

LECTURER NOTES

ON

Th4. HIGHWAY ENGINEERING

Diploma Civil Engineering ,4th Semester



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A. COURSE OBJECTIVES

On completion of the course students will be able to -

1. Realize significance of the highway transportation and professional bodies associated with this,
2. Acquaint themselves with road geometric terms and understand the purpose of providing necessary features including angles and curvature during road construction.
3. Select proper road construction materials based on required properties and test data.
4. Comprehend the pavements and their types and know the step wise construction processes.
5. Acquire knowledge on common construction equipment
6. Realize essence of drainage and maintenance on the highways and prescribe related practices.

B. TOPIC WISE DISTRIBUTION

Chapter	Name of topics	Periods
1	Introduction	05
2	Road Geometrics	20
3	Road Materials	09
4	Road Pavements	13
5	Hill Roads	07
6	Road Drainage	07
7	Road Maintenance :	07
8	Construction equipments:	07

Chapter No- 1

Introduction

- Importance of Highway transportation: importance organizations like Indian roads congress, Ministry of Surface Transport, Central Road Research Institute.
- Functions of Indian Roads Congress
- IRC classification of roads
- Organization of state highway department

Introduction

Transportation engineering is a branch of civil engineering that focuses on the **planning, design, operation, and maintenance** of transportation systems. Its goal is to ensure that people and goods can move efficiently, safely, and sustainably across various modes of transport—such as roadways, railways, airports, seaports, and transit systems.

Key Areas of Transportation Engineering:

1. **Highway Engineering:** This involves the design, construction, and maintenance of roadways. It includes elements like pavement design, traffic management, road safety, and signage to ensure the smooth flow of vehicles.
2. **Traffic Engineering:** This focuses on the movement of vehicles and pedestrians within a transportation system. It includes traffic flow analysis, signal timing, intersection design, and the management of congestion to ensure efficient traffic operations.
3. **Railway Engineering:** Transportation engineers also design and maintain railway systems, which involves the layout of tracks, stations, signaling systems, and safety protocols.
4. **Airport and Air Traffic Control:** This includes designing runways, terminals, air traffic management, and safety measures to facilitate efficient air travel.
5. **Urban Transportation Planning:** Engineers working in urban settings plan systems that manage public transit, biking, walking, and the integration of different transportation modes within cities.
6. **Environmental Impact:** Transportation engineers analyze the environmental effects of transportation systems, focusing on reducing pollution, enhancing sustainability, and ensuring that transportation projects comply with environmental regulations.
7. **Public Transit Systems:** This includes planning and designing buses, subways, trams, and other public transportation systems to ensure they meet the needs of urban populations efficiently.

Objectives of Transportation Engineering:

- **Safety:** Minimizing accidents and ensuring safe travel for both vehicles and pedestrians.
- **Efficiency:** Reducing delays, congestion, and improving traffic flow for faster movement.
- **Cost-effectiveness:** Designing transportation systems that provide value for money and are economically sustainable.
- **Sustainability:** Fostering transportation solutions that reduce environmental impact, conserve energy, and support green alternatives.
- **Accessibility:** Ensuring all population segments, including the elderly and disabled, can use transportation systems.

Importance of Highway transportation

- **Economic Growth:** Highways enable the movement of goods and services across regions, helping industries, businesses, and markets to function efficiently. This is critical for trade, both domestically and internationally.
- **Connectivity:** Highways connect cities, towns, and rural areas, fostering better access to services, education, healthcare, and employment opportunities.
- **Accessibility:** People can use highways for personal travel, making it easier to commute, visit family, go on vacations, and access a range of services.
- **Emergency Services:** Highways are essential for emergency vehicles, like ambulances, fire trucks, and police cars, enabling them to respond quickly to emergencies and save lives.
- **Safety:** While accidents do occur, highways generally provide safer routes for long-distance travel compared to other, less-maintained roads.
- **Time Efficiency:** Highways allow for faster travel by reducing congestion and providing more direct routes, which helps save time for both commuters and businesses.
- **Environmental Considerations:** Modern highways are designed with better infrastructure, which can help reduce fuel consumption and lower vehicle emissions when compared to poorly maintained, crowded roads.
- **Tourism:** Highways support the tourism industry by providing access to popular destinations, helping local economies by increasing visitor spending.
- **Job Creation:** Highway construction, maintenance, and associated industries provide millions of jobs globally, supporting a wide range of professions.

Importance organizations

The **Indian Roads Congress**, the **Ministry of Surface Transport**, and the **Central Road Research Institute** are key players in ensuring the development and maintenance of India's road

infrastructure. Their contributions improve safety, efficiency, sustainability, and innovation, which are critical to the economic growth and mobility of the country. These organizations work together to ensure that road transport continues to meet the demands of an increasingly urbanized and connected India.

1. Indian Roads Congress (IRC)

- **Setting Standards and Guidelines:** IRC is the apex body that sets standards and guidelines for the design, construction, and maintenance of roads and bridges in India. These guidelines help ensure that roads are built to a high standard of safety and quality.
- **Promoting Research and Development:** The IRC promotes research in road engineering, ensuring that new materials, technologies, and construction methods are used to improve road infrastructure.
- **Training and Capacity Building:** IRC organizes conferences, workshops, and training programs for engineers, government officials, and other stakeholders in the road sector, ensuring continuous learning and the adoption of best practices.
- **Policy Advocacy:** IRC actively participates in policy discussions, offering expert advice to the government on road-related issues, contributing to the development of road transport policy in India.

2. Ministry of Surface Transport (MoST)

- **Policy Formulation and Implementation:** The MoST is responsible for formulating policies related to surface transportation, including highways, roads, bridges, and ports. It oversees the implementation of national policies for road safety, traffic management, and infrastructure development.
- **Funding and Financing:** The Ministry ensures that adequate funds are allocated for the construction and maintenance of national highways and other critical road infrastructure projects. It often facilitates public-private partnerships to boost investment in road projects.
- **Development of National Highways:** The MoST plays a central role in the development and maintenance of the National Highways Authority of India (NHAI), which builds and maintains India's national highways, crucial for long-distance travel and freight movement.
- **Regulating and Monitoring:** The Ministry also regulates surface transport systems, monitors the performance of roads, and ensures compliance with safety standards.

3. Central Road Research Institute (CRRI)

- **Research and Innovation:** CRRI is one of the leading research institutions focused on road transport and infrastructure in India. It conducts advanced research to improve road materials, traffic management systems, and road safety technologies.
- **Road Design and Construction:** CRRI provides valuable research and technical expertise in the design and construction of roads. It develops innovative materials (e.g., high-quality bitumen, sustainable alternatives) and technologies that improve the durability and performance of road surfaces.
- **Road Safety Studies:** CRRI conducts studies to identify road safety hazards and suggests solutions to minimize accidents and fatalities. It is involved in developing guidelines for safer road designs and effective traffic control measures.
- **Environmental Sustainability:** CRRI also works on making roads more environmentally sustainable, researching techniques for reducing the environmental impact of road construction, such as using recycled materials or improving stormwater drainage.

Importance of These Organizations:

1. **Improved Road Quality and Safety:** These organizations play a critical role in ensuring that roads are not only built to a high standard but are also safe for users. They help reduce road accidents, improve traffic management, and enhance the overall driving experience.
2. **Efficient Transportation:** By setting guidelines and providing technical expertise, they help streamline the design and construction of roads, which reduces travel time, lowers transportation costs, and promotes economic activity.
3. **Economic Growth:** Well-maintained roads are crucial for the smooth movement of goods and services across the country. These organizations contribute to building and maintaining an efficient road network that supports economic development and job creation.
4. **Sustainability:** With an increasing focus on environmental impact, these organizations help make road infrastructure more sustainable, using better materials and reducing pollution from road construction and traffic.
5. **Technology and Innovation:** Through research and policy advocacy, they bring in modern technologies, intelligent transportation systems, and materials that make roads more durable and cost-effective in the long run.
6. **Policy Development:** Their work is instrumental in shaping policies related to road transport, ensuring that regulations evolve in line with technological advancements, safety concerns, and environmental needs.

Functions of Indian Roads Congress

The **Indian Roads Congress (IRC)** is the main organization in India that sets rules and guidelines for building and maintaining roads and highways. Its main functions in **highway engineering** are:

1. Making Rules & Guidelines

- Creates standards for road design, construction, and maintenance.
- Publishes manuals on road materials, safety, and traffic management.

2. Research & Innovation

- Supports research to improve roads and traffic systems.
- Works with research institutes and government bodies.

3. Giving Technical Advice

- Helps the government with road development plans and policies.
- Provides solutions for technical problems in road construction.

4. Training Engineers

- Conducts workshops, training, and conferences for road engineers.
- Shares knowledge through journals, research papers, and reports.

5. Improving Road Safety

- Suggests measures to reduce road accidents.
- Develops guidelines for road signs, signals, and traffic control.

6. Helping in Policy Making

- Advises the government on highway development projects.
- Supports programs like **Bharatmala** and **PMGSY** (rural road projects).

7. Ensuring Quality in Roads

- Sets rules for the use of materials like cement, bitumen, and concrete.
- Ensures proper construction methods are followed.

8. Designing Bridges

- Provides guidelines for safe and strong bridge construction.
- Ensures proper maintenance of bridges.

9. Eco-friendly Roads

- Promotes the use of recycled materials in road construction.
- Encourages green highways to protect the environment.

10. Working with Other Countries

- Learns from global road experts and follows best practices.
- Works with international road organizations.

IRC classification of roads

The **Indian Roads Congress (IRC)** classifies roads based on their importance and usage. The classification is mainly divided into **five categories**:

1. National Highways (NH)

- These are the main roads connecting major cities, states, and important places across India.
- Managed by the **National Highways Authority of India (NHAI)**.
- Example: **NH-44** (longest highway in India, from Srinagar to Kanyakumari).

2. State Highways (SH)

- Roads that connect important cities, towns, and districts within a state.
- Managed by the **State Public Works Department (PWD)**.
- Example: **Mumbai-Pune Expressway (SH-60 in Maharashtra)**.

3. Major District Roads (MDR)

- Connect district headquarters with towns and villages.
- Help in the movement of goods and people within a district.

4. Other District Roads (ODR)

- Connect smaller towns and rural areas to district roads.
- Used mainly for local transportation and rural development.

5. Village Roads (VR)

- These are basic roads that connect villages to nearby towns or district roads.
- Developed under rural road schemes like **PMGSY (Pradhan Mantri Gram Sadak Yojana)**.

Organization of state highway department

The **State Highway Department** (also known as the **Public Works Department - PWD**) is responsible for planning, constructing, and maintaining **State Highways (SH)** and other roads within a state. The organization structure generally follows a **hierarchical system** to ensure smooth management and execution of road projects.

Organizational Structure of the State Highway Department

1. Minister of Public Works (PWD Minister)

- Head of the department at the state level.
- Responsible for policy decisions and budget approval.

2. Chief Engineer (CE)

- Senior-most technical officer.
- Oversees all highway projects in the state.
- Approves major construction and maintenance works.

3. Superintending Engineer (SE)

- Manages highways in a particular region or zone of the state.
- Supervises multiple projects and divisions.
- Ensures quality and timely execution of road works.

4. Executive Engineer (EE)

- Heads a district or division office.
- Manages the construction, maintenance, and repair of roads and bridges.
- Monitors contractors and ensures project completion.

5. Assistant Engineer (AE)

- Assists the Executive Engineer in technical matters.
- Supervises roadwork at the site and ensures compliance with standards.

6. Junior Engineer (JE)

- Works at the field level, overseeing road construction and maintenance.
- Ensures work is done as per specifications and quality standards.

7. Other Supporting Staff

- **Surveyors, Draftsmen, Clerks, and Technicians** help in road design, documentation, and execution.
- **Contractors & Laborers** handle actual road construction work.

Functions of the State Highway Department

- Planning & designing state highways.
- Constructing new roads and bridges.
- Repairing & maintaining existing roads.
- Ensuring road safety and traffic management.
- Implementing government road schemes like **PMGSY & Bharat Mala**.

Working of the State Highway Department – Explanation with Case Study

The **State Highway Department** is responsible for the planning, construction, maintenance, and management of state highways. The department works in a structured manner, following a systematic process for project execution. Below is a detailed explanation of how the organization functions, followed by a case study of a real-world project.

Working of the State Highway Department

The department operates in a **phased approach**, from planning to execution and maintenance.

1. Planning & Feasibility Study

- **Identification of the Project**
 - A new highway or an expansion is proposed based on traffic demand, economic benefits, or public requests.
 - Example: Widening an existing two-lane highway to four lanes due to increasing traffic.
- **Feasibility Study & Surveys**
 - The Planning Wing conducts traffic surveys, soil testing, and economic feasibility studies.
 - Land acquisition requirements and environmental impact are analyzed.
- **Approval & Budget Allocation**
 - The proposal is sent to the **State Government** and, if needed, to the **Central Government** for funding assistance.
 - The project is included in the annual **State Road Development Plan**.

