TRANSPORTATION Engg.

1. Highway planning and Geometric design of Highways.
2. pavement material characteristics and design of pavement
3. Traffic Engineering.

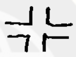
UNIT - XVI

Traffic Engineering:

1. Traffic surveys
2. Traffic census

Traffic surveys:-

1. Objectives:-

1. It is helping in Geometric design features
2. Traffic control for safety. 
3. Efficient traffic movement. 

1. Traffic volume study:-

Is the number of vehicles crossing at a particul section of the road per unit time. (veh/hr)

2. passenger car unit (PCU):-

It is a conversion factor converting all the classification of vehicle into single unit.

PCU values:-

Car - 1

2 W - 0.5

3 W - 1.5

Buses - 3

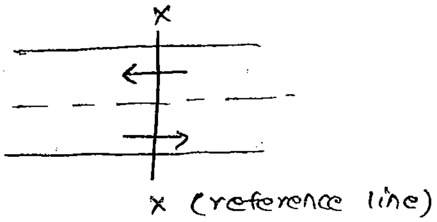
Heavy weight trucks - 4

Bullock cart - 6 (or) 8

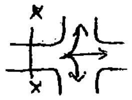
Methods of conducting traffic volume study:-

1. Manual method:-

Time	SMW		FMW		
	cycle	Auto	2W	3W	car
8-8:30			2		1



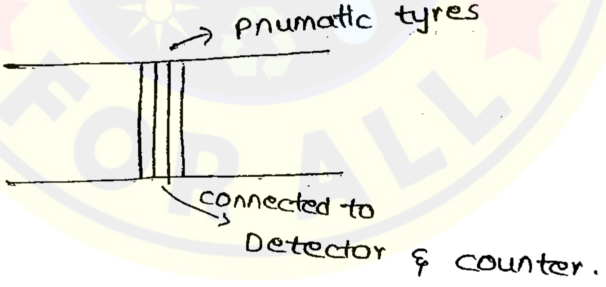
Advantages:-



1. Classification of vehicles is possible.
2. Directional movement of traffic at the intersection is possible.
3. Disadvantages:-
   1. Longer periods is not possible
   2. Difficult to conducting on bad wheather.

2. Mechanical method:-

By using instruments like Magnetic detectors, Ultrasonic device, photo electric cells



These are called Automatic detecting counters.

Advantages:-

1. Longer period is possible
2. possible to conduct in bad weather.

Disadvantages:-

1. classification of vehicle is not possible
2. It is not possible the directional movement of traffic at the Intersection.

** Hourly volume:-

7 days per 1 hour interval

7 x 24 = 168 hourly volume.

Max.	S.NO.	Hourly volume
⋮	1	1st highest hourly volume
⋮	2	2nd highest hourly volume

→ The 30th hourly volume is considered as designed hourl volume for geometric features of Highway.

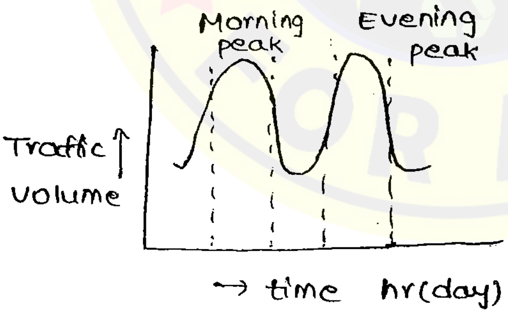
Representation of traffic volume data:-

1. AADT – Annual Average Dialy traffic.

$$= \frac{\text{Total number of vehicles moving in 1 year}}{\text{No. of days in a year}}$$

2. ADT – Average Dialy traffic.

$$= \frac{\text{Number of vehicles moving in survey period}}{\text{No. of days in survey}}$$



Speed Study:-

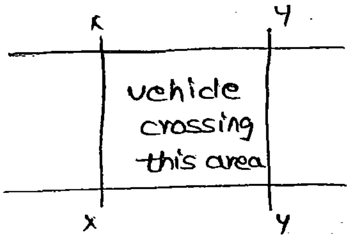
1. Spot speed study
2. Speed and Delay study

Spot speed study:-

The instantaneous speed of a vehicle at a particula section of the road is known as spot speed.

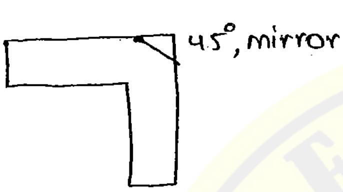
Methods of spot speed study:-

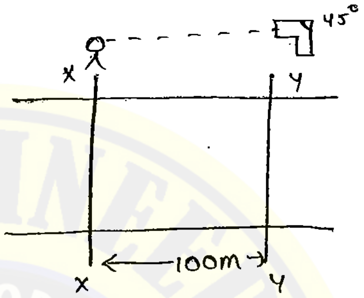
1. pavement marking method:-



2. A Emoscope method:-

Enoscope is a L-shaped mirror box, mirror is placed at an angle of 45°





3. Rador Gun:-

It works under the principle of "Laser rays".

Cumulative Frequency table:-

S.NO.	speed class (or) Range (kmph)	Mid point of speed	No. of vehicles and Frequency	% frequency	cumulative % frequency
1.	20-25	22.5	veh 2	x	x
2.	26-30	28.5	veh 6	y	x+y
3.	31-35	⋮	⋮		
4.	36-40		veh 1		

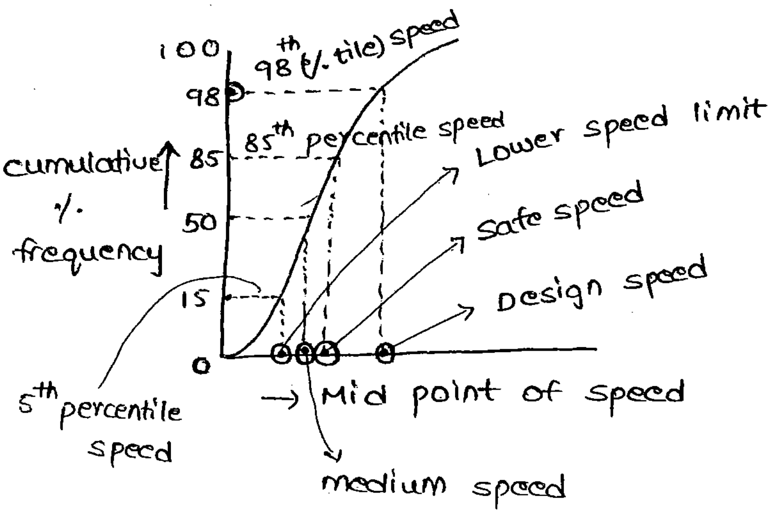
veh 1 = 36.5 kmph

veh 2 = 23 kmph

veh 3 = 83 kmph

veh 4 = ⋮

Draw a graph between cumulative % frequency and mid point of speed:- ③



98th percentile speed:-

Speed below which 98% of vehicles travel. It is used as design speed in Geometric features of highway

85th percentile speed:-

The speed below 85% of vehicles travel. It is used for safe speed finding the speed limits for traffic regulatio therefore it is known as safe speed.

15th percentile speed:-

The speed below 15% of vehicles travel. It is usec to find the lower speed limit on major highway faciliti such as express way

Average speed or Mean speed:-

1. Time Mean speed:-

The arithmatic average of spot speeds of vehicles

$v_1, v_2, v_3, \ldots\ldots v_n$ are spot speed of vehicles

$$\text{speed} = \frac{v_1 + v_2 + v_3 + \cdots\cdots + v_n}{n}$$

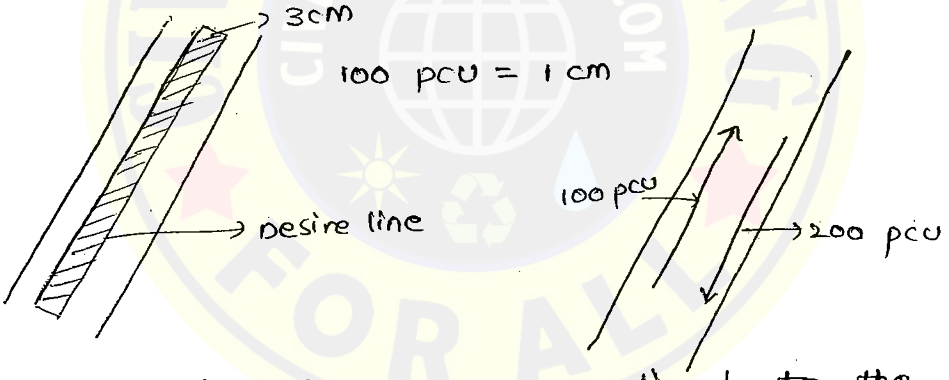
Speed and Delay study:-

It gives running speed Overall speed variation of speed amount of delay frequency of delay and causes of delay between the two stations. Generally Delays are two types i) Fixed delay ii) Operational delay.

** → Test car method (or) moving car method are best suitable for speed and delay study.

Originate Destinate study:-

1. For planning of a transportation facility such as Metro rail.
2. To plan the road network.
3. plan the schedule of different modes of transportation.
4. The home interview method is best suitable
5. Desire lines are plotted in this survey.



→ width of desire line is proportional to the number of trips in both directions

Intersection:-

It is classified into two types

1) Intersection at Grade
2) Grade separated Intersection

↓

where the traffic is living at different levels

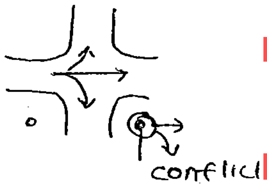
Ex:- Fly overs, cloverleaf.

Intersection at Grade:-

Traffic is moving at one level at intersection.

