UGMIT RAYAGADA

Lecture Note

Of

HE, 4th Sem.

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Highway Engineering

Dt - 18/07/19

Ch-1 Introduction

Engineering Application of science & mathematics in the real world.

Highway Engineering

The planning, design, construction & maintenance of road and roadway facilities to fulfil the needs of traffic is called Highway engineering.

Importance of Highway:

→ Roads are used by various types of road vehicles like passenger cars, buses, trucks, cycles etc.

→ Road transport requires a relatively small investment for the Govt. as compared to railways and airways.

→ Road transport offers a complete freedom to road users. i.e. The flexibility of changes in location, direction, speed and timings of travel.

→ Road transport saves time particularly for short distance

→ The road safety is basically less because of breaking the lane discipline as compared to railways & airways.

→ Road transports provide door to door service which is not possible in the case of other mode of transportation.

Assignment - Ministry of surface transport. Dt - 23/07/19

Indian Roads Congress (IRC)

→ IRC is a semi-official, technical body formed by central govt. in 1934 as a recommendation

→ The purpose of constituting IRC was

(i) to provide a common platform for regular sharing and exchanging of experience, ideas on matters related to planing, construction & maintenance of roads in India.

(ii) To recommend standard specification (a set of rules & protocols)

(iii) To publish standard codes, journals, research publications related to designs of highways in India.

∴ IS code of steel → 800

→ The technical activities of IRC are mainly carried out by HRB (Highway Research Board) and committee consisting of experts in different subjects.

→ It has played an important role in formulation of three 20yr road development plans.

→ It works in close colaborcation with Roads wing of ministry of surface transports Govt. of India.

Central Road Research Institute (CRRI)

→ CRRI was constituated as per the recommendations of Jaykar Committee as a central organisation of research & dissemination (spread) of information related to highways in the year 1950.

→ The functions of CRRI are :

(i) To carry basic research for design, construction and maintenance of highways.

(ii) To carry research on traffic safety & transport economics.

(iii) To carry research on economic utilisation of locally available materials for construction of highways.

(iv) To carry research of new machinery, tools, equipments & instruments for highway engineering

(v) To provide technical advice & consultancy services to various organisations.

IRC classifications of roads -

According to IRC, roads are divided into 5 categories.

1. National Highways (NH)
2. State Highways (SH)
3. Major District Roads (MDR)
4. Other District Roads (ODR)
5. Village roads (VR)

(1) NH :-

→ These are the major roads running through length & breadth of India, connecting major ports, foreign highways, capitals of large states, tourist centers etc.

→ All NHs are assigned a respective numbers. The highway connecting Delhi - Ambala - Amritsar is denoted as NH 1.

The highway connecting Madurai - Rameswaram is NH - 49 &

Bombay - Agra is NH - 3

→ These highways posseses highest design specification.

② SH -

→ These are the roads of a state connecting the NHs of adjacent states, District head-quarters of a state.

→ NH & SH have same design speed and geometric design specifications.

→ Some times SH carry heavier traffic than some of National Highways.

③ MDR -

→ These are the roads within a district serving areas of production and connecting those with eachother or with the main highways of a district.

→ These roads have lower speed and geometric design specifications than NH & SH.

④ ODR -

→ These roads connect rural areas, town centres to MDR of higher importance.

→ They provide facilities for transportation of raw materials or goods mainly of agricultural products from rural towns to higher markets & vice versa.

→ These roads have lower design speed specification than MDR.

⑤ VR :-

→ These are the roads connecting rural villages with one other.

→ They have design specifications & speed lower than ODR.

→ Most of the roads are not even metalled (stone chips + tar).

Organisation of State Highway Department :-

→ State highway plays a major role in economic development of people as it connects major and important places of a state as well as neighbouring states. Also development of these roads will improve tourism activities in state as it connects major tourist places.

→ During the year 2013-14, Govt. has introduced a new scheme "State Highway Development Programme" (SHDP) for development of existing 2158 km of state highways with an outlay of 3000 crore.

→ During 2017-18 the budget provision of RS-500 crore for development of for another 500km of state highways.

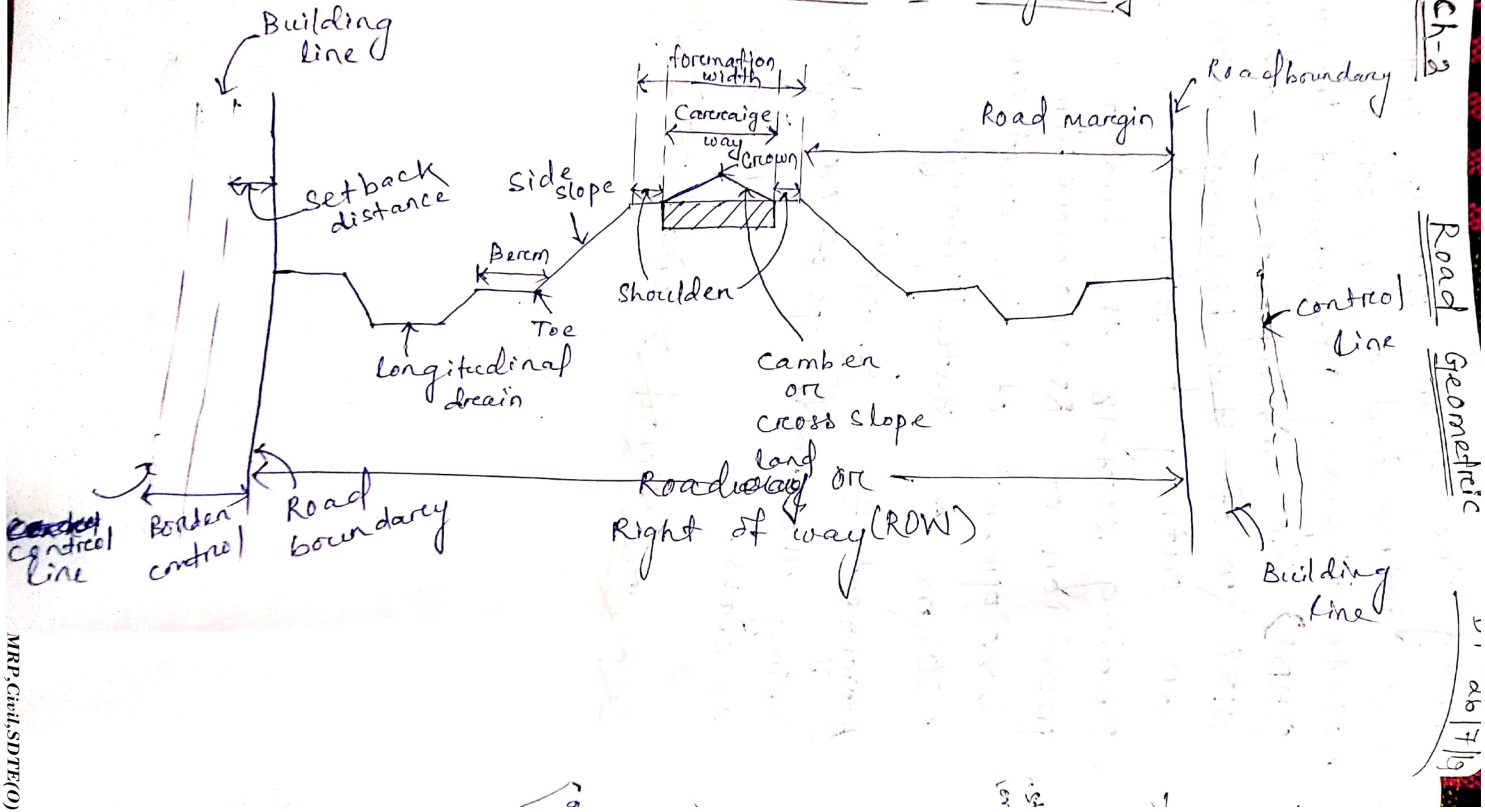
Assignment-2 Dt-25|7|19

Bring the road maps of Odisha & India to class.

Dt-26|7|19

~~Cross sectional elements of Highway~~

Cross - sectional elements of Highway



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Geometric Design of Highway -

→ It deals with the study of dimensions and layout (arrangement) of various elements of highway.

→ Geometric design of highways deals with (a) cross section elements
(b) Sight distance considerations (stopping / overtaking)
(c) Horizontal alignment details
(d) Vertical alignment details
(e) Intersections.

Factors controlling Geometric design of highway -

Geometric design of highways depends on several factors they are ① Design speed :-

[operating speed / speed limit]

AASTHO (American association of State transport Highway officials)

→ As per AASTHO design speed is defined as the selected speed used to determine various geometric features of road way.

→ It is the most important factor controlling all geometric design elements of highway.

→ In India different design speed Standards have been assigned depending upon the importance / class of road. such as, NH, SH, MDR, ODR, VR.)

→ Design speeds are also modified based on terrai / topography of that place.

(IV) Topography -

→ Topography or terrai conditions influence the geometric design of highway significantly.

→ For example - The design speed of NH & SH on plane terrain with cross slope upto 10%. is 100 kmph whereas the speed on rolling terrain with cross slope upto 25% is 80 kmph & that on mountaineous terrain with cross slope upto 60% is 50 kmph.

Stiff - more than 60%.

→ So, as topographic ~~affect~~ factors affect the design speed & design speed controls all the geometric elements of highway, thus, topography affect the geometric design of highway.

(III) Traffic factor -

→ Factors associated with traffic that control geometric design of highways are vehicular characteristics and human characteristics of road users.

→ Different classes of vehicles like passenger cars, trucks, buses, motor cycles etc have different dimensions and weights which affects the geometric design of highways.

Dt - 1/8/19

→ Also physical, mental, psycological characteristics of dreivers and pedestrians controls the geometric design of highway upto a great extent.

(IV) Design hourly volume & capacity —

(i) Volume of traffic that is total no. of vehicles moving on the road fluctuates with time ranging from a very low value during off-peak hours to a very high value during peak houres.

(ii) So, It will be uneconomical to design the road way facilities for peak traffic volume/highest traffic volume. Therefore, a reasonable volume of traffic volume is choosen from extensive traffic volume studies. which is called Design hourly volume, used to design all the roadway facilities.

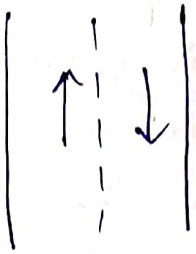
(iii) The maximum no. of vehicles that a particular road way can accomodate is called capacity.

(iv) Also the ratio of volume to capacity affects the LOS of road. (Level of service)

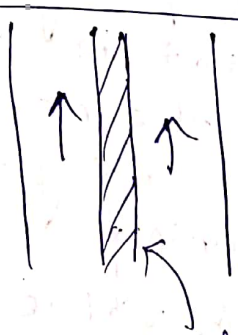
(v) Environmental & Other factors -

1-lane 1-way

1-lane 2-way



2-lane 1-way



2 lane 2-way

Environments factors like Aesthetics, landscaping, air pollution, noise pollution etc should be given due consideration during geometric designs of highways.

Highway cross-section elements -

(i) Pavement surface characteristics.
- Friction → Skid, Slip
- Surface unevenness
- Light reflecting characteristics

(ii) Camber / cross slope

(iii) Carriage way

(iv) Traffic separator / median

(v) Kerbs

(vi) Road margin
- Shoulder
- Parking lane
- Lay-bye
- frontage roads
- Drive ways
- Cycle tracks
- Foot path / Sidewalk
- Guard rail
- Embankment slopes

(vii) Formation width

(viii) ROW

(a) **Friction** -

- Friction between the vehicle tyre & road surface plays a very important role in determining the operating speed and distance required in stopping and accelarating the vehicle.

(i) Skidding - occurs when vehicle slides without the revolving of wheels, i.e the path travelled by the wheels of vehicle on the road will be greater than the circumferencial movement of the wheels of vehicle.

→ It normally occurs on horizontal curves due to greater speeds after applying breaks partially or fully called lateral skidding.

(ii) Slip -

→ It occurs when wheels revolve more than the corresponding longitudinal movement on roads, i.e Here circumferencial movement is greater than the path travelled by the wheels of vehicle on the road.

→ It occurs when vehicle rapidly accelarates from slow speed or stop position or when road surface is muddy.

Factors affecting friction/skid resistance.

① Type & condition of pavement surface.

② Roughness of surface.

③ Type & condition of tyre

④ Speed of the vehicle
speed $\propto \frac{1}{\text{friction}}$

⑤ Load & tyre pressure

⑥ Temperature of pavement surface. (inverse)

⑦ Breaking efficiency
(The extent to which wheels are locked / arrested on application of breakes)

As per IRC	
longitudinal coefficient of friction (stopping site distance overtaking site distance)	= 0.35 - 0.5
lateral coefficient of friction (design of Horizontal curves)	= 0.15

(b) Surface / Pavement unevenness :-
↓
not being a level surface
comfort ↓, fuel consumption ↑, operating speed ↓
safety ↓, VOC ↑
↓
vehicle operation cost
(owning + operate + maintain or repair)

- Bump integrator
- cm/km

→ Pavement unevenness is commonly measured by using an equipment called bump integrator, in terms of unevenness index.

→ If unevenness increases then operating speed, ~~VOC~~ comfort, safety decreases & VOC, fuel consumption & wear & tear of

tyres increases.

→ Unevenness index is the cummulative measure of vertical undulations of pavement surface for unit horizontal length of road. It is measured in cm/km.

→ For a good pavement surface it should be less than 150 cm/km.

⑥ Light reflecting Characteristics –

→ White road surface i.e, cement concrete roads have good visibility at night but causes glare during day time.

→ Black road surface i.e, Bituminous road has No glare during day but has poor visibility at night.

→ The glare caused by reflection of head light is considerebly more on wet pavement surface than on dry pavement surface.

⑦ Camber/cross-slope/rant –

→ It is defined as the transverse slope provided to road surface by raising the middle portion of road, for drainage of rain water for better performance on road.

→ It is expressed in 1 in n and x%. (x in 100).

→ Objectives of providing camber –

(I) To drain out rainwater from road surface as quickly as possible, so that the surface gets dry soon after rain, & safe value of skid resistance.

(II) To prevent entry of water into bituminous pavement layers, as continuous contact of water causes stripping of bitumen from aggregates i.e, water loosens the bonding between bitumen & aggregate, which will lead to deterioration of pavement layers.

(III) To prevent entry of surface water into subgrade soil because the strength and stability of ~~surface~~ subgrade gets adversely affected when infiltration of water takes place through it.

→ The required camber of a pavement surface depends on (a) type of pavement surface (b) Amount of rainfall.

IRC has recommended following values of camber for different types of road surface as shown in table below.

Sl No	Type of pavement surface	Range of camber in areas of rainfall Heavy to Light
1.	Cement concrete road & thick bituminous surface	1 in 50 to 1 in 60
2.	Thin bituminous surface	1 in 40 to 1 in 50

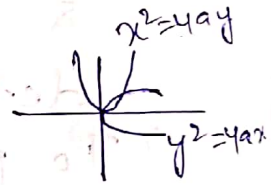
3	WBM & Gravel type pavement WBM - Water Bound Macadam	1 in 33 to 1 in 40
4	Earthen road	1 in 25 to 1 in 33

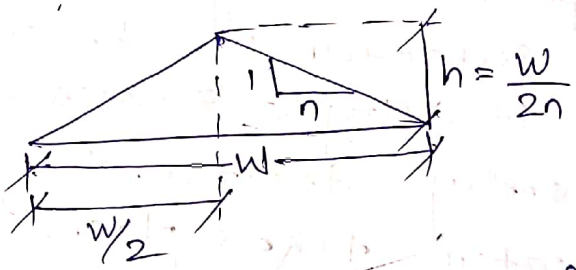
→ There are generally 3 types of camber provided on road surface

They are -

(a) Straight line camber
(b) Parabolic camber
(c) Combination of straight line & parabolic camber.

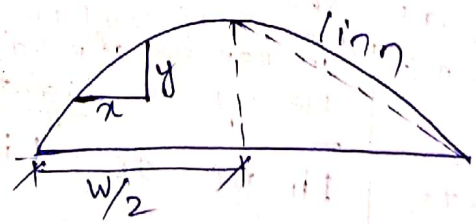
(a) Straight line camber -





Normally these types of cambers are provided in PCC and RCC type of pavements.

(b) Parabolic camber -



$$y = \frac{2x^2}{nW}$$

$y \propto x^2$

$$\Rightarrow \frac{y}{x^2} = \frac{h}{\left(\frac{W}{2}\right)^2}$$

$$\Rightarrow \frac{y}{x^2} = \frac{h}{\left(\frac{W}{2}\right)\left(\frac{W}{2}\right)} = \frac{1}{n \times \frac{W}{2}}$$

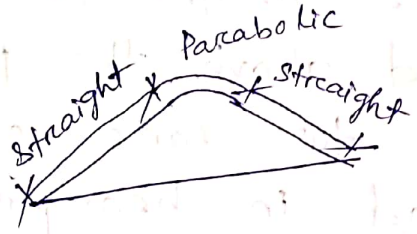
$$\left(\because \frac{h}{\frac{nW}{2}} = \frac{1}{n}\right) = \frac{2}{nW}$$

$$\Rightarrow y = \frac{2x^2}{nW}$$

These are generally provided for their better drainage property, but these are difficult to construct.

(c) Combination of straight line & parabolic camber –

These are also called composite camber.



It will decrease the intensity of pressure because Area increases.

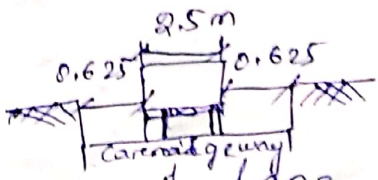
& $P \propto \frac{1}{A}$

Dt - 8/8/19

(c) Width of Pavement / carriageway –

It is the part of a roadway over which vehicles travel.

As per IRC standard width of a vehicle is 2.44m ≃ 2.5 assuming a side clearance of 0.625m on both sides the standard carriage way width for a single lane road will be 2.5 + 0.625 + 0.625 = ≃ 3.75m.



For roads more than 1 lane, the standard width of carriageway is equal to 3.5m per lane.

For example:- width of carriageway for a 3-lane road = (3.5 × 3).m

→ The width of pavement / carriageway depend upon following 3 factors.

