Highway Engineering.

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,elevetor,ropeway… etc.

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

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 ¼ to 1/5 of that required by road.
- Safety

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

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

ROLE /IMPACT OF TRANSPORTATION

- Economic Development
- Social Development
- Spatial Development
- Cultural Development
- Political Development

Characteristics of road transport

- Roads are used by various types of road vehicles, like passenger cars, buses, trucks, pedal cycle and animal drawn vehicle.
- It requires a relatively small investment for the government.
- It offers a complete freedom to road users to transfer the vehicle from one lane to another and from one road to another according to need and convenience.
- Speed and movement is directly related with the severity of accident.
- Road transport is the only means of transport that offers itself to the whole community alike.

HISTORICAL DEVELOPMENT OF ROAD CONSTRUCTION

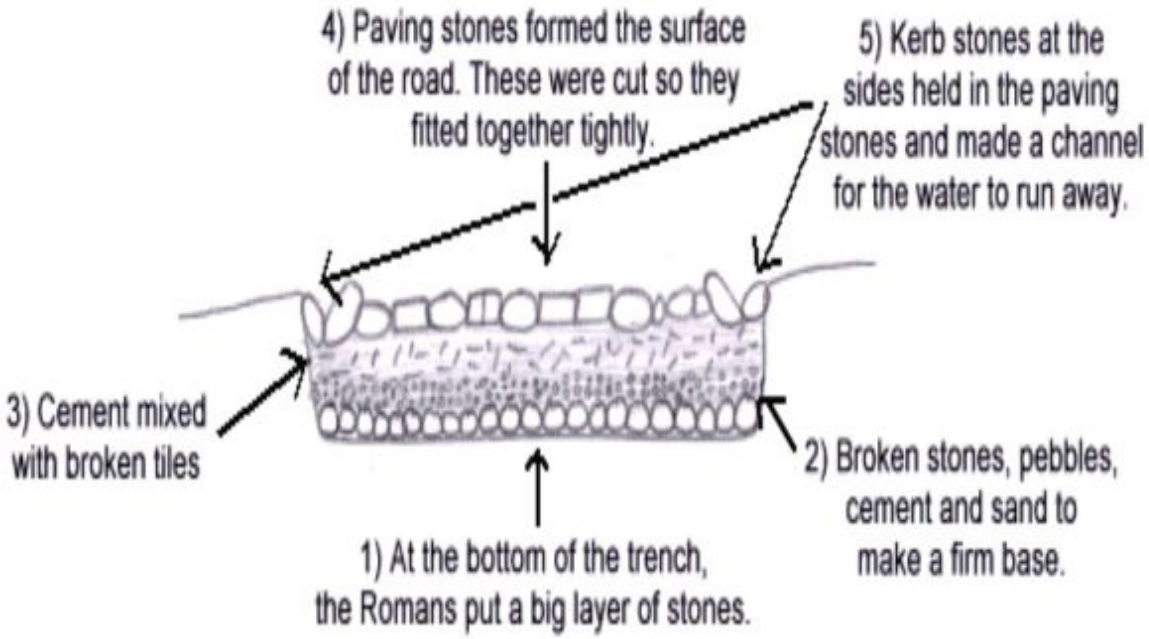
- Oldest mode
  - Foot paths- animal ways, cart path……..
- As civilization evolved the need for transportation increased

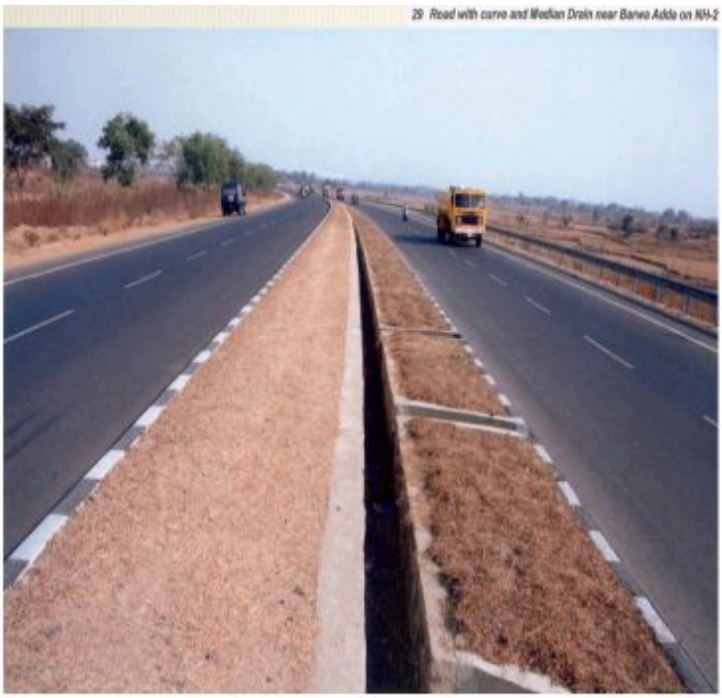
ROMAN ROAD-(500 B.C.)

- They were built straight regardless of gradient
- They were built after the soft soil was removed and a hard stratum was reached.
- Thickness varies from 0.75 m to 1.2m

Roman Road Construction

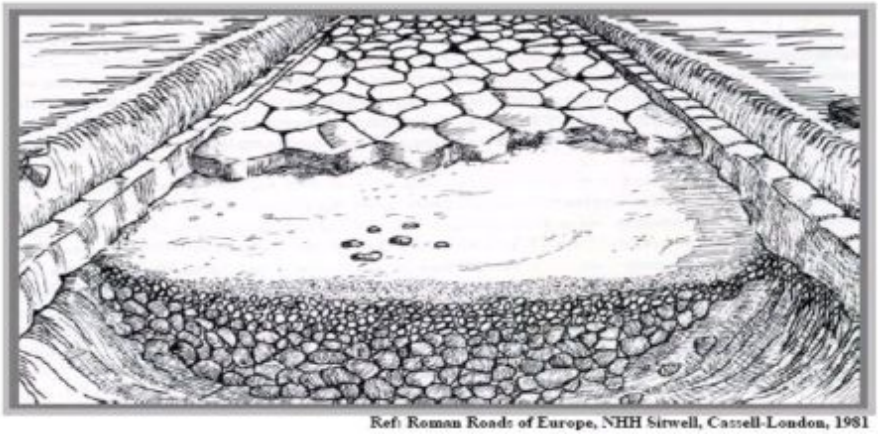
Basic cross section





Modern Highway

Roman Roads



Ref: Roman Roads of Europe, NHH Sirwell, Cassell-London, 1981

Other oldest road transport are

- Tresaguet construction
- Metcalf construction
- Telford construction
- Mecadam construction

Indian Roads

- India has a large road network of over 3.314 million kilometers of roadways (2.1 million miles), making it 3rd largest road network in the world.

- At 0.66 km of highway per square kilometer of land the density of India's highway network is higher than that of the United States (0.65) and far higher than that of China's (0.16) or Brazil's (0.20).

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)**

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. Jaykar 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 reveneu is to be retain as a central reveneu 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.

Central Road Fund , 1929

CRF Act , 2000

Distribution of 100% cess on petrol as follows:

- 57.5% for NH
- 30% for SH

} **MORTH**

- 12.5% for safety works on rail-Road crossing.

50% cess on diesel for Rural Road development

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 organisation in India and abroad.
- To collect and correlation services.
- To collect result 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)

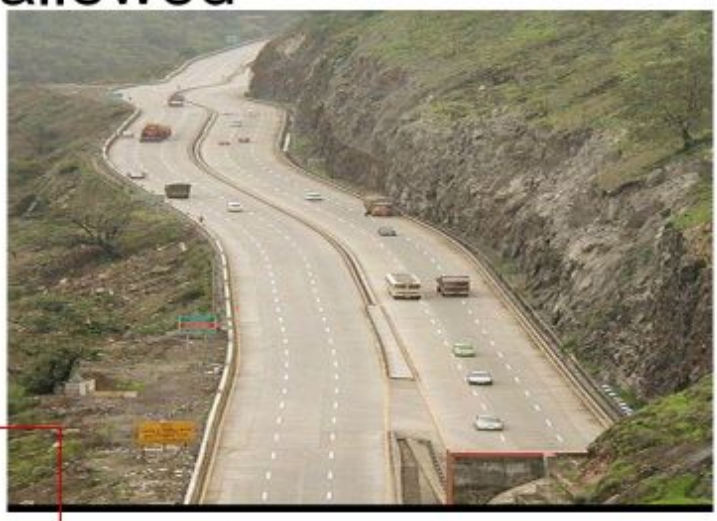
- National highway (NH)
- State highway (SH)
- Major district road (MDR)
- Other district road (ODR)
- Village road (VR)

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.



The Mumbai-Pune Expressway as seen from Khandala

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 Kı**
  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.

First 20-years road plan cont…

- The formulae were based on star and grid pattern of road network.
- An allowance of 15% is provided for agricultural industrial development during the next 20-years
- The length of railway track in the area was also consider in deciding the length of first category road. The length or railway track is directly subtracted from the estimated road length of metalled roads.

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 plans 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…

- the maximum distance from any place in a semi develop area would be 12.8 km from metalled road and 4.8 from any road
- 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
- 5% are to be provided for future development and unforeseen factor

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.

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

Factors controlling alignment cont...

Obligatory points

- Obligatory points through which alignment is to pass

  Examples:-bridge site, intermediate town , Mountain pass etc...

- 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

Economy

- Alignment finalised based on total cost including initial cost, maintenance cost and vehicle operation cost.

Other consideration

- Drainage consideration, political consideration
- Surface water level, high flood level
- Environmental consideration

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 and pavement materials

stability

- A common problem in hilly roads is land sliding
- The cutting and filling of the earth to construct the roads on hilly sides causes steepening of existing slope and affect its stability.

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.

Engineering Surveys for Highway locations

Before a highway alignment is finalised in highway project, the engineering survey are to be carried out. The various stages of engineering surveys are

- Map study (Provisional alignment Identification)
- Reconnaissance survey
- Preliminary survey
- Final location and detailed surveys

MAP STUDY

- From the map alternative routes can be suggested in the office, if the topographic map of that area is available.
- The probable alignment can be located on the map from the fallowing details available on the map.
  - Avoiding valleys, ponds or lake
  - Avoiding bend of river
  - If road has to cross a row of hills, possibility of crossing through mountain pass.
- Map study gives a rough guidance of the routes to be further surveyed in the field

RECONNAISSANCE SURVEY

- To confirm features indicated on map.
- To examine the general character of the area in field for deciding the most feasible routes for detailed studies.
- A survey party may inspect along the proposed alternative routes of the map in the field with very simple instrument like abney level, tangent clinometer, barometer etc.... To collect additional details.
- Details to be collected from alternative routes during this survey are,
  - Valleys, ponds, lakes, marshy land, hill, permanent structure and other obstruction.
  - Value of gradient, length of gradient and radius of curve.

RECONNAISSANCE SURVEY cont..

- Number and type of cross drainage structures.
- High Flood Level (HFL)
- Soil Characteristics.
- Geological features.
- source of construction materials- stone quarries, water sources.

- Prepare a report on merits and demerits of different alternative routs.
- As a result a few alternate alignments may be chosen for further study based on practical considerations observed at the site.

Preliminary survey

Objective of preliminary survey are:

- To survey the various alternative alignments proposed after the reconnaissance and to collect all the necessary physical information and detail of topography, drainage and soil.
- To compare the different proposals in view of the requirements of the good alignment.
- To estimate quantity of earthwork materials and other construction aspect and to workout the cost of the alternate proposals.

Methods of preliminary survey:

a) **Conventional approach**-survey party carries out surveys using the required field equipment, taking measurement, collecting topographical and other data and carrying out soil survey.

Preliminary survey cont…

- Longitudinal and cross sectional profile.
  - Plain Terrain` : 100 – 200m
  - Rolling Terrain : 50m
  - Hilly Terrain : 30m
- Other studies
  - Drainage, Hydrological survey, soil survey, Traffic and Material survey.

b) Modern rapid approach-

By Aerial survey taking the required aerial photographs for obtaining the necessary topographic and other maps including details of soil and geology.

- Finalise the best alignment from all considerations by comparative analysis of alternative routes.

Final location and detailed survey

- The alignment finalised at the design office after the preliminary survey is to be first located on the field by establishing the centre line.

Location survey:

- Transferring the alignment on to ground.
- This is done by transit theodolite.
- Major and minor control points are established on the ground and centre pegs are driven, checking the geometric design requirements.
- Centre line stacks are driven at suitable intervals, say 50m interval in plane and rolling terrains and 20m in hilly terrain.

Final location and detailed survey cont..

Detailed survey:

- Temporary bench marks are fixed at intervals of about 250m and at all drainage and under pass structure.
- Earthwork calculations and drainage details are to be workout from the level books.
- Cross sectional levels are taken at intervals of 50-100m in Plane terrain, 50-75m in Rolling terrain, 50m in built-up area, 20m in Hill terrain.
- Detail soil survey is to be carried out.
- CBR value of the soils along the alignment may be determined for design of pavement.
- The data during detailed survey should be elaborate and complete for preparing detailed plans, design and estimates of project.

Drawing and Report

- Key map
- Index map
- Preliminary survey plans
- Detailed plan and longitudinal section
- Detailed cross section
- Land acquisition plans
- Drawings of cross drainage and other retaining structures
- Drawings of road intersections
- Land plans showing quarries etc

New highway project

- Map study
- Reconnaissance survey
- Preliminary survey
- Location of final alignment
- Detailed survey
- Material survey
- Geometric and structural design
- Earth work
- Pavement construction
- Construction controls

HIGHWAY

Page No. 1

Highway Geometric Design :—

The geometric design of highway deals with the dimension and layouts of visible features of the highway such as alignment (horizontal, vertical), sight distance (stoping, over) and intersection.

→ Geometric of highway should be design to provide optimum efficiency in traffic operation with maximum safety reasonable cost.

Geometric design of highway deals with following elements :—

(i) Cross-section element
(ii) Sight distance consideration
(iii) Horizontal alignment
(iv) Vertical alignment
(v) Intersection element

Highway Cross-section Elements :—

Under highway cross-section element the consideration for the width of pavement formation and (land) the surface characteristics.

→ The pavement surface depends on the type of pavement which is decided based on the availability of the material

a single traffic lane.

→ The lane width is determine on the basis of the vechicle width & minm. side clearance, which is provided for the safety prerpose.

→ The maxm width of vechicle as per IRC (India road congress specifications) is 2.44m.

→ The width of carriage lane for various classes of road recommanded by IRC are given below:-

Class of Road	Width of carriage way
(i) Single lane	→ 3.75 m.
(ii) Two lane, without raised kerbs	→ 7.0 m.
(iii) Two lane, with raised kerbs	→ 7.5 m.
(iv) Intermediate Carriage way (except on imp. road)	→ 5.5 m.
(v) Multi-lane pavement	→ 3.5 m per lane

Traffic Separator / Median :-

Main function of traffic separator is to prevent head on collision on accident between vechicle moving in opposite dir?' or of the same p lane.

The separator may also help to
→ Channelized traffic into stream at intersection.
→ Shadow the crossing & turning traffic.
→ Seggregate slow traffic and to protect pedestrians.
→ Traffic separator used may be in the form of pavement marking, physical dividers or area separators.

KERB :-

The boundary between the pavement and soulder or sometime island or footpath or kerb parking space.
→ It is classified into 3 groups based on their functions.

(i) Low or mountable kerb :-

The ht of the kerb is about 10cm above the pavement edge.

This type of kerb is provided for longitudinal drainage system at median & channelization schemes.

(ii) Semi-barrier type kerb :—

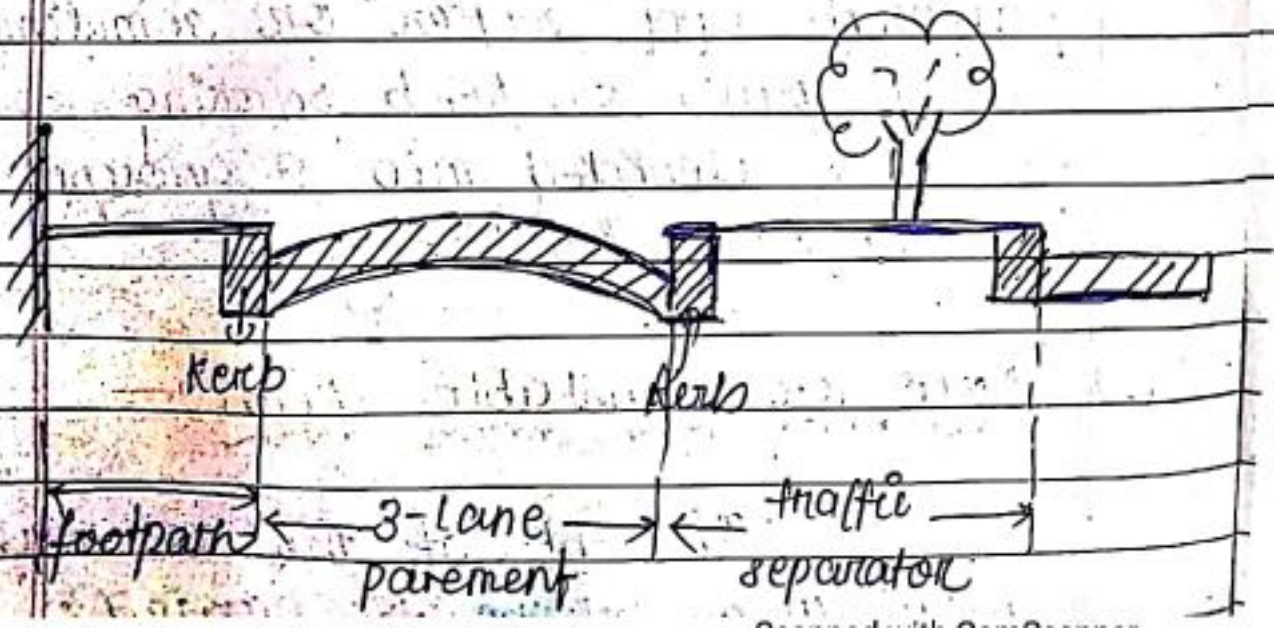
It is provided on the periphery of a roadway where pedestrian traffic is high or more.

→ this type of kerb has a ht of about 15cm above the pavement edge.

