates:** Used under flat-footed rails to increase the bearing area on wooden sleepers and provide the correct rail tilt.
- **Sleepers (or ties):** These are transverse supports laid under the rails. They are made of wood, steel, or prestressed concrete. Their functions are to:
    1. Hold the rails at the correct gauge.
    2. Transfer and distribute the wheel load from the rails to the ballast.

3. Provide elasticity to absorb shocks and vibrations.

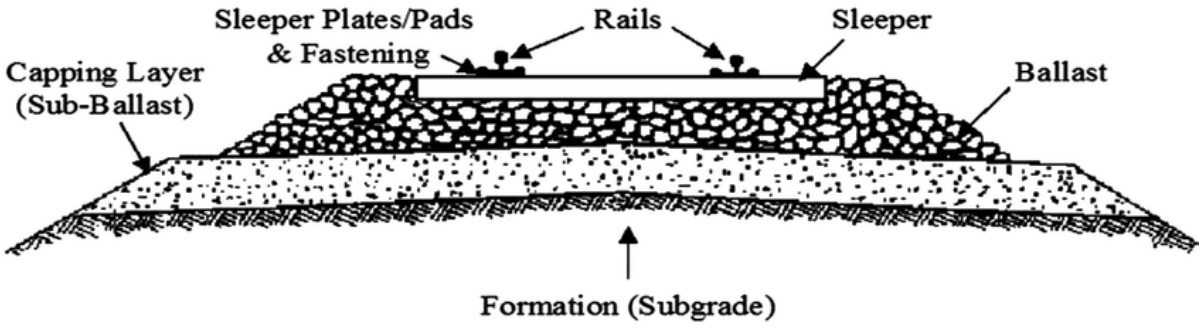
- **Ballast:** This is a layer of crushed stones or other granular material placed under and around the sleepers. Its main functions are to:

  1. Hold the sleepers in place and provide stability against lateral and longitudinal movement.
  2. Distribute the load evenly from the sleepers to the subgrade.
  3. Provide effective drainage to prevent water accumulation.

Subgrade

The subgrade, or formation, is the ground on which the track is built, and it supports the entire track structure.

- **Formation (or Subgrade):** The prepared ground surface on which the ballast and the rest of the track structure rest. It provides a stable and uniform base and also helps with track drainage.



2.Explain the necessity and formula for super elevation.

Answer:

Super elevation is provided on horizontal curves to counteract the outward centrifugal force that pushes a vehicle toward the outside of the curve. By raising the outer edge of the pavement relative to the inner edge, a component of the vehicle's weight acts as an inward force, preventing the vehicle from skidding or overturning and allowing it to maintain speed safely.

Primary purposes

- **Safety:** Prevents vehicles from skidding or overturning on curves by counteracting centrifugal force.
- **Stability:** Helps fast-moving vehicles pass through curves with greater stability.
- **Prevents collisions:** Keeps vehicles on the correct side of the road, especially in opposing lanes, to avoid head-on collisions on curves.

Secondary benefits

- **Improved drainage:**

Facilitates rainwater to drain towards the inner side of the road, eliminating the need for side drains on the outer edge.

- **Reduced wear and tear:**

Distributes wheel load more evenly, which leads to less wear on tires and springs and lower road maintenance costs.

- **Increased traffic flow:**

Allows vehicles to maintain a higher, more consistent speed through curves, increasing the volume of traffic that can pass through safely.

Formula: $\boldsymbol{e = \frac{Gv^2}{127R}}$

Where

- e = super elevation (mm)
- G = gauge (mm)
- v = speed (km/h)
- R = radius of curve (m)

Advantages:

- Reduces wear on outer rail.
- Improves comfort and safety.
- Allows higher train speeds on curves.

3.Explain types of turnouts with neat sketches.