They are :- (a) Width of the vehicle
(b) No. of Lanes
(c) Side clearance

Q) Determine the height of the crown of the road above the pavement edge for a two lane cement concrete road in heavy rainfall region.

width of road for two Lane

= 3.5 × 2 m

= 7.0 m

Range of camber for cement concrete road in heavy rainfall region = 1 in 50

Height of camber =

$y = \frac{2x^2}{nW}$

$= \frac{2 \times (\quad)^2}{50 \times 7.0}$

$h = \frac{W}{2n}$

$= \frac{7.0}{2 \times 50}$

$= 0.07$ m

Q) Findout the height of the crown above the pavement edge for a gravel road two lane highway in low rain fall region.

width of road for two lane
$= 3.5 \times 2$
$= 7.0\ m$

Range of camber for a gravel road in low rain fall region = 1 in 40

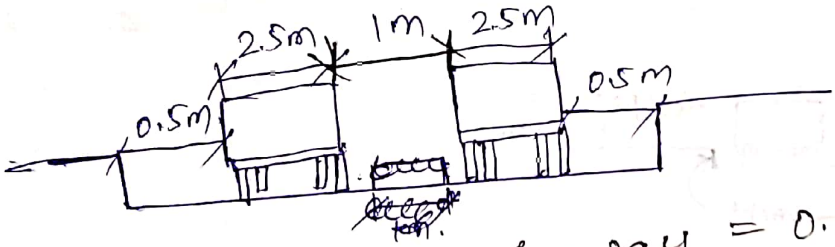
Height of camber $h = \frac{W}{2n}$

$= \frac{7.0}{2 \times 40}$

$= 0.087\ m.$

Dt - 9/8/19.

For two lane road -



width of carriageway $= 0.5 + 2.5 + 1 + 2.5 + 0.5$
$= 7\ m.$

Classification

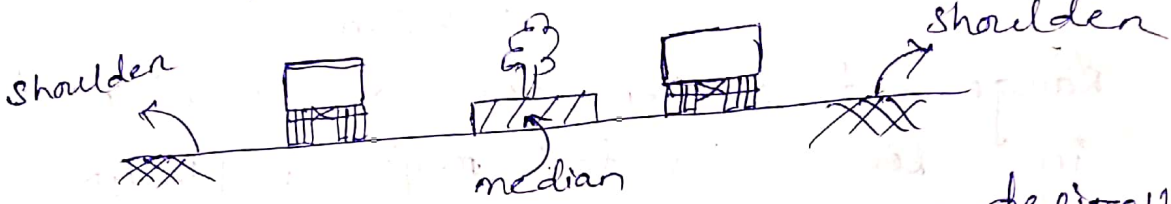
1. 1 Lane road
2. 2 lane, without kerbs
3. 2 lane with kerbs
4. Intermediate carriageway
5. Multi-lane pavement

Width of the carriageway

- 3.75 m
- 7 m
- 7.5 m
- 5.5 m
- 3.5 m per lane

Medians –

The main purpose of providing medians on the road is to prevent, avoid head-on collisions between vehicles moving in opposite direction.



→ IRC recommends a minimum desirable width of 5m per medians on rural highways, It may be reduced to 3m. where land is restricted and on long bridges 1.2m. It is reduced to 1.2 – 1.5 m.

Kerbs

It indicates the boundary between carriageway and footpath or shoulder.

→ kerbs are divided into 4 types based on their height & slope –

(a) Low/Mountable type kerb
(b) Semi barrier type kerb
(c) Barrier type kerb
(d) Submerged type kerb

(a) Low / mountable type kerb -

→ Height = 10cm

→ These are provided to encourage the traffic to remain in the lane and also to allow the driver to enter into shoulder or footpath areas in emergency with a little difficulty.

(b) Semi barrier type -

→ Height = 15cm

→ These are provided when pedestrian traffic is high.

(c) Barrier type -

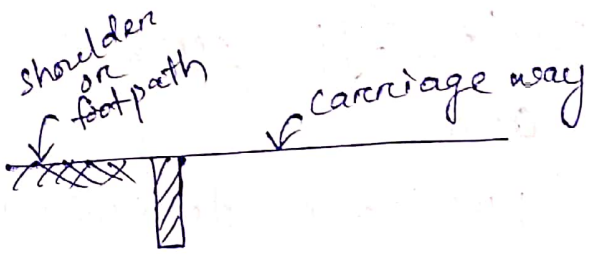
→ Height = 20cm

→ These are provided when there is considerable amount of pedestrian traffic.

(d) Submerged type -

→ Used in rural roads at pavement edges between pavement edge and shoulder.

→ These kerbs provide lateral confinement and stability to the pavement.

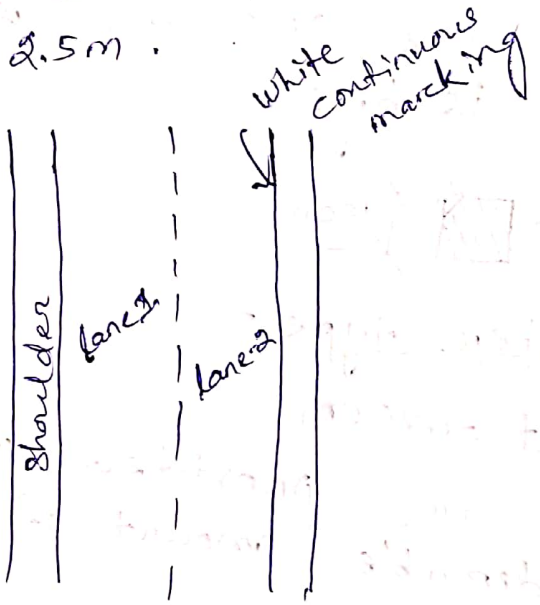


Road margin -

Shoulder -

→ These are provided along the road edge that is adjacent to the carriage way to serve as an emergency lane for vehicles that have broken down.

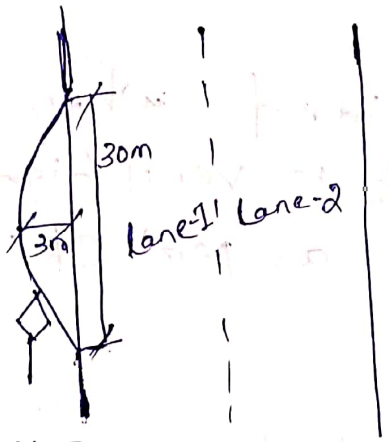
→ Minimum width of shoulder as per IRC is 2.5m.



Lay-bye

→ These are provided adjacent to the shoulder near public convineance guide map / facilities where vehicles can stop for a while without interrupting the through traffic.

→ These are of 3m width. and length 30m.



Bus-bay -

These are designated spots on the side of road where buses stop for picking/dropping passengers/goods without interrupting the through traffic.

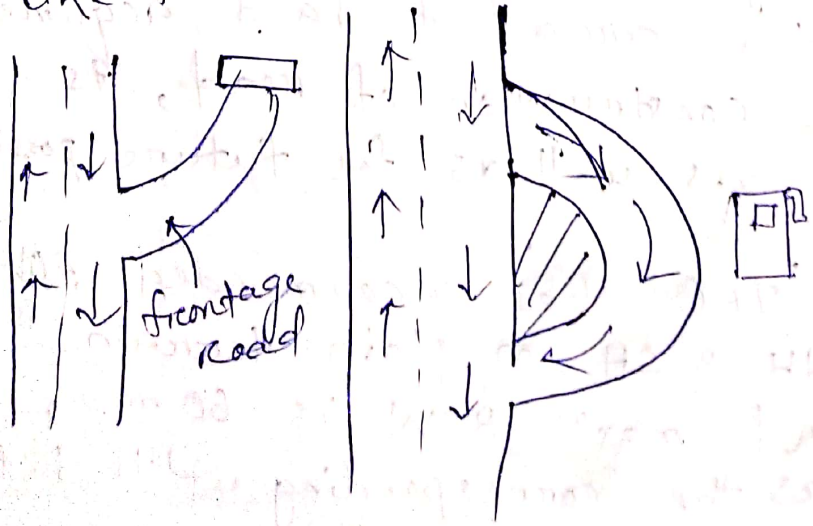
Frontage road - (or service road)

→ These are provided to give access to different properties like schools, colleges, temples, hospitals etc. along the highways.

→ These are also called service roads.

Drive ways -

→ These are the roads connecting highways with commercial establishments like fuel stations.



Cycle track -

→ These are provided when volume of cycle traffic is very high.
→ Minimum width as per IRC = 2m.

Foot path -

→ These are provided when volume of pedestrian traffic is very high.
→ Minimum width as per IRC = 1.5 m on either side of road.

Guard rails -

→ These are provided at the edge of shoulder constructed on an embankment, to prevent vehicles from running off Caway) ~~from~~ the embankment.

Formation width -

→ It is the sum of width of carriageway ~~and~~ including shoulders on both sides and Separadors if any.

ROW (Right of way) -

→ It is the area of land acquired for the construction of road, its elements as well as for future possible extension.
→ As per IRC the recommended ROW for NH & SH on plain terrain is 45 m and max^m ROW is 60 m., where as the corresponding width

Building lines is 80m and between control lines is 150m.

Dt - 13/08/19

Sight Distance

Sight Distance -

How far you can see.

It is defined as the actual distance along the road surface that a driver from a specified height (1.2m) above the carriageway can see clearly any moving/stationary (rest) obstruction.

→ It is of 4 types. They are -

1 inch = 2.5 cm
1 ft = 12 inch
1 m = 3.3 ft
1 ft = 30 cm

(a) Stopping sight Distance (SSD)
(b) Over taking sight Distance (OSD)
(c) Head light sight Distance (HSD)
(d) Intermediate Sight Distance (ISD)

(a) Stopping Sight Distance (SSD) -

→ It is the minimum distance available to the vision of a driver intending to stop the vehicle without colliding with any moving/stationary obstructions.

→ As per IRC, It is the distance between a moving vehicle with the eye level of the driver at a height of 1.2m and an object of 0.15m, so that no collision occurs if a situation arises to stop the vehicle.

→ Factors affecting SSD are -

1. Total reaction time of the driver (2.5 sec as per IRC)
2. Speed of the vehicle
3. Efficiency of Brakes
4. Friction between the tyre of the vehicle and road surface
5. Gradient of the road, if any.

(I) Total reaction time of the driver -

→ It is the time taken from the instance the object is visible to the driver to the instance the brakes are applied effectively.

→ As per IRC, it is taken as 2.5 sec.

→ It may be split up into two parts/-

(a) Perception time

(b) Brake reaction time

(a) Perception time -

Time interval from the instance object is visible to the driver to the moment when he/she realises that vehicles need to be stop/brakes should be applied.

(b) Brake reaction time -

Time taken to apply the brakes effectively

(II) Speed of the Vehicle -

$SSD \propto Speed$

SSD increases with the increase in speed of the vehicle & vice-versa.

(III) Efficiency of Brakes -

$$SSD \propto \frac{1}{\text{Braking efficiency}}$$

→ It is defined as the extent up to which the wheels are locked after application of brakes.

→ It is inversely proportional to SSD.

100% braking efficiency is undesirable. Because it will result in 100% skidding.

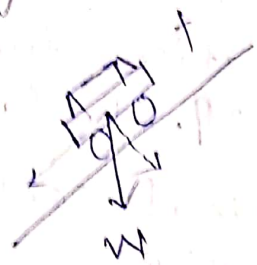
(IV) Friction between tyre of the vehicle & road surface

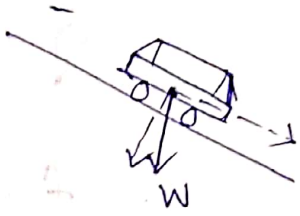
$$SSD \propto \frac{1}{\text{friction}}$$

A higher value of friction between tyre of the vehicle and road surface will require a lesser SSD and vice-versa.

(v) Gradient of the road, if any -

→ SSD will be lesser incase of an up gradient and SSD in higher incase of a down gradient.





Dt - 14/8/19

Formula of SSD :-

Stopping sight Distance

= lag distance + Breaking distance

↓

Distance travelled by the vehicle during total reaction time.

$= (V\ m/s \times t\ s) + \frac{V^2}{2gf}$

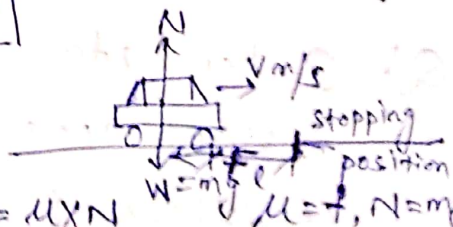
$\Rightarrow \boxed{SSD = Vt + \frac{V^2}{2gf}}$

Breaking distance

It can be found by equating Kinetic energy possessed by the vehicle with the workdone against frictional resistance force between vehicle tyre & road surface.

F = frictional force

μ = coefficient of friction



equating, K.E = workdone against frictional resistance

$\frac{1}{2}mv^2 = (\text{frictional resistance}) \times l$

$= (f \times mg) \times l$

$\Rightarrow \boxed{l = \frac{V^2}{2gf}}$

where, v = speed of the vehicle in m/s.

t = total reaction time of the driver in sec.

g = acceleration due to gravity $= 9.81\ m/s^2$

f = longitudinal coefficient of friction.

$1\ m = 10^{-3}\ km$

$1\ hr = 60 \times 60 = 3600\ sec$

$1\ sec = 1/3600 = 2.78 \times 10^{-4}$

$1\ km/hr = \frac{1000}{3600} = 0.278$

$1\ m/s = 10^{-3} / 2.78 \times 10^{-4} = 3.6\ km/hr$

$$SSD = 0.278 Vt + \frac{(0.278 * V)^2}{2 \times 9.81 \times f}$$

$$= 0.278 Vt + \frac{3.94 \times 10^{-3} V^2}{f}$$

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

Q) Calculate the min^m SSD for design speed of 50 km/hr. Assume coefficient of friction as 0.37 & Reaction time of driver as 2.5 sec.

$V = 50\ kmph$

$f = 0.37$

$t = 2.5\ sec$

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

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

$$= 61.35 \text{ m}.$$

Effect of slope i.e gradient.

$$SSD = Vt + \frac{v^2}{2g\left(f \pm \frac{n}{100}\right)}$$ (+ve for −3%, −ve for +3%)

Effect of braking efficiency

$$SSD = Vt + \frac{v^2}{2gf \times \eta}$$ ← Braking efficiency

Effect of both slope & braking efficiency

$$SSD = Vt + \frac{v^2}{2g\left(f \pm \frac{n}{100}\right) \times \eta}$$

* For one way road, minimum sight distance = SSD
* For two way road, $SSD = SSD_1 + SSD_2$
* For 2-lane 2 way, SSD = SSD.

Q) Calculate the SSD on a highway at a descending gradient of 2% for a design speed of 80 kmph. Assume other data As per IRC.

V = 80 kmph

n = 2 (−ve)

$f = 3.5$

$t = 2.5$ sec

$$SSD = 0.278Vt + \frac{V^2}{254\left(f - \frac{\eta}{100}\right)}$$

$$= 0.278 \times 80 \times 2.5 + \frac{(80)^2}{254\left(3.5 - \frac{2}{100}\right)}$$

$$= 131.95 \text{ m.}$$

$$= 132 \text{ m.}$$

Q) Calculate the min^m SSD require to avoid a headon collision upto two cares approaching from the opposite direction at 90 & 60 kmph. Assume a reaction time of 2.5 sec, f of 0.7 and a brake efficiency of 50%. in either case.

For 1st case -

$V = 90$ kmph

$t = 2.5$

$f = 0.7$

$\eta = 50$

~~$SSD_1 = 0.278Vt + \frac{(V^2)}{254 f \times \eta}$~~

$= 0.278 \times 90 \times 2.5 + \frac{(90)^2}{}$

$= 63.4$

$$V = 90 \times \frac{1000}{3600} = 25$$

$$SSD_1 = vt + \frac{V^2}{2gf\eta}$$

$$= 25 \times 2.5 + \frac{(25)^2}{2 \times 9.81 \times 0.7 \times 0.5}$$

$$= 153.51 \text{ m}$$

$$V = 60 \qquad v = \frac{60 \times 1000}{3600} = 16.67 \text{ m/s}$$

$$SSD_2 = 16.67 \times 2.5 + \frac{(16.67)^2}{2 \times 9.81 \times 0.7 \times 0.5}$$

$$= 82.14 \text{ m}$$

$$SSD = SSD_1 + SSD_2$$

$$= 153.51 + 82.14$$

$$= 235.65 \text{ m.}$$

Q. Calculate the values of
① Headlight sight distance = SSD
② Intermediate sight distance = 2 × SSD
for a highway with a design speed of 65 kmph. Assume any other data required. V = 65 kmph, f = 0.35, t = 2.5 sec.

$$SSD = 0.278 \times 65 \times 2.5 + \frac{(65)^2}{254 \times 0.35}$$

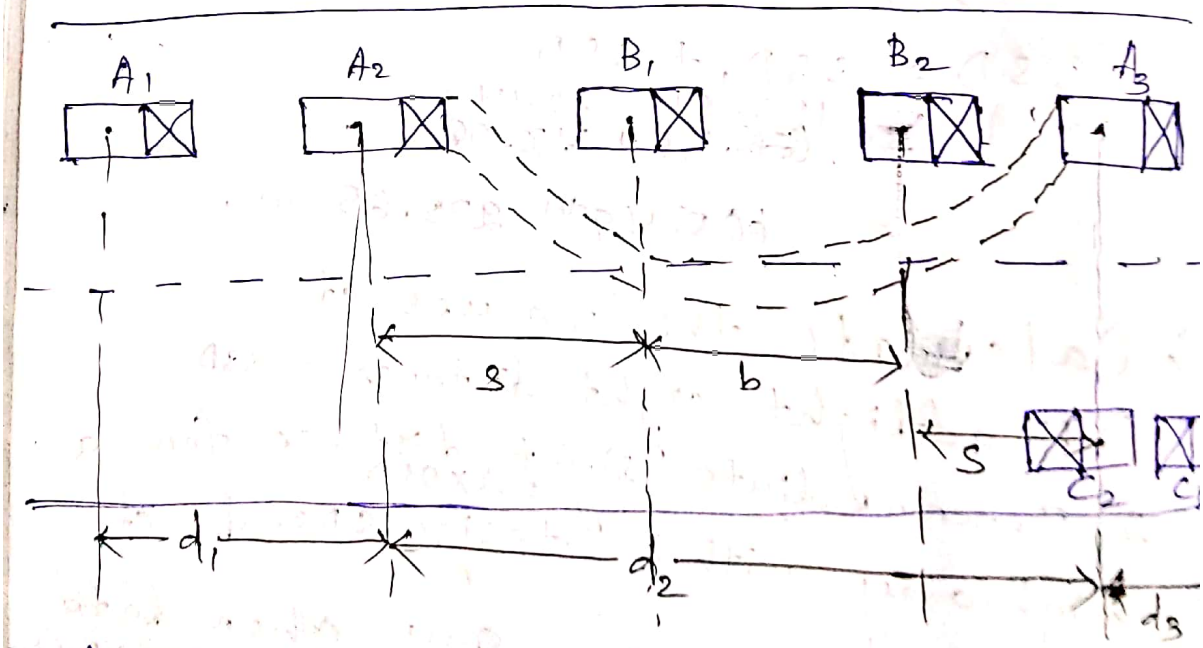
$$= 92.7 \text{ m.}$$

$$ISD = 92.7 \times 2 = 185.4 \text{ m.}$$

(b) Overtaking sight distance:-

It is defined as the minimum distance available to the vision of a driver intending to overtake the slow moving vehicle ahead with safety against the traffic of opposite direction.

