

Highway Engineering

An aerial photograph of a modern highway interchange featuring a large roundabout. The roundabout has a central green island surrounded by a red-paved curb. Several cars are visible on the roads, and the surrounding area includes green grass and some trees. The text is overlaid on the image in red.

BY

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Abids

Transportation engineering

Transportation engineering is the application of technology and scientific principles to the planning, functional design, operation and management of facilities for any mode of transportation in order to provide for the safe, efficient, rapid, comfortable, convenient, economical, and environmentally compatible movement of people and goods from one place to other

MODES OF TRANSPORTATION

Basic mode of transportation are

- Land
 - ✓ Roadway
 - ✓ railway
- Water
- Air



MODES OF TRANSPORTATION

- **Highways** :Car, Bus, Truck, non-motorized ..etc

- **Railways**

Passenger and Goods

- **Airways**

Aircraft and Helicopters

- **Waterways**

Ships, boats...

- **Continuous Flow systems**

Pipelines, belts, elevator, ropeway...etc.

- •Merits and Demerits: Based on accessibility, mobility, cost, tonnage

Highways

- It gives the maximum Service to one and all
- It gives maximum flexibility for travel with reference to route, direction, time and speed of travel
- It provide door to door service
- Other modes are depend on it
- It requires small investment for the government
- Motor vehicles are cheaper than other carriers like rail locomotive and wagons
- It saves the time for short distance
- High degree of accident due to flexibility of movement

Airways

- Fastest among all other modes
- More comfortable
- Time saving
- Uneconomical

Waterways

- slowest among all other modes
- It needs minimum energy to haul unit load through unit distance.
- This can be possible between ports on the sea routes or along the river
- economical

Railways

- The transportation along the railways track could be advantageous by railways between the stations both for the passengers and goods, particularly for long distance.
- It depends upon the road transport i.e. road could serve as a feeder system.
- Energy require to haul a unit load through unit distance by the railway is only $\frac{1}{4}$ to $\frac{1}{5}$ of that required by road.
- Safety

Highway Development in India

- **Jayakar Committee (1927)**
- **Central Road Fund (1929)**
- **Indian Roads Congress (IRC), 1934**
- **Central Road Research Institute (CRRI), 1950**
- **Motor vehicle act (1936)**
- **National Highway Authority of India (NHAI), 1995**
- **First twenty year road plan (1943-61)**
- **Second twenty year road plan (1961-81)**
- **Highway Research board (1973)**
- **National Transport Policy committee (1978)**
- **Third twenty year road plan (1981-2001)**

Ministry of Road Transport & Highways

- Planning, development and maintenance of National Highways in the country.
- Extends technical and financial support to State Governments for the development of state roads and the roads of inter-state connectivity and economic importance.
- Evolves standard specifications for roads and bridges in the country.
- It stores the data related to technical knowledge on roads and bridges.

Scope of highway engineering

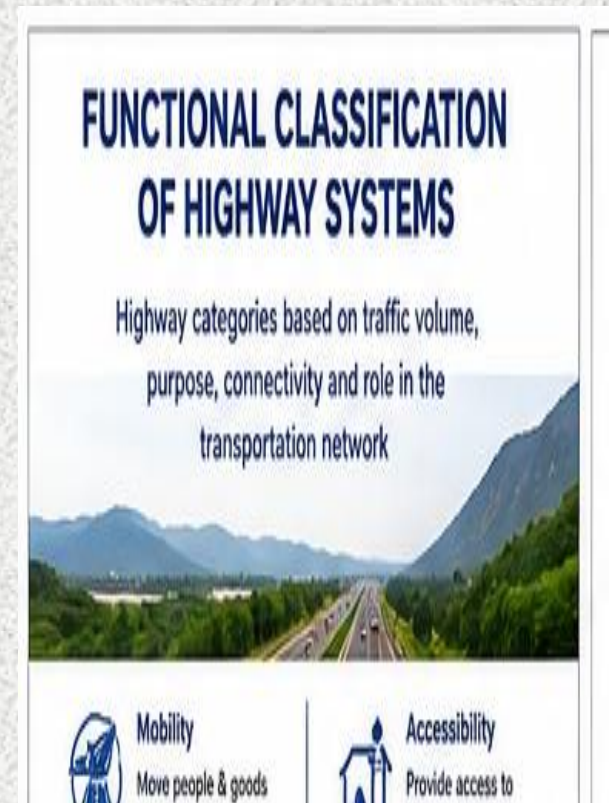
- Development, planning and location
- Highway design, geometric and structure
- Traffic performance and its control
- Materials, construction and maintenance
- Economic, finance and administration

Functional Classification of Highway Systems

- **Functional classification of highways** is the process of grouping roads according to their **function, traffic volume, travel distance, connectivity, access control, and the type of trips they serve.**
- It helps highway authorities plan, design, construct, maintain, and manage roads according to their importance in the transportation network.

1. Functional Classification of Highway Systems

- Grouping highways according to their function in the transportation network.
- Classification considers traffic volume, trip length, speed, connectivity, access control and importance of destinations.
- Main objective: develop a safe, efficient and hierarchical road network.



2. Introduction to Functional Classification

- Functional classification identifies the role performed by each road.
- It helps determine appropriate design standards, capacity and access management.
- A road network should balance mobility and accessibility.

1. INTRODUCTION

- Functional classification is the process of grouping roads according to the function they perform in the overall transportation network.
- It is based on traffic volume, trip length, speed, connectivity, access control, land use and importance of destinations.
- The objective is to develop a hierarchical road network where each road performs its function efficiently.
- A good road system balances two



3. Mobility vs Accessibility

- Mobility: movement of people and goods quickly over longer distances.
- Accessibility: ability to reach properties, villages, markets and services.
- Higher-order roads emphasize mobility; lower-order roads emphasize accessibility.

2. MOBILITY vs ACCESSIBILITY

MOBILITY	ACCESSIBILITY
Move people & goods quickly	• Reach properties, villages & services
Long distance trips	• Short distance trips
Higher speed & capacity	• Lower speed & capacity
Fewer intersections	• More intersections
Controlled access	• Greater roadside access



4. Hierarchy of Highway Systems

- Expressways / Freeways
- National Highways
- State Highways
- Major District Roads
- Other District Roads
- Village Roads



5. Expressways / Freeways

- Highest level of highway facility for mobility.
- Designed for high-speed, long-distance travel.
- Controlled access and grade-separated intersections.
- Divided carriageways and high capacity.
- Example: Delhi–Mumbai Expressway.

 quickly over long distances	 properties, villages, markets & services
1	

4. EXPRESSWAYS / FREEWAYS • Highest level of highway facility. • Designed for high-speed, long-distance travel. • Access is completely controlled. • Entry/exit only at interchanges. • No direct access to individual properties. • Divided carriageway with multiple lanes. • Grade-separated intersections. • Pedestrian, slow vehicles & roadside activities are restricted	
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6. National Highways (NH)

- Primary road network of the country.
- Connect major cities, state capitals, ports, industrial and economic centres.
- Carry high inter-state passenger and freight traffic.
- May be 2-lane, 4-lane, 6-lane or wider.
- Example: NH-44.

competing functions: mobility and accessibility.