Answer:

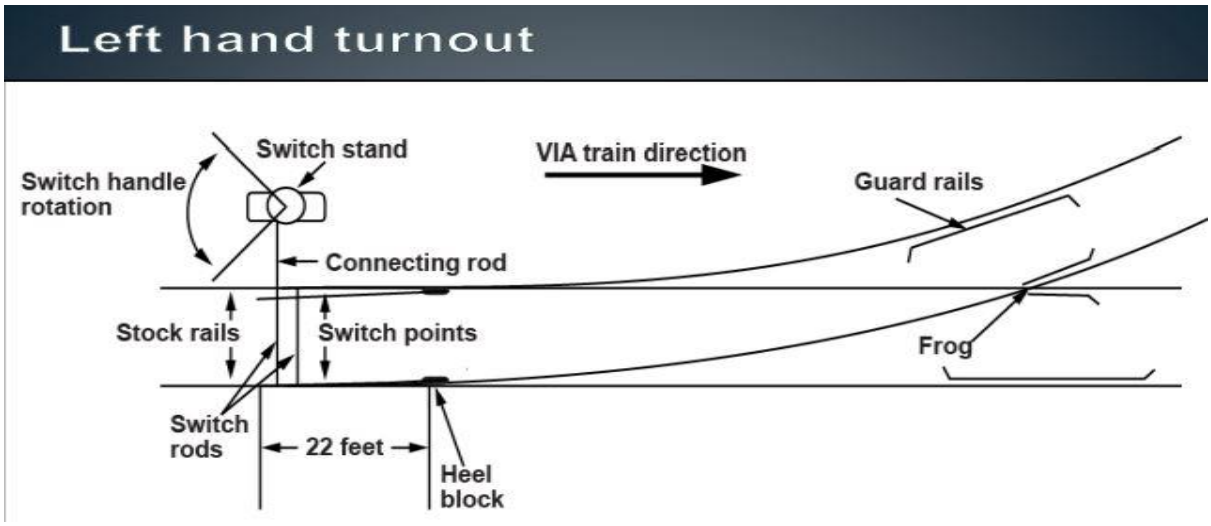
A turnout is an arrangement used to divert trains from one track to another.

Types of Turnouts:

- Left-Hand Turnout
- Right-Hand Turnout
- Symmetrical Turnout

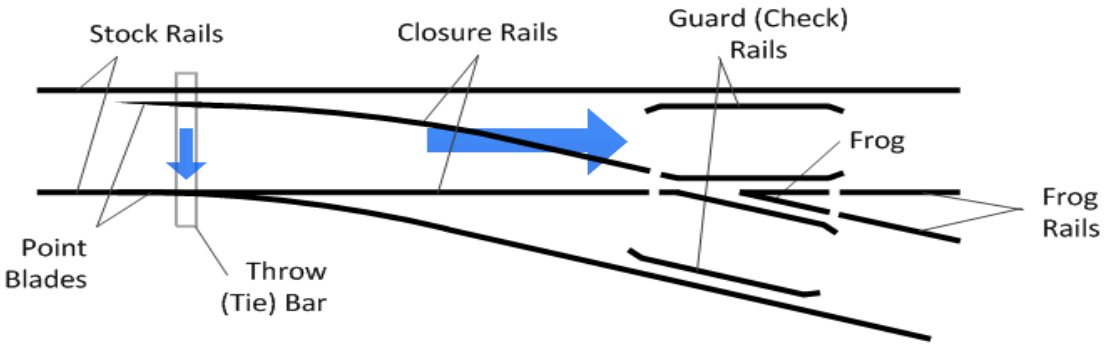
1.Left-Hand Turnout

A left-hand turnout is a railway component that diverts a train to the left of the main track. It's a combination of points and crossings that allows a train to move from one track to another, with the main diversion point being a leftward curve from the facing direction.



2.Right-Hand Turnout

A right-hand turnout in a railway is a set of tracks that diverts a train to the right of the main line when viewed from the perspective of the train's facing direction. It is a key component that allows trains to move from one track to another, and its direction is crucial for railway layout design and safe train operation.



3.Symmetrical Turnout

A symmetrical turnout, also known as a symmetrical split, is a railway junction where a straight track divides into two curved tracks of equal radius, diverting traffic in two symmetrical directions. This layout is used to divide a straight line into two equal, opposite branches, providing a layout that is symmetrical about the original track's centreline.