→ As per IRC, it is the distance along the length of road which a driver with eye level at a height of 1.2 m above the road surface can see the top of an object of height 1.2 m above the road surface.



A = Overtaking vehicle moving at desi
Speed v m/s or V kmph.

B = Slow moving vehicle moving at a
Speed lesser than design speed
V_b m/s or V_b kmph.

C = vehicle coming from opposite direction at design speed V m/s & V kmph.

Total OSD = $d_1 + d_2 + d_3$

d_1 = Distance moved by vehicle A during the reaction time (2 sec).

$$d_1 = V_b \text{ m/s} \times t \text{ s.} = 0.278\, V_b \times t$$

$$d_2 = b + 2s$$

$$b = V_b \times T$$

As per IRC $S = 0.7\, V_b + 6$ or $0.2\, V_b + 6$

S = minimum spacing between vehicles for safety

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

$$\Rightarrow b + 2s = V_b T + \frac{1}{2}aT^2$$

$$\Rightarrow b + 2s = b + \frac{1}{2}aT^2$$

$$\Rightarrow 2s = \frac{1}{2}aT^2$$

$$\Rightarrow T = \sqrt{\frac{4s}{a}}$$

$$T = \sqrt{\frac{4s}{a}} = \sqrt{\frac{4s}{0.278A}} = \sqrt{\frac{14.39s}{A}} = \sqrt{\frac{14.4s}{A}}$$

a m/s², A kmph/se

$a = 0.278\, A$

$$T = \sqrt{\frac{14.4s}{A}}$$

Where,

T = total time taken for overtaking operation in sec.

a = uniform acceleration of the overtaking vehicle A during overtaking operation in m/s².

b = distance moved by slow moving vehicle B during overtaking time.

A = uniform acceleration of the overtaking vehicle in kmph/sec.

If, v_b is not given then,

$$v_b = v - 4.5 \text{ m/s}$$

or

$$V_b = V - 16 \text{ km/h}$$

$$d_3 = vT \text{ m or } 0.278 VT$$

$$OSD = d_1 + d_2 + d_3$$

$$= v_b t + b + 2s + vT$$

$$= v_b t + v_b T + 2s + vT$$

$$OSD = v_b t + v_b T + 2(0.7\, v_b + 6) + vT$$

where, v is the speed in m/s.

$$OSD = 0.278 V_b t + 0.278 V_b T + 2(0.2 V_b + 6) + 0.278 VT$$

where, V is the speed in kmph.

* For 1 way traffic

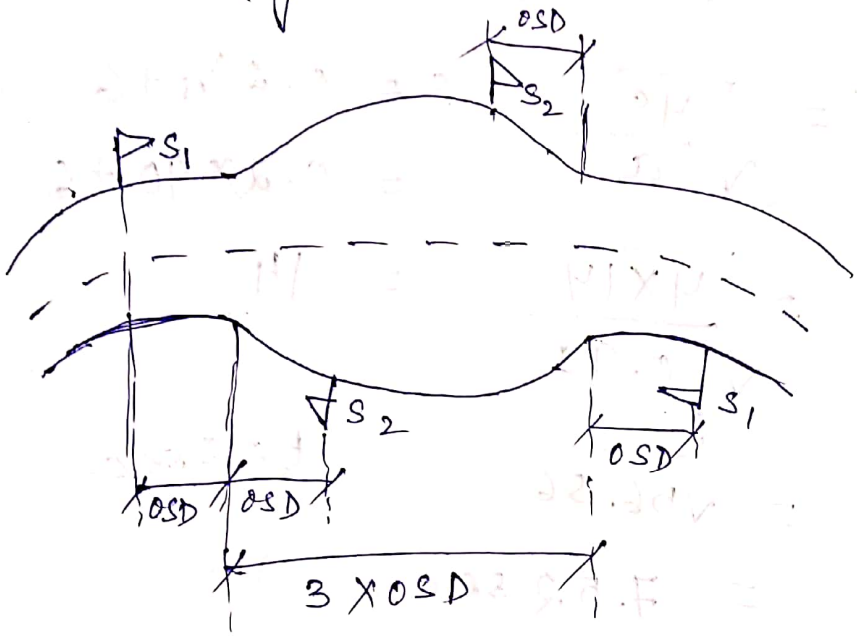
$$OSD = d_1 + d_2$$

Assignment

Explain PIEV theory.

Overtaking zone –

The zones / stretches provided along the length of road meant for overtaking are called 'overtaking zones.



Minimum length of overtaking zone
$= 3 \times OSD$

Design length of overtaking zone
$= 5 \times OSD$

S_1 = sign post "Overtaking zone ahead".

S_2 = sign post "End of overtaking zone".

Q) The speed of overtaking & overtaken vehicles are 70 & 40 kmph resp on a two way traffic road. If the acceleration of overtaking vehicle is $0.99\ m/s^2$. Then

1. Calculate safe OSD.
2. Mention minimum length of overtaking zone.
3. Draw a sketch of overtaking zone and show the positions of sign boards

$V = 70$ kmph

$V_b = 40$ kmph

$a = 0.99\ m/s^2$

$T = \sqrt{\frac{4s}{a}}$; $s = 0.2V_b + 6$

$= 0.2 \times 40 + 6$

$= \sqrt{\frac{4 \times 14}{0.99}}$ $= 14$

$= \sqrt{56.56}$; $t = 2$ sec

$= 7.52$ sec

(a)

$OSD = 0.278\, V_b t + 0.278\, V_b T + 2(0.2V_b + 6) + 0.278\, VT$

$= 0.278 \times 40 \times 2 + 0.278 \times 40 \times 7.52 + 2 \times 14 + 0.278 \times 70 \times 7.52$

$= 22.24 + 83.62 + 28 + 146.34$

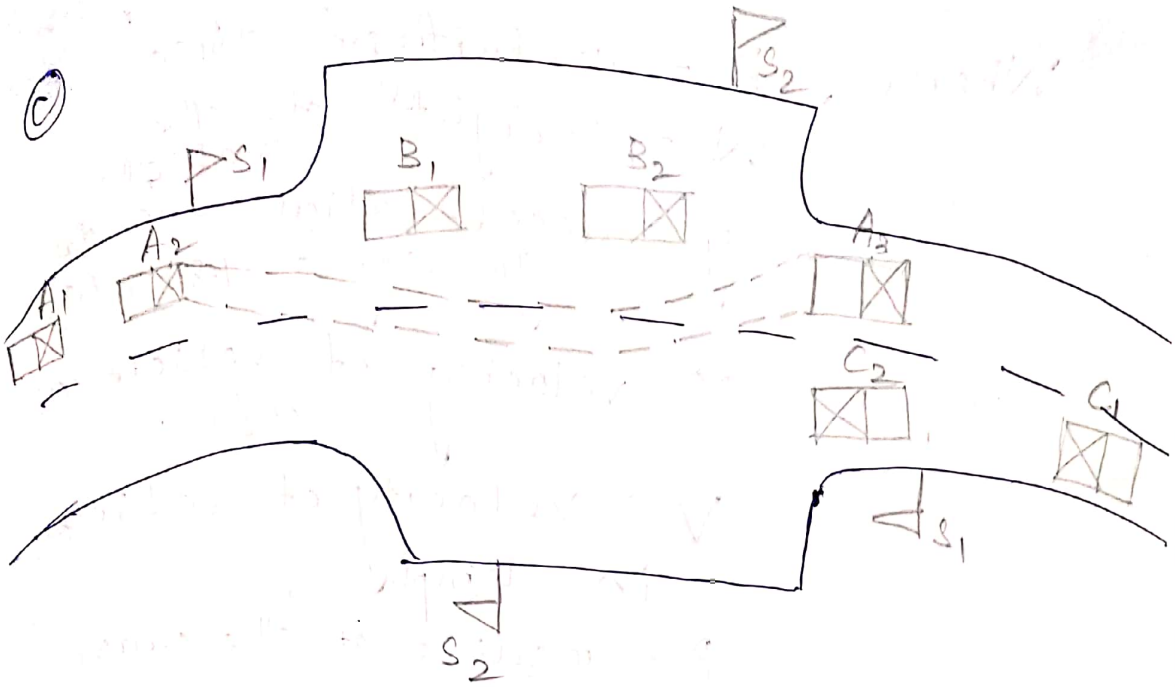
$= 280.2$ m.

(b) Minimum length of overtaking zone $= 3 \times OSD$

$= 3 \times 280.2 = 840.6$ m

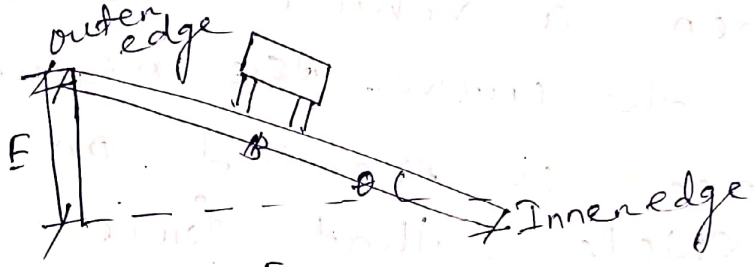
(c) Desirable length $= 5 \times OSD$

$= 1401$



Supercelevation

Dt - 27/8/19



$\sin\theta = \frac{E}{B}$

$\sin\theta \simeq \tan\theta$

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

$\Rightarrow \boxed{E = e \cdot B}$

→ The transverse slope (⊥r to the direction) provided by raising the outer edge of pavement with respect to the inner-edge on Horizontal curves to counter act centrifugal force, is called supercelevation.

[Centrifugal force $P = \frac{mv^2}{R} = \frac{Wv^2}{gR}$]

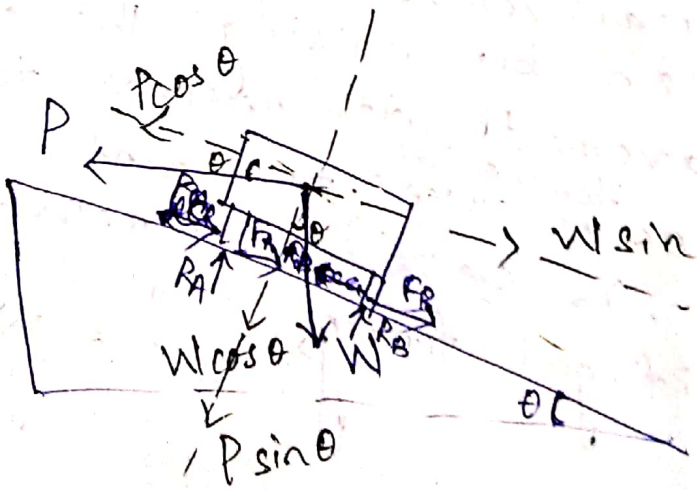
$$\boxed{P = \frac{W \times V^2}{127\, R}}$$

Where, P = centrifugal force.
W = weight of the vehicle
g = acceleration due to gravity = 9.81 m/s²
v = velocity of vehicle in m/s.
V = velocity of vehicle in kmph
R = radius of the curve

When a vehicle is moving on the curve ~~force~~ one outward force is exerted on the vehicle, that force is known as centrifugal force.]

→ It is represented by e.
$e = \tan\theta$.

Analysis of superelevation —



Considering equilibrium of forces ∥ to plane.

$$P\cos\theta = W\sin\theta + F_A + F_B$$

$$F_A = f \times R_A$$

$$F_B = f \times R_B$$

$$P\cos\theta = W\sin\theta + f(R_A + R_B) \quad \text{—①}$$

Considering equilibrium of forces ⊥r to the plane

$$R_A + R_B = W\cos\theta + P\sin\theta$$

putting the value of $R_A + R_B$ in eqn ①

$$P\cos\theta = W\sin\theta + f(W\cos\theta + P\sin\theta)$$

$$P\cos\theta - fP\sin\theta = W\sin\theta + fW\cos\theta$$

dividing $W\cos\theta$,

$$\frac{P}{W} - f\frac{P}{W}\tan\theta = \tan\theta + f$$

$$\frac{P}{W} = \tan\theta + f + f\frac{P}{W}\tan\theta$$

$$= \tan\theta + f\left(1 + \frac{P}{W}\tan\theta\right)$$

$$\frac{P}{W} = \tan\theta + f + f\frac{P}{W}\tan\theta$$

$$\frac{P}{W} - f\frac{P}{W}\tan\theta = \tan\theta + f$$

$$\frac{P}{W}(1 - f\tan\theta) = f + \tan\theta$$

$$\Rightarrow \frac{P}{W} = \frac{\tan\theta + f}{1 - f\tan\theta}$$

$f = 1.5$

$\tan\theta$ max^m value $= 7\%$

$= \frac{7}{100}$

$= 0.07$

$1 - f\tan\theta$

$= 1 - (1.5 \times 0.07)$

$= 0.99$

$[0.99 \simeq 1]$ it can be neglected.

So, $\frac{P}{W} = e + f \quad (\tan\theta = e)$

$P = \frac{WV^2}{gR}$

$\frac{P}{W} = \frac{V^2}{gR}$

$$\boxed{e + f = \frac{V^2}{gR} = \frac{V^2}{127R}}$$

Step-3

Again check, if, $f < 0.15 \rightarrow$ ok.

$f > 0.15$, take

$f_{max} = 0.15$ & $e_{max} = 0.07$, find V_r.

restricted design speed from

V_r = restricted design speed.

$e_{max} + f_{max} = \frac{(V_r)^2}{gR}$

or V_r

Equilibrium Super Elevation –

$f = 0$

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

$$\boxed{(e)_{eqm} = \frac{v^2}{gR} = \frac{V^2}{127R}}$$

If $f = 0$ super elevation is called equilibrium super elevation and can be found by $(e)_{eqm} = \frac{v^2}{gR}$.

Design of Super elevation –

Step 1 :– Calculate e from –

~~$e = \frac{V^2}{225R}$~~ considering mixed traffic

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

$$= \frac{(0.75V)^2}{127R}$$

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

Step 2 :–

Then check, if $e < 7\%$ (0.07) → then ok.

if $e > 7\%$, then take

$e_{max} = 0.07$ & find f

from $e_{max} + f = \frac{V^2}{gR} = \frac{V^2}{127R}$

Q) The radius of a horizontal circular curve is 100m. The design speed is 50 Kmph & the lateral coefficient of friction is 0.15 m.

(1) Calculate super elevation required if full lateral friction is assumed to developed (f = 0.15)

(2) Calculate coefficient of friction is no super elevation is provided.

(3) Calculate equilibrium super elevation.

Given

R = 100 m

V = 50 Kmph

f = 0.15 m

(1) $e + f = \frac{V^2}{127R}$

$e + 0.15 = \frac{(50)^2}{127 \times 100}$

$e + 0.15 = 0.196$

$e = 0.196 - 0.15$

$= 0.047$

(2) $e + f = \frac{V^2}{127R}$ $(e = 0)$

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

$= 0.197$

(3) $e = \frac{V^2}{127 \times R} = \frac{(50)^2}{127 \times 100}$

$= 0.197$

Q. Design the rate of super elevation for a horizontal highway curve of radius, 500m & design speed is 100kmph.

Step-1 :-

Calculate e from.

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

$$= \frac{(100)^2}{225 \times 500}$$

$$= 0.089$$

Step-2 -

then check $e < 7\%$

$e = 0.07$

$$e_{max} + f = \frac{V^2}{127R}$$

$$0.07 + f = 0.157$$

$$f = 0.157 - 0.07$$

$$= 0.087$$

$f = 0.087$

$f < 0.15 \longrightarrow$ ok.

Q. The design speed of a highway is 80kmph there is a horizontal curve of radius 200m on a certained locality. Calculate the super elevation needed to maintain its speed. If the max^m super elevation of 0.07 is not to be exceeded, calculate max^m allowable on this curve.

$V = 80$ kmph $R = 200$m $f = 0.07$

$$e + f = \frac{V^2}{225R} = \frac{(80)^2}{225 \times 200}$$

$$= 0.14$$

$$e > 0.07$$

$$e_{max} = 0.07$$

$$e_{max} + f = \frac{V^2}{127R}$$

$$0.07 + f = \frac{80^2}{127 \times 200} = 0.25$$

$$f = 0.25 - 0.07 = 0.18$$

$$f > 0.15$$

$f_{max} = 0.15$ & $e_{max} = 0.07$

$$e_{max} + f_{max} = \frac{V_R^2}{127R}$$

$$0.07 + 0.15 = \frac{V_R^2}{127 \times 200}$$

$$0.22 = \frac{V_R^2}{25400}$$

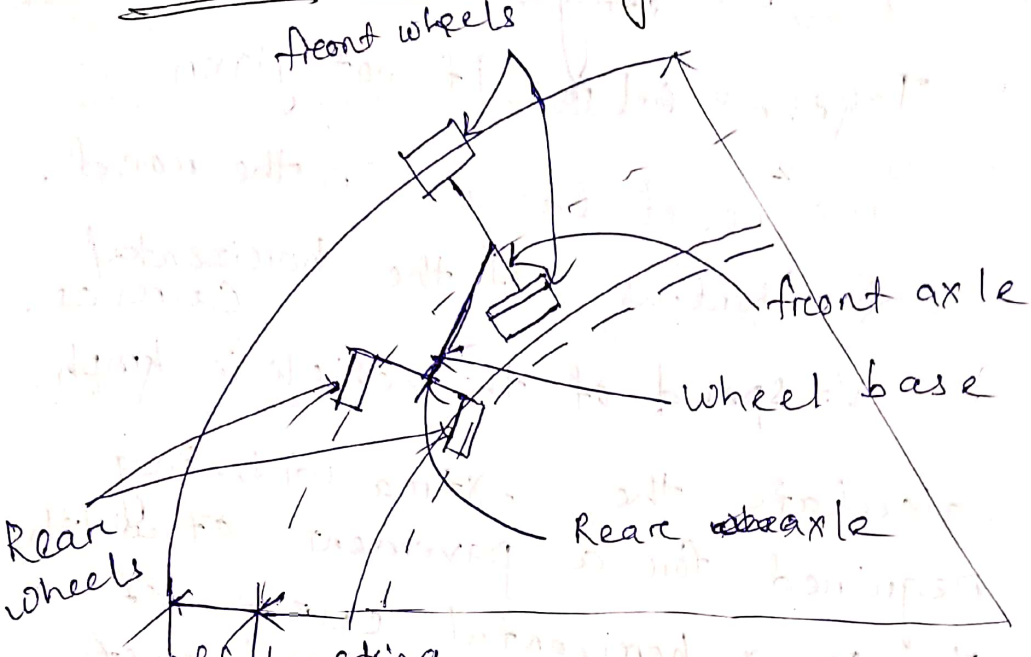
$$V_R^2 = 5588$$

$$V_R = \sqrt{5588}$$

$$= 74.75 \text{ kmph}$$

Dt - 30/8/19

Extra Widening



off tracking $= \frac{l^2}{2R}$ for single lane road;

$= \frac{nl^2}{2R}$ for multi lane roads.

where n = no. of lanes.