High Mobility ↔ High Accessibility
Low Accessibility ↔ Low Mobility

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5. NATIONAL HIGHWAYS (NH)

- Primary road network of the country.
- Connect state capitals, major cities, ports, industrial & economic centres.
- Carry very high volumes of inter-state passenger & freight traffic.
- Higher design standards.
- May be 2-lane, 4-lane, 6-lane or wider.
- Important sections may be controlled



Example: NH-44

7. State Highways (SH)

- Major road network within a state.
- Connect state capital, district headquarters and important towns.
- Provide links between National Highways and district roads.
- Carry significant inter-city traffic.
- Example: SH-15 in Maharashtra.

		
STATE HIGHWAYS (SH) Secondary road system of a state. Connect state capital with district headquarters & important towns. Provide links between NHs and important district roads. Carry high inter-city traffic. Design standards lower than NHs but	 Example: SH-15 in	7. MAJ • Connect c • important • production • Link high • smaller ro • Carry mor • Important • agricultur • goods & p

8. Major District Roads (MDR)

- Connect district headquarters with important towns and production centres.
- Link higher-order highways with smaller roads.
- Carry moderate traffic volumes.
- Important for agricultural products, industry and local passenger movement.

Village Roads (Highest Accessibility)  INCREASE

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MAJOR DISTRICT ROADS (MDR)

Connect district headquarters with towns, markets & production centres.

Link higher-order highways with smaller roads.

Carry moderate traffic volumes.

Important for movement of agricultural products, industrial goods and passengers within district.



Example: MDR to

9. Other District Roads (ODR)

- Connect smaller towns, villages and rural production areas.
- Provide intermediate connectivity between villages and MDRs.
- Carry low to moderate traffic.
- Short-distance trips are common.

Example: Delhi-Mumbai Expressway

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8. OTHER DISTRICT ROADS (ODR)

- Connect smaller towns, villages & rural production areas.
- Provide intermediate connectivity between MDRs and villages.
- Carry low to moderate traffic.
- Short distance trips are common.
- Lower geometric & pavement standards than MDRs.



Example: ODR connecting villages to MDR

10. Village Roads (VR)

- Lowest level in the rural road hierarchy.
- Connect villages with one another and with higher-order roads.
- Provide access to schools, markets, hospitals and services.
- Carry low traffic but have high social importance.

Access: (Srinagar to Kanyakumari) 6

9. VILLAGE ROADS (VR)

- Lowest level in rural road hierarchy.
- Provide access between villages and connect villages to higher-order roads.
- Carry low traffic volumes.
- Low design speed & capacity.
- High accessibility: every property can be reached.



Example: Village road in rural area

Expressway
National Highway
State Highway
Major District Road
Other District Road
Village Road

11. Comparison of Highway Classes

- Expressway: very high mobility, very high capacity, highly controlled access.
- NH: national/inter-state connectivity and high traffic.
- SH: state/regional connectivity.
- MDR/ODR: district and local connectivity.
- VR: local rural accessibility.

12. Role of Traffic Volume

- Traffic volume is an important factor, but not the only basis for classification.
- Other factors include strategic importance, connectivity, tourism and industrial activity.
- Key measures: ADT/AADT, peak-hour traffic, PCU, heavy-vehicle percentage and future growth.

Agricultural Market

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ROLE OF TRAFFIC VOLUME

Traffic volume is an important factor but not the only criterion. Roads with low traffic may be very important due to:

- Strategic, economic or social importance
- Proximity to remote or border areas
- Proximity to industrial or agricultural importance

Important traffic parameters:

- Annual Daily Traffic (ADT)
- Annual Average Daily Traffic (AADT)
- Peak Hour Traffic (PHT)
- Passenger Car Unit (PCU)
- Heavy Vehicles, Directional distribution



13. Trip Purpose

- Passenger trips: work, education, shopping, recreation and tourism.
- Freight trips: agricultural products, construction materials, industrial goods and raw materials.
- Higher-order roads generally serve longer-distance trips.
- Lower-order roads generally serve local trips.

14. Through Traffic vs Local Traffic

- Through traffic travels between major locations without needing roadside access.
- Local traffic travels to destinations located along or near the road.
- Higher-order highways are suited to through traffic.
- Lower-order roads are suited to local access traffic.

15. Traffic Movement Through the Hierarchy

- Traffic typically moves from local roads to higher-order roads for longer-distance travel.
- Near the destination, traffic moves back to lower-order roads.
- Typical sequence: VR → ODR → MDR → SH → NH → Expressway / Urban Arterial.



16. Urban Road Hierarchy

- Urban hierarchy: Expressway → Arterial → Sub-Arterial → Collector → Local Street.
- Arterials emphasize mobility.
- Collectors distribute traffic between local streets and arterials.
- Local streets primarily provide property access.

Functional variation & future growth

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15. URBAN ROAD HIERARCHY				
				
Expressway	Arterial Road	Sub-Arterial	Collector Road	Local Street
High speed	High volume mobility	Moderate volume distribution	Collect traffic from local streets	Low volume Property access

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17. Importance in Highway Planning

- Helps select design speed, lane width, capacity and geometric standards.
- Supports pavement design and maintenance prioritization.
- Improves intersection planning and access management.
- Supports land-use planning and future widening.
- Improves safety and reduces congestion.



18. Real-Life Examples in India

- Delhi–Mumbai Expressway — Expressway.
- NH-44 — National Highway.
- State Highway — regional/state connectivity.
- MDR — district-level connectivity.
- ODR and Village Roads — rural/local access.

17. REAL LIFE EXAMPLES (INDIA)

 Delhi-Mumbai Expressway (Expressway)	 NH-44 in Punjab (National Highway)	 SH-79 in Rajasthan (State Highway)
 MDR in Karnataka (Major District Road)	 ODR in Uttar Pradesh (Other District Road)	 Village Road in Bihar (Village Road)

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- Functional
- It considers
- Importance
- Mobility at
- Higher-order
- A properly
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- Other D

19. Key Takeaways

- Functional classification is based on the role a road performs in the network.
- Traffic volume, trip length, speed, connectivity and access control are important factors.
- Mobility and accessibility are the two basic functions.
- Higher-order highways provide mobility; lower-order roads provide accessibility.

20. Summary

- Higher-order roads: higher traffic, longer trips, higher speed, higher capacity and greater access control.
- Lower-order roads: lower traffic, shorter trips, lower speed and greater accessibility.
- A properly planned hierarchy creates a safe, efficient and well-connected transportation system.
- Basic hierarchy: Expressway → NH → SH → MDR → ODR → VR.

