LEARNING MATERIAL

SEMESTER & BRANCH : 4th SEMESTER CIVIL ENGINEERING

THEORY SUBJECT : HIGHWAY ENGINEERING (TH – 4)

NAME OF THE FACULTY : ER. SWARNAPRAVA PARIDA

&

ER. SUNIL KUMAR SAHU

Unit 1 21 April 2021

Highway :- The road of national or state importance in a country is known as highway.

Highway engineering :- It is the branch of engineering science which deals with the study of planning, designing, construction and maintainace of the road depending upon nature and volume of traffic

Importance of highway engineering :-

Highway transportation plays vital role for the country's industrial economic and cultural progress as well as in the defence of our country.

The following points indicate the importance of highway transportion.

(1) The highway helps in the overall development of a country in the field of industry and culture.

(2) The highway play an important role in the defence and military sporation.

(3) The highway help in maintaining law and order of various states within the country.

(4) The highway help in the movement of traffic from one place to another.

(5) The highway help in increasing the trade relations and increasing the economic activities.

(6) The highway transportion in cheap and convenient mode of transportion in most of the cases.

(7) The highway transportion provide goods commercial links between various villages, towns and cities.

(8) The highways serves as feeder lines for airways, railways and waterways.

(9) The highways are the only source of transporting goods and passengers where other mode of transportion are not available.

Important organization promoting road development:-

(i) Indian road congress (I.R.C)
(ii) Ministry of surface transportion (MORTH)
(iii) Central road research institute (CRRI)

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(i) Indian road congress (I.R.C)

- The indian road congress was established by central government in 1934 as per recommendation of Jayakar committee
- The IRC was constituted to provide a forum for regular pooling of and ideas on all matters

affecting the construction and maintance of road in India.

* presently the indian road congress has become the active body to recommended specifications regarding design and construction of roads and bridges.
* The IRC works in close collaboration with road wings of ministry of surface transportion Govt of India.
* IRC publishes journals standard specifications and guidlines on various aspects of highway engineering.
* The technical activities of the IRC are carried out by expets in each subject.

IMP Functions of Indian road congress :—

The IRC is a body of professional highway engineers having the following functions :—

* To provide forum of expression of collective opinion of its member for all matters affecting the construction and maintance of roads in India.
* To promote the use of standerad specifications and practices.
* To suggest improved method of planning, desiging, construction and maintanance of road.
* To conduct periodical meeting to discuss technical questions regarding road.

→ To make laws for the development improvement and protection of road.

Central road research Institute (C.R.R.I)

⇒ In 1950, The central road research institute was started at delhi for road research work in the country.

⇒ This is one of the chain of national laboratories under council of scientific and industrial in India.

⇒ The institute has the following objective

(i) To carry out the basic and applied research for design, construction and maintenance of various road.

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

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(iii) To research on economical utilisation of locally available materials for construction and maintenance of road.

(iv) To develop new mechinary tool equipment and instrument for high way engineering.

(v) To provide technical advice and consultancy.

(vi) To provide library and documentation services.

(vii) The institute is headed by a director and has following wing.

(i) General project
(ii) Documentation
(iii) Soil and Geotechnical engg.
(iv) Flexible pavement
(v) Rigid pavement
(vi) Extension
(vii) Traffic and transportation
(viii) Work shop
(ix) Electrical instrumentation
(x) Environmental safety

Ministry of road transport and highways (MoRTH)

(i) MoRTH is an organisation of central government.
(ii) It is formed with the task to formulate in consultation with other department of central and state government policies of road transport. National highways and transport research with a view to increasing the mobility and efficiency of road transport system in the country.

⇒ It has two wings
(i) Road wing (ii) transport wing

Road wing :—

Road wings deals with development and maintenance of national ways in the country.

Transport wings :—

Transport wing deals with matter relating to road transport.

Main responsibilities of road wings :—

- planning development and maintenance of national highway in the country.
- Extends technical and financial support to state governments for the develop of state roads and the road inter-state connectivity and economic importants.
- Develops standard specificalton for roads and bridges in the country.
- Serves as a store of technical knowledge on roads and bridges.

Main responsibilities of transpoot wing :—

- Making Laws of motor vehicle.
- Administration of motor vehicle act 1988.
  - > Regulation administration of the road transport corporation act 1950.
  - > Taxation of motor vehicle.

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→ Compulsory insurance of motor vehicle.
→ Develop road safety standards in the form of national policy on road safety.
→ Preparing and implementing the annual road safety plan.
→ Maintaining road accident statistics and takes steps for developing a road safety culture.

Classification of road :—

Road are classified into following two broad catagories.

(I) urban road
(II) Non-urban road / Rural Road

Urban road

- urban are those which fall with the Jurisdiction of municipalties and Cantoment boards.
- urban roads are classified as follows :—
  (i) Express way
  (ii) Arterial streets
  (iii) Sub-Arterial streets
  (iv) Collecter streets.
  (v) Local streets

Non-urban road :-

- Non-urban roads are those located in the areas other than urban areas. They are also known as rural road.

- The non-urban roads are classified into five categories :

I.M.P - This classification is popularly known as I.R.C classification of road.

(I) National highway (N.H)

(II) State highway (S.H)

(III) Major district road (M.D.R)

(IV) other district road (O.D.R)

(V) village road (V.R)

(1) Express ways :-

- These are divided arterial highways for motor traffic and provided generally with grade separation at intersection.
- The main function of express way is to provide for movement of heavy traffic At high speed.

(2) Arterial streets :-

- Arterial streets primarily meant for through traffic usually on a continuous route.
- Arterial streets along with express ways serve as the principal network for through traffic flow.
- A properly developed and designated arterial streets system would help to identify residential.

neighbourhoods, Industrial areas and Commercial areas.

- These streets are spaced generally at less than 1.5 km in central business area and at 8 km or more in developed urban.

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(3) Sub-arterial Streets :-

> These are streets of some what lower level of mobility than arterial streets.
> These are spaced at 0.5 km in the central business area and 3 to 5 km in sub-urban areas.

(4) Collector Streets :-

> These are intended for collecting and distributing the traffic to and from local street.
> it also provide access to arterial streets.

(5) Local streets :-

> These are primerly intended for access for residence business and other abutting property.
> These street do not large volume of traffic.

Classification of rural roads as per IRC classification.

(1) National highway (NH)

⇒ The main highways running through the length and breadth of the country connecting state capitals and foreign highways, large town etc are known as national highways.

⇒ These are of national importance for strategic, administrative and other purpose.

⇒ All the national high ways are assigned the respective number.

⇒ The highway connecting Amritsar - Ambala - Delhi is denoted as NH-1, NH 100 is Chalna - Hazaribag - Bogudar and NH-953 Vyara - Nizang - Rajpipla Bedeli.

⇒ The total length of national highway is 76818 Km.

(2) State highway :-

⇒ The high ways district head quarters and important cities with in state or connecting them, with national highway of other state are known as state highways.

⇒ These highway serve as main arteries of traffic to and from district roads.

(3) Major district road (M.D.R) :-

⇒ The important road with the district serving areas of production and market and connecting these with each other or with the highways are known as major district roads.

⇒ The road have roughly the same specification as the state highways.

(4) Other district Road (O.D.R) :-

⇒ ODR are the road serving rural areas of production and providing them with outlet to tehsil head quarters, market centre etc.

⇒ These roads have some-what lower specification than major district roads.

(5) village Road (V.R) :-

⇒ village road some road connecting villages or group of villages, with each other or with nearest district road main highway, railways etc.

⇒ The road are very important from the point of veiw of rural areas development.

⇒ The construction and maintenance of these road are responsibility of local district authority.

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Importance of geometric design —

> The geometric design of a highway deals with the dimension and layout of visible features of the high way such as segment sigh distances and intersection etc.

> The geometrics of highway should be designed to provide optimum efficiency in traffic operations. with maximum safety at reasonable cost.

> The designer may be exposed to either planning of a new highway network or improvement of existing highway to meet the requirements of existing road.

> It is possible to design and construct the pavement of the road in stages. but it is very expensive and rather difficult to improve the geometric element of the road in stages at a later date.

> Therefore it is important to plane and design the geometrical features of the road during the initial alignment itself taking into consideration the future growth of traffic flow and pussibility of road. the road being upgraded to a higher category or to a higher category design speed standard at a later stage.

> Geometric design of highway deals with the following elements.

(i) Cross-section elements

(ii) Sight distance considerations.

(iii) Horizontal alignment details.

(iv) Vertical alignment details.

(v) Intersections elements.

(i) Cross-section elements:-

> The considerations for the width of the pavement, formation and land. Surface characteristics and cross-slpp of pavement are included.

(ii) Sight distance considerations:-

> The clear visible distance ahead a drive a horizontal and vertical curves and at intersection govern the safe movement of vehicles.

(iii) Horizontal alignment details:-

> The change in the road direction are made possible by introducing horizontal curves.

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Design controls and criteria:-

* Design speed
* Topography
* Traffic factors
* Design hourly volume and capacity.

Design speed :-

- In india different speed standards have been assigned for different class of road.

Ex:- Express ways - speed → 120 km/hr

N·H speed -> 100 km/h

S·H speed → 80 km/h

- Design speed may be modified depending upon terrain condition.

Topography :-

classification based on the general slope of the country.

(i) Plane terrain < 10%.

(ii) Rolling terrain 10% - 25%.

(iii) Mountainous terrain · 25% - 60%.

(iv) Steep terrain · > 60%.

Traffic factor :-

- vehicular characteristics and human characteristics road user.
- Different vechicle classes have different speed and acceleration characteristics, different dimension and weight.
- Human factor includes the physical mental and phychological characteristics of driver and pedestrain.

Design hourly volume and capacity :-

- Traffic flow fluctuating with time.
- Low value dercing off peak hours to the heighest value during peek hours.
- So it is uneconomical to design the road way for peak traffic flow.

Environmental and other factors :-

* Aesthetics
* Land scaping
* Air pollution
* noise pollution

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Pavement surface characteristics :-

Pavement surface depend on the type of pavement which is decided base on
(i) Availability of matterial
(ii) volume and composition of traffic
(iii) soil sub grade
(iv) climatic condition.
(v) construction facility
(vi) cost consideration.

Importance surface characteristics :-

The importance surface characteristics are (i) Friction
(ii) pavement un evenness
(iii) Light reflecting characteristics
(iv) Drainage of surface water.

(1) Friction :-

Skidding → when the path travel along the road surface is more than the circumferential moment of the while due to rotation is called as skidding ($L > R$)

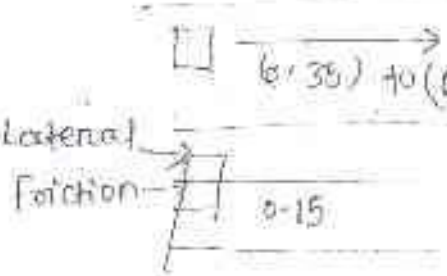
Sliping - ($R > L$)

⇒ When whel revolves more than the corresponding longitudinal movement along the road.

Factors affecting the friction :-

(i) Type of pavement surface
(ii) Roughness of pavement
(iii) Condition of pavement
(iv) Type and Condition of type.
(v) Speed of the vehicle
(vi) Breaks efficiency
(vii) Load and type pressure
(viii) Temperature of type and pavement.

⇒ The smooth and worned tyre offer height friction factor factor on dry pavement. but new tyre with treads gives higher friction fricton on wet pavement.



=> IRC recommended the longitudinal co-efficient friction varies from 0.35 - 0.40 and coefficient of lateral friction of 0.15.

(ii) Unevenness of pavement surface :-

The unevenness of pavement material surface cause by

(i) use of inferior pavement material
(ii) poor maintenance
(iii) Improper construction equipment / machinary.
(iv) Improper surface and subsurface drainage.
(v) In adequate compaction of the fill subgrade and pavement layers.

=> Un-scientific construction practises including the use of boulder stones and bricks as soiling course over loose sub-grade soil.

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Pavement unevenness

=> Higher operating speed are possible on even surface than uneven surface.
=> It affects vehicle operation cost, comfort and safety, fuel consumption, wear and tear of types and other moving parts.
=> It is commonly measured by an equipment called Bump integrater.

> Bump integrater is the cumulative measure of vertical undulation of the pavement surface recorded per unit horizonial length.

> 250 cm/km for speed of 100 km/h and more than 350 cm/km considered very unsatisfactory even at speed of 50 km/h.

Light reflecting characteristics :-

> Night visibility very much depends upon the light reflecting characteristics of the pavement.

> The glare caused by the reflection of head light is high on wet pavement surface than on dry pavement surface.

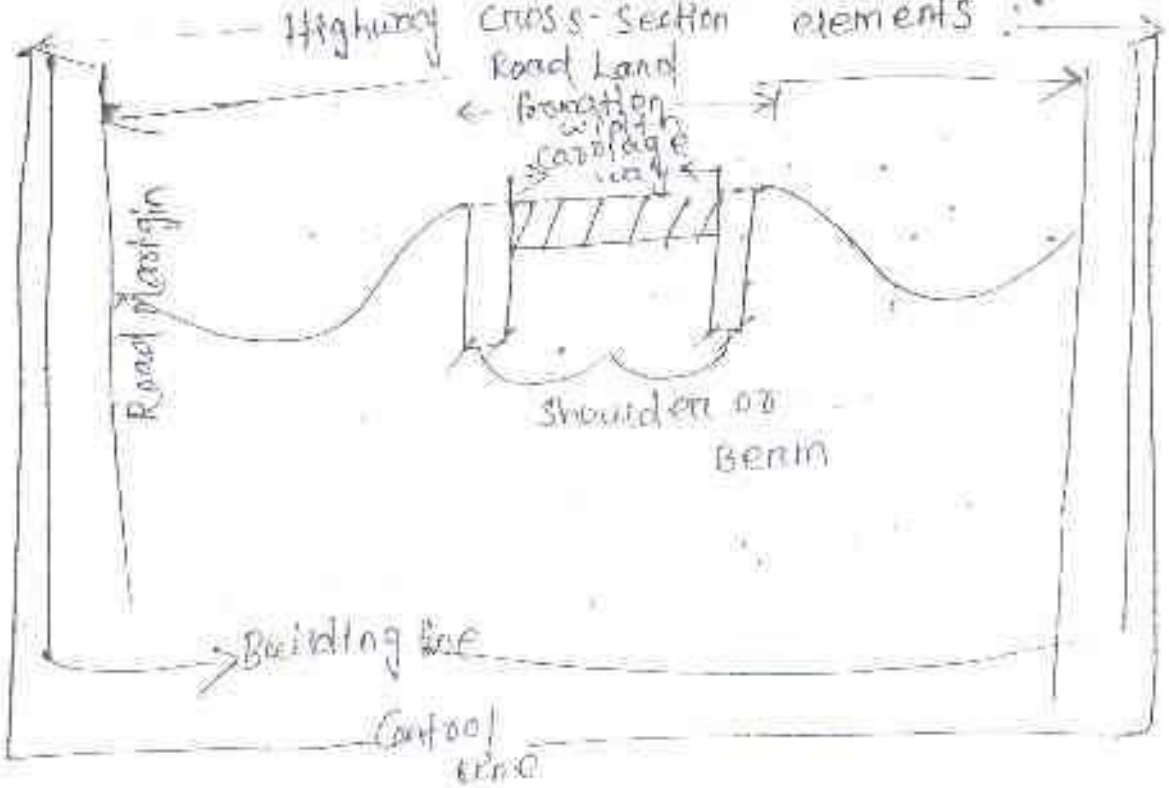
> Light coloured or white pavement or rigid pavement surface give good visibility at night particularly during rain.

Drainage of surface water :-

> The pavement surface should be absolutely impervious to prevent the entry of seepage water into the pavement layer.

Highway cross-section elements:→

(i) Carriage way
(ii) Shoulder
(iii) Road width
(iv) Right of way
(v) Building line.
(vi) Control line
(vii) Median
(viii) Camber
(ix) Crown
(x) Side slope
(xi) Kerb
(xii) Guard rail
(xiii) Side rail
(xiv) other facilities



Building lane :-

In order to reserve sufficient space for further development of roads. It is desirable to control the building activities on either side of the road boundri beyound the lane width. acquired for the land.

Control line :-

In addition to building line it is desirable to control the nature of building up to future set back distance.

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Camber :-

> It is the slope provided to the road surface in the transverse direction to drainout the water from the pavement.

> objective of Camber :-

*To prevent the entry of surface water into the subgrade through paverd.

* To prevent the entry of water into the bitumimous pavement layer.

* To remove the rain water from the pavement. surface as quick as possibe and to allow the pavement to get dry soon after the rain.

* It is expressed as a percentage or 1 V : N H

* It depends on the pavement surface ... of rainfall.

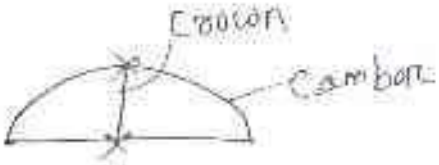
Shape of the camber

* parabolic shape (fast moving vehicle)

* straight line shape

* Combination of straight and parabolic

parabolic ← → straight



Recommended values of camber for different type of road surface :

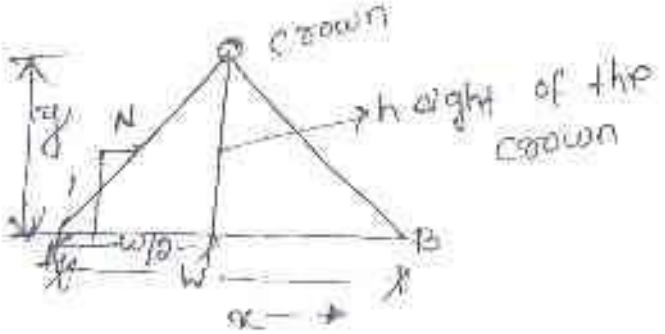
SL NO	Types of road surface	Range of camber in areas rain fall range	
		heavy	Light
1	cement concrete and high type bituminous surface	1 in 50 (2%)	1 in 60 (1.7%)
2	Thin bituminous surface	1 in 40 (2.5%)	1 in 50 (2%)
3	W.B.M and gravel pavement	1 in 33 (3%)	1 in 40
4	Earth	1 in 25 (4%)	1 in 33 (3%)

Example - 1

In a district where rain fall is heavy. MDR of W.B.M pavement 3.8 m. wide and a state highway of bituminous concrete pavement 7.0 m wide are to be constructed. what should be

camber -

(1) straight line camber -

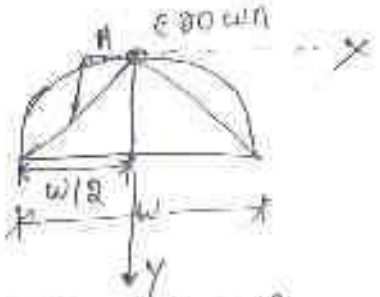


$$\tan\theta = \frac{y}{w/2}$$

$$\Rightarrow \frac{1}{N} = \frac{y}{w/2}$$

$$\Rightarrow \boxed{y = \frac{w}{2N}}$$

(2) parabolic camber -



$y = 0$ when $x = 0$

$y = y$ when $x = w/2$

$y = ax \Rightarrow y = a(w/2)$

$$\Rightarrow a = \frac{2y}{w}$$

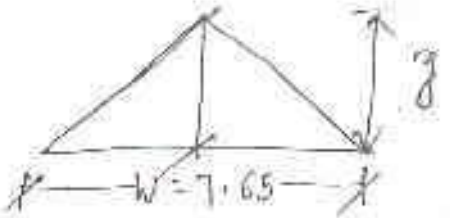
$$\boxed{y = \frac{2x^2}{Nw}}$$

Combination of straight line and parabolic camber -

$$\boxed{y = y_1 + y_2}$$

16. A 2 lane NH passing through a heavy rainfall area, made up of bituminous cement concrete surface, what will be the camber height?

Soln: A square camber is straight line.



Heavy rainfall area $\frac{1}{N} = 2\gamma = \frac{2}{100} = \frac{1}{50}$

$$y = \frac{W}{2N} = \frac{W}{2} \times \frac{1}{N}$$

$$= \frac{7.00}{2} \times \frac{1}{50} = 0.07 \text{ m}$$

Kerb

> It indicates the boundary betⁿ pavement and shoulder.