2. Detailed Project Report (DPR) & Tendering

- **Preparation of DPR**
 - The **Design & Planning Wing** prepares a **Detailed Project Report (DPR)**, including designs, estimates, and project execution plans.
- **Tendering & Contractor Selection**
 - The project is floated for bidding through a public **tender process**.
 - Private contractors or Public Sector Units (PSUs) submit bids, and the lowest technically qualified bidder is selected.

3. Execution & Construction

- **Supervision & Implementation**
 - Work is monitored by **Executive Engineers, Assistant Engineers, and Junior Engineers** at various stages.
 - Contractors begin construction, following approved designs and quality standards.
- **Quality Control & Inspections**

- **Quality Control Wing** ensures material quality, proper road alignment, and safety standards.
- Periodic site inspections are conducted by higher officials.

4. Maintenance & Monitoring

- **Post-Construction Inspection**
 - The newly constructed highway undergoes final inspection before opening for public use.
 - Defects, if any, are corrected by the contractor under the defect liability period.
- **Routine & Periodic Maintenance**
 - The **Maintenance Division** ensures proper upkeep, including pothole repairs, resurfacing, and road safety measures.
 - Funds for maintenance are allocated annually.

Case Study: Expansion of a State Highway – Odisha SH-10 Widening Project

Project Overview

- **Highway:** Odisha **State Highway 10 (SH-10)**
- **Scope:** Widening from **two lanes to four lanes**
- **Length:** **100 km** stretch from **Sambalpur to Rourkela**
- **Estimated Cost:** **₹1,200 crores**
- **Execution Period:** 3 years

1. Planning & Feasibility Study

- Odisha's **State Highway Department** identified SH-10 for expansion due to **increasing traffic** and industrial development in the region.
- **Traffic Survey Findings:**
 - Current traffic volume exceeded design capacity.
 - Heavy movement of trucks due to industrial hubs in **Jharsuguda and Rourkela**.
- **Land Acquisition & Environment Clearance:**
 - **200 hectares** of land were acquired.
 - **Environmental clearance** was obtained to ensure minimal ecological impact.

2. DPR & Tendering

- The **Detailed Project Report (DPR)** was prepared, including:
 - Road alignment, widening plans, bridges, and flyovers.
 - Estimated project cost and execution timeline.
- The **tender was floated**, and a **leading construction company** won the bid.

3. Execution & Construction

- **Supervision:**
 - The project was divided into **five segments**, each monitored by an Executive Engineer.
 - Daily progress reports were submitted to the **Superintending Engineer**.
- **Key Developments:**
 - **New bypasses** were constructed to reduce congestion in urban areas.
 - **Four major bridges** and **two flyovers** were built to enhance connectivity.
- **Challenges Faced:**
 - **Land acquisition delays** in some areas.
 - **Monsoon season** slowed down construction.

4. Maintenance & Monitoring

- After completion, the highway was inspected and inaugurated.
- A **5-year maintenance contract** was given to the contractor for:
 - Regular resurfacing.
 - Fixing potholes and safety improvements.

Impact of the Project

- Reduced travel time** from Sambalpur to Rourkela from **3.5 hours to 2 hours**.
- Boosted industrial growth** in Odisha's western region.
- Improved road safety** with better lane design and signage.

Conclusion

The **State Highway Department** follows a structured approach in handling projects, ensuring smooth execution from **planning to maintenance**. The **SH-10 expansion project** in Odisha is a

perfect example of how a highway department improves **connectivity, safety, and economic growth**.

Let me know if you need more details or another case study! 🚗 🚧

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You said:

explain working of above organisation how it work with example

ChatGPT said:

Working of the State Highway Department with Example

The **State Highway Department** functions through a **systematic workflow** involving multiple stages: **planning, execution, and maintenance**. Below, we will explain how the department works, using a **real-world example** of a state highway improvement project.

How the State Highway Department Works?

The department operates in **five major phases**:

1. Planning & Identification of Project

- The department **identifies roads** that need improvement based on **traffic congestion, road conditions, and economic development needs**.
- Surveys are conducted to analyze **traffic flow, accident records, and road damage**.
- If a new highway is needed, a **feasibility study** is conducted to assess its benefits and environmental impact.

◆ **Example:**

- The **Odisha State Highway Department** identified **State Highway 10 (SH-10)** between **Sambalpur and Rourkela** as a road requiring widening.
- The road had **increased industrial traffic**, causing frequent congestion and accidents.

2. Feasibility Study & Approval

- A **Detailed Project Report (DPR)** is prepared, including:
 - **Technical designs** (road widening, flyovers, drainage systems).
 - **Estimated budget** and project cost analysis.
 - **Environmental impact assessment** and land acquisition requirements.
- The DPR is submitted to the **State Government** and, if needed, to the **Central Government** for funding.

◆ **Example:**

- For **SH-10 widening**, engineers analyzed road capacity, land availability, and **proposed a four-lane expansion**.
- ₹1,200 crores were allocated for the project from both **state funds and public-private partnerships (PPP)**.

3. Tendering & Contractor Selection

- The department **invites tenders** from construction companies.
- The company that offers the **best quality work at the lowest cost** is awarded the contract.
- Contracts may also include a **5-10 year maintenance period**.

◆ **Example:**

- A private construction company won the contract to execute the **SH-10 widening** project.
- The contractor was responsible for completing the work within **3 years**.

4. Execution & Construction

- Project implementation begins with **land acquisition, road alignment, and construction of flyovers, bridges, and drainage systems**.
- The work is **supervised by Engineers**:
 - **Chief Engineer (CE)** – Oversees the project.
 - **Superintending Engineer (SE)** – Monitors progress at different locations.
 - **Executive Engineer (EE)** – Ensures quality control.
 - **Junior Engineers (JE)** – Conduct daily inspections.

◆ **Example:**

- The **SH-10 project** was divided into **five segments**, each handled by an **Executive Engineer**.
- Major construction included:
 - **New bypasses** to avoid traffic congestion in towns.
 - **Four new bridges** over rivers.
 - **Road dividers and lighting** to improve safety.
- The biggest challenge was **land acquisition delays** in some areas, causing temporary project slowdown.

5. Maintenance & Monitoring

- After the highway is completed, **regular monitoring and maintenance** are conducted.
- The contractor is responsible for **repairs, pothole filling, and resurfacing** for a few years.
- The State Highway Department ensures **road safety measures** like traffic signs, speed limits, and accident response units.

◆ **Example:**

- After completing the **SH-10 expansion**, the road was monitored for **surface quality and safety**.
- **Regular inspections** identified minor cracks, which were **fixed under the contractor's maintenance period**.
- The improved highway **reduced travel time from 3.5 hours to 2 hours** and boosted industrial growth in Odisha.

Chapter N0-02

Road Geometrics

- Glossary of terms used in geometric and their importance, right of way, formation width, road margin, road shoulder, carriage way, side slopes, kerbs, formation level, camber and gradient
- Design and average running speed, stopping and passing sight distance
- Necessity of curves, horizontal and vertical curves including transition curves and super elevation, Methods of providing super – elevation

Road Geometrics in Highway Engineering

Road Geometrics refers to the shape, size, and design of a road to ensure **safety, efficiency, and comfort** for drivers. It includes various elements such as road width, curves, slopes, and visibility. The **Indian Roads Congress (IRC)** provides standards for road geometric design in India.

Main Elements of Road Geometrics

1. Cross-Section Elements (Width & Surface Features)

- **Carriageway Width** → The main road surface for vehicle movement. (Example: 3.5m per lane for highways)
- **Shoulders** → Extra space on the sides for emergency stops. (1.5m to 2.5m)
- **Medians** → Dividers between lanes on highways for safety.
- **Kerbs** → Raised edges along roads to guide traffic and drainage.

2. Horizontal Alignment (Curves & Visibility)

- **Straight Sections** → Used in long stretches for faster travel.
- **Horizontal Curves** → Curves used to change road direction.
- **Super Elevation** → Tilting of the road surface on curves to prevent skidding.
- **Transition Curves** → Smooth joining of straight and curved sections for comfort.

3. Vertical Alignment (Gradients & Slopes)

- **Gradient** → The slope of the road to allow climbing and drainage.
- **Summit Curves** → Upward curves (humps) to adjust for elevation changes.
- **Valley Curves** → Downward curves (dips) to adjust for road dips.

4. Sight Distance (Visibility for Drivers)

- **Stopping Sight Distance (SSD)** → Minimum distance required for a vehicle to stop safely.
- **Overtaking Sight Distance (OSD)** → Distance needed for safe overtaking.
- **Intermediate Sight Distance** → Twice the stopping sight distance.

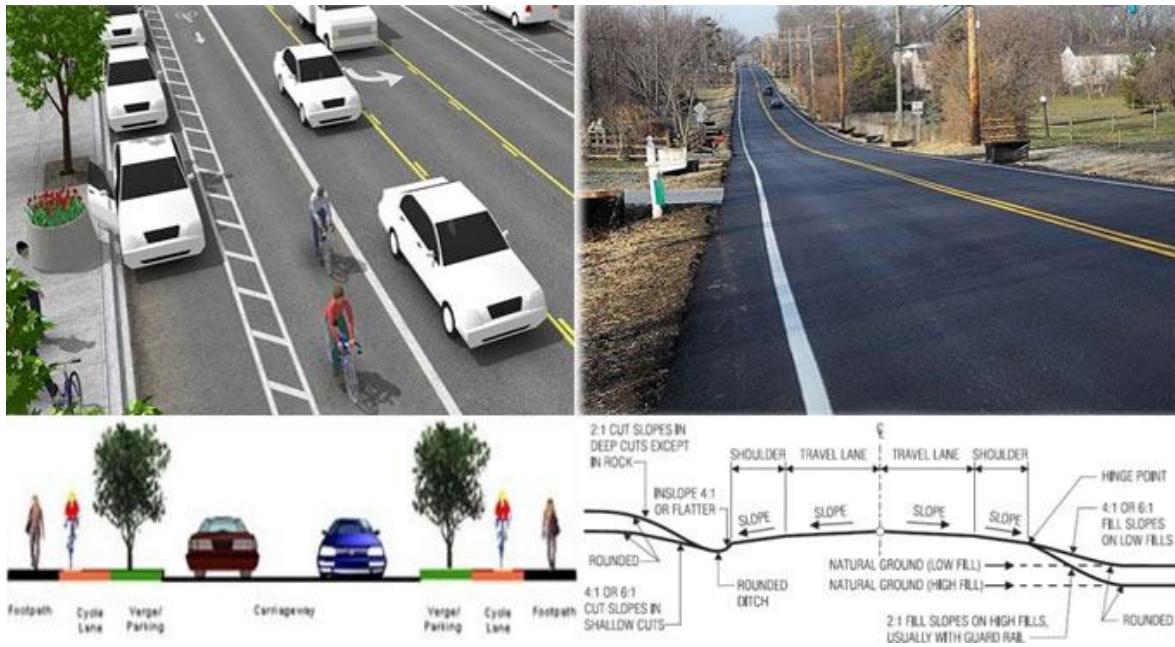
5. Road Intersections & Junctions

- **T-Intersections & Crossroads** → Meeting points of roads.
- **Roundabouts** → Circular intersections for smooth traffic flow.
- **Flyovers & Underpasses** → Used in busy areas to separate traffic levels.

Importance of Road Geometrics

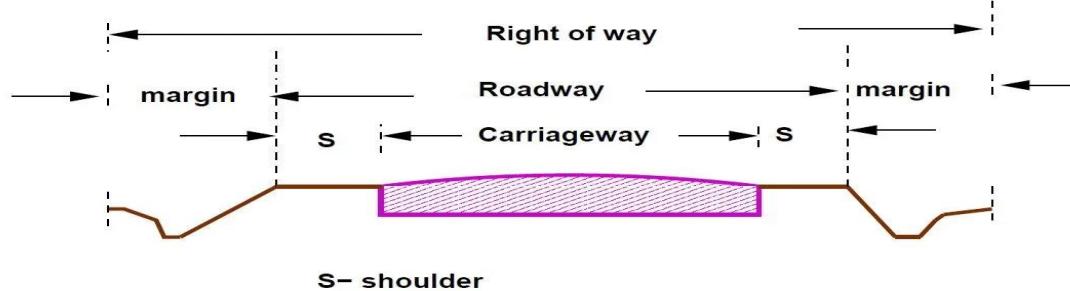
- Ensures safe driving conditions.
- Improves traffic flow and efficiency.
- Reduces accidents and vehicle skidding.
- Enhances driver comfort and road durability.

Glossary of Terms Used in Road Geometrics & Their Importance



1. Right of Way (ROW)

- a. The total land width legally acquired for road construction, including the carriageway, shoulders, sidewalks, and other features.
- b. **Importance:** Ensures space for road expansion, utility services, and road safety measures.



A typical Right of way (ROW)

2. Formation Width

- a. The total width of the road embankment, including the carriageway, shoulders, and slopes.
- b. **Importance:** Provides structural stability and accommodates all road users.