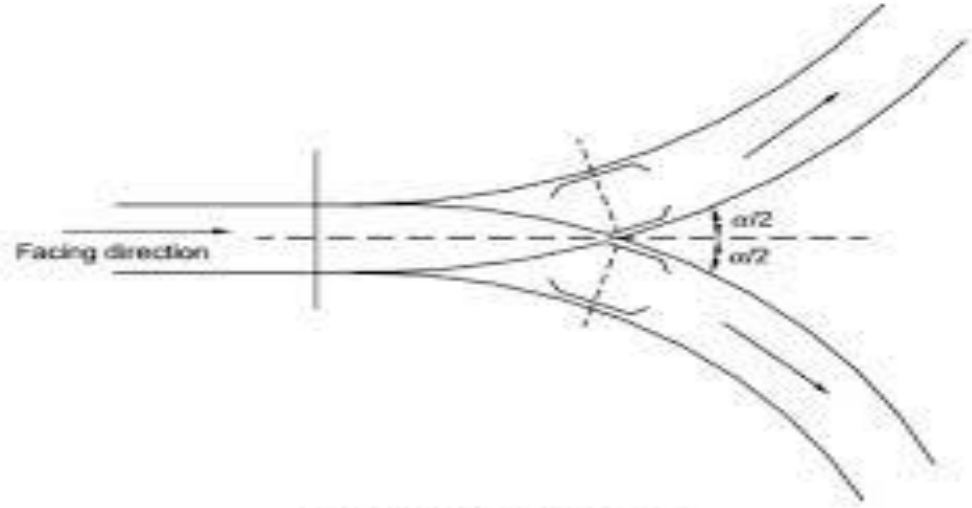


Fig. 15.3 Symmetrical split

4.Classify the railway stations.

Answer:

Railway stations can be classified by their function, such as terminal, junction, and wayside stations, or by their operational type, like block stations (A, B, C class) and non-block stations (including flag stations and halts). Another system classifies stations by service type: Non-suburban (NSG), Suburban (SG), and Halt (HG).

Classification by function

- **Terminal/Terminus:** A station where a line ends, and trains can only enter and exit in one direction.
- **Junction:** A station where multiple railway lines converge, allowing trains to switch between different routes.
- **Wayside Station:** A standard station along a route that is not a terminal or a junction. It is used for crossing and overtaking trains.
- **Halt Station:** The simplest type of station, it is a stopping place for certain trains, often without a building or staff, and has only a platform.

Classification by operational type

- **Block Stations:** Stations where the "block" system is implemented for train control. They are further categorized into A, B, and C classes.
- **Non-Block Stations:** Stations where the block system is not in place, such as D-class or flag stations.

Classification by service type

- **Non-suburban (NSG):** Major stations with high traffic, categorized into grades 1-6.
- **Suburban (SG):** Stations serving suburban areas, categorized into grades 1-3.
- **Halt (HG):** Basic stopping places with limited facilities, categorized into grades 1-3.

5.Explain the functions of a marshalling yard.

Answer:

A marshalling yard's main functions are to receive goods trains, sort them by destination, break them up into individual wagons, and then reform them into new, through trains for dispatch. These yards act as a central hub for railway freight by facilitating the receiving, sorting, reforming, and dispatching of trains and wagons to various destinations. They are crucial for the efficient movement of goods, as they also provide other services like loading, unloading, and the maintenance of rolling stock.

- **Receiving trains:** Incoming freight trains are received into the yard.
- **Breaking up trains:** Terminating trains are broken down into individual wagons or smaller groups of cars, a process often facilitated by a hump yard which uses gravity to separate the cars.
- **Sorting wagons:** The wagons are sorted based on their final destination.
- **Reforming trains:** Wagons are reassembled into new trains, or "through trains," destined for specific locations.
- **Dispatching trains:** The newly formed trains are then dispatched to their next destination.
- **Loading and unloading:** The yard provides facilities for the loading and unloading of goods and vehicles.
- **Maintenance:** It also provides facilities for the maintenance of rolling stock, such as locomotives and wagons.

Ten marks questions with answer

1.Describe various types of track junctions (crossover, scissors crossover, diamond crossing, and track triangle) with neat diagrams.

Answer:

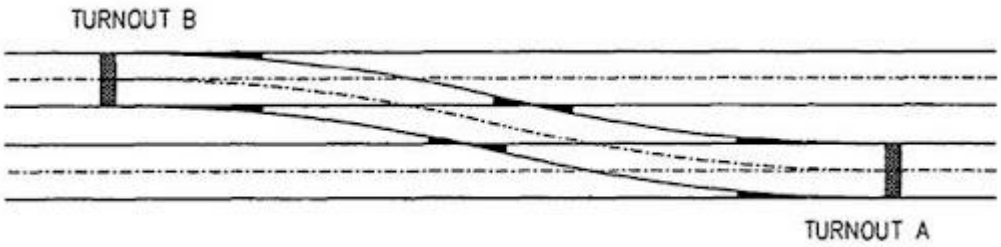
- **Crossover:**

  A railway crossover is a connection between two adjacent, continuous tracks that allows trains to change from one track to another. It is formed by two sets of turnouts, often with a straight section in between. A double crossover or scissor crossover is a specific type that combines two single crossovers in opposite directions, enabling trains to switch between both parallel tracks without reversing and saving space.