> It is desirible to provide Kerbs in urban areas.

> It is of three type.

① Low ② mountable type

② semi - barrier type.

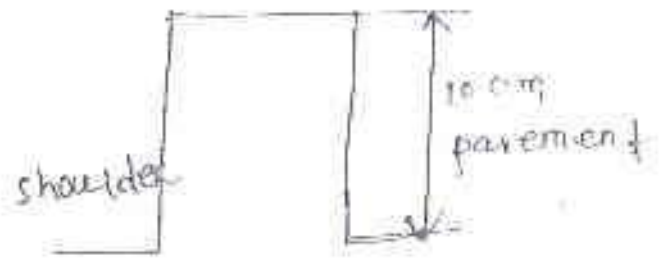
③ barrier type.

Low or mountable Kerb :-

> It is rectangular in shape

> It allows the driver to enter the shoulder area with little difficulty.

> the height of this type of shoulder Kerb is about 10 c.m. above the pavement edge. with slope to help the vehicle climb the kerb easily.



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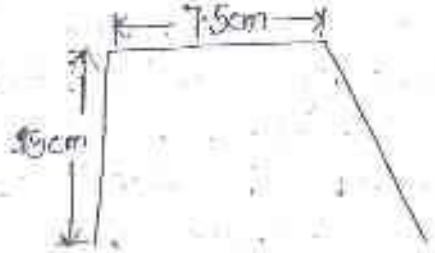
Semi barrier Kerb :-

(i) It is trapizodal in shape.
(ii) It is provided on the periphery of a road way where the pedestrain traffic is high.
(iii) Height above 15 cm above the pavement edge with batter of 1:1 on the top. 7.5 cm.



(iv) It prevent parking the vehicle but during emergency it is difficult to drive over this kerb with some difficulty.

Barrier type kerb :-

(i) It is trapezoidal in shape
(ii) It is provided in built-up area adjacent to the footpath with considerable pedestrain traffics.

The height of the kerb is about 20cm above the pavement edge with a steeper batter 1v:0.25H

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Right of way :-

⇒ It is the area of land acquired for the road along its alignment. The width of this acquired land is known as land width.

⇒ Land width depends on the Importance of the road and possible future development.

⇒ The land width is governed by the following factors.

(i) Width of the formation depending on the category of highway and width of road way and road margin.

(ii) Height of embankment or depth of cutting which is governed by the topography and the vertical alignment.

(iii) Side slope of embankment or cutting which depend on the height of slope soil type.

Guard rails :-

⇒ These are provided at the edge of the shower when the road is constructed so that vehicles are prevented from running off the embankment

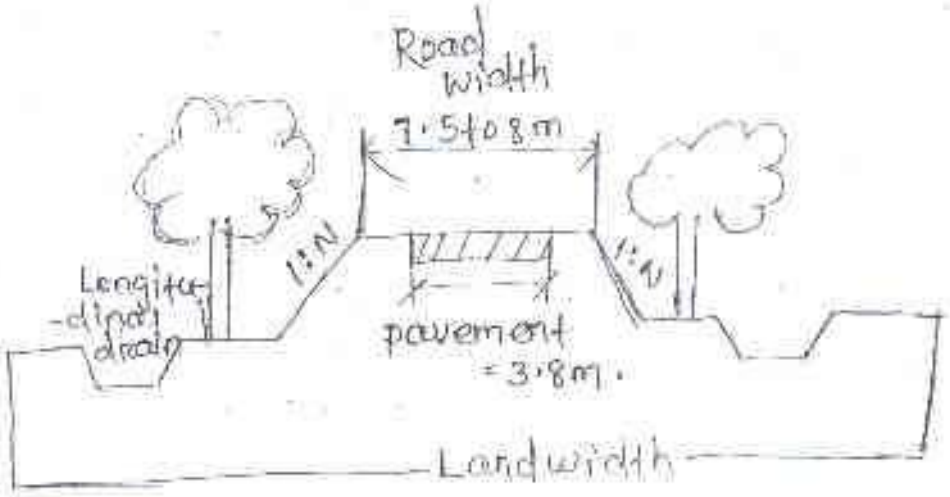
⇒ When the height of the fill exceeds 3m Guard rails are provided.

Footpath :- These are provided in urban areas when the vehicular as well as pedestrian traffic are heavy.

⇒ To provide protection to pedestrain and to decrease accidents.

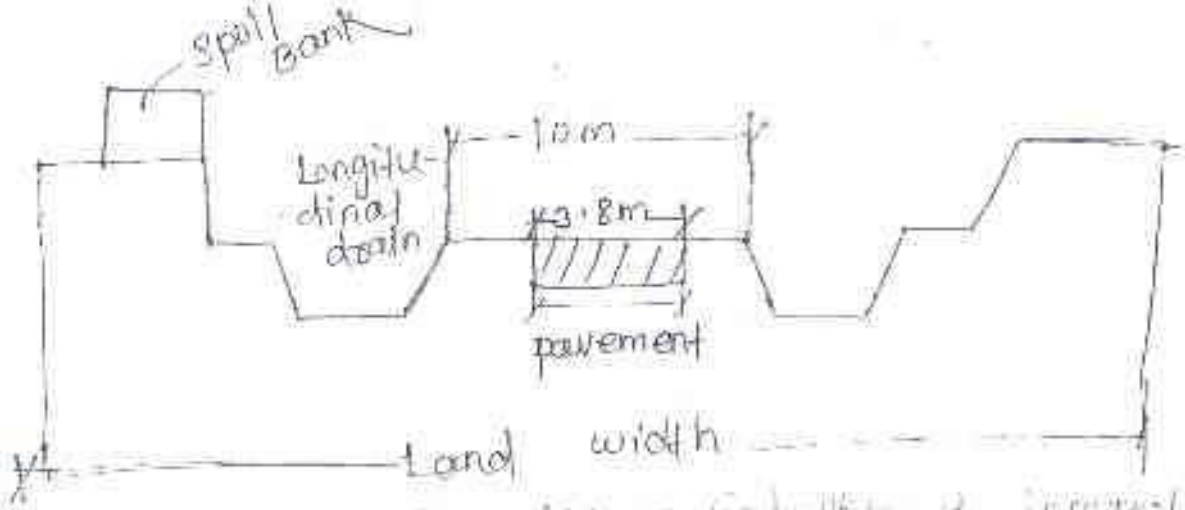
⇒ The minimum width of footpath is 1.5m.

Typical cross-section of road :

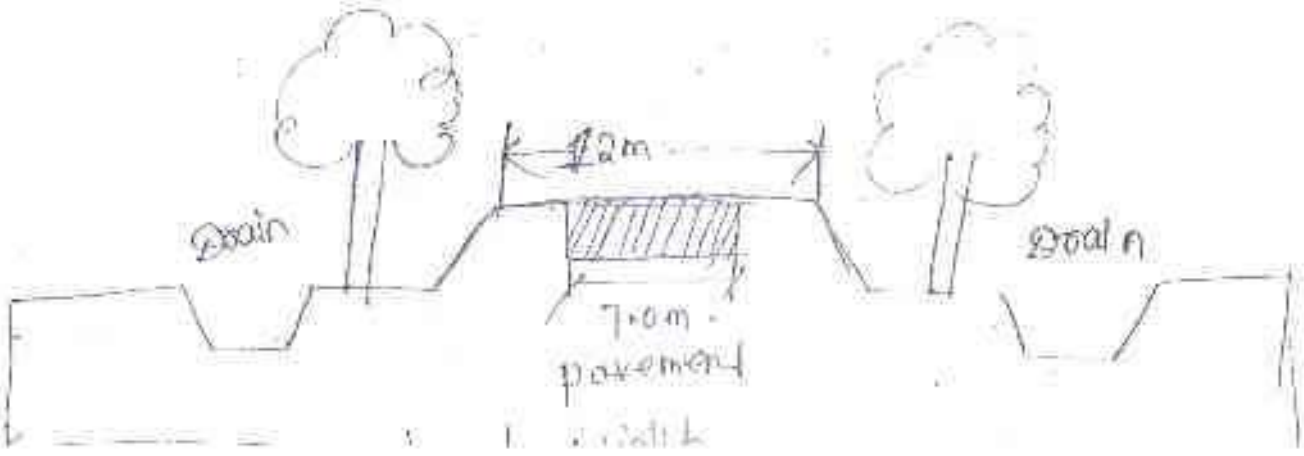


V.R or ODR in Embankment in rural area.

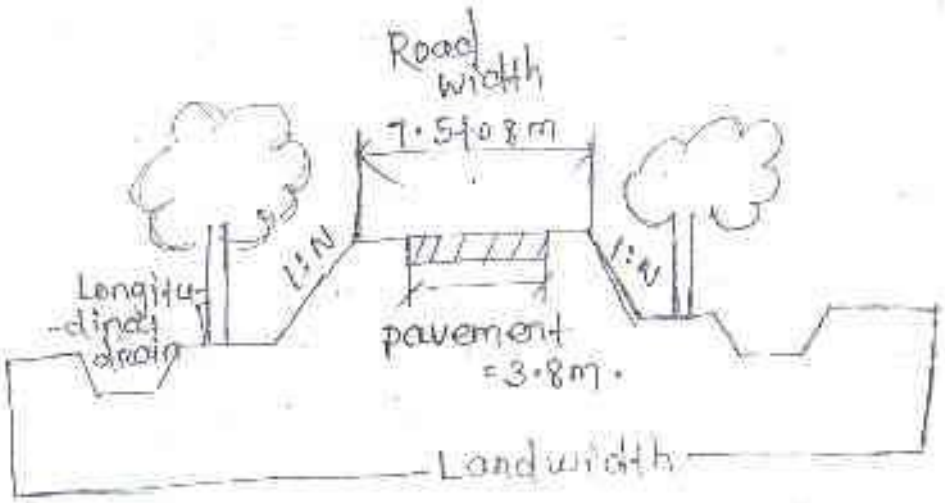
Cross-section of MDR in cutting in rural area.



Cross-section of NH/SH in Embankment in rural area

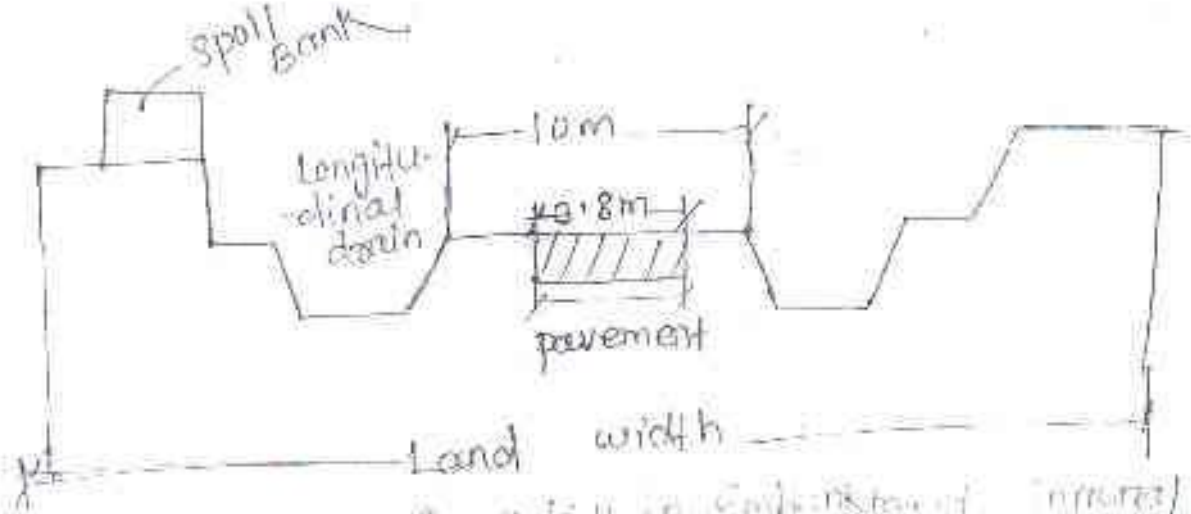


Typical cross-section of roads :-

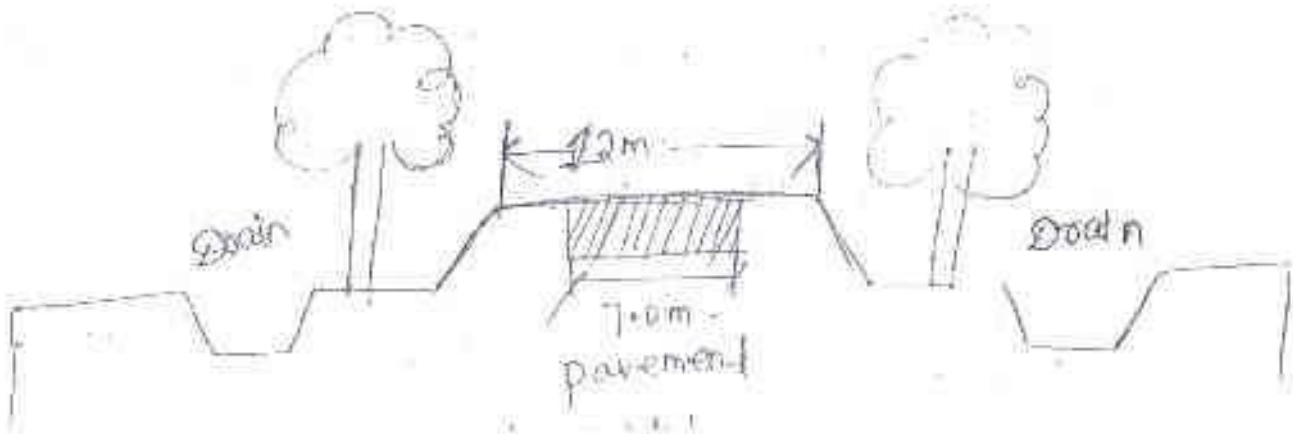


V.R or ODR in Embankment in rural area.

Cross-section of MDR in cutting in rural areas



Cross-section of MDR/SH in Embankment in rural areas



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Traffic Separators or median :-

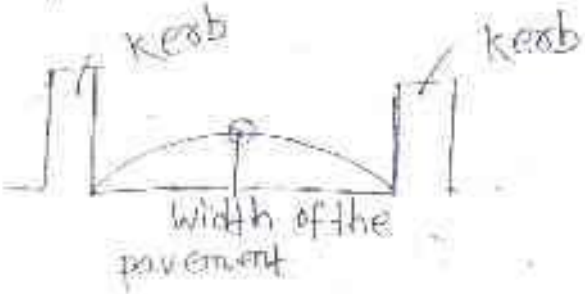
> The fuction is to prevent head on collision betn the vehicle moving in opposite direction.

> segregate slow traffic and to protect the pedestrians.

> IRC recommends a minm desirable width of 5m. and may be reduced to 3m. where land is restricted.

Crown :-

The heighest point on the road surface is called crown



Drive way :-

> It connects the highway with commercial establishment like fuel station, service station etc.

> It should be located away from the intersection.

cycle track :-

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

~~Traffic on the road is high~~

> A minimum width of 2m. is provided for cycle track.

Footpath :-

> These are provided in urban areas when the vehicular as well as pedestrain traffic is heavy.
> To protect the pedestrian and decrease accident.
> Minimum width of 1.5 m is provided.

Sight distance considerations :-

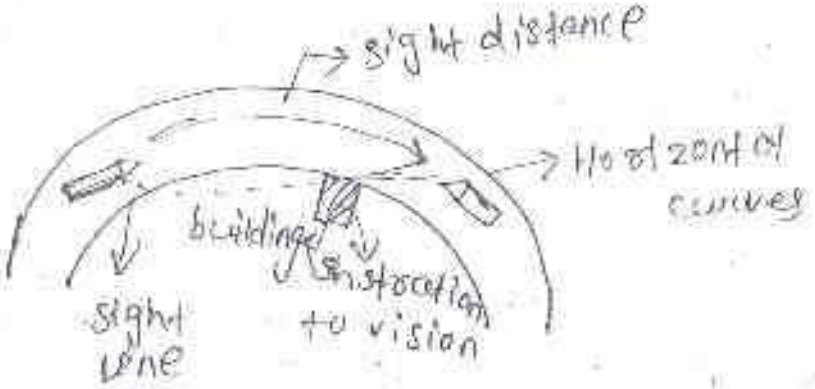
Sight distance :-

> It is the length of road visible ahead to the driver at any instance.
> Sight distance is the actual distance visible from driver's eye level (1.2m) at a specific height of obstruction (0.15m) on the road surface ahead.
> Sight distance is very important for safe operation of vehicles.

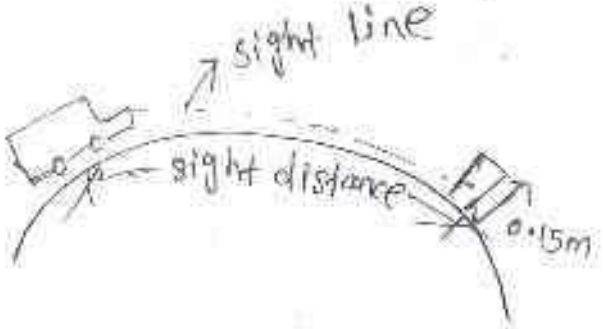
Restrictions to sight distance :-

① At horizontal curves
② At vertical curves
③ At intersection

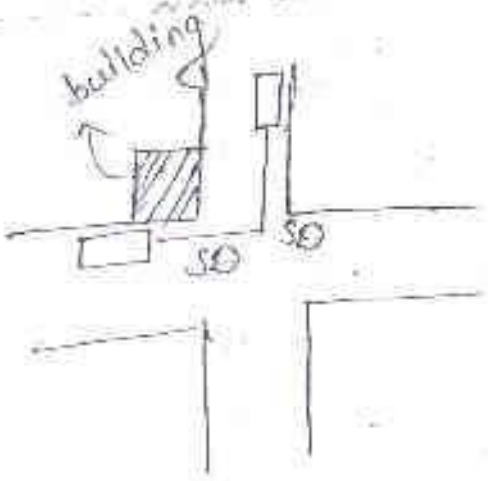
Sight distance at horizontal curve :-



Sight distance at vertical curves :-



Sight distance at intersection :-



Types of sight distance :- 15 may 2021

(i) SSD ⇒ stopping sight distance / Absolute min^m sight distance

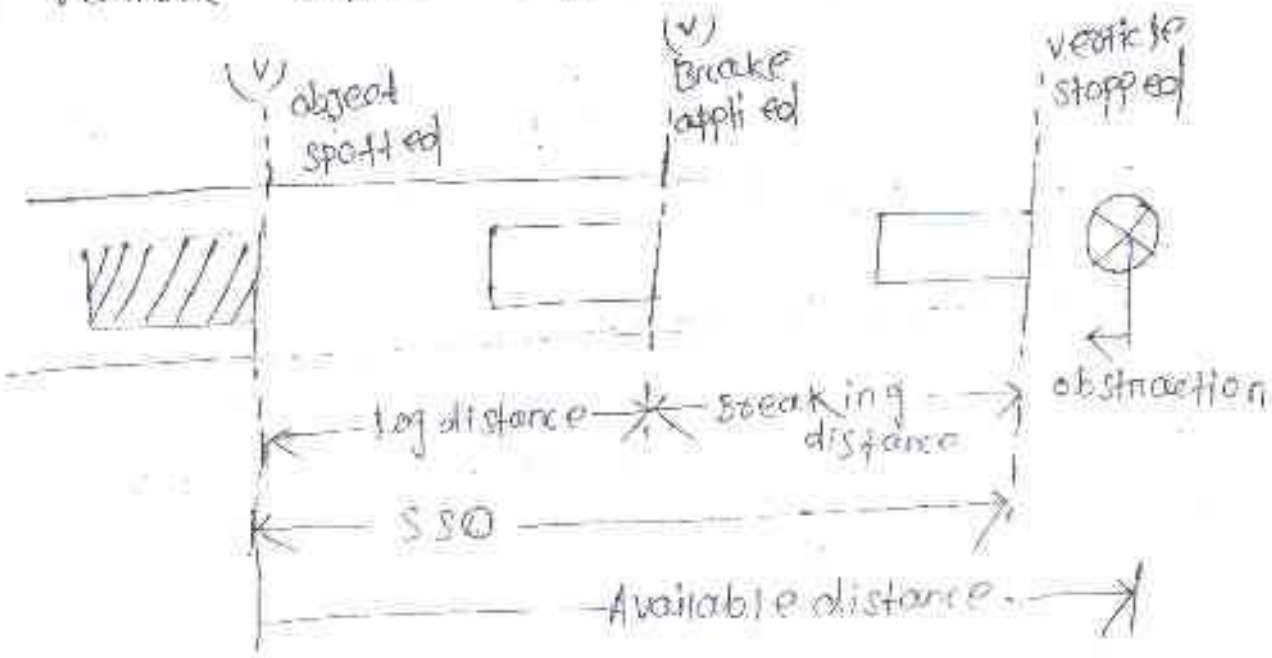
(ii) over taking sight distance / passing sight distance (OSD)

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

Apparat from these above 3 situations IRC provides more two situation.

