TRANSPORTATION ENGINEERING

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BY

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COs	Course outcomes
CO1	Understand the importance of highway development of India and classification of roads and road patterns.
CO2	Design various geometric elements like curves, gradients, super elevation etc.
CO3	Capable of performing various traffic surveys and study basics of traffic engineering and regulations.
CO4	Analyze traffic signals intersections and road markings and their designs
CO5	Understand construction of cement concrete pavements, construction of joints in cement concrete pavements joint filter.

UNIT– I
HIGHWAY DEVELOPMENT AND PLANNING

CLOs	Course Learning Outcomes
CLO 1	Understand necessity for highway planning, different road development plans.
CLO 2	Study classification of roads, road network patterns, highway alignment.
CLO 3	Capable of performing various traffic surveys.
CLO 4	Study factors affecting alignment, engineering surveys, drawing and reports, highway project.

JAYAKAR COMMITTEE,1927

- After the first World War, motor vehicle using the roads increases, this demanded a better road network.
- In 1927, Indian road development committee was appointed by the government with M.R. Jayakar as chairman.
- Road development in the country should be made as a national interest since local govt. do not have financial and technical capacity for road development.
- An extra tax should be levied on petrol from road users to create the road development fund.
- To establish a semi-official ,technical institution to pool technical knowledge, sharing of ideas and to act as an advisory body.
- To create a national level institution to carry research , development works and consultation.

Central Road Fund

- It was formed on 1st March 1929
- The consumers of petrol were charged an extra leavy of 2.64 paisa per litre of petrol to built up this road development fund.
- From this 20% of annual revenue is to be retained as a central revenue for research and experimental work expenses..etc
- Balance 80% is allowed by central govt. to various states based on actual petrol consumption or revenue collected.

Indian Roads Congress, 1934

- Central semi official body known as IRC was formed in 1934.
- To provide national forum for regular pooling of experience and ideas on matters related to construction and maintenance of highways.
- It is a active body controlling the specification, standardization and recommendations on materials, design of roads and bridges.
- It publishes journals, research publications and standard specifications guide lines.
- To provide a platform for expression of professional opinion on matters relating to roads and road transport.

Motor Vehicle Act

- It was formed in 1939
- To regulate the road traffic in the form of traffic laws, ordinances and regulations.
- Three phases primarily covered are control of driver, vehicle ownership and vehicle operation
- It was revised on 1988

Central Road Research Institute(1950)

- Engaged In Carrying Out Research And Development Projects.
- Design, Construction And Maintenance Of Roads And Runways, Traffic And Transportation Planning Of Mega And Medium Cities, Management Of Roads In Different Terrains.
- Improvement Of Marginal Materials.
- Utilization Of Industrial Waste In Road Construction.
- Landslide Control.
- Ground Improvements, Environmental Pollution.
- Road Traffic Safety

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.

Highway Research Board

- To ascertain the nature and extent of research required
- To correlate research information from various organizations in India and abroad.
- To collect results on research
- To channelise consultative services

Classification of Highways

- ✓ Depending on weather
  - All weather roads
  - Fair weather roads
- ✓ Depending the type of Carriage way
  - Paved roads(WBM)
  - Unpaved roads(earth road or gravel road)
- ✓ Depending upon the pavement surface
  - Surfaced roads(bituminous or cement concrete road)
  - Un surfaced roads

Classification of Highways

- Based on the Traffic Volume
  - Heavy
  - Medium
  - Light
- Based on Load or Tonnage
  - Class 1 or Class 2 etc or Class A , B etc Tonnes per day
- Based on location and function (Nagpur road plan)
  - National highway (NH)
  - State highway (SH)
  - Major district road (MDR)
  - Other district road (ODR)
  - Village road (VR)

Based on modified system of Highways classification

- Primary
- Expressways
- National Highways
- Secondary
- SH
- MDR
- Tertiary
- ODR
- VR

Expressways

- Heavy traffic at high speed (120km/hr)
- Land Width (90m)
- Full access control
- Connects major points of traffic generation
- No slow moving traffic allowed
- No loading, unloading, parking.

National Highways

- NH are the main highways running through the length and breadth of India, connecting major parts, foreign highways, capital of large states and large industrial and tourist centres including roads required for strategic movements for the defence of India.
- The national highways have a total length of 70,548 kms. Indian highways cover 2% of the total road network of India and carry 40% of the total traffic.
- The highway connecting Delhi-Ambala-Amritsar is denoted as NH-1, whereas a bifurcation of this highway beyond Jalandar to Srinagar and Uri is denoted NH-1-A
- The longest highway in India is NH7 which stretches from Varansi in Uttar Pradesh to Kanyakumari in the southern most point of Indian mainland.

National Highways cont...

- The shortest highway is NH47A which stretches from Ernakulam to Kochi and covers total length of 4 Kms.
- Golden Quadrilateral – (5,846 Kms) connecting Delhi-Kolkata-Chennai-Mumbai

- NH-2 Delhi- Kol (1453 km)
- NH 4,7&46 Che-Mum (1290km)
- NH5&6 Kol- Che (1684 m)
- NH 8 Del- Mum (1419 km)

State Highways

- They are the arterial roads of a state, connecting up with the national highways of adjacent states, district head quarters and important cities within the state.
- Total length of all SH in the country is 1,37,119 Kms.
- Speed 80 kmph

Major District Roads

- Important roads with in a district serving areas of production and markets , connecting those with each other or with the major highways.
- India has a total of 4,70,000 kms of MDR.
- Speed 60-80kmph

Other district roads

- Serving rural areas of production and providing them with outlet to market centers or other important roads like MDR or SH.
- Speed 50-60kmph Village Roads
- They are roads connecting villages or group of villages with each other or to the nearest road of a higher category like ODR or MDR.
- India has 26,50,000 kms of ODR+VR out of the total 33,15,231 kms of all type of roads.
- Speed-40-50kmph

Urban Road Classification

- Arterial Roads
- Sub Arterial
- Collector
- Local Street
- Cul-de-sac
- Pathway
- Driveway

ARTERIAL

- No frontage access, no standing vehicle, very little cross traffic.
- Design Speed : 80km/hr
- Land width: 50 – 60m
- Divided roads with full or partial parking
- Pedestrian allowed to walk only at intersection.

SUB ARTERIAL ROAD

- Bus stops but no standing vehicle.
- Less mobility than arterial.
- Spacing for CBD : 0.5km
- Design speed : 60 km/hr
- Land width: 30 – 40 m

Collector Street

- Collects and distributes traffic from local streets
- Provides access to arterial roads
- Located in residential, business and industrial areas.
- Full access allowed.
- Parking permitted.
- Design speed : 50km/hr
- Land Width: 20-30m

Local Street

- Design Speed : 30km/hr.
- Land Width : 10 – 20m.
- Primary access to residence, business or other abutting property
- Less volume of traffic at slow speed
- Unrestricted parking, pedestrian movements. (with frontage access, parked vehicle, bus stops and no waiting restrictions)

CUL–DE- SAC

- Dead End Street with only one entry access for entry and exit.
- Recommended in Residential areas.

Driveway

- A driveway is a type of private road for local access to one or a small group of structures, and is owned and maintained by an individual or group.
- Driveways are commonly used as paths to private garages, fuel stations, or houses

Road Patterns

- Rectangular or Block patterns
- Radial or Star block pattern
- Radial or Star Circular pattern
- Radial or Star grid pattern
- Hexagonal Pattern
- Minimum travel Pattern

First 20-years road plan(1943-63)

- The conference of chief engineer held at Nagpur in 1943 finalized the first 20-years road development plan for India called Nagpur road plan.
- Road network was classified into five categories.
- The responsibility of construction maintenance of NH was assign to central govt.
- The target road length was 5,32,700 km at the end of 1961.
- Density of about 16km of road length per 100 sq. km area would be available in the country by the year 1963.

Second 20-years road plan(1961-81)

- It was initiated by the IRC and was finalised in 1959 at the meeting of chief engineers.
- It is known as the Bombay road plan.
- The target road length was almost double that of Nagpur road plan i.e. 10,57,330 km.
- Density about 32 km per 100 sq. km. and an outlay of 5200 crores
- Every town with population above 2000 in plains and above 1000 in semi hill area and above 500 in hilly area should be connected by metalled road

Second 20-years road plan cont…

- Expressways have also been considered in this plan and 1600km of length has been included in the proposed target NH.
- Length of railway track is considered independent of road system

Third twenty years road plan (1981-2001)

- The future road development should be based on the revised classification of roads system i.e. primary, secondary and tertiary
- Develop the rural economy and small towns with all essential features.
- Population over 500 should be connected by all weather roads.
- Density increases to 82 km per 100 sq. km
- The NH network should be expanded to form a square grids of 100 km sides so that no part of the country is more than 50 km away from the NH

Third twenty years road plan cont…

- Expressway should be constructed along major traffic corridors
- All towns and villages with population over 1500 should be connected by MDR and villages with population 1000-1500 by ODR.
- Road should be built in less industrialized areas to attract the growth of industries
- The existing roads should be improved by rectifying the defects in the road geometry, widening, riding quality and strengthening the existing pavement to save vehicle operation cost and thus to conserve energy

Highway alignment

- The position or lay out of centre line of the highway on the ground is called the alignment.
- It includes straight path, horizontal deviation and curves.
- Due to improper alignment ,the disadvantages are,

➢ Increase in construction

➢ Increase in maintenance cost

➢ Increase in vehicle operation cost

➢ Increase in accident cost

- Once the road is aligned and constructed, it is not easy to change the alignment due to increase in cost of adjoining land and construction of costly structure.

Requirements of highway alignment

- Short
- Easy
- Safe
- Economical

Factors controlling alignment

- Obligatory points
- Traffic
- Geometric design
- Economics
- Other considerations

Additional care in hill roads

- Stability
- Drainage
- Geometric standards of hill roads
- Resisting length

Obligatory points through which alignment should not pass.

Examples:-religious places, costly structure, unsuitable land etc…

- Traffic
- origin and destination survey should be carried out in the area and the desire lines be drawn showing the trend of traffic flow.
- New road to be aligned should keep in view the desired lines, traffic flow patterns and future trends.

Geometric design

- Design factors such as gradient ,radius of curve and sight distance also govern the final alignment of the highway.
- Gradient should be flat and less than the ruling gradient or design gradient.
- Avoid sudden changes in sight distance, especially near crossings
- Avoid sharp horizontal curves
- Avoid road intersections near bend

Topographical control points

The alignment, where possible should avoid passing through

- Marshy and low lying land with poor drainage
- Flood prone areas
- Unstable hilly features

Materials and constructional features

- Deep cutting should be avoided
- Earth work is to be balanced; quantities for filling and excavation
- Alignment should preferably be through better soil area to minimize pavement thickness
- Location may be near sources of embankment

Drainage

- Avoid the cross drainage structure
- The number of cross drainage structure should be minimum.

Geometric standard of hilly road

- Gradient, curve and speed
- Sight distance, radius of curve

Resisting length

- The total work to be done to move the loads along the route taking horizontal length, the actual difference in level between two stations and the sum of the ineffective rise and fall in excess of floating gradient. Should kept as low as possible.

UNIT– II
HIGHWAY GEOMETRIC DESIGN

CLOs	Course Learning Outcomes
CLO 5	Understand Importance of geometric design.
CLO 6	Analyze factors affecting highway geometric design. Design controls and criteria.
CLO 7	Understand highway cross section elements including shoulder, kerb, and carriageway.
CLO 8	Analyze sight distance elements, stopping sight distance, overtaking sight distance and intermediate sight distance.
CLO 9	Analyze design of horizontal alignment, design of super elevation and extra widening.
CLO 10	Analyze design of transition curves, design of vertical alignment, gradients, and vertical curves.

Importance of Geometric Design

- The geometric design of a highway deals with the dimensions and layout of visible features of the highway such as alignment, sight distance and intersection.
- The main objective of highway design is to provide optimum efficiency in traffic operation with maximum safety at reasonable cost.
- Geometric design of highways deals with following elements :
  - Cross section elements
  - Sight distance considerations
  - Horizontal alignment details
  - Vertical alignment details
  - Intersection elements

Design Controls and Criteria

- Design speed
- Topography
- Traffic factors
- Design hourly volume and capacity
- Environmental and other factors

Design speed

- In India different speed standards have been assigned for different class of road
- Design speed may be modified depending upon the terrain conditions.

Topography

- Classified based on the general slope of the country.

✓ Plane terrain- <10%
✓ Rolling terrain- 10-25%
✓ Mountainous terrain- 25-60%
✓ Steep terrain- >60%

Traffic factor

- Vehicular characteristics and human characteristics of road users.
- Different vehicle classes have different speed and acceleration characteristics, different dimensions and weight.
- Human factor includes the physical, mental and psychological characteristics of driver and pedestrian.