  Types of crossovers

- **Single Crossover:**

  Consists of two turnouts that enable a train to move from one track to another. The two tracks are typically parallel but not always, and the turnouts can be straight or curved.

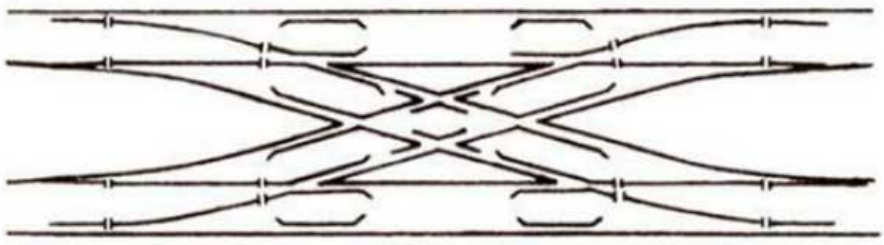


- **Double Crossover (Scissor Crossover):**

A more compact arrangement that combines two single crossovers of opposite handedness on top of each other.

1. It uses a more complex arrangement of switches and crossings, including four pairs of points and six acute angle crossings.

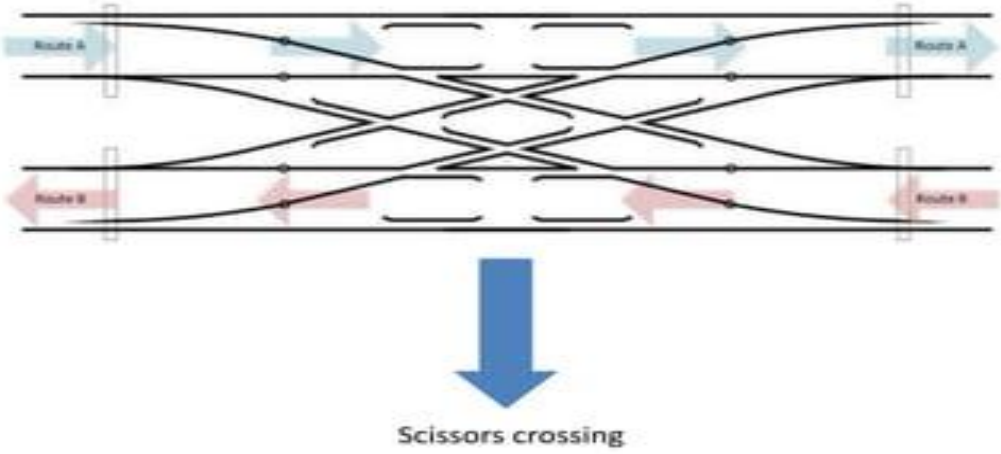
1. It is commonly used in areas with limited space, like near stations or in railway yards.