19. SUMMARY

Order Highways		Lower-Order Roads
• Higher traffic volume		• Lower traffic volume
• Longer trips		• Shorter trips
• Higher speed		• Lower speed
• Higher capacity		• Lower capacity
• Greater access control		• Open access
• Greater emphasis on mobility		• Emphasis on accessibility

Each road class performs the function for which it is best suited, creating an efficient and balanced highway system.

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Design Controls in Highway Engineering

Design controls are the physical, operational, traffic and environmental factors that influence the **geometric design of a highway**. They determine important design elements such as **design speed, sight distance, gradients, curves, carriageway width, lane requirements, intersection design and road capacity**.

What Are Design Controls?

Factors that establish the limits within which a highway can be safely and economically designed.

- Design controls are the physical, human, vehicle, traffic and operational conditions that influence highway geometry.
- They determine or influence design speed, sight distance, lane width, shoulder width, horizontal curves, vertical curves and gradients.
- Controls may be fixed (terrain, existing development) or variable (traffic demand, vehicle mix and desired LOS).
- Some controls conflict: a higher design speed improves mobility but usually increases curve radii, sight-distance requirements and right-of-way needs.
- Good design selects a practical combination of controls rather than optimizing one factor alone.
- During planning, the designer should identify existing conditions, forecast future demand and select the appropriate functional standard.

Major controls

1. Topography
2. Driver behaviour
3. Vehicle characteristics
4. Traffic capacity
5. Level of Service

Design outcome

Safe + efficient + comfortable + economical highway

Design Controls in Highway Engineering

Influence of topography, driver behaviour, vehicle characteristics, traffic capacity and Level of Service

1. Topography

Terrain controls alignment, gradients, curves, earthwork, drainage and construction cost.

2. Driver Behaviour

Perception, reaction, speed choice and manoeuvring influence sight distance and safety.

3. Vehicle Characteristics

Vehicle dimensions, turning radius, acceleration and braking affect geometric design.

4. Traffic Capacity

Demand, lanes, traffic composition and roadway conditions determine required capacity.

5. Level of Service

LOS describes the quality of traffic operations from free flow (A) to breakdown (F).

1. Topography as a Design Control

Terrain strongly influences the geometric and economic design of a highway

- Topography is the natural shape and slope of the land through which the highway passes.
- Typical terrain categories used in Indian highway design include plain, rolling, mountainous and steep terrain.
- Terrain influences horizontal alignment, vertical alignment, gradients, sight distance, curve radius and drainage.



Hilly highway: alignment follows terrain

- Plain terrain generally permits longer tangents, flatter grades and higher design speeds.
- Mountainous/steep terrain may require contour alignment, hairpin bends, retaining structures, tunnels or viaducts.
- Alignment should follow the terrain as far as practical while satisfying safety, economy and functional requirements.

Topography: Direct Effects on Highway Geometry

Horizontal alignment

Curve radius, transition curves, sight distance and setback are affected by terrain.

Vertical alignment

Gradients and vertical curves must suit terrain and vehicle performance.

Earthwork

Cutting and filling increase with difficult terrain and may control route selection.

Drainage & slope stability

Hills require cross-drainage, side drains and protection against erosion/landslides.

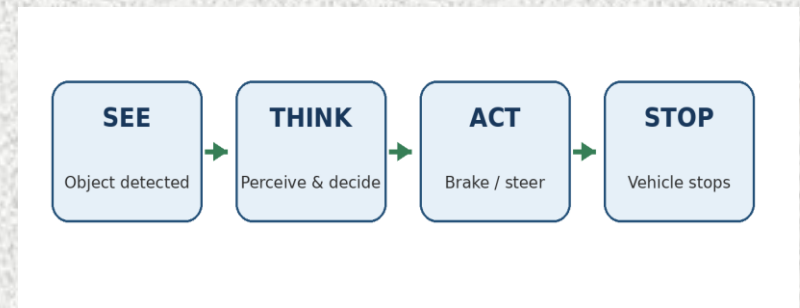


Example: winding alignment in hilly terrain

2. Driver Behaviour as a Design Control

Highway geometry must match human perception, reaction and decision-making.

- Drivers continuously perceive road geometry, signs, vehicles and hazards and make speed and manoeuvring decisions.
- Perception-reaction time is important in determining stopping sight distance.
- Drivers tend to select speeds based on road appearance, alignment, traffic and environmental conditions.
- Unexpected changes in curvature, narrow lanes or poor visibility can create unsafe operating conditions.
- Design consistency helps drivers anticipate the next road element and reduces sudden speed changes.
- Important design responses include adequate sight distance, clear signs, markings, smooth transitions and consistent alignment.



Driver perception → decision → action

Key design implication

Provide enough time and distance for the driver to detect a hazard, understand it, decide and complete the required manoeuvre.

Driver Behaviour: Perception–Reaction and Stopping

Stopping distance is strongly influenced by speed and the time required for the driver to react.

- Stopping Sight Distance (SSD) consists of the distance travelled during perception-reaction plus braking distance.
- During perception-reaction time, the vehicle continues to move at approximately its initial speed.
- After braking begins, stopping distance depends on speed, tyre-road friction, braking performance and road gradient.
- A simplified level-road relationship is $SSD = vt + v^2/(2gf)$, subject to the assumptions used in the design method.
- As speed increases, braking distance grows rapidly because it is approximately proportional to the square of speed.
- Therefore, higher design speeds require longer available sight distance and more generous geometry.

Formula

$$SSD = vt + v^2/(2gf)$$

v = speed, t = perception-reaction time, g = gravity, f = longitudinal friction factor

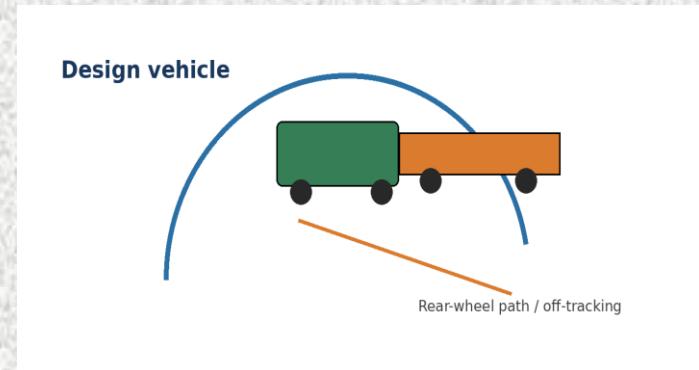
Example concept

If speed increases, both reaction distance and braking distance increase. A curve or obstruction that is safe at one speed may not be safe at a much higher speed.

3. Vehicle Characteristics: Design Vehicle

The design vehicle is a representative vehicle used to establish geometric requirements.

- Vehicle characteristics include length, width, height, wheelbase, axle arrangement and turning capability.
- Operational characteristics include acceleration, deceleration, braking and ability to maintain speed on grades.
- Passenger cars are important for many speed and sight-distance considerations.
- Heavy commercial vehicles are particularly important for grade design, intersection turning and capacity.
- Large vehicles may require greater horizontal clearance, wider turning paths and larger intersection corner radii.
- Design should consider the expected mix of vehicles rather than assuming that every vehicle behaves like a passenger car.