Stoping sight distance (SSD)

It is the length of the road visible ahead to the driver from specified height above the carries way of any instant of time to safety stop the vehicle before collision.



SSD = Log distance + Breaking distance

↓ Reaction time

↓ After application of Break

SSD ≤ Available distance

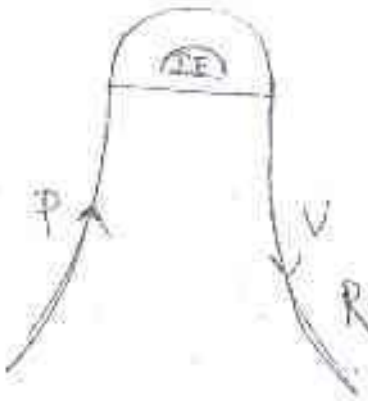
Log distance - Distance travelled in reaction time

Log distance = V · tR → sec

↓ m/sec

As per IRC : Total reaction time (t_R) = 2.5 sec

t_R consists of PIEV Theory :—



P → perception time :—

It is the time required to perceive any object.

I → Intellection time :—

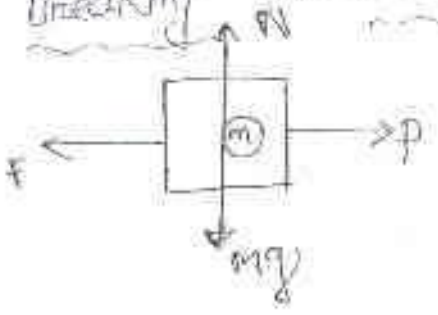
It is the time required for understanding and comparing different situation.

E → Emotion time :— It is the time last in emotional sensation like angry fear

V → volition time :— It is the time required in the application of brakes.

Total distance :- (S)

Breaking



$N = mg$ —— (1)

$P = F$

$= \mu N$

$P = \mu mg$

$F = \mu N = fN$

Loss in Kinetic energy = workdone against friction

$\Rightarrow \left(\frac{1}{2}mv^2 - 0\right) = F \cdot S$

$\Rightarrow \frac{1}{2}mv^2 = fNS$

$\Rightarrow \frac{1}{2}mv^2 = fmgS$

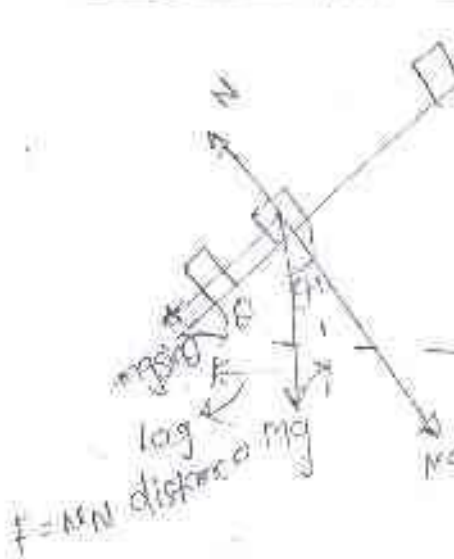
$\Rightarrow S = \frac{v^2}{2gf}$

$SSD = V + R + \frac{v^2}{2gf}$

effective

17 may 2021

Effect of gradient



Loss in K.E = workdone friction

$\Rightarrow \frac{1}{2}mv^2 = (F + mg\sin\theta)S$

$\Rightarrow \frac{1}{2}mv^2 = \left(f\,mg\cos\theta + mg\sin\theta\right)S$

$\Rightarrow \frac{v^2}{2} = g\cos\theta\left(F + \frac{g\sin\theta}{g\cos\theta}\right)$

$\Rightarrow \frac{v^2}{2} = g\cos\theta(f + \tan\theta)S$

$S = \frac{v^2}{2g\cos\theta(f + \tan\theta)}$

θ is very small

$\cos\theta = 1$

$\sin\theta = \tan\theta = \theta = \alpha$

$S = \frac{v^2}{2g(f + \alpha)}$ ——> upward gradient

$S = \frac{v^2}{2g(f - \alpha)}$ ——> Downward gradient

$$SSD = Vt_R + \frac{v^2}{2g(f \pm \alpha)b}$$

b → breaking efficiency (100% = 1)

plane terrain $\alpha = 0$, $b = 1$

$$SSD = Vt_R + \frac{v^2}{2gf}$$

SSD

(1) Two lane Two way  $SSD = SSD$

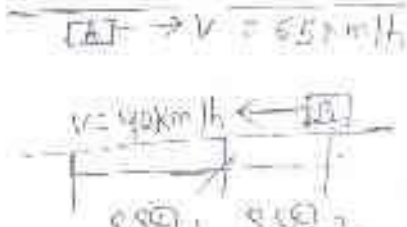
(2) Two lane one way  $SSD = SSD$

(3) one lane Two way  $SSD = SSD_1 + SSD_2$

(4) One lane one way  $SSD = SSD$

Q Two vehicles travelling in opposite direction with 65 kmph and 40 kmph. Find the min^m distance to avoid head on collision. $f = 0.35$

Soln



To avoid head on collision (same lane opposite direction)

$SSD = SSD_1 + SSD_2$

$SSD_1 = V_1 t_R + \frac{V_1^2}{2g(f \pm n)b}$

So $n = 0$, $b = 1$

$SSD_1 = V_1 t_R + \frac{V_1^2}{2gf}$

$t_R = 2.5$ sec

$V_1 = 65 \times \frac{5}{18} / 65/36$

$= 18.05$

$V_2 = 40/36$

$= 11.11$ m/sec

$V_1 = 18.05$ m/sec

$= 18.05 \times 2.5 + \frac{(18.05)^2}{2 \times 9.81 \times 0.35}$

$= 92.56$ m.

$SSD_2 = V_2 t_R + \frac{V_2^2}{2gf}$

$V_2 = 11.11$ m/sec

$SSD_2 = 11.11 \times 2.5 + \frac{(11.11)^2}{2 \times 9.81 \times 0.35}$

$= 45.75$ m.

$SSD = SSD_1 + SSD_2$

$= 92.56$ m $+ 45.75$ m.

$= 138.31$ m.

2Q Calculate the stopping distance on a high way at a descending gradient of 2% for a design speed of 80 kmph. (Assume other data as per IRC)

Soln $SSD = V t_R + \frac{V^2}{2g(f \pm n)b}$

$b = 1$ gradient = -ve

$$SSD = v t_R + \frac{v^2}{2g(f-\alpha)}$$

$V = 80$ kmph $= 80 \times \frac{5}{18}$

$= 22.22$ m/sec

$t_R = 2.5$ sec, $f = 0.35$

$\alpha = 2\% = \frac{2}{100} = \frac{1}{50} = -0.02$

$$= 22.22 \times 2.5 + \frac{(22.22)^2}{2 \times 9.81 (0.35 - 0.02)}$$

$= 131.80$ m.

18 may 2021

3.8 The design speed for a road is 65 km/h longitudinal co-efficient of friction is 0.36 and reaction time of driver is 2.5 sec calculate (i) Head light sight distance (ii) Intermediate sight distance.

HSD = SSD

Data given :-

design speed (v) $= 65$ km/h

$= \frac{65}{3.6} = 18.05$ m/s

Coefficient friction (f) $= 0.35$

Reaction time (t_R) $= 2.5$ sec

$$SSD = v t_R + \frac{v^2}{2g(f \pm \alpha)}$$

$$SSD = v_1 R + \frac{v^2}{2gf} = 18.05 \times 2.5 + \frac{(18.05)^2}{2 \times 9.81 \times 0.35}$$

$$= 92.56 \text{ m.}$$

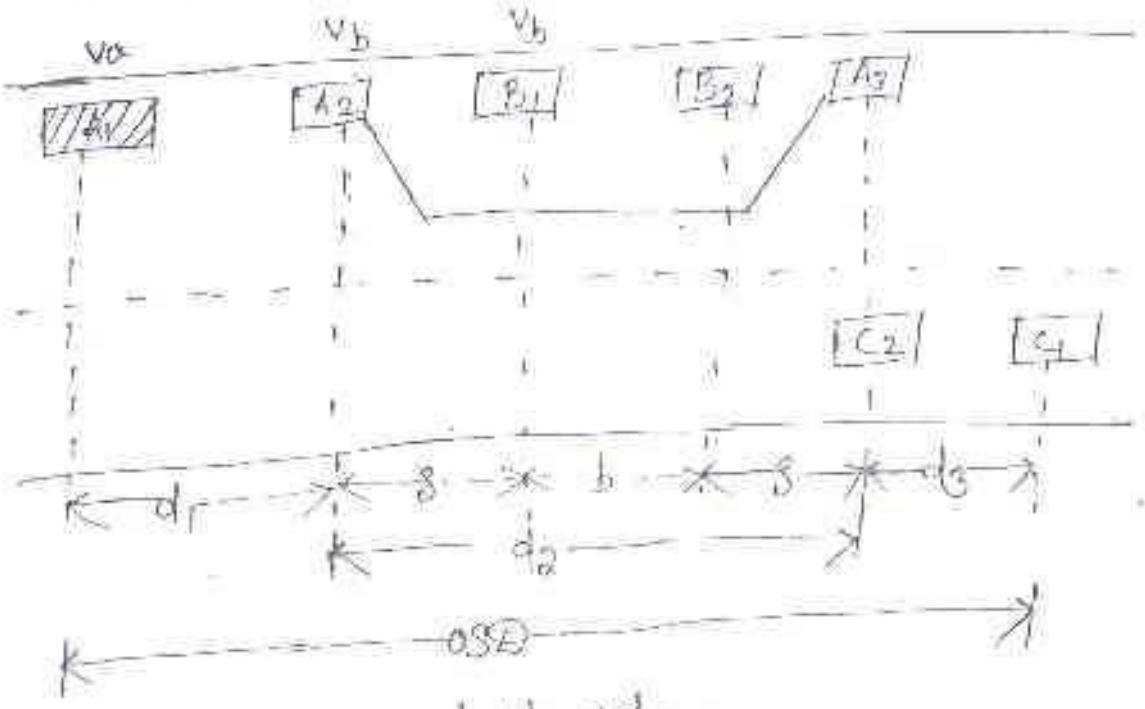
$$HSD = SSD = 92.56 \text{ m.}$$

$$ISD = 2 \times SSD$$

$$= 2 \times 92.56 = 185.12 \text{ m.}$$

OSD

> It is the min^m distance available to driver of vehicle trying to overtake slow vehicle ahead with safety against traffic direction.



$$OSD = d_1 + d_2 + d_3$$

d_1 → distance travelled by over taking vehicle in reaction time.

(In this time the vehicle 'A' is force to move with slower speed i.e V_b.

$d_1 = V_B \times t_R$ (As per IRC $t_R = 2$ sec)

d_2 → distance travelled by over taking vehicle while accelerating

$d_2 = V_b \cdot T + \frac{1}{2} a t^2$ — eq^n (1)

$d_2 = b + 2S$

b → distance travelled by overtaken vehicle.

$d_2 = V_b T + 2S$ — (ii) eq^n

Equating eq^n (i) and eq^n (ii)

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

$T = \sqrt{\frac{4S}{a}}$

S : min^m space interval beg^n two vehicles.

$$S = 0.2\ V_b(\text{km/h}) + 6$$

$$S = 0.1 V_b(\text{m/s}) + 6$$

d_3 → distance travelled by vehicle C_1 to C_2 in opposite direction.

$d_3 = V \cdot T$

keys points to remember :-

→ speed of overtaking vehicle at the time of overtaking = speed of slower vehicle.

→ If speed of slow moving vehicle is not given, take it as = speed of overtaking vehicle in km/h − 16 km/h

→ If minimum spacing is not given take it as $= 0.7\,v_b\,(m/s) + $ avg length of wheel base (6m)

$= 0.7 v_b (m/s) + 6$

$= 0.2 v_b (km/h) + 6$

→ If overtaking time is not given. Take it as $T = \sqrt{\frac{4S}{a}}$

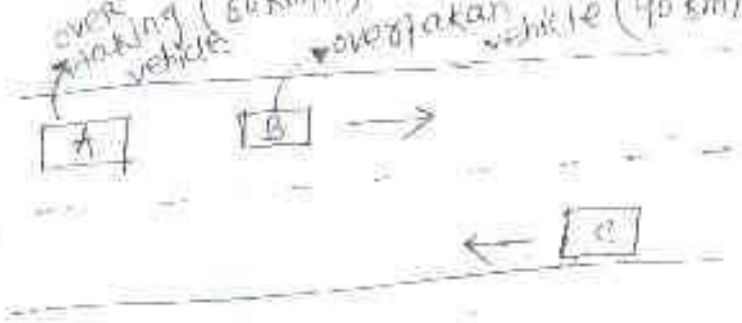
$T = \sqrt{\frac{2S_1 + S_2}{a}}$

→ If the speed of opposite moving vehicle is not given Take $V_c = V_A$

→ for one way traffic $d_3 = 0$

18. on a two way traffic road speed of overtaking and overtaken vehicle are [illegible] km/h and [illegible] km/h respectively. If avg. acceleration is [illegible] m/s². find [illegible] OSD ?

Soln



OSD $= d_1 + d_2 + d_3$

$d_1 = V_b t_R$

$= \frac{40}{3.6} \times 2 = 22.22$ m.m.

$d_2 = V_B T + 2S$

$T = \sqrt{\frac{4S}{a}}$

$S = 0.2 V_B + 6$

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

$T = \sqrt{\frac{4 \times 14}{0.92}}$

$= 7.80$ sec

$d_2 = V_B T + 2S$

$= 11.11 \times 7.80 + 2 \times 14 = 114.65$ m.

$V_A = V_C$

$d_3 = V_C T$

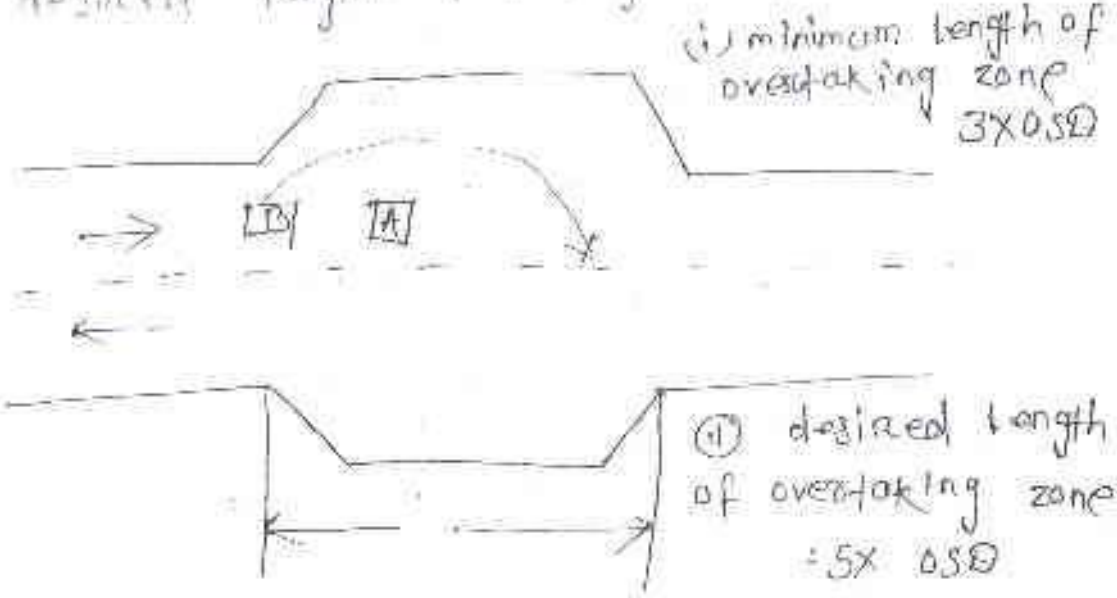
$= \frac{65}{3.6} \times 7.80$

$= 140.83$m.

OSD $= d_1 + d_2 + d_3$

$= 22.22 + 114.65 + 140.83 = 277.7$m.

Ex: On a two way traffic road speed of overtaking and overtaken vehicle are 50 kmph and 40 kmph respectively if the avg acceleration is 3 m/s² find OSD? (i) min^m length of overtaking zone & desired length of taking zone.



$OSD = d_1 + d_2 + d_3$

$d_1 = V_b t_1$

$= \left(\frac{50}{3.6}\right) \times 2$

$= 27.78$ m.

$d_2 = V_b T + 2S$

$T = \sqrt{\frac{4S}{a}}$

$S = 0.2 \times 50 + 6$

$= 16$ m.

$T = \sqrt{\frac{4 \times 16}{1}}$

$T = 8$ sec

$d_2 = \left(\frac{50}{3.6}\right) \times 8 + 2 \times 16 = 143.11$ m.

$d_3 = VT = \left(\frac{60}{3.6}\right) \times 8 = 133.33$ m.

$OSD = d_1 + d_2 + d_3$

$= 27.777 + 143.11 + 133.33$

$= 304.21$ m.

Min^m length of overtaking zone

$3 \times OSD = 3 \times 304.21$

$= 912.63$ m.

desired length of overtaking zone.

$5 \times OSD = 5 \times 304.21$

$= 1521.05$ m. Ans

20 may 2021

Q. Calculate the shortest safe overtaking sight distance for a design speed of 96 km/h. Assume all other data suitable.

Soln

$OSD = d_1 + d_2$ for one way traffic

$OSD = d_1 + d_2 + d_3$ for two way "

speed of overtaking vehicle

$V_a = 96$ km/h

speed of overtaken vehicle

$V_b = V_a - 16$ km/h

$= 96 - 16$ km/h

$= 80$ km/h

$d_1 = V_b t_R$

$= \left(\frac{80}{3.6}\right) \times 2 = 44.44\ m.$

$d_2 = V_b T + 2S$

$S = 0.2\ V_b + 6$

$= 0.2 + 80 + 6 = 22\ m.$ $\quad a = 1\ m/sec^2$

$T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 22}{1}} = 9.38\ sec$

$d_2 = V_b T + 2S = \left(\frac{80}{3.6}\right) \times 9.38 + 2 \times 22 = 252.44\ m.$

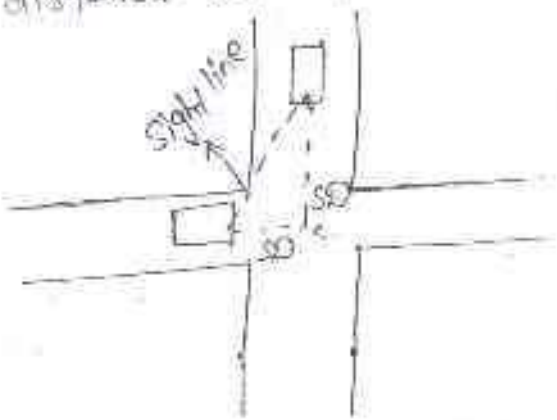
$d_3 = V_c T = \left(\frac{96}{3.6}\right) \times 9.38 = 250.13\ m.$

OSD on one way traffic road : $d_1 + d_2 = 44.44 + 252.44$
$= 296.88\ m.$

OSD on two way traffic road : $d_1 + d_2 + d_3$
$= 44.44 + 252.44 + 250.13 = 547.01\ m$

(3) safe sight distance on uncontrolled intersection :-

> The sight distance needed by the driver of a vehicle to see another vehicle approaching the intersection reacts and applying the breaks to bring his vehicle to stop at the intersection without any collision or accident is called as safe sight distance at intersection.