3. Road Margin

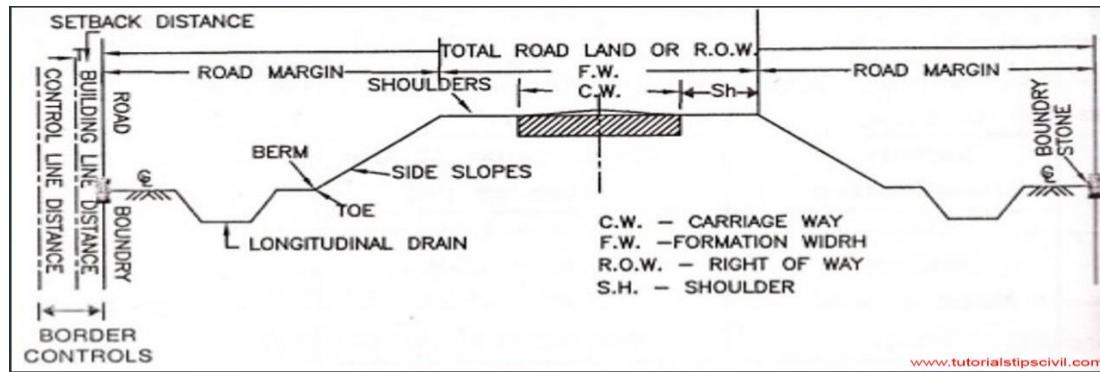
- a. The area beyond the main carriageway, including shoulders, footpaths, and medians.
- b. **Importance:** Offers space for drainage, pedestrian movement, and emergency stops.

4. Road Shoulder

- a. The extra strip of road on both sides of the carriageway, usually unpaved.
- b. **Importance:** Provides space for vehicles to stop in emergencies and supports road stability.

5. Carriageway

- a. The main part of the road used for vehicle movement. The width varies based on traffic requirements (e.g., single-lane, two-lane, or multi-lane roads).
- b. **Importance:** Ensures smooth vehicle movement and determines road capacity.



6. Side Slopes

- a. The sloping surface of road embankments or cuttings to provide stability.
- b. **Importance:** Prevents landslides and erosion, ensuring road durability.

7. Kerbs

- a. Raised edges along the road to separate the carriageway from footpaths or medians.
- b. **Importance:** Guides traffic, improves aesthetics, and helps in water drainage.

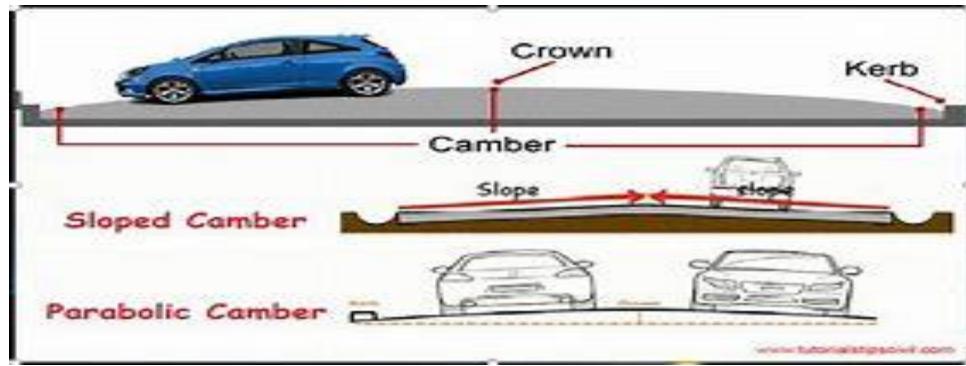


8. Formation Level

- a. The final prepared level of the road surface before paving is done.
- b. **Importance:** Ensures proper drainage and road strength.

9. Camber

- a. The slight slope given to the road surface to allow water to drain off.
- b. **Importance:** Prevents water accumulation, reducing skid risks and road damage.



10. Gradient

- The slope or steepness of the road, expressed as a ratio (e.g., 1 in 20).
- **Importance:** Helps in vehicle movement on hilly roads, improves drainage, and enhances driving safety.

Design and average running speed, stopping and passing sight distance

Design Speed, Average Running Speed, Stopping Sight Distance, and Passing Sight Distance

1. Design Speed

- It is the speed selected for designing various geometric features of the road, such as curves, gradients, and sight distances.
- **Set by IRC** based on road type, terrain, and traffic conditions.

Examples of Design Speed (as per IRC):

- Expressways: **120 km/h**
- National Highways: **80–100 km/h**
- State Highways: **60–80 km/h**
- Rural Roads: **40–60 km/h**

Importance: Ensures safe, efficient, and comfortable travel while designing road curves, super-elevation, and sight distances.

2. Average Running Speed

- The average speed of a vehicle when it is in motion, **excluding** stoppages or delays at signals, intersections, or due to traffic.
- It is always lower than the **design speed** but higher than the overall journey speed.

Importance: Helps in traffic flow analysis and setting speed limits for different road types.

3. Stopping Sight Distance (SSD) / Safe Sight Distance

- The **minimum** distance required for a driver to stop the vehicle safely **without collision** when an obstacle appears ahead.



Formula:

$$SSD = Vt + \frac{V^2}{2g(f + G)}$$

Where:

- V = Speed of vehicle (m/s)
- t = Perception-reaction time (usually 2.5 sec)
- g = Acceleration due to gravity (9.81 m/s²)
- f = Coefficient of friction (depends on road surface & weather)
- G = Gradient (slope of road)



Typical SSD values (for level roads as per IRC):

- 50 km/h → **45 m**
- 80 km/h → **120 m**
- 100 km/h → **180 m**

Importance: Prevents accidents by ensuring drivers have enough distance to stop safely in emergencies.

4. Passing Sight Distance (PSD) / Overtaking Sight Distance

- The **minimum** distance required for a vehicle to safely **overtake** another vehicle **without collision** with oncoming traffic.
- Longer than **SSD** as it involves acceleration, lane changing, and clearance for opposite traffic.



✓ Formula:

$$PSD = d_1 + d_2 + d_3$$

Where:

- d_1 = Distance covered by overtaking vehicle while deciding to overtake.
- d_2 = Distance covered while overtaking.
- d_3 = Clearance distance for safety after overtaking.

✓ Typical PSD values (as per IRC):

- 50 km/h → **230 m**
- 80 km/h → **470 m**
- 100 km/h → **640 m**

Necessity of Curves in Roads

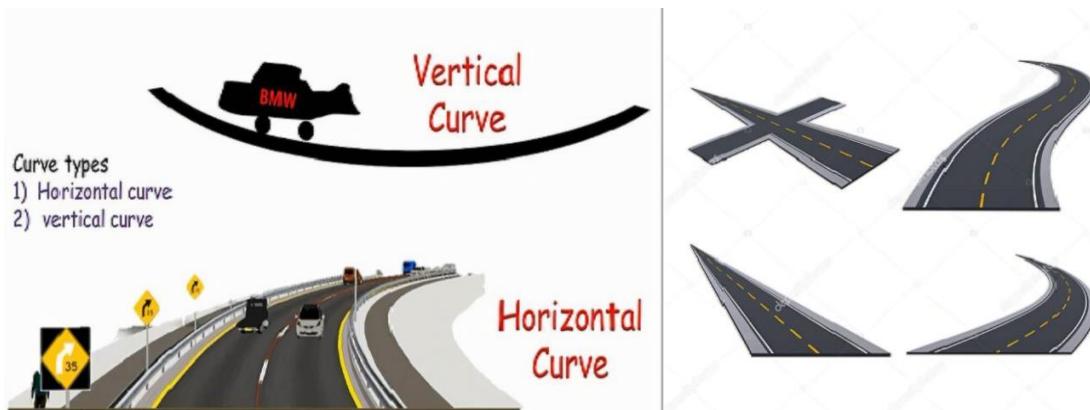
Curves are essential in road design to ensure smooth vehicle movement, safety, and comfort when changing direction or elevation. Roads cannot always be straight due to **terrain, obstacles, and alignment requirements**.

✓ Importance of Curves:

1. **Ensures Safe Turning** → Prevents sharp, sudden direction changes.
2. **Improves Visibility** → Helps drivers anticipate road changes.

3. **Enhances Comfort** → Reduces abrupt acceleration or braking.
4. **Reduces Skidding** → Provides controlled navigation on slopes and turns.

Types of Curves in Road Design



1. Horizontal Curves (Change in road direction)

- Used where roads turn left or right.
- Prevents sharp turns that can cause accidents.

Types of Horizontal Curves:

- **Simple Curve** → A single circular curve connecting two straight roads.
- **Compound Curve** → Two or more circular curves of different radii.
- **Reverse Curve** → Two opposite curves with a common tangent (S-shape).
- **Transition Curve** → A gradual curve to smoothly enter or exit a circular curve.

2. Vertical Curves (Change in road elevation)

- Used where roads move **up or down** due to hills or valleys.

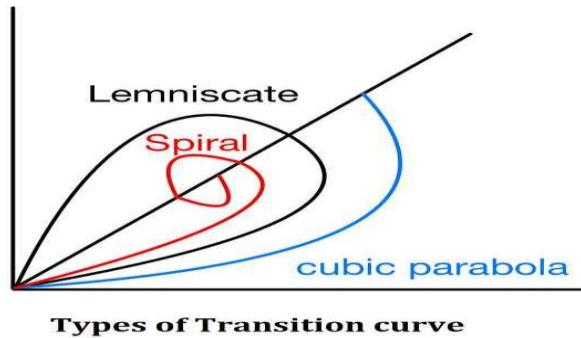
Types of Vertical Curves:

- **Summit Curve** → Upward curve (convex) used when the road rises and then falls.
- **Valley Curve** → Downward curve (concave) used when the road dips and then rises.

3. Transition Curves



- **Definition:** A curve that provides a **gradual change** from a straight road to a circular curve.
- **Purpose:** Ensures smooth entry and exit from curves without sudden steering.
- **Commonly Used Transition Curve: Spiral (Clothoid) Curve**



Super Elevation (Banking of Roads)

- **Definition:** The inward tilting of a road at curves to counteract the effect of centrifugal force and prevent skidding.
- **Formula (IRC Recommended):**

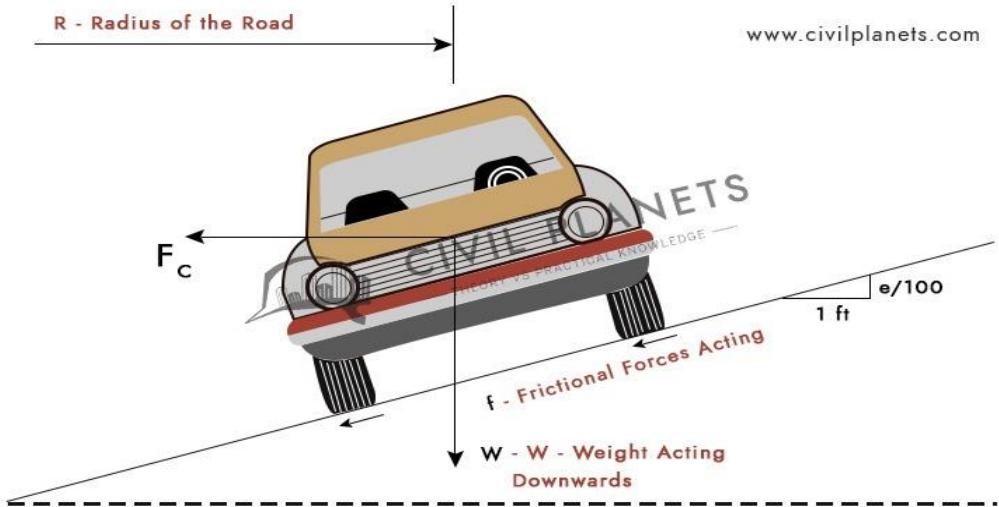
$$e + f = \frac{V^2}{gR}$$

Where,

- e = Super elevation
- f = Side friction factor
- V = Speed (m/s)
- R = Radius of curve (m)
- g = Acceleration due to gravity (9.81 m/s²)

Importance of Super Elevation:

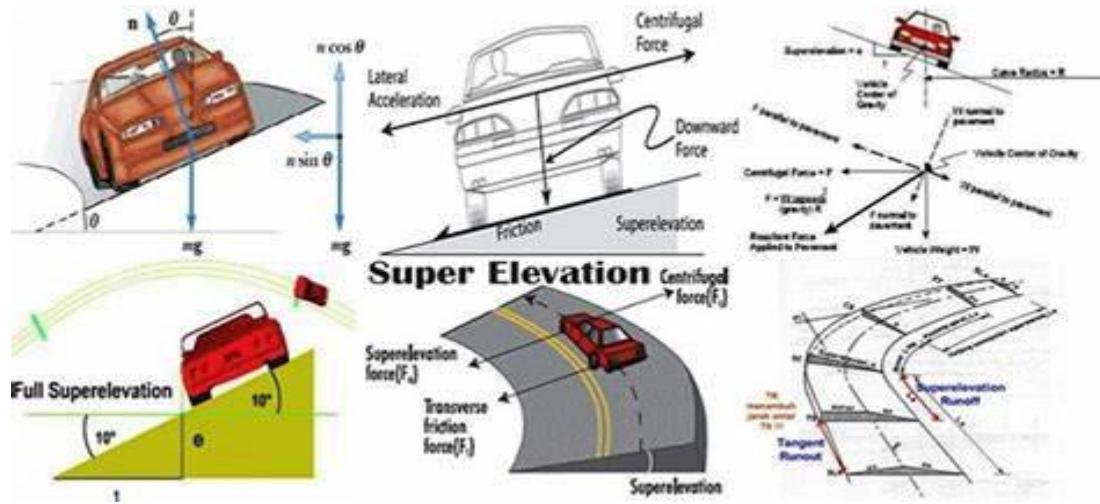
1. **Prevents Vehicles from Skidding** → Balances outward force on curves.
2. **Reduces Tire Wear** → Distributes vehicle load evenly.
3. **Allows Higher Speed on Curves** → Reduces need for braking.