Pschycological widening $= \frac{V}{9.5\sqrt{R}}$

(to permit overetaking & crossing on curves)

Finally Extra widening (We) = off tracking + pschycological widening

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

↓ V.V.V Imp.

$l = 6.1$ m

Where, l = length of the wheel base.

Take $l = 6.1$ m. if not given.

n = no. of lanes in the road.

R = Radius of the horizontal curves.

V = speed of the vehicle in kmph.

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 7.0 m. Design speed is 70 kmph.

$n = 1$ $\quad b = 7$

$l = 7.0$ m. $\quad$ 1 Lane $b = 3.5$ m

$R = 250$ m. $\quad$ for 7m $= \frac{7}{3.5}$

$V = 70$ kmph. $\quad n = 2$

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

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

$$= 0.196 + 0.466$$

$$= 0.662 \text{ m}$$

Q. Find the total width of a pavement on a horizontal curve for a new national highway to be aligned along a rolling terrain with a rolling min^m radius. Assume all the data.

$V = 80$ kmph.

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

$e = 0.07$

$f = 0.15$

$n = 2$

$l = 6.1$ m.

$w = 2 \times 3.5 = 7$ m

$R = \frac{V^2}{127(e+f)}$

$= \frac{(80)^2}{127(0.07+0.15)}$

$= 229.1$

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

$= \frac{2 \times (6.1)^2}{2 \times 229.1} * \frac{80}{9.5\sqrt{229.1}}$

$= 0.162 * 0.556$

$= 0.718$

finally total pavement of road

$= 7 + 0.718$

$= 7.718$ m.

$$(V_R)^2 = (0.07 + 0.15)(127R)$$

$$= 0.22\,(127 \times 250)$$

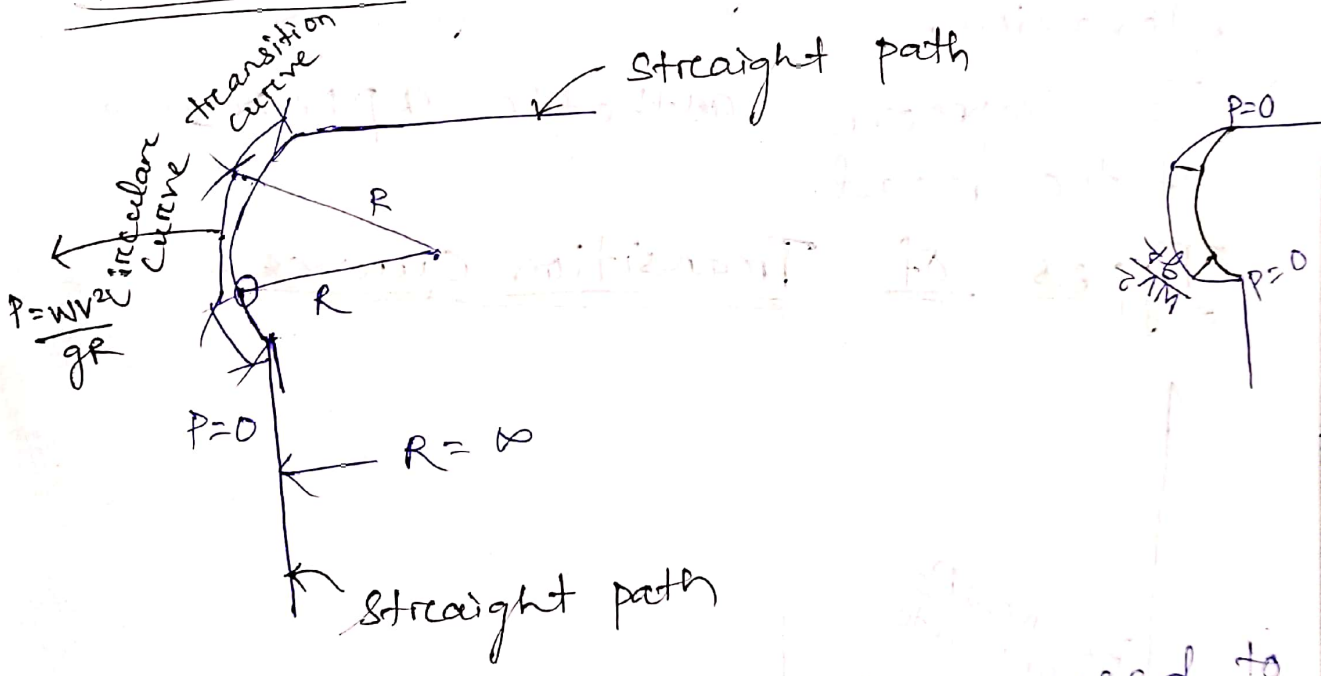
$$V_R^2 = 6985$$

$$V_R = \sqrt{6985}$$

$$= 83.58 \text{ kmph.}$$

Transition Curves (gradual change)

Dt:- 10/09/19



It is the curve which is used to join a straight path to a circular curve and ~~vice-versa~~ And whose radius decreases from ∞ to R a designed value of radius and vice-versa.

Objectives or functions of transition curves -

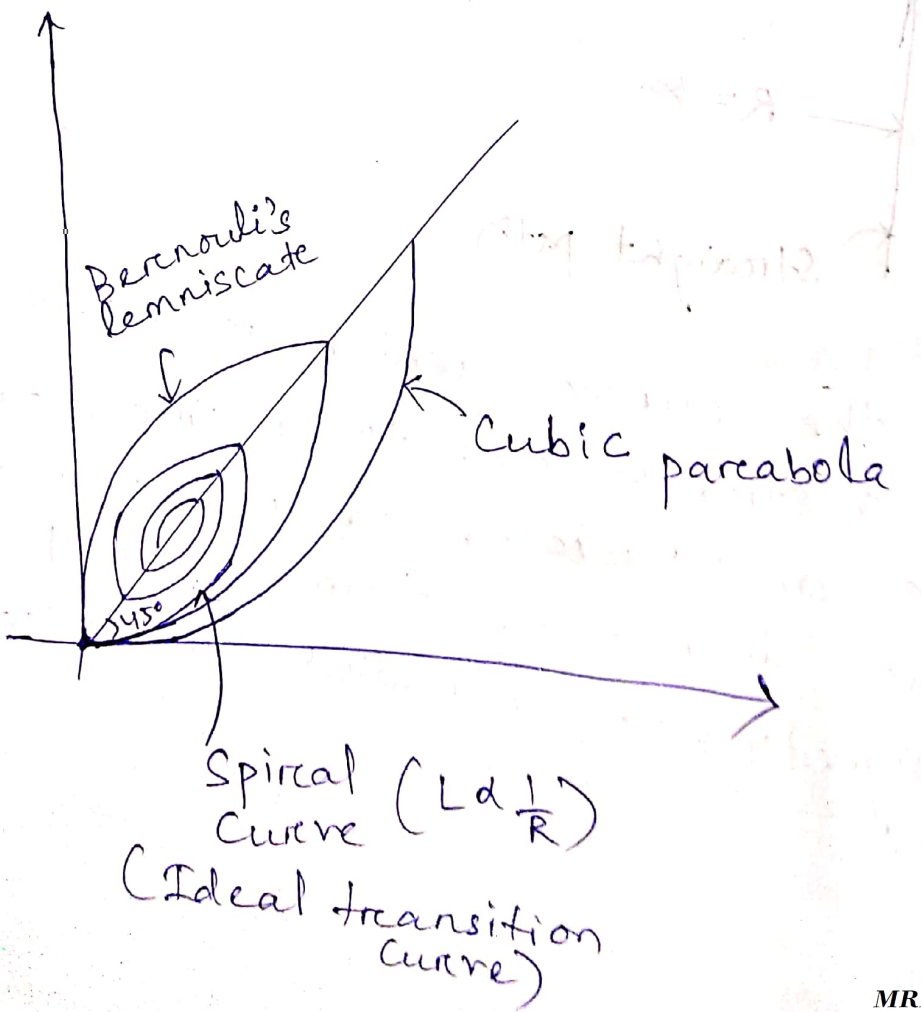
→ To introduce gradually the centrifugal force. Thus, avoiding sudden jerk on the vehicle.

→ To enable the driver turen the staring gradually.

→ To introduce gradually the super elevation.

→ To improve aesthetic appearance of the road.

Types of Transition Curves -



Length of transition curve-

(I) Based on rate of change of centrifugal acceleration (C)

$$L = \frac{V^3}{CR} = \frac{0.0215\,V^3}{CR}$$

where, $C = \frac{80}{75+V}$, $0.5 < C < 0.8$

(II) Based on rate of introduction of super elevation

N = rate of introduction of super elevation

$$L = \frac{eN \cdot (W + We)}{2}$$ (rotation about centre line)

$$= eN(W + We)$$ (rotation about inner edge)

e = Design value of super elevation

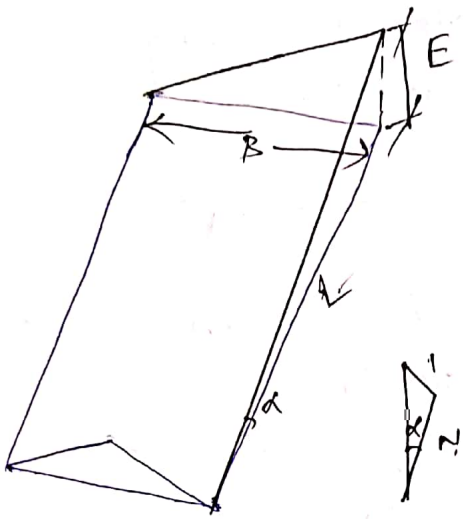
(III) Empercical formula, as per IRC

$$L = \frac{2.7V^2}{R}$$ (plain & Rolling terrain)

$$= \frac{V^2}{R}$$ (mountaneous)

Among the three values maximum one, is taken.

Length of transition curve will be equal to maxm of (I), (II), (III).



(1)

(2)

$$\tan\alpha = \frac{1}{N}$$

$$= \frac{E}{L}$$

$$\frac{1}{N} = \frac{E}{L}$$

$$\Rightarrow L = E \times N \qquad E = e \times B$$

$$= e N (B)$$

$$= e N (N + We)$$

Q) Assignment.

While aligning a highway in a populated area, it was necessary to provide a horizontal circular curve of radius 325 m. Design the following.

1. Super elevation
2. Extra widening
3. Length of transition curve

Given data are

$V = 65$ kmph

Length of wheel base = 6 m

pavement width = 3 lane $- 3.5 \times 3 = 10.5$.

① $e = \frac{V^2}{225R}$

$= \frac{(65)^2}{225 \times 325}$

$= 0.058$

$e < 0.07 \longrightarrow$ ok.

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

$= \frac{3 \times (6)^2}{2 \times 325} + \frac{65}{9.5\sqrt{325}}$

$= 0.166 + \frac{65}{9.5 \times 18.03}$

$= 0.166 + 0.379$

$= 0.545$

③ (i) Based on rate of change of centrifugal force (c)

$L = \frac{0.0215 V^3}{CR}$

$= \frac{0.0215 \times (65)^3}{0.57 \times 325}$

$= 31.87$ m.

$C = \frac{80}{75+V}$

$= \frac{80}{75+65}$

$= 0.57$

(ii) Based on rate of introduction of super elevation.

$W = 3.5 \times 3 = 10.5$

$L = eN(W + We)$

$= 0.058 \times 150 \ (10.5 + 0.545)$

$= 96.09$

N = rate of introduction of superelevation (N = 150 → not given)

(iii) Empercical formula as per IRC,

$$L = \frac{2.7 V^2}{R}$$

$$= \frac{2.7 \times (65)^2}{325}$$

$$= 35.1 \text{ m}$$

PIEV Theory

1. Perception
2. Intellection
3. Emotion
4. Violation

1) **Perception time :-**
It is the time required for the sensations received by the eyes or eares of the driver to be transmitted to the brain through the nervous system spinal cord or it is the time required to perceive an object or situation.

2) **Intellection time :-**
It is the time required for the driver to understand the situation it is also the time required for comparing the different thoughts

3) Emotion time :-

It is the time elapsed during emotional sensational and other mental disturbance such as fear, anger or any other emotional feeling superstition etc.

4) Violation time -

It is the time taken by the driver such as for the final action brake application.

Dt- 18|9|19

Q) Calculate the total widening on a horizontal curve for a straight highway, given V = 60kmph. pavement width W = 7m, l = 7m. Radius is rulling min^m radius.

$$e_{max} + f_{max} = \frac{V^2}{127R}$$

$$0.07 + 0.15 = \frac{(60)^2}{127R}$$

$$0.22 \times 127R = 3600$$

$$R = \frac{3600}{27.94} = 128.84\ m.$$

$$We = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}} = \frac{2\times(7)^2}{2\times128.84} + \frac{60}{9.5\sqrt{128.84}}$$

$$= 0.38 + 0.56$$

Total widening = 7 + 0.94 = 7.94 m.

② Design super elevation for a horizontal curve of radius 750 m and speed 100 kmph.

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

$$e = \frac{(100)^2}{225 \times 750}$$

$$= 0.059$$

$0.059 \not< 0.07 \longrightarrow$ ok

$\therefore$ design S.E = 5.9% $\simeq$ 6%

V = 110 kmph.

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

$$= \frac{(110)^2}{225 \times 750}$$

$$= 0.0717 \simeq 0.072$$

As $0.072 > 0.07$

2nd step

$$e_{max} + f = \frac{V^2}{127R} \qquad e_{max} = 0.07$$

$$0.07 + f = \frac{(110)^2}{127 \times 750}$$

$$f = 0.127 - 0.07$$

$$= 0.057$$

$0.057 < 0.15 \longrightarrow$ ok

$\therefore$ design S.E = 7%

3) Calculate the safe SSD for a design speed of 100 kmph. Take total reaction time, t = 2.5 sec. f = 0.35.

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

$$= 0.278 \times 100 \times 2.5 + \frac{(100)^2}{254 \times 0.35}$$

$$= 181.98\,m \simeq 182\,m.$$

$\therefore$ SSD = 182 m.

4) The speed of over taking & over taken vehicles are 70 & 40 kmph speed on a 2 way traffic road. if a of overtaking vehicle is 0.99 m/s². Calculate

① Safe OSD

② Minᵐ length of overtaking zone.

$V_b = 40$ kmph
$V = 70$ kmph
$t = 2s$.

$S = 0.2V_b + 6$
$= 0.2 \times 40 + 6$
$= 14$ m.

$$T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 14}{0.99}} = 7.52 \text{ s.}$$

① OSD (safe) $= 0.278 V_b t + 0.278 V_b T + 2(0.2V_b + 6) + 0.278 VT$

$= 0.278 \times 40 \times 2 + 0.278 \times 40 \times 7.52 + 2 \times 14 + 0.278 \times 70 \times 7.52$

$= 22.24 + 83.62 + 28 + 146.34$

$= 280.2$ m.

② Min^m length of overtaking zone
$= 3 \times OSD$
$= 3 \times 280.2$
$= 840.6$ m. $\simeq 840$ m.

$\therefore$ OSD $= 280.2$ m,

min^m length of overtaking zone
$= 840$ m.

Ch-3 Dt - 19/9/19

Highway Materials

Soil -

It forms the major portion of a road pavement structure because it provides support to the pavement.

→ The main function of subgrade is to provide sufficient strength to the whole pavement structure.

properties of soil -

→ Stability
→ In compressibility
→ permanency of strength
→ Good drainage

CBR Test:-

CBR - Carliforcnia Bearing Ratio
To know the strength of soil this test is used.

→ This is a penetration test used for evaluating the strength and stability of soil subgrade.

→ The laborcatory CBR apparatus consists of a mould of 150 mm dia. with a base plate and a colare, a loading frame with a cylindrical plunger of 50mm dia. and dial gauge for measuring penetration value.

→ This test consists of penetrating a cylindrical plunger into the soil at 1.25 mm/min. The load values to cause 2.5 mm and 5.0 mm penetration are recorded.

$$CBR\,(\%) = \frac{\text{Actual Load required to cause 2.5mm or 5.0 mm penetration}}{\text{Standard load required to cause 2.5mm or 5.0mm penetration.}}$$

Standard Load for 2.5 mm → 1370 kg.
5.0 mm → 2055 kg

*For example

Let Actual load at 2.5mm = 1000 kg

then $CBR]_{2.5\,mm}(\%) = \frac{1000}{1370} \times 100 = 72.99\%$

Actual load at 5mm = 2000 kg.

$$CBR]_{5mm}(\%) = \frac{2000}{2055} \times 100 = 97.32\%$$

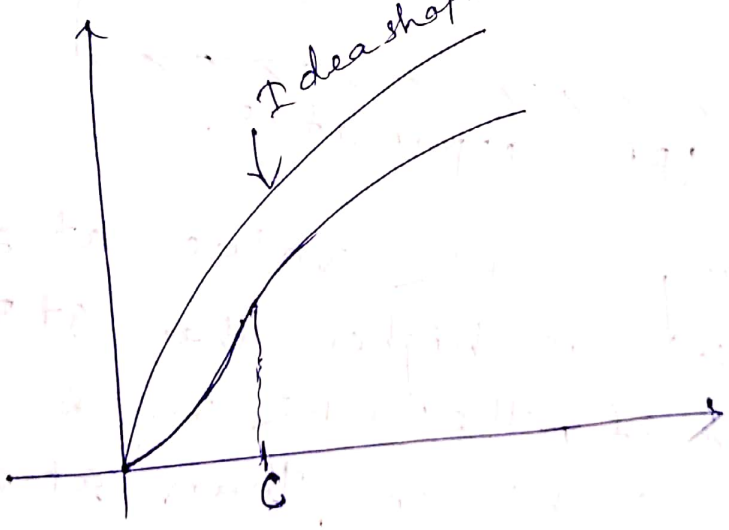
Greater value will be taken as CBR value.