Illustrative design vehicle and off-tracking

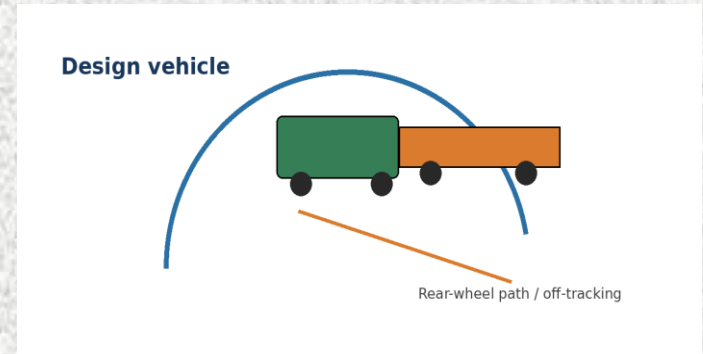
Why it matters

A road can have adequate nominal lane width but still operate poorly if long vehicles cannot turn, merge or negotiate curves comfortably.

Vehicle Characteristics: Turning and Off-Tracking

Long vehicles do not follow exactly the same path as their front axle during a turn.

- Off-tracking is the difference between the path of the front wheels and the path followed by the rear wheels during a turn.
- It becomes more significant for longer wheelbases and certain multi-unit vehicle configurations.
- Insufficient turning width can cause heavy vehicles to mount kerbs, encroach into opposing lanes or obstruct adjacent traffic.
- Intersection design therefore requires consideration of the largest vehicle expected to use the facility regularly.
- Turning templates or swept-path analysis can be used to check whether a proposed intersection geometry accommodates the design vehicle.
- Channelization, corner radii and lane widths should be selected to balance large-vehicle movement with pedestrian and safety needs.



Rear-wheel path differs from front-wheel path

Applications

Intersections • roundabouts • terminals • industrial access • bus routes • freight corridors

Vehicle Characteristics: Grades, Braking and Acceleration

Vehicle performance changes with road gradient and vehicle loading.

- On upgrades, engine power and vehicle weight influence the speed that can be maintained.
- Heavy vehicles may travel substantially slower than passenger cars on long grades, creating platoons.
- On downgrades, gravity increases the demand on the braking system.
- Long severe downgrades may require special attention to braking, speed control, escape facilities where appropriate and warning systems.
- Acceleration characteristics influence merging, weaving, intersection discharge and recovery of speed after stops.
- These differences are important when evaluating capacity because heterogeneous traffic does not behave like a stream of identical cars.

Upgrade

Truck speed ↓ → speed differential ↑ → platooning/overtaking difficulty ↑

Downgrade

Braking demand ↑ → speed control and safety become more important

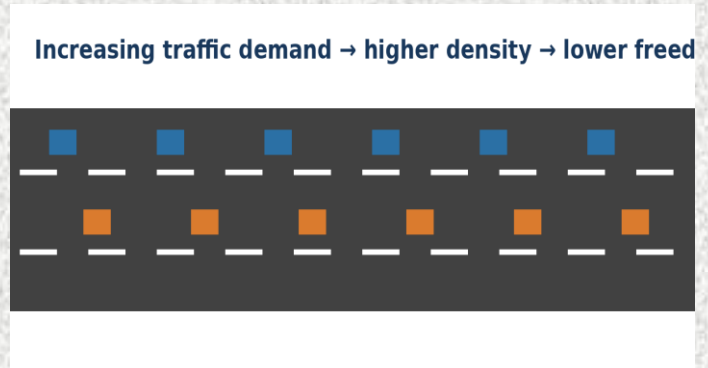
Operational implication

Consider grade length, heavy-vehicle percentage and need for climbing or speed-management treatments.

4. Traffic Capacity: Meaning

Capacity is a fundamental control for deciding the required highway cross-section.

- Capacity is the maximum sustainable rate at which vehicles can pass a point or section under specified roadway, traffic and control conditions.
- Capacity is normally expressed as vehicles per hour; in heterogeneous traffic, PCU/hour may be used for analysis.
- Capacity is not a fixed property of a road alone; it changes with lane width, grade, traffic composition, access, intersections and other conditions.
- Traffic demand is the amount of traffic wishing to use the facility; capacity is the service the facility can provide.
- When demand approaches capacity, small disturbances can produce large reductions in speed and increases in delay.
- Future design should consider projected demand rather than only present-day traffic.



Increasing traffic density

Core comparison

Demand < Capacity → stable operation
Demand ≈ Capacity → constrained operation
Demand > Capacity → queues and breakdown

Traffic Capacity: Major Influencing Factors

Capacity depends on roadway, traffic, control and environmental conditions.

- Roadway factors: number of lanes, lane width, shoulder condition, median, grade, curvature and access control.
- Traffic factors: total flow, directional distribution, vehicle mix, heavy-vehicle percentage and speed distribution.
- Control factors: signal timing, intersection spacing, merging, weaving, pedestrian crossings and parking.
- Roadside friction: frequent accesses, commercial activity and uncontrolled roadside movement reduce effective capacity.
- Environmental conditions: rain, fog, poor visibility and incidents can reduce operating capacity.
- Improving capacity is not always achieved by widening; access management, intersection improvements and traffic management can also be effective.

Capacity improvement options

Additional lane • wider/managed intersections • access control • signal coordination • grade separation • public transport priority where appropriate

Important

Capacity analysis should reflect realistic prevailing conditions and the expected future operating environment.

Traffic Capacity: Volume-to-Capacity Ratio

The v/c ratio is a simple indicator of how close traffic demand is to capacity.

- v/c = traffic volume or demand divided by available capacity for the same time period and direction as applicable.
- A low v/c generally indicates greater reserve capacity and more freedom to manoeuvre.
- As v/c increases, traffic interactions, delay and speed variability generally increase.
- At or above capacity, queues may develop and discharge can become unstable.
- Example: if demand is 1,700 PCU/h and capacity is 3,267 PCU/h, $v/c \approx 0.52$.
- Design decisions should not rely on v/c alone; LOS, safety, access, heavy vehicles and future growth must also be considered.

Worked example

$$v/c = 1700 / 3267 \approx 0.52$$

Interpretation: the demand is about 52% of the stated capacity under the assumed conditions.

Design interpretation

If projected demand rises substantially, the same cross-section may move toward a poorer LOS and require capacity or operational improvements.

5. Level of Service (LOS): Concept

LOS describes the quality of traffic operation from the user's perspective.

- LOS is a qualitative description of operating conditions rather than a single physical road characteristic.
- It reflects factors such as speed, density, travel time, delay, freedom to manoeuvre and traffic interruptions.
- Six categories are commonly represented by A through F.
- LOS A represents very good operating conditions with substantial freedom to manoeuvre.
- LOS E represents operation near capacity, where small disturbances can cause significant deterioration.
- LOS F represents breakdown or forced flow, with queues, severe delay and very limited freedom to manoeuvre.