Methods of Providing Super Elevation

1. **Rotation About Inner Edge** → Outer edge is raised while the inner edge remains at the same level.
2. **Rotation About Center Line** → Both inner and outer edges are adjusted.
3. **Rotation About Outer Edge** → Inner edge is lowered while the outer edge remains fixed.

- ◆ **Best Method: Rotation about the center line** (as recommended by IRC) because it minimizes drainage issues.



Necessity of curves, horizontal and vertical curves including transition curves and super elevation, Methods of providing super – elevation

1. Necessity of Curves

Curves are essential in road design to provide smooth and safe vehicle movement when there's a change in direction or elevation.

Key Reasons for Curves:

- To adjust the road alignment based on terrain.
- To provide safe turning for vehicles.
- To enhance driving comfort and reduce abrupt steering.
- To maintain visibility and prevent accidents.

2. Types of Curves

A. Horizontal Curves

- Used when the road changes direction horizontally (left or right).
- Help vehicles navigate turns safely without sudden steering.

Types:

1. **Simple Curve** – A single circular curve connecting two straight sections.
2. **Compound Curve** – Two or more curves of different radii in the same direction.
3. **Reverse Curve (S-Curve)** – Two opposite curves with a common tangent.
4. **Transition Curve** – Gradual curve between a straight road and a circular curve.

B. Vertical Curves

- Used when the road changes elevation (uphill or downhill).
- Provide a smooth gradient change to maintain vehicle stability.

Types:

1. **Summit Curve** – Convex curve at hilltops.
2. **Valley Curve** – Concave curve in depressions or valleys.

C. Transition Curves

- A gradual curve that eases vehicles into a circular curve.
- Ensures smooth change in steering, speed, and super elevation.

Common Type:

- **Spiral or Clothoid Curve** – Most effective for highway designs.

3. Super Elevation

Definition:

Super elevation is the inward tilting or banking of the road at curves to counteract the outward centrifugal force experienced by vehicles.

Formula (IRC Standard):

$$e + f = \frac{V^2}{gR}$$

Where:

- e = Super elevation
- f = Side friction factor
- V = Speed of the vehicle
- R = Radius of the curve
- g = Acceleration due to gravity

Importance:

- Prevents vehicles from skidding off curves.
- Allows safe driving at higher speeds.
- Reduces tire wear and improves road safety.

4. Methods of Providing Super Elevation

1. Rotation About the Inner Edge:

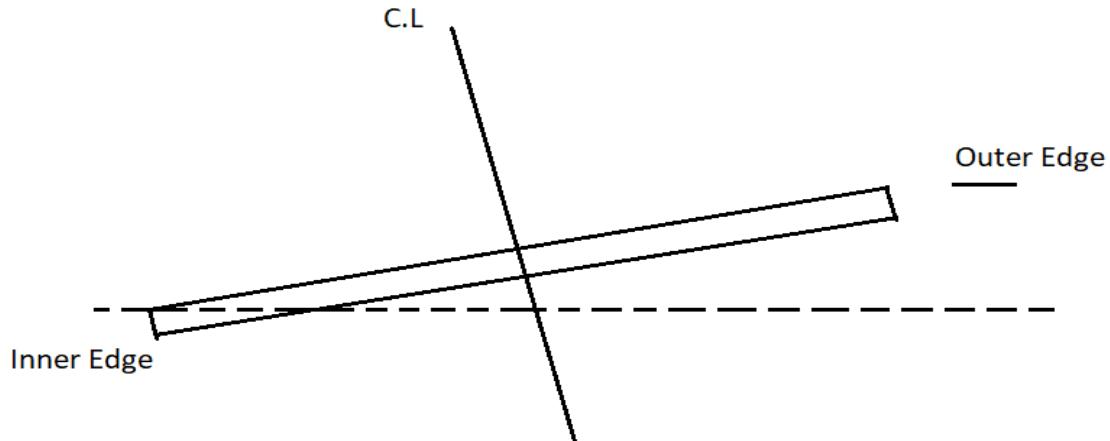
- Outer edge is raised while the inner edge remains fixed.
- Suitable for roads with drainage considerations.

2. Rotation About the Center Line:

- a. Both inner and outer edges are adjusted equally.
- b. **Most common method** recommended by IRC.

3. Rotation About the Outer Edge:

- a. Inner edge is lowered while the outer edge remains fixed.
- b. Rarely used due to drainage issues.



Chapter No- 3

Road Materials



Road Materials

- Difference types of road materials in use: soil, aggregates, and binders
- Function of soil as highway Subgrade
- California Bearing Ratio: methods of finding CBR valued in the laboratory and at site and their significance
- Testing aggregates: Abrasion test, impact test, crushing strength test, water absorption test & soundness test

Road Materials in Highway Engineering

Road materials are the **basic building blocks** used in the construction of roads to ensure **strength, durability, and safety**. The selection of materials depends on factors like **traffic load, climate, soil conditions, and cost**.

1. Types of Road Materials

A. Soil

- **Role:** Used as a base for road foundations and embankments.
- **Types:** Clay, silt, sand, gravel.
- **Importance:** Provides stability; soil tests determine its strength for road layers.

B. Aggregates (Crushed Stones, Gravels, Sand)

- **Role:** Provide strength, stability, and durability to road surfaces.

- **Types:**
 - **Coarse Aggregates:** Crushed stones used in base layers.
 - **Fine Aggregates:** Sand used for filling gaps between coarse aggregates.
- **Importance:** Resist wear and distribute traffic load evenly.

C. Bituminous Materials (Asphalt, Tar, Bitumen)

- **Role:** Acts as a **binding agent** in flexible pavements.
- **Types:**
 - **Hot Mix Asphalt (HMA)** – Used for highways.
 - **Cold Mix Asphalt** – For temporary or low-traffic roads.
- **Importance:** Provides a smooth, waterproof, and flexible road surface.

D. Cement and Concrete

- **Role:** Used in rigid pavements, bridges, and curbs.
- **Types:**
 - **Plain Cement Concrete (PCC)** – For footpaths and base layers.
 - **Reinforced Cement Concrete (RCC)** – For heavy-load roads and bridges.
- **Importance:** High durability, low maintenance, and long lifespan.

E. Bricks and Cobblestones

- **Role:** Used for rural roads, footpaths, and decorative pavements.
- **Importance:** Cost-effective for low-traffic areas.

F. Stabilizing Materials

- **Role:** Improve the properties of weak soils.
- **Types:** Lime, cement, bitumen, fly ash.
- **Importance:** Enhances load-bearing capacity and reduces moisture sensitivity.

G. Geosynthetics (Modern Materials)

- **Role:** Used for soil reinforcement, drainage, and erosion control.
- **Types:** Geotextiles, geomembranes.
- **Importance:** Improves road life and reduces maintenance costs.

Note- Importance of Using Quality Road Materials

- Ensures road **strength and durability**.
- Reduces **maintenance costs**.
- Improves **riding comfort** and **safety**.
- Withstands **traffic load** and **weather conditions**.

Different Types of Road Materials in Use

Road construction involves the use of three main categories of materials: **Soil, Aggregates, and Binders**. Each of these materials plays a crucial role in ensuring the **strength, durability, and stability** of the road.

1. Soil

Soil forms the **foundation or subgrade** of the road. It supports the entire pavement structure.

Types of Soil Used:

- **Clay:** Fine-grained, cohesive soil. Good for embankments but poor drainage.
- **Silt:** Similar to clay but less cohesive. Not suitable for load-bearing layers.
- **Sand:** Non-cohesive, good drainage, used for sub-base layers.
- **Gravel:** Coarse soil with high strength, used in base layers.
- **Moorum:** A reddish-brown soil rich in iron oxide, commonly used in rural roads.

Importance:

- Provides a **stable base** for road layers.
- Determines the **load-bearing capacity**.
- Requires **stabilization** (using lime, cement) if weak.

2. Aggregates

Aggregates provide **strength, durability, and load distribution** in road construction. They form the **base, sub-base, and surface layers**.

Types of Aggregates:

- **Coarse Aggregates:** Crushed stones, gravel (20–40 mm size), used in base and surface layers.
- **Fine Aggregates:** Sand, crushed stone dust (less than 4.75 mm), used for filling gaps and mixing with binders.
- **Natural Aggregates:** River gravel, pebbles.
- **Crushed Stone:** Basalt, granite, limestone—high strength and durability.

Properties of Good Aggregates:

- **Hardness & Toughness:** To resist wear and tear.
- **Shape:** Angular aggregates interlock better than rounded ones.
- **Durability:** Resistance to weathering.
- **Cleanliness:** Free from dust, clay, and organic materials.

Uses:

- **Sub-base & Base Layers:** Provide structural support.
- **Surface Layer:** Offers a **smooth, skid-resistant** finish.

3. Binders

Binders are materials that **hold aggregates together** to form a strong, durable road surface. They are crucial for **flexible pavements**.

Types of Binders:

A. Bituminous Binders (Flexible Pavements):

- **Bitumen:** Most common binder in asphalt roads.
- **Tar:** Previously used, less common today due to environmental concerns.
- **Emulsified Bitumen:** Used in cold conditions and for maintenance work.

Properties:

- **Adhesion:** Binds well with aggregates.
- **Water Resistance:** Prevents water penetration.
- **Flexibility:** Adjusts to temperature changes.

B. Cementitious Binders (Rigid Pavements):

- **Ordinary Portland Cement (OPC):** Used in concrete roads.
- **Lime:** Used for soil stabilization in subgrade layers.

Properties:

- **High Compressive Strength:** For rigid pavements.
- **Durability:** Long-lasting with minimal maintenance.

Comparison of Soil, Aggregates, and Binders

Material	Role in Road Construction	Types	Key Properties
Soil	Base foundation (subgrade)	Clay, silt, sand, gravel, moorum	Load-bearing capacity, drainage
Aggregates	Structural layers (base, surface)	Coarse, fine, natural, crushed	Hardness, toughness, durability

Binders	Binding agent (flexible/rigid roads)	Bitumen, tar, cement, lime	Adhesion, flexibility, strength
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Conclusion:

- **Soil** forms the base, **aggregates** provide strength, and **binders** hold everything together.
- The **right combination** of these materials ensures a **strong, durable, and safe** road.

Functions of Soil as Highway Subgrade

The **subgrade** is the **bottom-most layer** of a road structure, consisting of compacted soil. It serves as the **foundation** for all other pavement layers, making it crucial for the **strength, stability, and durability** of the road.

Key Functions of Soil as Highway Subgrade:

- 1. Load-Bearing Support:**
 - The subgrade **bears the weight** of the pavement structure and the **traffic load** passing over it.
 - It distributes the load **evenly** to prevent settlement and road damage.
- 2. Load Distribution:**
 - Transfers traffic loads from the pavement layers to the natural ground below.
 - Helps in reducing **stress concentration**, preventing pavement cracking.
- 3. Provides Stability:**
 - A well-compacted subgrade ensures the road remains **stable** under heavy traffic and weather changes.
 - Prevents **rutting, potholes, and surface deformation**.
- 4. Acts as a Working Platform:**
 - Provides a **firm base** during road construction for equipment movement and laying of upper layers.
 - Ensures proper alignment and smoothness of the pavement.
- 5. Resists Environmental Effects:**
 - Controls the effects of **moisture, frost action, and temperature changes** that can weaken the pavement.

b. Reduces **erosion** and prevents water from seeping into upper layers.

6. Drainage Support:

a. Facilitates **drainage** to prevent waterlogging, which can reduce soil strength and cause pavement failure.

7. Cost Efficiency:

- a. Using local soil as subgrade reduces the **cost of construction** as compared to importing materials.
- b. Proper soil stabilization can improve weak soils, making them suitable for subgrade use.