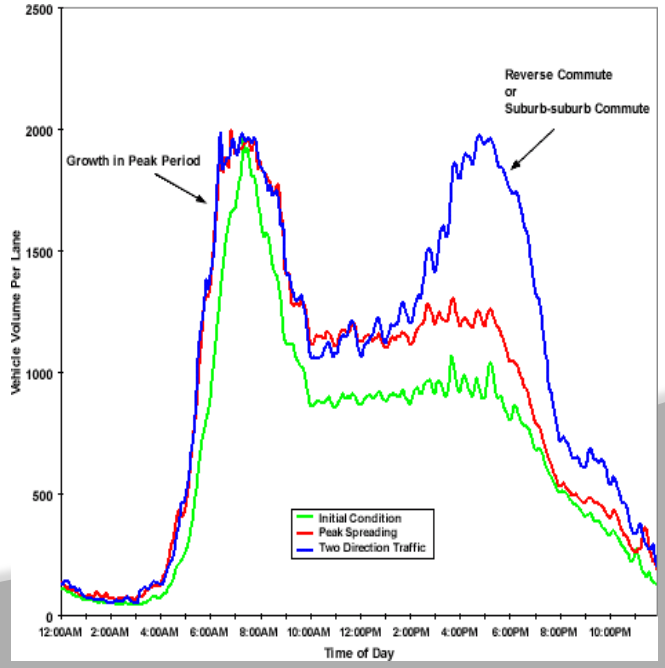
Design hourly volume and capacity

Traffic flow fluctuating with time

- Low value during off-peak hours to the highest value during the peak hour.
- It is uneconomical to design the roadway for peak traffic flow.

Environmental factors

- Aesthetics
- Landscaping
- Air pollution
- Noise pollution



Pavement Surface Characteristics

Pavement surface depend on the type of pavement which is decided based on the,

- Availability of material
- Volume and composition of traffic
- Soil subgrade
- Climatic condition
- Construction facility
- Cost consideration

The important surface characteristics are:

- Friction
- Pavement unevenness
- Light reflecting characteristics
- Drainage of surface water

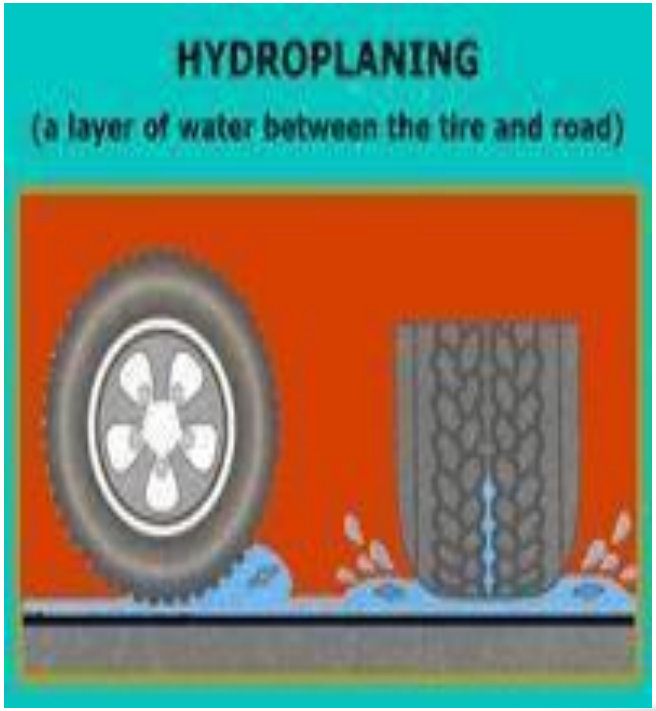
Friction

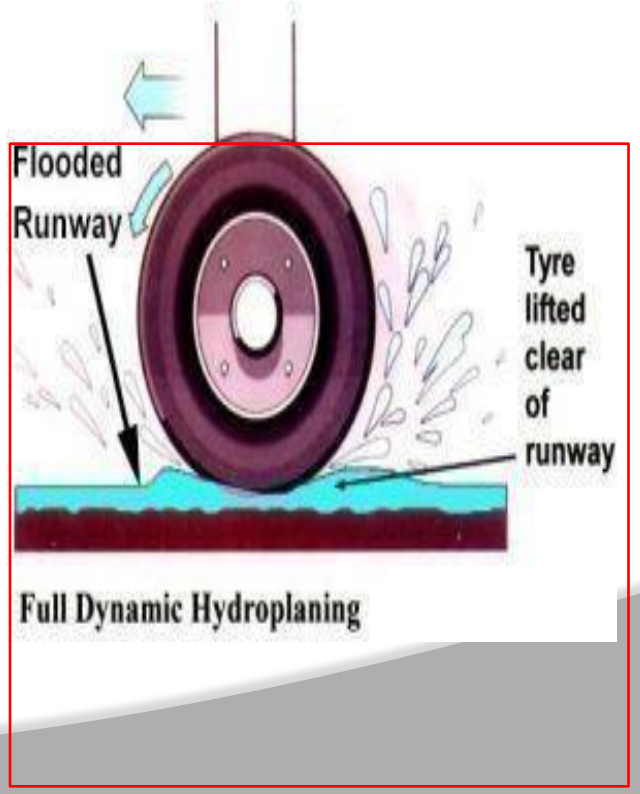
- Skidding: when the path travelled along the road surface is more than the circumferential movement of the wheels due to their rotation.
- Slipping: when a wheel revolves more than the corresponding longitudinal movement along the road.

Factors affecting the friction or skid resistance

- Types of pavement surface
- Roughness of pavement
- Condition of the pavement: wet or dry
- Type and condition of tyre
- Speed of the vehicle
- Brake efficiency
- Load and tyre pressure
- Temperature of tyre and pavement

- Smooth and worn out tyres offer higher friction factor on dry pavement but new tyre with good threds gives higher friction factor on wet pavement
- IRC recommended the longitudinal co-efficient of friction varies 0.35 to 0.4 and lateral co-efficient of friction of 0.15





Pavement unevenness

- Higher operating speed are possible on even surface than uneven surface.

  It affects,
- Vehicle operation cost
- Comfort and safety
- Fuel consumption
- Wear and tear of tyres and other moving parts
- It is commonly measure by an equipment call “Bump Integrator”
- Bump integrator is the cumulative measure of vertical undulations of the pavement surface recorded per unit horizontal length.
- 250 cm/km for a speed of 100kmph and more than 350 cm/km
- considered very unsatisfactory even at speed of 50 kmph.

- Unevenness of pavement surface may be caused by
- In adequate compaction of the fill, subgrade and pavement layers.
- Un-scientific construction practices including the use of boulder stones and bricks as soiling course over loose subgrade soil.
- Use of inferior pavement material.
- Improper surface and subsurface drainage.
- Improper construction machinery.
- Poor maintenance

Light reflecting characteristics

- Night visibility very much depends upon the light reflecting characteristics of the pavement surface
- The glare caused by the reflection of head light is high on wet pavement surface than on dry pavement particularly in case of black top pavement or flexible pavement.
- Light colored or white pavement or rigid pavement surface give good visibility at night particularly during the rain, and produces glare or eye strain during bright sunlight.

Highway cross section elements

- Carriageway
- Shoulder
- Roadway width
- Right of way
- Building line
- Control line
- Median
- Camber/ cross slope
- Crown

Carriageway:

- It is the travel way which is used for movement of vehicle, it takes the vehicular loading .
- It may be cement concrete road or bituminous pavement.
- Width of carriageway is determined on the basis of the width of the vehicle and the minimum side clearance for safety.
- As per IRC specification, the maximum width of vehicle is 2.44m, minimum clearance of 0.68 in case of single lane and 1.02m in case of doublelane.


Twolanetwo-way road
carriageway

Shoulder

- It is provided along the road edge to serve as an emergency lane for vehicle.
- It act as a service lane for vehicles that have broken down.
- The minimum shoulder width of 4.6 m so that a truck stationed at the side of the shoulder would have a clearance of 1.85m from the pavement edge.
- IRC recommended the minimum shoulder width is 2.5 m
- It should have sufficient load bearing capacity even in wet weather.
- The surface of the should be rougher than the traffic lanes so that
  vehicles are discouraged to use the shoulder as a regular traffic.
- The colour should be different from that of the pavement so as to be distinct.

shoulder

Cycletrack

Footpath


unTreated shoulder
Treated shoulder

Width of the roadway or formation width

- It is the sum of the width of the carriageway or pavement including separators if any and the shoulders.

Right of way:

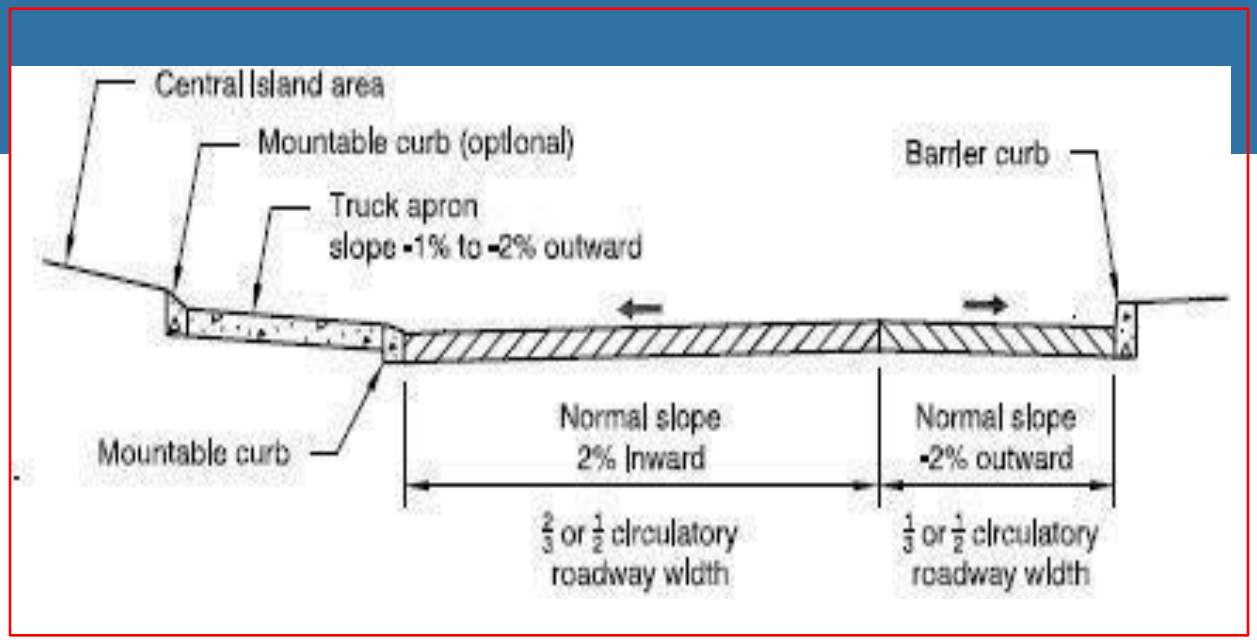
- It is the total area of land acquired for the road along its alignment.
- It depends on the importance of the road and possible future development.
- It is desirable to acquire more width of land as the cost of adjoining land invariably increases very much , soon after the new highway is constructed.