Illustrative progression from LOS A to F

LOS A, B and C: Good to Stable Operation

These levels generally provide usable mobility, but traffic interaction increases as the letter moves upward.

LOS A – Free Flow

Very low traffic interaction; high freedom to select speed and manoeuvre; minimal delay; incidents have relatively limited network impact.

LOS B – Reasonably Free

Vehicles begin to interact, but drivers retain good freedom to manoeuvre; speeds remain relatively stable; minor disturbances are usually absorbed.

LOS C – Stable Flow

Traffic interactions become noticeable; freedom to change lanes or overtake is reduced; speed and delay become more sensitive to additional demand.

Teaching point

A, B and C do not mean identical conditions. Moving from A toward C means progressively greater traffic interaction and less operational freedom.

LOS D, E and F: Constrained to Breakdown

At high demand, the road becomes increasingly sensitive to disturbances.

LOS D – High Density

Limited freedom to manoeuvre; speed and travel time are increasingly affected by traffic; a small incident can cause noticeable deterioration.

LOS E – Near Capacity

Traffic operates at or close to the maximum sustainable flow; very limited manoeuvring; minor disturbances can trigger queues.

LOS F – Breakdown

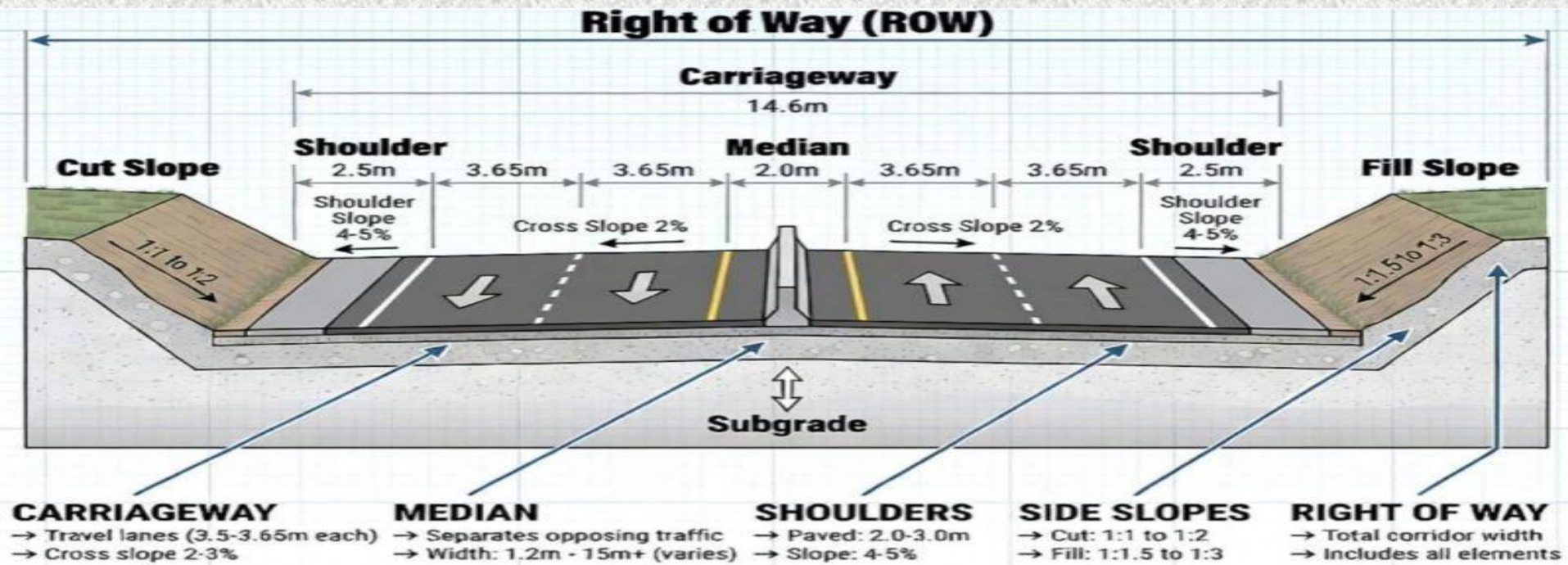
Demand exceeds available capacity; queues form; speeds become unstable; severe delay and forced flow occur.

Planning implication

The target LOS should be selected according to road function, location, cost, demand, available right-of-way and user expectations—not simply by choosing the best possible LOS everywhere.

Geometric Design Fundamentals

Geometric design is the process of determining the physical dimensions and layout of a highway so that vehicles can travel **safely, comfortably, efficiently and economically**.