Factors Affecting Subgrade Performance:

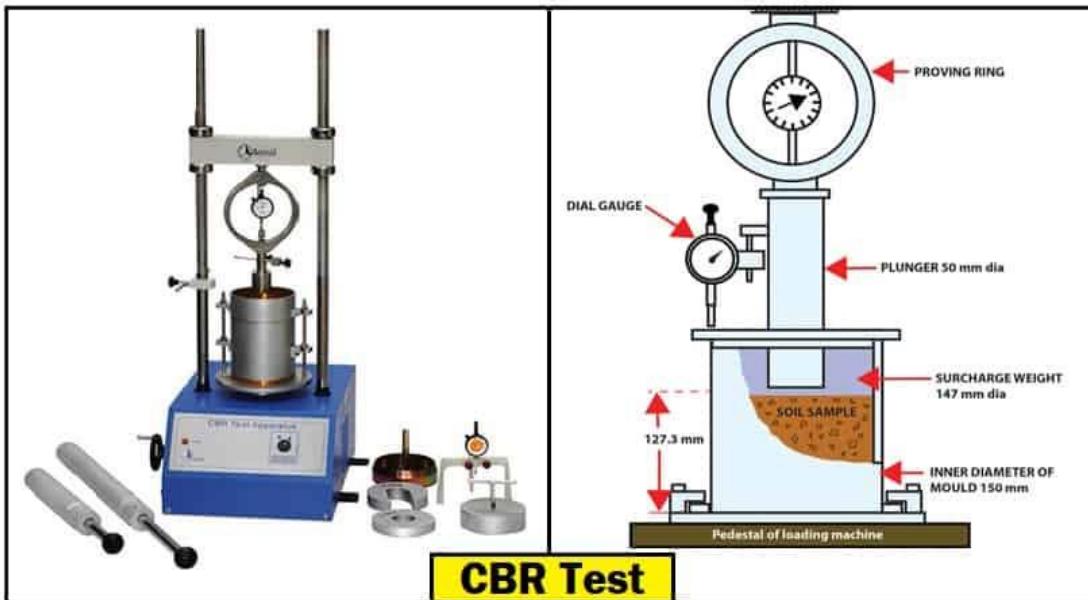
- **Soil Type:** Clayey soils retain water, while sandy soils offer better drainage.
- **Compaction:** Well-compacted soil increases strength and reduces settlement.
- **Moisture Content:** High moisture weakens the subgrade; proper drainage is essential.
- **Soil Stabilization:** Adding lime, cement, or bitumen improves weak subgrade soils.

Conclusion:

The **subgrade** is the **backbone of the pavement structure**. A strong, stable, and well-compacted subgrade ensures **longer pavement life**, reduces maintenance costs, and provides a **safe driving surface**.

California Bearing Ratio (CBR) Test

The **California Bearing Ratio (CBR)** is a **penetration test** used to determine the **strength of subgrade soil, sub-base, and base course materials** for road and pavement design. It measures the **resistance of soil** to penetration under controlled conditions.



Significance of CBR Test:

1. **Determines Soil Strength:** Evaluates the load-bearing capacity of subgrade and pavement layers.
2. **Pavement Thickness Design:** Helps in deciding the **thickness of road layers** required to withstand traffic loads.
3. **Comparison with Standard Material:** Compares the soil's strength to that of a **standard crushed stone (CBR = 100%)**.
4. **Quality Control:** Ensures that construction materials meet the required strength specifications.

Methods of Finding CBR Value

CBR can be determined in two ways:

1. Laboratory CBR Test

Apparatus Needed:

- CBR testing machine with a loading frame

- Standard penetration piston (50 mm diameter)
- Mould with collar
- Weights for compaction
- Dial gauge for measuring penetration

Procedure:

1. **Sample Preparation:**
 - a. Take soil samples and **compact them** in a mould at **optimum moisture content** using a standard compaction method.
 - b. Soak the sample (if required) for 4 days to simulate worst conditions (for soaked CBR).
2. **Loading:**
 - a. Place the sample under the **CBR machine**.
 - b. Apply a **standard load** using a penetration piston at a rate of **1.25 mm/min**.
3. **Penetration Measurement:**
 - a. Record the **load readings** at **penetrations of 0.5 mm, 1.0 mm, 1.5 mm, up to 12.5 mm**.
 - b. Plot the **load vs. penetration curve**.
4. **CBR Calculation:**

$$\text{CBR (\%)} = \left(\frac{\text{Measured Load}}{\text{Standard Load}} \right) \times 100$$
 - The **CBR value** is usually taken at **2.5 mm** and **5 mm** penetrations.
 - The **higher value** between the two is considered the **CBR of the soil**.
 - a. The **CBR value** is usually taken at **2.5 mm** and **5 mm** penetrations.
 - b. The **higher value** between the two is considered the **CBR of the soil**.

2. Field CBR Test (In-situ Test)

Apparatus Needed:

- CBR penetration plunger
- Loading jack with a reaction frame
- Dial gauge
- Proving ring for load measurement

Procedure:

- 1. Site Preparation:**
 - a. Level the ground where the test will be conducted.
 - b. Place the **CBR apparatus** directly on the subgrade.
- 2. Loading:**
 - a. Apply load through the **penetration piston** at a rate of **1.25 mm/min**.
 - b. Measure the load required for different penetration levels (similar to lab test).
- 3. CBR Calculation:**
 - a. Use the same formula as the laboratory test to calculate the **CBR value**.



Differences Between Laboratory and Field CBR Tests:

Aspect	Laboratory CBR Test	Field CBR Test
Location	Conducted in controlled lab conditions	Performed directly on-site
Sample	Compacted soil samples	Natural, in-situ soil
Purpose	For design and comparison of materials	To verify field compaction and soil strength
Moisture Control	Easy to control moisture content	Difficult to control moisture in the field
Accuracy	More accurate under controlled conditions	Reflects actual field conditions



Typical CBR Values:

- **Crushed Stone:** 80–100%
- **Granular Base:** 40–80%
- **Well-compacted Subgrade:** 10–30%
- **Poor Soil (Clay, Silt):** <10%

Applications of CBR Test:

- Design of **flexible pavements** (as per IRC guidelines).

- Evaluation of **existing pavements** for strengthening.
- Assessing **compaction quality** on-site.

Testing aggregates: Abrasion test, impact test, crushing strength test, water absorption test & soundness test

Aggregate Testing in Highway Engineering

Aggregates are key materials in road construction, providing **strength, durability, and stability**. To ensure their quality, several tests are conducted to assess their performance under traffic loads and environmental conditions.

1. Abrasion Test

Purpose:

To determine the **resistance of aggregates to wear and tear** caused by traffic loads.

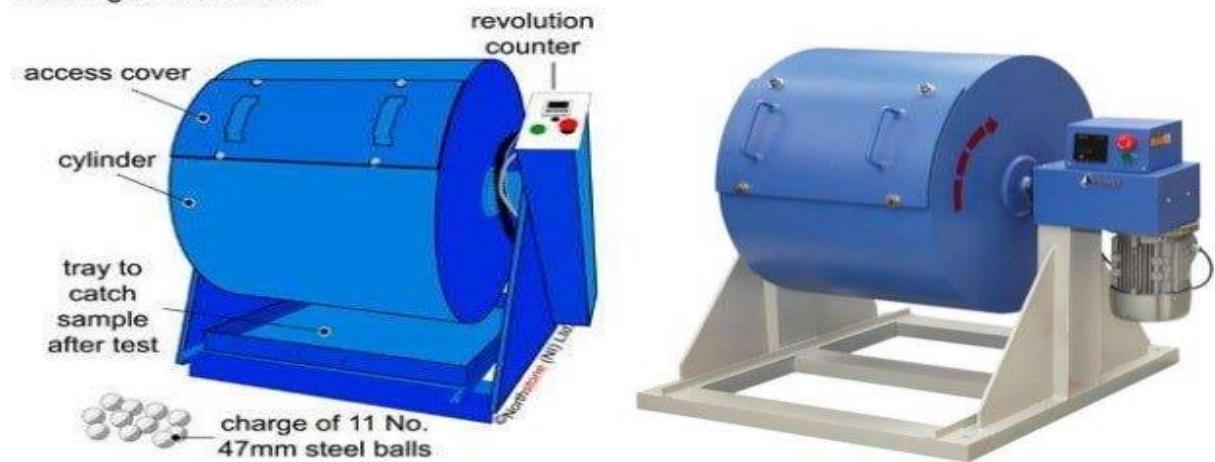
Common Method:

- **Los Angeles (L.A.) Abrasion Test**

Apparatus:

- Los Angeles Abrasion Machine
- Steel balls (abrasive charge)
- Weighing balance

Los Angeles machine



Los Angeles abrasion test setup

Procedure:

1. Take a specified weight of **dry aggregates**.
2. Place them in the **drum with steel balls**.
3. Rotate the drum at **30–33 revolutions per minute** for a set number of revolutions (usually 500 or 1000).
4. After rotation, sieve the aggregates to separate fine particles.
5. Weigh the remaining aggregates.

Calculation:

Calculation:

$$\text{Abrasion Value (\%)} = \left(\frac{\text{Weight of material lost}}{\text{Original weight of sample}} \right) \times 100$$

Significance:

- Indicates **durability** of aggregates.
- **Lower values** mean better resistance to abrasion (ideal for high-traffic roads).

2. Impact Test

Purpose:

To determine the **toughness of aggregates**, i.e., their ability to resist sudden shocks or impacts.

Apparatus:

- Aggregate Impact Testing Machine
- Steel hammer
- Cylindrical Mould



Procedure:

1. Fill the mould with aggregates in three layers, each layer compacted properly.
2. Place the mould under the impact testing machine.
3. Drop a **13.5 kg hammer** from a height of **38 cm** for **15 blows**.
4. Sieve the crushed aggregates through a **2.36 mm sieve**.
5. Weigh the fines produced.

Calculation:

$$\text{Aggregate Impact Value (AIV) (\%)} = \left(\frac{\text{Weight of fines}}{\text{Original weight of sample}} \right) \times 100$$

Significance:

- Indicates the **shock-absorbing capacity** of aggregates.
- Suitable for **pavements subjected to dynamic loads**.
- **Lower AIV** indicates tougher aggregates.

3. Crushing Strength Test

Purpose:

To determine the **compressive strength of aggregates**—their ability to withstand crushing under a gradually applied load.

Apparatus:

- Compression Testing Machine
- Cylindrical mould
- Plunger



Procedure:

1. Fill the mould with aggregates in three layers, compacting each layer.
2. Place the mould under the compression testing machine.
3. Apply a **gradual load** at a rate of **4 tons/min** until the aggregates fail (crush).
4. Weigh the crushed material passing through a **2.36 mm sieve**.

Calculation:

Calculation:

$$\text{Aggregate Crushing Value (ACV) (\%)} = \left(\frac{\text{Weight of crushed fines}}{\text{Original weight of sample}} \right) \times 100$$

Significance:

- Indicates **compressive strength**.
- **Lower ACV** = stronger aggregates.
- Suitable for **high-load-bearing pavements**.

4. Water Absorption Test

Purpose:

To determine the **porosity of aggregates** by measuring how much water they can absorb.

Apparatus:

- Weighing balance
- Water container
- Wire basket



Procedure:

1. Weigh **dry aggregates** (W_1).
2. Immerse aggregates in water for **24 hours**.
3. Remove, surface dry, and weigh again (W_2).
4. Finally, oven-dry the sample and weigh (W_3).

Calculation:

Calculation:

$$\text{Water Absorption (\%)} = \left(\frac{W_2 - W_3}{W_3} \right) \times 100$$

Significance:

- Indicates the **porosity** and **durability** of aggregates.
- **Lower water absorption** means less susceptibility to weathering.

5. Soundness Test

Purpose:

To determine the **resistance of aggregates to weathering**, especially under **freeze-thaw cycles** or exposure to chemicals.

Apparatus:

- Sodium sulfate or magnesium sulfate solution
- Sieves
- Weighing balance

Procedure:

1. Soak aggregates in a **sodium sulfate solution** for **16–18 hours**.
2. Dry the aggregates at **105°C** for several hours.
3. Repeat this cycle for **5 to 10 times**.
4. Weigh the aggregates and note the loss in weight.

Calculation:

$$\text{Soundness Loss (\%)} = \left(\frac{\text{Weight loss after cycles}}{\text{Original weight}} \right) \times 100$$

SOUNDNESS TEST OF AGGREGATE



Significance:

- Measures **resistance to disintegration** under adverse conditions.
- **Lower soundness loss** indicates better durability.

💡 Summary Table:

Test	Purpose	Key Property Tested	Good Value Indicator
Abrasion Test	Resistance to wear and tear	Hardness	Low abrasion value
Impact Test	Resistance to sudden shocks	Toughness	Low impact value
Crushing Strength Test	Resistance to crushing loads	Compressive strength	Low crushing value
Water Absorption Test	Porosity and water retention	Water absorption capacity	Low absorption
Soundness Test	Weather resistance (freeze-thaw)	Durability against disintegration	Low weight loss

Chapter No- 4

Road Pavements

- Road Pavement: Flexible and rigid pavement, their merits and demerits, typical cross-sections, functions of various components
- Flexible pavements:
 - Sub-grade preparation:
Setting out alignment of road, setting out bench marks, control pegs for embankment and cutting, borrow pits, making profile of embankment, construction of embankment, compaction, stabilization, preparation of subgrade, methods of checking camber, gradient and alignment as per recommendations of IRC, equipment used for subgrade preparation
 - Sub base Course:
Necessity of sub base, stabilized sub base, purpose of stabilization (no designs)
 - Types of stabilization
 - Mechanical stabilization
 - Lime stabilization
 - Cement stabilization
 - Fly ash stabilization
 - Base Course:
Preparation of base course, Brick soling, stone soling and metalling, Water Bound Macadam and wet-mix Macadam, Bituminous constructions: Different types
 - Surfacing:
 - Surface dressing
 - (i) Premix carpet and (ii) Semi dense carpet
 - Bituminous concrete
 - Grouting
 - Rigid Pavements:
Concept of concrete roads as per IRC specifications

Road Pavement

A pavement is a hard surface designed to carry vehicular and pedestrian traffic safely. Pavements are broadly classified into **Flexible Pavement** and **Rigid Pavement**, based on their structural behavior and material composition.