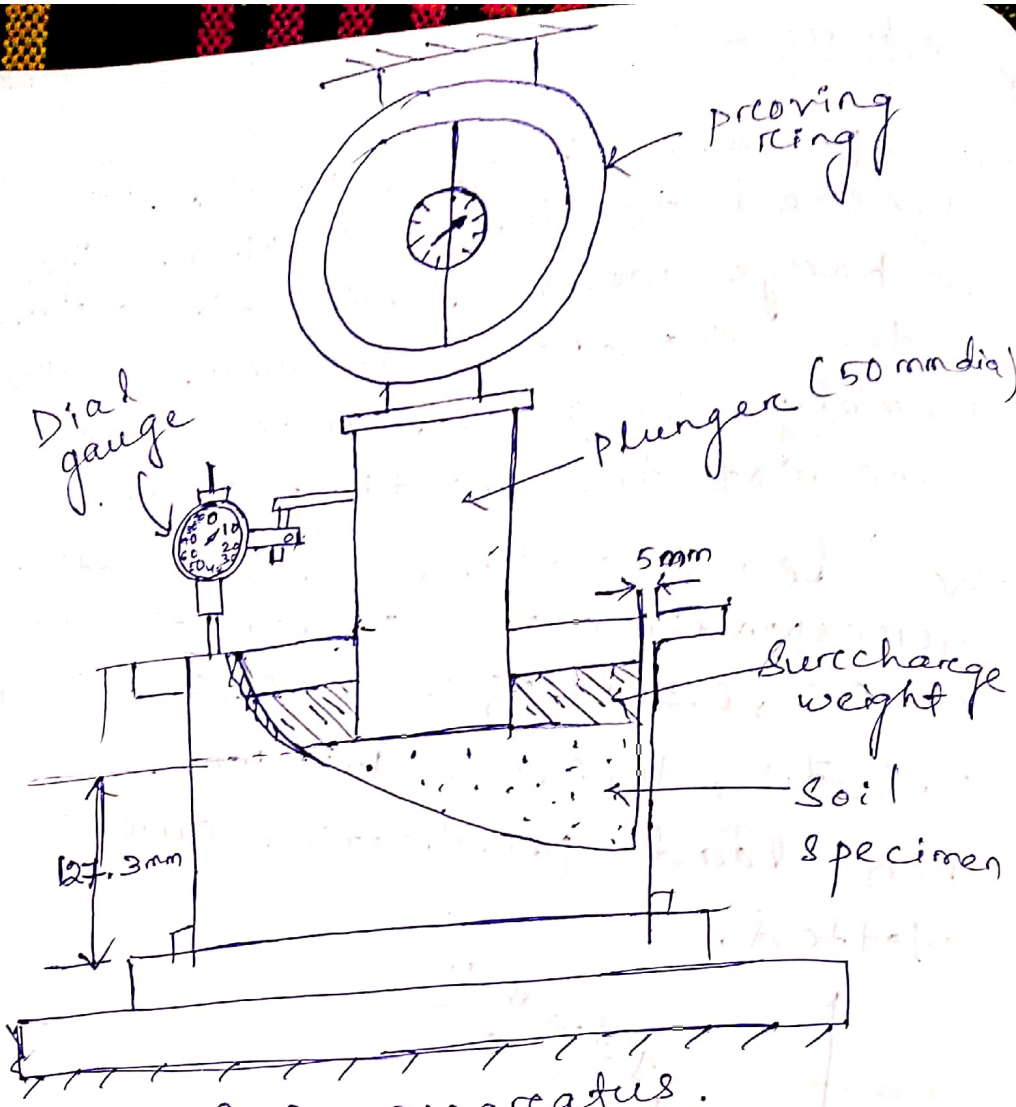
procedure -

① The specimen in the mould is subjected to 4 days soaking. The surcharge weight (extra wt.) is placed on the top of the specimen and the assembly is placed under the plunger of the loading frame.

② The load values are noted corresponding to penetration values of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0, and 12.5 mm.

Then load - penetration curve is plotted.





CBR apparatus.

→ Normally CBR value at 2.5 mm penetration is higher than at 5.0 mm. However if the CBR value at 5.0 mm is higher than at 2.5 mm then the test is to be repeated.

Example-

The load penetration values of CBR tests conducted on two specimen of a soil sample are given below. Determine the CBR value of soil.

If 100 divs of load dial represents 190 kg load.

Penetration of plunger (mm)	Load dial readings, divs	
	Specimen 1	Specimen 2
0	0	0
0.5	8	0.5
1.0	15	1.5
1.5	23	2.5
2.0	29	6.0
2.5	(34)	(13)
3.0	37	20
4.0	43	30
5.0	(48)	(38)
7.5	57	50
10.0	63	58
12.5	67	63

100 div = 190 kg

$$1 \text{ div} = \frac{190}{100} \text{ kg} = 1.9 \text{ kg}$$

34 div = $1.9 \times 34 = 64.6$

48 div = $1.9 \times 48 = 91.2$

$$CBR]_{2.5mm} = \frac{64.6}{1370} \times 100 = 4.71\%$$

$$CBR]_{5mm} = \frac{91.2}{2055} \times 100 = 4.44\%$$

Final CBR value of specimen 1
$\simeq 4.71\%$

Specimen-2

13 div = $1.9 \times 13 = 24.7$

38 div = $1.9 \times 38 = 72.2$

$$CBR]_{2.5mm} = \frac{24.7}{1370} \times 100 = 1.80$$

$$CBR]_{5mm} = \frac{72.2}{2055} \times 100 = 3.51$$

Test is to be repeated.

⑤ Aggregates –

Aggregates form major portion of pavement structure. They have to bear stresses occuring due to the wheel loads on pavement & surface coarse.

properties of road aggregates –

→ Strength (Resistance to crushing)
→ Hardness (Resistance to abbrasion)
→ Toughness (Resistance to impact load)
→ Durability (soundness test)

→ Shape of the aggregate -

① Rounded ○
② flakey ◇
③ Angular △
④ Elongated 

Flakeyness index Test
Elongation index Test

→ Adhesion with bitumen Adhesion test.

Tests for Aggregates -

① Crushing strength Test -

This test provides a relative measure of resistance to crushing under gradually applied compressive load.

The apparatus used for this test are. ① steel cylinder of 15.2cm dia with a base plate and a plunger.
② Compression testing machine.
③ Cylindrical measure of dia 11.5cm & height 18cm.
④ Tamping rod (25 blows)
⑤ Sieve - 2.36mm.

procedure -

① Dry aggregate passing through 12.5 mm IS sieve and retaining on 10 mm IS sieve is filled in the cylindrical measure in 3 layers. And each layer being tamped 25 times by the tamping rod.

② The test sample is weighed (W1) gm. and placed in the test cylinder. The plunger is placed on the top and the load of 40 tonne is applied at a rate of 4 tonnes per minute. The load is applied for 10 min.

③ The crushed aggregate is sieved to 2.36 mm IS sieve. The aggregate passing the sieve is weighed (W_2) gm.

∴ Therefore, Aggregate crushing value = $\frac{W_2}{W_1} \times 100$.

* This value should not exceed 45% for base coarse.
* And for surface coarse ~~40~~ 30%

Abrasion Test -

Attrition - rubbing bet^n Agg.
Abrasion - rubbing bet^n Agg & other foreign material

LOS Angeles - Abrasion Test -

The principle of this test is to determine the percentage wear (loss) due to relative rubbing action between Aggregate

and steel balls used as abbrasive charege.

(2) The LOS - Angeles machine consists of a hollow cylinder closed at both ends having inside dia. 70cm and Length 50cm and mounted to rotate about its horizontal axis.
The abbreassive charege consists of cast iron spheres of dia 4.8cm. and weight of 390 – 445gm

(3) 5 to 10 kg of aggregates (W1) gm based on the gradation is placed in the machine with the abbreassive charge. The machine is rotated at a speed of 30 - 33 rpm (revolution per min) for specified no. of revolutions (500-1000 based on the gradation)

(3) The abraded aggregates is then sieved on 1.7 mm Is sieve. and the weight of powdered aggregate passing 1.7mm Is sieve is weighed. (W_2) gm.

$$LAV = \frac{W_2}{W_1} \times 100$$

Loss Angeles abrasion value

* It, ≯ 30% fore good quality Agg.

③ Impact Test –

This test is used to evaluate the toughness of aggregates ie resistance to repeated impact load.

The aggregate impact machine consist of ① a metal base and ② a cylindrical steel cupof internal dia 10.2cm and height 5 cm in which the aggregate specimen is placed.

③ A metal hammer of weight 13.5-14kg with a free fall from a height of 38 cm.

procedure –

① Aggregates passing through 12.5mm sieve and retaining on 10 mm sieve is fill in a cylindric measure in 3 layers by tampi each layer by 25 blows by a tamping rod.

(2) The sample is transferred from the measure to cup of aggregate impact testing machine and compacted by tamping 25 times. The hammer is raised to a height of 38 cm and allowed to fall freely on the specimen.

(3) After subjecting the test specimen (by rammer) to 15 blows the crushed aggregate is shift on 2.36 mm IS sieve. and the aggregates passing through the 2.36 mm sieve is weighed and recorded. (W_2) gm.

$$AIV = \frac{W_2}{W_1} \times 100$$

(Aggregate Impact value)

for Surface coarse AIV ≯ 30%.

for base coarse AIV ≯ 35 – 40%.

(4) Soundness test:

→ This test is used to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycle.

(1) Clean dry aggregate specimen of specified size is weighed then it is immersed in saturated solution Na_2SO_4, $MgSO_4$ for 16 to 18 hrs.

(2) Then the specimen is dried in an oven at 105 - 110°C thus making one cycle.

(3) In this way 7 - 10 cycles are completed on the same aggregate.

(4) After completing the final cycle the sample is dried and average loss in weight of aggregates is measured.

(5) The avg. loss in weight of aggregates for pavement construction after 10 cycles of wetting drying ~~is~~ ≯ 12% for

Na_2SO_4 and ≯ 18% for $MgSO_4$.

D+-24/9/19

Shape test -

There are 3 shape tests are performed on aggregate.

(I) Flakeiness index
(II) Elongation index
(III) Angularity number.

Flakiness Index -

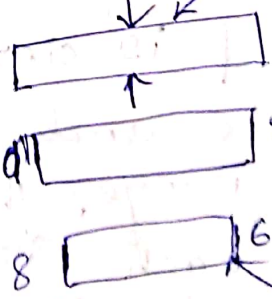
→ Flakiness Index of an aggregate as the percentage by weight of aggregate particles whose least dimension (thickness) is less than 3/5 or 0.6 times the mean dimension.

→ This test is applicable to aggregate sizes greater than 6.3mm.

→ The sample of aggregates to be tested is sieved through a set of sieves and separated into specified size ranges.

12.5 mm → 100 gm
10 mm → 50 gm
8 mm → 100 gm
6.3 mm

Thickness of slot = (0.6 or 3/5) × (12.5+10)/2 = _____



Thickness gauge.

FI = (passing / Total weight) × 100

→ The material passing the slot from each size range are added up and let the weight be "w" then

$$\text{Flakiness Index} = \frac{w}{W} \times 100$$

where w = Total wt. of aggregate passing.

→ For use in road construction
FI < 15%.

Elongation Index —

→ It is defined as the percentage by weight of particles by greatest dimension (length) is greater than $\frac{9}{5}$ or 1.8 times the mean dimension.

→ $$\text{Elongation Index} = \frac{\Sigma \text{Retaining}}{W} \times 100$$

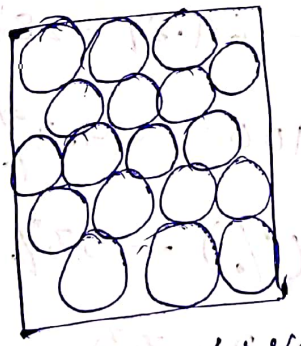
→ This test is applicable for sizes greater than 6.3mm.

→ Procedure
The sample of aggregate to be tested is sieved through a set of sieves and separated into different size range. Then the aggregates from each size range is individually passed through appropriate length gauge to separate elongated particles.

→ The aggregates whose length is greater than specified gauge is weighed and expressed as the percentage of total weight of aggregate particles known as elongation index.

→ Limit -
For use in road construction
E.I ≯ 15%.

③ Angularity Number -
It represents the degree of angularity of the aggregate particles.
It is defined as the volume of voids in excess of 33%.



V_v = 33% for perfectly rounded aggregate.

44%
A.N = 44 − 33 = 11

Example -
450 gms of aggregates was filled in a container of volume 3l. The sp. gr. of agg. is 2.65. Find the angularity number of the aggregate.

Ans:-

$1m^3 = (100)^3 cm$

$= 10^6 \, 1m^3 = 1000 \, l$.

$1 l = \frac{1}{1000} m^3$

$3l = 0.001 \times 3$

$= 0.003 m^3$

$1m = 100 cm$

$1m^3 = 100 cm^3$

$0.003 m^3 = 0.003 \times 10^6 cm^3$

$= 0.3 cm^3$

$\rho_s = \frac{m_s}{V}$

$= \frac{0.450}{0.003}$

$V = 0.003 m^3$

$= 0.003 \times 10^6$

$= 3000 cm^3$

$M_s = 450 gm.$

$\rho_s = \frac{M_s}{V_s} = \frac{450}{V_s}$

$\Rightarrow 2.65 = \frac{450}{V_s}$

$\Rightarrow V_s = \frac{450}{2.65}$

$= 169.81 cm^3$

$G_s = \frac{\rho_s}{\rho_w}$, $\rho_w = 1$

$\rho_s = 1 \times 2.65$

$= 2.65 g/cm^3$

1 lit = 1000 cc

$1m^3 = 1000 l$.

$1 l = \frac{1}{1000} m^3$

$1 cm^3 = 1 ml$

$3 l = \frac{3}{1000} m^3$

$V_v = V - V_s = 3000 - 169.81 = 2830.19 cm^3$

$V_v\% = \frac{2830.19}{3000} \times 100 = 94.3\%$

Angularity no = $V_v(\%) - 33\%$

$= 94.3 - 33$

$= 61\%$

Procedure -

→ The apparatus required for angularity numbere test consists of a metal cyllinden of capacity 3l, a tamping rood.

→ The test sample is sieved and filled in 3 layeres in the cyllinden by tamping each layer 100 times.

Specific Gravity & Water absorption -

Specific gravity of aggregate is considered to measure the quality or strength of a material. About 2kg of dry aggregate sample is placed in a wire basket (W_1) and immersed in water for 24 hres.

→ The sample is weighed in water (W_2) and the weight is recorded. Then the aggregates are taken out and made saturated surface dry by wiping with a cloth. (W_3)

→ The aggregates are again placed in an oven for 24hrs at an temperature 100 ÷ 110°C and the dry weight is determined. (W_4)

→ The specific gravity is calculated by dividing dry weight of aggregate to the weight of equal volume of water

$$G = \frac{W_3}{W_3 - (W_1 - W_2)}$$

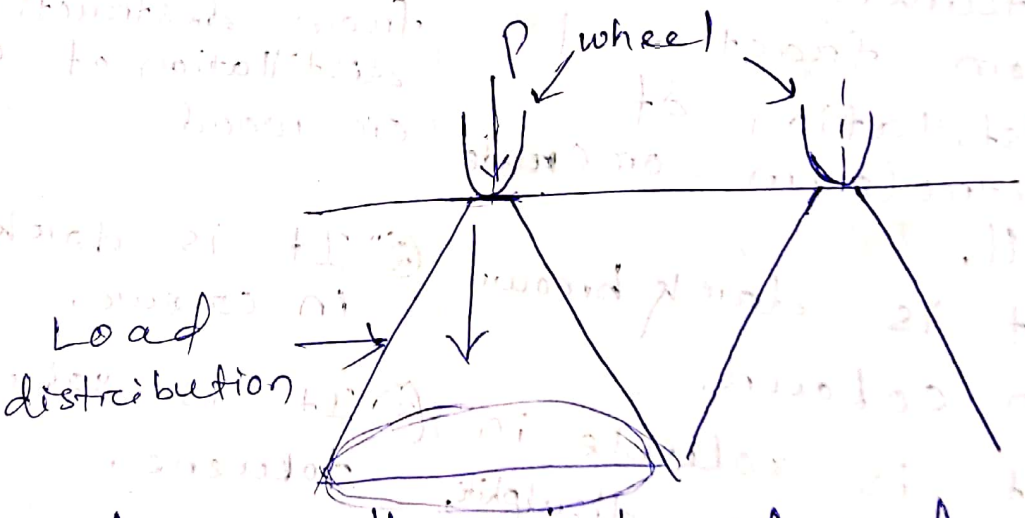
$$\text{water absorption}(\%) = \frac{W_3 - W_4}{W_4} \times 100$$

Ch-4 Highway Pavements

Pavement-

Pavement is defined as the whole structure consisting of subgrade, sub-base, base & surface starting from bottom useful for vehicle movement.

→ It is assumed that load is transferred from surface to bottom layers in the form of a truncated cone shape. So, impercior quality materials are used in the lower layers as the stress gets decreased.



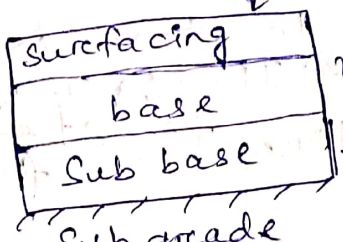
→ Based on the structural behaviour pavements are divided into two types —

They are —

(a) Flexible pavements
(b) Rigid pavements.

(a) Flexible pavements — Rigid pavements

(1)



(2) A typical flexible pavement structure consists of following layers.

① subgrade soil
② sub base
③ base
④ surfacing.

(3) It consists of series of layers with highest quality materials at or near the top.