Building line

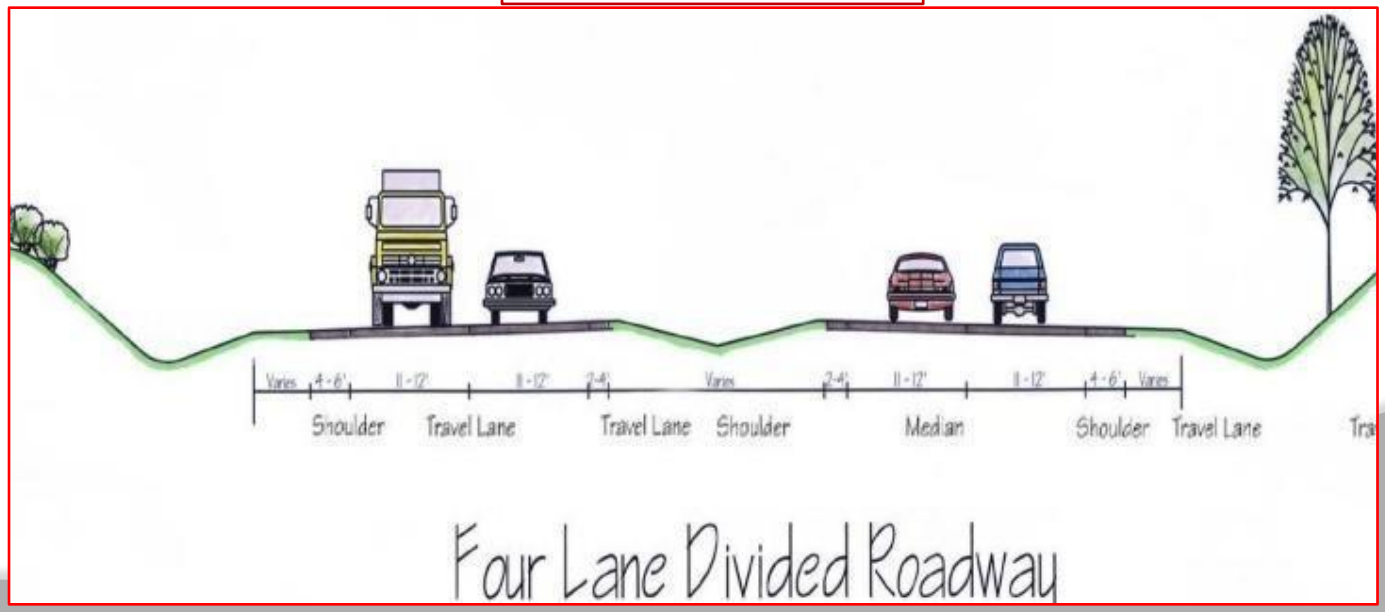
- In order to reserve sufficient space for future development of roads, It is desirable to control the building activities on either side of the road boundary, beyond the land width acquired for the land.

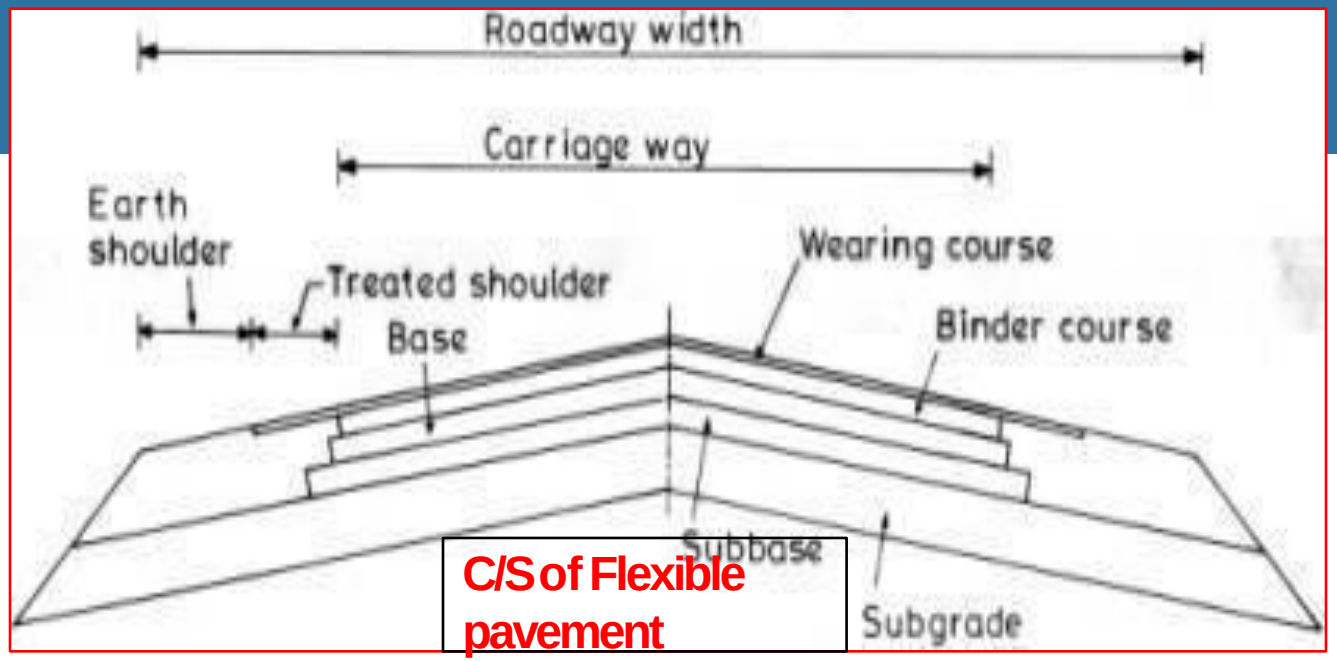
Control lines:

- In addition to “building line”, it is desirable to control the nature of building upto further “set back distance” .

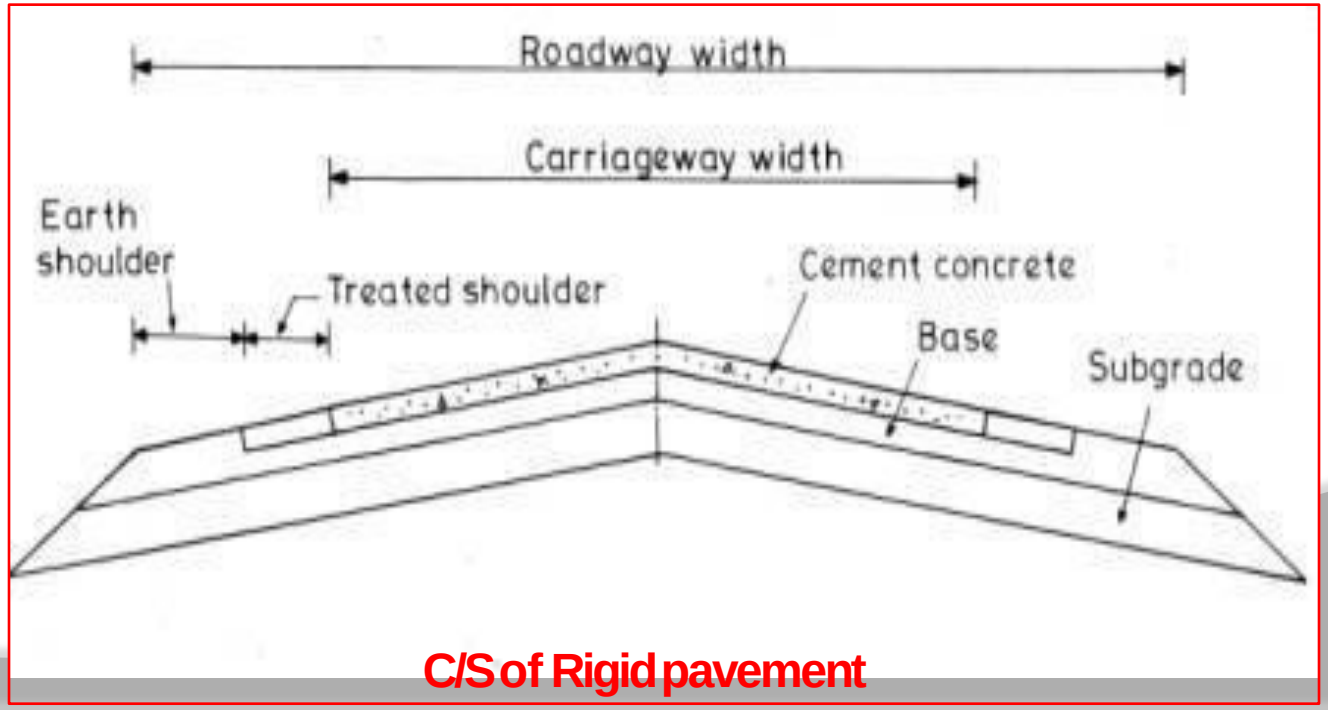


c/s of road in built-up area





C/S of Flexible pavement



C/S of Rigid pavement

Traffic separators or Median

- The main function is to prevent head on collision between the vehicle moving in opposite direction.
- Channelize traffic into streams at intersection.
- Segregate slow traffic and to protect pedestrians.
- IRC recommends a minimum desirable width of 5 m and may be reduce to 3 m where land is restricted.
- The minimum width of median in urban area is 1.2m.

Cross slope or camber

- It is the slope provided to the road surface in the transverse direction to drain off the rain water from the road surface.
- To prevent the entry of surface water into the subgrade soil through pavement.
- To prevent the entry of water into the bituminous pavement layer.
- To remove the rain water from the pavement surface as quick as possible and to allow the pavement to get dry soon after the rain.
- It is expressed as a percentage or 1V:Nh.
- It depends on the pavement surface and amount of rainfall.

Shape of the cross slope

- Parabolic shape(fast moving vehicle)
- Straight line
- Combination of parabolic and straight line

Too steep slope is not desirable because of the following reasons

- Uncomfortable side thrust and unequal wear of the tyres as well as road surface.
- Problem of toppling over highly laden bullock cart and truck.
- Tendency of most of vehicle travel along the centre line.

Kerb:

- It indicates the boundary between the pavement and shoulder.
- It is desirable to provide kerbs in urban areas.
- It is of three types

Low or mountable kerb:

- It allow the driver to enter the shoulder area with little difficulty.
- The height of the this type of shoulder kerb is about 10 cm above the pavement edge with slope to help the vehicle climb the kerb easily.

2-Semi-barrier kerb

- It is provided on the periphery of a roadway where the pedestrian traffic is high.
- Height of about 15 cm above the pavement edge with a batter of 1:1 on the top 7.5 cm.
- It prevents parking the vehicle but during emergency it is possible to drive over this kerb with some difficulty.

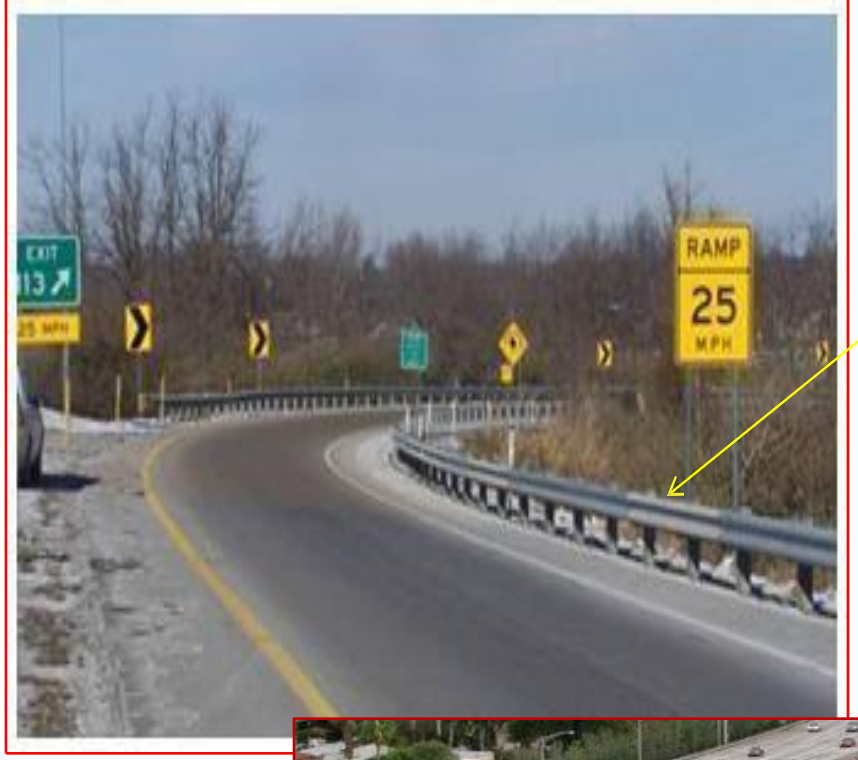
3-Barrier type kerb:

- It is provided in built-up area adjacent to the foot paths with considerable pedestrian traffic.
- The height of the kerb is about 20 cm above the pavement edge with a steep batter of 1V:0.25H.

kerb

Guard rail

- It is provided at the edge of the shoulder when the road is constructed on a fill exceeds 3 m.
- It is also provided on horizontal curve so as to provide a better night visibility of the curves under the head light of the vehicle.