(iii) Barrier type curve :—

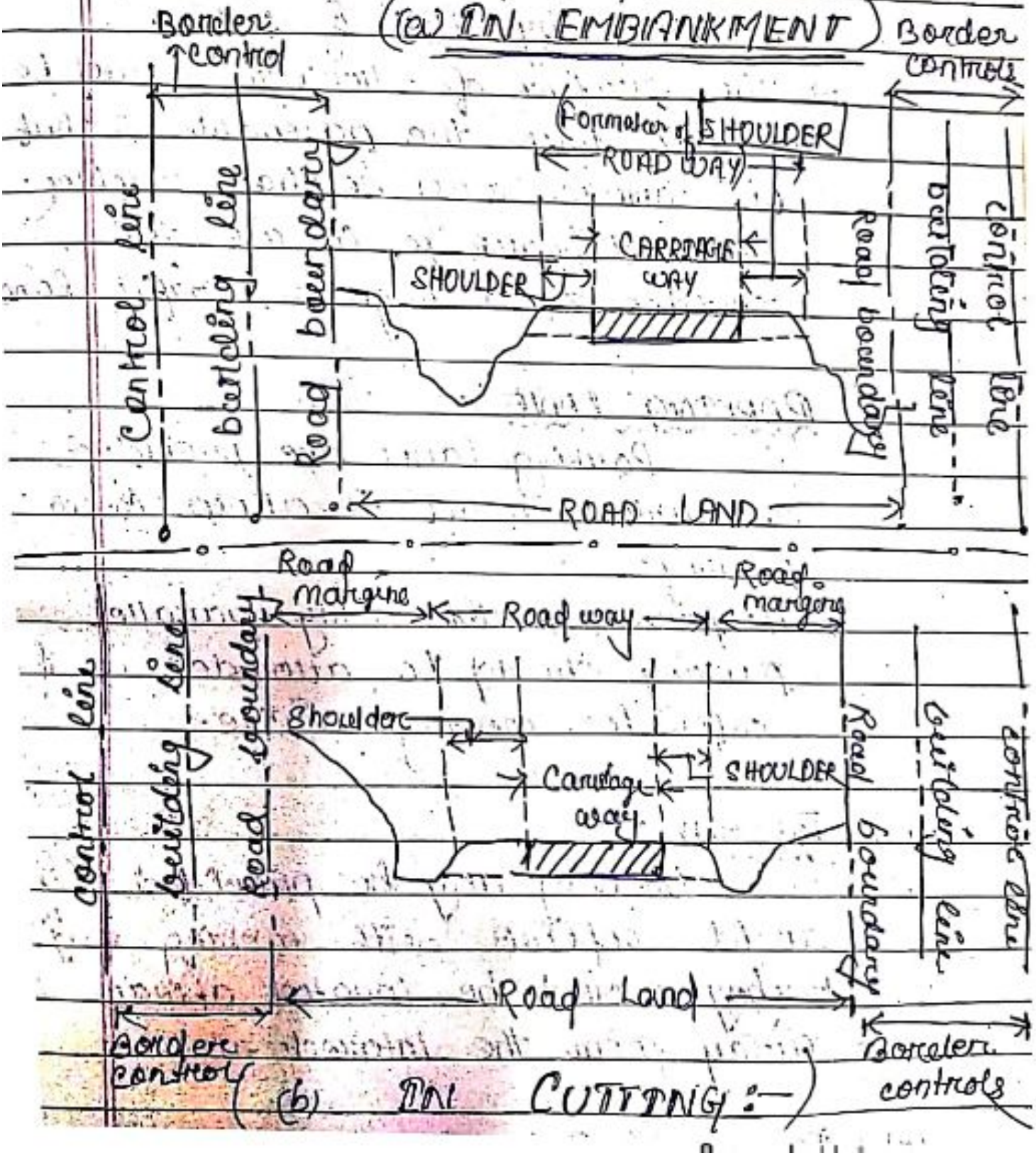
It is provided to build up area adjustant to footpath with considerable pedestrian traffic.

→ The ht of kerb is about 20 cm. non assessible for vehicle.



Road Margine :—

The various elements included in the road margines are shoulder, parking lane, frontage road, drive way cycle track, footpath, guard rail and embankment slope.



(1) SHOULDER :—

Soulders are provided along the road edge to serve as an emergency lane for vechle. Shoulder also act as service road for vechles that have broken down.

→ The minimum shoulder width recommended by IRC is 2.5 m.

→ The surface of shoulder should be roughen than the parement so that on carriage way so that vechles are discourage to use the soulder as a regular traffic lane.

(2) PARKING LANE :—

Parking lanes are provided on urban road to allow kerb parking.

→ As far as possible only parallel parking should be allowded as it is safer for moving vechle.

(3) BUSBAY :—

Bus bay may be provided to avoid conflicts with moving traffic. Busbay should be located atleast 75m away from the intersection.

to give access to properties along an important highway with controlled access to express way or free way

→ Frontage roads or service road or extra road or parallel road provided parallel to highway or express way.

→ It provide private passage for the other connecting small local road.

(5) DRIVE WAY :-

A drive way is a piece of hard ground that leads from the road to the front of a house or garriage.

→ Drive way connect the highway with commercial establishment like fuel stations, service station etc. Drive way should be properly design and located fairly away from an intersection.

(6) CYCLE TRACK :-

It is provided in urban areas where the volume of cycle traffic on the road is very high.

→ Normal width 2m.

(7) FOOTPATH :- (Side walk)

Footpath or side walks are provided in urban area when the

vehicular as well as pedestrian traffic are heavy, to provide protection to pedestrian and to decrease accident.

→ Min. width should be 1.5 m.

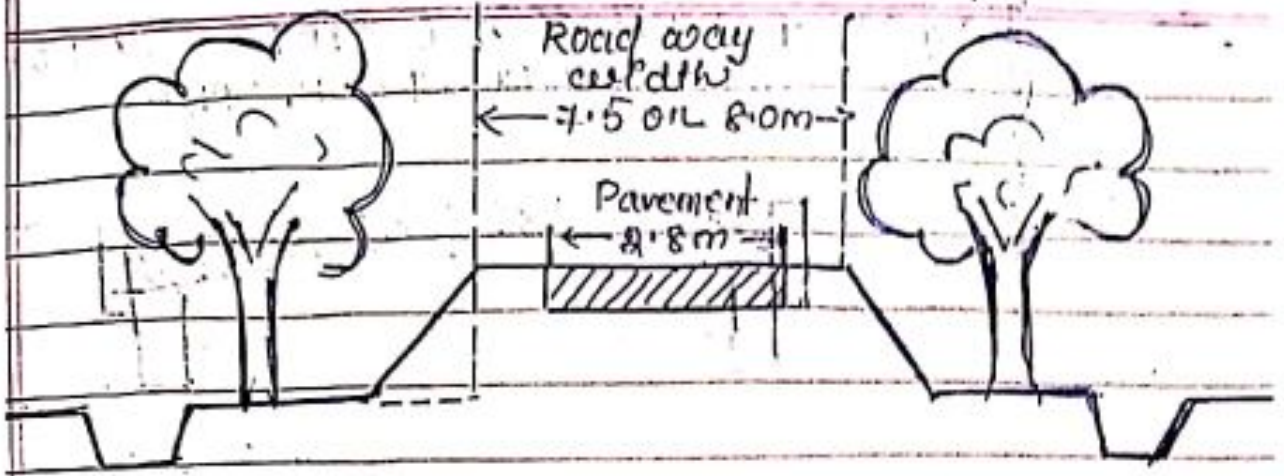
(B) GUARD RAIL :—

Guard rails are provided at edge of the shoulder when the road is constructed on a fill so that vehicles are prevented from running off or fall down the embankment specially when the height of the fill is more than 3 m.

→ Guard stones are installed at suitable intervals along the outer edge of formation at horizontal kerb of road to provide better night visibility.

⟹ (C) Width of formation / Road way :—

It is the sum of pavement or carriage width including separator if any and shoulder.

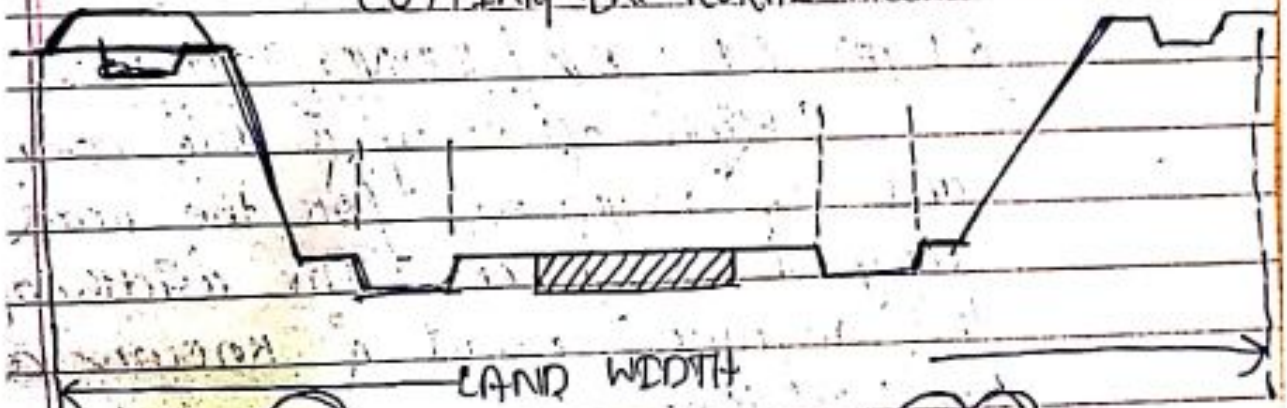


LAND WIDTH

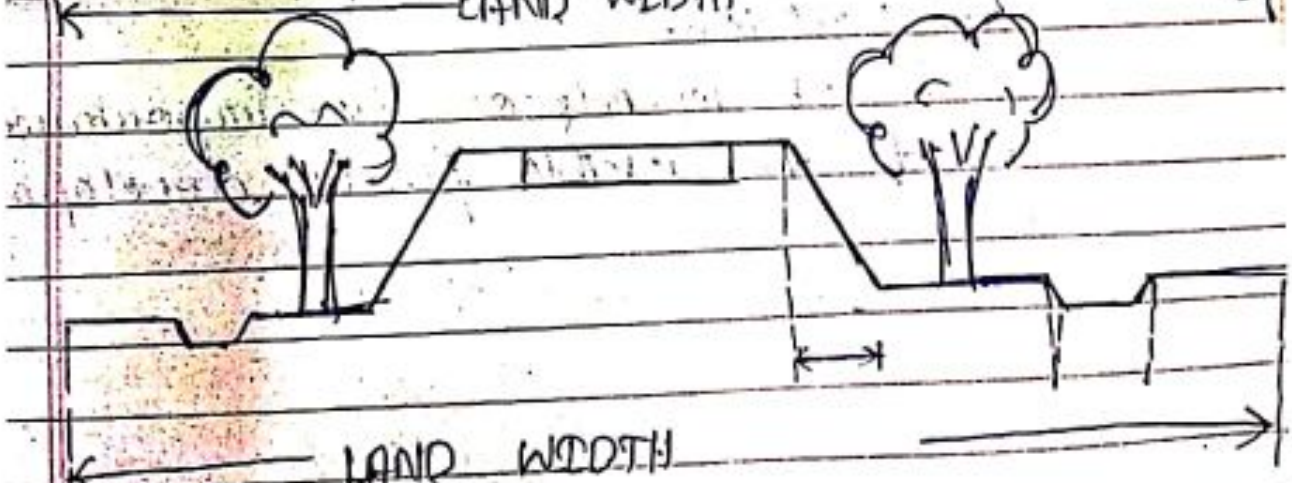
(A)

CROSS-SECTION OF IVR OR ODR IN EMBANKMENT IN RURAL AREA

CROSS-SECTION OF MAJOR DISTRICT ROAD IN CUTTING IN RURAL AREA



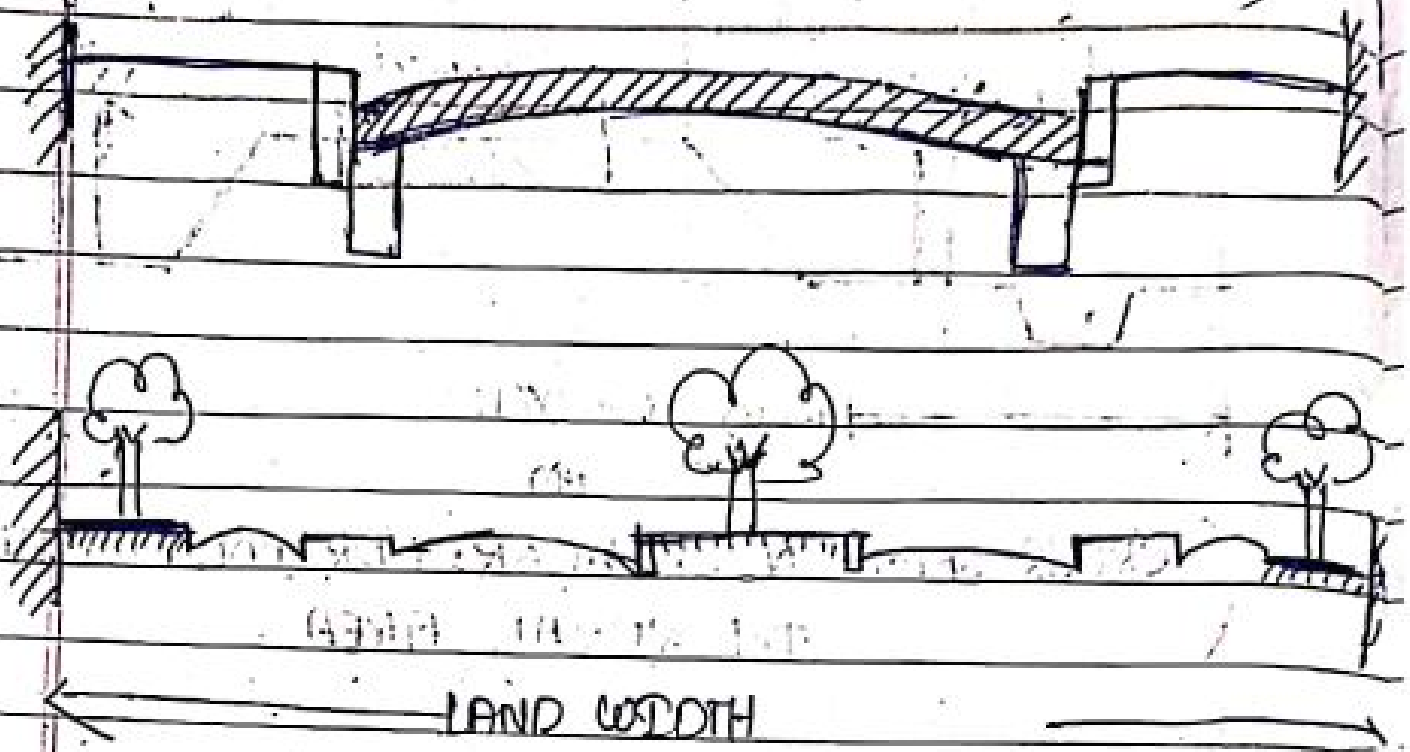
LAND WIDTH



LAND WIDTH

CROSS SECTION OF NATIONAL OR SH IN RURAL AREA

CROSS-SECTION OF TWO LANE CITY ROAD IN BUILT-UP AREA



DATE:

RIGHT OF WAY / LAND WIDTH:-

Right of way is the area of land to be acquired for the road along its alignment. The width of this acquired road is known as land width.

It depends on the importance of road and possible future development.

SIGHT DISTANCE CONSIDERATION :-

The feasibility to see ahead or visibility to is very important for safe vechle operation on a highway

→ Sight distance is the length of road visible ahead to the driver at any instance.

→ Sight distance required by driver apply to both geometric design of highway and for traffic control.

→ Three sight distance situations are consider in the design

(i) Stopping / absolute minimum sight distance

(ii) Safe overtaking / passing sight distance

(iii) Safe sight distance for entering into uncontrolled intersection.

(i) Stopping Sight distance :- (SSD) :

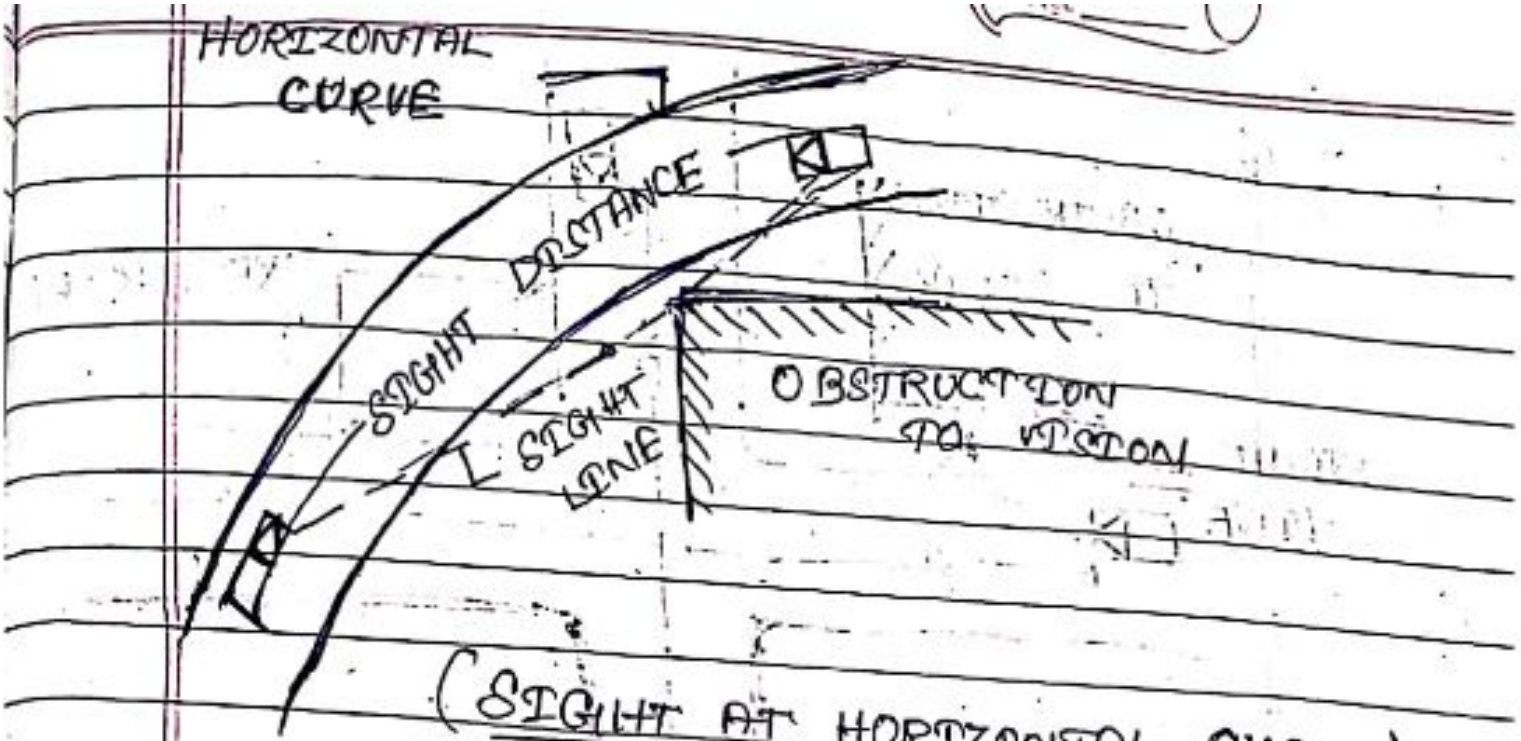
SSD is the distance required by a driver of a vechle, the driver/travelling in a given speed, to bring the vechle to a stop after an object/obstruction on the road way became visible.