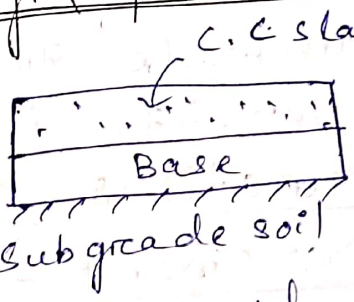
(4) It reflects the deformation of subgrade and subsequent layers on the surface.

(5) Load transfer takes place through the point of contact of aggregate particles. ie. grain to grain transfer.

→ life span is less ≃ 15 yrs

→ Joints not required

(1)



(2) A typical rigid pavement structure consists of following layers.

① sub grade soil
② Base
③ Cement concrete slab.

(3) It consists of one course portland cement slab of relatively high bending resistance.

(4) It is able to bridge over localised or minor failures.

(5) It distributes load over a wide area of subgrade because of the rigidity and high modulus of elasticity of the slab.

→ life span is more ≃ 30 yrs.

→ Joints are provided.

⑥ Pavement design is influenced by subgrade strength.

⑥ Flexural strength of concrete is an important factor in this design.

⑦ IRC-37:2001

⑦ IRC-58:2002

Functions of components of flexible pavement –

① Subgrade –

→ It is the lowest layer of natural soil prepaired to receive the other layers of pavement.

→ The load on the surfacing course is finally transmitted to the subgrade layer. which means that pressure on the top of subgrade should be within allowable limit to avoid failure.

→ Therefore, atleast top 50cm of subgrade soil is well compacted under controlled conditions of maximum dry density & optimum moisture content.

→ CBR test is performed to evaluate the strength of subgrade soil.

② Subbase & base –

→ These layers are made up of broken stones, bound or unbound aggregate.

→ Sometimes stabilized soil are used.

→ Subbase and base course mainly acts as a load transferring medium from surface to subgrade.

→ In rigid pavement base course has the following functions –

(a) Preventing mud pumping.
(b) Protecting subgrade against frost action (ice formation).

(3) Surfacing or wearing course —

Road's wear & tear is due to rubbing. So, it is also called wearing course.

→ It is the top most layer of a pavement structure.

→ It has following functions —

(a) To give a smooth riding surface.
(b) To resist pressure exerted by tyres and to take up wear & tear due to traffic.
(c) To provide a water tight layer.

→ Normally bituminous surfacing is used as wearing course in flexible pavement and cement concrete slab in rigid pavement.

Assignment —

(1) What do you mean by stabilisation? Explain briefly about different methods of soil stabilisation.
(1) Lime stabilisation
(2) cement stabilisation
(3) fly ash stabilisation

Ch-7

Road Maintenance

→ Broadly highway maintenance is divided into 3 types -

They are -

1. Routin maintenance (patch repairs or repair filling up of pot holes)
2. Periodic maintenance
3. special repair

→ (1) (1) shoulder maintenance
   (2) patch repairs
   (3) filling up of pot holes.

→ (2) (1) Renewale of surfacing coat / layer.

→ (3) (1) Reconstruction of pavement, repair of damages due to flood.
   (2) Providing additional safety measures

Pavement failures -

(a) failures in flexible pavements -

→ (1) Alligator cracking (map cracking)

→ (2) consolidation of pavement layers.

(3) shear failure

(4) longitudinal cracking

(5) Frost heaving.

(6) Lack of binding to lower course

(7) Reflection cracking

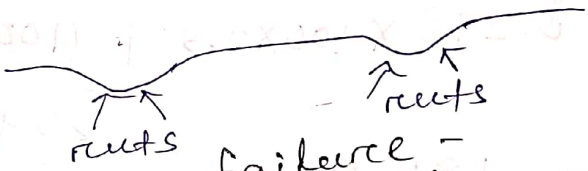
(8) Formation of waves & corrugations.

① Alligator cracking -

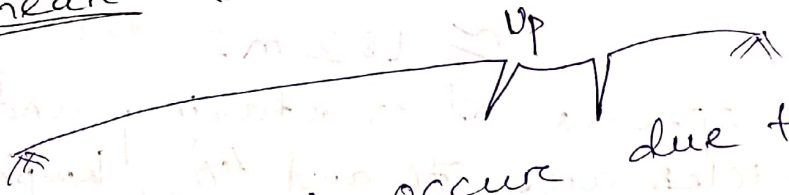
→ Due to relative movement of pavement layers materials.
→ Repeated application of heavy wheel loads.
→ Localised weakness in the underlined base course.

② Consolidation of pavement layers -

→ Due to consolidation of one or more pavement layers ruts are formed on the surfacing coats/layers.



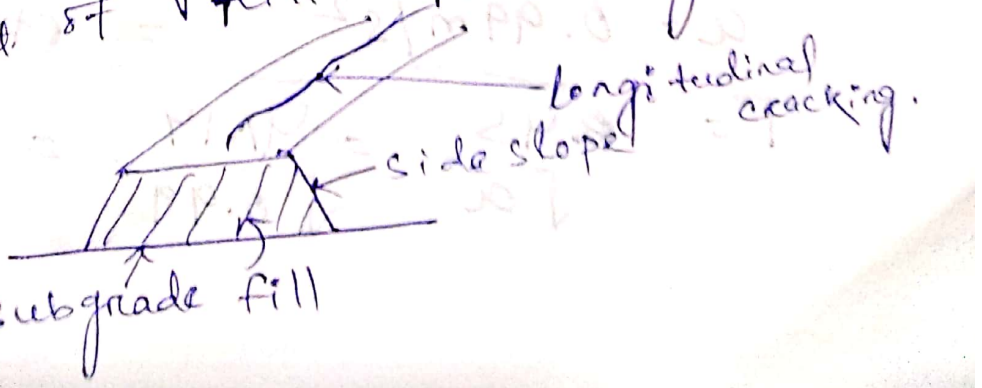
③ Shear failure -



→ Shear failures occur due to inherent weakness.
→ Due to inadequate stability or excessively heavy loading.

④ Longitudinal cracking -

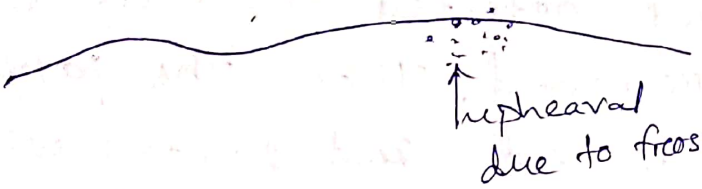
→ Due to frost action and differential volume change in subgrade or due to settlement of fill and sliding of side slopes.



Dt- 4/10/19

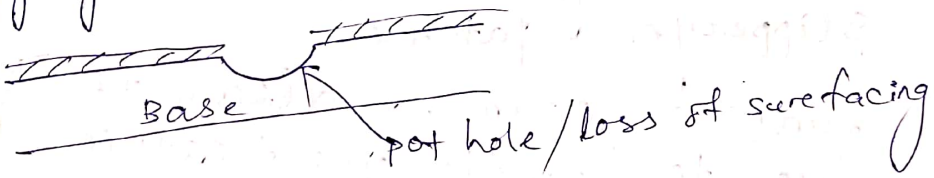
⑤ Frost heaving:-

A localized heaving up of pavement portion due to conversion of soil moisture into ice.



⑥ Lack of binding with lower layer:-

Pot holes or patches are formed on the surfacing course due to lack of proper bond between bitumen and aggregates.



⑦ Reflection cracking:-

Formation of the reflection cracks on the surface creats a path for ~~reading~~ water seepage which leads to mud pumping.

Maintenance of flexible pavement:-

Mainly there are 3 types of maintenance work in bituminous road.

(a) Patch repairs
(b) Surface treatment
(c) Resurfacing

(a) Patch repairs —

→ This include filling up of localized depressions or pot holes.

Procedure

(1) First pot holes are cut to rectangular shape and affected materials are totally removed. Then the patches are cleaned and painted with bituminous binder and emulsion is applied in the pot hole, so as not cause travelling (removal of agg. from the surface)

(b) surface treatment —

Excess bitumen in the surface leads to bleeding and pavements become slippery or patchy.

Surface coarse also gets damaged due to continuous traffic or heavy rainfall.

Such type of pavement surfaces are applied with a renewal coat called seal coat or surface dressing (bitumen & sand mixture)

To develop necessity amount of friction

(c) Resurfacing

When the pavement surface is completely damaged and develops a poor riding surface, it needs an additional surface coarse on the existing surface or resurfacing.

Dt. 15/10/19

Traffic signs & Signals

Traffic control devices -

Various majores and devices used to control, regulate and guide traffic are called traffic control devices.

Traffic control devices are divided into following two categories -

They are -

1. Signs
2. Signals
3. Markings
4. Islands.

Traffic signs -

Based on the purpose of signs, traffic signs are divided into three types -

(a) Regulatory or mandatory signs
(b) Warning signs
(c) Informatory signs.

[Placement of signs
The signs should be placed at a distance not less than 0.6m away from the edge of the kerb on roads with kerbs and 2-3m away from edge of the carriage on roads without kerbs]

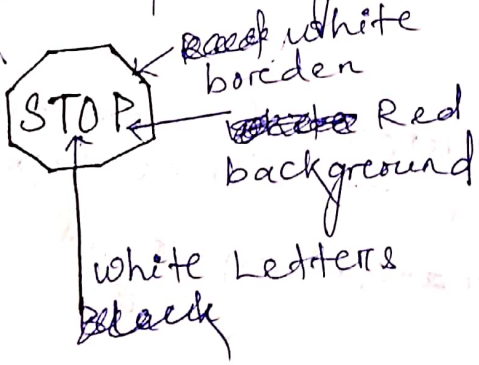
Sign post should be coloured black & white alternate each of 25cm thickness.

① Regulatory signs -

These signs are made to inform the road users about rules, laws, regulations & pohibitions.

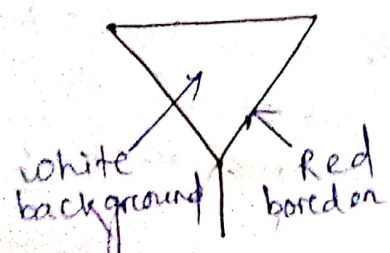
The signs which come under regulatory signs are —

1. Stop & Giveway signs.
2. Pichibitory sign
3. No parking & No stopping sign
4. Speed limit
5. Restriction end sign
6. Compulsory direction control sign

(1) 

Shape is octagonal

Giveway sign -

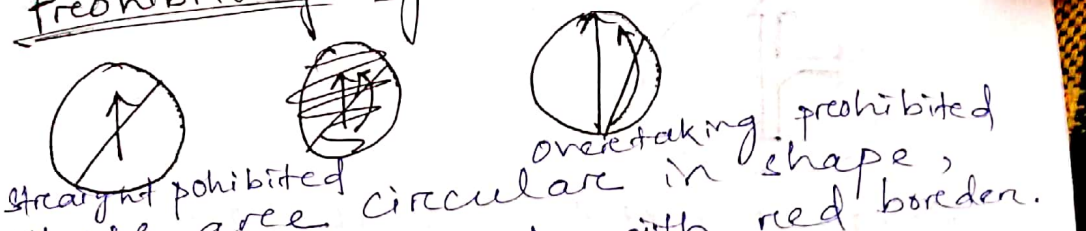


If there is a minor road from a major road, then stop and look any vehicle is coming or not, if no vehicle is coming then you can proceed

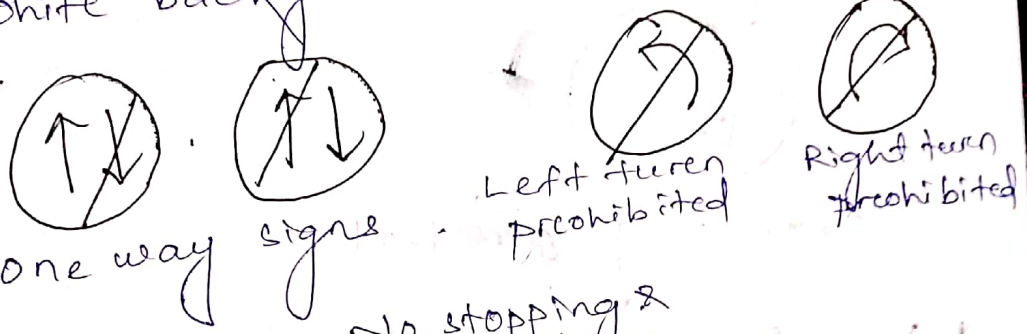
Shape -

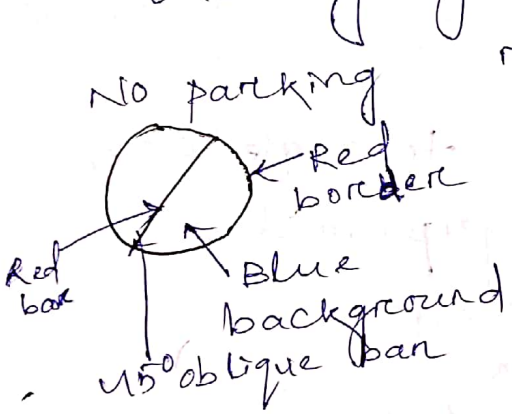
Triangular with apex pointing downward.

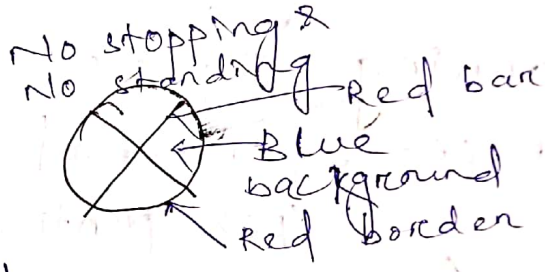
② Prohibitory signs -



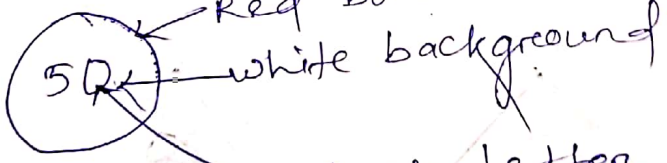
These aree circular in shape, white background with red boreden.





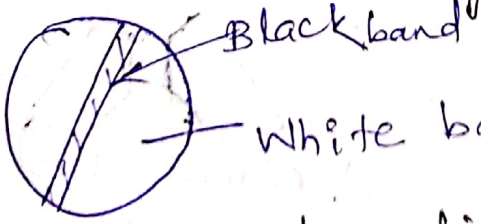


Speed limit -



Dt - 17/10/19

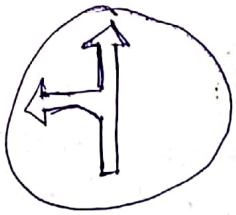
Restriction end sign -



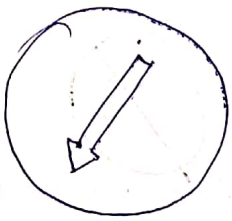
Compulsorcy direction control sign -

blue bdckground,

Compulsorcy left



Compulsory left or go ahead.



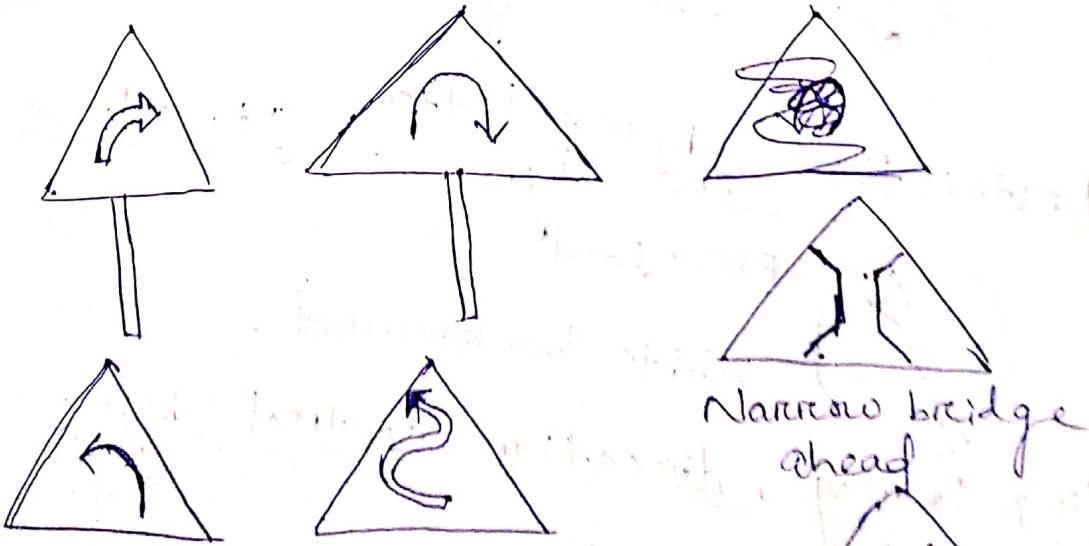
Compulsory ~~guide~~ keep left

(2) Warning Signs –

Shape - equilateral triangle with apex pointing upward.

white background
Red boreder
Black symbol/arrow

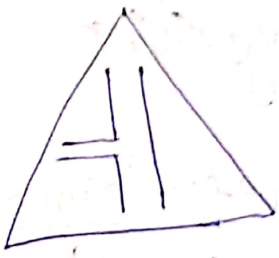
Examples



Reverse bend left

Narrow bridge ahead

Cross road ahead



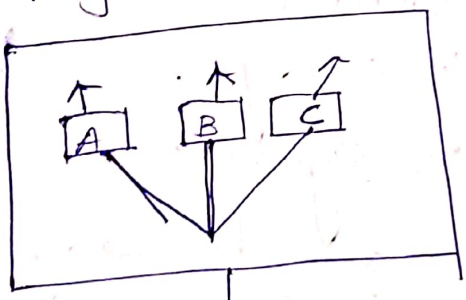
(3) Informatory signs -

Informatory sign used to guide road users along routes or roads along with distances.

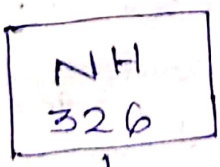
Shape - Rectangular.

Yellow/white background
black border
black letter and arrows.

(1) road junction approach



(2) Route marker.



(3) Hospital
(4) Petrolpump

(3) Traffic signals -

These are control devices used to direct the traffic to stop & proceed at intersections using Red, amber or yellow, green light signals automatically.

Types of traffic signals

Terms related to traffic signal –

(a) **Cycle** –
The time required for 1 complete sequence of Red-amber-green

(b) **Phase** –
Part of signal cycle allocated to traffic movement or combination of traffic movement is called phase.