Different types of intersection at grade are:

1. T – intersection. T
2. cross – intersection +
3. staggered Intersection 
4. Skewed Intersection. Y
5. Skewed cross Intersection X
6. Skewed staggered Intersection 
7. Y – Intersection Y
8. Multiple Intersection 



Consider a right angle and controlled Intersection :-

1. If both the routes are two way traffic the total no. of conflict points are 24.

2. If one of the road is one way the total number of conflict points are 11.

3. If both the roads are one way the number of conflic points are 6.

~~Consider~~

Ex:1. Two major roads crossing a urban area forming a uncontrolled intersection. The number of conflict points when both the roads are one way is 'x' and when both the roads are two way is 'y' then the ratio x to y is

A. $\frac{x}{y} = \frac{6}{24} = 0.25$

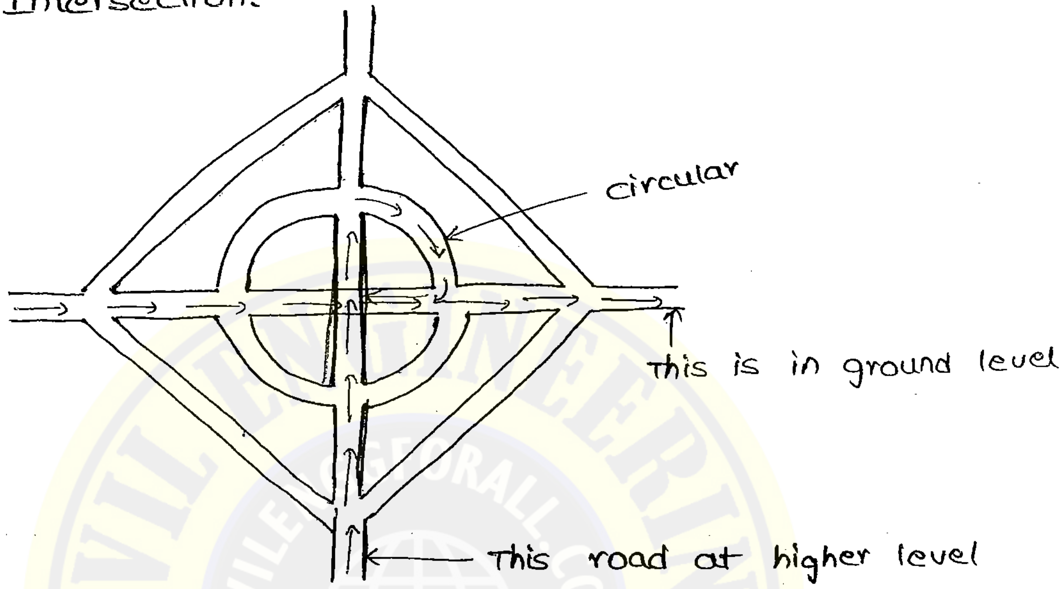
2. Grade separated Intersection:-

~~Cloverleaf Intersection:-~~

1. Traffic is moving at different levels at the intersection such intersection is called Grade separated Intersection.

Ex:- clover leaf intersection

Clover leaf Intersection:-



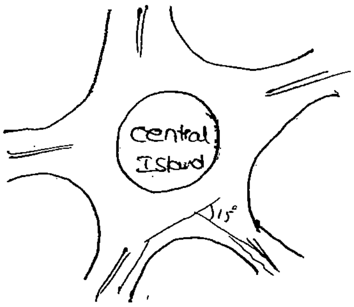
→ In clover leaf intersection, conflict points is zero and Delays are zero.

Limitations:-

1. Initial cost is high.

Exs of
Rotary Intersection (Intersection at Grade) :-

1. All the vehicles at rotary intersection are move in one direction.



→ The terms used for the construction of Rotary Intersectic

1. Design speed – 30 km for urban, 40 km for rural.

2. Weaving angle – The angle between the path of a vehicl entering the rotary and another vehicle living the rotary at adjacent road.

For smooth flow of traffic the weaving angle shoul be small but not less than 15°

3. Weaving distance (or) weaving Length (L) :-

The distance between two adjacent intersecting roads. The minimum weaving length is 30m for urban areas and minimum weaving length is 45 m for rural areas.

4. practical capacity of the Rotary :-

$$Q_p = \frac{280w\left(1+\frac{e}{w}\right)\left(1 \overset{-}{\cancel{+}} \frac{p}{3}\right)}{1+\frac{\cancel{w}W}{L}}$$

w = width of weaving section.

e = avg. width of the road at the entry and exit.

P = proportion of weaving traffic

$$P = \frac{\text{turning and crossing traffic}}{\text{total traffic}}$$

L = weaving distance and weaving length.

weaving means merging and diverging of vehicles.

the practical capacity of the rotary is dependent on the minimum capacity of the individual weaving section.

super elevation is not required at the rotary intersection.

Radius at the exist should be more than the radius at the entry

Rotary is unsuitable i) if pedestrian traffic is large.

ii) Having more number of slow moving vehicles.

iii) Having more than 7 approach roads.

Ex:- A rotary is provided with average entry width 8.4m width of weaving section 14m, Length of weaving section 35m. The crossing traffic and total traffic on the weaving section are 1000 and 2000 PCU/hr. The practical capacity of rotary

A. $$Q_p = \frac{280W\left(1+\frac{e}{W}\right)\left(1-\frac{P}{3}\right)}{1+\frac{W}{L}}$$

$W = 14\ m$

$L = 35\ m$

$e = 8.4m$

$$P = \frac{\text{crossing traffic}}{\text{total traffic}} = \frac{1000}{2000} = 0.5$$

$$Q_p = \frac{280\times14\left(1+\frac{8.4}{14}\right)\left(1-\frac{0.5}{3}\right)}{1+\frac{14}{35}}$$

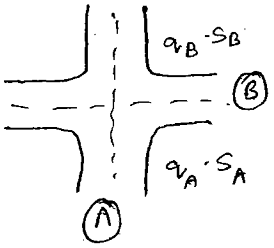
$= 3733.33$ PCU/hr.

Signal Design:-

1. Fixed Time ~~type~~ (FT) signals:-

Websters approach for design of FT signals.

consider a cross intersection where a straight traffic is permitted.



1. conduct traffic volume study to find normal $\overset{(q)}{\text{flow}}$ and saturation flow (s).

2. Normal flow is the traffic volume during design hours are peak hours. (PCU/hr)

3. Saturation flow is calculated by using 525 W, where 'W' is width of the road in meters. (PCU/hr)

Ex:- Find the ratio between Normal flow to saturation flow.

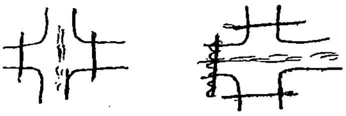
A) $y_a = \frac{q_a}{S_a}$, $y_b = \frac{q_b}{S_b}$

$y = y_a + y_b$

4. Total lost time per cycle = 2n+R

$L = 2n + R$

where, n = no. of faces



8. R = All-red time for pedestrian crossing

5. Optical cycle signal length, $C_o = \frac{1.5L+5}{1-y}$

6. Green time for A-road, $G_A = \frac{y_a}{y}(C_o - L)$

7. Green time for B-road, $G_B = \frac{y_b}{y}(C_o - L)$

8. Green time for A-road ≅ Red time of B-road

9. Green time for B-road ≅ Red time of A-road.

10. provide amber time two seconds for each face.

11. The traffic volume moving in the time period of Optimum signal cycle length as Green time, is known as Saturation flow.

Ex:-) In signal design the sum of ratios of normal flows to saturation flow is 0·5 and the total lost time per cycle is 10 sec. The optimum cycle length in sec is

A) $y = 0{\cdot}5$

$L = 10$ sec

$$C_0 = \frac{1{\cdot}5L+5}{1-y}$$

$$= \frac{1{\cdot}5(10)+5}{1-0{\cdot}5}$$

$$= \frac{20}{0{\cdot}5}$$

$C_0 = 40$ sec

Ex:-) For designing a two phase fixed time signal at an intersection having north south and east west roads where straight traffic only permitted. The time lost per cycle is 12 sec the cycle length as per webster approach.

A)

	N	S	E	W
Design hour volume $\left(\frac{PCU}{hr}\right)$	1000	700	900	550
saturation flow $\left(\frac{PCU}{hr}\right)$	2500	2500	3000	3000

A) $y_{north} = \frac{1000}{2500} = 0{\cdot}4$

$y_{south} = \frac{700}{2500} = 0{\cdot}28$

$\} \; y_{N-S} = 0{\cdot}4$ (max value)

$y_{east} = \frac{900}{3000} = 0{\cdot}3$

$y_{west} = \frac{550}{3000} = 0{\cdot}18$

$\} \; y_{E-W} = 0{\cdot}3$ (max value)

$y = y_{N-S} + y_{E-W}$

$= 0{\cdot}4 + 0{\cdot}3$

$y = 0{\cdot}7$

$$C_o = \frac{1 \cdot 5L + 5}{1 - y}$$

∴ L = 12 sec.

$$= \frac{1 \cdot 5(12) + 5}{1 - 0 \cdot 7}$$

$$= 76 \cdot 6 \text{ sec}.$$

Ex:- An intersection approach the normal flow rate 1000 $\frac{veh}{hr}$ and saturation flow rate 2800 veh/hr, optimum signal cycle Length is 90 sec, Green ratio for the given approach road 0·55. What is the critical capacity of the approach road and average delay per vehicle under this conditions.

A) Normal flow, $q = 1000$ veh/hr

$C_o = 90$ sec

Saturation flow, $S = 2800$ veh/hr

The capacity of the road = saturation flow x Green ratio

$$C = S \times \left(\frac{g \,\cancel{ratio}}{C_o} \right)$$

$$= 2800 \times 0 \cdot 55$$

$$= 1540 \text{ PCU/hr}$$

$$\text{Green ratio} = \frac{g}{C_o}$$

g = effective green time

C_o = Optimum signal cycle length.