Guard rails

Guard rail


LAY BAYS
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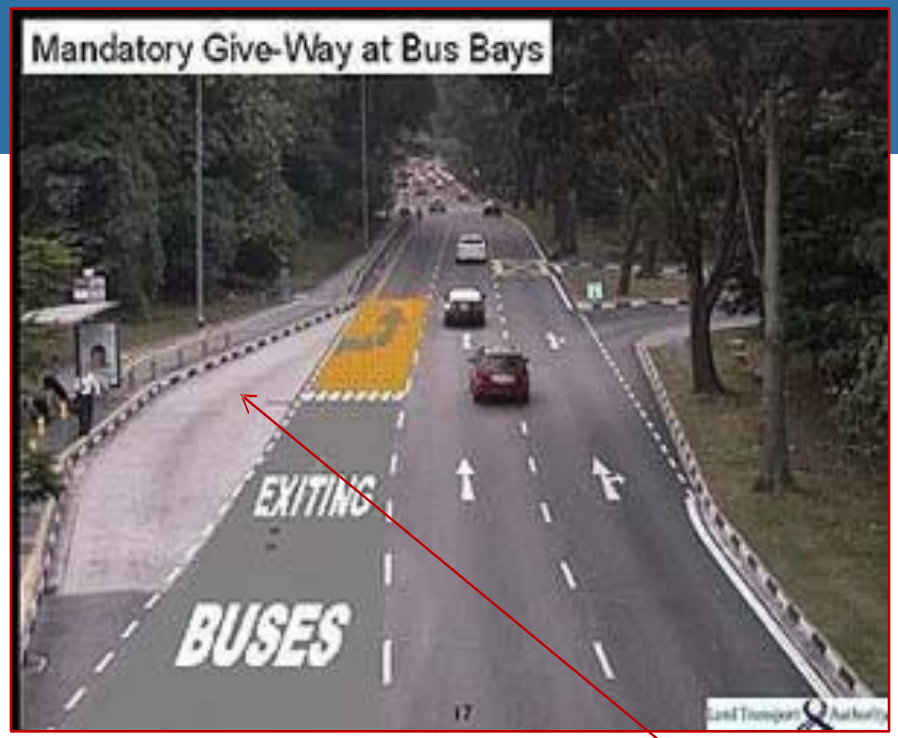

Mandatory Give-Way at Bus Bays
EXITING
BUSES


BUS
BUS


HARD MARKING
BUSES

Bus bays

Frontage road

SIGHT DISTANCE

- Sight distance available from a point is the actual distance along the road surface, which a driver from a specified height above the carriageway has visibility of stationary or moving objects.

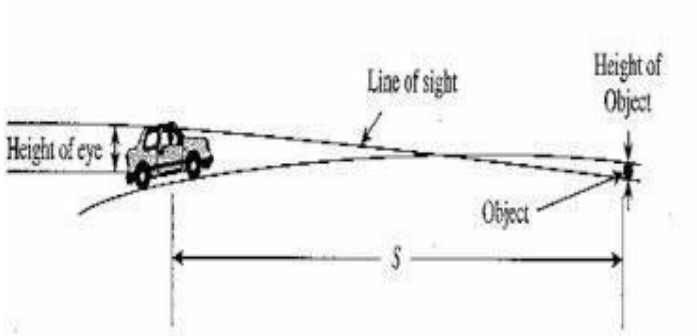
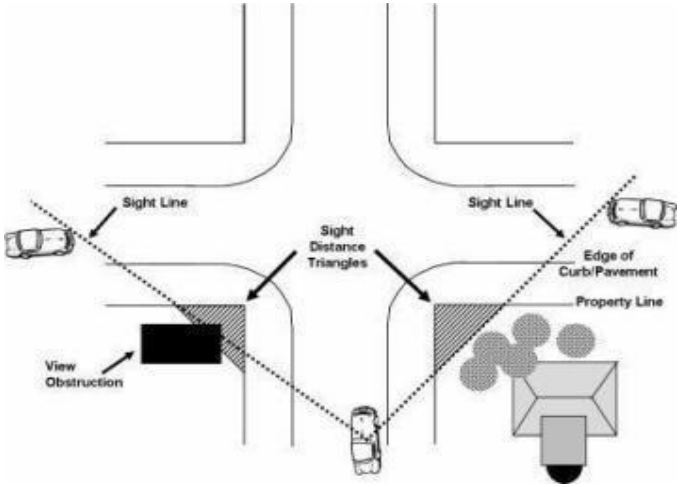


FIGURE 4.8
Stopping sight distance diagram for crest vertical curve.



Types of sight distance

- Stopping or absolute minimum sight distance(SSD)
- Safe overtaking or passing sight distance (OSD)
- Safe sight distance for entering into uncontrolled intersection.
- Intermediate sight distance
- Head light sight distance

Stopping sight distance

- The minimum sight distance available on a highway at any spot should be of sufficient length to stop a vehicle traveling at design speed, safely without collision with any other obstruction.

Over taking sight distance:

- The minimum distance open to the vision of the driver of a vehicle intending to overtake slow vehicle ahead with safety against the traffic of opposite direction is known as the minimum overtaking sight distance (OSD) or the safe passing sight distance.

Sight distance at intersection:

- Driver entering an uncontrolled intersection (has sufficient visibility to enable him to take control of his vehicle and to avoid collision with another vehicle.

Intermediate sight distance

- This is defined as twice the stopping sight distance. When overtaking sight distance can not be provided, intermediate sight distance is provided to give limited overtaking opportunities to fast vehicles.

Head light sight distance:

- This is the distance visible to a driver during night driving under the illumination of the vehicle head lights. This sight distance is critical at up-gradients and at the ascending stretch of the valley curves.

Stopping Sight Distance

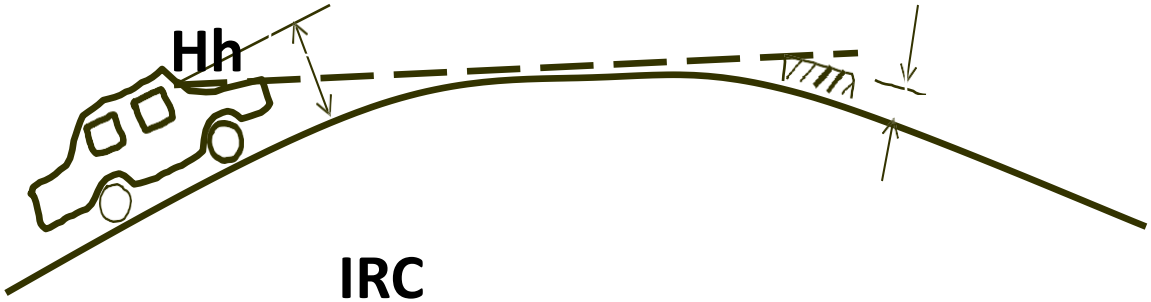
- SSD is the minimum sight distance available on a highway at any spot having sufficient length to enable the driver to stop a vehicle traveling at design speed, safely without collision with any otherobstruction.

It depends on:

- Feature of road ahead
- Height of driver's eye above the road surface(1.2m)

Criteria for measurement

- **Height of driver's eye above road surface (H)**
- **Height of object above road surface(h)**



IRC

- **H = 1.2m**
- **h = 0.15m**

Factors affecting the SSD

- Total reaction time of driver
- Speed of vehicle
- Efficiency of brakes
- Frictional resistance between road and tyre
- Gradient of road
- Total reaction time of driver:

Perception time

- It is the time from the instant the object comes on the line of sight of the driver to the instant he realizes that the vehicle needs to be stopped.

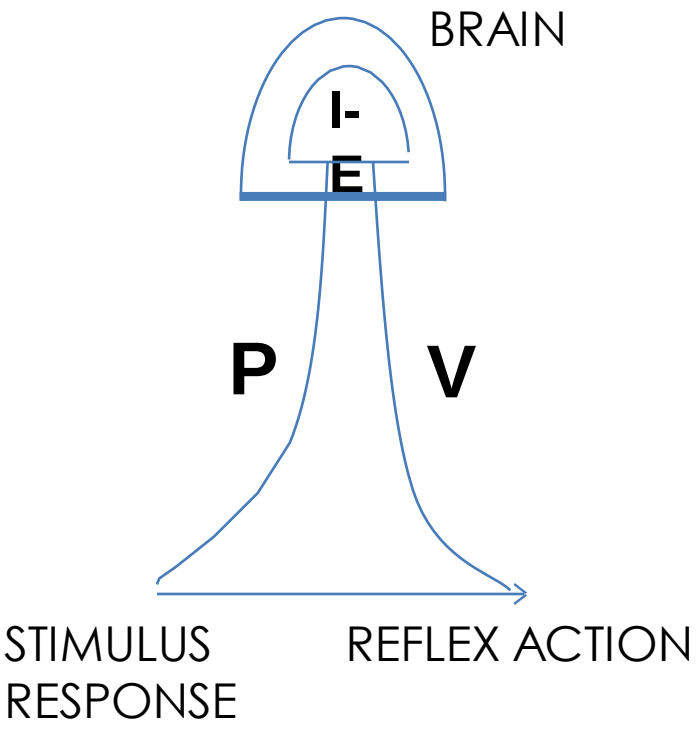
Brake reaction time:

- The brake reaction also depends on several factor including the skill of the driver, the type of the problems and various other environment factor.
- Total reaction time of driver can be calculated by "PIEV" theory

“PIEV” Theory

Total reaction time of driver is split into four parts:

- P-perception
- I-intellection
- E-Emotion
- V-Volition



- It is the time elapsed during emotional sensation and disturbance such as fear, anger or any other motional feeling such as superstition etc, with reference to the situation.

  Volition:

- It is the time taken for the final action

Analysis of SSD

- The stopping sight distance is the sum of lag distance and the braking distance.

Lag distance:

- It is the distance, the vehicle traveled during the reaction time
- If ‘V’ is the design speed in m/sec and ‘t’ is the total reaction time of the driver in seconds,

Braking distance

- It is the distance traveled by the vehicle after the application of brake. For a level road this is obtained by equating the work done in stopping the vehicle and the kinetic energy of the vehicle.
- work done against friction force in stopping the vehicle is $F \times l = f W l$, where W is the total weight of the vehicle.

Analysisof OSD

- D1 is the distance traveled by overtaking vehicle "A" during the reaction time t sec of the driver from position A1 to A2.
- D2 is the distance traveled by the vehicle A from A2 to A3 during the actual overtaking operation, in time T sec.
- D3 is the distance traveled by on-coming vehicle C from C1 to C2 during the over taking operation of A, i.e. T sec.
- B is the overtaken or slow moving vehicle.

- B is the overtaken or slow moving vehicle moving with uniform speed Vb m/sec or Vb Kmph;
- C is a vehicle coming from opposite direction at the design speed V m/sec or V kmph
- The distance traveled by the vehicle Aduring this reaction time is d1 and is between the positions A1 and A2. this distance will be equal to Vb.t meter
- where t is the reaction time of the driver in second= 2 sec.

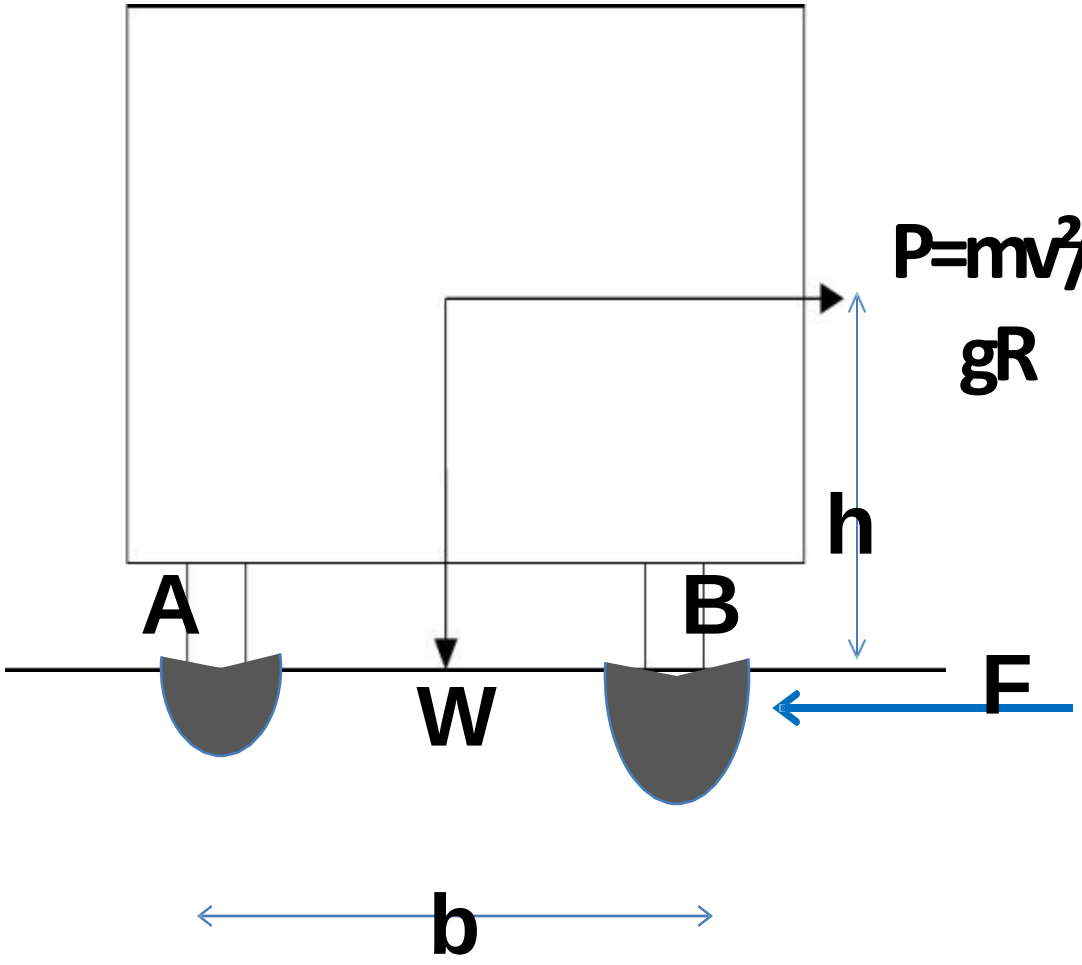
Photo: Dan Nabors, VHB

Horizontal

- A horizontal highway curve is a curve in plan to provide change in direction to the central line of a road. When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally outwards through the centre of gravity of the vehicle.
- **$P = W v^2 / gR$**