It includes the distance travel during driver - car perception - reaction time and the vehicle breaking distance.

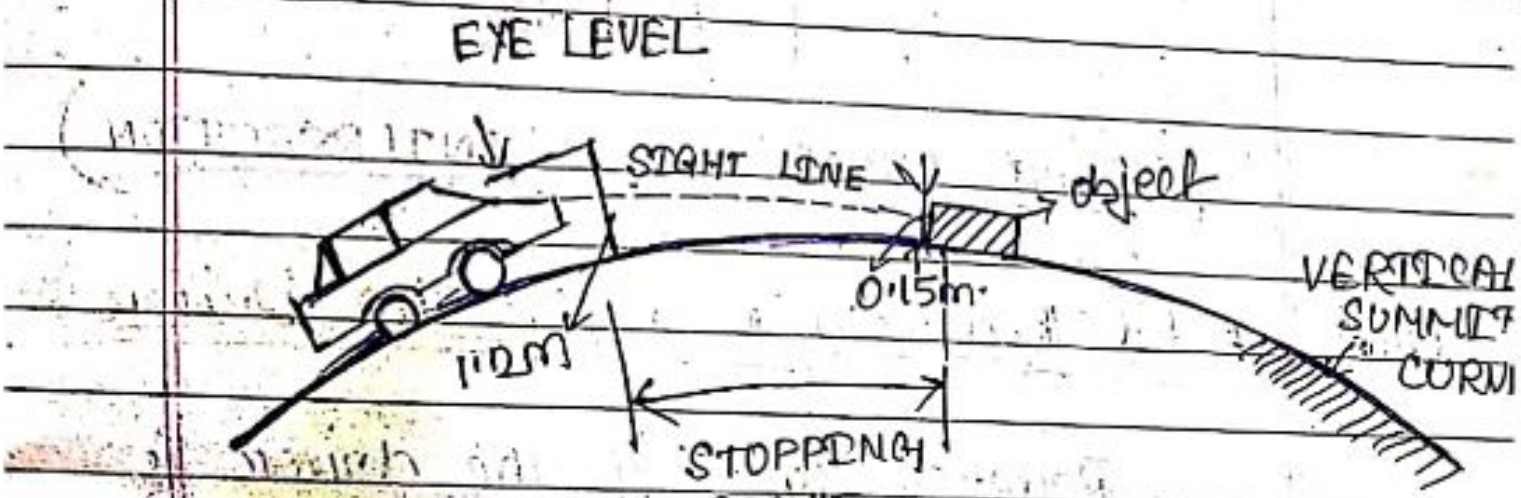
→ For the purpose of measuring the stopping sight distance / visibility IRC has suggested the height of eye level of driver as 1.2m. and the height of the object 0.15m. above the road surface.

→ The distance with in which a motor cycle can be stop depends upon the vehicle factor listed below :—

(i) Total Reaction Time of the Driver.
(ii) Speed of the Vehicle.
(iii) Efficency of break
(iv) Friction Resistance between the road and tyre
(v) Gradient of the Road.
(vi) Feature of the road ahead.
(vii) Height of driver eye
(viii) Height of object etc.



(SIGHT AT HORIZONTAL CURVE)



(SIGHT DISTANCE AT VERTICAL SUMMIT CURVE)

(SIGHT DISTANCE AT INTERSECTION)

(4)(a) Total Reaction Time of the Driver :-

Reaction time of the driver is the time taken form the instant the object is visible to the driver to the instant the breaks are effectively applied.

So, it consist of two part
- Perception time
- Brake reaction time.

(a) Perception Time :-

Perception time is the time

required for the driver to realized that break must be applied.

(e) Break Reaction Time:—

The break reaction time is the time that elapses between the recognisation of an object or hazard in the road way and the application of the break.

PIEV:—

According to this theory the total reaction time of the driver is split into 4 parts

(i) Perception (P)
(ii) Intellection (I)
(iii) Emotion (E)
(iv) & Volition (V)

(i) Perception:—

It is the time required for the sensation received by the eye or ear to be transmitted to the brain through the nerve system and spinal cord.

(ii) Intellection:—

It is the time required for the understanding the situation, it also the time required for comparing diff thoughts, re-grouping

and registering new concepts.

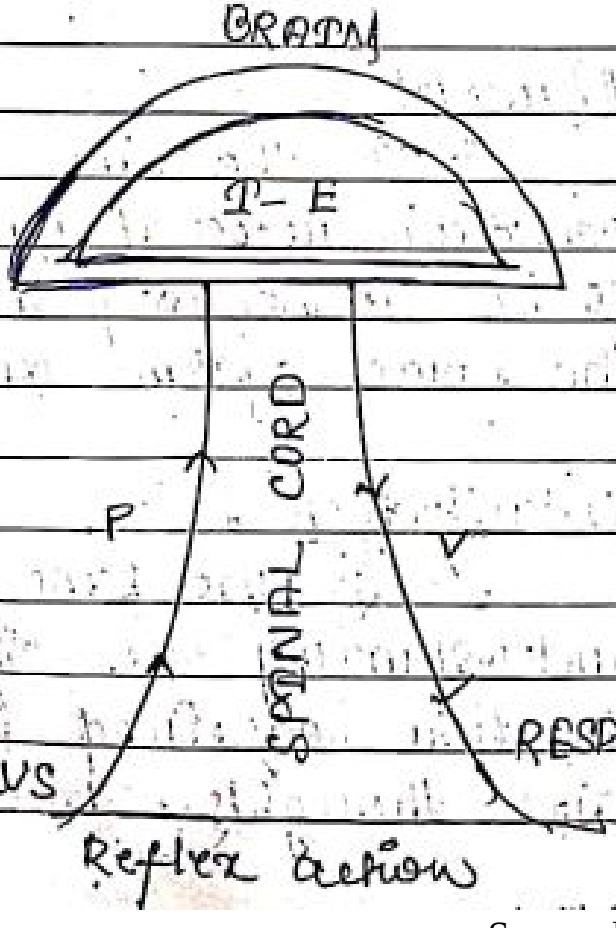
(iii) Emotion :—

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

(iv) Volition :—

It is the time taken for the final action.

→ The total R^n time of the driver may varies from 3-4 sec. or even more in complex situation



(2) SPEED OF VEHICLE :-

Stopping distance depends very much on the speed of the vehicle higher with the speed, higher will be the stopping distance similarly, lower the speed, lower will be the stopping distance / viceversa.

(3) Efficiency Of Break :-

The efficiency of break is to be 100 % of the wheels are fully locked preventing them from rotating on application of break.

→ To avoid speed breaking force should not exceed to the frictional force bet^n the wheels & tyres.

(4) 0.35 - 0.4 (Longitudinal)
0.15 (Lateral)

(5) Gradient of the road :-

when there is an ascending gradient of +n % the breaking distance decreases, similarly in descending gradient -n % breaking distance increases.

Stopping distance = lag distance + braking distance

$$SSD = Vt + \frac{V^2}{2gf}$$ (V in m/s)

∴ where V = Speed of vehicle in m/s

f = design co-efficent of friction

g = acceleration due to gravity (9.81 m/sec²)

km/h → 10^3

3.6×10^5 m/s

$$SSD = 0.278Vt + \frac{V^2}{254f}$$ (V in km/h)

For ascending gradient & descending gradient SSD is

$$SSD = Vt + \frac{V^2}{2g(f \pm 0.01n)}$$

$$SSD = 0.278Vt + \frac{V^2}{254(f \pm 0.01n)}$$

NOTE :-

On roads with restricted width or on single the min^m. stopping sight distance equals to twice the stopping distance.

PROBLEM :-

Calculate the safe stopping Distance (SSD) for design speed of 50 km/h. for

(i) Two lane two way road

(ii) Two way single land road

Assume-

Co-efficient of friction (f) = 0.37

(t) = 2.5s

Ans- $SSD = 0.278Vt + \frac{V^2}{254f}$

$= 0.278 \times 50 \times 2.5 + \frac{50^2}{254 \times 0.37}$

$= 61.35 \text{ m}$

- For 2 lane two way road

  SSD = 61.35 m.

- For two way single land road

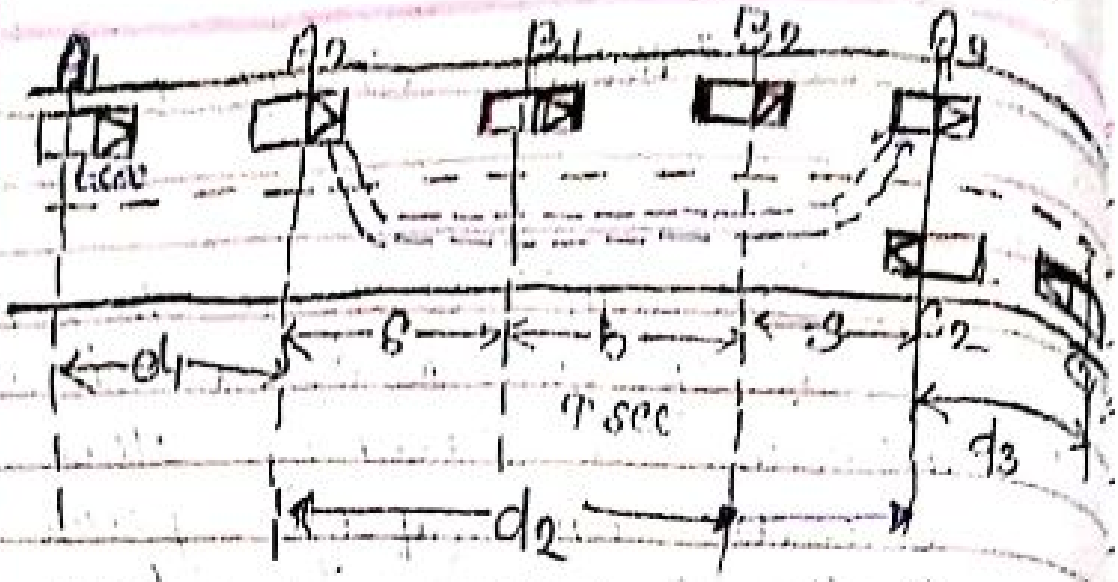
  SSD = 61.35 + 61.35 = 122.7 m

  SSD = 2 x Stopping Sight distance

OVER-TAKING SIGHT DISTANCE :- (OSD)

The min^m distance open to the vision of driver of a vehicle just intending to overtake slow vehicle already with safety against the traffic of opposite direction is known as overtaking sight distance.

* The important factors on which the minimum OSD depends are :-
  (i) Speed of overtaking vehicle, overtaken vehicle and vehicle coming from opposite direction
  (ii) Distance between the overtaking & overtaken vehicle.
  (iii) Skill and reaction time of the driver.
  (iv) Rate of acceleration of overtaking vehicle.
  (v) Gradient of the road.



→ 'A' is the over-taking vehicle originally travelling at a design speed of 'v m/sec / V km/h'.

→ 'B' is the over-taken or slow moving vehicle moving with uniform speed of 'V_b' km/h or V_b m/sec.

→ 'C' is a vehicle coming from opposite direction at design speed of 'v m/sec' or 'V km/h'.

The overtaking process may be split up into 3 operation. Thus, dividing the overtaking sight distance into 3 parts :-

d1, d2, d3.

→ 'd1' is the distance travelled by overtaking vehicle 'A' during the reaction time 't sec' of the driver from position A1 to A2 -

$d_1 = v \times t$

suppose $t = 2\,sec$

then $\boxed{d_1 = V \times 2 = 2V_b}$

→ 'd_2' is the distance travelled by the vehicle 'A' from A_2 to A_3 during over-taking process of A in time 'T sec'

The min^m. clear dist^n bet^n A_2 & B_2 may be taken as the min^m. spacing 'S' of the two vehicles while moving with the speed of V_b m/sec.

$$\boxed{S = 0.7 V_b + 6}$$

The min^m. distance between B_2 & A_3 may be also assume equal to 'S'. If the time taken by the vehicle 'A' for overtaking operation from position $A_2 - A_3$ is T sec. The distance covered by slow moving vehicle 'B' travelling at speed of V_b m/s.

$$\boxed{b = V_b \times T}$$

$$d_2 = s + b + s = 2s + b$$

$$d_2 = 2S + (V_b \times T)$$

$$\boxed{s = ut + \frac{1}{2}at^2}$$

$$d_2 = V_b \cdot T + \frac{1}{2} a T^2$$

$$V_b T + \frac{1}{2} a T^2 = 2s + V_b T$$

$(d_2 = d_2)$

$$\Rightarrow 2s = \frac{1}{2} a T^2$$

$$\Rightarrow \frac{2s \times 2}{a} = T^2$$

$$\Rightarrow \frac{4s}{a} = T^2$$

$$\Rightarrow \boxed{T = \sqrt{4s/a}}$$

$$\boxed{d_2 = v \times T}$$

$$\boxed{d_2 = 2s + V_b T}$$

Overtaking sight distance (OSD):-

$$O.S.D = d_1 + d_2 + d_3$$

$$= V_b t + (2s + V_b T) + vT$$

$$\boxed{OSD = \left(V_b t + 2s + V_b T + vT\right) (m/s)}$$

(t = reaction time in sec.

T = normal time $\sqrt{4s/a}$

s = spacing of vehicle $(0.7 V_b t_6)$

$$OSD = 0.278\, V_b t + 2s + 0.278\, V_b T + 0.278\, vT$$

↑ ÷ (for km/h)

NOTE :—

On cash of speed of overtaken vehicle V_b is not given, the same may be assumed as $V - 16$.

V = km/h

$$V_b = V - 16$$

OVER-TAKING ZONE :—

There may be stretches (certain distance) where the safe overtaking sight distance cannot be provided; in such zone overtaking or passing is not safe / not possible.

→ Sign post should be installed indicating no portion, "No passing" or "overtaking is prohibited" before such restricted zone starts.

The zones which are mean for overtaking opportunity for vehicle moving a design speed of an overtaking zone are called

$$OSD = 0.278\, v_b t + 2s + 0.278\, V_b T + 0.278\, vT$$

↑ ÷ (for km/h)

NOTE :—

On cash of speed of overtaken vehicle V_b is not given, the same may be assumed as V-16.

V = km/h

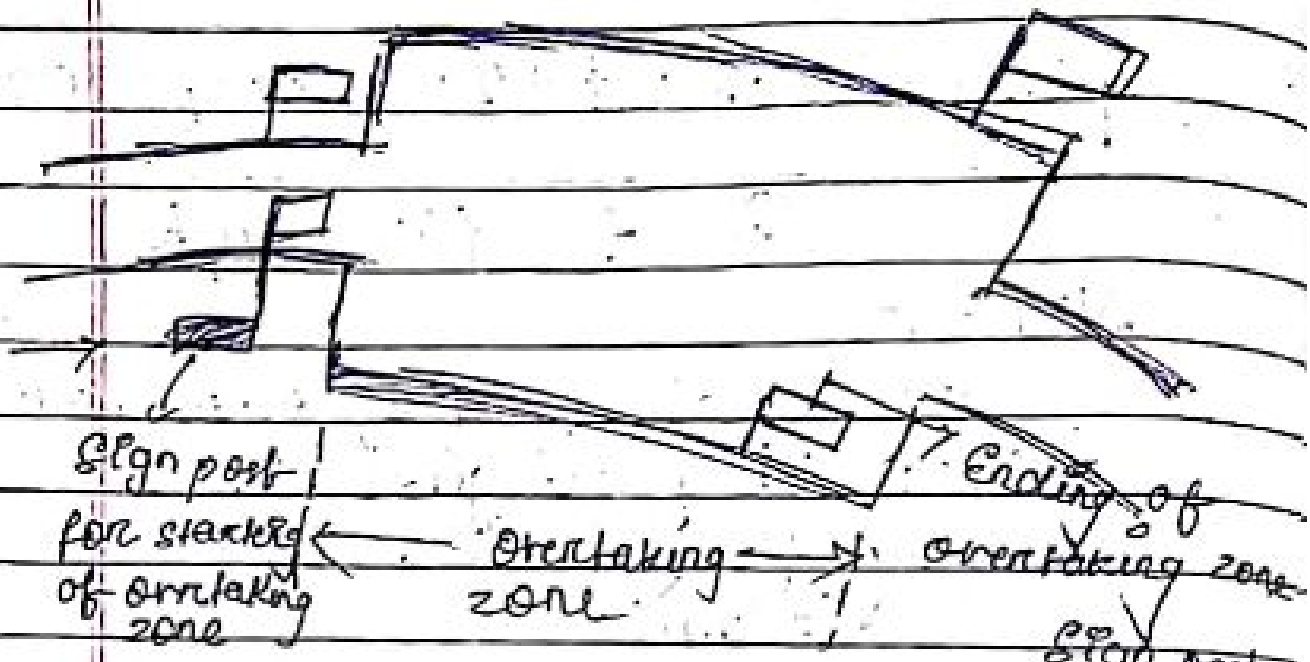
$$V_b = V - 16$$

OVER-TAKING ZONE :—

There may be stretches (certain distance) where the safe overtaking sight distance cannot be provided, in such zone overtaking or passing is not safe / not possible.

→ Sign post should be installed indicating no parking, "no passing" or "overtaking is prohibited" before such restricted zone starts.

The zones which are mean for overtaking opportunity for vehicle moving a desired speed of an overtaking zone are called



The min^{m} length of overtaking zone should be 3 time of the safe overtaking distance / SOD, for one way road.

(•) Overtaking zone for 1 way
$= 3 \times (d_1 + d_2)$

(•) Overtaking zone for 2 way
$= 3 \times (d_1 + d_2 + d_3)$

→ The desirable length of over taking zone is 5 times of safe overtaking distance.

(•) for 1 way overtaking zone
$= 5 \times (d_1 + d_2)$

(•) For 2 ways overtaking zone
$= 5 \times (d_1 + d_2 + d_3)$

(•) For 1 way road

$5(d_1+d_2)$

$= 5(44.44+251.50)$

$= 1479.7m = 1.47km$

(•) For 2 way road

$5(d_1+d_2+d_3)$

$= 5 \times (545.74)$

$= 2728.7m = 2.72km$

(•) Design Of Horizontal Alignment :→

Various factors to be considered in hor. alignment are design speed, radius of circular curve type en length of transition curve.

→ Design speed is a selected speed used to determine the various geometric feature of the road way;

→ Geometric Design speed of roads depends upon class of roads, or type of road and the terrain.

→ The sight distance, radius of horizontal curve super elevation, extra widening of pavement, length of hot transition curve, the length of summit and valley curve are all depended on design speed.