→ effective green time, $g = \underset{time}{\overset{\nearrow Green}{G}} + \overset{\rightarrow Amber}{A_{time}}$ − Total lost time

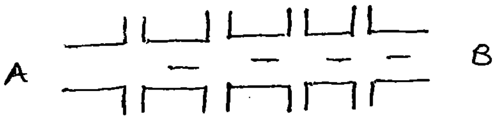
$= G_{time} + A_{time} - T_L$ (start up lost tim + clearance lost ti

$$\text{Delay } (d) = \frac{\frac{C_o}{2}\left[1 - \frac{g}{C_o}\right]^2}{1 - \frac{\text{Normal flow } (q)}{\text{Saturation flow } (S)}}$$

$$= \frac{\frac{90}{2}\left[1 - 0 \cdot 55\right]^2}{1 - \frac{1000}{2800}}$$

$$= 14 \cdot 57 \text{ sec}$$

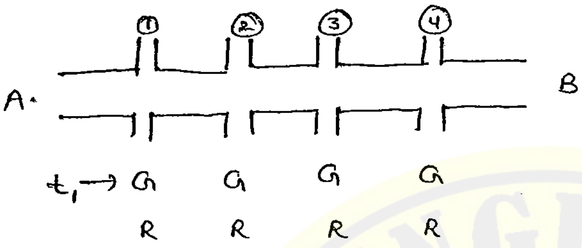
Signal coordination :-



There are four types of signal coordination is there:

1. Simultaneous system:-

In this system it shows the same indication of the same time at all the intersections.



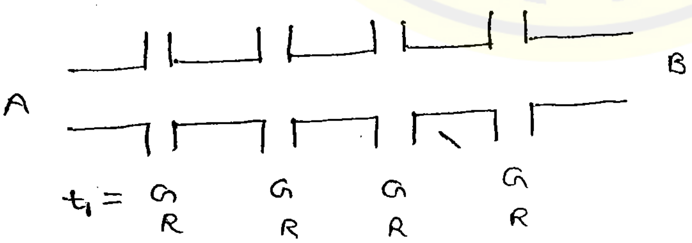
Conditions:-

1. All the intersection should be provided with fixed time signals. (F.T)

2. Optimum signal cycle length (C_0) should be same for all the Intersection.

2. Alternate system:-

A group of signals shows the opposite ~~direction~~ indication at the same time.



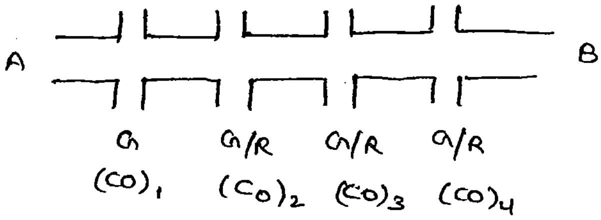
Conditions:-

1. All the intersection should be provided with fixed time signals (F.T)

2. Optimum signal cycle length (C_0) should be same for all the Intersection.

3. simple progressive system:-

Each signal system is a fixed time signal but having different signal cycle length at different Intersections.



conditions:-

1. All the intersections are provided with fixed time signals
2. "C_0" for all the intersection is not same for all intersectio

4. Flexible progressive system:-

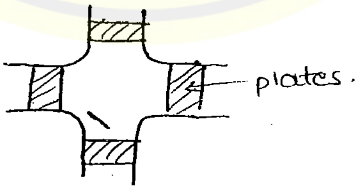
It is possible to change length of the cycle and time schedule @ each intersection.

Conditions:-

1. All the intersection sections are not provided with fixed time signals.
2. C_0 at a particular intersection will not same.

Note:-

Most efficient system is flexible progressive system.



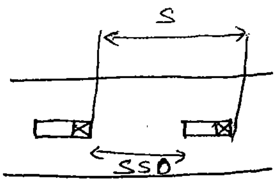
Capacity of the Highway:-

The maximum no. of vehicles that the road can accomodate.

Design capacity:-

The maximum no. of vehicles that can pass at particul section of road during 1 hour without any delay under given road way conditions and traffic conditions.

$$c = \frac{1000V}{S}$$



V = speed vehicle in kmph

S = space head way in m

c = capacity in PCU/hr/lane (or) veh/hr/lane

Space head way:-

Distance between two successive vehicles in a traffic stream.

$$S = SSD + L\text{(vehicle length)}$$

$$S = (\text{Lag distance} + \text{Break distance}) + L$$

$$S = \left(0.278\,Vt + \frac{V^2}{254f}\right) + L$$

where

V = velocity in kmph

t = total reaction time of the driver in sec

f = longitudinal coefficient of friction.

Ex:-) A single line eo uni-direction highway has a design speed of 65 kmph. The total reaction time of the driver 2.5 sec Avg. length of the vehicle 5m. The coefficient of longitudinal section (f=0.4). The capacity of the road length of veh/hr/lane (or) PCU/hr/lane.

A) Given speed = 65 kmph L = 5m

t = 2.5 sec f = 0.4

$$c = \frac{1000V}{S}$$

$$S = SSD + L$$

$$= \left(0.278\,Vt + \frac{V^2}{254f}\right) + L$$

$$= 45.175 + 41.58 + 5$$

$$= 91.75$$

$$c = \frac{1000 \times 65}{91.75} = 708.37 \text{ PCU/hr/lane.}$$

Basic capacity (or) theoritical capacity:-

The maximum no. of vehicles that can pass out at a given section of road during one hour under ideal road was condition and Traffic condition.

$$C = \frac{1000V}{S}$$

V = speed of 'v' in kmph

S = space head way in 'm'.

S = SSD + L

=(lag distance) + (Length of 'v') L

= 0.287vt + L

t = ~~time~~ total time reaction of driver

The total reaction time of the driver is 0.7 sec.

Ex:-) The theoritical capacity of a traffic lane with a speed at 40kmph and avg. length of the vehicle 5m is

A) v = 40 kmph

t = 0.7 sec

L = 5 m

S = SSD + L

= LD + L

= (0.278 × 40 × 0.7) + ~~0~~ 5

S = 12.784

$$C = \frac{1000 \times 40}{12.784} = 3128.9 \text{ PCU/hr/lane}$$

P.g No:- 70

1. S = 30 m

V = 60 kmph

$$C = \frac{1000\,V}{S} = \frac{1000 \times 60}{30} = 2000 \text{ PCU/hr/lane}.$$

TRAFFIC SIGNS

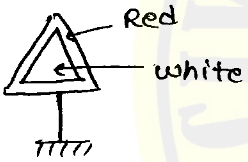
According to Indian motor vehicle act traffic signs are divided into 3 categories.

1. Regulatory (or) Mandatory sign:-

   1. straight movement of traffic is prohibited 
   2. One way traffic
   3. Right turn is prohibited 
   4. U-turn not allowed 
   5. NO parking 
   6. Speed limit 

   7. Over taking is prohibited 

2. Warning signs or cautionary signs:-



 Right turn is allowed

 Hair pin bend / sharp curve

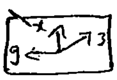
 Reverse curve

 T-intersection

 Narrow Bridge

3. Informatory signs:-

The signs which ~~under~~ comes under this category

1) Direction and place identification sign 

2) Facility information sign such as hospital, school, parking sign → 

Traffic characteristics:-

1. Road user (Driver, pedestrian)
2. vehicular → static characteristics (L, W, H)
   → Dynamic characteristics (~~v,a~~ velocity acceleration).

Maximum dimensions of the vehicles according to IRC :-

1. Width of the vehicle maximum is 2.5 m

2. Height → a) single deck → 3.8 m
   b) Double deck → 4.75 m

3. Length of the vehicle for a) single unit truck → 11 m
   b) single unit bus → 12 m
   c) Tractor → 16 m
   d) Trailer / Tractor → 18 m

parking studies :-

There are two types of parking systems.

1. On street parking / kerb parking (Divider between Foot pa
   and carriage way)
2. Off - street parking

On street parking :-

1. parallel parking :-

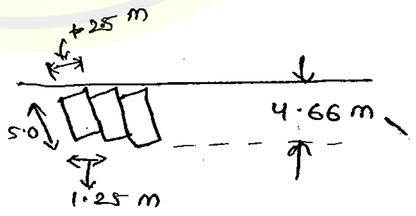
width of the road less

$N = \frac{L}{5.9}$

2. Angular parking :-

30° angular parking

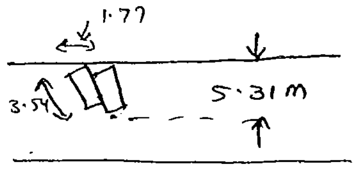
$$N = \frac{L - 1.25}{5}$$



N = No. of parking
lot ~~roads~~

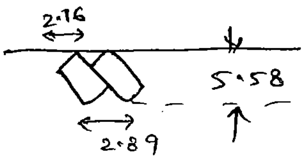
45° angular parking

$$N = \frac{L - 1.77}{3.54}$$

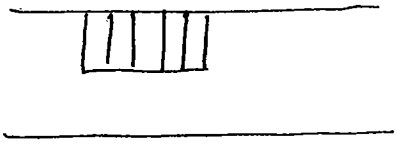


60° angular parking

$$N = \frac{L - 2.16}{2.89}$$



90° angular parking



$N = \frac{L}{2.5}$

Off street parking:-

The various types of parkings are

1. surface parking
2. Multi storey parking
3. Roof parking
4. Mechanical parking
5. Under ground parking.

Parking Index:-

percentage of available no. of parking base with respective no. of base available.

$$= \frac{\text{NO. of base occupied}}{\text{NO. of base available}}$$

parking turnover:-

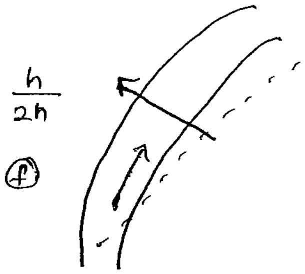
The rate of usage of available parking space

Ex:- 100 parking lot~~es~~

If there are 100 parking spaces used by thousand vehicles in a period of 12 hours then parking turn over is equal to $\frac{1000}{100} = 10$ veh/parking space for a period of 12 hours.