  Where,

  - P = centrifugal force, kg
  - W = weight of the vehicle, kg
  - R = radius of the circular curve, m
  - v = speed of vehicle, m/sec
  - g = acceleration due to gravity = 9.8 m/sec^2


P=mv²/
gR
h
A
B
W
F
b

Impact factor the centrifuge ratio is thus equal to $\mathbf{v^2/gR}$

- The centrifugal force acting on a vehicle negotiating a horizontal curve has two effects
- ➢ Tendency to overturn the vehicle outwards about the outer wheels
- ➢ Tendency to skid the vehicle laterally, outwards

Overturning effect

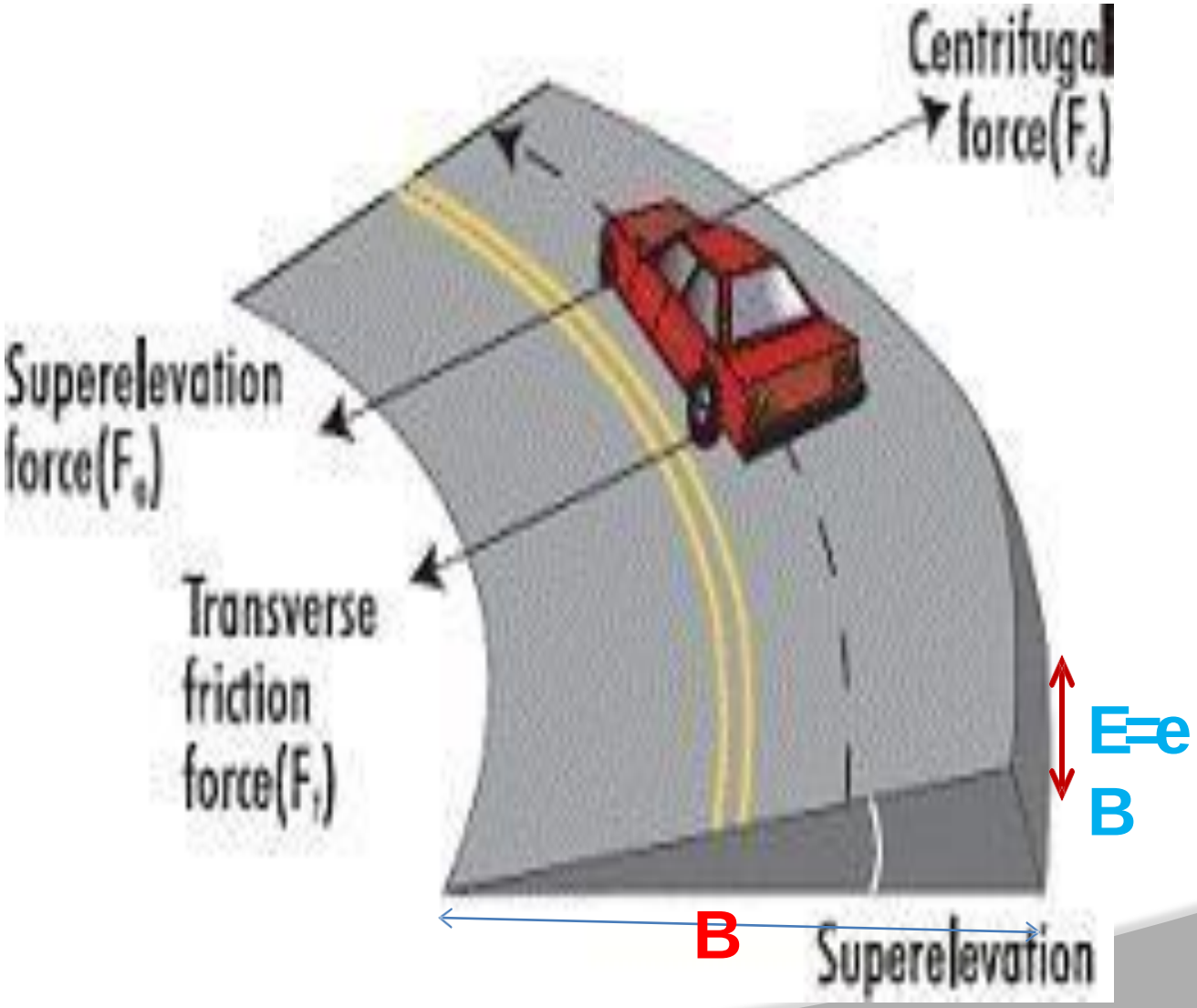
- The equilibrium condition for overturning will occur when Ph = Wb/2, or when P/W = b/2h. This means that there is danger of overturning when the centrifugal when the centrifugal ratio P/W or v^2/gR attains a values of b/2h.

Transverse skidding effect

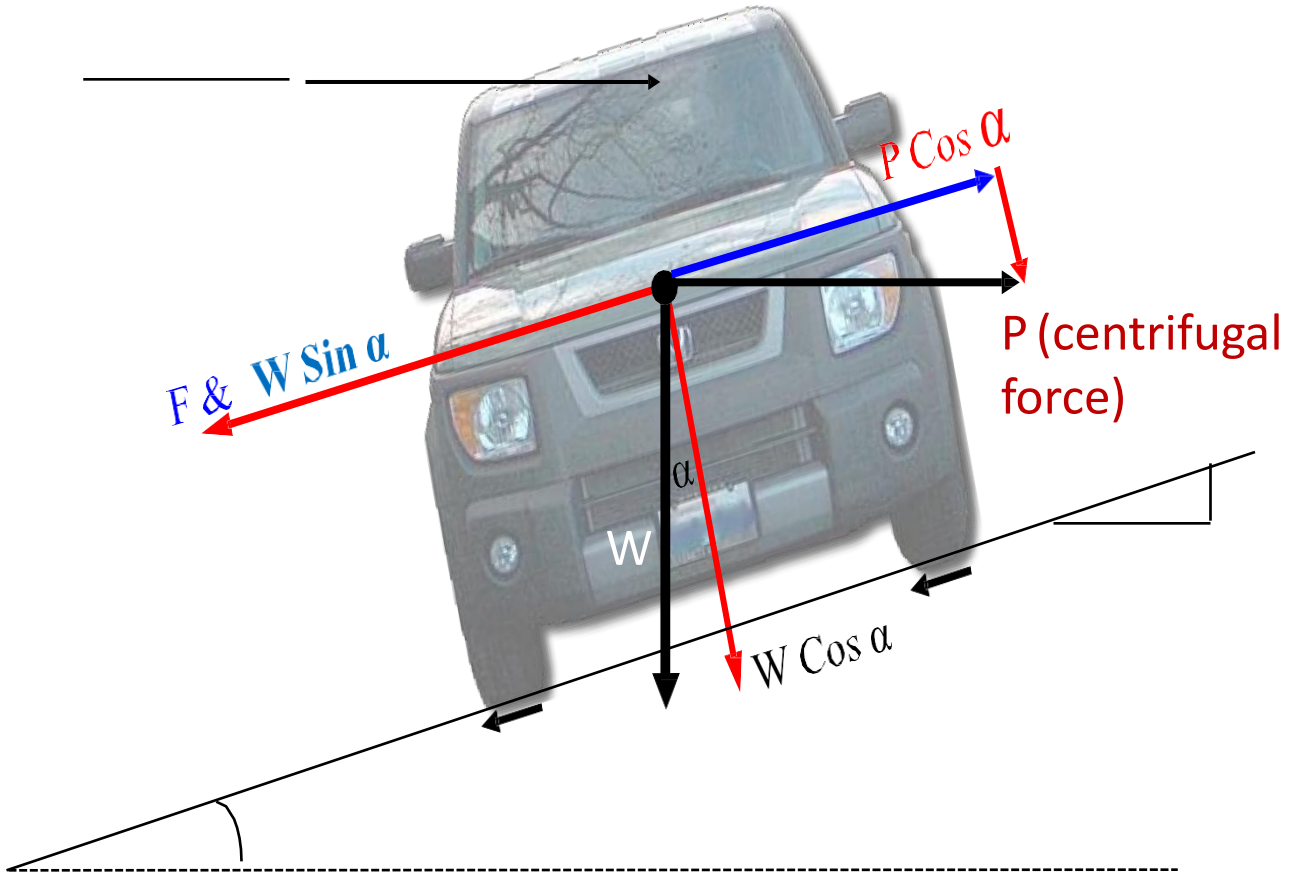
- P = FA+ FB= f(RA+RB) =fW
- Since P = f W, the centrifugal ratio P/W is equal to ‘f ‘. In other words when the centrifugal ratio attains a value equal to the coefficient of lateral friction there is a danger of lateral skidding.
- Thus to avoid overturning and lateral skidding on a horizontal curve, the centrifugal ratio should always be less than b/2h and also ‘f’
- ‘f’ is less than b/2h.-The vehicle would skid and not overturn
- b/2h is lower than ‘f’-The vehicle would overturn on the outer side before skidding

Superelevation

- In order to counteract the effect of centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to the inner edge, thus providing a transverse slope throughout the length of the horizontal curve, this transverse inclination to the pavement surface is known as Superelevation or cant or banking.
- The Superelevation ‘e’ is expressed as the ratio of the height of outer edge with respect to the horizontal width.


Centrifugal force(F_c)
Superelevation force(F_e)
Transverse friction force(F_t)
E=e
B
B
Superelevation

Super elevation



Analysis of Superelevation

- The force acting on the vehicle while moving on a circular curve of radius R meters, at speed of v m/sec are
- The centrifugal force $P = Wv^2/gR$ acting horizontal outwards through the centre of gravity, CG
- The weight W of the vehicle acting vertically downloads through the CG

- e = rate of Superelevation = tan Θ
- f = design value of lateral friction coefficient = 0.15
- v = speed of the vehicle, m/sec
- R = radius of the horizontal curve, mg = acceleration due to gravity = 9.8 m/sec²

Superelevation

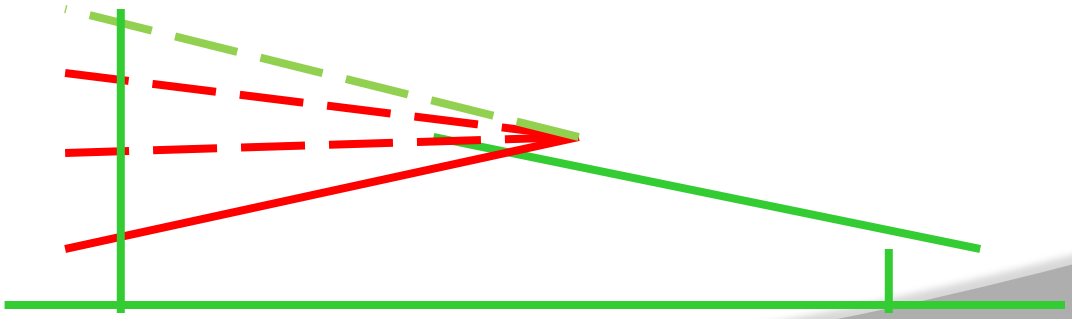
- From drainage consideration it is necessary to have a minimum cross slope to drain off the surface water. If the calculated Superelevation is equal to or less than the camber of the road surface, then the minimum Super elevation to be provided on horizontal curve may be limited to the camber of the surface.