Horizontal Curve :—

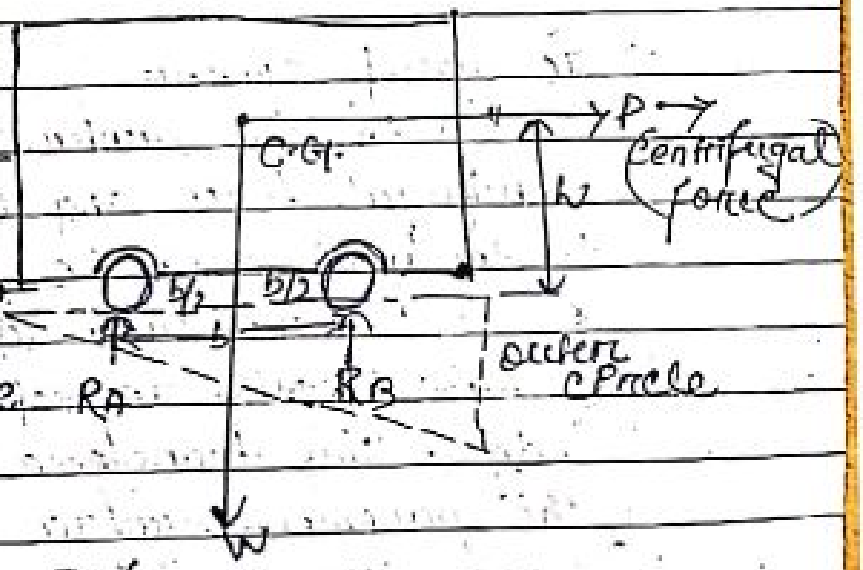
→ A horizontal highway curve is a curve in plan to provide change in direction to the central line of a road.

→ When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally outward through the CG (centre of gravity) of vehicle.

→ The centrifugal force acting on a vehicle negotiating a horizontal curve has two effects :—

(i) Tendency to overturn the vehicle outward about the outer wheels.

(ii) Tendency to skid the vehicle laterally.



$W \times b/2 = P \times h$

$P = W \times \frac{b}{2h}$ (Centrifugal force)

Centrifugal force $P = \frac{mv^2}{R}$ Lateral skidding

→ To avoid overturning on a horizontal curve, the centrifugal ratio should always be $< b/2h$ and f.

$$P = \frac{Mv^2}{R} \qquad \left(\because W = mg,\ M = \frac{W}{g}\right)$$

$$P = \frac{W}{g} \times \frac{v^2}{R}$$

$$\boxed{\frac{P}{W} = \frac{v^2}{gR}}$$

$\therefore$ [P/W = Centrifugal Ratio]

→ Frictional force :—

$$(R_A + R_B)f = P$$

$$[P = f]$$

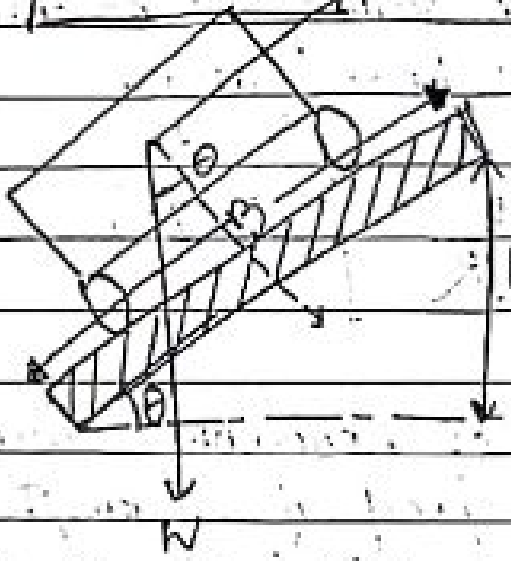
Super Elevation :— (e)

→ To avoid overturning

In order to counteract the effect of centrifugal force and to reduced the tendency of a vehicle to overturn or skid, the outer edge of the pavement is raised with respect to the inner edge. This transverse inclination to the pavement surface is known as "Super Elevation" or "Cant" or "Banking".

→ The super elevation 'e' is expressed as the ratio of the height of the outer edge to the horizontal width of road way.

$$e = \frac{E}{B}$$



$$e = \tan\theta \simeq \sin\theta = \frac{E}{B}$$

→ The forces acting on the vehicle while moving on a circular curve of radius 'R' metre at speed of v m/s.

(•) Centrifugal force $(P) = \frac{mv^2}{R}$

(•) The weight of vehicle = w

(•) The frictional force developed between the wheels and pavement surface.

m/s → $e + f = \frac{v^2}{gR}$; Km/h $e + f = \frac{v^2}{127R}$

$$e + f = \frac{v^2}{gR} = \frac{P}{W}$$

e = Super elevation, R = radius

P = frictional force

→ If the co-efficient of friction is neglected i.e. $f = 0$, the equilibrium super elevation required to counteract the centrifugal force fully.

So $\boxed{e = \frac{v^2}{gR}}$ (m/s)

(i.Q) The radius of horizontal curve is 100m The design speed is 50 km/h & the design of co-efficient of lateral friction is 0.15. (i) Calculate the super elevate required.

(ii) Calculate the co-efficient of friction is no super elevation is provided

(iii) Calculate the equilibrium super elevation.

Ans:- $R = 100m$

$V = 50 km/h = 50 \times 10^3 / 3600 = 13.88 m/se$

$f = 0.15$

(i) $e + f = \frac{v^2}{gR}$

$\Rightarrow e + 0.15 = \frac{(13.88)^2}{9.81 \times 100}$

$\Rightarrow e + 0.15 = \frac{192.65}{981}$

$\Rightarrow e + 0.15 = 0.196$

$\Rightarrow e = 0.196 - 0.15 = 0.046$ m/s

(ii) No super elevation means $e = 0$

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

$0+f = 0.196$

On $e+f = \frac{v^2}{127R}$

$f = \frac{(13.88)^2}{127 \times \frac{100}{100}}$ $\left\{ \frac{192.65}{127.00} \right.$

$f = 0.015$ }

To km/h $e+f = \frac{v^2 \text{ (km/h)}}{127R}$

$f = \frac{(50)^2}{127 \times 100} = 0.196$

(iii) If frictional force $= 0$

$e+f = \frac{v^2}{127R} \Rightarrow e = \frac{(50)^2}{127 \times 100}$

$e = 0.196$

$\boxed{f = 0.15}$

Attainment Of Superelevation :—

The attainment of super elevation is devided into 2 parts :—

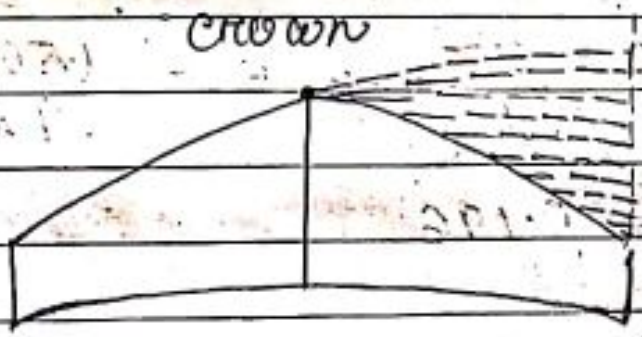
1- Elimination of crown of the cambered section.

2- Rotation of pavement to attain full superelevation.

1- Elimination of crown of the cambered section :—

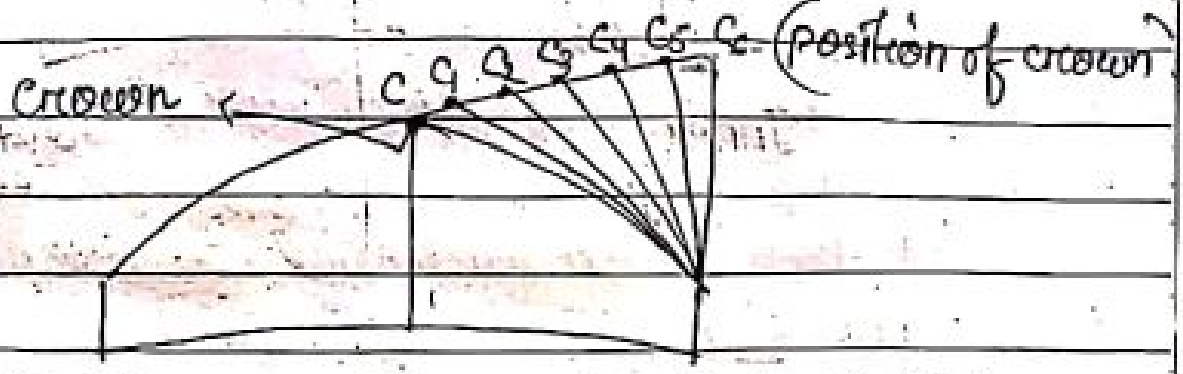
This may be done by 2 methods :—

(a) In the 1st method the outer half of the cross slope is rotated about the crown at a desired rate such that the surface fall on the same plane as the inner half and the elevation of centered line is not disturbed.



(Outeredge rotated about the crown)

(b) In the 2nd method of eliminating the crown known as diagonal crown method, the crown is shifted outward thus increasing the width of inner half of the cross section.

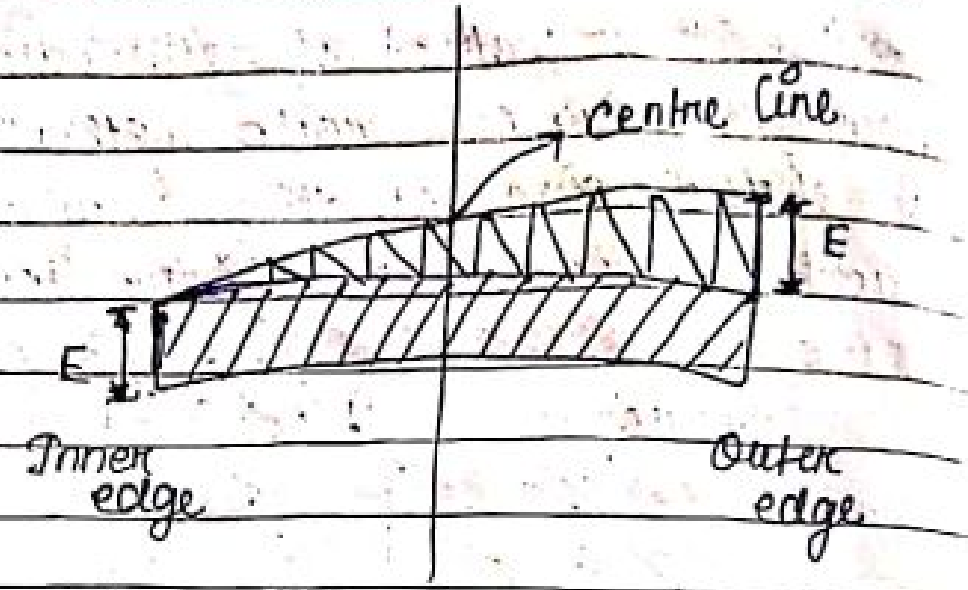


(Crown shifted to outer edge / diagonal crown method)

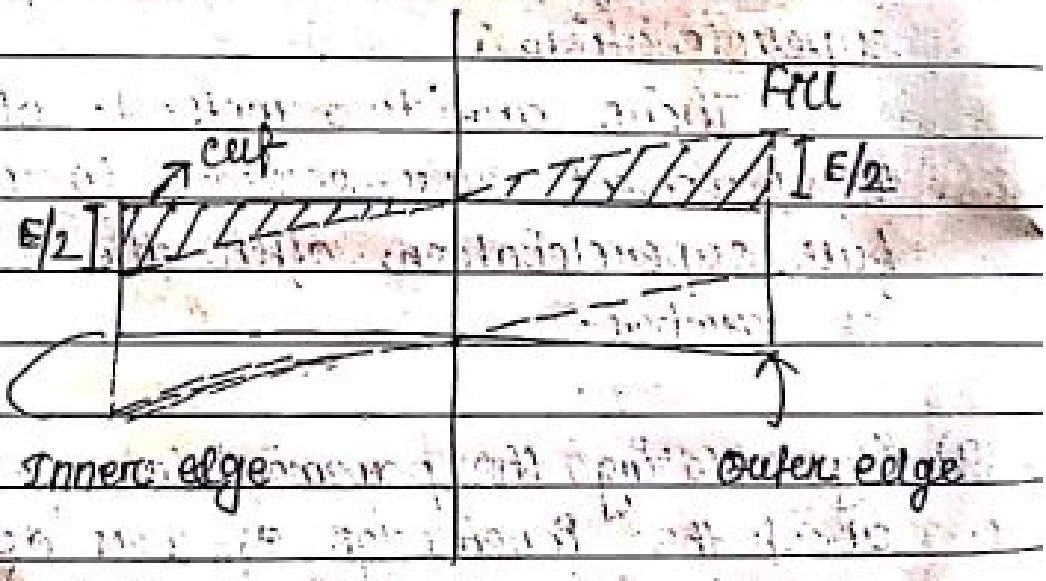
2- Rotation of pavement to attain full superelevation.

There are two methods of rotating the pavement cross-section to attains the full superelevation after the elimination of camber.

(a) By rotating the pavement cross-section about the inner edge ~~as well as~~ of the pavement section raising both the centre as well as the outer edge of the pavement such that the outer edge is raised by the full amount of super-elevation.



(b) By rotating the pavement section about the centre line; depressing the inner and; grazing the outer edge each by half the total amount of super-elevation i.e. by E/2 w.r.t the centre.



Radius of the horizontal curve
Rulling radius / minimum radius of horizontal curve

$$e+f = \frac{V^2}{gR} \Rightarrow R_{min} = \frac{v^2}{(e+f)g}$$

$$OR,\ R_{min} = \frac{v^2}{127\,(e+f)}$$

Widening of Pavement on horizontal curve:-

On horizontal curve when there not of very large radii, it is common to widen the pavement slightly more than the normal width.

The object of providing extra widening of pavement on horizontal curve are due to following reasons:—

→ At speed ever higher than the design speed when the superelevation and lateral friction developed are not fully able to counteract the centrifugal force come traverse skidding may occurde and the rear wheel may take path on the outer side of the pavement layer on the horizontal curve.

→ While two vechicle cross each other at horizontal curve there is a psycological tendency to maintain greater clearance between the vehicles.

→ In order to take curved path with longer radius and to have greater visibility at curve, the driver have tendency not to follow the central path of the lane, but to use outer side at the beginning of a curve.

→ The extra widening of pavement on horizontal curve is devided into 2 part.

(a) Mechanical widening

(b) psycological widening

Extra widening (ee)

$$= Nl + W_s = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

n = no. of traffic lanes

l = length of wheel base (6m)

V = design speed in km/h

R = radius of hor. curve

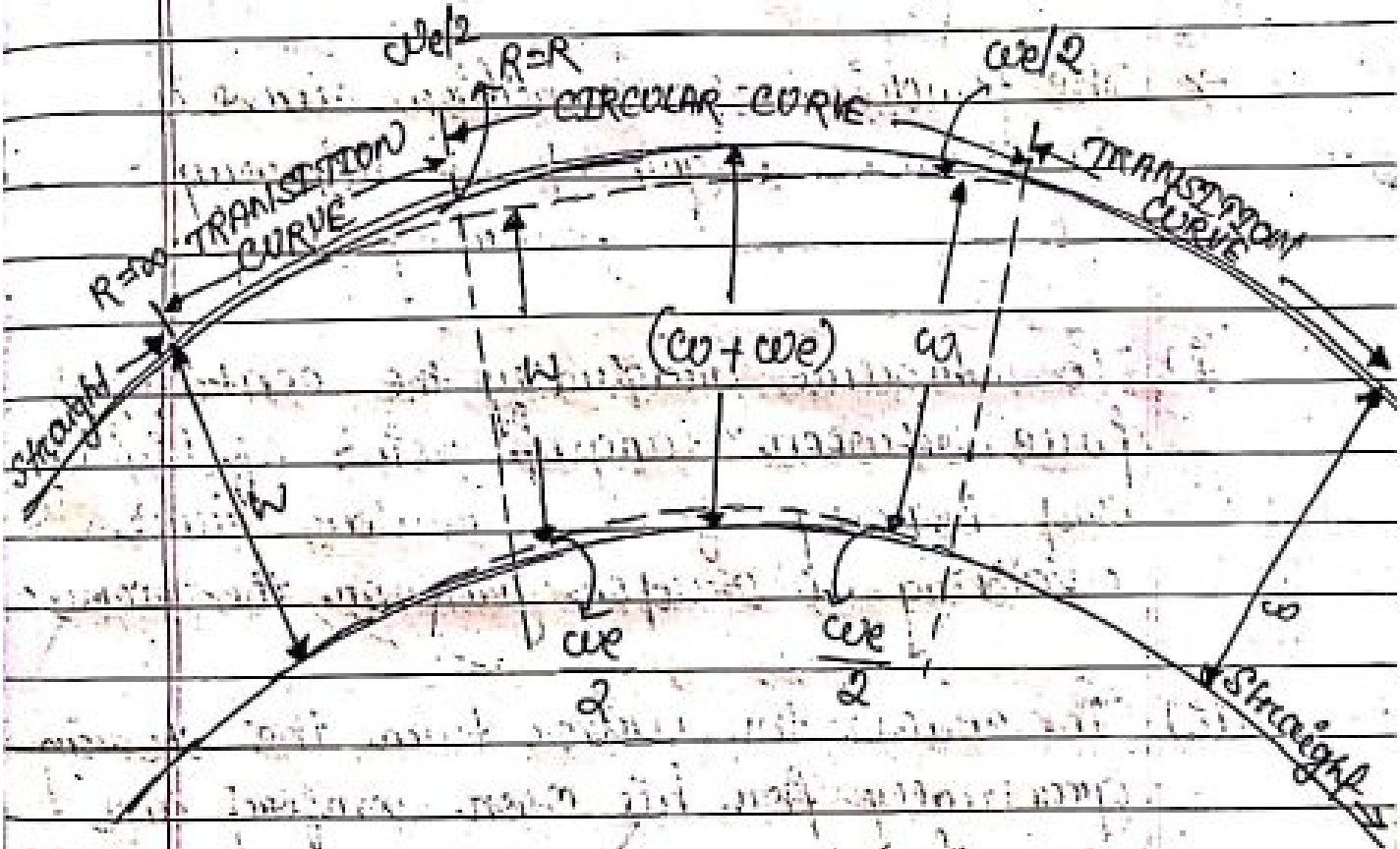
Q) Calculate the extra widening required for a pavement of width 7m on a horizontal curve of radius 250 m. If the longest wheel base of vehicle is 7m. and design speed is 70 km/h

Ans:- n = 2, l = 7m, V = 70 km/h, R = 250 m.

$$We = \frac{n l^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

$$= \frac{2 \times 7^2}{2 \times 250} + \frac{70}{9.5\sqrt{250}}$$

$$= 0.196 + 0.46 = 0.66m$$



EXTRA WIDENING OF PAVEMENT ON HORIZONTAL CURVE

Transition Curve :-

→ A transition curve has a radius which decreases from infinity at tangent point to a design radius of circular curve, when a transition curve is introduced between straight and circular curve, the radius of transition curve decrease becomes minimum at the beginning of the circular curve.

→ The function of transition curve is horizontal alignment of highway the following point...