Accident:

1. Road user (Driver, pedestrian)
2. vehicle
3. Road characteristics
4. Environmental conditions



⇒ The frequency of accident occuring at same place that place are called Black spots.

Black spot:-

Three or more accidents occuring at the same place in a year is known as Black spot.

Objectives of Accident studies:-

1. To identify high accident locations for detailed study
2. To improve general Geometric design standards in religio to accidents.
3. To workout financial losses in accidents.
4. To evaluate safety programs
~~5. To planning the data and enforcement actions~~
5. To furnish the data for planning of education and enforcement actions.

Collision diagram:-

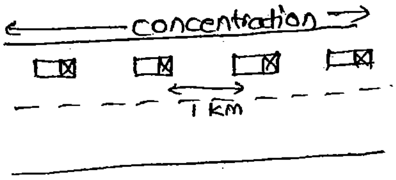
1. It shows the approximate path of vehicles and pedestrians involved in the accidents.
2. The symbols used are "⟶" motor vehicle moving in forward direction. "⟵⟵⟵" then motor vehicle moving in reverse direction. "- - - ⟶" then pedestrian, "⧄ - parked vehicle," □ - Fixed object,  over taking,  out o control, ⟶●⟵ fatal accident (or) death accident, ⟶○⟵ person injury.

~~Accident control measures~~:- Verification of Geometric design feature of highway:-

1. Engineering
2. Enforcement
3. Education
~~4. concentration (ideas~~

Concentration :-

concentration it is also called Density.



the no. of vehicles in present in 1 km length of the road.

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UNIT-II

GEOMETRIC DESIGN OF HIGHWAYS

Alignment:-

Layout of the centre line of the highway on the ground. There are the two types of Alignment.

i) Horizontal Alignment

ii) Verticle Alignment

Basic requirements of Alignment:-

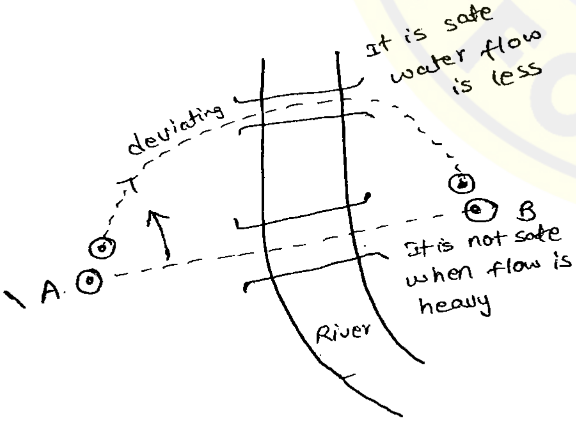
1. short
2. Easy
3. safe
4. Economy

Obligatory points:-

* Main control points to controlling the Alignment

1. Obligatory points where the Alignment is passing

Ex:- Bridge site, Mountains or hills, Intermediate town



Bridge site

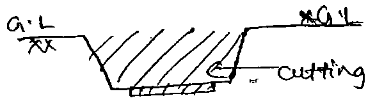
2. Where the alignment should not pass.

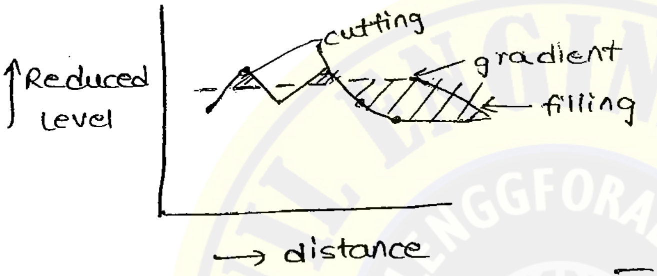
Ex:- Religious places, Grave yards

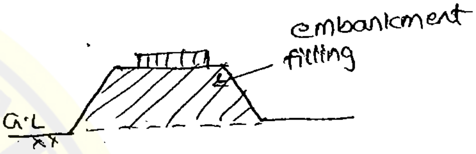
Engineering surveys:-

The four stages of engineering surveys are

1. Map study → Rough guidence of alternate alignments
2. Reconnaissance survey → select the possible alternate alignment
3. prilimінary survey → select the most suitable alignment
4. Final location and detailed study → preparation of longitudinal section and cross section for the selected Alignment.

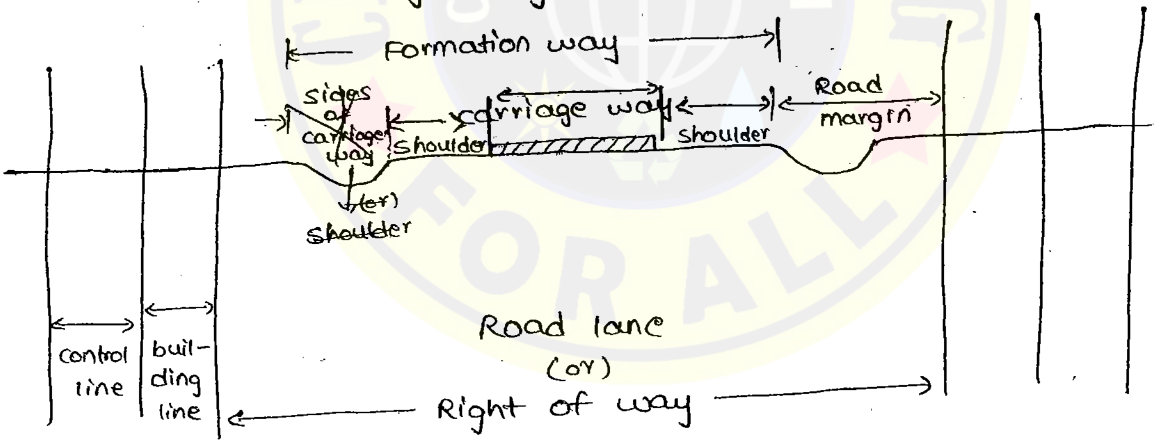






UNIT - III

Cross section of High way:-



The surface characteristics of the pavement are

1. Friction
2. Undulation
3. cross slope (or) camber

Friction:-

Friction is developed between wheels of the vehicles and pavement surface. Ex:- Skid 

Slip 

Skid:-

The longitudinal movement of vehicle is more than the rotational movement of wheels of vehicle.

Slip:-

The rotational movement of wheels of vehicle is mo than the longitudinal movement of vehicle.

Observation:-

1. It is considered in terms of longitudinal coeficient of friction(f) in stopping side distance (SSD). It ranges fro 0·35 to 0·40
2. It is also considered in terms of lateral coefficient of friction in super elevation. It is denoted with 'e'. This value is equal to 0·15

2. Undulation (or) uneveness:-

1. cumulative verticle undulations of the pavement surfac per unit length of the road.

It is expressed (cm/km)

IRC given some undulations:-

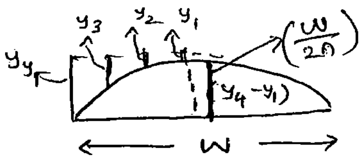
1. upto 150 cm/km → good pavement
2. Upto 250 cm/km → Satisfactory
3. Greater 300 cm/hr → Uncomfortable

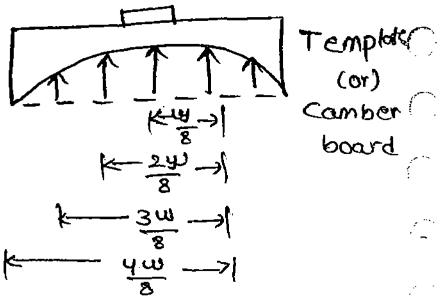
2. The instrument used for measurement of Uneveness (or) Bump indicator and Uneveness indicator.

3. Camber (or) Cross slope:-

1. The slopes provided in transverse direction of pavemen to drain of rain water from the pavement surface to the sides.

a. parabolic camber :-





consider the parabolic equation

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

where, a = constant which is equal to $\frac{nw}{2}$

$$\therefore a = \frac{nw}{2}$$

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

where, n = Rate of camber

w = width of the road

x = distance from middle section of the road to the side.

$$x_1 = \frac{w}{8} \Rightarrow y_1$$

$$x_2 = \frac{2w}{8} \Rightarrow y_2$$

$$x_3 = \frac{3w}{8} \Rightarrow y_3$$

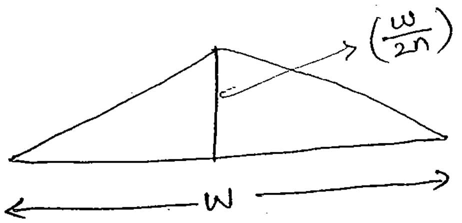
$$x_4 = \frac{4w}{8} \Rightarrow y_4$$

Note:-

Height of the crown (or) Height of the middle section of pavement is equal to $2n/8 \left(\frac{w}{2n}\right)$.

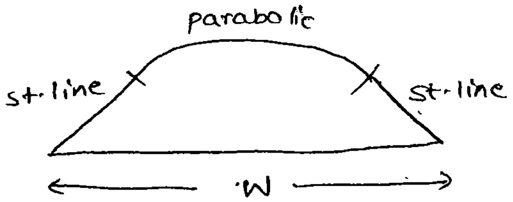
1. It is comfortable for fast moving vehicles.

b. Straight line camber:-



1. It is comfortable for slow moving vehicles.

c. combination of both parabolic and straight line:



It is comfortable for both slow moving vehicles and fast moving vehicles.