Attainment of super elevation

Split-up into two parts

- Elimination of crown of the cambered section
- Rotation of pavement to attain full superelevation Elimination of crown of the cambered section

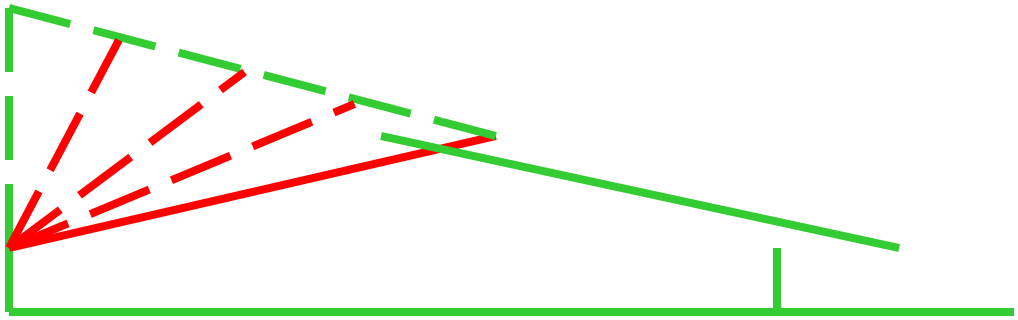
1st Method: Outer edge rotated about the crown



Attainment of superelevation

Disadvantages

- Small length of road – cross slope less than camber
- Drainage problem in outer half



Disadvantages

- Large negative superelevation on outer half
- Drivers have the tendency to run the vehicle along shiftedcrown

Attainment of superelevation

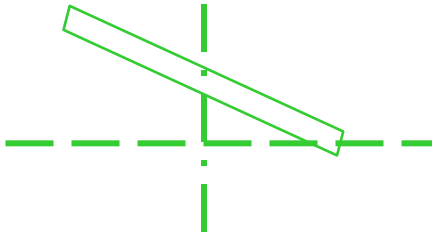
2nd Method: Rotation about the Inner edge (raising both the centre as well as outer edge – outer edge is raised by the total amount of superelevation)

Advantages

- No drainage problem

Disadvantages

- Additional earth filling
- C/L of the pavement is also raised (vertical alignment of the road is changed)



- Design the super elevation for a horizontal highway curve of radius 500m and speed 100kmph
- The design speed of highway is 80kmph. There is horizontal curve of radius 200m on a certain locality. Calculate the superelevation needed to maintain this speed.

Off tracking

- An automobile has a rigid wheel base and only the front wheels can be turned, when this vehicle takes a turn to negotiate a horizontal curve, the rear wheel do not follow the same path as that of the front wheels. This phenomenon is called off tracking.
- The required extra widening of the pavement at the horizontal curves depends on the length of the wheel base of the vehicle ‘l’, radius of the curve ‘R’ and the psychological factors.

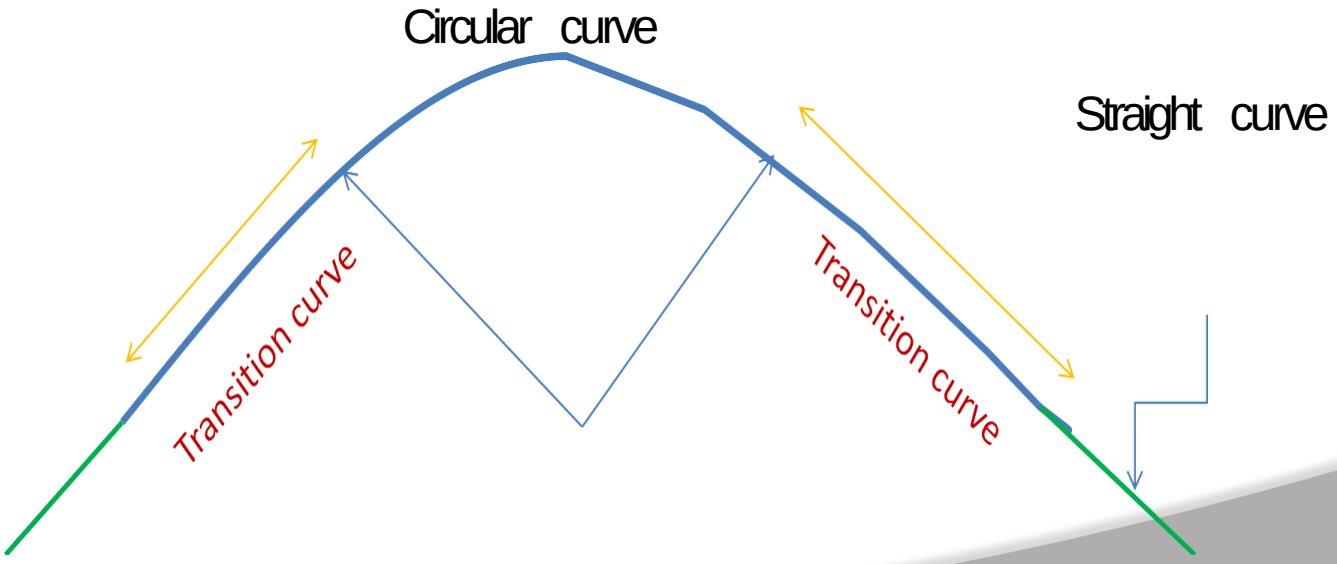
Where, R = Mean radius of the curve in m, n=no. of traffic lanes

R = Mean radius of the curve, m

l= Length of Wheel base of longest vehicle , m (l = 6.0 m or 6.1m for commercial vehicles)

Horizontal transition curves

- When a non circular curve is introduce between a straight and a circular curve has a varying radius which decreases from infinity at the straight end (tangent point) to the desired radius of the circular curve at the other end (curve point) for the gradual introduction of centrifugal force is known as transition curve.



Objectives for providing transition curve

- To introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, avoiding sudden jerk on the vehicle. This increases the comfort of passengers.
- To enable the driver turn the steering gradually for his own comfort and security
- To provide gradual introduction of super elevation
- To provide gradual introduction of extra widening.

- IRC recommends spiral as the transition curve because it fulfills the requirement of an ideal transition curve, that is rate of change or centrifugal acceleration is consistent
- Radius of the transition curve is infinity at the straight edge and changes to R at the curve point (Ls α1/R)and calculation and field implementation is very easy.

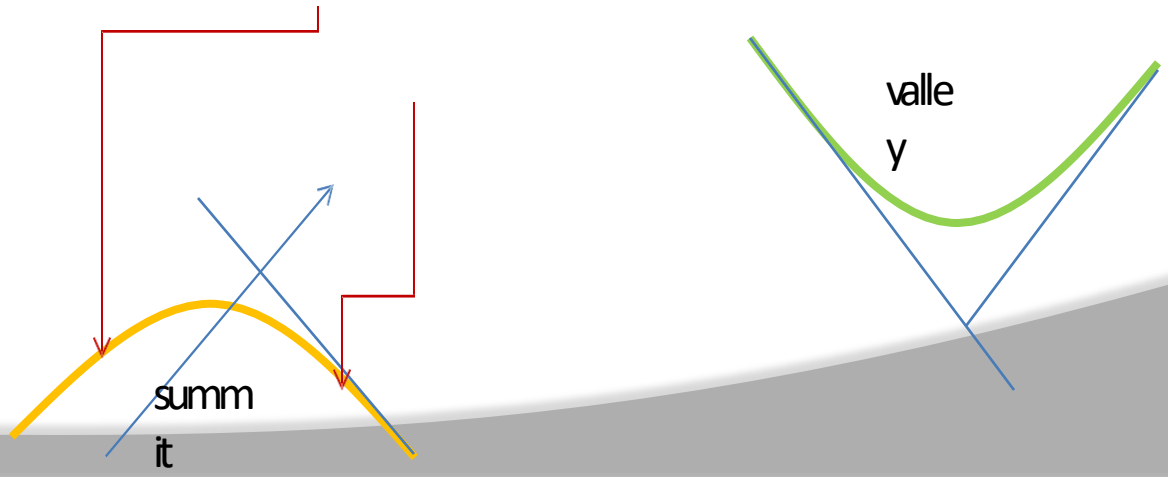
Vertical Alignment

The vertical alignment is the elevation or profile of the centre line of the road.

The vertical alignment consist of grade and vertical curve and it influence the vehicle speed, acceleration, sight distance and comfort in vehicle movements at high speed.

Gradient

- It is the rate of rise or fall along the length of the road with respect to the horizontal. It is expressed as a ratio of 1 in x (1 vertical unit to x horizontal unit). Some times the gradient is also expressed as a percentage i.e. n% (n in 100).



Typical Gradients

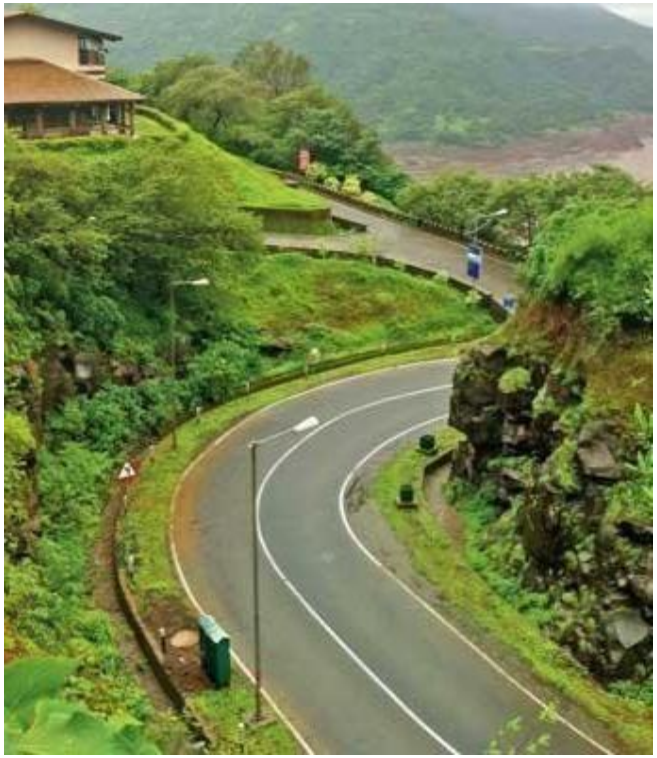
- Ruling Gradient
- Limiting Gradient
- Exceptional gradient
- Minimum Gradient
- Ruling gradient (design gradient):
- It is the maximum gradient within which the designer attempts to design the vertical profile of road, it depends on
- Type of terrain
  - Length of grade
  - Speed
  - Pulling power of vehicles
  - Presence of horizontal curves
  - Mixed traffic

Limiting Gradient

- Steeper than ruling gradient. In hilly roads, it may be frequently necessary to exceed ruling gradient and adopt limiting gradient, it depends on
  - Topography
  - Cost in constructing the road

.

- At the horizontal curve ,due to the turning angle α of the vehicle, the curve resistance develop is equal to T(1-Cos α). When there is a horizontal curve in addition to the gradient, there will be a increase in resistance to fraction due to both gradient and curve. It is necessary that in such cases the total resistance due to grade and the curve should not exceeded the resistance due to maximum value of the gradient specified.
- Maximum value generally taken as ruling gradient



UNIT– IIII
TRAFFIC ENGINEERING AND REGULATIONS

CLOs	Course Learning Outcomes
CLO 11	Study basics of traffic engineering and regulations.
CLO 12	Predict basic parameters of traffic, volume, speed and density, traffic volume studies.
CLO 13	Analyze Parking studies, on street and off street parking , road accidents , causes and preventive measures
CLO 14	Study and need for road markings, types of road markings, design of traffic signals, Webster method.

Traffic Engineering

It is the science of measuring traffic and travel, the study of the basic laws relating to traffic flow and generation and application of this knowledge to the professional practice of planning, designing and operating traffic systems to achieve safe and efficient movement of persons and goods.

Objective of traffic engineering:

- Achieve efficient ‘free and rapid’ flow of traffic
- Reduce the no. of accidents.

Various phases of traffic engineering are: (3E's)

- Engineering (constructive i.e. geometric design of road)
- Enforcement (traffic laws, regulation and control)
- Education (publicity and through school and television)

Scope of traffic engineering

- Traffic characteristics:-improvement of traffic facilities (vehicle , human[road user])
- Traffic studies and analysis
- Traffic operation-control and regulation:- laws of speed limit, installation of traffic control device
- Planning and analysis
- Geometric design:-Horizontal and vertical curve design
- Administration and management:- ‘3E’concept

Traffic characteristics

- Road user characteristics
  - Physical
  - Mental
  - Psychological
  - Environmental
- Vehicular characteristics
  - Vehicle dimension
  - Weight of loaded vehicle
  - Power of vehicle
  - Speed of vehicle
  - Braking characteristics

Road user characteristics

- Physical characteristics: The permanent physical characteristics of the driver are vision, hearing, strength and the general reaction to the traffic situations.
- Mental Characteristics: Knowledge, skill, intelligence, experience and literacy can affect the road user characteristics.
- Psychological factors: These effect reaction to traffic situations of road users to a great extent. Attentiveness, anger, fear, anxiety, phobias, superstition, and impatience may effect the traffic performance to great extent.
- Environment factors: The various environmental conditions affecting the behavior of road user are traffic stream characteristics, facilities to the traffic, atmospheric conditions and locality.