(i) To introduce gradually the centrifugal force between tangent point of highway and beginning of the circular curve avoiding a sudden jerk on the vehicles.

(ii) To enable the driver turn the steering gradually for his own comfort and security.

(iii) To enable gradual introduction of the design superelevation and extra widening of pavement at the start of circular curve:

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(ii) To enable the driver turn the steerin gradually for his own comfort and security.

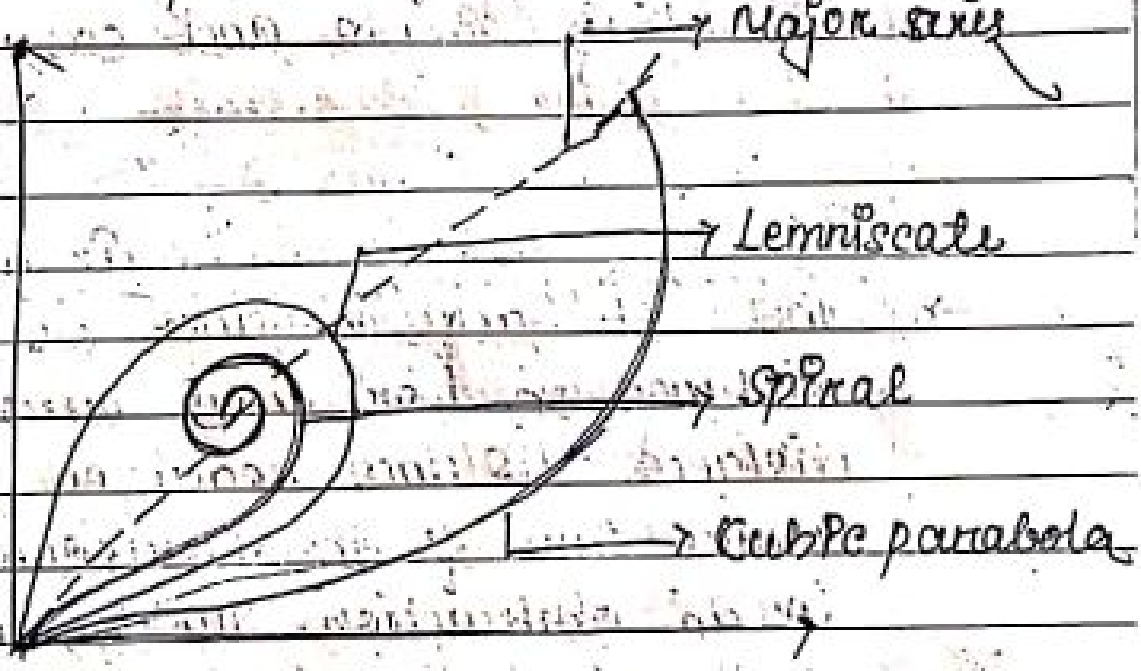
(iii) To enable gradual introduction of the design superelevation and extra widening of pavement at the start of circular curve:

(iv) To improve the aesthetic appearance of the road.

Types of Transition Curve :—

The types of transition curve commonly adopted in horizontal alignment are :—

(i) Spiral
(ii) Lemni-scate
(iii) Cubic parabola



DIFFERENT TYPE OF TRASITION CURVE

* In spiral curve the radius is inversely proportional to the length and the rate of change of centrifugal acceleration is uniform throughout the length of curve, thus the spiral fulfil the condition of an ideal transition curve.

→ The IRC recommends the use of spiral as transition curve in the horizontal alignment of highway due to following seven reason :-

(i) The spiral curve satisfies the requirement of ideal transition.

(ii) The geometric property of spiral is such that the calculation and setting out of the curve in the field is simple and easy.

Set back distance or horizontal curve:

→ The set back distance or clear distance on horizontal curve is the distance distance measured from the centre line of the horizontal curve to an obstruction on the inner side of the curve to provide adequate sight distance.

→ It depends on the following factors :

(i) Required sight distance
(ii) Radius of horizontal curve
(iii) Length of transition curve

Vertical Alignment :—

The vertical aligoment is the elevation and profile of the centre line of the road.

→ It is consist of - grade and vertical curves and its influences the design speed, accelerations, stopping distance, sight distance and comfort in vehicle movement at high speed.

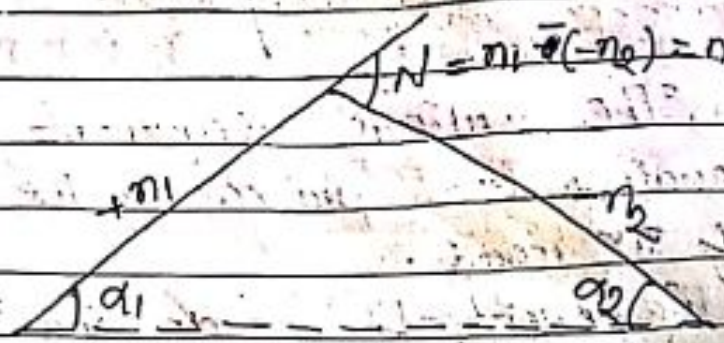
Gradient :-

Gradient is the rate of rise or fall along the length of road w.r.t the horizontal. It is expressed as the ratio of "1 in x" (1 vertical unit to x horizontal unit)

→ The ascending gradients are given +Ve sign and are denoted as $+n_1$, $+n_2$ etc....

→ The descending gradient are given -Ve sign & denoted as $-n_1$, $-n_2$ etc....

→ The angle which measures the change of direction at intersection of two grades is called the "deflection Angle" (N)



Gradients are devided into following categories;

(1) Ruling Gradient
(2) Limiting Gradient
(3) Excaptional Gradient
(4) Minimum Gradient

(1) Ruling Gradient

(•) Ruling gradient is the maximum gradient with which, the designer attempt to design the vertical profile of a road.

→ The Ruling gradient are adopted as Gradient upto design gradient of vertical alignment.

→ Hence ruling gradient is also known as design gradient.

(•) → The IRC has recommanded ruling gradient values of 1 in 30 on plane and rolling terrain

1 in 20 on mountaneous terrain, and 1 in 16.7 on steep terrain.

Limiting Gradient :-

(●) Where topography of a place consist of stiffer gradient than ruling gradients, limiting gradient are used.

Exceptional Gradient :-

(●) In some extra-ordinary situation it may be unavoidable to provide stiffer gradient atleast for short length and in such cases the stiffer gradient upto Exceptional gradient is provided.

Minimum Gradient :-

(●) The min^m gradient is provided for drainage purpose. The minimum gradient depend on rainfall / run off, types of soil, topography and other conditions.

Grade Compensation :-

When sharp hor. curve is to be introduced on a road which has already max^m permissible gradient, then the gradient should be decrease to compensate for the loss of tractive Effective Effort due to the curve.

→ This reduction in gradient in hor. curve is called "Grade compensation"

→ Grade compensation

$= \frac{30+R}{R}$ or $\frac{75}{R}$

min^m value

NOTE:- According to IRS the grade compensation is not necessary for gradient flatter than 4%.

Q) While aligning a hilly road with a ruling gradient of 6%, hor. curve of radius 60m is encountered. Find the compensated gradient of the curve.

Ans:- Ruling gradient = 6%

R = 60m.

Grade compensation $\frac{30+R}{R} = \frac{30+60}{60} = 1.5$

$\frac{75}{R} = \frac{70}{60} = 1.25$ (min^m)

Compensated gradient = Ruling Gradient - min^m value

→ 6 - 1.25 = 4.75 %

(∵ Grade compensation min^m value is 4%)

Vertical Curve :—

The vertical curved used in highway is classified into 2 categories ;

(i) Summit Curve or, crest curve (∩)

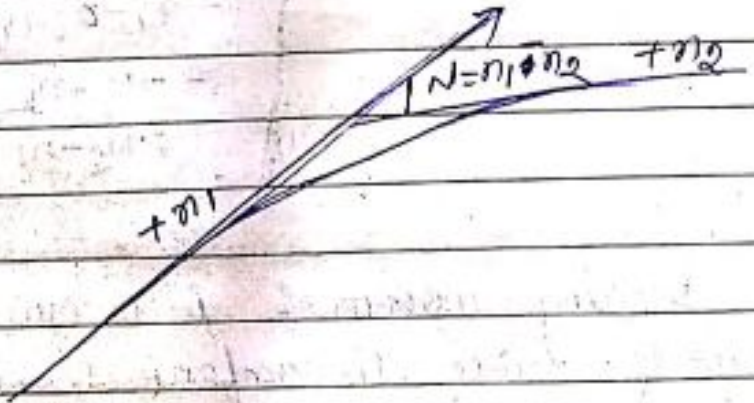
(ii) Valley curve or sag curve (∪)

(i) Summit Curve or, Crest curve :—

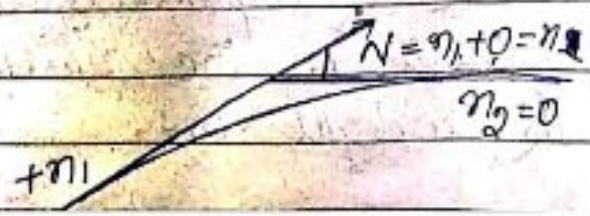
When 2 grades meet at the summit and the curve have convexity upward, the curve is simply referred as the summit curves.

They are form under the four following conditions

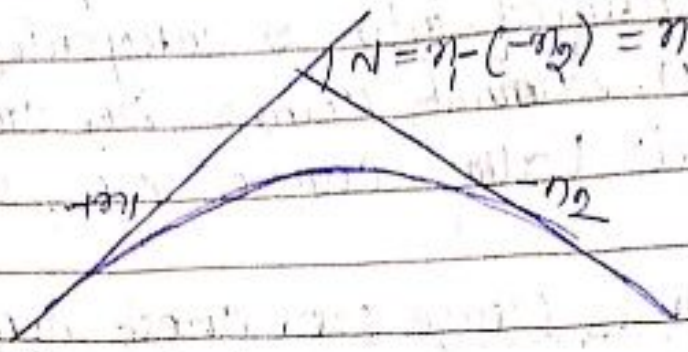
1- when a +ve gradient meet another mild positive gradient



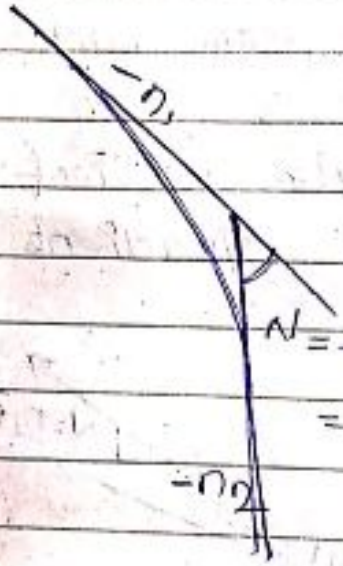
2- when +ve gradient meet a level of zero gradient



3- When a +ve gradient meet with a -ve gradient.



4- When a -ve gradient meet with another -ve gradient.

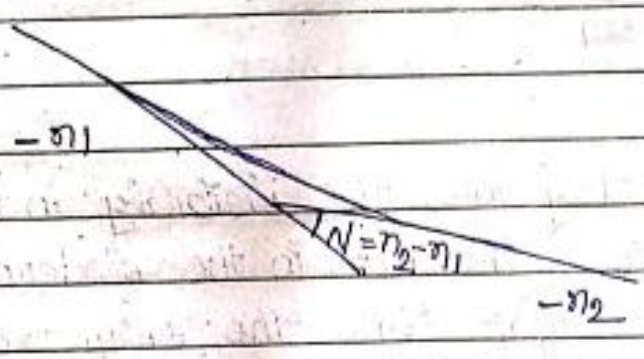


→ During movement in a sabmit curve there is less discomfort to the passenger because the centrifugal force developed by the movement of the vehicle on a sabmit curve act upward with which is opposite to the direction in which the weight act.

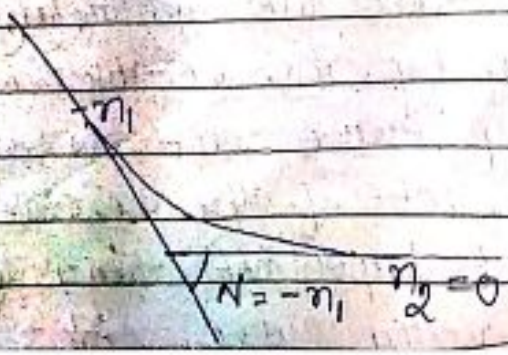
→ A simple parabolic curve is preferred in summit curve due to its easy implementation in the field, good riding comfort during driving and easy computation.

(2) Valley vertical curve / sag curve :-
When 2 grades meet at the valley or sag and the curve have convexity downward. Then the curve is refered as valley / sag curve.
They are formed under the 4 following condition;

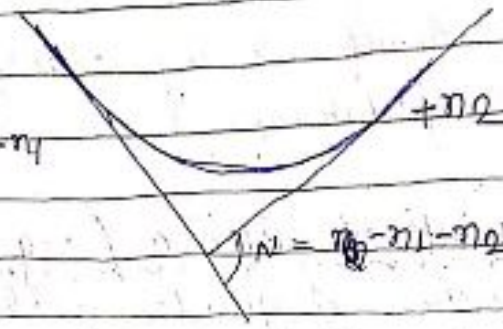
1- When a -ve gradient meet another -ve negative gradient



2- When a -ve gradient meet a level/zero gradient

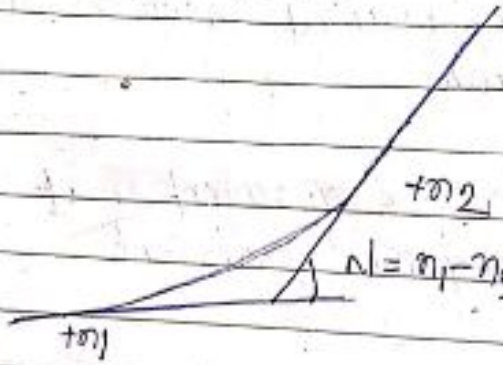


3- When a -ve gradient meets with +ve gradient



4- When a +ve gradient meets with another different gradient

steeper +ve



→ During day time the visibility in valley curve are not obstruct in the hindered but during night time the only source of visibility is head light in the absence of street light.

→ In valley curve the centrifugal force generated by the vehicle moving along a valley curve act downward with the wt of the vehicle. Thus the most important thing is to consider during valley curve are; design of

1- Impart and jerking free movement of veichle at design speed.
2- Availability of stopping sight distance under head light of veichle during night time.

→ The best shape of a vally curve is a transition curve but mostly cubic parabola is preferred in vertical vally curves.
→ It simple parabolic

(Highway Material) (3rd)

1. Subgrade Soil :-
Subgrade soil is an integral or most important part of the road pavement structure as it provide the support to the pavement from beneath.

→ The important fit function of subgrade soils are
1- To provide an adequate (sufficient) support to the road pavement.
2- To provide stability to the pavement
3- To provide good drainage of rain water percolating through the pavement.

CBR [Californian Bearing Ratio Test]

- CBR test is a "penetration test" used to evaluate the subgrade strength of road and pavement.
- The results of these test are used with the empirical curve to determine the thickness of pavement and its component layers.
- Used to design of flexible pavement.

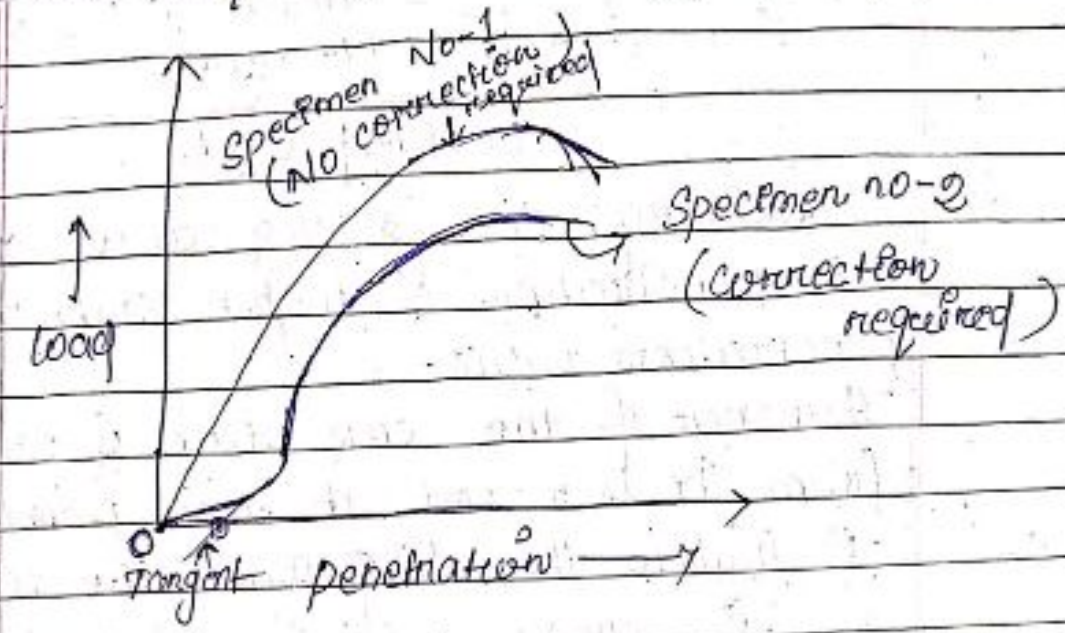
Test Procedure :-

- The laboratory CBR apparatus consist of a mould 150mm dia. with base plate, and a collar, a loading frame with cylindrical plunger of 50mm dia. and dial gauge for measuring the expansion on soaking and penetration values.

- The specimen in the mould is subjected to 4days; soaking & the swelling and water absorption values are noted.
- The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame.
- The load values are noted corresponding to the penetration values at 0, 0.5

1, 1·5, 2, 2·5, 3, 4, 5, 7·5, 10, and 12·5

(•) The load to penetration graph is plotted.



Two typical types of curves may be obtained;

→ The normal curve is with convexity upward and, the load corresponding to 2.5 & 5mm penetration are noted.

→ But, sometime a curve with initially upward concavity is obtained, indicating the necessity of correction of curve. In this case the corrected origine is established by drawing a tangent from the steepest point on the curve.

→ The load values corresponding to 2.5 & 5mm penetration value from the corrected origine and noted.

The C.B.R value is calculated,

$$C.B.R\ (\%) = \frac{\text{load/penetration or pressure sustained by the specimen at 2.5 or, 5.0mm penetration}}{\text{standard load}} \times 100$$

→ Normally, the C.B.R value are 2.5 penetration is higher than 5mm penetration value.
However if the CBR value is obtained from the test at 5mm penetration is higher than 2.5 than the test is to be repeated. If the cheak test again give similar result, the higher value obtained at 5mm penetration is repeated as CBR value.

→ The cause for initially concavity of the load penetration curve are due to

(•) The bottom surface of the plunger & the top surfeve of soil sample specimen not Horizontally placed.
(•) The top layers of specimen is too soft or irregular.