Standard values of camber as recommended by IRC:-

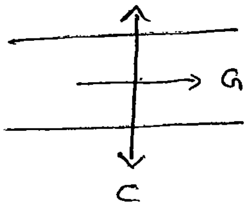
S.No.	pavement surface	Rainfall	
		Heavy	Light
1.	Cement concrete high bituminous pavement	1 in 50 (2%)	1 in 60 (1.7%)
2.	Thin bituminous surface	1 in 40	1 in 50
3.	WBM Road (combination of Aggregate and soil)	1 in 33	1 in 40
4.	village road (or) earthen road	1 in 25	1 in 33

1. The amount of camber depends on type of pavement surface and intensity of rainfall.
2. Flatter cambers are provided for high quality of pavement surface.

w = width of the road

3. width of single traffic lane is 3.75 m (or) 3.8 m
4. width of two lane road is 7 m. width of two lane with ~~Curve~~ Kerb is 7.5 m
5. Additional lane increase the pavement by 3.5 m
6. width of three lanes = 7 + ~~1~~(3.5) = ~~10~~ 10.5 m
7. width of four lane = 7 + 2(3.5) = 14 m
8. width of intermediate lane is 5.5 m

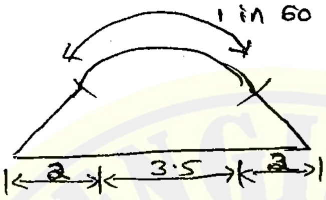
9. For better drainage and smooth flow of traffic and camber of the road should be equal to half of the longitudinal gradient.



$C = \frac{1}{2}G$

$2C = G$

EX:-) A road camber is given in the following figure the equation used for design is



A) $y = \frac{2x^2}{nw}$

$n = 60$ $\quad w = 2+2+3.5 = 7.5\,m$

$y = \frac{2 \times x^2}{60 \times 7.5}$

$y = \frac{x^2}{225}$

EX:-)

List - I	List - II
A. WBM	1. 1 in 72
B. Bituminous	2. 1 in 60
C. Rigid pavements (CC)	3. 1 in 48
D. Earth	4. 1 in 25

A) D - 4, C - 1, B - 2, A - 3

Ex:-) A straight line camber for cement concrete road for areas of light rainfall width of the road 3.5m. Calculate the height of the ~~ground~~? crown?

A) $\frac{W}{2n}$ 1 in 60

$n = 60$

$= \frac{3.5}{2 \times 60}$

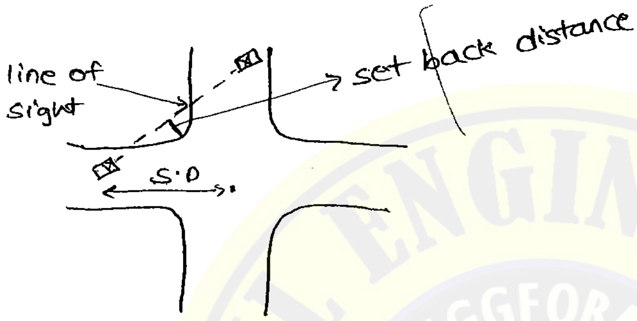
$= \frac{3.5 \times 100 \times 10}{2 \times 60}$

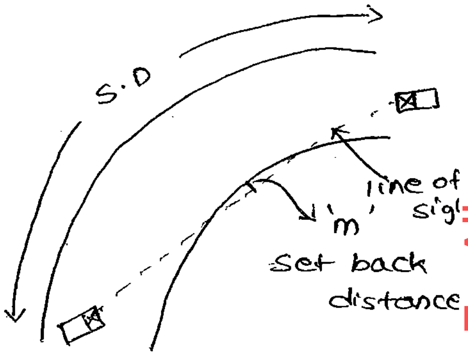
$= 29.2$ mm

UNIT - V

Sight Distance :-

consider a horizontal curve, a cross intersection





sight ~~Side~~ distance situations are consider in three ways:-

1. Stopping sight distance (SSD)
2. Over taking sight distance (OSD)
3. Intermediate sight distance (ISD)

Stopping sight distance :-

(or) Non passing sight distance

1. The length of the road required to stop the vehicle without any accident.

2. At verticle summit curve the height of high level of driver 1.2m and height of object 0.15m above the road surface then the distance b/w these two is stopping sight distance.

SSD = lag distance + breaking distance.

Lag distance → Distance travelled by the vehicle total reaction time of driver.

breaking distance → Distance travelled by the vehicle after the application of breakes

$$\boxed{SSD = vt + \frac{v^2}{2g(f \pm 0.01n)}}$$

v = speed of vehicle 'm/sec'

t = total reaction time of driver in sec.

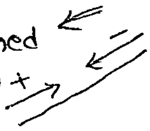
g = Acceleration due to gravity

f = longitudinal coefficient of friction = 0.35 to 0.4 based on vehicle

n = slope of the road = gradient in %

$$SSD = 0.278\,vt + \frac{v^2}{254(f \pm 0.01n)}$$

(use only inclined surface) +



Use '+' sign for ascending gradient and '-ve' sign for descending gradient

⇒ If vehicle is moving on leveled surface

$$\boxed{S.S.D = \cancel{0.27\,vt}\ 0.278\,Vt + \frac{v^2}{254f}}$$

Break efficiency :- (η) :-

$$S.S.D = 0.278\,vt + \frac{v^2}{254(f\eta)}$$

⇒ Minimum stopping sight distance = stopping sight distance calculated for one way traffic lanes ⇉

⇒ Minimum SSD = SSD calculated for two or more lanes with two way traffic. ⇄

⇒ Minimum SSD = 2× SSD calculated for single lane two way traffic

⇒ The desleration, retardation in the process of breaking dist is given as $\boxed{a = fg}$

a = retardation (or) desleration

g = acceleration due to gravity.

⇒ Total reaction time of the driver includes perception time and break reaction time.

⑰

⇒ Based on PIEV (perception Intellectual Emotion violation) under normal conditions. The total reaction time of the driver is 2·5 sec

~~Ext~~ P·g No:- 18

1. Breaking distance = 76·5 m

$v = 80$ kmph

Breaking distance $= \frac{v^2}{254f}$

$$76 \cdot 5 = \frac{80^2}{254 f}$$

$$f = 0 \cdot 33$$

2. $v = 50$ kmph

$f = 0 \cdot 37$

$t = 2 \cdot 5$ sec

S·S·D~~B·D~~ $= 0 \cdot 278\, vt + \frac{v^2}{254f}$

$= 0 \cdot 278\,(50)(2 \cdot 5) + \frac{(50)^2}{254\,(0 \cdot 37)}$

$= 61 \cdot 34$ m

3. $v = 80$ kmph ; $t = 3$ sec ; $f = 0 \cdot 5$

$SSD = 0 \cdot 278 \overset{v}{} t + \frac{v^2}{254f}$

$SSD = 117 \cdot 11$ m.

4. $V = 60$ kmph ; $f = 0 \cdot 4$; $t = 3$ sec

$SSD = 0 \cdot 278 \times 60 \times 3 + \frac{60^2}{254 \times 0 \cdot 4}$

$SSD = 85 \cdot 47$ m

For two lane two way traffic = 85·47 m

But for single lane two way traffic min. SSD = 2 × 85·47

= 171 m.

6. v = 80 kmph, t = 2·5 sec; f = 0·4

$$SSD = 0·278 \times 80 \times 2·5 + \frac{80^2}{254(0·4)}$$

$$= 55·6 + 62·9 \Rightarrow 118·6$$

9. v = 80 kmph, t = 2 sec, f = 0·4, n = 5 % (falling gradient)

$$SSD = 0·278\, vt + \frac{v^2}{254(f - 0·01n)}$$

$$= 0·278 \times 80 \times 2 + \frac{80^2}{254(0·4 - 0·01 \times 5)}$$

SSD = 116·47 m

12. f = 0·4, a = fg, g = 9·81 m/sec²

$a = 0·4 \times 9·81$

$= 3·92\ m/s^2$

14. v = 72 kmph, n = 2 % ↑, t = 1·5 sec, f = 0·15

$$SSD = 0·278 \times 72 \times 1·5 + \frac{72^2}{254(0·15 + 0·01 \times 2)}$$

= 150 m

18. v = 80 kmph; n = 2 % ↓ t = 2·5 sec (assume) f = 0·35 (∵ table)

$$SSD = 0·278 \times 80 \times 2·5 + \frac{80^2}{254(0·35 - 0·01 \times 2)}$$

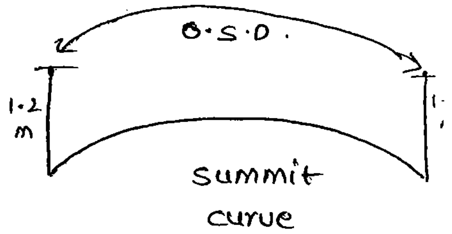
= 132 m

V (kmph)	20-30	40	50	60	65	80	100
f	0·4	0·38	0·37	0·36	0·36	0·35	0·35

Overtaking sight distance (or) Safe passage sight distance :-

To over take slow moving vehicle with respect to opposite coming vehicle the length of the road required is the over taking sight distance. (or)

At verticle summit curve the height of eye level of driver and height of object is 1.2m above the road surface then the distance b/w these two is over taking sight distance



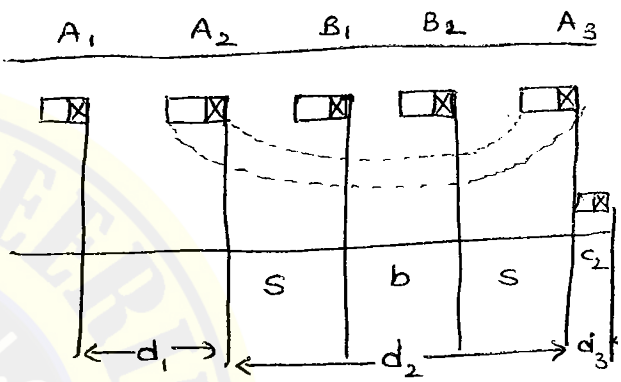
A = fast moving vehicle

A = over taking vehicle

B = slow moving vehicle

i.e., over taken vehicle

C = opposite coming vehicle



$OSD = d_1 + d_2 + d_3$

d_1 = distance travelled during total reaction time of the driver

d_2 = distance travelled by the vehicle during over taking process.

d_3 = distance travelled by Opposite coming vehicle.