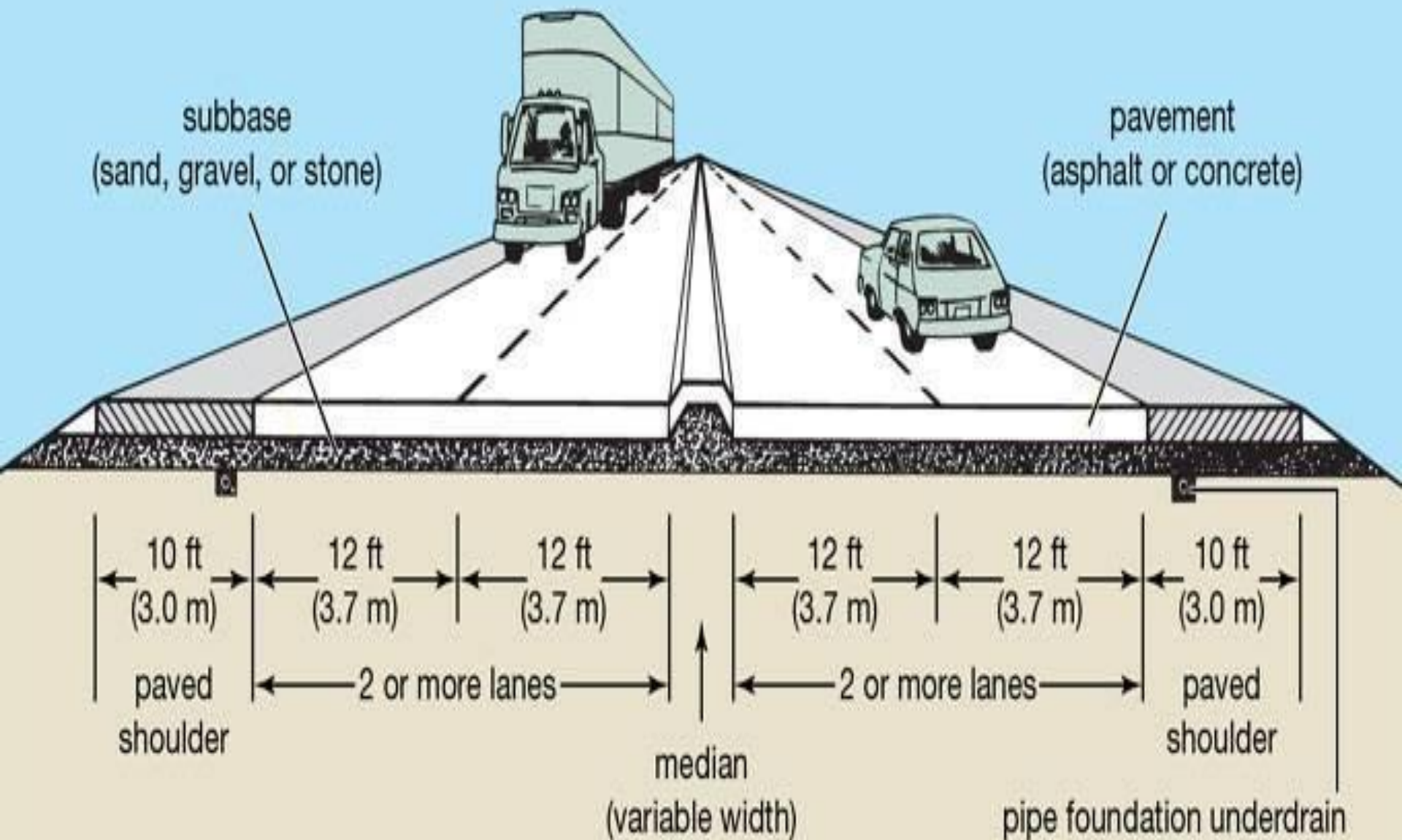


DIMENSION TABLE

Element	Urban	Rural	Highway
Lane width	3.5m	3.5m	3.65m
Shoulder	1.5-2.0m	2.0-2.5m	3.0m
Median	1.2-4.0m	2.0-6.0m	6.0-15m
Cross slope	2%	2%	2%
Shoulder slope	4%	4-5%	4-5%

Design for a typical highway section

GEOMETRIC DESIGN OF HIGHWAY

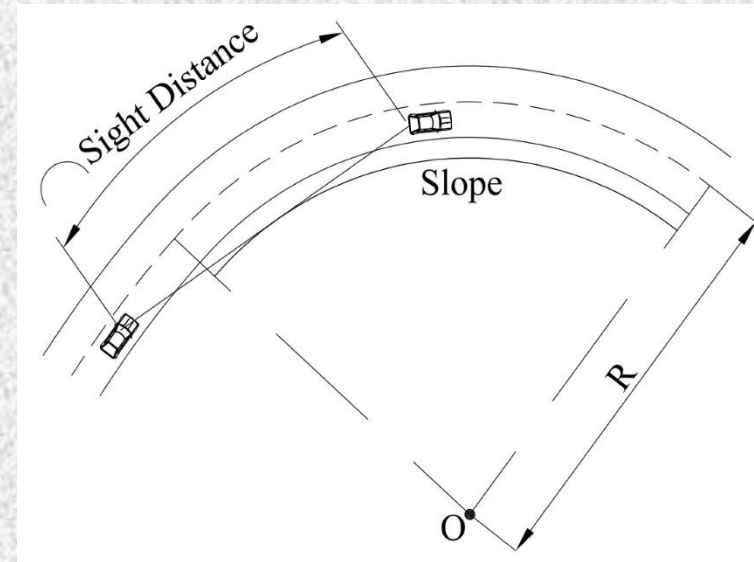


Objectives of Geometric Design

The main objectives are:

1. Safety

- Provide adequate **stopping and decision sight distance**.
- Avoid sudden changes in alignment, gradient and road width.
- Provide appropriate curves, superelevation and visibility.
- Reduce the possibility and severity of crashes.



2. Comfort

Provide smooth transitions between straight and curved sections.

Avoid excessive vibration and sudden changes in acceleration.

Maintain acceptable pavement smoothness and ride quality.



3. Efficient Traffic Movement

Provide adequate carriageway and lane width.
Accommodate the expected traffic volume.
Minimize unnecessary delays and congestion.
Facilitate safe overtaking, merging and turning.

4. Economy

A good geometric design should balance:

- Construction cost
- Land acquisition
- Earthwork
- Vehicle operating cost
- Travel time
- Maintenance cost

Important: The cheapest initial construction is not necessarily the most economical solution over the highway's entire life.



5. Drainage

The geometric design should allow rainwater to drain quickly from the pavement.

This requires:

- Camber/cross fall
- Longitudinal gradient
- Side drains
- Properly designed shoulders
- Cross-drainage structures



6. Environmental Considerations

Modern highway design should minimize:

- Excessive cutting and filling
- Damage to natural drainage
- Land acquisition
- Deforestation
- Noise and other environmental impacts.

Major Elements of Geometric Design

The **major elements of geometric design** determine the physical dimensions, alignment, safety, drainage, comfort and operational performance of a highway. Each element must be designed according to **traffic volume, design speed, terrain, vehicle characteristics and driver behaviour**.

The main elements include:

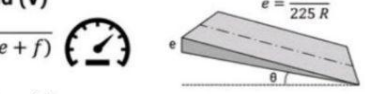
- 1.Road margins
- 2.Carriageway and lane width
- 3.Shoulders
- 4.Camber
- 5.Horizontal alignment
- 6.Vertical alignment
- 7.Sight distance
- 8.Superelevation
- 9.Skid resistance
- 10.Road roughness
- 11.Intersections
- 12.Roadside safety features

Highway Geometric Design

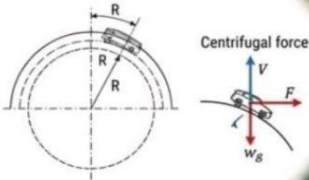
1 Design Speed (V)

$$V = \sqrt{127 R (e + f)}$$

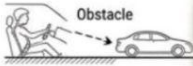

2 Superelevation (e)

$$e = \frac{V^2}{225 R}$$


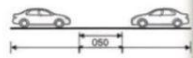
3 Horizontal Curve Design



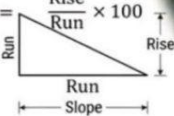
4 Stopping Sight Distance (SSD)

$$SSD = vt + \frac{v^2}{2 g f}$$


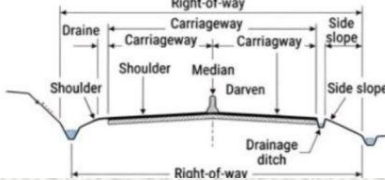
5 Overtaking Sight Distance

$$\text{Gradient} = \frac{\text{Rise}}{\text{Run}} \times 100$$


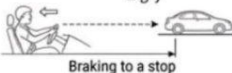
6 Gradient / Longitudinal Slope

$$\text{Gradient} = \frac{\text{Rise}}{\text{Run}} \times 100$$


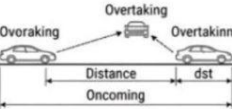
10 Highway Cross Section



4 Stopping Sight Distance (SSD)

$$SSD = vt + \frac{v^2}{2 g f}$$


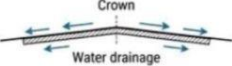
5 Overtaking Sight Distance (OSD)