Double Crossover

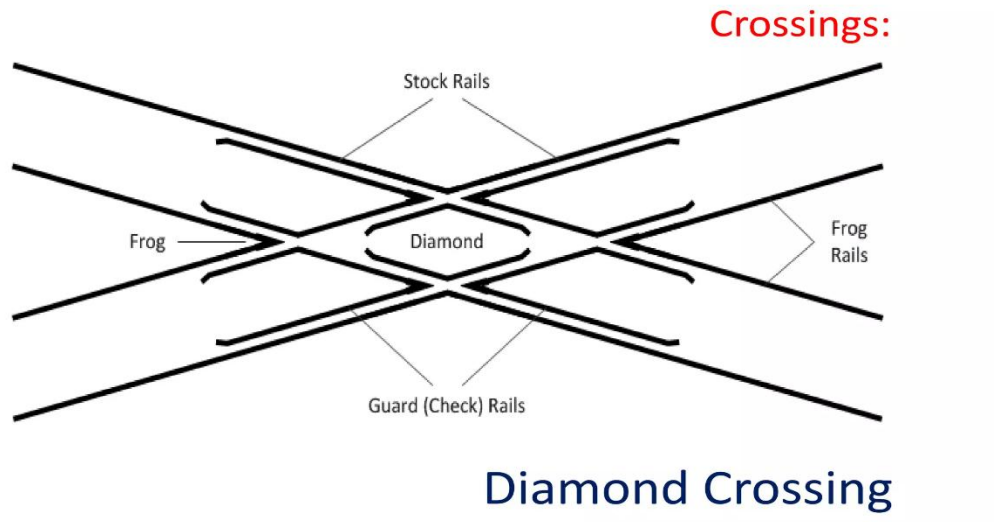
- **Scissors Crossover:**

A scissors crossover, also known as a double crossover, is a railway track layout that combines two standard crossovers into a single structure to allow trains to switch to an adjacent track in either direction. It is often used in space-constrained situations and consists of four turnouts and a central diamond crossover where the tracks intersect.



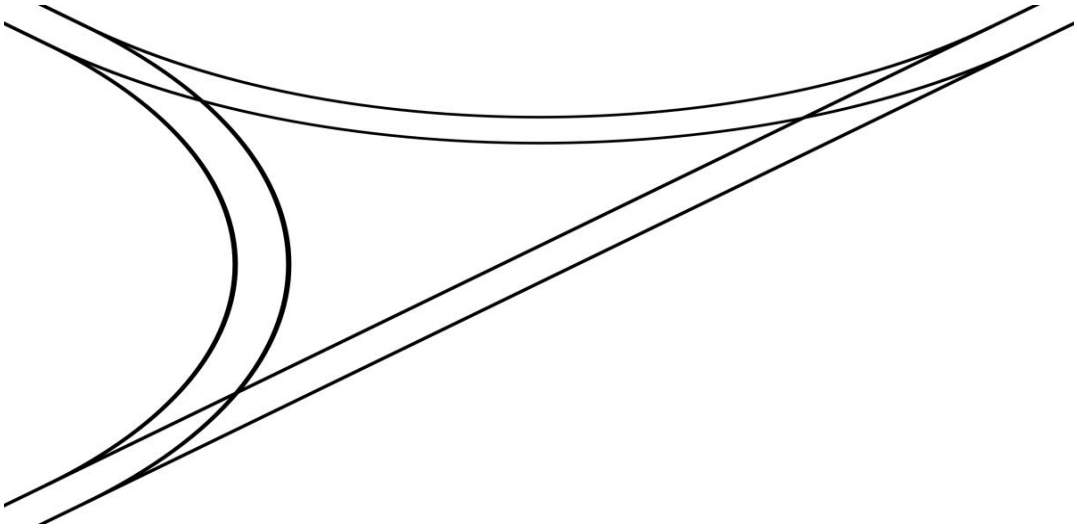
- **Diamond Crossing:**

A diamond crossing is a railway junction where two tracks intersect, allowing trains to cross between different lines. It is formed by a combination of two acute and two obtuse angle crossings, which create a diamond shape. This design is used when tracks of the same or different gauges cross each other.



- **Track Triangle:**

  A railway track triangle, also known as a wye or three-sided junction, is a triangular layout of tracks used to change the direction of a locomotive or turn a train around. It consists of a symmetrical split with two turnouts and lead rails, allowing an engine to reverse its direction by going to each of the three points in sequence. While more relevant for older steam locomotives, modern diesel and electric engines are often designed to operate from both ends, making triangles less critical for them, but they are still used for diverting trains or crossing between parallel tracks.



2.With suitable diagrams, explain the following:

(a) Super elevation

(b) Cant deficiency

(c) Coning of wheels

(d) Tilting of rails

Answer:

- **Super elevation**

Super elevation, or cant, is the practice of raising the outer rail of a railway track on a curve above the inner rail to counteract the centrifugal force acting on a train. This improves stability, passenger comfort, and load distribution, and is calculated using the formula