$OSD = V_b t + (V_b T + 2s) + VT$

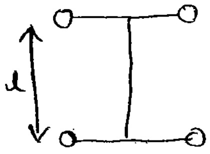
V_b = speed of slow moving vehicle in m/s

t = total reaction time of the driver

T = Time taken for over taken process

s = Spacing b/w two vehicles

V = speed of fast moving vehicle in m/s



$s = 0.7 V_b + l$

l = length wheel base of vehicle

$T = \sqrt{\frac{4s}{a}}$ a = acceleration of fast moving vehicle in m/sec².

T in sec

$OSD = (0{\cdot}278\, V_b\, t) + [(0{\cdot}278\, V_b\, T) + 2S)] + (0{\cdot}278\, V T)$

$S = 0{\cdot}2 V_b + l$

For v = kmph
V_b T = sec
s = m.

$T = \sqrt{\frac{14{\cdot}4S}{A}}$ ← if 'A' is in km/hr/sec
(use this)

V_b = slow moving vehicle
V = fast moving vehicle

A = km/hr/sec

V_b in kmph l in 'm'.

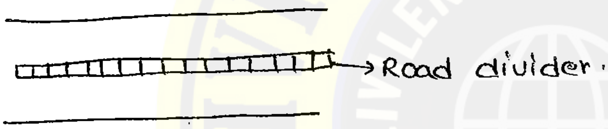
Assumptions:-

In problems design speed is given only, then

(I) V = design speed and $V_b = (V - 16)$ kmph

(ii) $t = 2$ sec

(iii) OSD for divided high way OSD $= d_1 + d_2$ only
OSD $= (0{\cdot}278\, V_b t) + (0{\cdot}278\, V_b T + 2S)$



(iv) For one way traffic lanes

OSD $= d_1 + d_2$ only

Overtaking zone:-

Min length of over taking zone is equal to 3 times of OSD

→ Desirable length of overtaking zone = 5 times OSD.

P.g NO:- 21

4. $S = 30$ m ; $a = 1{\cdot}3$ m/sec^2

$T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4\times 30}{1{\cdot}3}}$

$T = 9{\cdot}6$ sec.

2. The speeds of over taking and over taken vehicles are 80 kmph and 50 kmph respectively. The acceleration of over taking vehicle is 2.5 kmph/sec spacing b/w the vehicle is 16 m Reaction time of driver 2 sec. calculate the OSD for one wa traffic road?

A. $V = 80$ kmph $V_b = 50$ kmph, $a = 2.5$ kmph/sec, $t = 2$ sec, $S = 16$

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

$$= \sqrt{\frac{14.4 \times 16}{2.5}}$$

$$T = 9.6 \text{ sec}$$

$$OSD = (0.278 V_b t) + (0.278 V_b T + 2S)$$

$$= (0.278 \times 50 \times 2) + (0.278 \times 50 \times 9.6) + 2 \times 16$$

$OSD = 193.24$ m for one way traffic.

3. Calculate the over taking sight distance for two way traffic

A. $d_3 = 0.278\, VT$

$= 0.278 \times 80 \times 9.6$

$= 21.35$

$OSD = 193.24 + 213.5$

$= 406.74$ m.

Intermediate sight distance (I.S.D):-

When ever it is not possible to provide the required over taking sight distance (OSD) then consider intermediate sight distance (ISD) which is equal to 2 times of OSD

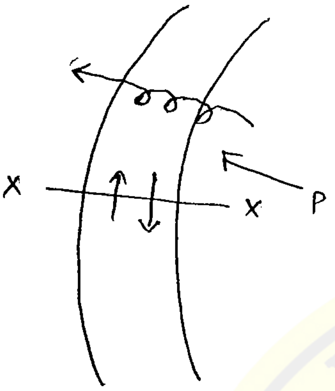
$$\boxed{ISD = 2 OSD}$$

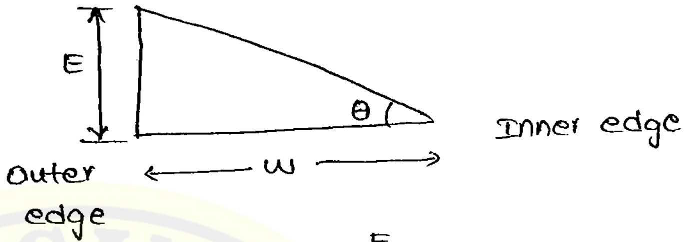
UNIT - VII

Horizontal Curves:-

Super Elevation :-

Raising of outer edge of pavement with respect to inner edge along the width of the road on horizontal curve is known as Super Elevation.





$\tan\theta = \frac{E}{W}$

$E = W\tan\theta$

$E = We$

E = Height at the outer edge of the pavement

e = Amount of Super elevation

(or)

Rate of super elevation.

W = Width of ~~super~~ e the road

The basic equation of super elevation is $e+f = \frac{v^2}{gR}$

f = lateral coefficient of friction

f = 0.15

v = speed of the vehicle in m/sec

g = Acceleration due to gravity

R = Radius of curve in m.

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

V = kmph

R = 'm'

(i) Max value of super elevation

a. $e_{max} = 7\% = 0.07$ – For plane terrain

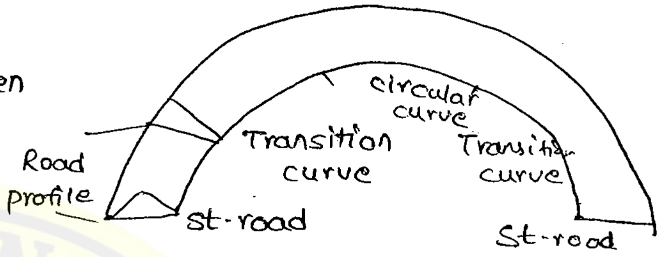
b. $e_{max} = 10\% = 0.10$ – For Mountaneous

(ii) Min. super elevation :

If calculated super elevation is less than or equal to camber of road surface then the min. super elevation is equa to camber of road surface.

If $e_{cal} <$ camber then

e_{min} = camber



(iii) Equilibrium super elevation:-

The pressure on inner wheels and outer wheels is equal then substitute lateral coefficient of friction $(f)=0$

$$e_{equilibrium} = \frac{v^2}{127R}$$

(iv) Super elevation for mixed traffic -

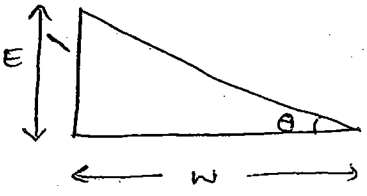
a. consider 75% of design speed

b. substitute lateral coefficient of friction $(f)=0$

$$\boxed{e = \frac{(0.75v)^2}{127R}}$$

(or)

$$\boxed{e = \frac{v^2}{225R}}$$



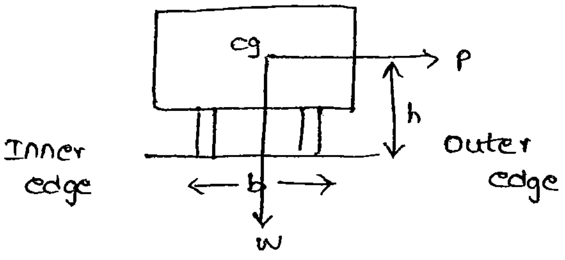
$\tan\theta = e$

$\tan\theta = \frac{E}{w}$

$E = w \tan\theta$

$E = ew$

consider without super elevation



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

P = centrifugal force

w = weight of vehicle

h = height of C.G. of vehicle above road surface.

b = width of wheel base of vehicle.

1. There is danger of over turning when centrifugal ratio $\frac{P}{W}$ or v^2/gR is equal to $b/2h$.
2. There is a danger of lateral skidding if centrifugal ratio $\frac{P}{W}$ or $\frac{v^2}{gR}$ = Lateral coefficient of friction.
3. The vehicle takes place lateral skidding with out over turning if the value of lateral coefficient of friction (f) is less than $b/2h$.
4. The vehicle takes place over turning before skidding if the value of $b/2h <$ than lateral coefficient of friction (f).

Design of super elevation:-

1. Consider 75% of design speed by neglecting lateral coefficient of friction then calculate super elevation.

$$e+f = \frac{v^2}{127R} \Rightarrow e+0 = \frac{(0.75\ v)^2}{127\ R}$$

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

2. Compare calculated super elevation with design values of super elevation.
3. If $e_{cal} > e_{max}$ then super elevation is restrict to maximum super elevation.
4. If $e_{cal} < e_{max}$ the super elevation is restrict to calculated super elevation.
5. Calculate lateral coefficient of friction for design value of super elevation.

$$f_{cal} = f = \frac{v^2}{127R} - e_{max}$$

6. compare $f_{cal} < 0.15$ the design speed is suitable for Super elevation.

7. If $f_{cal} > 0.15$ then calculate restricted speed (or) allowable Speed (or) permissible speed.

8. calculate allowable speed by considering design values of super elevation and lateral coefficient of friction.

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

P.g NO:- 24

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

$e_{equ} + 0 = \frac{50^2}{127 \times 100}$

$e_{equ} = 0.196$

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

$e + 0.15 = \frac{60^2}{127 \times 150}$

$e = 0.038$

$= 3.8\%$

6. $e + 0.15 = \frac{60^2}{127 \times 128}$

$e = 0.0714$

$= 7.14\%$

8. $e+f = \frac{V^2}{127R}$ but for mixed traffic

$e_{mix} = \frac{(0.75V)^2}{127R} - 0$

$e_{mix} = 0.154$

15. Without superelevation

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

$f = 0.1$ and $e = 0$

$0 + 0.1 = \frac{V^2}{9.81 \times 98}$

$V^2 = 96.138$

$V = 9.8$ m/sec

17. $b = 2.4m$, $H = 4.2m$; $f = 0.1$

$\frac{b}{2h} = \frac{2.4}{2 \times 4.2}$

$= 0.286$

$f < \frac{b}{2h}$ therefore lateral skidding occur first.