> The sight distance at intersection should be sufficient to satisfy the following conditions:

(i) To unable vehicle to change its speed.

(ii) To enable vehicle to stop.

(iii) To enable stopped vehicle to cross a main road.

(i) Enabling the approaching vehicle to change speed:-

> The sight distance should be sufficient to enable either one or both the approaching vehicles to change the speed to avoid collision.

> The vehicle approaching from the minor road should slow down.

> The total reaction time required for the driver to decide to change speed may be assumed as two second & atleast one more sec. will be needed for making the change in speed.

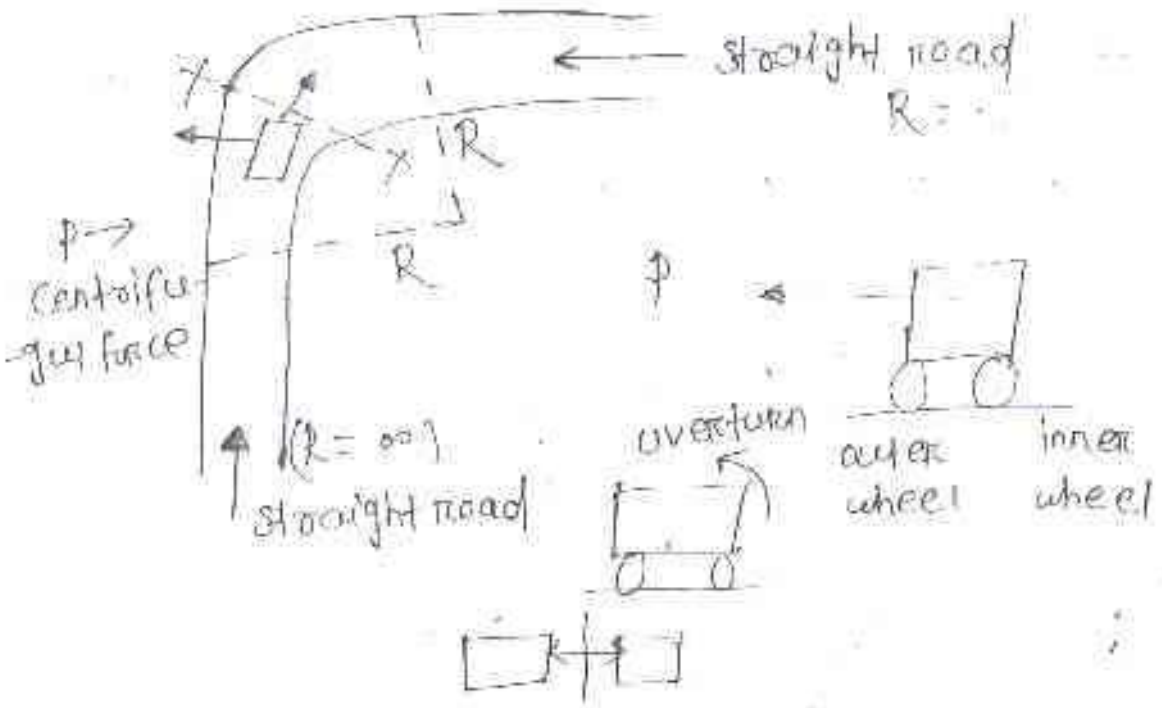
Horizontal alignment details :- 21 May 21

Horizontal curve :-

When a vehicle moves in horizontal curve. centrifugal force act horizontally outwards through C.G of the vehicle. which cause two effects.

(i) overturning the vehicle about outer wheel

(ii) Skid the vehicle laterally outward.



Centrifugal force

$$P = \frac{mv^2}{R}$$

$$\Rightarrow P = \frac{wv^2}{gR}$$

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

$w = mg$

$m = \frac{w}{g}$

$\frac{P}{W}$ → centrifugal ration / impact factor.

Road → $\frac{P}{W} = \frac{1}{4}$, Railway → $\frac{1}{8}$

$$P = \frac{mv^2}{R}$$

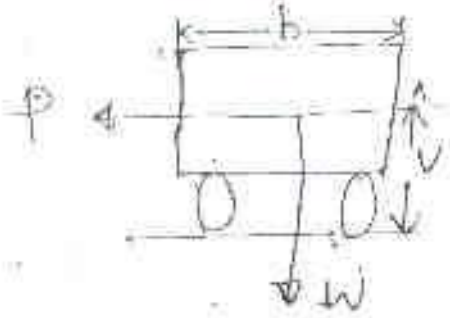
$$P \propto \frac{1}{R}$$

R → more → wild curve (P - less)

R → less → sharp curve (P - more)

Overturning effect

Taking moment of force with respect to outer wheel when vehicle is just about to overturn.



P → centrifugal action / impact factor

Road → $\frac{P}{W} = \frac{1}{4}$; Railway → $\frac{1}{8}$

$P = \frac{mv^2}{R}$

$P \propto \frac{1}{R}$

R → more →

taking moment of forces about outer wheel

$P \times h = W \times \frac{b}{2}$ → Resisting moment.

overturning moment

$\Rightarrow \frac{P}{W} = \frac{b}{2h}$

$\Rightarrow \frac{P}{W} = \frac{v^2}{gR} = \frac{b}{2h}$

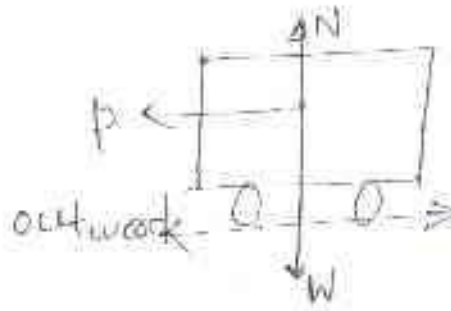
Hence for vehicle to be safe in overturning.

$\left(\frac{P}{W} = \frac{v^2}{gR}\right) \leq \frac{b}{2h}$

b → gap b/n inner and outer wheel.

h → height of c.G of the vehicle.

Lateral skidding :-



So lateral force (outward) is balanced by friction force (inward) to avoid skidding

$P = F$

$P = fW$

$\Rightarrow \frac{P}{W} = f$

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

To be safe in lateral skidding

$\left(\frac{P}{W} = \frac{v^2}{gR}\right) \leq f$ → Co-efficient of Lateral friction.

(3) To be safe in overturning and skidding both

$\left(\frac{P}{W} = \frac{v^2}{2g}\right) \leq \frac{b}{2h} \; 2f$

12 Braking distance of a vehicle is thrice when it travels down gradient on the same road as compared to up gradient find gradient (if $f = 0.4$)

$+$ → up gradient $S = \frac{v^2}{2g(f+x)}$

$-$ → down gradient $S = \frac{v^2}{2g(f-x)}$

$$\frac{3v^2}{2g(f+x)} = \frac{v^2}{2g(f-x)}$$

$$\Rightarrow \frac{3}{f+x} = \frac{1}{f-x}$$

$$\Rightarrow 3(f-x) = f+x$$

$$\Rightarrow 3f - 3x = f+x$$

$$\Rightarrow 2f = 4x$$

$$\Rightarrow 4x = 2f$$

$$\Rightarrow x = \frac{f}{2} = \frac{0.4}{2} = 0.2$$

12 May 2021

Q) The driver of a vehicle traveling at [illegible] kmph requires 9 m less on up gradient compared to down ward gradient on the same road after [illegible] the applies brakes. What is gradient if f = 0.4

+ve ⇒ up gradient $\Rightarrow \frac{v^2}{2g(f+x)}$ — breaking distance

-ve ⇒ down " $\frac{v^2}{2g(f-x)}$

Sol^n
$$\frac{v^2}{2g(f+x)} + 9 = \frac{v^2}{2g(f-x)}$$

$$\Rightarrow \frac{v^2}{2g(f+x)} - \frac{v^2}{2g(f-x)} = -9$$

$$\Rightarrow \frac{v^2}{2g}\left(\frac{1}{f+x}-\frac{1}{f-x}\right)=-9$$

$$\Rightarrow \frac{(60/36)^2}{2\times 9.81}\times\left(\frac{1}{0.4+x}-\frac{1}{0.4-x}\right)=9$$

$$\Rightarrow 14.15\left(\frac{0.4-x-(0.4+x)}{(0.4+x)(0.4-x)}\right)=-9$$

$$\Rightarrow 14.15\left(\frac{0.4-x-0.4-x}{0.4^2-x^2}\right)=-9$$

$$\Rightarrow \frac{-2x}{0.16-x^2}=\frac{-9}{14.15}=-0.63$$

$$\Rightarrow -2x=-0.63(0.16-x^2)$$

$$\Rightarrow 2x=0.63(0.16-x^2)$$

$$\Rightarrow 2x=0.10-0.16x^2$$

$$\Rightarrow +0.63x^2+2x-0.10=0$$

$$\Rightarrow 0.63(x^2+3.17x-0.15)=0$$

$$\Rightarrow x^2+3.17x-0.15=0$$

$$x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

$$x=1 \qquad b=3.17 \qquad c=-0.15$$

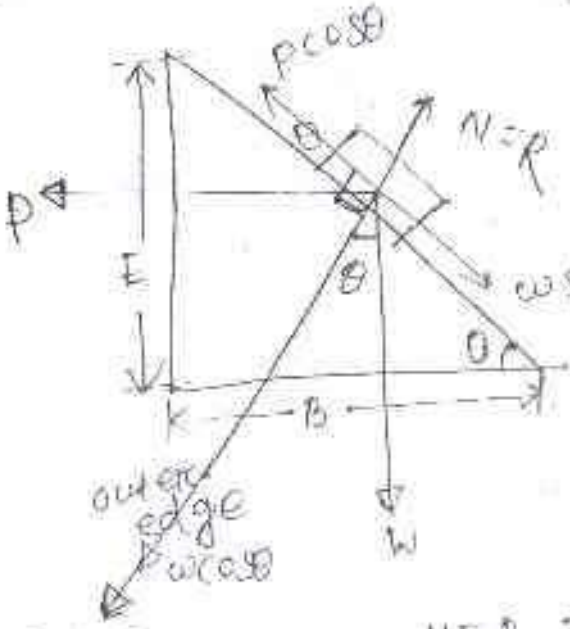
$$x_1=\frac{-3.17+\sqrt{3.17^2-4\times1\times(-0.15)}}{2\times1}$$

$$=0.04$$

gradient $=4>$

Analysis of super elevation

When a vehicle moves under a circular curve, A force is acting on the C.G of vehicle i.e centrifugal force. In order to reduce the effect of centrifugal force and to reduce the tendency of the vehicle of overturn or skid. The outer edge of the pavement is raised w.r.t inner edges through out the curve is called as supper elevation.



$N = R = w\cos\theta + p\sin\theta$

$f = \mu N$

$= \mu (w\cos\theta + p\sin\theta)$

$p\cos\theta = w\sin\theta + f$

$\Rightarrow p\cos\theta = w\sin\theta + fN$

$\Rightarrow p\cos\theta = w\sin\theta + f(w\cos\theta + p\sin\theta)$

$\Rightarrow p\cos\theta = w\sin\theta + fw\cos\theta + fp\sin\theta$

$\Rightarrow p\cos\theta - fp\sin\theta = w\sin\theta + fw\cos\theta$

$p(\cos\theta - f\sin\theta) = w(\sin\theta + f\cos\theta)$

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

$$\Rightarrow \frac{P}{W} = \frac{\sin\theta + f\cos\theta}{\cos\theta - f\sin\theta}$$

Dividing by $\cos\theta$

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

$$\Rightarrow \boxed{\frac{P}{W} = \frac{v^2}{gR} = \frac{\tan\theta + f}{1 - f\tan\theta}}$$

use when θ has some significant value.

$$\frac{v^2}{gR} = \frac{\tan\theta + f}{1 - f\tan\theta} \quad (f = 0.15)$$

when θ is very very small

$\tan\theta = \sin\theta = \cos\theta = \theta = e$

e - (super elevation)

$$\frac{v^2}{gR} = \frac{e+f}{1-fe}$$

$f = 0.15$

$e = \frac{7}{100} = 0.07$

$fe = 0.01$

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

21 may 2021

where e → super. elevation

f → co-efficient of lateral friction (0.15)

v → speed of vehicle (m/sec)

g → 9.81 m/sec²

R → Radious of curve (m)

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

where e = 0

$$f = \frac{v^2}{gR}$$

$$v = \sqrt{fgR}$$

m/sec

(kmph) $= \sqrt{f \cdot 127 R}$

Max^m and min^m superelevation:—

① plane terrain / Rolling terrain => 7%

② Hilly terrain => 10% = 0.10 = 0.07

③ Urban area / building areas = 4%

0.04

Min^m superelevation:—

e_{min} = camber

Superelevation design :—

(IRC - 38 - 1988)

In a mixed traffic flow, the different vehicle will move with different speed. providing high value of 'e' is comfortable for slower vehicle and discomfortable for faster moving vehicle. provided less value of 'e' is discomfortable

Design procedure of superelevation as IRC

Step 1

e is calculated on 75% of design speed.

$$e_{design} = \frac{0.75V^2}{gR} = \frac{V^2}{225R}$$

$e_{design} \leq e_{max}$ → 0.07 ≥ 7%.

If design 'e' is less than max^m 'e' (7%) then stop calculation e_{design} be the superelevation

If e design value is greater than e_{max} (7%) then provide $e = e_{max}$ and go to 2nd step.

Step-2 check for friction.

use $e = e_{max}$ and calculate f

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

If $f \leq 0.15$: safe and stop design procedure

If $f > 0.15$, no of safe and go to step-3

step-3 Restrict the speed (by putting $= 7\%$ & $f = 0.15$)

$$e_{max\ tf} = \frac{v^2}{gR} = \frac{v^2}{127R}$$

'v' is calculated

note:- based on this calculated speed we calculate super elevation 'e' from the eqn $e_{design} = \frac{v^2}{225R}$

16. The radius of a horizontal circular curve is 100m. the design speed is 50 km/h and design co-efficient of lateral friction > 0.15

(a) Calculate the super elevation if full lateral friction is assumed to develop.

(b) calculate the co-efficient of friction needed if no super elevation is provided.

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

$\Rightarrow e + 0.15 = \frac{50^2}{127R}$

$\Rightarrow e = \frac{50^2}{127 \times 100} - 0.15 = 0.0516$

$= \frac{1}{21.73}$

$= 1 \text{ in } 21.73$

when $e = a$

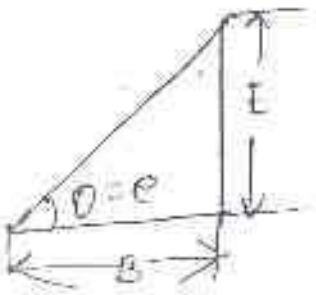
$$e + f = \frac{v^2}{127R} \Rightarrow f = \frac{v^2}{127R}$$

1 June 2021

Q6 A two lane road with design speed 80 km/h has $R = 480$ m. Design 'e' for mixed traffic if width of the pavement at horizontal curve in 7.5m. How much should be the outer edge of pavement raised

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

$$E = e \times B$$



Sol

$$e_{design} = \frac{v^2}{225R}$$

$$= \frac{80^2}{225 \times 480}$$

$$= 0.05$$

$e_{max} = 7\% = 0.07$

$e_{design} < e_{max}$

$(0.05) \quad (0.07)$

$e_{design} = 0.05$

$$E = e \times B$$
$$= 0.05 \times 7.5$$
$$= 0.375\ m.$$

2) Design the rate of superelevation for a horizontal highway curve $R = 500\ m$. and speed $= 100\ km/h$.

Soln Step-1

$$e\ design = \frac{v^2}{225R} = \frac{100^2}{225 \times 500} = 0.08$$

$$e\ max = 7\% = 0.07$$

$$e\ design > e\ max$$

Step-2

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

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

$e \Rightarrow e\ max$

$$f = \frac{100^2}{127 \times 500} - 0.07 \qquad [\because f = 0.15]$$

$$f = 0.08$$

$$f = 0.08 < f = 0.15$$

$e = e\ max \quad f = 0.08$ Ans

36 Design speed (V) = 80 kmlh

Radious (R) = 200m (certain locality)

f = 0.15

(a) Calculate 'e' to mantain the speed.

(b) If e ≠ 0.07 calculate 'v' as it is not possible to increase the radious.

Step 1

$e_{design} = \frac{v^2}{225R}$

$= \frac{80^2}{225 \times 200} = 0.14$

$e_{max} = 0.07$

$e_{design} > e_{max}$

Step 2

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

$\Rightarrow f = \frac{v^2}{127R} - e$

$\Rightarrow f = \frac{80^2}{127 \times 200} - 0.07$

$\Rightarrow 0.18$

$f_{max} = 0.15$

$f_{design} > f_{max}$

Step-3

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

$$\Rightarrow 0.07 + 0.15 = \frac{Va^2}{127R}$$

$$\Rightarrow 0.22 \times 127R = Va^2 \Rightarrow 27.94R = Va^2$$

$$\Rightarrow Va = \sqrt{27.94R}$$

$$\Rightarrow Va = \sqrt{27.94 \times 200}$$

$$= 74.75 \text{ km/h}$$

$$\boxed{Va = 74.75}$$

2 June 2021

extra - widening :-

The object of providing extra widening of pavements on horizontal curves are due to the following two sources :—

(i) To avid off tracking due to rigidity of wheel base.

(ii) At speed higher than design speed to encounter transverse skidding.

(iii) To increase the vibility of curve.

⇒ To encounter the psychological in overtaking.

Analysis of extra widening on curve:-

The extra widening of pavement on horizontal curves is divided into two parts.

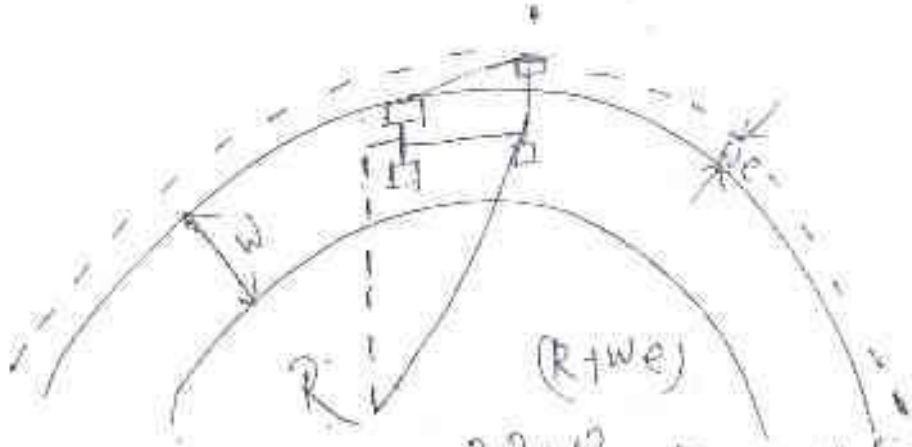
(i) Mechanical widening (Wm)

(ii) Psycological widening (WPS)

$$We = Wm + WPS$$

Mechanical widening (Wm) :-

The widening required to account for the offtracking due to the rigidity of wheel base is called as mechanical widening (Wm).



$$l^2 = 2RWe$$

$$We = \frac{l^2}{2R}$$

↓ offtracking

$$We = \frac{n l^2}{2R}$$

$$R^2 + l^2 = (R+We)^2$$

$$\Rightarrow R^2 + l^2 = R^2 + We^2 + 2R \times We$$

We → is very small.

We² → is very small

n = no of between lanes

l = length of axle of the vehicle (6m)

R = Radius of curve

w_m = mechanical widening.