2. Aggregate :-

Aggregate form the major portion of pavement structure and the prime material used in pavement construction.

→ Aggregate have to bear stresses occuring due to the wheel load on the pavement and they also have to resist wear due to abrasive action of traffic.

→ Desirable properties of road aggregate :-

1. Strength :-

The aggregate should be used in road construction should be sufficiently strong to withstand, the stresses due to traffic wheel load.

2. Hardness :-

The aggregates used in the surface coarse are suffected to constant rubbing or abrasion due to moving traffic. They should be hard enough to resist wear due to abrasion action of traffic.

3. Toughness :-

Aggregates in the pavement are also suffected to impact, due to moving wheel loads.

The resistance to impact or toughness is another desirable property of the aggregates.
(Impact - sudden load)

4. Durability :—
The stone used in pavement construction should be durable and should resist disintegration due to action of weather (small parts) - Separate.
The properties of the stone withstand the adverse action of weather is called "soundness".

5. Shape of Aggregate :—
It is evident (proved) that the flaky and elongated particles will have less strength and durability, when compare with cubical, angular, or rounded particle of the same stone. Hence too flaky and too much elongated aggregate should be avoided for construction of road pavement.

6. Addition with Bitumen :—
The aggregates used in bituminous pavement should have less affinity (attract) with water. otherwise bituminous coating on the aggregate will be stripped off (separated) due to presence of water.

→ Test for Road Aggregates :—

In order to decide the suitability of the road stone for used in construction the following tests are carried out ;

(i) Crushing Test :— (Strength)
Strong aggregates gives low aggregate crushing values. The aggregate crushing values for good quality aggregate shall not exceed 45% for base course & 35% for surface course

(ii) Abrasion Test :— (Hardness)
The abrasion value of good aggregate acceptable for cement concrete, bituminous concrete and other high quality pavement materials should be less than 30%. For base course it should be less than 50%. (water-bound macadam and bituminous macadam.)

(iii) Impact Test :— (Toughness)
Impact test is design to evaluate the toughness of the stone or the resistence of the aggregates to fracture under repeated impact. The agg. impact value should not exceed 30% for aggregate used in wearing course / surface course of pavement.

→ The max^{m} permissible value is 35% for bituminous macadam & 40% for water bound macadam base coarse.

(iv) Soundness Test:-

Soundness Test is used to study the resistance of aggregate through weathering ~~ackon~~ action by conducting "weathering test cycle". The average loss in weight of aggregate to be used in pavement construction after 10 cycles should not exceed 12% when tested with ~~Ato~~ sodium sulphate and 18% when tested with magnesium sulphate.

(v) Specific Gravity & water absorption test

The specific gravity of an aggregate is considered to a measure of the quality or strength of the material. Stones having higher water absorption values are porous and thus weak.

→ The sp. gravity of rock varies from 2.6 to 2.9. Rock having less than 0.6% water absorption are considered ~~useless or weak~~ alone strong stones or aggregates.

BITUMINOUS MATERIAL

Bituminous binder used in pavement construction work includes both bitumen and tar.

BITUMEN	TAR
(i) Bitumen is found in black to brown colour.	(i) Tar is usually found in brown colour.
(ii) Bitumen is obtained from fractional distillation of crude oil.	(ii) Tar is obtained by distructive distillation of coal or wood.
(iii) Bitumen is soluable in Carbon disulphide.	(iii) Tar is soluable in toluene and carbon tetra-chloride.
(iv) Bitumen shows resistance to coating of wood aggregate and also does not retained in presence of water	(iv) Tar coat more easily and retained it in presence of water.
(v) Free Carbon content is less.	(v) Free carbon content is more.
(vi) It shows more resistance to weathering action.	(vi) It show less resistance to weathering action.

(vii) Less temperature susceptive susceptibility (viii) More temperature susceptibility.

Desirable property of Bitumen:-

(●) Viscosity:-

The viscosity of bitumen at the time of mixing and compaction should be adequate. This is achieved by heating the bitumen and aggregate prior to mixing.

(●) Temperature susceptibility:-

The bituminous material should not be highly temperature susceptable. During the hotest weather of region the bituminous mix should not become too soft or unstable.
During cold weather the mix shouldn't become too hard and brittle, causing cracking.

(●) Adhesion property:-

In presence of water the bitumen should not strip off from the aggregate. There has to be adequate affinity and adhesion between the bitumen & aggregate.

Requirement of Bitumen :—

→ To maintain the stability under adverse weather condition.
→ To maintain sufficient flexibility and thus avoid cracking of bituminous surface
→ To have sufficient adhesion with aggregate in the presence of water.
→ Retain Attainment of desired stability of the mix.
→ Mixing of material, construction method temperature during mixing should be proper.

Different form of Bitumen

(1) Cutback Bitumen :—

→ Cutback bitumen is defined as the bitumen, the viscosity of which has been reduced by a "volatile diluent".
→ For use in surface dressing some type of bitumen makadum & soil stabilization, It is necessary to have bitumen a fluid binder which can be mixed relatively at low temperature. Hence to increase the fluidity of the bituminous binder at low temperature the binder is mixed with a volatile solvent.

→ The viscosity of cut-back and the rate of which it harden on the road depend on the characteristics and quality of both bitumen & volatile oil, used as diluent.

→ After the cut back mix is used in construction work the volatile gets evaporated & the cut back develops the binding properties.

→ Cut back are available in 3 types :-
(i) Rapid curing
(ii) Medium curing
(iii) Slow curing.

→ The cut back with the lowest viscosity is designated by numeral zero such as RC-0, MC-0, & SC-0
Suffix numerals 0, 1, 2, 3, 4 & 5 designate progressively thicker or more viscous cutback as the no. increases.

(2) Bitumen Emulsion :-

Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an "aqueous medium". and stabilized by suitable materials.
(mostly in hilly area.)

The bitumen content in emulsion is around 60% and the remaing is water. When the emulsion is applied to the roads, it breaks down resulting in release of water & the mixed starts to set.

3 types of bitumen emulsion are available which are (i) rapid setting
(ii) Medium setting
(iii) slow setting

→ Rapid setting type emulsion is suitable for surface dressing and penetration macadam type of construction.

→ Medium setting type is used for pre-mixing with coarse aggregate. and

→ Slow setting type is used for fine aggregate mixes.

TEST ON BITUMEN :-

Bitumen is available in a verity of types and grade. To judge the suitability of these binder various physical test have been specified. The various test on bitumen materials are

(c) emulsion & tar.

→ According to this method, viscosity is measured by determining the time taken by 50 ml of the material to flow from a cup to a specified orifice under standard test cond^n & specified temp. through

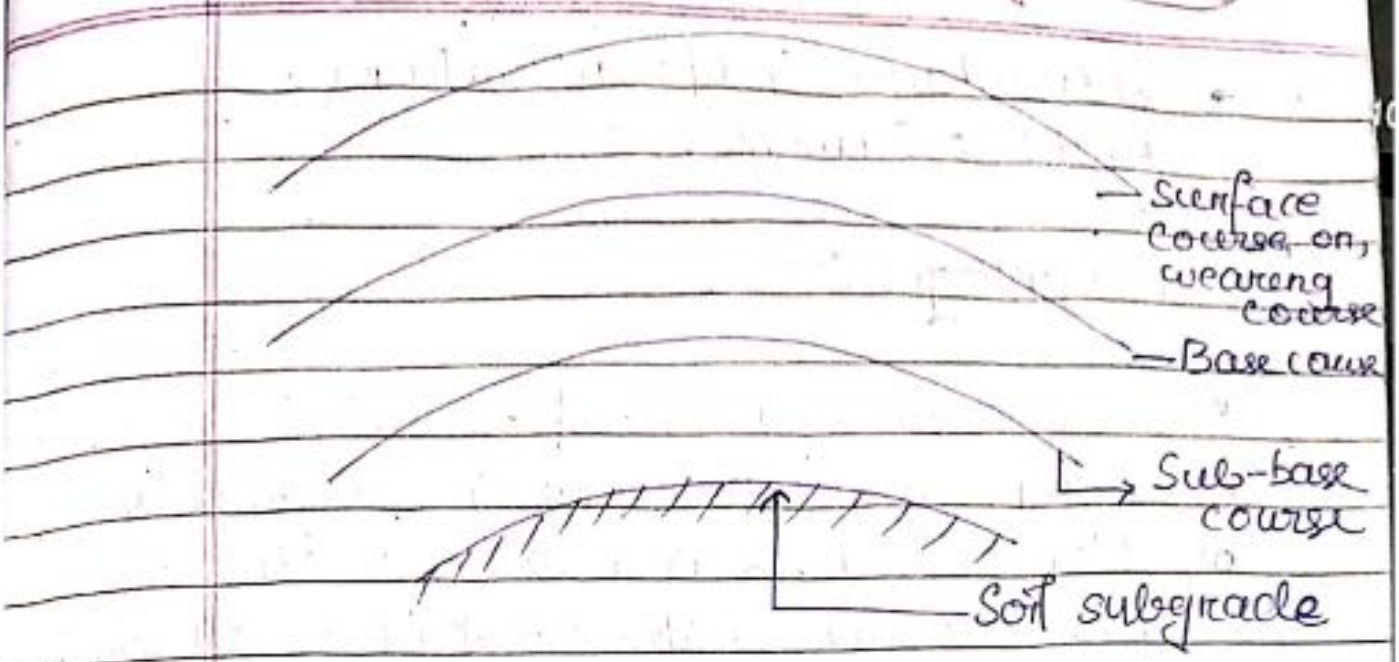
→ Higher the viscosity of the binder higher will be the time required.

↳ it is the no. of sec required for 50 ml material to flow through an orifice of specified size

4. Design Of Highway Pavement

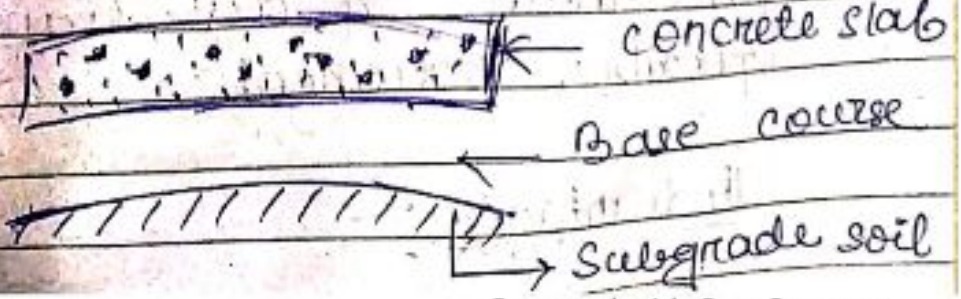
Based on structural behaviour pavements are classified into 2 categories
1. Flexible pavement
2. Rigid pavement

A typical flexible pavement consist of 4 components ; (layer)
(i) Soil subgrade
(ii) Sub-base course
(iii) Base course
(iv) Surface course (wearing coarse)



→ The flexible pavement layer transmit the vertical or compressive stresses to the lower layers by grain-to-grain transfer through the pt. of contact in the granular structure.

→ The rigid pavement consist of cement concrete slab; base course and soil subgrade. The rigid pavement are made of portland cement concrete either plain or reinforce or pre-stressed conc. The rigid pavement has the slab action and is capable of transmitting the wheel load stresses through a wider area below.



Chap- 6th

:- (Highway Maintainance) :-

Road maintainance is one of the imp. component of the entire road system. The maintainance operation involve the assessment of road condition, diagnosis of root problem & adopting the most appropriate maintainance steps.

(a) Cause Of Pavement Failure :-

1- Deffects in quality of material used
2- Deffects in construction method & quality controlled during construction.
3- Inadequate surface & subsurface drainage in the pavement layers.
4- Increase in magnitude of wheel load & the no. of load repeatation due to increase in traffic volume.
5- Settlement of foundation of embankment
6- Environmental factors including heavy rainfall, soil erosion, high water table, snowfall, frost action etc.

(b) Classification of Maintainance Work :-

Highway maintainance work is classified into 3 categories;

(i) Routine Maintainance :-

This includes filling up of pot-hole and patch repairs, maintainance of shoulder & cross slope, road side drains and clearing choked culvert, maintainance of miscellaneous items like road sign

agents arboriculture, Inspection bungalos,

(ii) Periodic Maintainance:-

This includes renwal of wearing coarse of pavement surface and preventive maintainance of various items.

(iii) Special Repaire / maintainance:-

This includes strengthening of pavement structure or overlay construction.

-> Reconstruction of pavement; widening of road repaires of damaged caused by flood etc.

(•) Failures in Flexible Pavement:-

Following are the 2 main reasons for feilure in subgrade:-

1- Excessive stress application:-

If the pavement thickness is inadequate or the loads are in excess of the design value than it harms the pavement structure as load repeation are increased.

2- Inadequate Stability:-

The resistance to deformation under stresses is known as stability. The inadequate stability of subgrade is developed due to the weakness of soil or excessive moisture or improper compaction.

(a) Failure in sub-base or base courses

The main reason which contribute to the failures in subbase or base course are as follows:

(1) Inadequate strength:-

The poor mix proporsion or inadequate thickness of pavement lead to the lack of stability or strength.

(2) Inadequate wearing course:-

If the wearing coarse is of inadequate thickness then the base & sub-base courses are exposes to damage.

(3) Lack of lateral confinment:-

If lateral confinement is not provided the action of traffic causes the material of these courses to spread out.

(4) Use of inferior material:-

(b) Failures in wearing courses:-

Following are the reason for fail failure of wearing coarse.

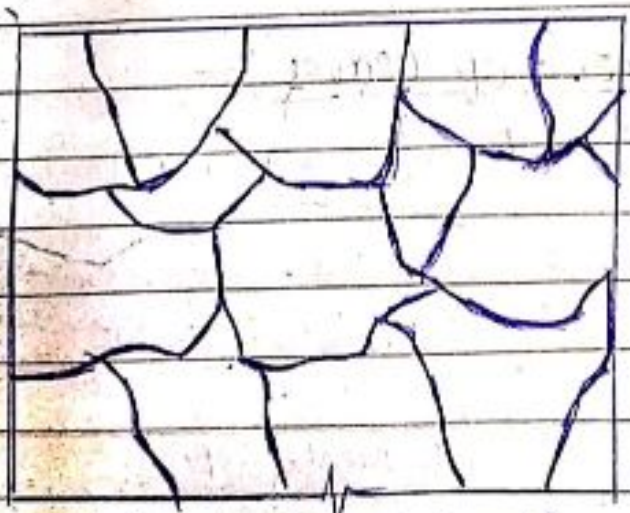
(1) Lack of proper mixed design:-

If the mix design doesn't provide for adequate binding or content the bituminous surface will perform poorly under the action of traffic.

(2) Quality controlled :-
It is necessary to provide a high degree of quality controlled in the bituminous construct?
(3) Volatization & oxidation of Binder :-
It is the bituminous surface brittle due to volatization & oxidation of binder.

Typical Flexible pavement failures :-
Following are the typical flexible pavement failure :-
(1) Alligator or, map cracking :-
(2) Consoli-dation of pavement layers
(3) Formation of wave
(4) Frost heaving
(5) Lack of binding with lower course
(6) Longitudinal cracking
(7) Reflection cracking (8) Shear failure

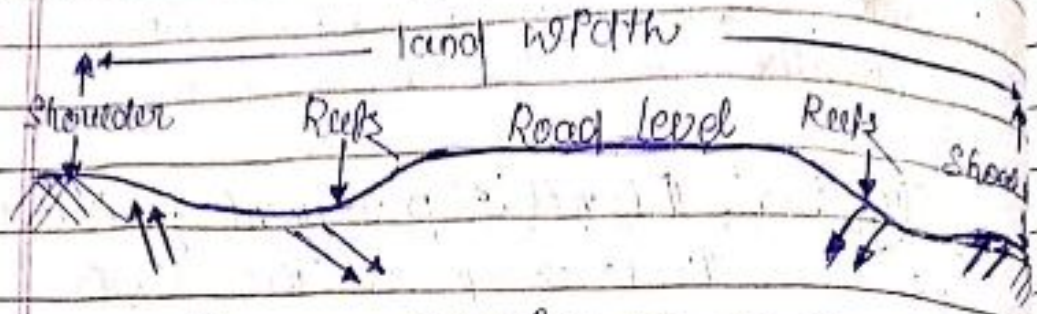
(1) Alligator or, map cracking :-



The alligator or map cracking of the surface course occurs in the pattern as shown in fig. This is the most common type of flexible

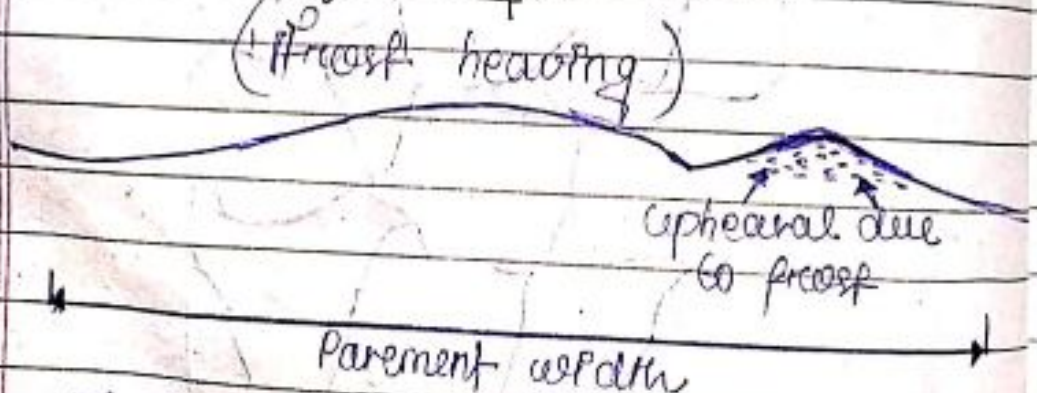
pavement failure. It mainly occurs due to fatigue & localized weakness in the underlying base course.

(2) Consolidation of pavement layers :-



The consolidation of one or more layers of pavement leads to the formation of ruts, as shown in fig. The term consolidation deformation is used to indicate the cumulative deformation which occurs due to the repeated application of load on the same spots on the road width. Depending upon the width of ruts it can be decided, whether the consolidation deformation has occurred in the subgrade or in subsequent layers.

(3) Formation of waves :-



The formation of waves and corrugation on the flexible pavement surface takes places for the following reasons :-

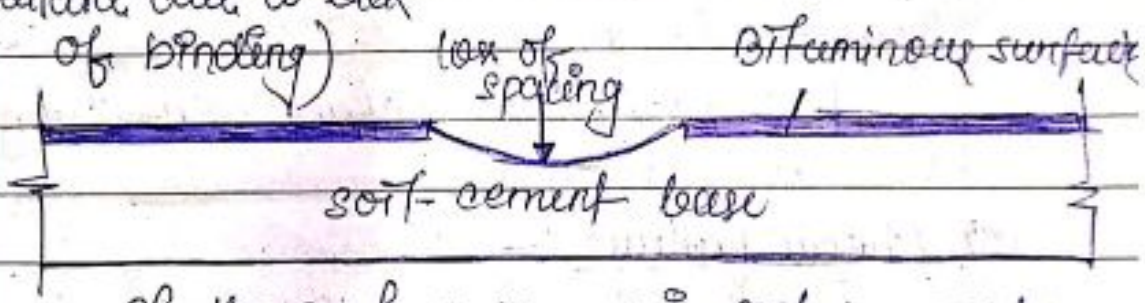
(i) Excessive speed of vehicles combined with harmonic spring action.
(ii) Defective rolling
(iii) Spongy foundation / sub-base &
(iv) Use of unsuitable binding materials.