19. $r = 100m$; $v = 50$ kmph

$f = 0.15$

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

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

$$e = 0.047$$

$e = 1$ in 21.3

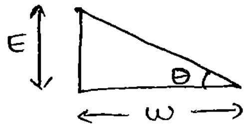
20. $r = 200m$, $f = 0.15$, $v = 40$ kmph

$$e_{equal} + 0 = \frac{40^2}{127 \times 200}$$

$$e_{equ} = 0.063$$

$$= 63\%.$$

21. For mixed $e + 0 = \frac{(0.75v)^2}{127R}$



$$e = \frac{(0.75 \times 80)^2}{127 \times 480}$$

$$e = 0.059$$

$$E = ew$$

$$= 0.059 \times 7.5$$

$$E = 0.4425 \text{ m}$$

Design speed :-

Classification of Highway	Plain Terrain		Mountaneous terrain	
	Ruling (v)	Minimum (v')	Ruling (v)	Minimum (v')
NH & SH	100	80	50	40
M.D.R	80	65	40	30
O D R	65	50	30	25
V R	50	40	25	20

1. Calculate ruling, minimum radius by considering ruling design speed (v) by using basic equation of super elevation.

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

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

2. calculate absolute min radius of considering min design speed (v') by using basic equation of super elevation.

$$\boxed{R_{ab} \cdot \min = \frac{v'^2}{127(e+f)}}$$

P.g NO. 24

7. $R_{ruling} = \frac{v^2}{127(e+f)}$

$= \frac{100^2}{127(0.07+0.15)}$

$R_{rul} = 357.9 \text{ m}$

12. $R_{abs} = \frac{v^2}{127(e+f)}$

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

$R_{abs} = 229.06 \text{ m}$

13. $V = 100$ kmph, $e = 0.10$, $f = 0.15$

$R_{ruling} \cdot \min = \frac{100^2}{127(0.1+0.15)}$

$= 314.9 \text{ m}$

25. $V = 100$ kmph, $e = 0.08$, $f = 0.12$

$R_{abs} = \frac{100^2}{127(0.08+0.12)}$

$= 393.7 \text{m}$

26. For NH on plain terrain design speed = 80 kmph

$e = 0.07$

$R_{min} = \frac{80^2}{127(0.07+0.15)} = 229.06 \text{ m}$

$R_{min} = \frac{100^2}{127(0.07+0.15)} = 357.9 \text{ m}$

Take higher for min. radius.

28. $R = \frac{100^2}{127(0.07+0.15)}$

$R = 357$ m

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

$f = \frac{100^2}{127 \times 400} - 0.07$

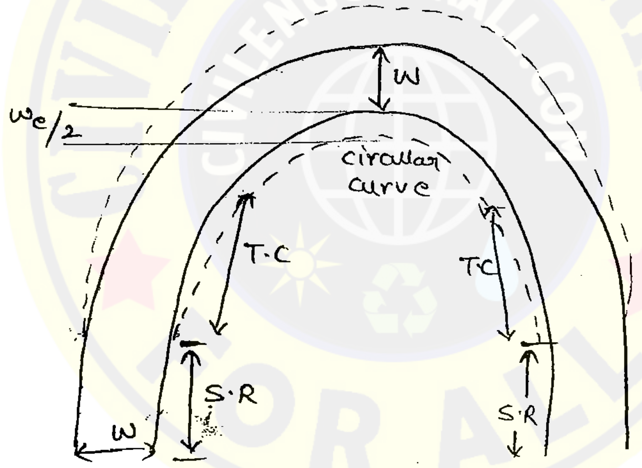
$f = 0.126$

$f \simeq 0.13$

UNIT - VIII

Extra width of pavement (W_e) :-

consider entire horizontal curve which consists of straight road, transition curve and circular curve.



W_e = mechanical widening of pavement + psychological widening of pavement.

$W_e = W_m + W_{ps}$

W_m = Mechanical widening is provided to overcome the off tracking of a vehicle.

The path tracked by front wheels of vehicle. does not match with path tracked by back wheels of vehicle. this is known as off-tracking.

$$\boxed{R_{ab}\cdot \min = \frac{v'^2}{127(e+f)}}$$

P.g NO. 24

7. $R_{ruling} = \frac{v^2}{127(e+f)}$

$= \frac{100^2}{127(0.07+0.15)}$

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Take higher for min. radius.

28. $R = \frac{100^2}{127(0.07+0.15)}$

$R = 357$ m

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

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UNIT - VIII

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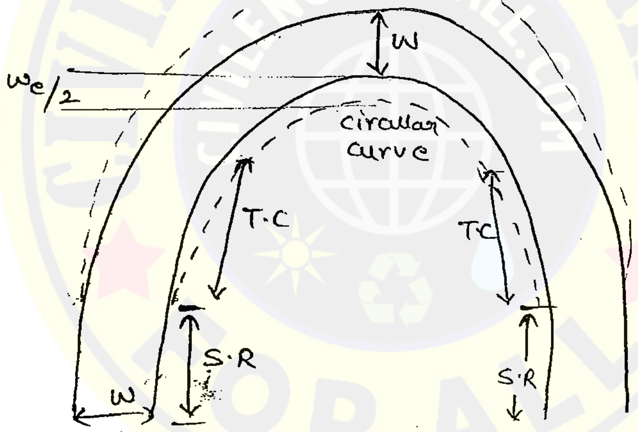


w_e = mechanical widening of pavement + psychological widening of pavement.

$w_e = w_m + w_{ps}$

w_m = Mechanical widening is provided to overcome the off ~~s~~tracking of a vehicle.

The path tracked by front wheels of vehicle. does not match with path tracked by back wheels of vehicle. this is known as off-tracking.

$$w_e = w_m + w_{ps}$$

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

where

n = no. of traffic lanes

l = length of wheel base of vehicle

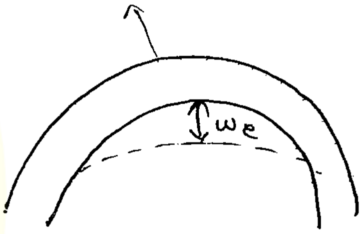
R = Radius of curve in 'm'

v = speed of vehicle in kmph.

For extra width = 14 m, $n = \frac{14}{3.5} = 4$ No's.

1) If radius of curve are less than 50 m, then extra width of pavement is provided inside of the curve.

ii) If radiums of curve is greater than or equal to 50 m then extra width is equally distributed on both sides of the curve.



iii) The mechanical widening $\frac{l^2}{2R}$ is provided for one vehicle along one traffic lane on Horizontal curve.

iv) The mechanical widening $\frac{nl^2}{2R}$ is required for 'n' no. of vehicles along 'n' no. of traffic lanes on horizontal curve

P.g NO:- 28

1. $w_m = \frac{nl^2}{2R}$

$= \frac{1 \times 6.5^2}{2 \times 125}$

$w_m = 0.169$

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

$= \frac{2 \times 6^2}{2 \times 150} + \frac{60}{9.5\sqrt{150}}$

$w_e = 0.755$ m

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

$$= \frac{2\times6^2}{2\times400} + \frac{100}{9.5\sqrt{400}}$$

$$= 0.616\ m$$

4. $$w_m = \frac{nl^2}{2R}$$

$$= \frac{n(2l)^2}{2\times R}$$

$$w_m = 4\left(\frac{nl^2}{2R}\right)$$

$\Rightarrow$ 4 times

6. $r = 300\ m$, $l = 6.1\ m$, $V = 80$ kmph

$$w_e = \frac{2\times 6.1^2}{2\times300} + \frac{80}{9.5\sqrt{300}}$$

$$= 0.124 + 0.486$$

$$= 0.61\ m$$

7. $$w_{ps} = \frac{V}{9.5\sqrt{R}} = \frac{95}{9.5\sqrt{100}} = 1.0\ m$$

UNIT - X

Transition curve:-

A transition curve is introduces b/w a straight road and a circular curve. The radius of transition curve is infinity at the end of straight road and min. at the starting of circular curve.

Types:-

1. Spiral curve 2. Leminiscate curve 3. cubic parabola.

i) spiral is the best transition curve as IRC recommended.

ii) In spiral curve radius is inversly proportional to length of curve and rate of change of centrifugal acceleration is uniform through out the length of the curve. (c in m^3/s^3)

iii) All the three follow the same path upto the deflection angle 4°

Length of Transition curve :-

(i) Length of the transition curve, $L = \frac{V^3}{CR}$ → m/sec

R = Radius of the curve in 'm'.