$$e = \frac{GV^2}{127R}$$

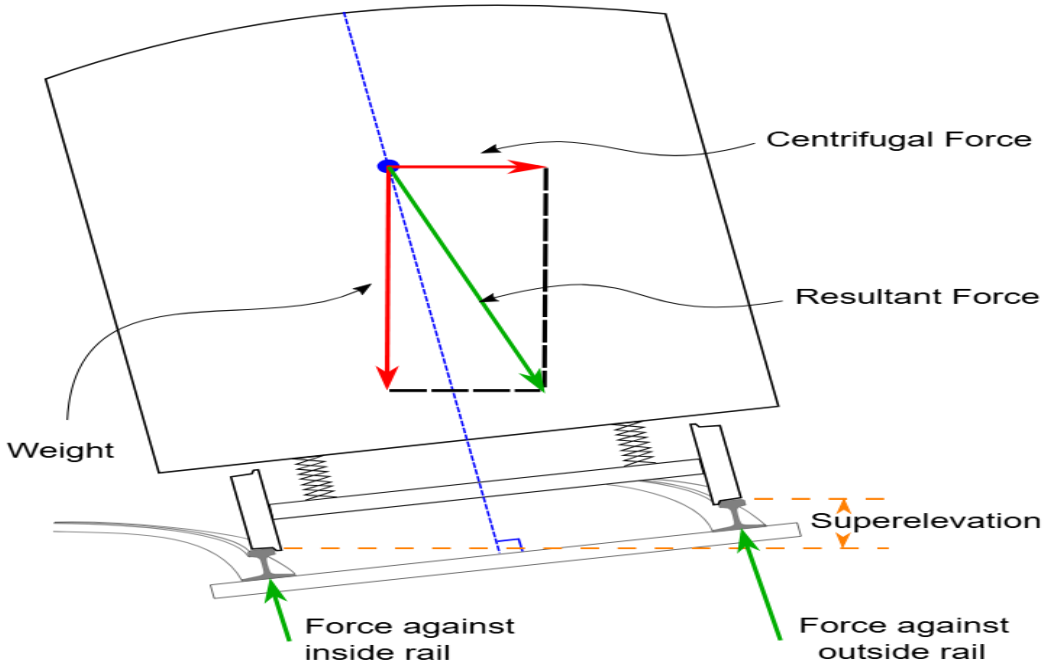
where

e is the super elevation,

G is the track gauge,

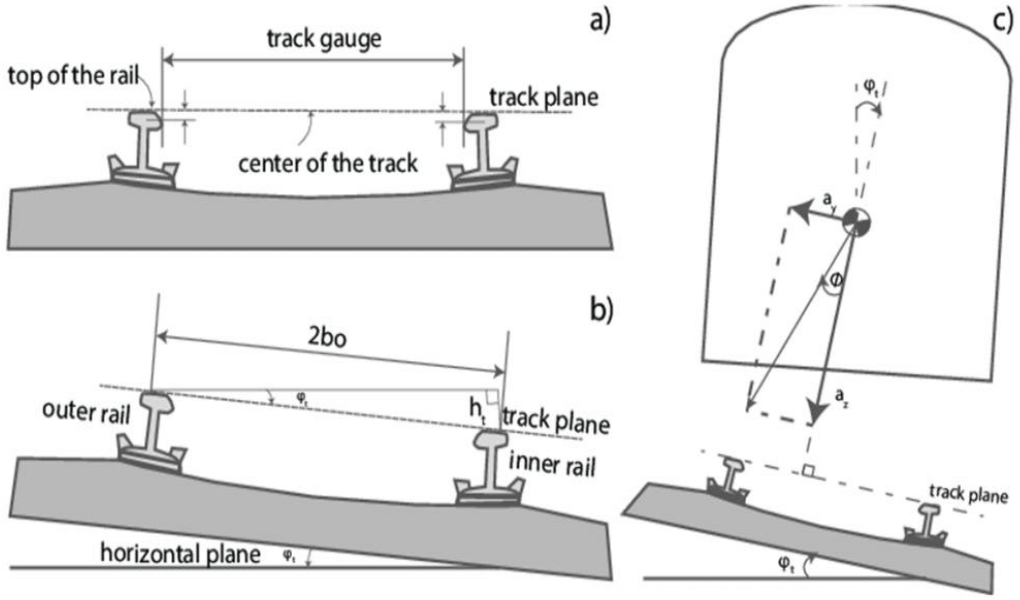
V is the train speed, and

R is the radius of the curve



(b) Cant deficiency

Cant deficiency in railways occurs when a train travels on a curve at a speed higher than the equilibrium speed for the provided cant (superelevation). This happens because the actual cant provided is less than the theoretical amount needed to fully counteract the centrifugal force at that speed. This difference is managed by setting maximum allowable limits for cant deficiency to ensure train stability and passenger comfort.