Psychological widening :-

$$w_{ps} = \frac{V}{9.5\sqrt{R}}$$

$V \rightarrow$ speed in kmlh

$R \rightarrow$ Radius in mt

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

NOTE :-

(i) If only mechanical widening is given asking total extra widening.

Equate $\frac{l^2}{2R}$ = mechanical widening

R : Calculate

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

(ii) Generally provide $\left(\frac{w_e}{2}\right)$ to both side equally $50m \leq R \leq 300m$

(iii) If $R \geq 50m$ (sharp bend) total extra widening is only on inner side.

(iv) If $R > 300m \rightarrow$ Then extra widening may be avoided.

⑥ on a single lane road only mechanical extra widening is provided.

10 Calculate the extra widening required for a pavement of within '7m' on horizontal curve of radious 250m. if the longest wheel base of vehicle expected on the road is 7.0m design speed is 70 km/h Compare the value obtained with IRC recommendation.

Sol Extenal widening required

$$We = Wm - TWPS$$

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

n = 2 (two lanes for pavement width 7.0m)

R = 250

V = 70 km/h

L = 7.0m.

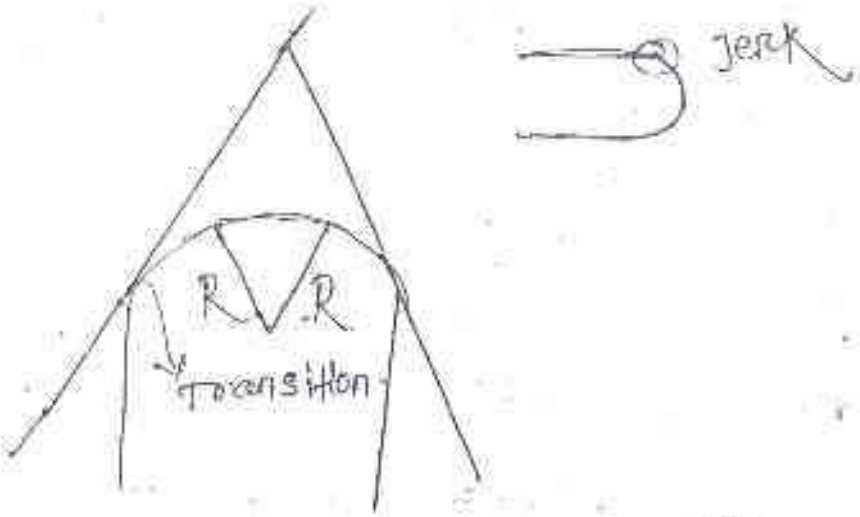
$$We = \frac{nl^2}{2R} + \frac{V}{9.5R} = \frac{2\times7^2}{2\times250} + \frac{70}{9.5\times250}$$

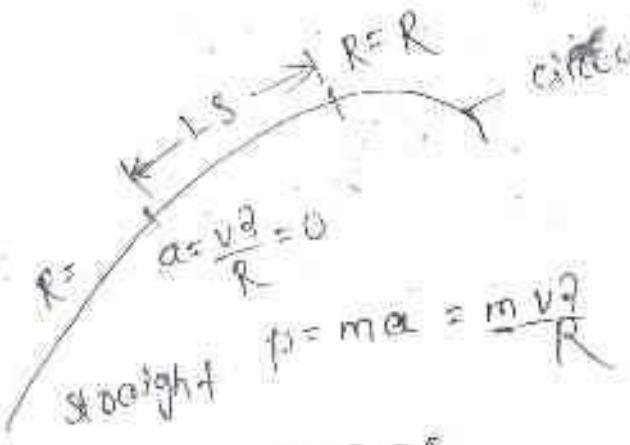
IRC We = 0.6

= 0.66 m.

Radious of curve	up to 200	201 to 400m	401 to 600m	601 to 1000m	1001 to 3000m	above 3000m
extra width in m.						
Two lane	1.5	1.5	1.2	0.9	0.6	NIL
Single lane	0.9	0.6	0.6	NIL	NIL	NIL

Transition curve diagram





$p = ma = \frac{mv^2}{R}$

$R \to \infty \to a = 0$

$R \to R \to a = \frac{v^2}{R}$

Rate of change of radial acceleration :-

$C = \frac{d\vec{a}}{dt} = \frac{d}{dt}\left(\frac{v^2}{R} - 0\right)$

Jerk.

$J = \frac{\left(\frac{v^2}{R} - 0\right)}{LS/v}$

$C = \frac{v^3}{LSR} \Rightarrow LS = \frac{v^3}{CR} \cdot \frac{m/sec}{m}$

$0.5 \leq C \leq 0.8$

$C = \frac{80}{75 + V_{Kmph}}$ m/sec^3

Transition curve :-

> A curve having varing radious is known as transition curve.
> It is curve of radious of changes gradually from ∞ to R.
-> It is provided between straight and circular curve. for the following objects :-

(i) To gradually introduce centrifugal force to avoid jerk.
(ii) Comfort and security of driver.
(iii) For gradual introduction of super elevation and extra - widening.
(iv) To improve asthetic appearance

Calculation of Length of transition curve :-

(i) Based on the change of radial acceleration.

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(ii) As per rate of change of superelevation
Length of transition curve.
(a) $L_S = 150\ x$ → plain / Rolling terrain.
(b) $L_S = 100\ x$ → Building area.
(c) $L_S = 60\ x$ → Hilly Area.

x → rate of outer edge.

Case - I

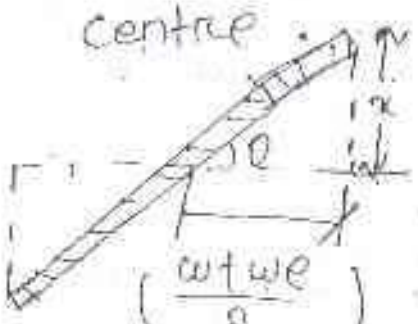
When pavement is rotated about edge.

Inner edge (w + we) Outer edge

$$e = \tan\theta = \frac{x}{(w + we)}$$

$$\Rightarrow x = e\,(w + we)$$

Case - II When pavement rotated about centre



$$e = \tan\theta = \frac{x}{\left(\frac{w + we}{2}\right)} \Rightarrow x = e\left(\frac{w + we}{2}\right)$$

As per empirical formula :—

$$L_s\ (m) = 2.7\,\frac{v^2}{R}$$ (Plain / Rolling terrain)

$$L_s\ (m) = \frac{v^2}{R}$$ (Hilly terrain)

{ v → kmph, R → m }

NOTE Max^m of above three criteria should be at least provided as a length of transition curve.

Ideal form of transition curve – spiral

Q1 Find the length of transition curve and extra widening required on a horizontal curve of radious 300m of two lane High way passing through rolling terrain for design speed of 80 km/h. (Assume pavement is rotated about inner edge)

Soln Data given:-

Design speed (V) = 80 km/h

Radious of curve (R) = 300m

two lane highway (n) = 2

length of area of the vehicle (l) = 6m.

width of road = 7m.

Rolling terrain e = 7% = 0.07

$We = Wmt - Wps$

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

$We = \frac{2 \times 6^2}{2 \times 300} + \frac{80}{9.5\sqrt{300}}$

$= 0.6m$

Length of transition curve :-

(i) Based on rate of change radial acceleration.

$C = \frac{80}{75+V} - \frac{80}{75+80} = 0.516 \text{ m/sec}^3$

$0.5 \leq C \leq 0.8$

$$L_S = \frac{V^3}{CR} \rightarrow m/sec$$

$$= \frac{\left(\frac{80}{3.6}\right)^3}{0.916 \times 300} = 70.8\,m.$$

(ii) Based on superelevation :-

Length of transition curve

$$L_S = 156\,x$$

pavement rotated about inner edge

$$x = e(W + We) = 0.07(7 + 0.6)$$

$$= 0.532\,m.$$

put the value of 'x' in the equation

$$L_S = 150 \times x$$

$$= 150 \times 0.532$$

$$= 79.8\,m.$$

(iii) Based on empirical formula

$$L_S = 2.7\,\frac{V^2}{R}$$

$$= 2.7 \times \frac{80^2}{300} = 57.6\,m.$$

$$L_S = \begin{cases} 70.89\,m. \\ 79.80\,m. \\ 57.60\,m. \end{cases}$$

So the length of transition curve

$$= 79.80\,m.$$

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Shift of Curve :-

When there is no transition curve in b/w straight and circular portion. Then circular curve has to be shift below to introduce transition in between circular curve and straight path.

⇒ shift is denoted by S

$$S = \frac{L_s^2}{24R}$$

where L_s ⇒ length of transition curve in mt.

R ⇒ Radius of curve in mt.

Q $$S = \frac{L_s^2}{24R} = \frac{79.80^2}{24 \times 300} = 0.88 \text{ m}.$$

10 calculate the length of transition curve and shift using the following data.

Design speed : 65 Km/h

Radius of curve : 220m.

pavement rotated about centre line : 1 in 150

pavement including extra widening : 7.5m.

Sol'n Step-1

$$C = \frac{80}{75+V} = \frac{80}{75+65} = 0.57 \text{ m/sec}^3$$

The value of 'c' lies between 0.5 to 0.8 so it is accepted.

$$L_S = \frac{V^3}{CR} = \frac{\left(\frac{65}{3.6}\right)^3}{0.57 \times 220} = 46.93 \text{ m}.$$

Step 2

Super elevation rate

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

$$= \frac{65^2}{225 \times 220} = 0.085$$

$e_{cal} > e_{allowable}$, So $e = 0.07$.

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

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

$$\Rightarrow f = \frac{65^2}{127 \times 220} - 0.07 = 0.08 < 0.15$$

$f = 0.08$, $e = 0.07$, $V = 65$ km/h

$B = 7.5$ m (wt.we)

$$x = \left(\frac{wt + we}{2}\right)e = \frac{7.5}{2} \times 0.07$$

$$= 0.26$$

Rate of introduction of superelevation

1 in 150 $= 150 \times x$

$L_S = 150 \times 0.26 = 39$ m.

Step-3

$$L_s = 2.7\frac{v^2}{R}$$

$$= 2.7 \times \frac{65^2}{226} = 51.85\,m.$$

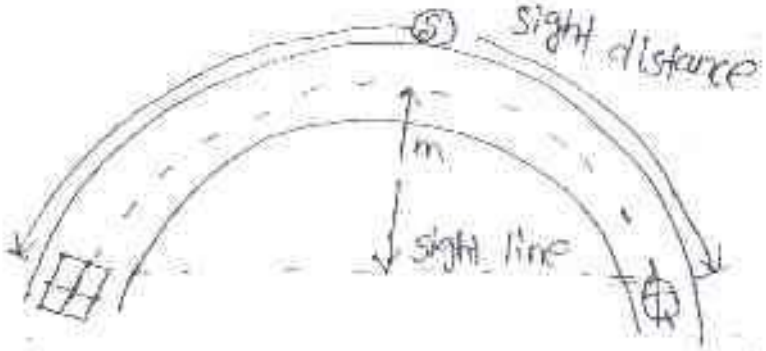
So Length of transition curve

$$\therefore L_s = 51.85\,m.$$

Step-4

$$\text{Shift } (s) = \frac{L_s^2}{24R} = \frac{51.85^2}{24 \times 220} = 0.50\,m.$$

Set back distance on horizontal curve etc.
(clearance)



> Maximum distance to be maintained from centre of the road to any obstruction on inner side. So that visible distance should not be less than sight distance for which set back is to be designed.

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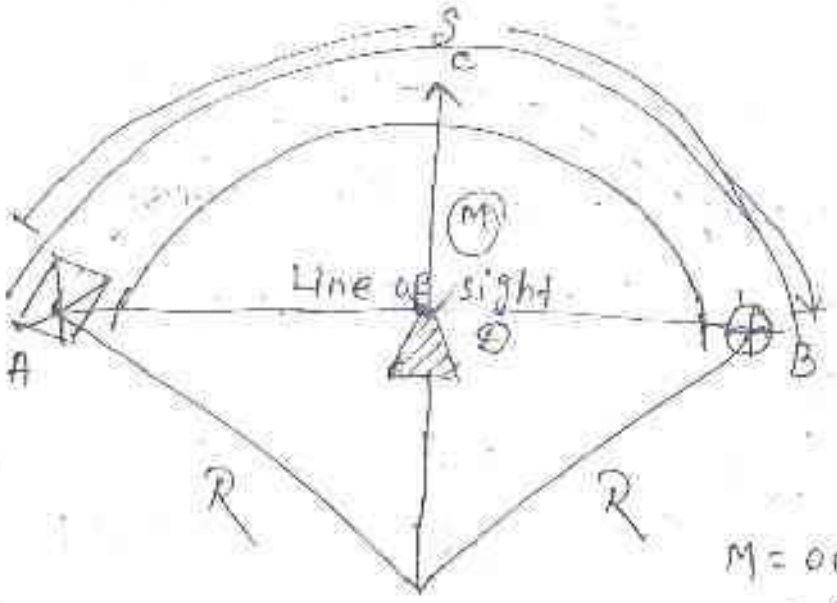
> set back is always required from centre of the road.

Case-1 (single lane road $L_c > S$)



$M = OC - OD$

$= R - R\cos\frac{\alpha}{2}$

$= R\left(1 - \cos\frac{\alpha}{2}\right)$

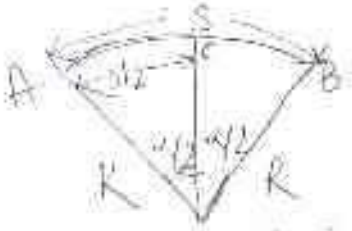
Setback eq^n(M) =

Formula

Single lane $L_c > S$

Setback(M) $= R\left(1 - \cos\frac{\alpha}{2}\right)$

$\frac{\alpha}{2} = \frac{S}{2R} \times \frac{180}{\pi}$

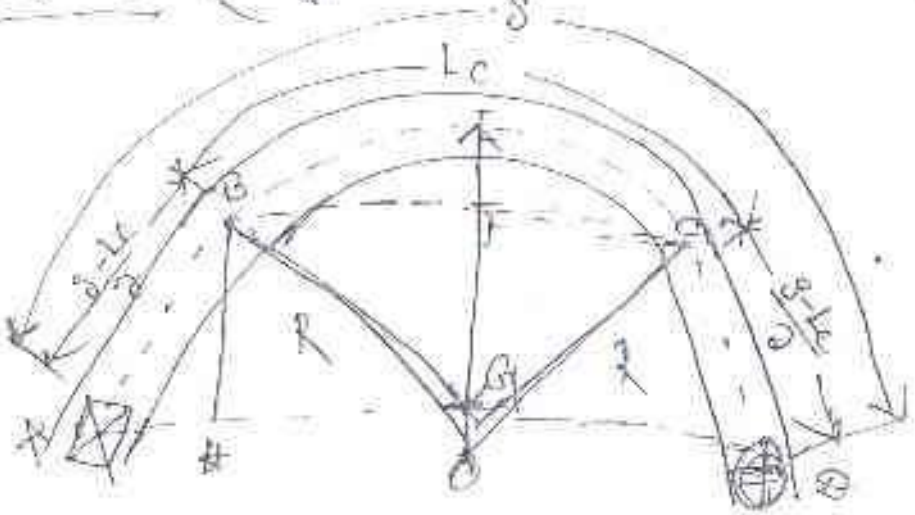


$R\frac{\alpha}{2} = \frac{S}{2}$

$\Rightarrow \frac{\alpha}{2} = \frac{S}{2R}$ radian

$\Rightarrow \frac{\alpha}{2} = \frac{S}{2R} \times \frac{180^\circ}{\pi}$

Case-2 (single lane road $L_c < S$)



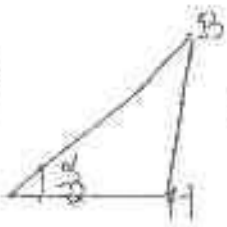
$EG = EF + FG$

$= (OE - OF) + FG$

$= (OE - OF) + BH$

$= R - R\cos\frac{\alpha}{2} + \left(\frac{S-Lc}{2}\right)\sin\frac{\alpha}{2}$

$FG = BH$



$BH = \left(\frac{S-Lc}{2}\right) \times \sin\frac{\alpha}{2}$

$M = R\left(1 - \cos\frac{\alpha}{2}\right) + \left(\frac{S-Lc}{2}\right)\sin\frac{\alpha}{2}$

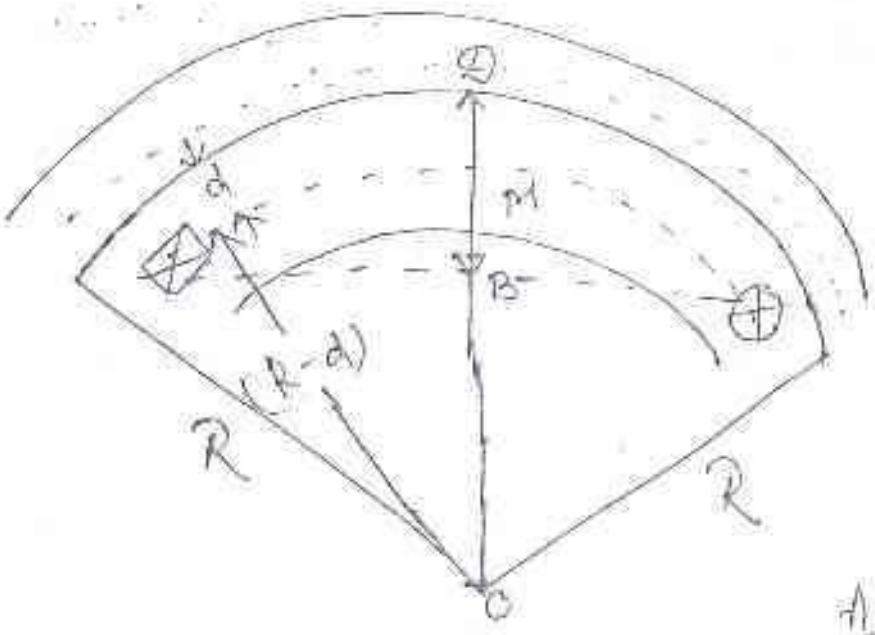
To calculate 'α'

$R \cdot \frac{\alpha}{2} = \frac{Lc}{2}$

$\frac{\alpha}{2} = \frac{Lc}{2R}$ radian

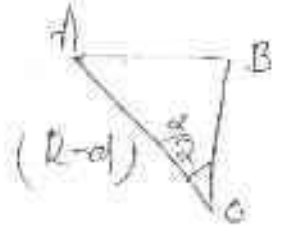
$\Rightarrow \frac{\alpha}{2} = \frac{Lc}{2R} \times \frac{180^0}{\pi}$

Case-3 (Double Lane road $Lc > S$)



$BD = OD - OB$

$= R(R-d)\cos\frac{\alpha}{2}$



To find set back

Set back from centre inner lane

$EB = BD - ED$

$= (R-d) - (R-d)\cos\frac{\alpha}{2}$

Set back $BD = OD - OB$

$= R - (R-d)\cos\frac{\alpha}{2}$

from centre of road.

$\Rightarrow EB = BD - ED$

Case - iv

Double Lane road ($L_c < S$)

$m = R - (R-d)\cos\frac{\alpha}{2} + \left(\frac{S-L_c}{2}\right)\sin\frac{\alpha}{2}$

$\frac{\alpha}{2} = \frac{L_c}{2(R-d)} \times \frac{180^\circ}{\pi}$

Q If a vehicle is running on a 2 lane highway of 7.5m on a 300m curve, if SSD is 80m and length of curve is 200m. Find set back distance.

Sol^n Given data:-

Length of curve (L_c) = 200m.

SSD = 80m.

width of the road = 7.5m

Radius of curve (R) = 300m.