The formation of waves & corrugations can be minimized to a great extent by controlling vechile speed careful rolling, effective drainage combined with formation on good soil & using a stable binder.

(4) Frost heaving:-

Depending upon the ground water & climatic condⁿ a localized heaving up of portion of pavement takes place due to the action of frost, as shown in fig.

(5) Lack of binding with the lower course:-



If the surface course is not properly keyed or bonded with the lower course, the slipping occurs and it leads to the loss of pavement material forming patches / pot holes.

This types of failure is common in the case where the bituminous surfacing is provided over the existing cement concrete base course or soil cement base course.

(6) Longitudinal cracking :-

The longitudinal cracking in pavement occurs due to frost action and differential volume changes in the subgrade it may traverse through the full pavement thickness. The other two causes of this type of failure are sliding of side slope & settlement of filling materials.

(7) Reflection cracking :-

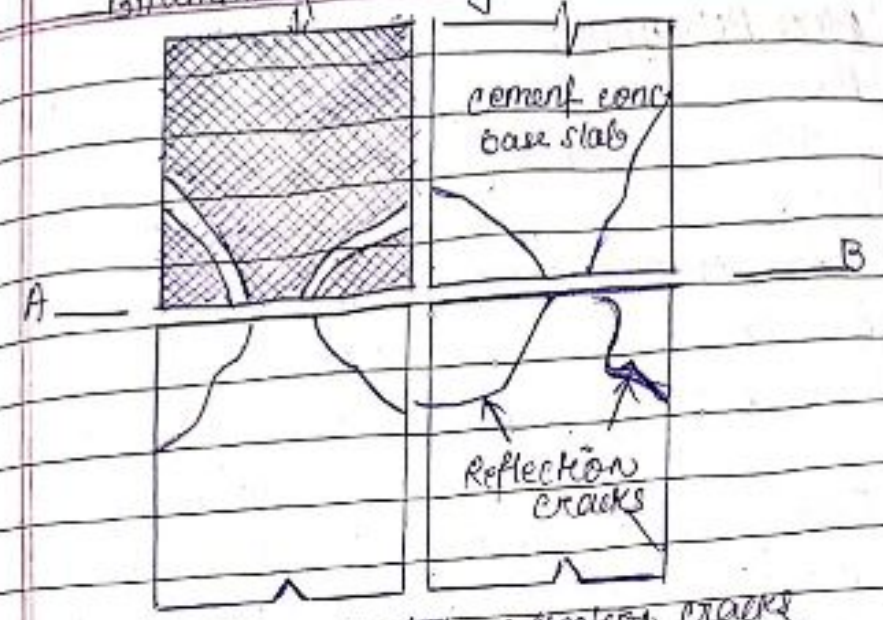
When a bituminous overlay is provided over the existing cement concrete pavement & due to some reason, the cement concrete pavement fails, the same pattern of cracking in the form of reflection cracks is seen on the bituminous overlay.

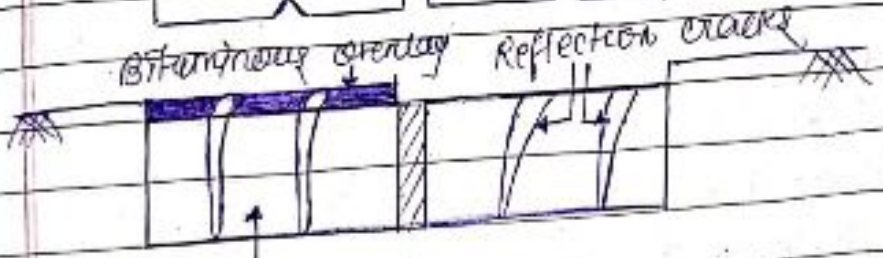
The reflection cracks don't affect the structural action of pavement section but they cause damage to the subgrade on, due and pumping as surface water gets enter through these cracks.

(8) Shear failure :-

If the shearing resistance of the pavement is lower, the shear failure cracking occurs. The upheaval of pavement materials is caused by the formation of cracks. The inadequate stability or excessively heavy loading contributes to the poor shear resistance of the pavement mixture.

Formation of Reflection Cracks





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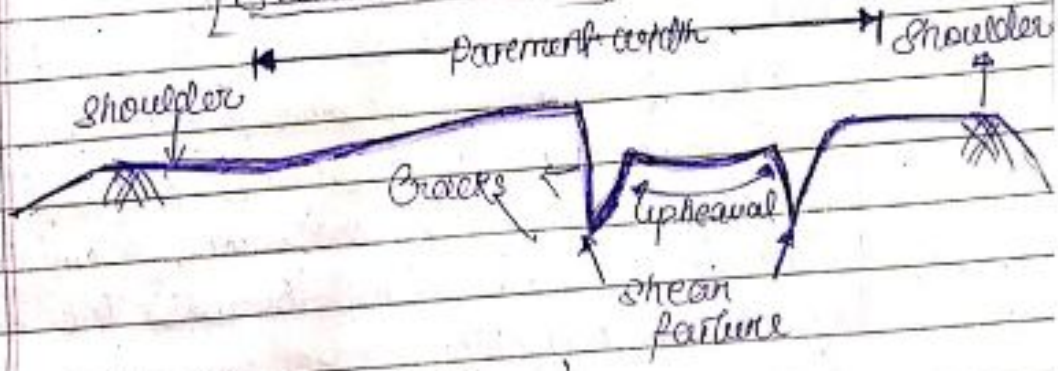


(Shear failure)

Typical Rigid Pavement Failure :-

Following are some of the typical rigid pavement failure

(i) Mud pumping
(ii) Scaling of cement conc.
(iii) Shrinkage cracks
(iv) Spalling of joints
(v) Structural cracks
(vi) Warping cracking

(1) MUD PUMPING :-

The water infiltrates through the joints, cracks & edge of the rigid pavements and forms the soil slurry known as mud. When heavy load passes over the pavement, the mud is ejected out through the joints & cracks of pavement & thus the mud pumping occurs.

Due to repeated occurance of mud pump there is considerable loss of fine grained soil from the subgrade & it results in loss of support at these joints. The continued traffic movements further develop the cracking of pavement & thus the failure of rigid pavement due to mud pumping is generally of a progressive nature.

(2) Scaling of cement Concrete :-

Due to overall deterioration of the concrete, scaling is observed in cement concrete pavement and it mainly occurs due to the deficiency of conc. mix or presence of some chemical impurities which damage the mix. The scaling of cement concrete exposes the aggr. of the mix & the pavement surface becomes rough and shabby in appearance.

(3) Shrinkage Cracks :-

The shrinkage cracks are develop during the curing operation of cement conc. pavements immediately after their curing and they may be in transverse as well as longitudinal direction.

(4) Spacing of Joint :-
The pre-formed filler materials are sometimes placed in an inclined direction during constn. and this faulty alignment results in the overhang of a conc. layer on the top slab. The joint subsequently shows excessive cracking & subsidence.

(5) Structural Cracks :-
If the pavement thickness is inadequate to take up the load of vehicles, the structural cracking occurs & generally the pavements are found to crack at the corners and edge. The structural cracks may occurs in longitudinal as well as transverse dirn. The fact that the cracking has taken place due to structural inadequacy should be carefully ascertained.

(6) Warping Cracks :-
If the joints are not suitable designed to accommodate the warping of slabs at the edge excessive warping stresses are developed & the cracks on the slab are seen in an irregular pattern. For avoiding warping cracks, the hinged joints may be provided or adequate reinforcement should be placed at the joints to take up the warping stresses.

Types of bend provided on hill roads are as following :-

(i) Hair Pin bend :-

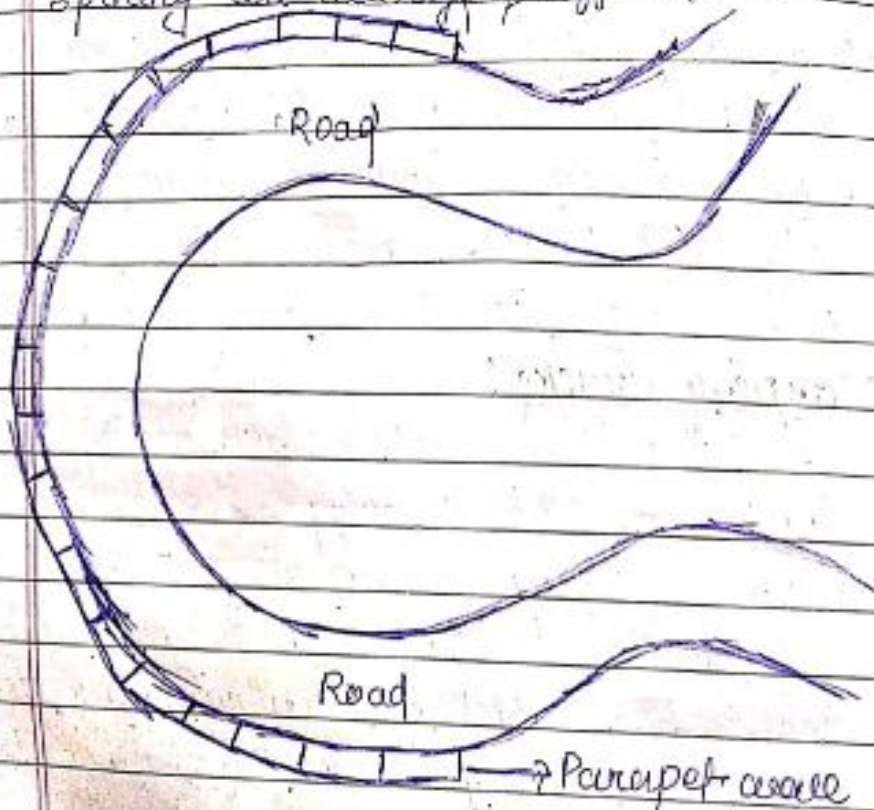
The bend in a hill road which changes its direⁿ through an angle of 180, down the hill on same side is known as hairpin bend.

→ This bend is called because it confirms the shape of a hairpin.

→ This types of bend should be located on hill side having the minⁿ slope and main stability.

→ It also safe from the view point of land slides & ground water.

→ Hair pin bend with long arms and further spacing are always preffered.

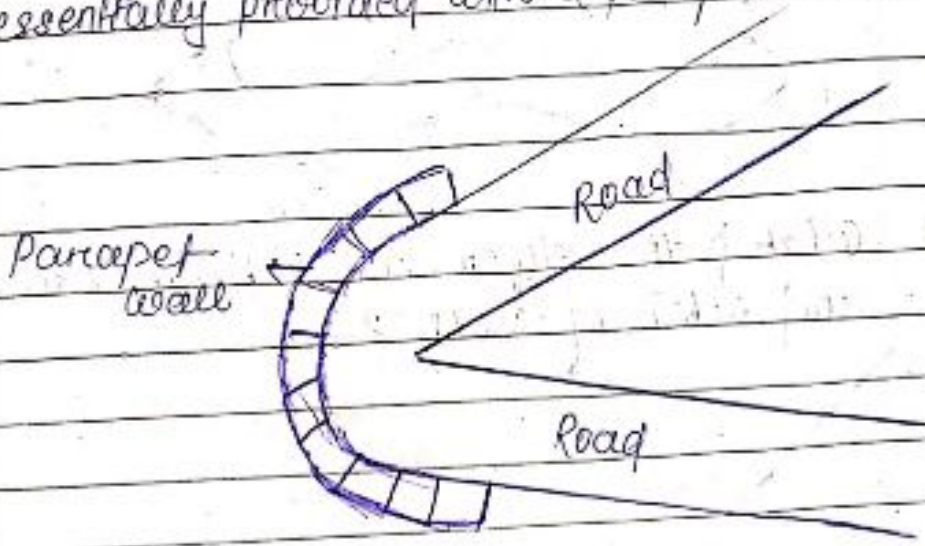


(ii) Salient Bend :-

The bend having the convexity in the outer edges of a hill road are called salient bend.

→ The centre of curvature of a salient bend lies towards hill sides.

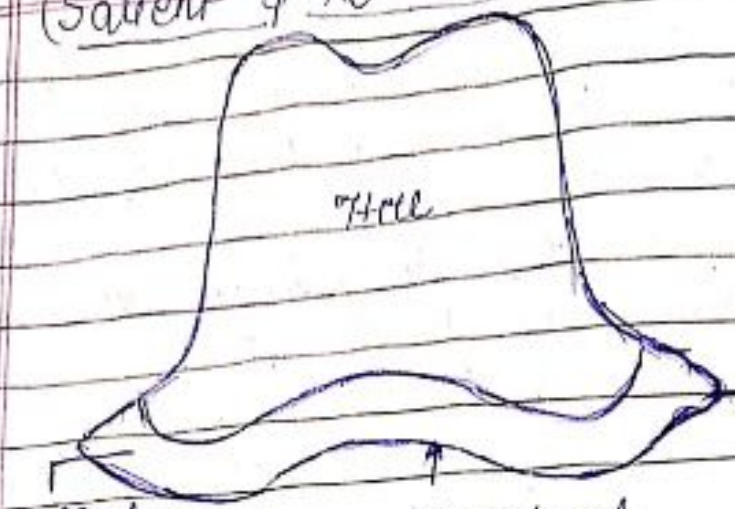
→ This type of bend occurse on the road length constructed on the ridge of a hill.
→ Salient bends are very dangerous for fast moving vehicle.
→ The outer edge of the road at such a bend is essentially provided with a parapet wall.



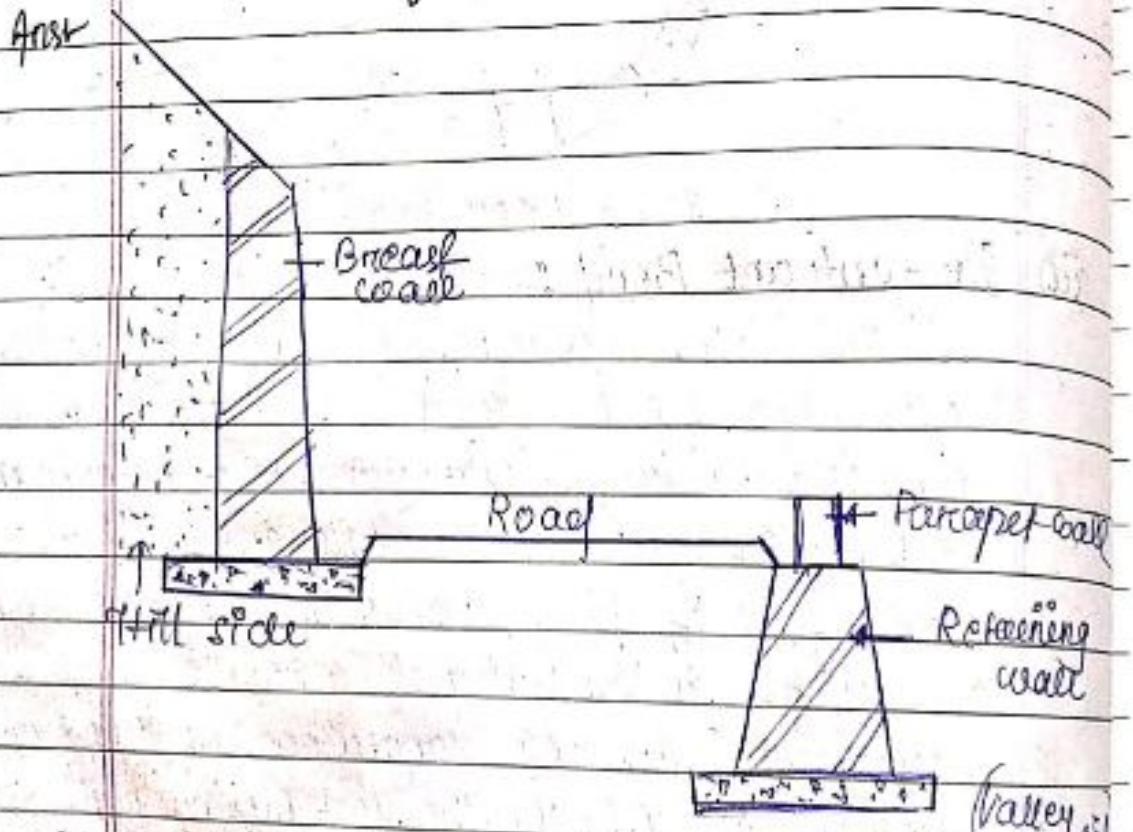
[CORNER BEND]

(iii) Re-entrant Bend :—
The bend having their convexity on the inner edge of a hill road are called re-entrant curve. The centre of curvature of a re-entrant bend lies away from the hill side.
→ This type of bend occurse in the road length constructed in the valley of a hill.
→ These bends are less dangerous as they provide adquate visibility to the fast moving traffic.
→ The parapet wall is provided only for safety of fast moving traffic

(Salient & Re-entrant Curves)



(*) What is the difference between Breast wall and retaining wall ?



(i) Breast wall & Retaining wall structure stand off to protect a freshly cut or old surface of a natural rock face.

(ii) Breast wall & retaining wall structures prevent of hill slopes under the action of weather & rain water flowing our hillslope.

(iii) Retaining wall is provided to the down side of the road while breast wall uphill side of the road in hilly area.

(iv) Impact of snow, land slides & surcharge are not considered in the design of breast wall while in retaining wall all factors are considered.

(v) R.W used to support artificial cutting while breast wall used to support natural slope.

(6) Height of breast wall shall not exceeds 3m. & for R.W less or greater than 3m.

(7) B.W are constructed on hill side & R.W are constructed on valley side of road.

Chap-7th TRAFFIC ENGINEERING :-

It is that branch of engg. which deals with the improvement of traffic performance of road networks and terminals.

→ The basic objective of traffic engg is to achieve efficient free & rapid flow of traffic with least no. of traffic accident.

→ The study of traffic engg. divided into following categories-

TRAFFIC CHARACTERISTICES :-

(•) The various factors which effects road users characteristics is classified as follows :-

(i) Phycological characteristics :-

→ These affect reaction to traffic situation of road user. the emotional factor i.e. fear, anger, superstation, attentiveness also come under this.

(2) Physical Characteristics :-

→ Physical charac of road users as vision, hearing, strength & the general reaction to traffic situation.

→ Vision include acuity of vision, peripheral vision and eye movement, glare vision, glare recovery and depth judgement.

→ Hearing helps, drivers & road, hence it is more important for pedestrians & cyclist.