1. Flexible Pavement

Flexible pavements are those which have multiple layers, and the load is transferred from the top surface to the subgrade through grain-to-grain contact of the granular material.

Typical Cross-Section of Flexible Pavement

A typical flexible pavement consists of the following layers (from top to bottom):

1. **Surface Course** – Bituminous layer that provides smooth riding quality and resists wear and tear.
2. **Base Course** – Provides load distribution and structural support.
3. **Sub-Base Course** – A secondary layer to improve drainage and prevent subgrade deformation.
4. **Subgrade** – The natural soil layer that supports all pavement layers.

Merits of Flexible Pavement

- Low initial construction cost.
- Can be laid in stages (easy maintenance and strengthening).
- Better skid resistance due to textured surface.
- Quick repairs and easy utility maintenance.

Demerits of Flexible Pavement

- Shorter lifespan compared to rigid pavements.
- Requires frequent maintenance and resurfacing.
- Prone to damage under high temperatures and heavy loads.

2. Rigid Pavement

Rigid pavements are made of **cement concrete** and distribute the load over a wider area due to their high flexural strength. The load is transferred through slab action rather than grain-to-grain contact.

Typical Cross-Section of Rigid Pavement

A typical rigid pavement consists of the following layers:

1. **Surface Course (Concrete Slab)** – Made of reinforced or plain cement concrete (PCC).
2. **Base Course** – Provides additional load-bearing capacity and drainage support.
3. **Sub-Base Course** – Helps in uniform load distribution and drainage.
4. **Subgrade** – Natural soil layer that supports all layers.

Merits of Rigid Pavement

- Longer lifespan (20-40 years).
- Less frequent maintenance compared to flexible pavements.
- Better resistance to weather changes.
- More fuel-efficient for vehicles due to reduced rolling resistance.

Demerits of Rigid Pavement

- Higher initial construction cost.
- Difficult and expensive repairs.
- More time-consuming to construct.
- Requires expansion joints to accommodate thermal expansion and contraction.

Comparison: Flexible vs. Rigid Pavement

Feature	Flexible Pavement	Rigid Pavement
Material Used	Bituminous mix	Cement concrete
Load Transfer	Grain-to-grain	Slab action
Initial Cost	Low	High
Maintenance	Frequent	Minimal
Lifespan	10-15 years	20-40 years

Riding Comfort	Moderate	Better
Weather Resistance	Less durable in high temperatures	More durable
Cost	Higher	Lower

Both types of pavements are used based on traffic conditions, cost considerations, and environmental factors.

Flexible Pavements: Sub-Grade Preparation

Sub-grade preparation is the foundation work required before laying a flexible pavement. A well-prepared sub-grade ensures the durability and performance of the pavement by providing a stable and strong base for load distribution.

1. Setting Out Alignment of Road

Before construction, the road alignment is marked on the ground using survey techniques. This involves:

- **Reconnaissance Survey:** Identifying possible routes.
- **Preliminary Survey:** Gathering topographical details.
- **Final Survey:** Establishing the exact centerline and profile.
- **Marking the Centerline:** Wooden pegs or lime powder is used to mark the alignment.

2. Setting Out Benchmarks

Benchmarks (BMs) are reference points used for leveling and ensuring uniform gradient throughout the road. These benchmarks are transferred from **permanent government benchmarks** and set up at intervals along the alignment.

3. Control Pegs for Embankment and Cutting

- **Control Pegs:** Placed at regular intervals to guide earthwork.
- **For Embankments:** Pegs define the width, height, and slopes.
- **For Cutting Sections:** Pegs help in maintaining the correct depth and slope of excavation.

4. Borrow Pits

- Borrow pits are excavated outside the road alignment to obtain earth for embankment construction.
- As per **IRC guidelines**, borrow pits should be at least **5m away from the road edge** and not deeper than **1.5m**.
- Proper drainage must be ensured to prevent water accumulation.

5. Making Profile of Embankment

- The embankment profile is **set out using levels and slope stakes** to match the design specifications.
- The embankment is built in **layers of 250mm thickness**, with each layer compacted before placing the next.

6. Construction of Embankment

- The embankment is constructed using selected **soil from borrow pits**.
- If the natural ground is soft, stabilization methods such as **sand replacement, lime stabilization, or geotextiles** are used.
- **Steps for Embankment Construction:**
 - Clearing and grubbing the site.
 - Spreading soil in layers.
 - Moistening the soil if necessary.
 - Compacting each layer using rollers.

7. Compaction of Sub-Grade

Compaction is essential for increasing the bearing capacity and reducing settlement.

- **Compaction Equipment Used:**
 - Sheep-foot rollers (for clayey soil).
 - Vibratory rollers (for granular soil).

- Pneumatic rollers (for mixed soil types).
- The compaction is done **up to 98% of the Maximum Dry Density (MDD)** as per **Proctor's Test**.

8. Stabilization of Sub-Grade

If the natural soil is weak, stabilization is required to improve its properties. Methods include:

- **Mechanical Stabilization:** Mixing soil with gravel, sand, or crushed stones.
- **Chemical Stabilization:** Adding lime, cement, or fly ash.
- **Geosynthetics Stabilization:** Using geotextiles or geogrids for reinforcement.

9. Preparation of Sub-Grade

- The **final sub-grade level is trimmed and dressed** to match the design profile.
- **Proper cross-slope (camber) is provided** for drainage.
- **Rolling is done** to achieve uniform compaction.
- **Surface Irregularities** are corrected using a straight edge and level checks.

10. Methods of Checking Camber, Gradient, and Alignment

- **Camber Check:**
 - Measured using a **camber board or template**.
 - Ensures proper slope for surface drainage.
- **Gradient Check:**
 - Checked using **umpy level and leveling staff**.
 - Ensures smooth vertical profile of the road.
- **Alignment Check:**
 - Done using **theodolite or total station**.
 - Ensures the road follows the intended horizontal curve and centerline.

11. Equipment Used for Sub-Grade Preparation

Various machines are used to achieve proper compaction and leveling, including:

- **Bulldozers** – For clearing and leveling the site.
- **Motor Graders** – For achieving correct slope and gradient.
- **Excavators** – For cutting and earthwork.
- **Rollers** – For compacting soil layers.
- **Water Tankers** – For moisture conditioning of soil.

A **properly prepared sub-grade** ensures the longevity of the pavement by preventing **settlements, rutting, and cracking**. Following **IRC guidelines** ensures **quality and durability** in road construction. 

Sub-Base Course in Flexible Pavement

1. Necessity of Sub-Base Course

The **sub-base course** is a secondary layer placed between the subgrade and the base course in flexible pavements. It serves the following purposes:

- Provides Structural Support** – Distributes the load from the pavement layers above.
- Prevents Subgrade Deformation** – Protects the subgrade from excessive stress.
- Improves Drainage** – Helps in water drainage to prevent pavement failure.
- Reduces Frost Action** – Prevents damage due to freeze-thaw cycles.
- Enhances Pavement Longevity** – Increases the overall lifespan of the pavement.

In some cases, **stabilized sub-base layers** are used to improve performance.

2. Stabilized Sub-Base

A **stabilized sub-base** is a modified sub-base layer that has been improved using stabilizing materials to enhance its **strength, durability, and load-bearing capacity**.

Purpose of Stabilization

- **Increase Strength** – Improves load-carrying capacity.
- **Reduce Permeability** – Minimizes water infiltration.
- **Improve Durability** – Resists deformation under traffic loads.
- **Utilization of Waste Materials** – Reduces environmental impact by using industrial by-products.

There are various types of **stabilization techniques**, classified based on the stabilizing material used.

3. Types of Stabilization

(A) Mechanical Stabilization

Method:

- Mixing **different types of soil, aggregates, and sand** in appropriate proportions.
- Improves gradation and load-bearing capacity.

Used When:

- The existing soil lacks **sufficient strength or gradation**.
- No chemical additives are available.

Example:

- A mixture of coarse aggregates and fines is used in **rural roads and low-cost pavements**.

(B) Lime Stabilization

Method:

- Lime (**CaO or slaked lime**) is mixed with clayey soil to **reduce plasticity and increase strength**.
- Lime reacts with soil minerals to form **cementitious compounds**.

Used When:

- The soil has **high clay content** and poor drainage properties.
- In **expansive soils like black cotton soil**, where swelling and shrinkage are major concerns.

Advantages:

- Reduces swelling and shrinkage.
- Improves **load-bearing capacity** and workability.
- Provides long-term strength.

(C) Cement Stabilization

Method:

- **Portland cement** is mixed with soil and compacted.
- A chemical reaction occurs between cement and soil moisture, creating a strong, durable sub-base.

Used When:

- The soil is **sandy or silty** with low binding properties.
- Roads experience **heavy traffic loads**.

Advantages:

- High strength and durability.
- Reduces permeability, preventing water infiltration.
- Provides a rigid base, reducing pavement thickness.

(D) Fly Ash Stabilization

Method:

- **Fly ash** (a by-product of coal combustion) is blended with soil to **improve gradation and stability**.
- Fly ash reacts with lime and water to form a **cementitious compound**.

Used When:

- Fly ash is available as an industrial by-product (e.g., near **thermal power plants**).
- The project aims for **cost-effective and eco-friendly solutions**.

Advantages:

- Reduces **construction costs** by utilizing waste material.
- Increases **soil strength and stability**.
- Improves **resistance to moisture and frost action**.

Comparison of Stabilization Methods

Stabilization Type	Best for Soil Type	Advantages	Common Usage
Mechanical	Poorly graded soil	Simple, cost-effective	Rural roads
Lime	Clayey soil	Reduces plasticity & swelling	Expansive soils
Cement	Sandy & silty soil	High strength, rigid base	Highways & heavy-load roads
Fly Ash	Soft & silty soil	Cost-effective, eco-friendly	Near thermal plants

Conclusion

The **sub-base course** plays a vital role in pavement construction by providing structural support and drainage. **Stabilization techniques** improve the performance of the sub-base, ensuring long-term pavement durability. The selection of a **suitable stabilization method** depends on **soil type, traffic conditions, and cost factors**. 

Base Course in Flexible Pavement

The **Base Course** is the primary load-distributing layer in a flexible pavement, located between the sub-base and the surface course. It plays a crucial role in providing strength, stability, and durability to the pavement structure.

1. Preparation of Base Course

The **base course is prepared** by following these steps:

Site Preparation:

- Clearing and leveling the area.
- Removing debris and unstable material.

Laying of Base Material:

- Materials such as **bricks, stones, aggregates, or bituminous mixtures** are placed in layers.

Compaction:

- Each layer is compacted using **rollers** to achieve required **density and strength**.

Checking Level & Slope:

- The base is checked for **camber, gradient, and thickness** to ensure proper drainage and stability.

2. Types of Base Course Construction

(A) Brick Soling

Method:

- **Bricks are laid flat or on edge** on a well-compacted sub-base.
- Joints are filled with **sand or stone dust**.

Used When:

- In **rural roads** with low traffic.
- Where stone aggregates are unavailable.

Advantages:

- **Cost-effective** and easy to construct.
- **Provides a firm base** for further layers.

Disadvantages:

- **Not suitable for heavy loads.**
- Bricks may **break under high stress.**

(B) Stone Soling and Metalling

Method:

- **Large stones (hand-packed or machine-laid)** are arranged with gaps filled using smaller stones.
- Surface is compacted using rollers.

Used When:

- In **temporary or low-traffic roads.**
- In areas where **stone is easily available.**

Advantages:

- Provides **good drainage.**
- **Long-lasting** in dry conditions.

Disadvantages:

- **Difficult to compact** properly.
- **Not suitable for high-speed roads.**

(C) Water Bound Macadam (WBM)

Method:

- **Crushed aggregates** are laid in layers and compacted.
- **Stone dust or sand** is spread and **water is applied** for binding.
- Rolling is done to achieve a compact base.

Used When:

- In **low-cost rural roads**.
- As a base for **bituminous or concrete roads**.

Advantages:

- **Economical** and easy to construct.
- **Provides good load distribution**.

Disadvantages:

- **Requires frequent maintenance**.
- **Susceptible to water damage**.

(D) Wet-Mix Macadam (WMM)

Method:

- **Pre-mixed aggregates, stone dust, and water** are laid and compacted using rollers.

Used When:

- In **modern roads and highways**.

Advantages:

- **Stronger and more durable** than WBM.
- **Better resistance to water and traffic loads**.
- **Faster construction** due to pre-mixing.