$L_c > S$

$m = R - (R-d)\cos\frac{\alpha}{2}$

$\frac{\alpha}{2} = \frac{S}{2(R-d)} \times \frac{180^\circ}{\pi}$

$= 1.68^0$

width of the road is given $d = \frac{w}{4} = \frac{7.5}{4} = 1.875$

width of the road is not given

$d = \left(\frac{\text{cot}\,\theta}{4}\right)$

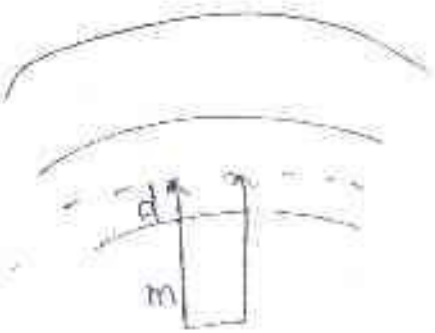
$M = 300 - (300 + 1875)\cos 1.68^0$

$= 4.95m$.

Q2 There is a horizontal highway curve of radious 400m. and length 800m. on this highway. Compute the set back distance required from the centre line on the inner side of the curve so as to provide fore safe overtaking sight distance of 300m.

The distance betn the centre line of the road and the inner lane = 1.9m.

Soln



Given data:-

OSD = 300m

$d = 1.9m$

$L_c = 200m$

$S = 300$ (transition curve OSD)

$L_c > S$

$\Rightarrow p - (R - 1)$

$L_c < S$

$$m = R - (R-d)\cos\frac{\alpha}{2} + S - \frac{Lc}{2}\sin\frac{\alpha}{2}$$

$$\frac{\alpha}{2} = \frac{Lc}{2(R-d)} \times \frac{180}{\pi}$$

$$\frac{\alpha}{2} = \frac{200}{2(400-1.9)} \times \frac{180}{\pi}$$

$$\Rightarrow 14.39^\circ \simeq 14.4^\circ$$

$$m = 400 - (400-1.9)\cos(14.4^\circ) + \frac{(300-200)}{\sin(14.4^\circ)}$$

$$= 26.84\ m.$$

O.S.M

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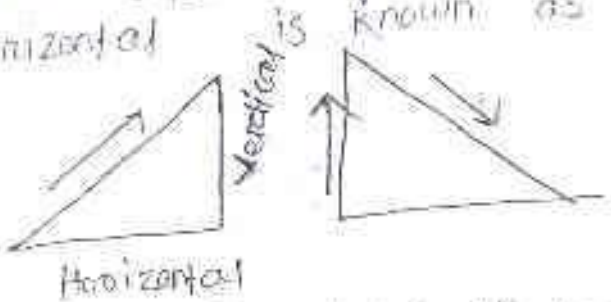
Vertical curve :-

As we know that the nature of the ground may not be uniform and may consist of different gradient (for instance the rising gradient may be followed by falling gradient and vice-versa). In such cases a parabolic path is provided in vertical plain in order to connect the gradient for easy movement of vehicle.

-> It should be safe and comfortable in operation, pleasing in appearance and adequate in drainage.

Gradient :- The rise or fall along the length of road with respect to horizontal is known as gradient.



There are four type of gradient.

① Ruling gradient :- It is the maximum gradient with which designer attempt to design the vertical profile of the road.

Ruling gradient

(ii) Limiting gradient :-

→ It is used when ruling gradient results in increase in cost of construction

→ It is steeper than ruling gradient.

(iii) Exceptional gradient

→ It is steeper than above two

→ It is provided when situation is unavoidable

→ It will not be provided more than 100m.

(iv) Minimum gradient :- It is provided from point of view of drainage system.

Concrete surface → $\frac{1}{500}$

Earthen surface → $\frac{1}{200}$

	Ruling gradient	Limiting gradient	Exceptional gradient
① Plain or rolling terrain	3.3%	5%	6.7%
② Hilly terrain elevation more than 3m above MSL	5%	6%	7%
③ Hilly terrain elevation not more than 3m below above MSL	6%	7%	8%

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Grade Compensation:—

o o o

10 When sharp horizontal curve is introduced on the road which has already permissible gradient. Then gradient should be decreased for the loss of tractive force due to curve.

→ Grade compensation is required for grade flatter than 4%

→ Grade compensation = $\frac{30 + R}{R}$ %

→ Maximum compensation allowed = $\frac{75}{R}$ %

where R → Radious of curve in m.

⇒ Compensated grade = Grade - Grade compensation

⇒ If compensated grade is less than 4%. take 4% as compensated grade.

10 If ruling gradient is $\frac{1}{20}$, what will be the grade compensation and compensated grade for a curve of radious 120m.

Sol Given:-

Radious of curve R = 120m.

Grade $\frac{1}{20} = \frac{1}{20} \times 100 = 5\%$

Grade Compensation $= \frac{30+R}{R}$

$= \frac{30+120}{120}$

$= 1.25\%$

Max^m Compensation allowed $= \frac{75}{R} = \frac{75}{120} = 0.625\%$.

Compensated grade = Grade - Max^m Compensation

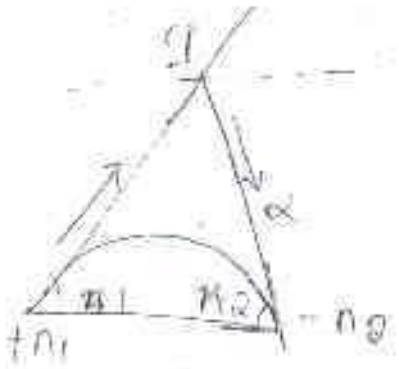
$5\% - 0.625\% = 4.375\% > 4\%$

Type of vertical curve (i) Summit curve (ii) valley curve

Summit curve

(i) Summit curve with convexity upward (^) may be formed by when intersection lies above the curve

(iii)



Deviation angle(N)

$|n_1 - n_2|$

$= |n_1 - (-n_2)|$

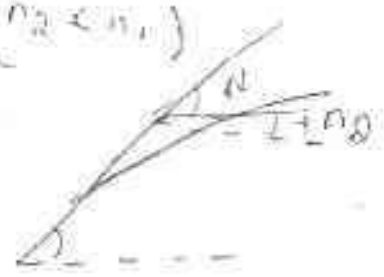
$= |n_1 + n_2|$

(iii)

$N = |n_1 - 0|$

$= n_1$

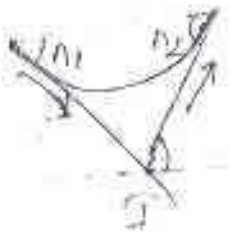
(iv) $(n_2 < n_1)$



valley curve

(i) valley curve with concavity upward (U) may be formed when intersection lies below the curve.

(ii)



Deviation angle(N)

$|-n_1 - n_2|$

$= |-n_1 - n_2|$

$= |-(n_1 + n_2)|$

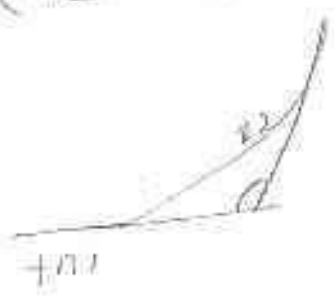
$= n_1 + n_2$

(iii)

$N = |-n_1 - 0|$

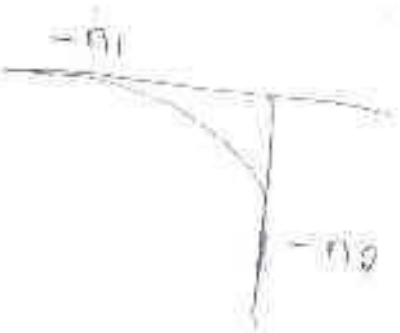
$= |-n_1| = n_1$

(iv) $(n_2 > n_1)$



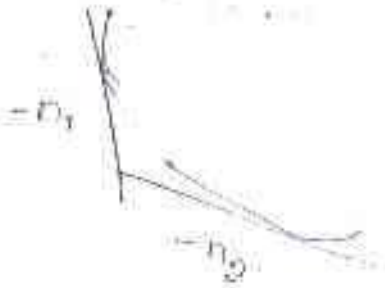
steep of gradient decreases.

(v)



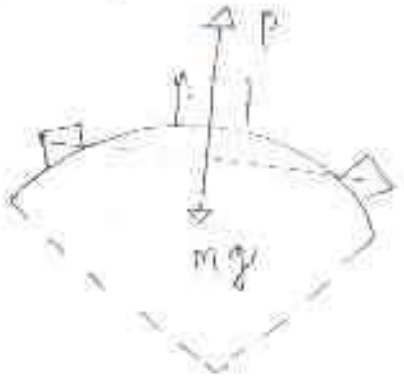
steepness of downward gradient increases.

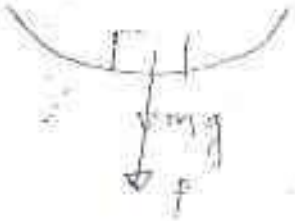
steeper in gradient



steepness of downward gradient, decreases.

(vi)





> problem of discomfort

(vii) > no problem of discomfort as weight of vehicle is balance by centrifugal force.

> drainage problem.

(viii) > no drainage problem

> no problem of sight distance (only driving night time problem)

(ix) > problem of sight distance

> transition curve is provided (cubic parabola)

(x) > parabolic curve is provided (square parabola)

~~> weight of valley curve :-~~

> $y = bx^3$

$b = \frac{2}{3}$ of $\frac{N}{L^2}$

(xi) > Length of summit curve :-

$$L = \frac{NS^2}{(\sqrt{2h_1} + \sqrt{2h_2})^2}$$

(xi) $y = ax^2$

$a = \frac{N}{2L}$

$N = |n_2 - n_1|$

L = Length of curve.

Length of Summit Curve

Case - I (L > S) (Length of curve is greater than sight distance)

$$L = \frac{NS^2}{(\sqrt{2H} + \sqrt{2h})^2}$$

N → deviation angle

S → sight distance (SSD / OSD / ISD)

H → Height of the drivers eye.

h → Height of the objects obstruction.

(a) SSD = S → H = 1.2 m h = 0.15 m.

$$L = \frac{NS^2}{4.4}$$

(b) ISD / OSD = S → H = 1.2 m h = 1.2 m.

$$L = \frac{NS^2}{9.6}$$

Case - II Length of curve < sight distance (L < S)

$$L = 2S - \left(\frac{\sqrt{2H} + \sqrt{2h}}{N}\right)^2$$

(a) SSD = S → H = 1.2m. h = 0.15m.

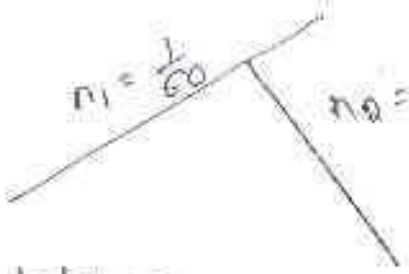
$$L = 2S - \frac{4.4}{N}$$

(b) OSD / ISD = S → H = 1.2m. h = 1.2m.

$$L = 2S - \frac{9.6}{N}$$

22 Jun 2021

Q1 An ascending gradient of $\frac{1}{60}$ meets with descending gradient of $\frac{1}{50}$. Find the length of summit curve for SSD of 180 m.



Soln

Given data :-

Ascending gradient $(+n_1) = \frac{1}{60}$

Descending gradient $(-n_2) = \frac{1}{50}$

Stoping sight distance (S) = 180 m.

Deviation angle $(N) = \left| \frac{1}{60} - \left(-\frac{1}{50}\right) \right|$

$$= \frac{11}{300}$$

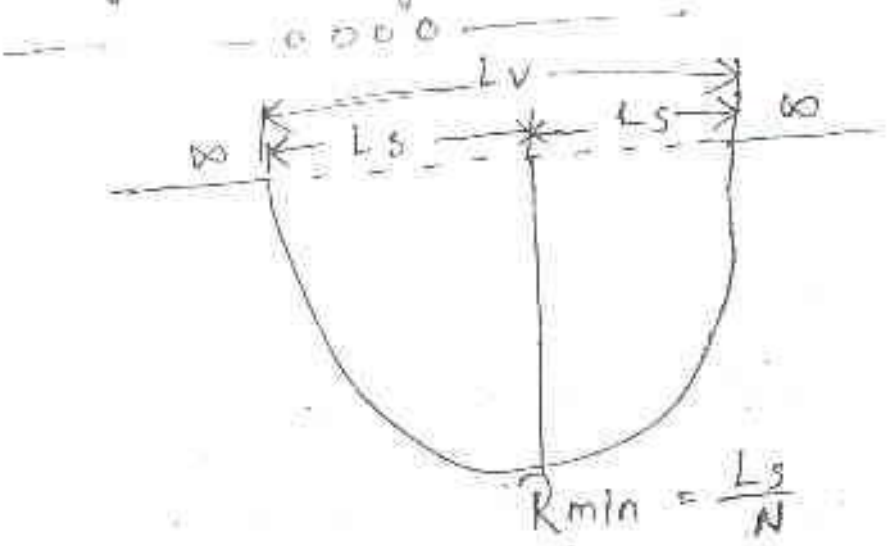
Assume the length of curve is greater than sight distance ($L > S$)

$$L = \frac{NS^2}{4.4} = \frac{\frac{11}{300} \times 180^2}{4.4} = 270 \text{ m.}$$

270 m > 180 m.

Assumption is correct. Length of summit curve 270 m.

Length of valley curve :-



Comfort condition :- Two transition curve is joined back to back to form a valley.

$$Ls = \frac{V^3}{CR} = \frac{V^3}{C\left(\frac{Ls}{N}\right)}$$

$$\Rightarrow C\left(\frac{Ls}{N}\right) Ls = V^3$$

$$\Rightarrow \frac{CLs^2}{N} = V^3$$

$$\Rightarrow Ls^2 = \frac{NV^3}{C}$$

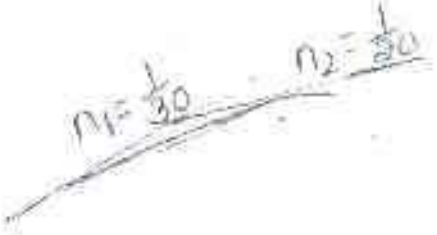
$$\Rightarrow Ls = \sqrt{\frac{NV^3}{C}}$$

$$Lv = 2Ls = 2\sqrt{\frac{NV^3}{C}} \text{ m/sec}$$

N → deviation angle
V → speed of the vehicle in m/sec

c → Rate of change of acceleration (0.6)

Q An ascending gradient of $\frac{1}{30}$ meets with ascending gradient of $\frac{1}{20}$. Find the length of summit curve for OSD of 90m.



Sol^n Data given :—

Ascending gradient ($+n_1$) = $\frac{1}{30}$

Ascending gradient ($+n_2$) = $\frac{1}{20}$

Deviation angle (N)

$= |+n_1 - (+n_2)| = \left| \frac{1}{30} - \frac{1}{20} \right|$

$= 0.16$

Length of curve is greater than sight distance condition :- OSD = S = 90m.

$L = \frac{NS^2}{9.6} = \frac{0.16(90)^2}{9.6} = 135 \text{ m} > 90 \text{ m}$

Assumption is correct. length of Summit curve = 135 m. Ans

23 Jun 2021 — DINNU SAI RAM

UNIT - 3 Highway materials

Sub-grade (soil as subgrade)

(i) Subgrade is the layer of pavement whose main fuction is to support the upper layers of the pavement. and to provide good drainage facility to the infiltrating the rain water.

(ii) It has to act as a single structure along with other layers of the pavement.

(iii) Soil is compacted to its max dry density which can be achieved by using the optimum moisture content and the methods of compactions control strength has to be ensured which is required for the given design thickness of the pavement.

(iv) Strength analysis and the thickness of the pavement are inter-linked because more thickness of the pavement is needed if the soil is weak. but if soil process good strength, then less thickness is needed.

(v) This is ensured by using the CBR test. which is produced by the california state highway department.

(3) C·B·R value(%) = Load required for soil sample / standard load value for standard aggregate.

C·B·R value at 2.5mm = Load req^d for 2.5mm penetrated x100 / 1350 kg

C·B·R value at 5mm = Load required for 5mm penetration / 2055 kg

> C·B·R value is used for flexural pavement.

> Generally 2.5mm CBR value is more than 5mm C·B·R value. But if 5mm CBR value is more 2.5mm CBR value. Then the test is conducted again and whichever value combs max^m will be taken as C·B·R.

> C·B·R value is avg of max^m of C·B·R value 3 specimen.

California bearing ratio test - (CBR test)

> This is a penetration test developed by the california division of highway as a method for evaluating the stability of soil subgrade and other flexible pavement materials.

(Load no - 2750)

> The test results have been connected with flexible pavement thickness requirement for highway and aire fields

25 June 2021

> The CBR test may be conducted in the Laboratory on a prepared specimen in a both mould or in-situ in the field.

> The Laboratory CBR apparatus consists of a mould 150 mm diameter with a base plate and a collar.

> A loading frame with the cylindrical plunger of 50 mm dia and dial gauges for measuring the expansion on soaking and the penetration value

> The penetration consists of causing a cylinder plunger of 50 mm diameter to penetrate a pavement component material 1.25 mm/min

> The load values to cause 2.5 mm and 5 mm penetration are recorded.

> These loads are expressed as percentage of standard load values at respective deformation Level to obtained CBR value.

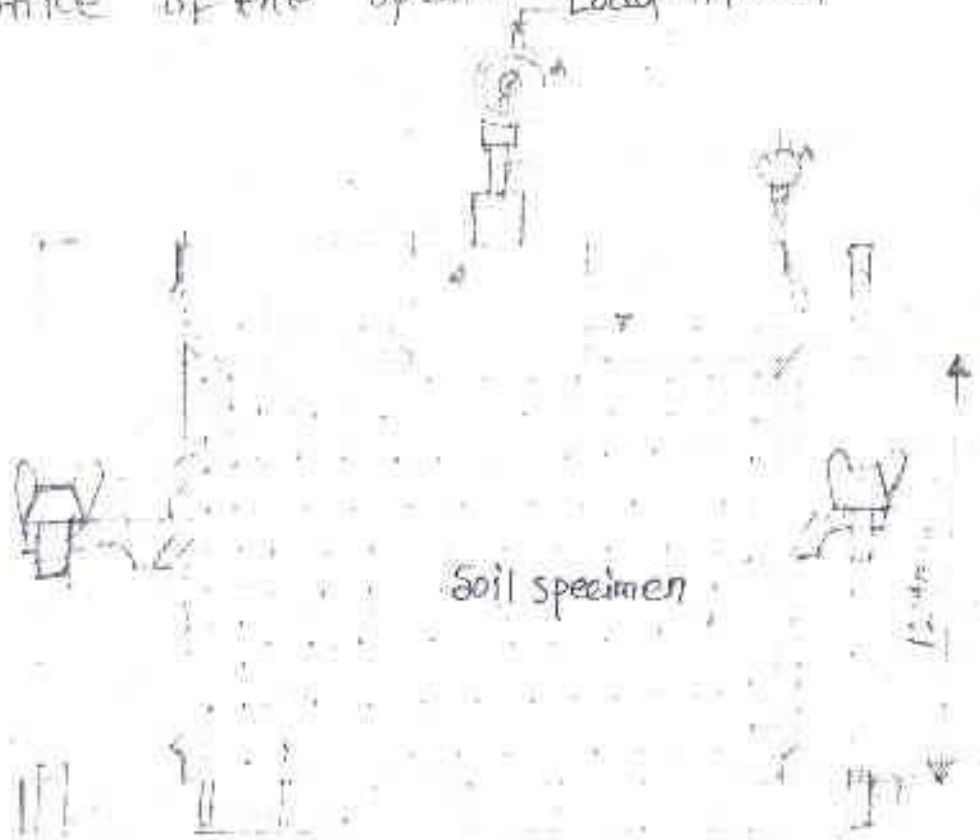
> The standard load values obtained from the from avg. of a large number of tests on crushed stones are 1370 kg and 2055 kg respectively at 2.5 and

and

Penetration - Test

The mould containing the specimen, with the base plate in position but the top face exposed, shall be placed on the lower plate of the testing machine. Surcharge weights, sufficient to produce an intensity of loading equal to the weight of the base materials and pavement shall be placed on the specimen. If the specimen has been soaked previously, the surcharge shall be equal to that used during the soaking period. To prevent upheaval of soil into the hole of the surcharge weight 2.5 kg annular weight shall be placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weight shall be placed. The plunger shall be seated under a load of 4 kg so that full contact is established between the surface of the specimen and the plunger. The load and deformation gauges shall then be set to zero (In other words, the initial load applied to the plunger shall be considered as zero when determining the load penetration relation). Load shall be applied to the plunger into the soil at the rate of 1.25 mm per minute. Reading of the shall be taken at penetration of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10.0 and 12.5 mm (The maximum load and penetration shall be recorded if it occurs for a penetration of ~~any~~ less than 12.5 mm). The plunger shall be raised and the mould detached from the loading equipment. About

20 to 50 g. of soil shall be collected from the top 30 m.m layer of the specimen and the water content determined according to I.S: 2720 - 1973. If the average water content of the whole specimen is desired, water content sample shall be taken from the entire of the specimen



(CRR Test)

Load penetration curve :-

The load penetration curve shall be plotted. This curve is usually convex upwards although the initial portion of the curve may be concave downwards due to surface irregularities. A correction shall then be applied by drawing a tangent to the point of greatest slop and then transposing the

axis of the load so that zero penetration is taken as the point where the tangent cuts the axis of penetration. The corrected load-penetration curve would then consist of the tangent from the new origin to the point of tangency on the re-sited curve and then the curve itself as illustrated.