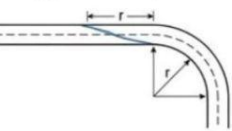
6 Gradient / Longitudinal Slope

$$\text{Gradient} = \frac{\text{Rise}}{\text{Run}} \times 100$$


7 Camber / Cross Slope



8 Transition Curve (Spiral Curve)



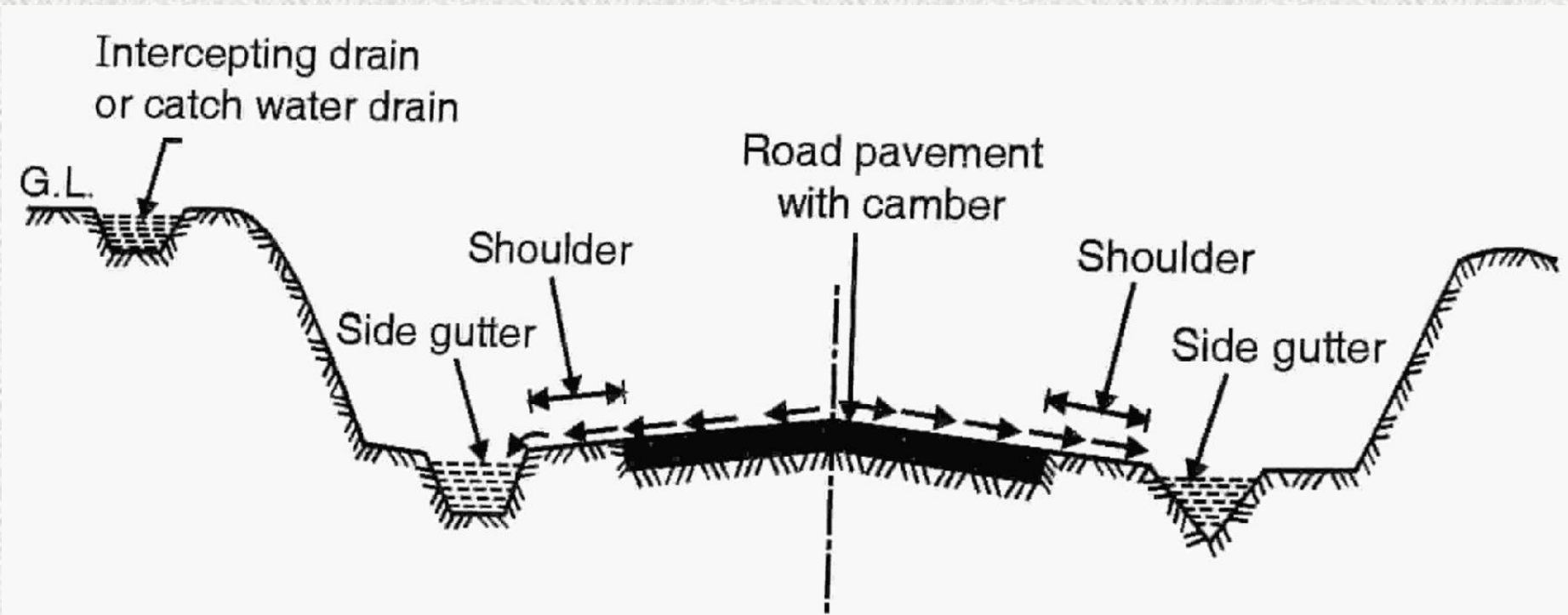
9 Extra Widening of Pavement



Step-by-Step Highway Geometric Design Process

- Step 1 – Select Design Speed
- Step 2 – Fix Road Alignment
- Step 3 – Design Horizontal Curves
- Step 4 – Provide Superelevation
- Step 5 – Calculate Sight Distance
- Step 6 – Design Vertical Curves
- Step 7 – Provide Camber and Drainage
- Step 8 – Determine Road Cross Section

Road Margins are the portions of the road outside the main carriageway that provide additional space for safety, drainage, pedestrian movement, roadside utilities and other functions.



Shoulder

The shoulder is the strip adjacent to the carriageway.

Functions:

- Provides emergency stopping space.
- Provides lateral support to pavement.
- Provides recovery area for errant vehicles.
- Improves safety.
- Can provide additional space for maintenance activities.

Verge

The verge is the area between the carriageway/shoulder and the boundary or other roadside facilities.

It may accommodate:

- Drainage
- Utilities
- Landscaping
- Pedestrian facilities where appropriate

Side slope

The side slope connects the road embankment or cutting to the natural ground.

Its stability is important to prevent:

- Erosion
- Slope failure
- Soil loss

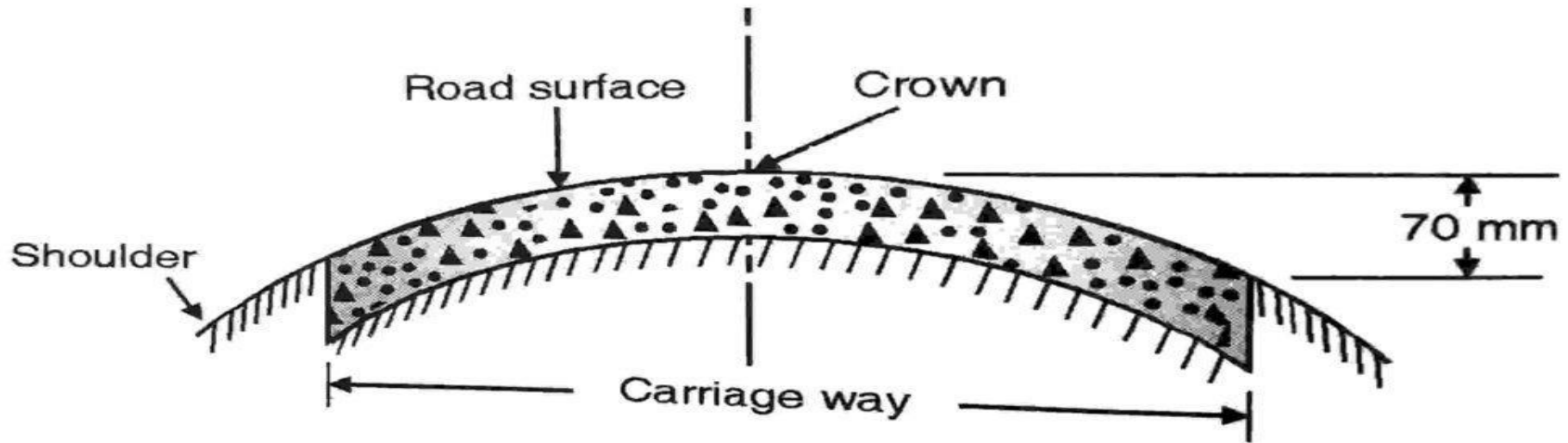
Drainage strip / side drain

Carries surface water away from the pavement and prevents water-related damage.