Disadvantages:

- **More expensive** than WBM.

3. Bituminous Base Course Construction

Bituminous base courses provide a **flexible and waterproof layer** that improves pavement strength.

Different Types of Bituminous Base Courses

Type	Description	Used for
Bituminous Macadam (BM)	Open-graded mix with coarse aggregates and bitumen binder.	Low-traffic roads.
Dense Bituminous Macadam (DBM)	Higher bitumen content and dense grading for better strength.	Highways and heavy traffic roads.
Bituminous Concrete (BC)	Fine-graded, durable, and skid-resistant layer.	Expressways and urban roads.
Semi-Dense Bituminous Concrete (SDBC)	Intermediate between DBM and BC, offering good durability.	Medium traffic roads.

Conclusion

The **Base Course** is a crucial layer that enhances pavement strength and durability. The choice of base material depends on **traffic load, environmental conditions, and budget**. In modern roads, **Wet-Mix Macadam and Bituminous Base Courses** are preferred for their superior performance.



Surfacing in Flexible Pavement

The **surfacing** is the **topmost layer** of a flexible pavement, providing a **smooth, durable, and skid-resistant** surface for vehicles. It protects the underlying layers from **water infiltration, weather effects, and traffic loads**.

1. Surface Dressing

Method:

- A thin layer of **bitumen binder** is sprayed over the prepared base.
- **Coarse aggregates** are spread evenly and compacted using a roller.
- A second coat of bitumen and aggregates may be applied (**double surface dressing**).

Used When:

- On **low-traffic roads and rural roads**.
- As a **protective layer** to prevent water damage.

Advantages:

- **Economical and quick** to apply.
- Provides **good skid resistance**.
- Reduces **water penetration** into the pavement.

Disadvantages:

- **Short lifespan** (requires frequent maintenance).
- Not suitable for **high-speed roads**.

2. Premix Carpet (PMC)

Method:

- **Bitumen and aggregates** are mixed in a **hot-mix plant** and laid over the road.
- The mix is spread using a paver and compacted with a roller.
- A **seal coat** is applied for waterproofing.

Used When:

- On **medium-traffic roads** as a **wearing course**.

Advantages:

- **Smooth riding surface**.
- **Good waterproofing properties**.

- **Easy to construct and repair.**

Disadvantages:

- **Limited strength** (not suitable for heavy traffic).
- Needs periodic maintenance.

3. Semi-Dense Carpet (SDC)

Method:

- Similar to **Premix Carpet**, but with a **higher bitumen content** and **denser grading of aggregates**.
- Provides **better durability** than PMC.

Used When:

- On **moderate to high-traffic roads**.

Advantages:

- **More durable** than Premix Carpet.
- **Better waterproofing**.
- **Smoothen riding surface**.

Disadvantages:

- **Higher cost** compared to PMC.
- Requires **proper drainage** to prevent damage.

4. Bituminous Concrete (BC)

Method:

- A dense mix of **bitumen, fine aggregates, and fillers** is laid and compacted.
- Applied using a **paver finisher and compacted with rollers**.

Used When:

- In **highways, expressways, and urban roads** where **high durability** is required.

Advantages:

- **Long-lasting and strong.**
- **Smooth and skid-resistant surface.**
- **Resistant to traffic wear and water penetration.**

Disadvantages:

- **Higher initial cost.**
- **Requires precise temperature control** during laying.

5. Grouting

Method:

- **Stone aggregates** are laid first.
- A **thin bitumen binder** is poured to fill gaps and **bind aggregates together**.
- Rolling is done for compaction.

Used When:

- On **low-traffic roads** and **temporary roads**.

Advantages:

- **Economical and simple** to construct.
- **Good load distribution.**

Disadvantages:

- **Less durable** than modern surfacing methods.
- **Prone to water damage.**

Comparison of Surfacing Types

Surfacing Type	Strength & Durability	Cost	Suitable for
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Surface Dressing	Low	Low	Rural & low-traffic roads
Premix Carpet (PMC)	Moderate	Medium	Medium-traffic roads
Semi-Dense Carpet (SDC)	Higher than PMC	Medium-High	High-speed roads
Bituminous Concrete (BC)	High	High	Highways & expressways
Grouting	Low-Moderate	Low	Temporary & low-traffic roads

Conclusion

The **choice of surfacing** depends on **traffic conditions, budget, and expected durability**. For **highway projects**, **Bituminous Concrete (BC)** is preferred due to its **strength and longevity**, whereas **Surface Dressing and Grouting** are cost-effective solutions for **low-traffic roads**. 

Rigid Pavements: Concept of Concrete Roads as per IRC Specifications

1. Introduction to Rigid Pavements

Rigid pavements are constructed using **cement concrete** and have high structural strength. Unlike **flexible pavements**, they distribute loads over a large area, reducing stress on the subgrade. The key feature of rigid pavements is that they rely on **slab action** rather than **layered structure performance**.

2. Concept of Concrete Roads

Concrete roads are built using **Portland Cement Concrete (PCC)** and are designed based on **Indian Roads Congress (IRC) specifications**. These roads offer **high durability, minimal maintenance, and a long service life**.

- Load Distribution:** The rigid slab distributes vehicle loads over a large area due to its high flexural strength.
- Joints in Construction:** To manage temperature variations and shrinkage, rigid pavements

require **expansion, contraction, and construction joints**.

- ✓ **Reinforcement:** In some cases, **reinforced concrete slabs** are used to improve structural integrity.
- ✓ **Drainage Considerations:** Since concrete is **impermeable**, proper drainage measures are essential.

3. IRC Specifications for Concrete Roads

The **Indian Roads Congress (IRC)** provides guidelines for the design and construction of rigid pavements, primarily in **IRC: 58-2015** and **IRC: 15-2017**.

A. Pavement Components (as per IRC)

A concrete pavement typically consists of the following layers:

- 1 **Subgrade** – The natural soil compacted to required strength.
- 2 **Sub-base Course** – Granular material like **crushed stone** or **GSB (Granular Sub-Base)**.
- 3 **Base Course (if required)** – Lean concrete (PCC) or Dry Lean Concrete (DLC).
- 4 **Concrete Slab (Surface Layer)** – Constructed using **Plain Cement Concrete (PCC)** or **Reinforced Cement Concrete (RCC)**.

B. Types of Joints in Rigid Pavements (as per IRC: 15-2017)

Since concrete expands and contracts with temperature changes, proper joints must be provided:

Joint Type	Purpose	Spacing (as per IRC)
Expansion Joints	Allow expansion of slabs	Every 10-15m
Contraction Joints	Control shrinkage cracks	4.5m – 5.5m spacing
Construction Joints	Separate sections of pavement built at different times	As required
Longitudinal Joints	Prevent cracking in wide slabs	Every 3.5m – 4.5m
<ul style="list-style-type: none">• Dowel bars are provided at expansion and contraction joints to transfer loads efficiently.• Tie bars are used in longitudinal joints to prevent slab separation.		

4. Types of Concrete Pavements (as per IRC: 58-2015)

(A) Jointed Plain Concrete Pavement (JPCP)

- No reinforcement, but has **expansion and contraction joints**.
- Load transfer is done using **dowel bars**.
- Used in **low-traffic urban roads and highways**.

(B) Jointed Reinforced Concrete Pavement (JRCP)

- **Reinforcement (steel bars or mesh)** provided to control cracking.
- Joints are spaced further apart (compared to JPCP).
- Used in **high-traffic roads and industrial areas**.

(C) Continuously Reinforced Concrete Pavement (CRCP)

- No joints, but **continuous reinforcement** prevents cracks from widening.
- **Higher durability** with minimal maintenance.
- Used in **high-speed expressways and heavy-load roads**.

5. Advantages of Concrete Roads

- Longer lifespan** (30-50 years).
- Minimal maintenance** compared to flexible pavements.
- High load-bearing capacity**, suitable for heavy traffic.
- Resistant to weathering** (heat, rain, etc.).
- Fuel-efficient for vehicles** due to smooth surface.

Limitations

- High initial cost.**
- Longer curing time** (concrete needs 28 days to reach full strength).
- More difficult repairs** compared to flexible pavements.
- Requires expansion joints** to prevent cracking.

6. Applications of Rigid Pavements in India

- **National and State Highways** (especially expressways).
- **Urban roads and city intersections.**
- **Airport runways and taxiways.**
- **Industrial and heavy-load zones.**

Conclusion

Rigid pavements, constructed as per **IRC specifications**, are a durable and long-lasting option for roads, though they require **higher initial investment and proper joint design**. Their **superior load-carrying capacity and minimal maintenance** make them ideal for **high-traffic highways, urban roads, and industrial zones.** 

Chapter No- 5

Hill Roads:

- Introduction: Typical cross-sections showing all details of a typical hill road in cut, partly in cutting and partly in filling
- Breast Walls, Retaining walls, different types of bends

Hill Roads

5.1 Introduction to Hill Roads

Hill roads are constructed in **mountainous and hilly terrains** where the road must **adapt to steep gradients, sharp curves, and unstable soil conditions**. Proper engineering techniques are required to ensure **stability, safety, and longevity**.

Typical Cross-Sections of Hill Roads

A hill road can have different cross-sections depending on the terrain conditions:

- Road in Cutting (Full Cut Section)**

- The road is entirely excavated from the hill slope.
- Suitable where the hill material is stable and strong.
- Less maintenance but higher excavation cost.

Road in Cutting & Filling (Partially Cut & Fill Section)

- One side of the road is cut from the hill, and the other side is supported by **filling**.
- Requires **retaining structures** to prevent soil erosion.
- Used where cutting alone is not feasible.

Road in Filling (Full Fill Section)

- Constructed on a **steep slope using embankment material**.
- Needs strong **retaining walls or breast walls** for support.
- More prone to landslides and erosion.

Features of Hill Roads

- **Steep Gradients**: Generally limited to **6-7% (1 in 16 to 1 in 20 slope)** for safety.
- **Proper Drainage**: Side drains and cross-drainage structures prevent waterlogging.
- **Retaining & Breast Walls**: Provide support and prevent landslides.
- **Protective Measures**: Hairpin bends, guard stones, and parapet walls enhance safety.

5.2 Breast Walls, Retaining Walls, and Bends

A. Breast Walls

Purpose:

- **Prevent landslides and erosion** from the hill slope above the road.
- Protect the **cut slope** from collapsing onto the road.

Construction Details:

- Made of **stone masonry or reinforced concrete**.
- Height depends on slope stability and soil type.
- Drain holes are provided to release water pressure.

B. Retaining Walls

Purpose:

- **Support the embankment or fill portion** of the road.
- Prevent the road from sliding downhill.

Types of Retaining Walls:

- 1 **Gravity Retaining Wall** – Made of **stone masonry or concrete**, relying on its weight for stability.
- 2 **Cantilever Retaining Wall** – Uses **reinforced concrete** with a cantilever beam for support.
- 3 **Counterfort Retaining Wall** – Has vertical slabs (**counterforts**) to reduce bending stress.
- 4 **Gabion Wall** – Uses **wire mesh boxes filled with stones**, allowing water drainage and flexibility.

C. Types of Bends in Hill Roads

Sharp curves (bends) are essential to **negotiate steep gradients** in hill roads.

1. Hairpin Bend

- A **sharp U-turn** with a **very small radius**.
- Used where roads climb **steep slopes**.
- Requires **wider turning radius** for large vehicles.

2. Loop Bend

- A **gradual circular curve** that climbs elevation slowly.
- Reduces gradient stress and improves **vehicle maneuverability**.

3. Zig-Zag Bend (Switchback)

- A series of **sharp turns in opposite directions**.
- Used when a **hairpin bend alone is not feasible**.

4. Compound Bend

- A combination of **two or more curves** with different radii.
- Used to **smoothen transitions** between bends.

5. Spiral Bend

- A gradually increasing curve used for **high-speed vehicles**.
- Provides smoother and **safer turning experience**.

Conclusion

Hill roads require **careful planning, proper cross-sections, and supporting structures** to ensure stability and safety. The use of **breast walls, retaining walls, and well-designed bends** helps in **preventing landslides, improving vehicle movement, and ensuring long-term road durability**. 

Chapter No- 6

Road Drainage:

- Necessity of road drainage work, cross drainage works
- Surface and sub-surface drains and storm water drains. Location, spacing and typical details of side drains, side ditches for surface drainage, intercepting drains, pipe drains in hill roads, details of drains in cutting embankment, typical cross sections.

Road Drainage

1. Necessity of Road Drainage Works

Road drainage is essential to ensure the **long-term stability and durability** of roads. Poor drainage can lead to:

- Pavement damage** due to water infiltration.
- Weakening of subgrade and base layers** leading to settlements.
- Erosion of embankments** causing road failure.
- Landslides in hilly areas** due to water accumulation.

Thus, an efficient drainage system is required to **collect, transport, and dispose of water safely** away from the road structure.

2. Cross Drainage Works

Cross drainage (CD) works ensure the smooth flow of natural streams, rivers, or stormwater **across the road alignment**.