Vehicular characteristics

Static Characteristics

- Design vehicle: the selected representative vehicle for the geometric design.
- Vehicle weight is important for the determination of pavement depths and maximum grades.

Dynamics characteristics of vehicles affecting road design are speed, acceleration and braking characteristics and some aspects of vehicle design.

- Power of vehicle: The power of the heaviest vehicles and their loaded weights govern the permissible and limiting values of gradient on roads.

Traffic studies

These studies helps in deciding the geometric design features traffic control for save and efficient traffic movement.

- The various traffic survey studies generally carried out are:
  - ✓ Traffic volume study
  - ✓ Speed study
  - ✓ Spot speed study
  - ✓ Speed and delay study
  - ✓ Origin and destination study
  - ✓ Traffic flow characteristics
  - ✓ Traffic capacity study
  - ✓ Parking study
  - ✓ Accident studies

Traffic volume study

- It is the number of vehicles crossing a section of road per unit time at any selected period.
- It is used as a quantity measure of flow: the commonly units are vehicles/day or vehicles/hour
- The objects and the uses of traffic volume study are:

➢ It is generally accepted as a true measure of the relative importance of roads and in deciding the priority for improvement and expansion.

➢ It is used in planning, traffic operation and control of existing facilities and also for planning the new facilities.

- It is used in the analysis of traffic patterns and trends.
- Useful in structural design of pavement
- Used in planning one-way streets and other regulatory measure.
- Turning movement study used in the design of intersections, in planning signal timings, channelization and control devices.
- Pedestrian traffic volume study is used for planning side walk, cross walks, subway and pedestrian signals.

Counting of traffic volume

- Mechanical count
- ➢ These may be fixed type or portable type, it is automatically record the total number of vehicle crossing a section of the road in a desired period.
- ➢ Other methods of working the mechanical detectors are by videos, radar detector.
- ➢ Advantage is that it can work throughout the day and night for the desired period.
- Manual count
- ➢ It is possible to obtain data which can not be collected by mechanical counter such as vehicle classification, turning movement.

equipments used for automatic counting methods

Figure : Electronic Counting Boards

Presentation oftraffic volume data

- Av8erage annual flow: (veh/year)
- Annual average daily traffic(AADT or ADT): Average daily traffic (ADT) represents the total traffic for a year divided by 365, or the average traffic volume per day.(veh/day)
- Hourly average traffic: (veh/hr)
- Thirtieth highest hourly volume or the design hourly volume is found from the plot between hourly volume and the number of hours in a year that the traffic volume is exceeded. The 30th highest hourly volume is the hourly volume that will be exceeded only 29 times in a year and all other hourly volumes of the years will be less than this volume. The 30th highest traffic volume is found to be satisfactory from both facility and economic considerations.

SPEED STUDY

- Spotspeed:- it is the instantaneous speed of a vehicle at a specified location.
- Average speed:- it is the average of spot speed of all vehicles passing at given points on the highway.
- Space mean speed:- (harmonic mean)Average speed of vehicles in a certain road length.

Given In stant.

$$V_s = \frac{n}{\sum_{i=1}^{n} \frac{1}{V_i}}$$

$$V_s = \frac{\sum n\ L}{\sum_{i=1}^{n} t_i}$$

$$V_t = \frac{\sum_{i=1}^{n} V_i}{n}$$

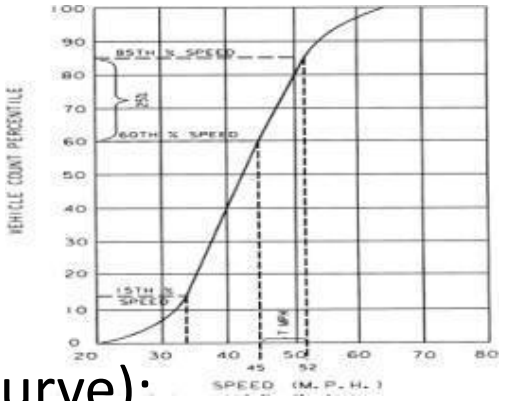
- Running speed:- it is the average speed maintained by a vehicle over a particular stretch of road, while the vehicle is in motion ; this is obtained by dividing the distance covered by the time during which the vehicle is actually in motion.
- Journey speed or travel speed:- it is the effective speed with which a vehicle traverse a particulars route between two terminals, it includes delay and stoppages.

Speed and delay study

- It gives the information such as the amount, location, duration and cause of delay in the traffic stream.
- The result of the spot and delay studies are useful in detecting the spot of congestion.
- The delay or time lost traffic during the travel period may be either due to fixed delays or operational delays.
- Fixed delay occurs primarily at intersections due to traffic signals and at level crossings.
- Operational delays are caused by the interference of traffic movement, such as turning vehicles, parking vehicles, pedestrian etc.

Presentation of spot speed data

- A graph is plotted with the average value of each speed group on X-axis and the cumulative percent of vehicles travelled at or below the different speeds on Y-axis. From the graph(i.e. Cumulative frequency distribution curve) followings can be obtained.



- 98th percentile speed-Design speed
- 85th percentile speed-Maximum speed
- 50th percentile speed-Median speed
- 15th percentile speed-Minimum speed

- Modal average speed(frequency distribution curve):
  - A frequency curve of spot speed is plotted with average value of each speed group of vehicle in X-axis and the percentage of vehicle in that group on the Y-axis.
  - The speed corresponding to peak value of curve is denoted as modal speed

Methods of speed and delay study

- Floating car or riding check method
- License plate or vehicle number method
- Interview method
- Elevated observations
- Photographic technique

- **Photographic Method:**

  This method is applicable to a short test section like intersection.

- **InterviewMethod:**

  In this method, the work can be completed in a short time by interviewing and collecting details from road users on the spot. However, the data collected may not provide with all the details correctly.

Origin and destinationstudies

- The objectofthisstudyis
  - Plantheroadnetworkandotherfacilitiesforvehiculartraffic
  - Plantheschedule ofdifferentmodesoftransportationforthe trip demand of commuters.
- It gives the information like the actual direction of travel, selection of routes and length of trip.
- Used in planning new highway facilities and in improving some of the existing system.
- To plan the transportation system and mass transit facilities in cities including route and schedules of operation
- To locate expressway or major routes along the desire lines.
- To locate terminals and to plan terminal facilities.

- To locate new bridge as per traffic demands.
- To locate intermediate stops of public transport. Methods of ‘O’ and ‘D’ survey:
- Road-side interview method
- Licenseplatemethod
- Return post card method
- Tag-on-car method
- Home interview method

Road side interview

Road side interview involves stopping vehicles into a designated interview area and asking a series of short questions.

- The information collected include place and time of origin and destination, purpose of trip etc.
- The dis advantage of this method is that it may be difficult to implement due to traffic disruption especially in urban areas

License Plate Method

License plate survey consists of noting the registration numbers of vehicles entering or leaving an area at survey points located on the cordon line.

By matching the registration numbers of vehicles at the points of entry and exit from the area, one is enabled to identify 2 points on the paths of the vehicle.

Traffic flow characteristics andstudies

- The basictraffic maneuversare diverging, merging, crossing andweaving.
- Traffic Flow(q):-the rate at which vehicles pass at a fix point (vehicles per hour)=N(3600/t).
- Traffic Density(k):-no. of vehicles(N) over a stretch of roadway(L) i.e. vehicles per kilometer = N/L
- Time headway:- Time interval between the passage ofthe fronts of the successive vehicles at a specified point.

- Average time headway= average travel time per unit distance x average space headway

  Space headway:- distance between front of successive vehicles.

  - Average space headway= space mean speed x average time headway

  Flow Density Relationship

- Flow= density x space mean speed
  - ❖ q= K x V
- Density= 1/ space headway
  - ❖ 1/hs
- Space mean speed = flow x Space headway
  - ❖ q x hs
- Density= flow x time per unit distance
  - ❖ K= q x t

Traffic capacity studies

Traffic capacity:

- The ability of a roadway to accommodate traffic volume. It is expressed as the maximum number of vehicle in a lane or a road that can pass a given point in unit time, usually an hour.
- Volume represent an actual rate of flow where as capacity indicates a maximum rate of flow with a certain level of service.

Basic capacity:

- It is the maximum no. of passenger car that can be pass a given point on a roadway during one hour under the most nearly ideal roadway and traffic conditions. It is otherwise known as theoretical capacity.

Possible capacity

- It is the maximum no. vehicle that can pass a given point on a roadway during one hour under prevailing roadway and traffic conditions.

Practical capacity:

- It is the maximum no. of vehicle that can pass a given point on a roadway during one hour, without traffic density being so great as to cause unreasonable delay, hazard or restriction to the driver freedom to maneuver under the prevailing roadway and traffic conditions.
- C=1000 V/S
- S= average spacing of vehicle in m, C is the capacity in vehicle per hour per lane.

Factors Affecting Practical Capacity

- Lane width – A width of 3.65 m is considered ideal for smooth flow.
- Smaller widths than this will reduce the capacity up to 25 per cent. Distance from the edge of the carriageway to an obstruction is also an important factor which can affect capacity.
- Lateral clearance – Lateral obstructions may be abutments such as sign posts, light poles and parked cars; if these are located closer than
- 1.83 m from the edge of a traffic lane, it reduces the capacity
- Shoulders – They help to maintain traffic flow. Paved shoulders of
- 1.2 m width increase the effective width of the lane by 0.3m.
- Horizontal alignment – Sharp curves and restrictive sight distances are also factors which tend to reduce lane capacity. The highway capacity manual contains tables to account for the influence of these factors on capacity.
- Intersections-at-grade – These affect the capacity significantly.

Peak-Hour Factor

- It is basically represent the variation in traffic flow with in an hour.
- Observations of traffic flow consistently indicate that the flow rates are found in the peak.
- A 15 minute period within an hour is not sustained through out the entire period and that is why we need to use the peak-hour factor.
- Normally on freeways the peak-hour factor values range from 0.80 to 0.95.

PCU value depends upon the several factors

- Vehicle characteristics
- Transverse and longitudinal gaps or clearance between moving vehicles.
- Speed distribution of the mixed traffic stream, volume to capacity ratio.
- Roadway characteristics.
- Regulation and control of traffic.
- Environmental and climatic conditions.

LEVEL OF SERVICES

- It is define as a qualitative measure describing the operational condition within a traffic stream, and their perception by motorist and passengers. Or Rating of acceptable level of congestion
- LOS definitions
  - A: Free flow, low traffic, high speed
  - B: Stable flow, noticeable traffic
  - C: Stable flow, traffic interactions,
  - D: Unstable flow, High density, movement restrictions
  - E: Unstable flow, lower speed, volume is nearly equal to capacity, little freedom
  - F: Unstable flow, no freedom, traffic volume can drop to zero, stop & go

LOS-A

- ✓ Free-flow operation
- ✓ no restriction in maneuvering.

LOS- B

- ✓ Reasonably free flow
- ✓ Ability to maneuver is only slightly restricted
- ✓ Effects of minor incidents still easily absorbed

- ✓ Speeds at or near FFS
- ✓ Freedom to maneuver is noticeably restricted
- ✓ Queues may form behind any significant blockage.