California Bearing ratio :- The CBR values are usually calculated for penetrations of 2.5 and 5 mm corresponding to the penetration value at which the CBR values is desired. corrected load value shall be taken from the load penetration curve and the CBR calculated as following California Bearing Ratio

$$= \frac{P_T}{P_S} \times 100$$

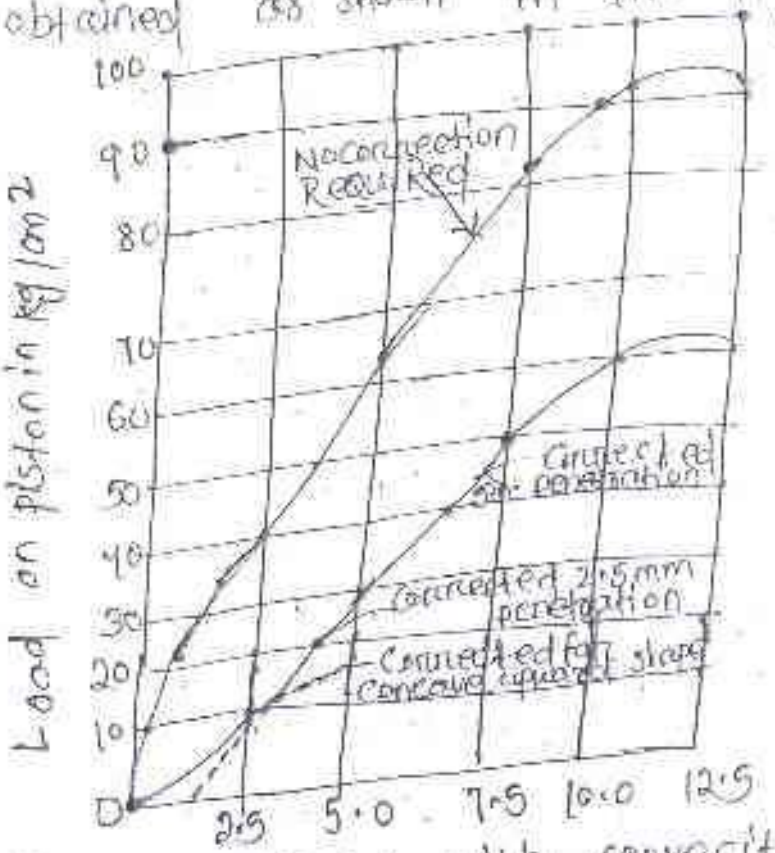
26 June 2021

> The specimen in the mould is subjected to 4 days soaking and swelling and water absorption values are noted.

> The surcharge weight is placed on the top of the specimen in the mould. and the speedy is placed under the pringer of the load.

> The load values are noted corresponding to the penetration values of 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 ---- 12.5 mm.

→ The load penetration graph is plotted. Two typical types of curves may be obtained as shown in the fig



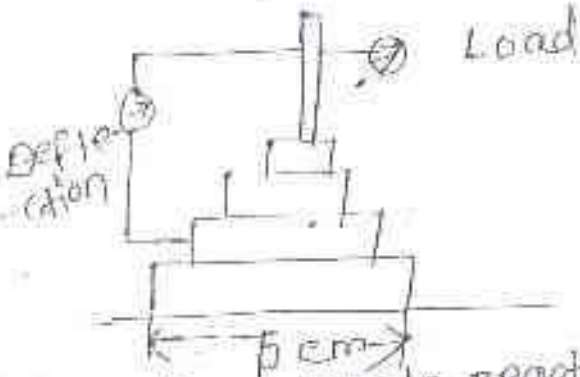
→ The curve is with convecity upwards as for specimen - 1 and the load corresponding to 2.5 and 5.0 mm penetration values are noted.

→ The CBR value is calculated as per

$$CBR(\%) = \frac{\text{Load sustained by the specimen at 2.5 or 5mm penetration}}{\text{Load sustained by standard aggregates at the corresponding penetration level}}$$

Plate Bearing Test :-

→ It is carried out on subgrade soil in the field with load bearing area to find power of subgrade and it is represented by modulus of subgrade reaction.



Modulus of subgrade reaction (K)

$$K = \frac{P}{\Delta} = \frac{P}{0.125 \cdot m} = kg/cm^3$$

→ standard size of plate = 75 cm

→ Data is used in both flexible and rigid pavement.

Empirical formula to find Δ :-

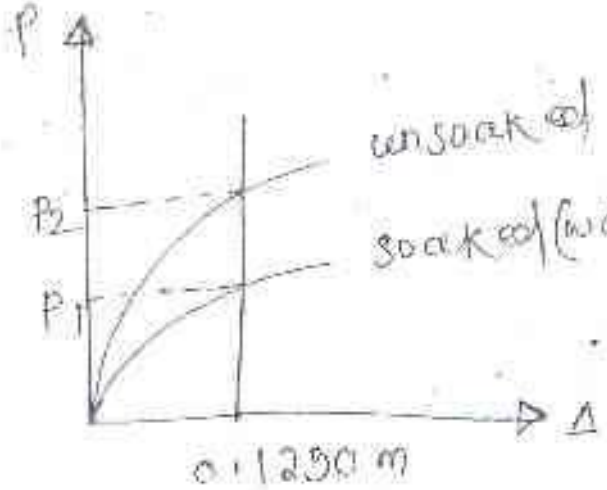
$\Delta = \frac{1.18\,PA}{ES}$ → Rigid plate / plate load test

$\Delta = \frac{1.5PA}{ES}$ → Flexible plate / wheel load test

a → contact radius

ES → modulus of elasticity of soil subgrade

Correction to moisture :-



$$K = \frac{P}{\Delta}$$

$$\Rightarrow \Delta = \frac{P}{K} = \text{Constant}$$

$$\boxed{\frac{PV}{KV} = \frac{PS}{KS}}$$

Plate bearing test :- 5 July 2021

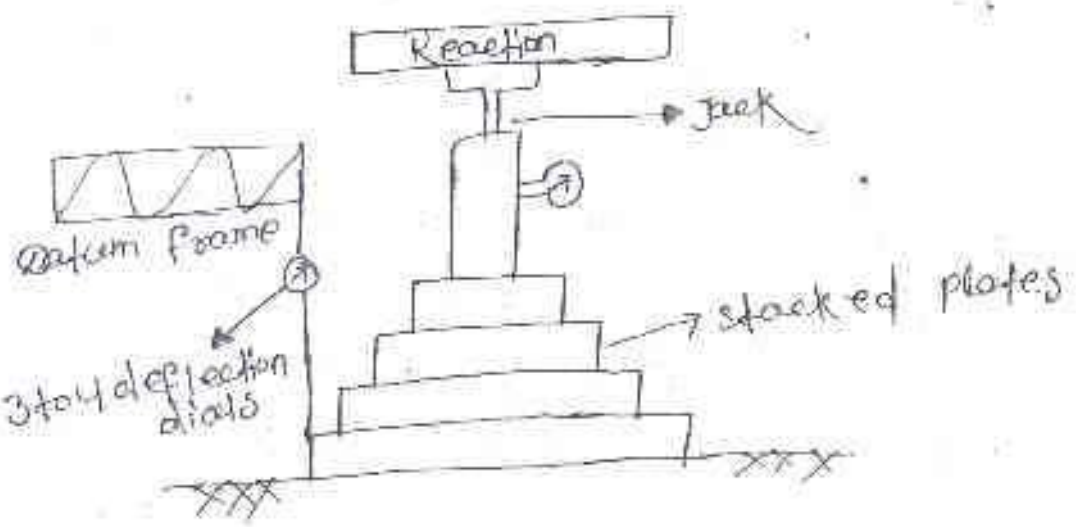
> The plate bearing test is used to evaluate the supporting power of subgrade for use in pavement design by using relatively large diameter of plate.

> The plate bearing test is carried out to find out the modulus of subgrade reaction in the westergaard's Analysis for wheel load stresses in cement concrete pavement

> The test set up consists of a set of plates of diameter 75 60 45 and 30 cm A loading device consisting of

jack and proving ring arrangement and a reactio frame, against which the jack can give a thust to the plate.

> A datum frame resting fonfrom the loaded area and dial gauges from this frame are used to measure the settlement of the loaded plate.



Modulus of subgrade reaction :-

Modulus of subgrade reaction (K) may be defined as the pressure sustained per unit deformation of subgrade at specified deformation using specified plate.

> The standard plate size fonfinding K-value is 75cm diameter.

> The test site is levelled and the plate is properly seated on the prepared surface.

→ The stiffening plates of decreasing diameters are placed and the jack and proving ring assembly are fitted to provide reaction against the frame.

→ Three or four dial gauges are fixed on the periphery of the plate from independent datum frame for measuring settlements.

6 July 2021

The test site is levelled and the plate is properly seated on the prepared surface and the jack and proving ring assembly are fitted to provide reaction against the frame.

→ Three or four dial gauge are fixed on the periphery of the plate from the idependent datum frame for measuring settlements.

→ A seating load of 0.07 kg/cm² (350 kg for 75cm) plain is applied and released after a few setting.

→ A load sufficient to cause approximately 0.25mm settlement is applied and when there is no increase in settlement or when the rate of settlement is less than 0.25mm. The reading of load is found out and the settlement is noted from the proving ring dial reading.

$$K = \frac{P}{0.125} \text{ kg/cm}^2$$

Stone aggregates :-

⇒ Aggregates from the major portion of pavement structure and they form the prime materials used in pavement construction.

⇒ Aggregates have to bear stresses occuring due to the wheel loads on the pavement and on the surface course They also have to resist wear due to abrasive action of traffic.

⇒ These are used in pavement construction in cement concrete, bituminous concrete and other bituminous constructions.

⇒ Most of the road aggregates are prepared from natural rock. Gravel aggregate are small rounded stones of different sizes which are generally obtained as such from some river beds.

⇒ Sand is fine aggregate from ~~which~~ weathering of rock. The properties of rock from which the aggregates are formed depend on the properties of constituent materials and the nature of bond betn them.

⇒ Based on the origin of rock are classified as Igneous, sedimentary metamorphic.

⇒ The aggregate are specified based on their grain size shape, texture and its gradations.

> Aggregate size is as contained by sieving through square sieves of successively decreasing sizes.

> The required aggregate sizes are chosen to fulfill the desired gradation. The grading of different road making purposes have been specified by various agencies like A.S.T.M, B.S.I, I.S.I and the IRC.

Desirable properties of road aggregate:

(i) Strength
(ii) Hardness
(iii) Toughness
(iv) Durability
(v) Shape of Aggregates
(vi) Adhesion with bitument

7 July 2021

(i) Strength :- The aggregates to be used in road construction should be sufficiently strong to withstand the stresses due to traffic wheel load.

> The aggregates which are to be used in the top layer of the pavements particularly in the wearing course have to be capable of withstanding high.

stresses in addition to wear and tear they should possess sufficient strength resistance to crushing.

(2) Hardness :-

=> The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. So they should be hard enough to resist the wear due to abrasive action of traffic.

=> Abrasive action may be increased due to presence of abrasive material like sand between the tyres of moving vehicles and the aggregates exposed at the top surface.

=> The mutual rubbing of stones is called attrition.

(3) Toughness :- Aggregates in the pavements are also subjected to impact due to moving wheel loads. Sever impact like hammering is quite common when heavily loaded steel tyred vehicles move on water bound macadam roads.

=> Jumping of the steel tyred wheels from one stone to another at different level causes sever impact on the stones.

=> The magnitude of impact would increase with the roughness of the road surface on the vehicle and other

vehicular characteristics.

⇒ The resistances to the impact is another desirable properties of aggregates.

(4) Durability :-

⇒ The stone used in the pavement construction should be durable and should resist disintegration due to the action of weather.

⇒ The property of the stones to with stand the adverse action of weather may be called as soundness.

⇒ The aggregates are subjected to the physical and chemical action of rain ground water etc. Hence it is desirable that the road stones used in the Construction should sound enough to withstand the weatherings.

(5) Shape of Aggregates :- The size of the aggregates is first qualified by the size of square sieve opening through which an aggregate may pass and not by shape.

⇒ Aggregates which happen to fall in a particular size range may have rounded cubical, Angular flaky or elongated shape of particles.

8 July 2021

Tests for road aggregate :-

The following tests are carried out for road aggregate.

(i) Crushing test
(ii) Abrasion test
(iii) Impact test
(iv) Soundness
(v) Shape test
(vi) Specific gravity and water absorption test.
(vii) Bitumen athesion test

Aggregate Crushing test :-

-> The strength of coarse aggregate is determined by aggregate crushing test.

-> The apparatus for standard test consist of a steel cylinder 15.2 c.m dia. with a base plate and a plunger / compressive testing machines, cylindrical measure of diameter 11.5 cm and height 18 c.m tamping rod and sieves.

-> Dry aggregate passing 12.5 mm is sieve and retained on 10mm sieve is filled in the cylindrical measure in three equal layers.

-> Each layer is tamped with 25 blows Then the test sample is weighted (w.g. and placed in the test cylinder in three equal layers tamping each layers 25 times.

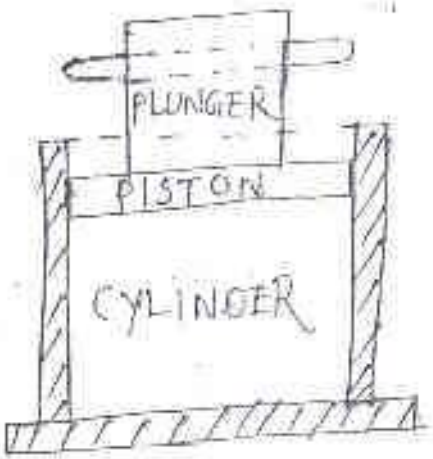
> The plunger is placed on the top of specimen and a load of 40 tonnes is applied at a rate of 4 tonnes per min by the compression machine.

> The crushed aggregate is removed and sieved on 2.36 mm IS sieve. The crushed material which passes this sieve is weighted equal to W_2 gm.

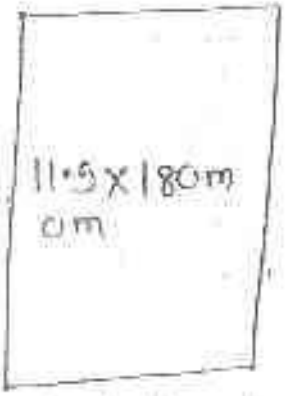
> The aggregate crushing value is the % of the crushed material passing 2.36 mm sieve in terms of original weight of the specimen.

$$\text{Aggregate crushing value} = \frac{W_1}{W_2} \times 100$$

> strong aggregates given low crushing value. the aggregate crushing value for good quality aggregate to be used in the base course shall not be exceed 45% and value for surface course shall be less than 30%.



Base plate



Cylindrical measure


Steel tamping Rod

10 July 2021

Abrasion tests:-

-> Due to the movements of traffic, the road stones used in the surface course are subjected to wearing action at the top.

-> Hence road stones should be hard enough to resist the abrasion due to traffic. Abrasion tests are carried out to check the hardness property of the stone.

-> The abrasion test may be carried out any one of the following three tests.

(i) Los angles abrasion test.
(ii) Deval abrasion test
(iii) Dorry abrasion test

Los angles abrasion tests :- 13 July 2021

(i) The principle of los angle abrasion t's to find the percentage of ware due to relative mo action betn the aggregate and steel balls used as abrasive charge.

(ii) The Los angles machine consists of a hollow cylender closed at both ends having inside dia 70 cm and length 50 cm and mounted so as to rotate about its horizontal axis as shown in the fig.

(iii) The abrasive charge consists of cast iron spheres of approximate diameter of 4.8 cm and each of weights

340 to 419 gm.

(iv) The number of spheres to be used as abrasive charge and their total weight havebeen specified on the grading of the aggregate sample.

(v) The specified weight of aggregate specimen (5 to 10kg) depending on gradation) is placed on the machine along with the abrasive charge

(vi) The machine is rotated at a speed of 30 to 33 rpm for the specified number of revolutions.

(vii) The abraded aggregate is then sieved on 1.7mm sieve and the weight of powdered aggregate passing this sieve is found.

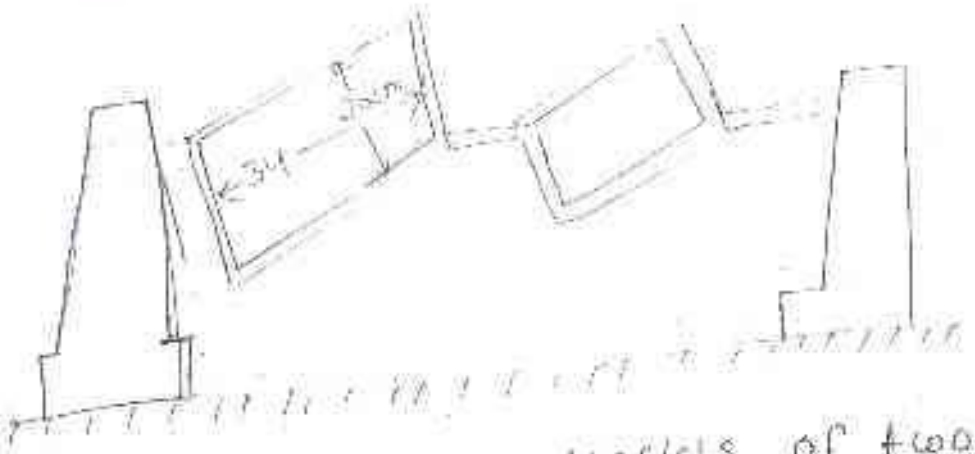
$$\text{Abrasive value} = \frac{\text{weight of aggregate passed on 1.7mm sieve}}{\text{original wt of the sample}} \times 100$$

(viii) The los angle abrasion value of good aggregates acceptable for cement concrete, bituminous concrete & other high quality pavement materials should be less than 30 %.

(ix) values up to 50 % are allowed in base course like water bound mechadam and bituminous mechadam

14 July 2021

.2: Deval abrasion test :-



(i) The Deval mechine consists of two hollow cylinder of diameter 20 c.m and length 34 cm mounted in such a way that the cylinder rotates about a horizontal axis. bot the axis of the cylinders make 30° angle with horizontal.

(ii) Specified quantity of dry aggregate specimen (4 kg to 5.5 kg) of any one of the specified gradings is placed in the cylinder.

(iii) The abrasive charge consists of 6 cast iron or steel spheres of about 4.8 cm diameter and total weight 2500 g is placed

(iv) Two tests may be carried out simultaneously using both the cylinders. The machine is rotated at a speed of 30 to 33 rpm. After 10,000 revolutions the material is sieved on 1.7 mm IS sieve. The material passing this sieve is expressed as the percentage of the original wt. of the sample and is reported as abrasion value.

(v) when the test is carried out by deval machine without using abrasive charges the test is known as deval abrasion test.