Types of Cross Drainage Structures:

1 Culverts (for small water flow)

- Pipe Culvert
- Box Culvert
- Slab Culvert

2 Bridges (for larger streams/rivers)

- Minor Bridges (span < 60m)
- Major Bridges (span > 60m)

3 Causeways (for seasonal water flow)

- Low-Level Causeway
- High-Level Causeway

These structures prevent **waterlogging, road submergence, and soil erosion**.

3. Surface and Sub-Surface Drains

A. Surface Drainage

Surface drains remove rainwater and prevent it from entering the pavement layers.

Types of Surface Drains:

- **Side Drains** – Run along the sides of the road to carry away water.
- **Side Ditches** – Excavated alongside embankments to collect surface runoff.
- **Intercepting Drains** – Prevent water from **flowing onto the road** from higher ground.
- **Storm Water Drains** – Large drains used in **urban areas** to carry excess rainwater.

◆ **Location & Spacing:**

- **Side drains** are placed at **regular intervals (every 30-50m)** in flat terrain.
- **Steeper slopes** require **closer spacing** of drains to prevent erosion.

- Stormwater drains are placed **at junctions or low points** in cities.

◆ **Typical Cross-Section of a Side Drain:**

- **Trapezoidal or rectangular** in shape for easy water flow.
- **Lined with stone, concrete, or bricks** to prevent erosion.

B. Sub-Surface Drainage

Sub-surface drainage removes **groundwater or infiltrated water** to prevent weakening of the road foundation.

Types of Sub-Surface Drains:

- 1 **Pipe Drains** – Perforated pipes buried in trenches to collect underground water.
- 2 **French Drains** – Gravel-filled drains with a perforated pipe to filter and drain water.
- 3 **Longitudinal Drains** – Laid parallel to the road to drain subsurface water.
- 4 **Drainage Blankets** – Layers of sand/gravel below the pavement to absorb water.

◆ **Typical Details of Pipe Drains in Hill Roads:**

- Placed **below or beside the road** to collect seepage water.
- Connected to **outlet drains** to discharge collected water safely.

4. Drains in Cuttings and Embankments

Drains in Cuttings:

- **Side ditches** are provided along the cut section to drain water away.
- **Catchwater drains** prevent water from running onto the road from higher slopes.
- **Lined drains** are used to avoid erosion.

Drains in Embankments:

- **Longitudinal drains** prevent water accumulation at the base.
- **Chutes and downdrains** direct water safely to lower levels.
- **Toe drains** protect the embankment from getting saturated.

5. Typical Cross-Sections of Road Drainage Systems

Flat Terrain Roads:

- **Side drains** with trapezoidal sections along both sides.
- Stormwater drains at low points.

Hill Roads:

- **Catchwater drains** above the road.
- **Toe drains & pipe drains** below the road.

Urban Roads:

- **Covered stormwater drains** with inlets.
- Proper gradient for efficient water flow.

Conclusion

Effective road drainage ensures **road longevity, prevents erosion, and maintains traffic safety**. Properly designed surface and sub-surface drains, along with cross-drainage structures, are essential for road infrastructure, especially in **hilly terrains and high-rainfall areas**. 

Chapter No- 7

Road Maintenance :

- Common types of road failures – their causes and remedies
- Maintenance of bituminous road such as patch work and resurfacing
- Maintenance of concrete roads – filling cracks, repairing joints, maintenance of shoulders (berm), maintenance of traffic control devices
- Basic concept of traffic study, Traffic safety and traffic control signal

Road Maintenance

Common Types of Road Failures – Causes and Remedies

Road failures occur due to **traffic loads, weather conditions, poor drainage, and material defects**.

A. Failures in Flexible Pavements (Bituminous Roads)

Type of Failure	Causes	Remedies
Potholes	Water infiltration, poor drainage, weak mix	Patch repair with bituminous mix
Rutting	Heavy traffic load, weak subgrade	Strengthen base course, improve drainage
Alligator Cracks	Aging of bitumen, repeated loads	Remove damaged layer, apply new overlay
Bleeding	Excess bitumen, poor aggregate gradation	Apply sand layer or remove excess binder
Raveling	Loss of binder, oxidation	Resurface with slurry seal or micro surfacing
Edge Breaks	Poor shoulder maintenance, traffic load	Strengthen shoulders, repair with asphalt mix

B. Failures in Rigid Pavements (Concrete Roads)

Type of Failure	Causes	Remedies
Cracking	Shrinkage, temperature change	Seal cracks with epoxy or bituminous filler
Faulting	Uneven slab settlement, poor sub-base	Provide dowel bars, lift and re-level slabs
Scaling	Surface wear, poor curing	Apply surface sealants, remove damaged layer

Joint Spalling	Traffic loads, improper joint sealing	Re-seal joints, replace damaged sections
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7.2 Maintenance of Bituminous Roads

A. Patch Work (Pothole Repair)

- 1 Cleaning** – Remove loose material from the pothole.
- 2 Applying Tack Coat** – A sticky bitumen layer to bond new material.
- 3 Filling with Bituminous Mix** – Compact the patch using a roller.

B. Resurfacing Methods

- **Slurry Seal** – Thin bituminous layer to restore surface texture.
- **Micro Surfacing** – Polymer-modified bitumen applied to improve skid resistance.
- **Overlay** – A new layer of asphalt (40-50mm thick) to strengthen the pavement.

7.3 Maintenance of Concrete Roads

A. Filling Cracks

- **Small Cracks (< 5mm):** Use epoxy or bituminous sealant.
- **Large Cracks (> 5mm):** Apply polymer-modified concrete or epoxy injection.

B. Repairing Joints

- **Cleaning and resealing** joints with bituminous or silicone-based sealants.
- **Dowel bar retrofitting** for better load transfer across joints.

C. Shoulder (Berm) Maintenance

- Remove debris, regrade gravel shoulders for proper drainage.
- Provide proper edge protection to prevent erosion.

D. Maintenance of Traffic Control Devices

- **Road Signs** – Regular cleaning, repainting, and replacement of faded signs.
- **Pavement Markings** – Repainting lane markings and zebra crossings.
- **Signals & Lights** – Checking electrical connections, replacing faulty bulbs.

7.4 Basic Concept of Traffic Study, Safety, and Traffic Control Signals

A. Traffic Studies

Traffic studies help in designing safe and efficient roads. Common types include:

- 1 **Traffic Volume Study** – Number of vehicles passing per hour/day.
- 2 **Speed Study** – Average vehicle speed on a road section.
- 3 **Origin-Destination Study** – Movement pattern of vehicles.
- 4 **Accident Study** – Identifying accident-prone areas (Black Spots).

B. Traffic Safety Measures

- Road Signs** – Regulatory, warning, and informative signs.
- Speed Limits** – Control vehicle speed in different zones.
- Pedestrian Crossings** – Markings for safe crossing at intersections.
- Road Barriers & Guardrails** – Prevent vehicles from running off the road.

C. Traffic Control Signals

Traffic signals help in managing vehicle movement at intersections.

- 1 **Fixed-Time Signals** – Set timing cycle (e.g., Red = 60 sec, Green = 40 sec).
- 2 **Actuated Signals** – Sensors detect vehicle presence and adjust timing.
- 3 **Pedestrian Signals** – Special signals to allow pedestrian movement.

- 4 **Flashing Signals** – Used at night or in low-traffic areas.

Conclusion

Proper **road maintenance and traffic management** ensure longer pavement life, smooth traffic flow, and safety. Regular **repair work, resurfacing, joint sealing, and drainage improvements** are essential for keeping roads in **good condition**. 

Construction equipments:

- Preliminary ideas of the following plant and equipment:
- Hot mixing plant
- Tipper, tractors (wheel and crawler) scraper, bulldozer, dumpers, shovels, graders, roller dragline
- Asphalt mixer and tar boilers
- Road pavers
- Modern construction equipment's for roads.

Construction Equipment for Roads

Hot Mixing Plant

A **Hot Mixing Plant** is used for **producing hot mix asphalt (HMA)** by combining aggregates, bitumen, and other additives at high temperatures. It ensures a **uniform and quality mix** that is suitable for road construction.

Types of Hot Mixing Plants:

- 1 Batch Type Plant** – Mixes a batch of material at a time. Suitable for high-quality mixes.
- 2 Continuous Type Plant** – Produces a continuous stream of hot mix, ideal for large-scale projects.

Key Components:

- Cold Aggregate Feed** – For feeding raw materials.
- Drying Drum** – For heating and drying the aggregates.
- Hot Mix Bin** – To store the produced mix.
- Bitumen Heater** – To heat the bitumen.
- Control Panel** – For monitoring and controlling temperature and mix proportions.

Advantages:

- Consistent mix quality.
- Allows for customization of mix proportions.
- Suitable for large-scale paving projects.

Construction Equipment for Roadwork

A. Tipper

A **tipper truck** (also known as a dump truck) is used to **transport bulk materials** like aggregates, soil, or asphalt.

- Features:** Hydraulic lifting mechanism for unloading materials.
- Usage:** For transporting aggregates, bitumen, and construction waste.

B. Tractors (Wheel and Crawler)

- Wheel Tractor:** Used on solid ground and smoother terrains.
- Crawler Tractor:** Used on rough, uneven terrain where traction is required.
- Usage:** Clearing, leveling, and hauling materials.

C. Scraper

A **scraper** is used for **cutting, hauling, and spreading soil**.

- **Usage:** Excavation, leveling, and earth moving.
- **Types:** Motorized scrapers and towed scrapers.

D. Bulldozer

A **bulldozer** is equipped with a **large blade** for pushing earth, debris, and other materials.

- **Usage:** Clearing, grading, and shaping the ground.
- **Variants:** Crawler dozer (more suitable for rough terrain).

E. Dumpers

Dumpers are heavy-duty trucks used to **haul loose material** across construction sites.

- **Types:** Articulated dumpers, rigid dumpers.
- **Usage:** Carrying and dumping loose materials, like aggregates or muck.

F. Shovels

Shovels (or **excavators**) are used for **digging and lifting materials**.

- **Usage:** Excavation work, digging foundations, and material handling.
- **Variants:** Wheeled and tracked shovels for different terrains.

G. Graders

A **grader** is used for **smoothing and leveling** the road surface.

- **Usage:** Final grading of road surfaces, shoulder grading, and snow removal.
- **Key Features:** Long adjustable blade for precise surface leveling.

H. Roller

A **roller** (also known as a **compactor**) is used for **compacting** the road base, subgrade, and bituminous surfaces.

- **Types:**
 - **Smooth Wheel Roller** – Used for asphalt compaction.
 - **Vibratory Roller** – Provides vibration for deeper compaction.
 - **Pneumatic Roller** – Uses inflated tires for compaction.

I. Dragline

A **dragline** is a type of **excavator** used to **excavate soil and rock**.

- **Usage:** Large-scale excavation projects, often in quarries.
- **Features:** Large bucket attached to a crane-like structure.

Asphalt Mixer and Tar Boilers

A. Asphalt Mixer

An **asphalt mixer** is used to **mix asphalt**, bitumen, and aggregates.

- **Usage:** Blending raw materials to produce hot mix asphalt (HMA).
- **Types:**
 - **Batch Mix Asphalt Plant** – Mixes material in batches.
 - **Continuous Mix Asphalt Plant** – Provides a continuous flow of mix.

B. Tar Boilers

Tar boilers are used to **heat bitumen or tar** to required temperatures before application.

- **Usage:** For road surface dressing, bituminous prime coats, or tack coats.
- **Key Feature:** Controlled temperature settings to prevent overheating.

Road Pavers

A **road paver** (also called an **asphalt paver**) is used to **lay hot mix asphalt** on road surfaces.

- **Types:**
 - **Tracked Pavers** – Suitable for large and rough terrains.
 - **Wheeled Pavers** – Suitable for smaller areas with smooth surfaces.

Features:

- **Auger Mechanism** – For uniform distribution of the asphalt.
- **Vibratory Screed** – To compact the laid asphalt surface.
- **Adjustable Controls** – For controlling the paving speed and layer thickness.

Usage:

- Ideal for highways, roads, and parking areas.
- Ensures smooth and even asphalt application.

Modern Construction Equipment for Roads

A. Milling Machines

A **milling machine** is used for **removing old, damaged layers** of asphalt from the road.

- **Usage:** Resurfacing projects or road rehabilitation.

B. Stabilizers

A **soil stabilizer** is used for **mixing soil and additives** to improve road subgrade quality.

- **Usage:** Stabilizing weak soils to improve load-bearing capacity.

C. Self-Loading Concrete Mixers

A **self-loading concrete mixer** is used for **mixing and transporting concrete** on site.

- **Usage:** For mixing concrete for small road structures or repairs.

D. High-Speed Road Rollers

Modern **high-speed rollers** use **advanced vibration technology** for better compaction at higher speeds.

- **Usage:** Large-scale projects with faster compaction needs.

Conclusion

Road construction relies on a wide range of **specialized equipment** to ensure quality, efficiency, and safety. From **mixing and paving** to **excavation and compaction**, modern machines play a vital role in ensuring smooth and durable roads. 