Camber

Camber, also called **cross fall**, is the transverse slope provided on the road surface to drain rainwater away from the pavement.



Why is camber required?

Without adequate camber:

Rainwater → remains on pavement → water infiltration → pavement damage → potholes/rutting → reduced service life

Functions of camber

- Removes rainwater from the pavement.
- Reduces water infiltration into pavement layers.
- Reduces the possibility of hydroplaning.
- Protects pavement materials.
- Improves skid safety during wet conditions.

Common forms

1. Straight/plane camber

- Surface consists of two straight slopes meeting at the crown.

2. Parabolic camber

- Pavement surface follows a parabolic profile.

3. Composite camber

- Combination of different slopes.

Important design consideration

Camber should be **sufficient but not excessive**.

Excessive camber can:

- Cause discomfort
- Create lateral movement of vehicles
- Affect vehicle stability
- Cause difficulties for cyclists and slow-moving vehicles

Skid Resistance

Skid resistance is the ability of the pavement surface to provide sufficient friction between the vehicle tyres and the road surface.

Why is skid resistance important?

Adequate skid resistance helps vehicles:

- Brake safely
- Maintain control while cornering
- Accelerate without excessive wheel slip
- Stop within the required distance

Factors affecting skid resistance

- Pavement surface texture
- Aggregate properties
- Aggregate polishing resistance
- Tyre condition
- Vehicle speed
- Water film thickness
- Pavement cleanliness
- Temperature and weather



Micro texture and Macrotexture

Micro texture

- Fine texture of individual aggregate particles.
- Important for tyre-pavement friction.

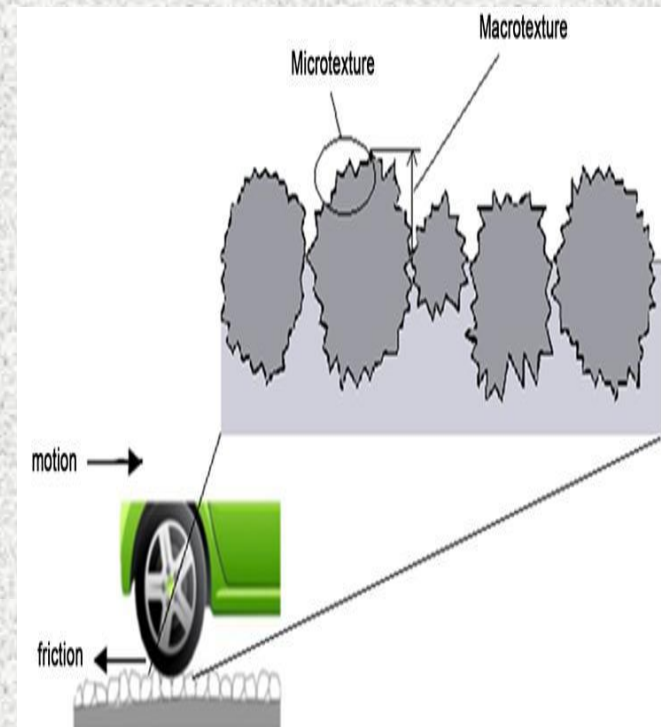
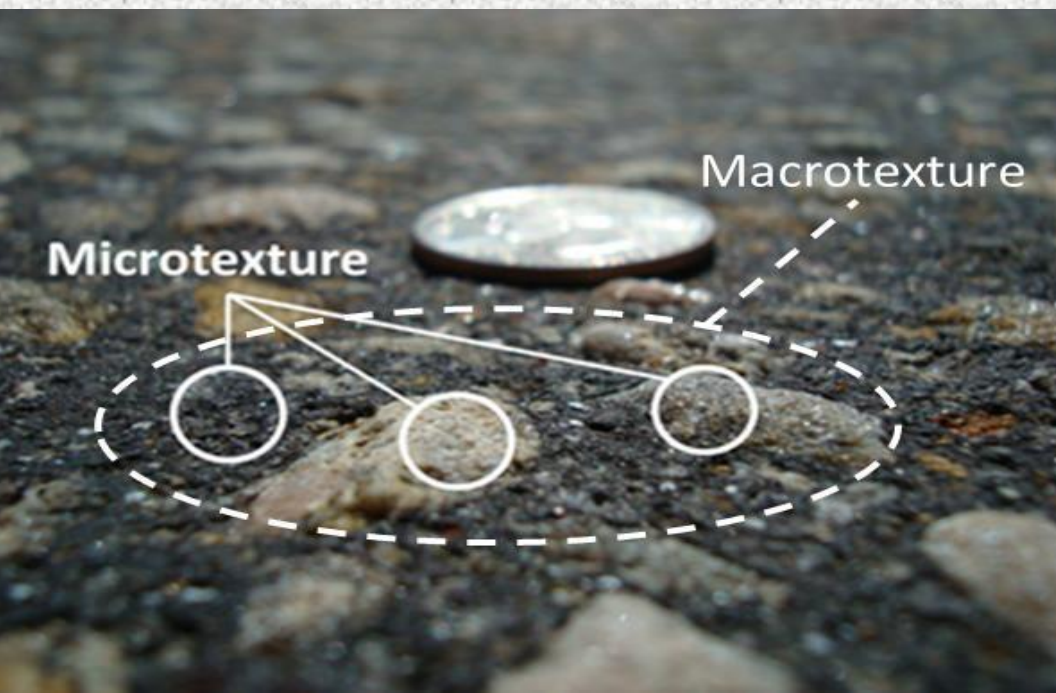
Macrotexture

- Larger-scale texture between aggregate particles.
- Helps water escape from beneath the tyre.

Loss of skid resistance

Polishing of aggregates and accumulation of contaminants can reduce friction.

Wet pavement + high speed + inadequate skid resistance = increased risk of skidding.



Road Roughness

Road roughness refers to the irregularities and deviations in the pavement surface that affect the smoothness of vehicle movement.

Causes of road roughness

- Poor construction
- Uneven pavement layers
- Settlement of embankment
- Potholes
- Rutting
- Cracking
- Poor maintenance
- Differential settlement
- Temperature and moisture effects



Effects of excessive roughness

On vehicles:

- Increased vibration
- Increased fuel consumption
- Higher vehicle maintenance cost
- Reduced passenger comfort

On highway operation:

- Reduced operating speed
- Reduced travel comfort
- Increased accident risk in severe cases
- Higher pavement maintenance requirements

On pavement:

- Dynamic vehicle loads increase
- Further deterioration can occur

Measurement

Road roughness is commonly quantified using the:

International Roughness Index (IRI)

IRI is generally expressed in:

m/km

Lower IRI generally indicates a smoother pavement.