(c) Coning of Wheels:

Coning of wheels is the process of shaping the treads of railway wheels to a conical form, with a slope of about 1 in 20. This design is crucial for allowing trains to navigate curves and straight tracks smoothly by self-centring the train on the tracks, reducing wear on wheels and rails, and preventing lateral movement.

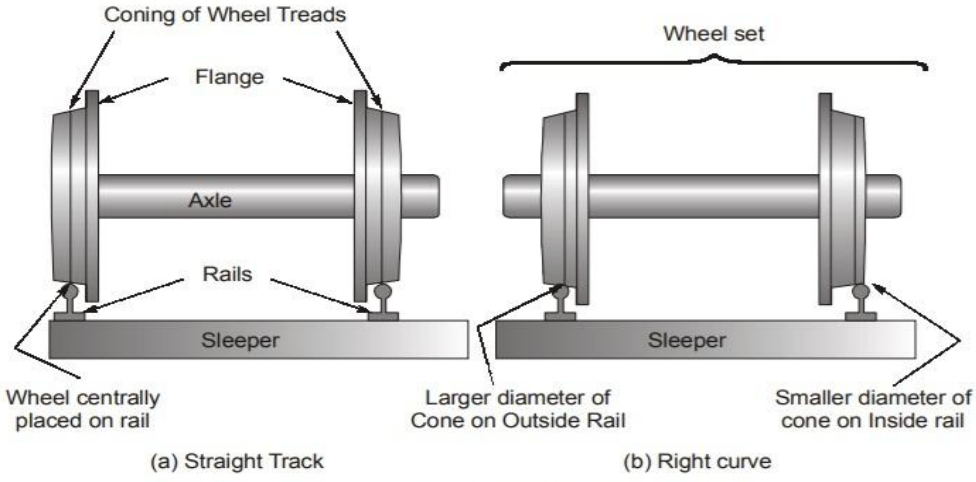


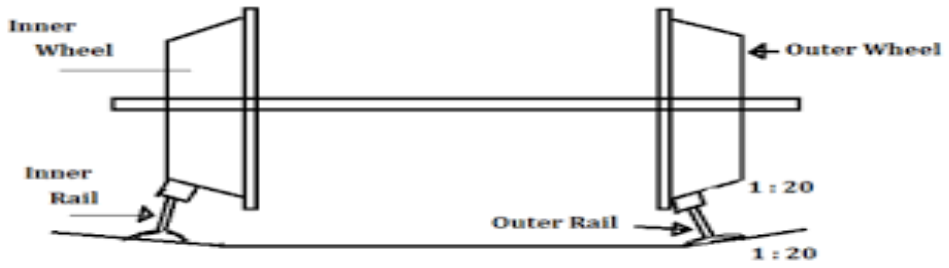
Fig. Coning of Wheels

How it works

- **On straight tracks:** The wheels naturally stay cantered because the coned shape causes them to roll along the centre of the rails without the flanges making contact.
- **On curved tracks:** When a train enters a curve, it naturally leans toward the outside. Coning automatically compensates for this by causing the outer wheel to travel on its larger diameter and the inner wheel on its smaller diameter. This difference in wheel diameters allows both wheels to cover different distances simultaneously, enabling the train to negotiate the curve smoothly.

(d)Tilting of rails:

Tilting of rails, also called canting, is the practice of inclining railway tracks inward by about 1 in 20 to better match the angled, coned shape of train wheels. This inward slope ensures the wheel tread makes full contact with the rail head, which prevents excessive wear on the wheels and rails, provides a smoother ride, especially on curves, and helps maintain the correct track gauge.



Key benefits of tilting rails

- **Reduces wear and tear:**
  It ensures the pressure from the train's wheels is distributed evenly across the wheel tread and the top surface of the rail, preventing excessive wear on specific areas.
- **Improves stability on curves:**
  It helps the train move smoothly through curves by compensating for the "coning of wheels" (the sloped shape of the wheel tread), which is designed to help the train stay centred on the track.

- **Increases lifespan:**
  By reducing wear, the life of both the rails and the sleepers (the supports beneath the rails) is extended.
- **Maintains proper gauge:**
  It helps ensure the correct distance between the rails is maintained.

How tilting is achieved

- **Adzing of sleepers:** The wooden sleepers are cut at a slope before the rails are laid on top.
- **Canted bearing plates:** Special plates with an inward slope are placed between the rail and the sleeper.

****