(c) **Interval** –
The time during which signal indication don't change.

Types of traffic signals –

Traffic signals are broadly classified into 3 types –
They are (a) Traffic control signal
(b) pedestrian signals.
(c) Special traffic signals.

Traffic control signal –

1. Fixed time signal
2. traffic actuated or automatic signal
3. Manually operated (with traffic police)

(a) Fixed time signal —

In this type of signals the timing of each phase of cycle is predetermined based on past traffic studies.

→ These are the simplest type of traffic signals which are electrically operated.

→ The main disadvantages of this type of traffic signals is that they operate with fixed timings yet sometimes the traffic flow on one road may be almost nil. and the traffic on cross road may be quite heavy.

(b) Traffic actuated —

In this type of traffic signals the timings of phase and cycle are changed according to traffic demand.

→ These are very costly as compared to fixed time signals.

→ Detectors are installed to assign the right of way for various traffic movement on the basis of traffic demand.

(c) Manually operated signals —

With the help of traffic police.

avg. walking speed - 1.2 m/s

(2) Pedestrian traffic signals -

These are meant to give right of way to pedestrians to cross a road during walk period.

Types of traffic signal system -

Based on the type of coordination between successive intersections traffic signal system is divided into four types.

They are -

(1) Simultaneous system
(2) Alternate system
(3) Simple progressive system
(4) Flexible progressive system (1st good)

(1) Simultaneous system -

All signals along a given roadway shows same indication at same time.

(2) Alternate system -

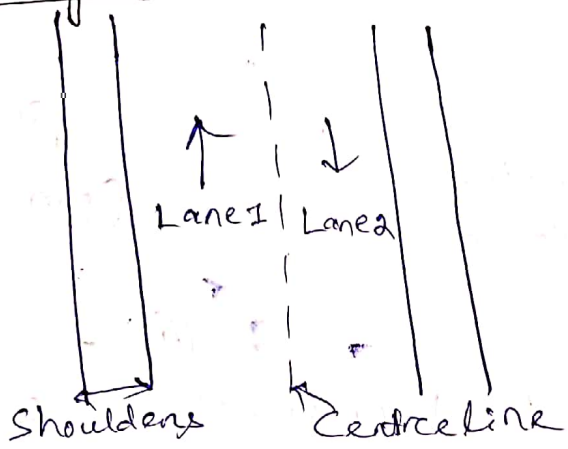
Alternate signals show opposite indication at same time.

(3) Simple progressive system -

Continuous operation of group of vehicles along a road at a resonable speed. Green signal at all intersection at a predetermined time schedule.

④ Flexible progressive system —
In this system it is possible to vary the cycle length, time schedule at each intersection with the help of a computer. It is the most efficient traffic signal system.

③ Markings —



Lines, patterens, words, symbol or reflectors on pavement, kerb etc are called road markings.
Road markings are usually available in 3 colours, they are, white, yellow, black.
Broadly road markings are divided into 4 types —
they are —
① Pavement marking
② Kerb marking
③ Object marking
④ Reflector unit marking

① Pavement marking -

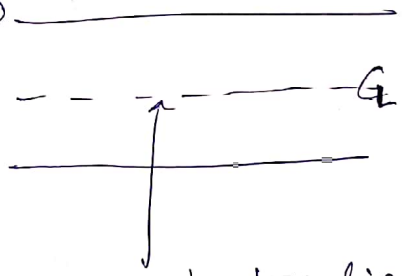
10 - 15 cm

(i) Centre line marking (single broken lines)

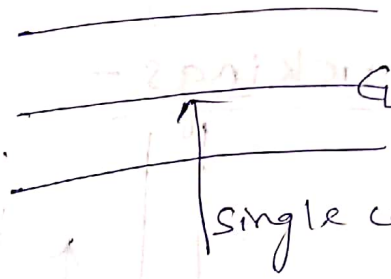
(ii) Lane marking (broken lines)

(iii) Border edge line (single continuous line)

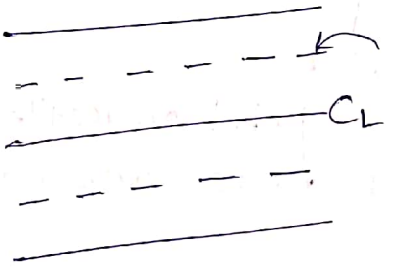
(iv)

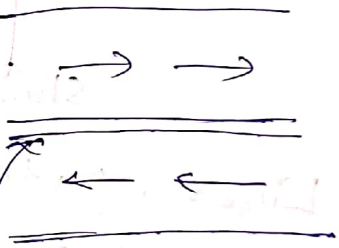
① 

Single broken line (vehicles are allowed to overtake)

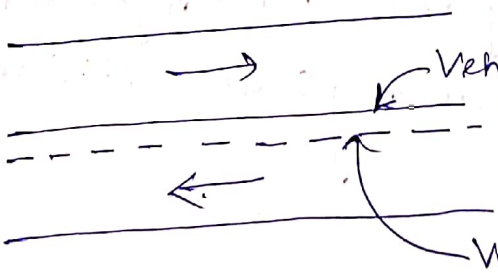
② 

Single continuous line (NO overtaking allowed)

③ 

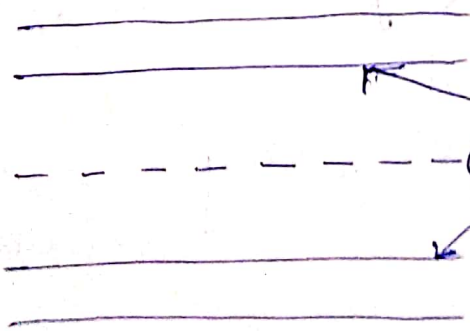
④ 

Overtaking strictly prohibited (normally white or yellow if visibility low)

⑤ 

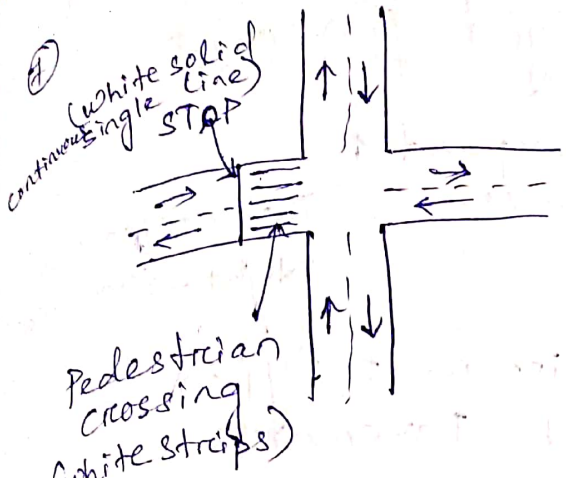
Vehicle on this side must not overtake

Vehicle on this side can overtake if it is safe.

⑥ 

Border edge line

(1)



(2) Kerb marking -

These are the markings on a kerb with alternate black & white lines to increase the visibility from a long distance.

(3) Object marking -

These are the markings provided to identify any physical obstructions on or near the roadway.

(4) Reflector unit marking -

Usually Yellow coloured reflectros are used on the roads for safe driving during night.

Hazardous marker -

Height - 0.8 to 1 m.

Colour - white & black.

Dt - 22/10/19

Failures of Rigid Pavement -

$\alpha \uparrow$ - temp ↑ - expand. ↑
concrete $\alpha = 12 \times 10^{-6}/°C$. Day - expansion
Night - contraction

Following are the different types of failures in Rigid pavements.

1. Scaling of cement concrete
2. Shrinkage cracks
3. Spalling of joints
4. Warping cracks
5. Mud pumping

(1) Scaling of cement concrete -

→ Scaling means peeling off or flaking off of top layer of concrete surface.

→ The reason behind scaling of cement concrete are :-

(a) Improper mix design
(b) Presence of chemical impurities in the mix.

(2) Shrinkage cracks -

↑
Reduction in volume

→ The reason behind shrinkage cracks is improper curing.

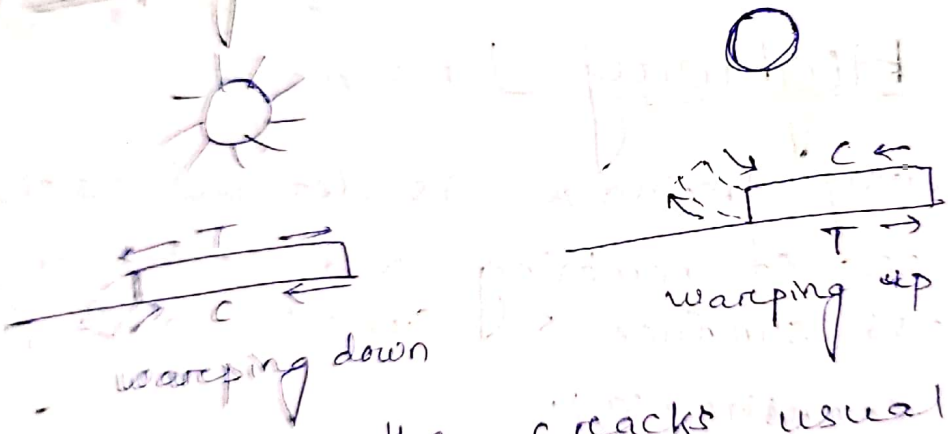
→ These cracks develop in transverse as well as in longitudinal direction

③ Spalling of joints -
(Breaking of joints)

→ Spalling of joints in rigid pavement occurs due to improper placement or faulty alignment of sealing materials or filler materials (bitumen or rubber bitumen)

→ Breaking of joints leads to development of excess stresses in concrete at or near the joints due to wheel load.

④ Warping cracks -

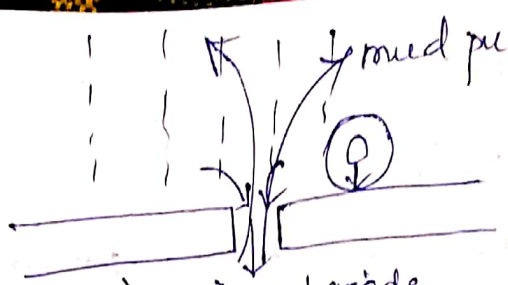


→ These are the cracks usually at the edges in a irregular pattern.

→ Proper design of joints can avoid these type of cracks in rigid pavement.

⑤ Mud pumping -

It is a phenomenon in which soil slurry (mud) comes out through the joints and cracks in cement concrete pavement during downward movement of slabs under heavy wheel loads.



$soil + H_2O = mud$

Factores which cause mud pumping are → Extend of slab deflection
→ Type of subgrade soil
→ Amount of free water

Dt - 24/10/19

Highway Drainage

Highway drainage is defined as the process of removing and controlling excess surface & subsoil water from the carriageway.

Importance of Drainage -

→ Excess moisture in soil subgrade reduces the strength & stability of subgrade.

→ If their exists clayey soil subgrade then variation in moisture content causes considerable variation in subgrade volume, which leads to pavement failure.

→ Poor drainage is also treated as the reason behind formation of webs & corrugations in flexible pavements.

→ Continuous contact of water with bituminous pavements causes stripping of bitumen from aggregates.

→ Presence of water in subgrade soil in rigid pavements leads to mud pumping.

→ Presence of water in subgrade also causes problems of frost action in cold countries.

→ Surface water also causes erosion of soil from top & slope of embankment.

Surface drainage – (collection + disposal)

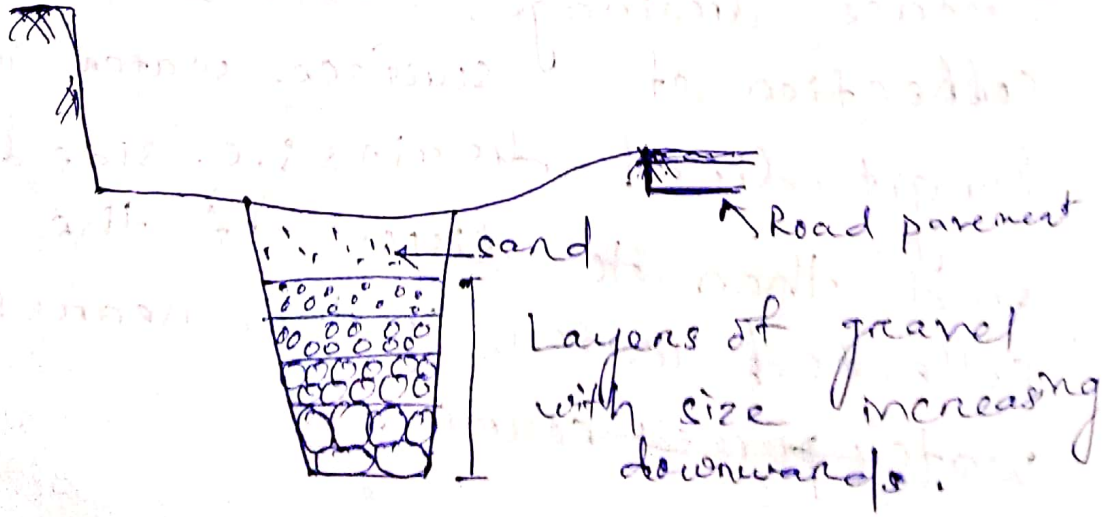
Surface drainage deals with collection of surface water into longitudinal drains i.e. side drains and then to dispose off the collected water in the nearest water ~~forest~~ course.

Methods of surface drainage :-

→ The water from the pavement surface is removed by providing camber or cross slope to the pavement. The amount of cross slope depends on the type of pavement surface and the amount of rainfall.

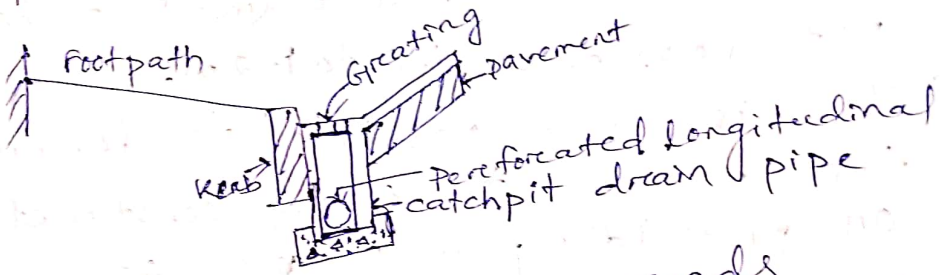
→ In rural road, the side drains which are generally opened kautcha (unlined) ~~drains~~ drains of trapezoidal shapes, with suitable longitudinal slope provided parallel to the road alignment.

→ The drainage ~~trenches~~ trenches are properly filled with the layers of coarse sand & gravel.



Drainage in rural roads

→ In urban roads due to limitation of land width and presence of footpath, Islands and other road facilities, It is necessary to provide under ground longitudinal drains between the kerb and the pavement.



Drainage in urban roads

Sub-surface Drainage -

→ Fluctuation in ground water percolation of rainwater, movement & rise of capillary water causes change in moisture content of the surface which should be properly taken care of by a process called sub surface drainage.

→

Following are the different methods of subsurface drainage.

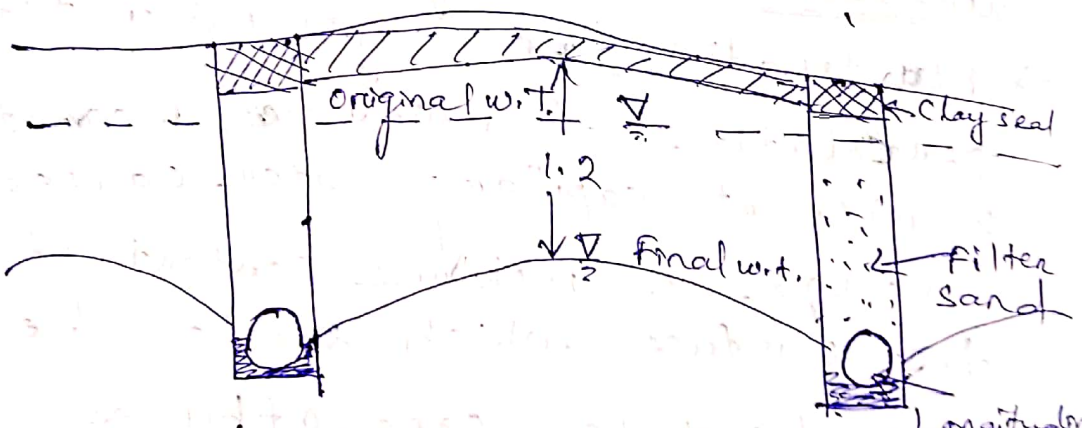
1. Lowering of water table
2. Control of seepage flow.
3. Control of capillary rise

① Lowering of water table —

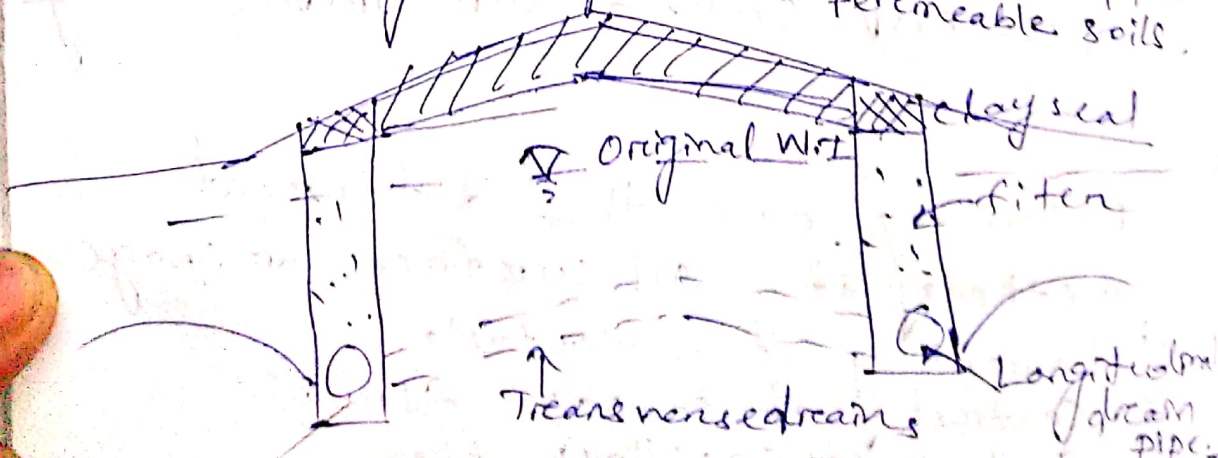
→ It is suggested that water table should be kept 1 to 1.2 m below the subgrade.