LOS- C

- ✓ Speeds decline slightly with increasing flows
- ✓ Density increases more quickly
- ✓ Freedom to maneuver is more noticeably limited
- ✓ Minor incidents create queuing

LOS- E

- ✓ Operation near or at capacity
- ✓ No usable gaps in the traffic stream
- ✓ Operations extremely volatile
- ✓ Any disruption causes queuing

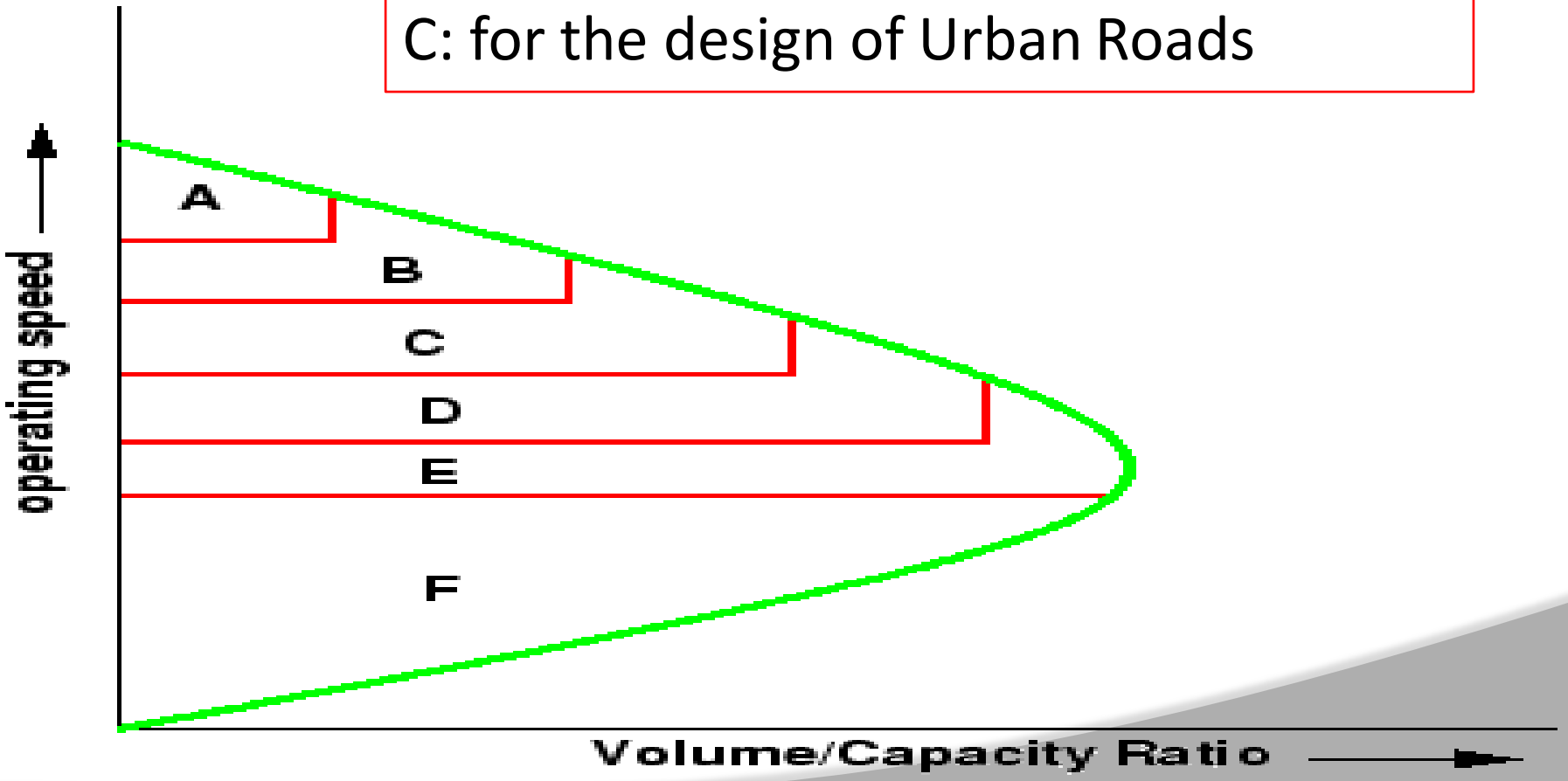
LOS- F

- ✓ Breakdown in flow
- ✓ Queues form behind breakdown points
- ✓ Demand > capacity

In India, As perIRC

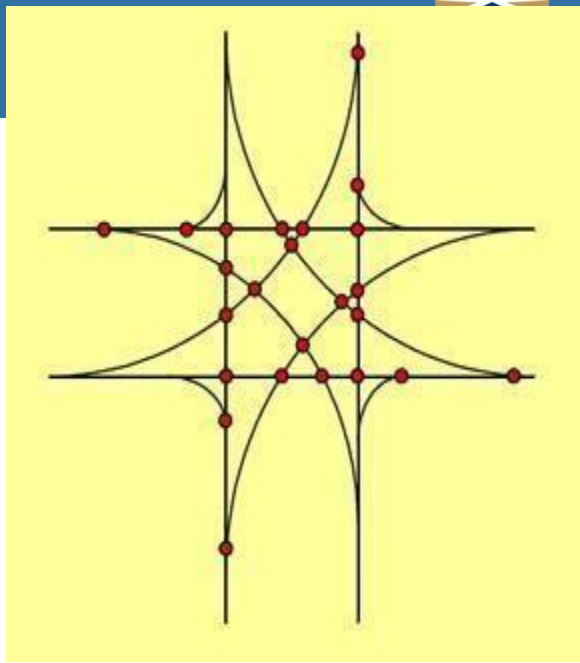
LOS- B: for design of Rural Roads LOS-

C: for the design of Urban Roads



Traffic operations

- Number of conflicts at intersection
  - Crossingconflicts
  - Mergingconflicts
  - Divergingconflicts



Number of lanes		Number of potential conflicts		
Road-A	Road-B	Both road two-way	A- One way B-two way	Both roads One way
2	2	24	11	6
2	3	24	11	8
2	4	32	17	10
3	3	24	13	11
4	4	44	25	18

UNIT– IV
INTERSECTION DESIGN

CLOs	Course Learning Outcomes
CLO 15	Understand types of Intersections, conflicts at intersections, requirements of at-grade intersection.
CLO 16	Understand types of at grade intersections, canalization traffic islands, types of grade separated intersections, rotary intersection.
CLO 17	Study concept of rotary, design factors of rotary, advantages and limitations of rotary intersections.

Intersection Design

Types of Intersections – Conflicts at Intersections-Requirements of At –Grade intersection- Types of at-Grade Intersections-Channelization -Traffic Islands - Types of Grade Separated Intersections- Rotary Intersection –concept of Rotary-Design factors of rotary-Advantages and limitations of rotary intersections

Operational Requirements

- Provide adequate sight distance – for approach and departure maneuvers
- Minimize turning and through conflicts
- Provide natural paths for permitted movements
- Avoid geometry (sharp curves/steep grades) that complicates the driving task and adversely impacts acceleration or deceleration

Sight Triangle

- Area free of obstructions necessary to complete maneuver and avoid collision – needed for approach and departure (from stop sign for example)
- Consider horizontal as well as vertical, object below driver eye height may not be an obstruction
- AASHTO assumes 3.5’ above roadway

ISD Cases

- No control: vehicles adjustspeed
- Stop control: where traffic on minor roadway must stop prior to entering major roadway
- Yield control: vehicles on minor roadway must yield to major roadway traffic
- Signal control: where vehicles on all approaches are required to stop by either a stop sign or traffic signal
- All way stop
- Stopped major roadway left-turn vehicles – must yield to oncoming traffic

Case B – Stop Control

- Three Sub Cases – Maneuvers
- Turn left on to major roadway (clear traffic left, enter traffic right)
- Turn right on to major roadway (enter traffic from left)
- Crossing (clear traffic left/right)

Case B – Stop Control

- Need ISD for departure and completion even if vehicle comes into view at point of departure = 1.47 $V_{major} * t_g$ where gap time, t_g**=7.5-11.5s**;
- add more time for grade or multilane;
- decrease by 1s. for right turns

UNIT– V
HIGHWAY MATERIAL CHARACTERIZATION

CLOs	Course Learning Outcomes
CLO 18	Understand Highway material characterization; sub grade soil, stone aggregate.
CLO 19	Explain construction of water bound macadam roads, construction of bituminous pavements.
CLO 20	Study surface dressing, bitumen bound macadam, bituminous concrete.
CLO 21	Study various types of bitumen materials, construction of gravel roads.
CLO 22	Understand construction of cement concrete pavements, construction of joints in cement concrete pavements joint filter.
CLO 23	Analyze seal pavement failures, maintenance of highways.

Function and Significance of Subgrade Properties

- Basement soil of road bed.
- Important for structural and pavement life.
- Should not deflect excessively due to dynamic loading.
- May be in fill or embankment.
- Compacted or Natural Subgrade

Subgrade Soil

- Granular or Coarse grained
- Fine Grained
- Organic

Properties Associated with Subgrade Soil

- Volume change with water.
- Load - Sustaining Power.
- Compression under static load.
- Workability during wet periods.
- Ease of drainage.
- Compactibility.

Desirable Properties of Soil as Subgrade

- Stability.
- Incompressibility.
- Minimum changes in volume and stability under adverse condition of weather and ground water.
- Permanency of strength.
- Good drainage.
- Ease of compaction.

- HRB (AASHO) classification
- Public Roads (PR -1928) A1-A7
- Group Index (GI)

A function of material passing through 200 mesh sieve(0.74mm)

$$GI = 0.2a + 0.005ac + 0.01bd \quad \text{Min}$$

GI = 0;

Max GI = 20; when passing 200 mesh sieve, LL and PI are 75,60 and 30 resp.

Higher GI = poorer soil as subgrade material A-6(4), A-6(16)

GROUND INDEX

Value of GI	Soil Condition
0	Excellent
1	Good
2 – 4	Fair
5 - 9	Poor
10 - 20	Very Poor

Subgrade Soil Strength

- Soil type
- Moisture Content
- Dry Density
- Internal Structure of the soil
- Type and Mode of Stress Application.

Tests

FOR SUBGRADE SOIL/ EMBANKMENT

- Grain size analysis.
- Proctor compaction (Both light & heavy)
- California Bearing Ratio (CBR)
- Differential Free swell (DFS)
- Liquid Limit (L.L.) & Plastic Limit (P.L.)

FOR SUB BASE / ADMIXTURE

- Grain size Analysis.
- Proctor compaction (Both light & heavy)
- California Bearing Ratio (CBR)
- Differential Free swell (DFS)
- Liquid Limit (L.L.) & Plastic Limit (P.L.)

Moisture Content

- Water table
- Precipitation
- Soil Permeability
- Drainage conditions
- Extent to which pavement is water proof

Evaluation of Strength of Subgrade Soil

- Shear Test
- direct shear test, triaxial compression test, and unconfined compression test.
- Bearing Test
- Penetration Test

California Bearing Ratio Test

- A penetration test wherein a standard piston, having an area of 3 in (or 50 mm diameter), is used to penetrate the soil at a standard rate of 1.25 mm/minute.
- The pressure up to a penetration of 12.5 mm and it's ratio to the bearing value of a standard crushed rock is termed as the CBR.

TEST ON AGGREGATES

1. Aggregate Impact Test
2. Flakiness and Elongation Test
3. Angularity Index Test
4. Los Angeles Abrasion Test
5. Water Absorption Test
6. Specific Gravity Test
7. Soundness Test

- Bitumen: distillation of petroleum crude.
- Tar: Destructive distillation of coal or wood.
- Paving grade: air fields, roads.
- Industrial grades: water proofing of structures, industrial floors, etc.

Density of Materials of Embankment and Subgrade

Type of Work	Maximum Dry Density withheavy Compaction – IS: 2720 (Part 8)
Embankment up to 3 m height, not subjected to extensive flooding.	Not less than 15.2 kN/cu. m
Embankments exceeding 3m height or embankments of any height subject to long periods of inundation.	Not less than 16.0 kN/cu. m
Subgrade and earthen shoulders/verges/backfill.	Not less than 17.5 kN/cu. m

Compaction of Embankment and Subgrade

Type of Work	Relative Compaction as percentage of max. laboratory dry density - IS:2720 (Part 8)
Subgrade and earthen shoulders	Not less than 97
Embankment	Not less than 95
Expansive Clays (of acceptableFSI) (a)Subgrade and 500 mm portionjust below the subgrade. (b)Remaining portion of Embankment	Not allowed Not less than 90

Construction Operation

- Setting out the alignment.
- Dewatering
- Compacting ground to support embankment / subgrade
- Spreading of materials and moisture content

Construction of WBM

- Constructed of twelve inches of stone over all.
- An eight-inch foundation is provided of hard quarry stone, laid on edge, with the longest dimension placed at a right angle to the side line of the drive.
- After the stones are placed they should be cleared of the irregular edges using hammer
- The pieces of stone so broken off should be used to fill in chinks.

Soft aggregates in WBM

- Overburnt brick metal
- Naturally occurring soft agg – kankar, laterite
- Crushed slag from blast furnace

Screening

- For filling the voids in compacted layer
- IRC suggests use of non plastic material – kankar, moorum or gravel.
- Should satisfy:
  - LL , 20%
  - PI , 6%
  - Portion of fines passing 0.075mm size sieve , 10%

Binding Material

- To prevent raveling and rubbing between aggregates
- Grained material
- PI 4 to 9 % (surfacing Course)
- PI , 6% (with sub base and base course with bituminous surfacing course)
- No binding material for moorum and Gravel (low PI)


Thank you