(vi) Los Angeles abrasion test :-

> The abrasion value of aggregate is also determined using Los Angeles abrasion testing machine. This is a British method.

> The machine consists of a flat circular iron disc of 60 cm diameter which is rotated in a horizontal plane at 28 to 30 rpm.

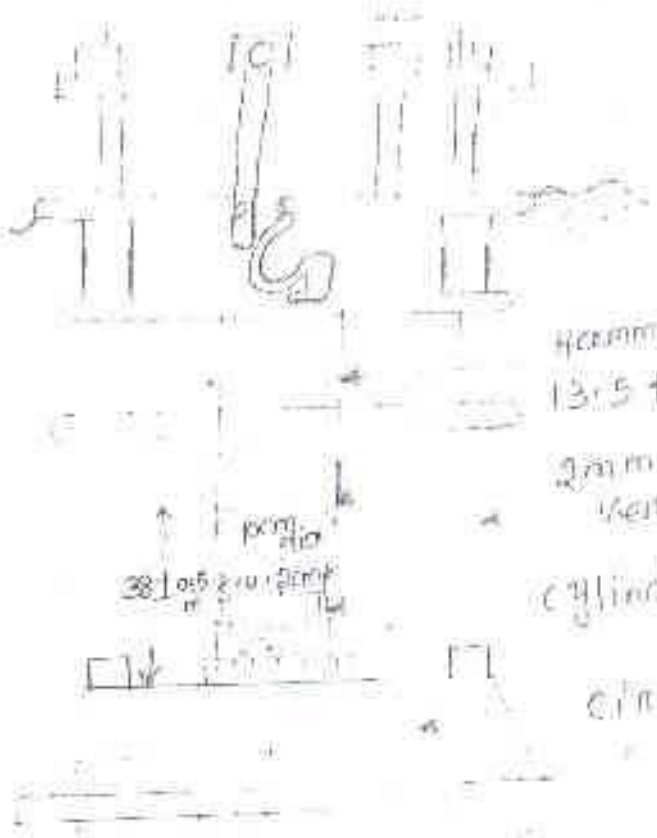
> Two rectangular trays are kept 36 cm from the centre of the disc to hold the aggregate sample in specified manner. Abrasive sand is fed through the funnel and the disc is subjected to 500 revolutions.

15 July 2021

Impact test :-

> A test designed to evaluate the toughness of stone or the resistance of aggregates to fracture under repeated impact is called impact test.

> The aggregate impact test is commonly carried out to evaluate the resistance to impact of aggregates.



⇒ The aggregate impact testing machine consists of a metallic steel base and cylindrical steel cup of dia 10.2cm and depth 5cm in which the aggregate specimen is placed.

⇒ A metallic hammer of wt of 13.5 - 14kg having a free fall from a height 38 cm is arranged to drop the vertical guides.

⇒ Aggregate specimen passing 4.5mm sieve and retained on 10mm sieve is filled in the cylindrical measure in 3 layers by tamping 25 blows each layer.

⇒ The sample is transformed from the measured in the cup of the aggregate impact testing machine and tamped compacted by tamping 25 times.

⇒ The hammer is raised to a height of 38cm above the upper surface of the aggregate and is allowed to fall freely on the cup

⇒ After subjecting the test specimen to 15 blows. the crushed aggregate is sieved on 2.36 mm sieve The impact value is expressed as the percentage fine formed in terms of total aggregate of sample.

⇒ The aggregate impact value for wearing course the pavement should not exceed 30%.

11 July 2021

Soundness Test :-

⇒ This test is carried out to study the resistance of aggregates to weathering action.

⇒ The resistance to disintigration of aggregate is determined by using saturated solution of sodium sulphate or magnesium sulphate.

Procedure :- Take individual samples in a wire mesh basket and immerse it in the solution of sodium sulphate or megnesium sulphate for not less than 16 hours nor more than 18 hours. In such a manner that the solution covers them to a depth of at least 15 mm.

⇒ After completion of the immersion period remove the samples from solution and allow it to drain for 15 minutes and place it in drying oven.

> Dry the sample until it attains a constant mass and then remove it from solution and allow and cool it to room it to drain for temperature

> After cooling again immerse it in the solution as described in step-1.

> The process of alternate immersion and drying is repeated until the specified number of cycles as agreed between the purchaser and the vendor is obtained.

> After completion of the final cycle and after the sample has been cooled. wash it to free from sodium sulphate or magnesium sulphate solution. This may be determined when there is no reaction of the wash water with barium chloride.

> Then dry each fraction of the sample to constant temp of 105 to 110°C and weight it.

> Sieve the fine aggregates over the same sieve on which it was retained before test.

> Sieve the coarse aggregate over the sieve shown below for the appropriate size of particles.

20 July 2021

specific gravity and water absorption test -

> The specific gravity of an aggregate is considered to a measure of the quality or strength of the materials.

> Stones having low specific gravity values are generally weaker than having higher values.

Procedure :-

⇒ About 2 kg of dry aggregate sample is placed in wire basket and immersed in water for 24 hours.

⇒ Then the sample is weighted in water and the boeyant weight is found.

⇒ The aggregate are then taken out weighted after drying the surface. Then the aggregates are dried in an oven for 24 hours at a temp. 100 - 110°C.

⇒ Then the dry weight is determined.

⇒ Specific gravity is calculated by dividing the dry weight of aggregate by weight of equal volume of water.

⇒ The water absorption is expressed as the percentage of water absorbed in terms of over dried weight of the aggregate.

⇒ The specific gravity of rocks vary from 2.6 to 2.9 where as the water absorption is not acceptable more than 0.6 percent.

Bituminous Materials :-

⇒ Bituminous binders used in pavement construction works include both bitumen and tar.

⇒ Bitumen is a petroleum product obtained by the distillation of petroleum where as road tar is obtained by the distructive distillation of coal or wood.

> Both bitumen and tar have similar appearance black in colour but they have different characteristics.

22 July 2021

Bitumen Bitumen is a petroleum by product obtained by the distillation of petroleum crude oil.

> It is a black or brown mixture of hydrocarbon.
> It is constructible in water.
> Bitumen contains:-
  (i) Carbon (87%)
  (ii) Hydrogen (11%)
  (iii) oxygen (2%)
> S.p gravity of bitumen -> 0.97 to 1.03
> Bituminous materials or asphalts are used for road way construction. primarily because of their excellent binding characteristics and water proofing properties and relatively low cost.
> When the bitumen contains some inert material or mineral. sometimes called asphalt.
> In India good bitumen suitable for road work is obtained from asphalt petroleum.

4th unit

Highway pavements

Pavements are generally classified into two categories ① Flexible pavement

② Rigid pavement

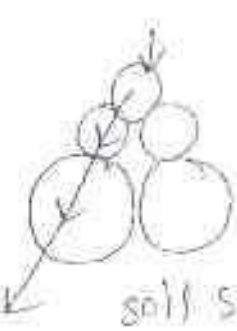
23 July 2021

Flexible pavement

(i) The life span is 15 yr.

(ii) Bitumen is used as binding material.

(iii) The load is transfered through grain to grain distribution



(iv) Initial cost is less but maintanance cost is high

(v) It takes less load.

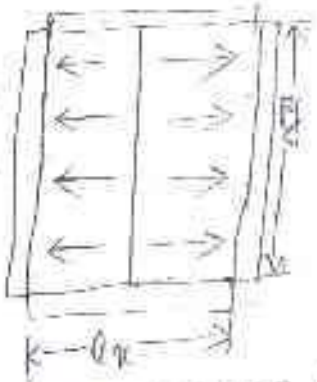
(vi) Thickness more

Rigid pavement

(i) The life span is 30 yrs

(ii) Concrete is used as binding material.

(iii) Slab action take place.



$\frac{l_y}{l_x} > 2$ = one way slab

l_y → longer span

l_x → shorter span

$\frac{l_y}{l_x} \leq 2$ this called as two way slab.

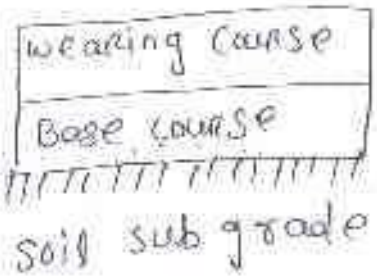
(iv) Joints are not required.

(v) Initial cost is high but maintenance cost is less.

(vi) It takes more load

(vii) Thickness is less.

(viii) Joint are required.



Flexible pavements :-

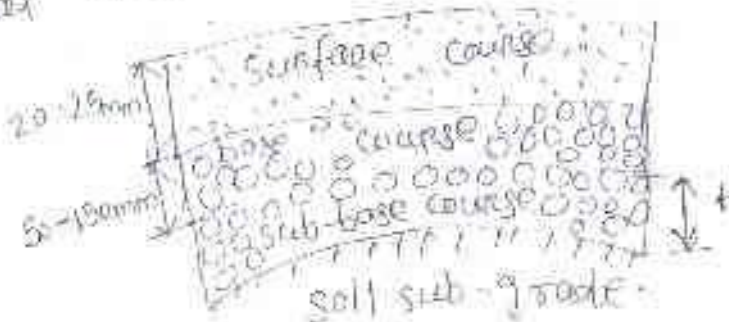
(i) Flexible pavements are those which on the whole have low flexural strength.

(ii) The flexible pavement layer reflect the deformation of the lower layers on the surface of the layer.

(iii) A typical flexible pavement consists of four components.

1. soil sub grade
2. base course
3. Sub-base course
4. surface course

Typical cross-section of flexible pavement :-



24 July 2021

> The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the point of contact of granular structure.

> A well compacted granular structure consisting of strong graded aggregate can transfer the compressive stresses through a wider area and form a good flexible pavement layer.

-> The load spreading ability of this layer depends on the type of materials and the mix design factors.

> The vertical compressive stress is max^m on the pavement surface directly under wheel load and is equal to the contact pressure under the contact pressure under the wheel.

Rigid pavement :-

> Rigid pavements are those, which posses worthy flexural strength.

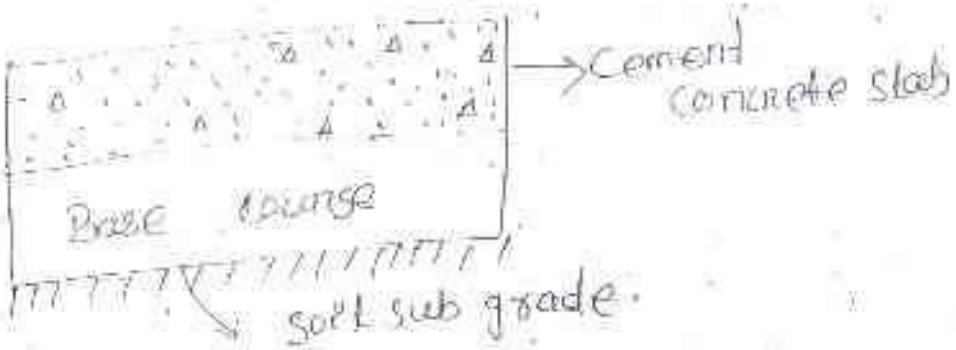
> The loads are transferred by slabaction.

> The rigid pavements are made of portland cement concrete. either plain or reinforce or prestressed concrete.

> The plain cement concrete slabs are expected to take up about 40 kg/cm² flexurable stress.

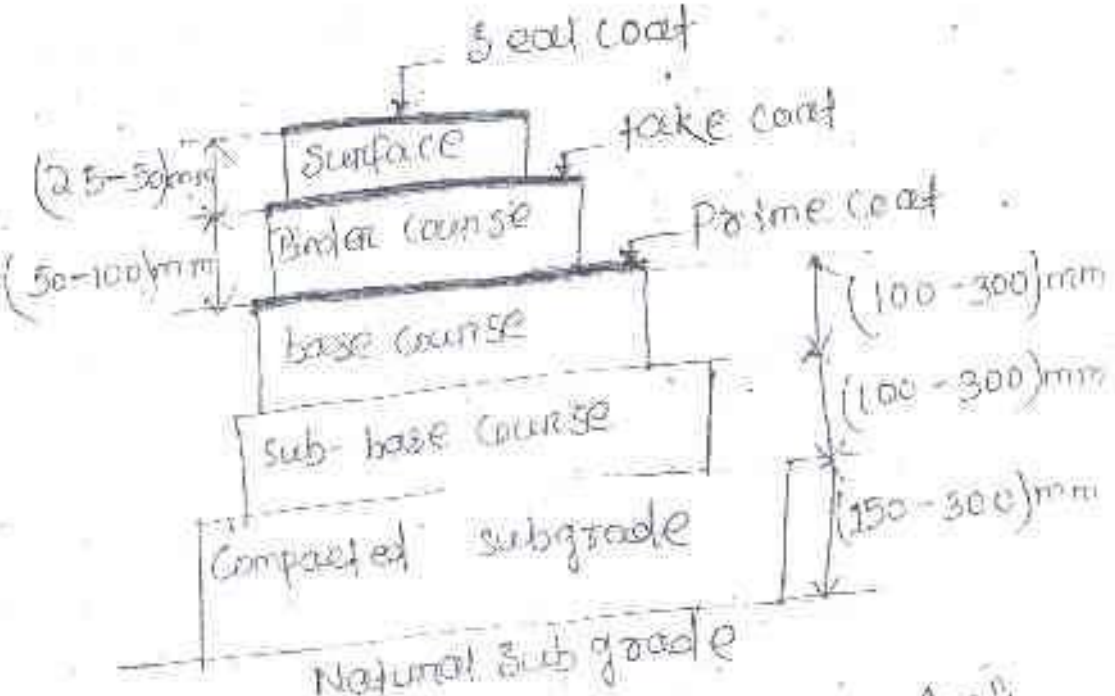
> The rigid pavement has the slab action and is capable of transmitting the wheel load stresses through a wider area below.

Typical cross-section of rigid pavement :-



26 July 2021

Functions of pavement Component



GSB - Granular Subbase (MP)
WBM - Water bound Macadam.

(1) Sub-grade :- The sub-grade is the Compacted soil layer that forms the foundation of the pavement system.

> Subgrade soils are subjected to lower stresses than the surface, base and sub-base courses, since load stresses decreased with depth. The controlling subgrade stress usually lies the top of the subgrade.
> It acts as bedding layer.

(2) Sub-base course :-

> The sub-base course serves as the principal structural component of the flexible pavement.
> It distributes the imposed wheel load to the pavement foundation the subgrade.
> It generally contains GSB (Granular sub base) layer and act as a drainage layer also and providing supports to base and surface course.

(3) Base-course :-

> The base course is the layer of material immediately beneath the surface of binder course.
> It provides additional load distribution and contributes to the sub-surface drainage
> It generally contains WBM / WMM.

21 July 2021

Surface course :- surface course is the layer directly in contact with traffic loads.

> They are usually constructed with dense graded bituminous concrete.

> It provides characteristics such as friction smoothness drainage, prevent the entrance of excessive quantities of surface water into the underlaying base, sub base and subgrade.

> It must be tough to resist the distortion under traffic and provide smooth and skid resistant riding surface.

> It contains bituminous layer.

Flexible pavement subgrade preperation :-

> The properation of subgrades site clearance grading (embankment and cutting) and compaction.

> The subgrade may be situated on embaekment or excavation or on the existing ground surface. In all the cases. The site should be cleared off and the top soil consists of grass, roots ruttist and other organic matter are to be removed.

-> The gradient operation is started so as to bring the critical profile of the subgrades to designed grade and camber.

-> Bull dozers scepers

28 July 2021

Soil compaction

By compaction of soil, the particles are mechanically constrained to be packed more closely be packed more closely by expelling part of the air void.

⇒ Compaction increases the density of and stability, reduces settlement and lowers the effect of moisture.

⇒ Hence proper compaction of fills, subgrade, sub base and base course are considered essential for proper highway construction.

⇒ The various factors influencing soil compaction include the moisture content amount and type of compaction soil type and stone content.

⇒ It is a well known fact that there an optimum moisture content (OMC) for a soil which would give maxm dry density. for a particular type and amount of Compaction. Hence it is always disireable to Compact the soil at the OMC after during the compaction equipment.

Compacting equipment :- Compaction is achieved in the field either by rolling ramming or by vibration. So the compacting equipment may also be classified as rollers, rammers and vibrators compaction of sands are also achieved by watering ponding and jetting.

Rollers :- The principle of roller is the application of pressure which is slowly increased or decreased.

→ The various type of the rollers are used for compaction are smooth wheel rollers pneumatic tyred roller, sheep foot rollers.

29 July 2021

Smooth wheeled roller :-

→ There are two types of smooth wheeled rollers

① Mecadam rollers.

② Tandem rollers

→ The gross or total wt of the mecadam roller varies between 4 to 18 tonnes. where as the tandem roller with two axles varies between 1 to 14 tonns.

→ The efficiency of the smooth wheeled Compacting of roller depends on wt. width and diameter of each roller.

→ The smooth wheeled rollers are suitable to roll a wide range of soils, granular soils and pavement materials for various layers.

Pneumatic tyred roller :-

> In this type number of pneumatic wheels are mounted on two or more axis under a loading platform.
> These rollers are pulled by tractores.
> This type of roller are suitable to compact nonplastic silt and fine sands.

Sheeps foot roller :- This type of roller consists of hollow steel cylinder with projecting feet.

> The wt of this type roller can be increased by filling the drum with wet soil.
> The wt diameter and width of the roller may be varied and also the shape and size of the feet.
> These may be pulled by tractors. The compaction effectings of this type of roller depends on the wt of roller and number of feet in contact with the ground at a time.
> This type of roller are suitable to compact clayey soil. During rolling operations. The soil under the projecting feet get compacted.
> The thickness of compacting layer is kept about 5c.m more than the length of each foot.
> About 24 or more number of passes of the roller may be necessary to obtained adequate compaction.
>

30 July 2021 8:57 PM

Rammer

> Rammers are useful to compact relatively small areas and where rollers can't operate such as compaction of trenches foundations and slopes. The output of rammer is much lower than that of roller.

Vibrators

> Vibrators are most suited for compacting dry cohesion less granular material.
> There are also vebrator mounted roller to give the combined effect of rolling & vibration.
> Vibratory are used in compacting a wide range of material.

Watering (Jetting & Ponding) :-

> It is considered to be an efficient method of compacting cohesionless sands, watering heavily and rolling by smooth wheel of pneumatic tyred roller may also give adequate compaction of cohesionless sand.

Field control for compaction :-

> For adequate quality control in construction it is essential to have proper field control in compaction. The two field control tests needed are
① Measurement of moisture content.

(iii) measurement of dry density.

The moisture content

31 July 2021

Excavation :-

(1) It is the process of cutting or removing and loosening earth, including rock form its original position, transporting and dumping it as a fill or spoil bank.

(2) The excavation or cutting may be needed in soil soft rock or even in hard rock before preparing subgrade. The selection of excavation equipment and the cost analysis is made based on the stiffness of the materials to be excavated.

(3) Earth excavation work may be devided as excavation or cutting, grading and compaction.

(4) The depth of excavation directly depends on the vertical profile of the road requirement.

(5) The slope to be provided is governed by the type of including stratification.

Embankment :- when it is need to raise the grade line of a highway above the existing ground level it becomes necessary to construct embankment.

> The grade line may be raised due to any of the following reasons.

(i) to keep the subgrade above the high ground water table.

(ii) To prevent damage to pavement due to surface water and capillarity water.

(iii) To maintain the design standard of the highway vertical alignment.

The design elements in highway embankment :-

① height
② fill material
③ settlement
④ stability of foundation
⑤ stability of slopes

Height The height of the embankment depends on the desired line of the highway and soil profile.

> Also the height of the fill is some times governed by stability of foundation particularly when the foundation soil is week.

3.8.21

(ii) fill material :-

> Granular soil is generally preferred as highway embankment material.
> clay, sand silts are considered less desirable.
> organic soils particularly peat are unsuitable.
> The best of the soils available locally is selected with a view to keep the cost and weight as low as possible at times light fill material like cinder may be used to reduce the wt when is week.

(iii) Settlement The embankment may settlement after completion of construction either due to consolidation and settlement of the foundation or due to settlement of both.