→ In places where water table is high, it is desirable to construct the road on embankment of height not less than 1.0 to 1.2 m.

→ It is also possible to lower the water table by constructing or providing a series of transverse drains.



Lowering of High W.T in permeable soils.



② Control

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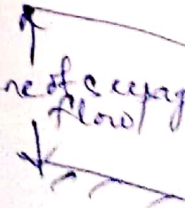
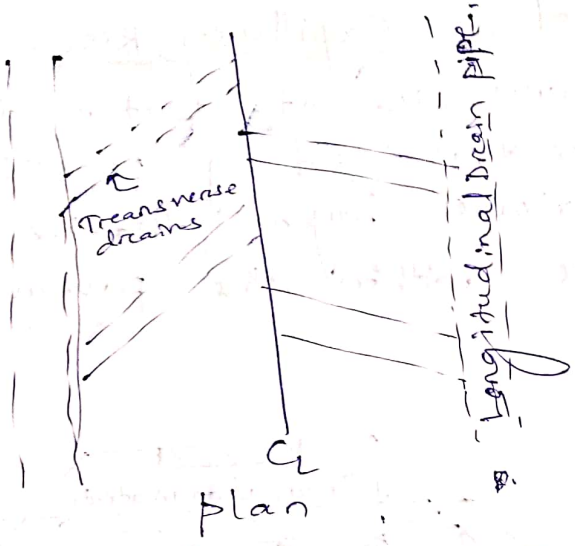


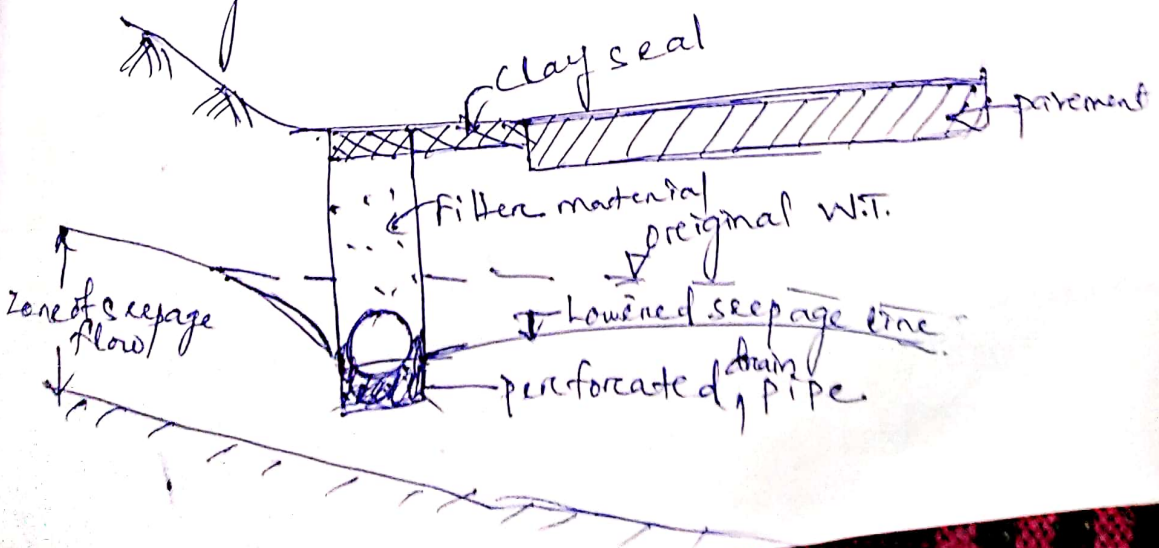


Plan

lowering of high W.T in less permeable soil.

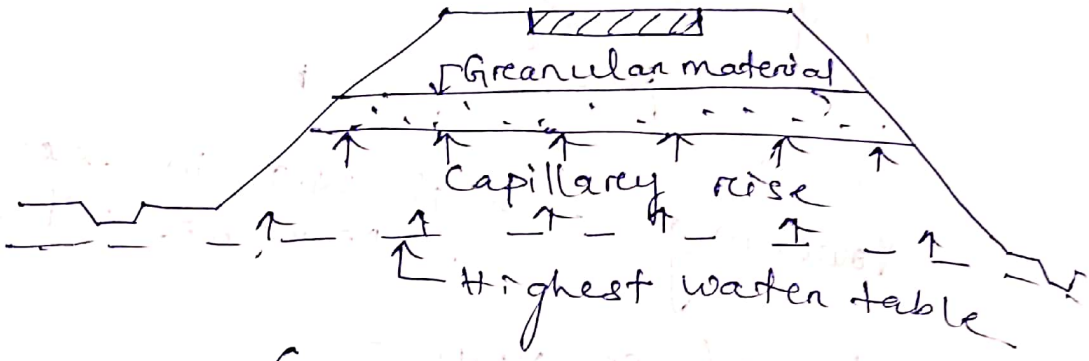
② Control of seepage -

When the general ground level is sloping the seepage flow can be controlled by providing longitudinal drain pipe in trench filled with sand. and a clay seal at top.



③ Control of Capillary Rise :-

Capillary rise of water table can be avoided by providing an impervious layer ~~Head~~ i.e. clay layer within the pavement.



Granular Capillary Cut-off

ch-10

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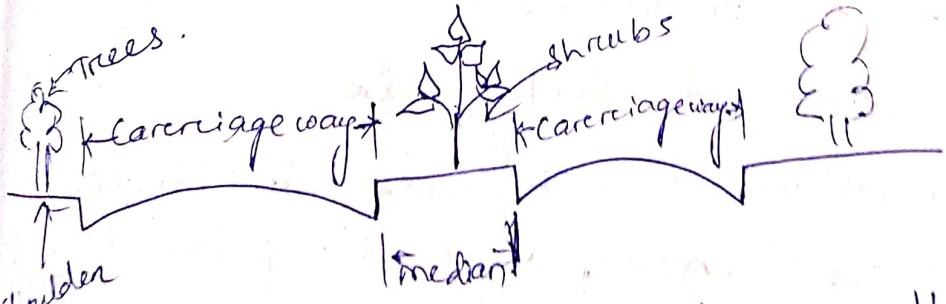
Dt:- 25/10/19

Ch-10 Landscaping And Arboriculture

Landscaping and Arboriculture deals with development of Aesthetic (appearance) and other amenities of road and the abutting land or right of way.

Following are the points to be considered for landscaping and arboriculture of highways.

1. Uniform and smooth horizontal & vertical alignment.
2. Wide ROW and shoulders in rural highways.
3. Flat side slopes in embankment and cut.
4. Suitable plantation of trees and shrubs and their proper maintenance.
5. Turfing on side slopes and on shoulds on rural road;



Shrubs on the reduce the headlight glare during night driving.

Dt- 29/10/19

Highway Construction -

The purpose of highway construction is to provide a stable and even surface for the carriage way which can withstand the stress caused due to no. of load applications.

→ Based on the method of construction highway construction is divided into mainly 3 types -

(a) Water bound Macadam (WBM) road
(b) Bituminous road or Black top road
(c) Cement concrete road.

Steps of Highway construction -

The highway construction project is broadly divided into two parts.

(a) Preparation of subgrade
(b) Pavement structure.

(a) Preparation of subgrade -

(i) Preparation of subgrade includes site clearance, greading and compaction.

(ii) The construction site should be cleared off and the top soil

consisting of grass, rubbish and other organic matter should be removed.

(iii) After site clearance, grading operation is started to bring the subgrade to the designed gradient and camber. Bulldozers, scrapers and blade graders are used for grading operation.

(iv) Compaction of soil subgrade is carried out after the grading operation to remove the air voids thus, increasing the density, strength, stability and the reduction of settlement. Rollers, smooth wheel roller, sheepfoot roller, pneumatic tyred roller. etc., rammers, vibrators are used as compaction equipments.

Pavement structure –

(a) Construction steps of WBM –

① WBM means crushed or broken aggregate mechanically interlocked by rolling and the voids are filled with screening and binding material with the help of water.

(ii) The thickness of WBM varies from 10cm to 7.5 cm generally.

(iii) It may be used as a subbase, base or surface coarse.

Steps -

Step (1) Preparation of foundation for receiving WBM layer.

The foundation layer is prepared to require grade and camber and dust, loose materials should be cleaned. Depressions, and pot holes, if any, should be filled.

Step (2) Provision of lateral confinment for WBM laying may be done by constructing shoulders in advance and then trimming the inner sides vertically equal to the thickness of WBM layer.

Step (3) Spreading of coarse Aggregates-

Coarse aggregates are spread uniformly to a proper thickness of 7.5cm to 10cm

④ After spreading of coarse aggregates rolling is started with a 3-wheeled roller of capacity 6-10 tonne starting from edges and gradually shifting towards the centre.

⑤ Application of screening - Smaller aggregates are applied to fill the voids or gaps and again rolling is conducted.

⑥ Sprinkling & grouting of water - After the filling up of voids. water is sprinkled on the surface swept and rolled.

⑦ Application of binding material - After application of screening and rolling binding material is applied at a uniform rate along with continuous sprinkling of water and rolling is done simultaneously.

⑧ Setting and drying - After final compaction WBM coarse is allow to set over-night. On the next day if there is any depression found then they should be filled with screening & binding material.

After proper drying the layer is opened to traffic.

(b) Bituminous road -

Based on the method of construction bituminous constructions are divided into following types -

(I) Prime coat
(II) Tack Coat
(III) Seal coat
(IV) whole BSD (Bituminous surface dressing)
(V) ~~Semi~~ pre-mix carpet
(VI) Bituminous concrete

(I) Prime Coat -

It is the first application of low viscosity liquid bituminous material over a WBM base course.

The main object of prime coat is to fill the voids of WBM surface and also to ~~bind~~ bind the mineral particles on the existing base course.

→ Usually MC or SC (medium (slow curing) cut back curing) bitumen of suitable viscosity are choosen for prime coat.

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(II) Tack coat -

After the application of prime coat bituminous material of higher viscosity like cut bitumen is spread at a rate of 4.9 to 9.8 kg/m².

→ In some cases bituminous emulsion is also used as a tack coat.

(III) Seal coat -

Seal coat is usually recommended as a top or final coat after the application of tack coat.

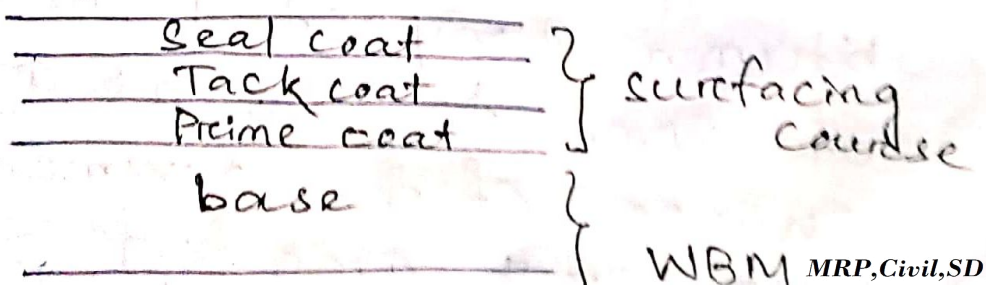
It is also provided over an existing damaged bituminous surface.

→ A pre-mixed sand bitumen mixture is commonly used as a seal coat.

→ The main functions of steel coat are -

(a) To develop necessary skid resistance.

(b) To act as a seal against ingrace of rain water.



(IV) Bituminous Surface Dressing -

→ BSD is provided overall existing pavement to act as a thin wearing coat.

→ It consists of single application of bituminous binder material then spreading of aggregates and rolling.

→ The main functions of BSD are -

(a) To protect the base course.

(b) To provide a water proof layer on the pavement surface.

(c) To provide a dust free and mud free movement.

(V) Pre-mix carpet -

→ Pre-mix carpet consists of coarse aggregate of 12.5 and 10mm pre-mixed with tare or bitumen compacted to a thickness of 20mm. to act as a surface course of the pavement.

→ When well graded aggregates are used for the construction of bituminous carpet of thickness 20-25mm. then it is called a

Semidensed carepet.

(VI) Bituminous concrete:-

Bituminous concrete is a densed graded mixture of coarse Agg, fine agg, mineral filler (fine sand, lime stone dust) and bitumen designed by an appropriate method.

→ The thickness of bituminous concrete varies bitumen 40-75 mm.

Construction steps of C.C pavement or Rigid pavement :-

(1) Construction of C.C pavements is divided into 2 groups -
   (a) Constructions of pavement slabs.
   (b) Constructions of joints.

(2) Constructions of pavement slabs :-
   (1) preparation of subgrade & subbase -
   → For laying concrete slabs depressions or soft spots should be properly taken care off.
   → Uniform compaction of subgrades & subbase, should be done atleast 30cm on either side of the width to be completed.
   → The subgrade or subbase should be kept in moist condition at time when cement concrete

(II) Placing of forms -

→ Usually steel or wooden forms are used.

→ the forms are jointed neatly and placed to the required grade and alignment.

(III) Batching & mixing of materials -

Coarse agg, fine agg and cement are suitably measured by weight and mixing is done in a batch mixer.

The mix should be uniform in colour and homogenity.

(IV) Transporting & placing -

Cement concrete is ~~placed~~ Placed to the required depth & width within the formwork.

→ while transporting and placing it should be observed that no segregation is taking place.

(V) compacting and finishing -

As soon as the concrete is placed needle vibrator or any compacting equipment should be used to remove the air voids from the concrete.

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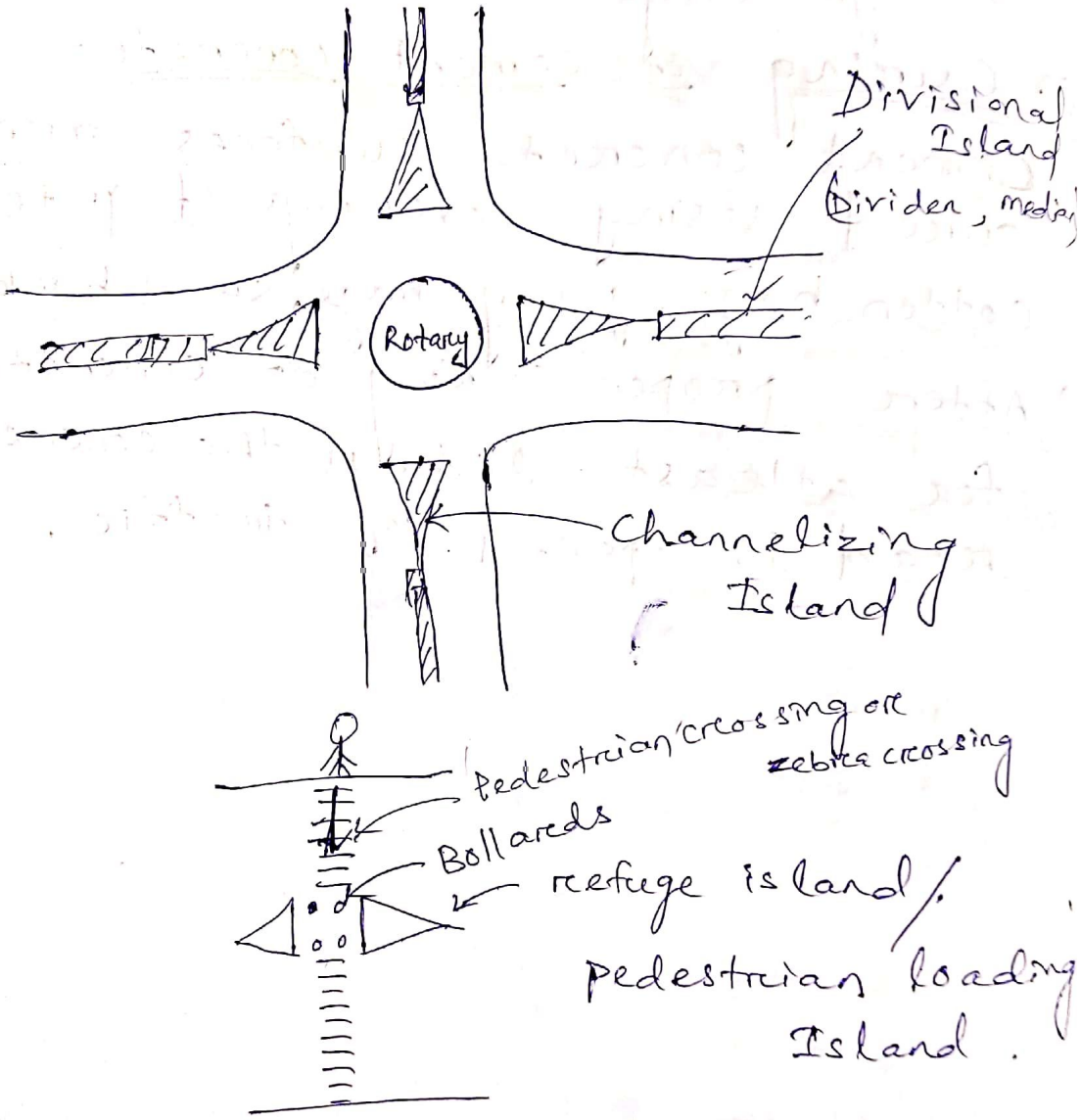
→ finishing of surface is done with the help of a Float and straight edge.

(VI) Curing of cement concrete -

Cement concrete surfaces are cured using coverings of jute bags, cotton bags, gunny bags, sand blanket, etc.

→ After proper curing of concrete for atleast 28 days the concrete road is opened to traffic.

Traffic island -



Traffic islands are defined as the raised areas constructed within the road way to regulate control and guide the traffic in appropriate directions.

Broadly traffic Islands are divided into foure types based on the purpose for which they are provided.

1. Divisional Island
2. channelizing Island
3. Rotary Island
4. Pedestrian load Island / Refuge Island.

① Divisional Island -

These are provided in order to separate traffic flow moving in opposite directions to avoid head on collision.

Example - medians or dividers provided on highways.

② channelizing Island -

These are provided to guide the traffic into proper channels at the intersection area.

→ These are very useful traffic control devices particularly when the area is large. It helps in changing the direction of flow and also in reducing possible conflict between traffic streams

(iii) Rotary -

This is a large central Island to convert the crossing manoeuvre in to weaving by providing sufficient weaving length.

→ Usually circular rotary Islands are preferred.

(iv) Refuge Island -

These islands are provided at, or near the cross paths to help and protect pedestrians in crossing the carriageway.

→ In multilane highways it is desirable to provide pedestrian refuge islands after two or three lanes.

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