(3) Mental Charac :-

Knowledge, skill, intelligence experience & attitude affect the road user charac.

(4) Environmental Factor :-

The various environmental cond" are traffic stream characteristics, facility to the traffic atmospheric cond" & the locality.

(•) VECHICULAR CHARACTERISTICS :-

The various vechicular charac. affecting the road design may be classified as :-

(1) Static Charac :-

Static charac. of vechicle affecting road design are dimension, max" turning angle & wt. the ht. of the vehicle affects the clearance of the overhead structure. the ht. of driver seat affects visibility distance & ht. of head light affect head light sight distance.

(2) Dynamic Characteristics :-

It affecting road design are speed, accel and breaking charac. & some aspects of

vechicle body design. The speed & accln. depends on the power of engine and the resistance to be overcome.

TRAFFIC STUDIES :-

Traffic studies or surveys are carried out to analyse the traffic charac. These studies helps in deciding the geometric design feature & traffic control for safe & efficient traffic movement. The traffic surveys for collecting traffic data are also called traffic census.

(i) Traffic volume study
(ii) Speed study → Spot speed study
→ Speed & delay study
(iii) Origin & destination study
(iv) Traffic flow charac.
(v) Traffic capacity study
(vi) Parking study
(vii) & Accident study

(i) Traffic volume study :-

Traffic vol. is the no of vehicle crossing a section of road per unit time at any selected period. Traffic vol study is used in planning, traffic operation & control of existing facilities & also for planning & design of new facility.

Counting of traffic vol.:-

Traffic vol. counts may be done by mechanical counters or, manual counters.

(*) Presentation of traffic volume data :-

- **Annual average daily Traffic (AADT):-**
  AADT of the total traffic as well as classified traffic are calculated. This helps in deciding the relative importance of a route & in phasing the road development programme.
- **Trend Chart:-**
  It shows volume trends over period of year are prepared. These data are useful for planning future expansion design & regulation.
- **Variation chart:-**
  It showing hourly, daily & seasonal variation. This helps in deciding the facility & regulation needed during peak traffic period.
- **Traffic flow map:-**
  Helps to find the traffic vol. distribution.
- **Volume flow:-**
  Vol. flow dia. of intersection drawn to a suitable scale or indicating traffic vol. for showing the details of crossing & turning traffic.
- **30th highest hourly volume or the design hourly volume:-**
  It is found from the plot between hourly vol & the no. of hours in an year that the traffic vol. is exceeded. The 30th highest hourly vol is the hourly vol. that could be expected exceeded only 29 time in a year & all other hourly vol. of the year will be less than this value.

(ii) Speed Studies :—

(•) Spot speed :—

Spot speed is the instantaneous speed of a vechicle at a specified section or location.

(•) Average speed :—

It is the avg. of the spot speed of all vehicles passing a given point on the highway.

(•) Running speed :—

It is the avg. obtain by a vehicle over a particular stretch of a road, while the vehicle is in motion.

(•) Overall speed or travel speed :—

It is the effective speed with which a vehicle travers a particular route bet^n 2 terminal. This is obtained by dividing the total

distance travel by the total time taken including all delays & stopages.

The travel time per unit length of road is inversely proposnal to the speed. If T is travel time 'V' is speed then

$$T(\text{min/km}) = \frac{60}{V}$$

$$T(\text{sec/km}) = \frac{3600}{V}$$

The fundamental relationship bt^n traffic vol. density & Speed is $\boxed{q = KVs}$.

where q = flow

K = density

Vs = Space-mean speed

* **Traffic Regulation :-**

In order to have safe traffic operation on road it is essential to impose adequate traffic regulation & traffic control devi

Traffic regulation and laws cover the following 4 phases.

(i) **Driver Controls :-**

These include driving licencence for light & heavy motor vehicle, driving test & min^m requirement, financial responsibility and civil liability.

(ii) **Vehicle controles :-**

Various regulations & controls of vehicles are vehicle registration,

requirement of vehicle, max. dimension wt. & fitness & inspection of vehicle, equipment & assessories.

(iii) Flow regulation

Regulation of traffic flow have been laid down such as dirc., turning & overtaking.

(iv) General control

Some other general regulations & provisions are made to reports accident & recording & disposing traffic violation

(f) Traffic control devices

The various aids and devices used to controls, regulates & guide traffic is known as traffic control devices. The most common amount is were :

Traffic sign, traffic signals, road marking, road function.

Traffic Sign - Traffic sign have been devided into 3 categories; (i) Regulatory sign → (ii) warning sign (iii) Informatory sign

The sign should be placed such that they could be seen, recognised by the road user easily & in time.

← (D-17.10.19)

(•) Warning Signs :-

Warning or cautionary sign are used to warn the road users of certain hazard condⁿ that exist on adjustent to the road way.

→ The warning signs are in the shape of equilateral triangle with its aper pointing upward. They have a white background reg boarder & black symbols.

→ warning signs are to be located at distance of 120, 90, 60 & 40m respectively from the hazard condⁿ on NH, MDR, ODR and VR.

→ Commonly use of warning signs are left hand or right hand kerb, left hand & right hand hair pin bend, narrow bridge on road ahead, gap in median, cross road, slippery road, cycle crossing, T junction, Y junction, school zone, railway crossing, falling rock, humps, round about, pedestrian crossing, men at works.

(•) Informetary Signs :-

→ These signs are used to guide the road user along routes, inform them of destination and distance & provide with information to make travel easier, safe and pleasant.

→ The information signs are grouped under the following subhead

(i) Direction & place identification
(ii) Facility information sign
(iii) Other useful information sign
(iv) Parking sign (v) flood gauge

→ Flood gauge sign should be installed at all gauge ways and submergible bridge & on culvert to indicate to the road user the ht. of flood above road level.

→ Parking Signs are set up parallel to the road using square sign with blue background and white coloured letter 'P'. 'P'

→ Other useful information sign includes no through road, no through side road.

→ The facility information signs are rectangular with blue background & white or black letter or symbols.
It includes public telephone, petrol pump, hospitals, reading place, testing place, fire service post.

→ The direction & place identification signs are rectangular with white background, black border & black letter and arrows. The sign of this group include destination sign, distance sign, route marker, and place identification sign.

Traffic Signals:-

are controlled devices which could alternately direct the traffic to stop and proceeds at intersection using red & green traffic light signals automatically. The main requirement of traffic signals are to draw attention, provide meaning & time to respond, and to have min^m. waste of time.

(●) Advantages of traffic signals :-

Properly design traffic signal have the following uses :-

→ They reduced certain type of accident
→ The signal allow crossing of the heavy traffic flow with safety.
→ The provide orderly movement of traffic & increase the traffic handling capacity of most of intersection at grade.
→ The quality of traffic flow is improve & it provide all the vehicle move at approximately at same speed.
→ Signal provide a chance to crossing the traffic of minor road to cross the path of continuous flow of traffic stream at reasonable interval of time.

(●) Disadvantages of traffic signals :-

→ The rear end collision may increase.
→ Improper design & location of signal may leads to violation of the controlled system.
→ Failure of traffic signals due to electric power failure or any other defect may cause confusion to the road users.

CYCLE :-

The period of time required for one complete sequance of signal indication is called cycle.

PHASE :-

A part of signal cycle allocated to a traffic movement or a comb. of traffic movement is called phase.

INTERVALS:-
Any of the division of the signal cycle during which signal indication don't change is called Intervals.

(a) Types of Traffic Signals:-
(1) Traffic controled signals:-
(i) Fixed time signal
(ii) Mannually operated signal
(iii) Traffic actuated signal/automatic signal
(2) Pedestrian Signal:-
(3) Special traffic signals

The traffic controled signal have 3 colours one for each phase of traffic flow. The Red light is meant for stop, the green light pedicals go and the amber or yellow light allowed the clearance for the vehicle

(1) Traffic control signal
(a) Fixed time signal:-
The signal are said to be regularly a cycle of red ambers and green light. The timing of each pedestrian phase of the cycle is predetermined based on the traffic studies & they are the simplest type of automatic traffic signal which are electrically operated.

(ii) Traffic actuated signals:-
These are those in which the timing of the phase and cycle are changed according to the traffic demand.

(2) Pedestrian Signals are meant to give the right of way to pedestrian to cross the road during the walk period after the vehicular traffic shall be stop.

(ii) Manual:- The traffic police are assign the duty to watch the traffic demand from suitable observation point during the peak hours on various approaches and to varies the timing of phase & cycle according to the actual traffic demand.

(3) Special traffic Signals
Flashing beacons are meant for to warn the traffic.

Road Marking:-

Traffic marking is called special sign intend to control, warn, guide or regulate the traffic. The markings are made using paints. The various type of marking are classified as
(i) Pavement marking (ii) Kerb marking
(iii) Object marking (iv) Reflect/unit marking

Traffic Island:-

These are raised areas constructed within the road way to established physical channel through which the vehicular traffic may be guided.

→ The traffic Island are classified based on the fun" as follows ;

(i) Divisional Islands
(ii) Channelizing Island
(iii) Pedestrian loading Island
(iv) Rotary.

(i) Divisional Island :—

→ These are intended to separate opposing flow of traffic on a highway with 4 or more lanes.
→ By dividing the highway into two one way road ways the head on collision are elimi= nated and accident are also reduced.

(ii) Channelizing Island :—

→ These are used to guide the traffic into Proper channel through the intersection area these are very useful as traffic controlled devices for intersection at grade.

(iii) Pedestrian loading Island :—

These are provided at regular bus stop and similar places for the protection of passenge A pedestrian Island at or near a ~~bus stop~~ cross work is use to protect pedestrian crossing the carriage way is termed as Pedestrian Refusing Island.

(iv) Rotary :—

Rotary Island is large central Island of a rotary intersection. This Island is much larger than the central Island of channalized intersection. The crossing manoeuvre (smooth more) is converted into ~~weave~~ weaving

by providing sufficient waving length.

ARBORI-CULTURE :-

It means the tree culture or care & plant of trees. It is the usual practice to grow trees on both side of a road.

→ Trees provide on both side on urban or rural road serve the following purpose

(i) To provide attractive landscape of roadside.
(ii) To provide shade to the road users.
(iii) To protect against moving sand in desert.
(iv) To provide fruit bearing trees and timber.

Spacing Of Trees :-

The trees should be atleast 1.8m away from the edge of road way.

→ The distance bt^n 2 trees varies from 10m to 18m. The normal being is 12m.

→ The trees should be located in such a way that they don't interference to the traffic & damage the road surface.

Date - 29.09.2019

1. Excavating Equipment :-

→ This equipment is a self which is used mainly exert a powerful tractive force for pulling other machine

→ when the traffic tractor is not required for hauling other machine it can be easily converted to serve as bulldozer and angle dozer.

2. Bulldozer And Angle dozer :-

These are used for the following purposes -

→ To clear the sight of curve.
→ To make the land level.
→ To escavate the material and haul for a distance of about 100m.

3. Grader :-

A grader is used to levelled the ground & sprayed the loose material.
→ It is a self propelled or towed by a tractor
→ It consist of 3-4m. long angle blade.
→ The various attachment of the grader are blade, bulldozer, snow plough, sccarifier elevator attachment & roller.

3. Scrapper :-

This equipment consist of a large bucket called as scraper and it is attached to tractor. It has a cutting edge on blade at the bottom and it is possible to dig earth to a depth of 250mm.

4. Escavator :-

It is the oldest types of machine which remove earth. It performs its work of moving the earth while the main unit is stationary.
→ The little effort is required to move the wt. of earth in a verttical movement.

5. Dredger :-

In order to provide necessary depth of water near the port, it is become essential to move the process the grazing by using this Equipment

6. Ripper / Rotor / Scarifier :—
This is an equipment which is sometimes attached to a tractor. It is mounted to the wheel and carries 2 or 4 teeth. The ripper is used to breakup the ground to pull off the roots. These loosen material can be removed by scraper.

7. Trenger or ditcher :—
To excavate the trenges of width from 250mm to 450mm & depth upto 4m. with accuracy & speed. This type of equipment is used.

2 Compacting Equipment :—
(1) Road roller :—
The principle on which a road roller is working is the application of pressure which is slowly increased and is then gradually decrease. Following are the 3 types of road roller.

(a) Pneumatic Roller :—
The rubber tyered rollers are found to be very efficient in the compaction of earth subgrade, granular soils in base course final operation for bituminous surface grasing etc.

(b) Sheep's-foot Roller :—
→ These rollers are considered more suitable for compacting clayey soil / soil containing mixture of sand & clay.
→ This type of roller consist of hollow steel cylindre each about 1.2 m long and 1.2 m dia with 150mm - 230mm projection extend

out from the curve surface of the cylinder.

(c) Smooth wheel Roller :-

These rollers are suitable to compact a wide range of soils (granular soil & pavement material for the various layer.

(2) Vibratory compactors :-

It consist of a vibrating unit mounted on a screed, plate or roller. This type of compaction is the most suitable for coarse grained soil.

(3) Rammer (Earth) :-

The Earth rammer may be static or vibrating.

→ The static earth rammer compact soil flows through the surface only. Hence the vibrating earth rammer are used to achieve better compaction of soil.

(*) Equipment for bituminous road (Hot mix plant) :-

(1) Bitumen Heater :-

For potable mixing plant as well as for hand mixing the bitumen heater is an essential equipments. It is also required for surface painting primary coat, Tack coat, and for penetration macadam.

→ The bituminous heaters are available in various sizes and they are heated either by steam, wood fl coal or by kerosene oil. The heated bitumen is carried to the sight of work in pouring can or pot & it is spread over the surface at predetermined rate of application.

(2) Bitumen Mixture:-
For big project there are no. of mixing plants available for the construction of bituminous road. They usually consist of the following components
(i) Aggregate dryer
(ii) Aggregate heating arrangement
(iii) Storage of ags of various sizes
(iv) Bitumen heater
(v) Bitumen storage tank
(vi) Mechanical mixture
(vii) Weighing machine

(3) Bitumen truck mixture:-
For facilitating the preparation of a quick & efficient mix the bitumen mixing unit have been installed in truck or tractor. Various types of truck mixers are available.

(4) Power:-
The power unit is a compromize bt a pneumatic tractor and a drumper. It consist of a chamber having capacity equal to that of drumper. Bringing bituminous mix from the central mixing plant. The chamber is provided with adjustable slight opening.

(*) Equipment for cement conc. road:-
1) Batching plant:-
The batching plant is a mechanical Equipment for measuring either by wt. or by vol. the quantities of diff. ingredient required to make up each complete charge of a conc. mixture.

The batching plant in which the quantity of diff. material & measure is called a weighing batcher.

(2) Conc mixtures
The conc. mixtures of various types and capacity are available. They are either of tilting type or non-tilting types. They are provided with power operated loading loading hopper. It consist of a drum with blade in the inside portion.

(3) Vibrating Screed
It is used for compaction and finishing of conc. It consist of a wooden or mild steel screed of suitable handle. It is driven by vibrating mi either electrically or by compressed air or by petrolled engine.

(4) Internal vibrator
It is employed to ensure the compaction of conc along the form to avoid any honeycombing a the edge of slab. It is also known as Emersi vibrator. comprises with a vibrating head.

(5) Float
The longitudinal float is made off from hard wood. It is provided with a handle. It is of 750mm length & 75mm width. It is used fo smoothening the concrete.

(6) Straight Edger
The st. edge is made of hard wood with mil steel plate at bottom. It is of 3m. length & 100mm width. It is provided with a handle and u to check the finished pavement surface in longi tudinal dir?.

(7) Belt:-

A canvas belt with 2 wooden handle at end is used for finishing the pavement surface before the cone harden. It is of 250mm width and 600mm longer than the width of the slab.

(8) Fibre brush:-

A fibre brush is used to make mark across the pavement surface so that it became skid resistance - provided with a handle about 2m long

(9) Miscellaneous:-

In addition to the above main tools various other miscellaneous tools and equipment used to required to finish of the works would be edging tools, spade, sovel, mortar pan, waterpot rod etc.

Questions

Q. Calculate the stopping sight distance for a design speed of 100 km/hr. Take the total reaction time as 2.5 second and coefficient of friction = 0.35.

Q. Find the stopping sight distance for a design speed of 65 km/hr. Assume suitable data.

Q. The speed of the overtaking and overtaken vehicles are 80 km/hr and 60 km/hr respectively. If the acceleration of the overtaking vehicle is 2.5 km/hr per second, calculate the safe passing sight distance for (a) one-way traffic
(b) two-way traffic.

Q. Find the safe overtaking sight distance for a highway having a design speed of 100 km/hr. Assume all other datas.

Q. Calculate the maximum allowable speed on a horizontal curve of radius 350 m if the maximum allowable values of lateral coefficient of friction is 0.15 and rate the super-elevation is 0.07.

Q. Calculate the extra width of pavement required on a horizontal curve of radius 700 m on a two lane highway, the design speed being 80 km/hr. Assume length of wheel base, l = 6 m.

Q. The radius of of a horizontal curve is 400 m, the total pavement width at curve is 7.6 m and the superelevation is 0.07. Design the transition curve length for a speed of 100 km/hr.

Q. A national highway passing through a flat terrain has a horizontal curve of radius equal to the ruling minimum radius. If the design speed is 100 km/hr, calculate absolute minimum sight distance, super-elevation, extra widening and the length of transition curve. Assume necessary data suitably.

Q. A vertical summit curve is formed when an ascending gradient of 1 in 25 meets an other ascending gradient of 1 in 100. Find the length of the summit curve to provide the required stopping sight distance for a design speed of 80 km/hr.

Q. The deviation angle at a summit curve is 0.05 and the overtaking sight distance is 300 m. Find the length of summit curve required.

Q. An ascending gradient of 1 in 50 meets a descending gradient of 1 in 80. Determine the length of summit curve to provide (a) ISD (b) OSD for design speed of 80 km/hr. Assume all other datas.

Q. A valley curve is formed by a descending gradient of 1 in 40 which meets an ascending gradient of 1 in 30. Design the total length of valley curve, if the design speed is 100 km/hr so as to fulfill both comfort condition and head light sight distance for night driving, after calculating the SSD required

Q. A radius of 250 m has to be provided at a locality, due to site restrictions in a National Highway with design speed 100 km/hr. Design the superelevation. Should there be restriction in speed?

Q. Explain the CBR test. How are the results obtained and interpreted.

Q. What are the various tests carried out on bitumin? Briefly mention the principle and uses of each test.

Q. Explain 'Flexible and Rigid' pavements and bring out the points of difference.

Q. Draw a sketch of flexible pavement cross section and show the component parts, Enumerate the functions and importance of each component of the pavement.

Q. Enumerate the steps for the preparation of the sub-grade.

Q. Explain the principles, application and method of construction of mechanical soil stabilization.

Q. Write short notes on :-

a) Seal coat.

b) Grouted macadam.

c) Water bound Macadam.

d) Wet-mix macadam.

e) Bitumin bound macadam.

Q. f) Mud-pumping.

g) Spalling of joints.

Q. What are the general causes of pavement failure?