C = Rate of change of centrifugal acceleration

$C = \frac{80}{75+V}$ → kmph

V = speed of the vehicle in kmph

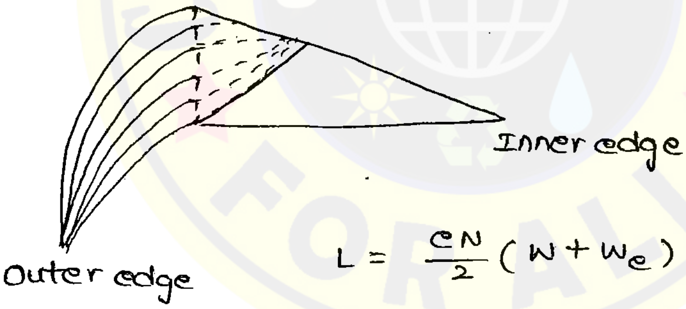
Generally 'c' value lies between 0·5 to 0·8

$$L = \frac{0.0215\, V^3}{\underset{\underset{m/sec^3}{\downarrow}}{C}\, R \rightarrow m} \rightarrow \text{kmph}$$

ii) By considering rate of introduction of super elevation (N):

— By changing camber shape to super elevation there are two types

a· pavement is rotated about centre line.



$$L = \frac{eN}{2}(W + W_e)$$

Outer edge of the pavement shifting

where, e = rate of super elevation

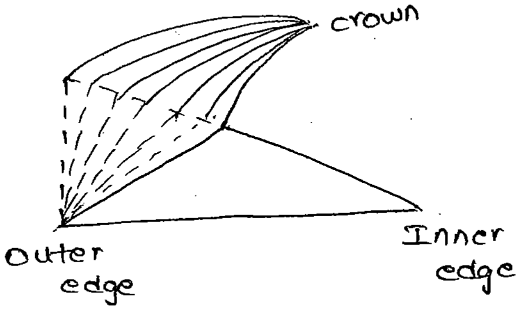
N = rate of introduction of super elevation

W = width of the pavement

W_e = extra width of the pavement

$W + W_e$ = total width of the pavement on horizontal curve.

b. pavement is rotated about inner shape:-



$$L = eN(w + w_e)$$

The crown is shifting slowly

iii) ~~Emprec~~ Empirical formula given by IRC

length of the transition curve = $L = \frac{2.7V^2}{R}$ (plain terrain)

$L = \frac{V^2}{R}$ (mountain terrain)

The maximum of above three is the actual length of transition curve

P.g NO:- 32

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

$V = 100$ kmph

$C = \frac{80}{75+100} \Rightarrow \frac{80}{175} \Rightarrow 0.457$

4. $L = \frac{v^3}{CR}$

$C = 0.3$ $\quad v = 15$

$R = 300$

$L = \frac{15^3}{0.3 \times 300}$

$= 37.5$ m

5. $N = 120$

$e = \frac{1}{15}$

$w + w_e = 10\,m$

$L = eN(w + w_e)$

$= \frac{1}{15}(120) \times 10$

$= 80\,m$

6. $L = \frac{v^2}{R}$

$v = 100$

$R = 100$

$= \frac{100^2}{100}$

$L = 100\,m$

7. $C = \frac{80}{75+v}$

$\therefore V = 80$ kmph

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

$= 0.52$

Shift of the curve:- ~~when transition curve is~~

When transition curve is introduced at the horizontal curve it is necessary to shift the main circular curve to inside of the curve.

$$\boxed{S = \frac{L^2}{24R}}$$

L = Length of transition curve in 'm'

R = Radius of the curve in 'm'.

Ex:- A two lane pavement in plane terrain with extra wideni 0.2m is provided on a horizontal curve of Radius 200m the rate of change of centrifugal acceleration is $0.6\frac{m}{s^3}$. The rate of change of introduction of super elevation, in 100. Design speed 60 kmph. The pavement is rotated about inne edges to acheive super elevation. Then the length of transi- tion curve in 'm' is.

A. i) Rate of change of centrifugal acceleration, $c = 0.6 \ m/s^3$

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

$$= \frac{0.0215 \times 60^3}{0.6 \times 200}$$

$$L = 38.7 \ m$$

ii) Rate of introduction of super elevation. pavement is rotated about inner edges

$$L = eN(W + W_e)$$

For plain terrain, $e = 0.07$ (assume)

$$N = 100$$

$$W + W_e = (\underset{\substack{\uparrow \\ \text{two lane} \\ \text{road}}}{7} + \underset{\substack{\nwarrow \\ \text{extra widening}}}{0.2 \ m}) = 7.2 \ m$$

$$L = 0.07 \times 100 \ (7.2)$$

$$= 50.4 \ m$$

iii)

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

$$= \frac{2.7 (60)^3}{200}$$

$$= 48.6 \ m$$

Longer of transition curve is, $L = 50.4 \ m$

Ex:-) calculate the value of shift of main circular curve in m.

A)

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

$$= \frac{(50.4)^2}{24 \times 200}$$

$$= 0.528 \ m.$$

Gradient :-

Slope provided along the longitudinal direction of pavemen

is known as Gradient.

Terrain	Ruling gradient	Limiting gradient	Exceptional gradi
plain terrain	1 in 30	1 in 20	1 in 15
Mountain terrain	1 in 20	1 in 16.7	1 in 14.3

→ Maximum length of the road is provided with ruling gradient. therefore it is known as design gradient.

→ The steeper gradient i.e., exceptional gradient is limited for shorter distances not exceeding about 60 m in 1 km length of the road.

Grade compensation:-

Reduction in gradient at the horizontal curve is known as Grade compensation.

$$G.C = \frac{30+R}{R}$$

R = Radius of the curve in 'm'.

$$Max\ G.C = \frac{75}{R}$$

R = Radus of the curve in 'm'.

Compensated gradient on horizontal curve is equal to ruling gradient - Grade compensation.

Note:-

As per limitation of IRC grade compensation is not necessary for gradiance flater than 4% i.e., gradiance need not be eased beyond 4% (1 in 25)

P.g No:- 14

1. Grade compensation, $G.C = \frac{30+R}{R}$

$= \frac{30+150}{150} = 1.2\ \%$

Max $G.C = \frac{75}{150} = 0.5\ \%$

$\therefore$ G.C is considered 0.5

2. $G.C = \frac{30+R}{R}$

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

$= 2\ \%$

Max $G.C = \frac{75}{R}$

$= \frac{75}{30} = 2.5\ \%$

considered $G.C = 2\ \%$

compensated gradient on horizontal curve $= (1 \text{ in } 20) - 2\%$

$= 5\% - 2\%$

$= 3\ \%$

$= 1$ in 33.33

so dont considered 1 in 33.33,

as per IRC considered 1 in 25

13. R = 60 m

$G.C = \frac{30+60}{60} = 1.5\ \%$

Max $G.C = \frac{75}{60} = 1.25\ \%$

Take $G.C = 1.25\ \%$

6. $G = 2C$

$C = \frac{1}{2}G$

camber = 1 in 48

Gradient = 1 in 24

7. $G.C = \frac{30+R}{R}$

$= \frac{30+80}{80}$

$= 1.375$

Max $G.C = \frac{75}{80} = 0.94$

Take $G.C = 0.94\ \%$

Ruling gradient $= 5\ \%$

$= 1$ in 20

compensated gradient

= Ruling gradient − G.C

$= 5 - 0.94$

$= 4.06\ \%$

$= 1$ in 25

Ruling Gradient = 6%

compensated Gradient $= 6 - 1.25$

$= 4.75\%$

$= 1$ in 20

Transition curve :-

The geometric design features considered from the starting of design transition curve are

i) super elevation

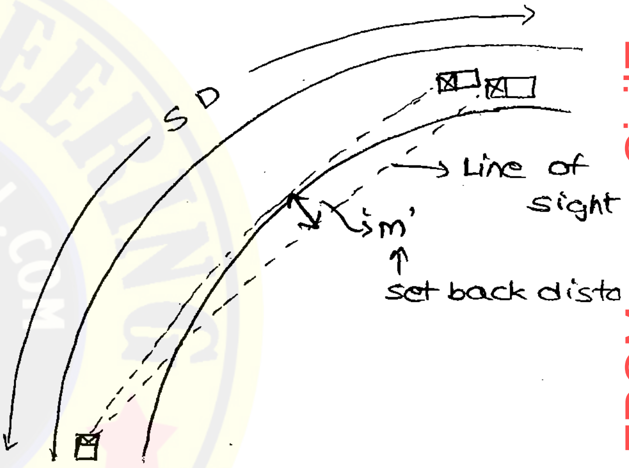
ii) Extra width of pavement

iii) Grade compensation.

UNIT – IX

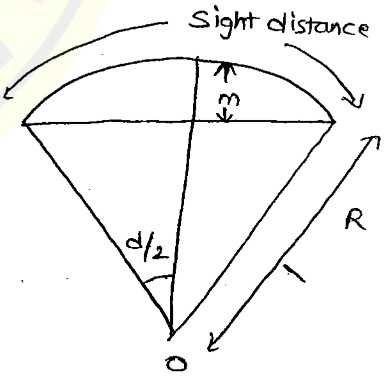
Set back distance :-

The distance free from obstructions provided inner side of the curve is known as set back distance.



(i) Length of the curve is greater than sight distance (L > SD)

ii) consider certain portion of horizontal curve, Radius of the curve



a iii) consider single lane road

$$m = R - R\cos(d/2)$$

$$\frac{d}{2} = \frac{180S}{2\pi R}$$

b. Multilane road

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

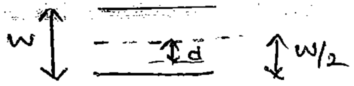
$$m = R - (R-d)\cos\frac{\alpha}{2}$$

$$\frac{\alpha}{2} = \frac{180S}{}$$

d = distance b/w centre line of the road and centre of inside lane of the road.

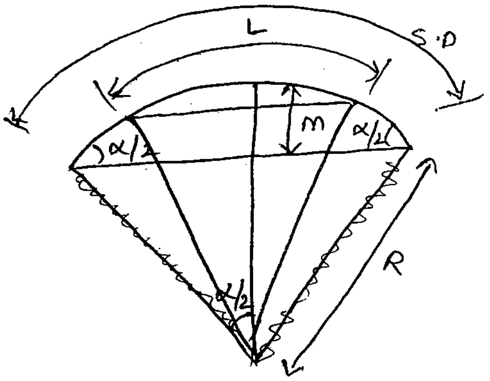
$$d = \frac{w}{4}$$

w= width of the road



$$d = \frac{\frac{w}{2}}{2} \Rightarrow \frac{w}{4}$$

ii) length of the curve is less than sight distance :- (L<SD)



a) For single lane road

$$\boxed{m = R - R\cos\frac{\alpha}{2} + \frac{S-L}{2}\sin\frac{\alpha}{2}}$$

$$\frac{\alpha}{2} = \frac{180L}{2\pi R} \text{ degrees}$$

b) consider multilanes

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

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

$$d = \frac{W}{4}$$

Approximate formula :-

1. $L > SD(s)$

$$m = \frac{s^2}{8R}$$

2. $L < SD(s)$

$$m = \frac{L(2S-L)}{8R}$$

P.g No:- 30.

2. S.D = 80 m

$m = 10$ m

$R = ?$

$$m = \frac{s^2}{8\cancel{0}R}$$

$$10 = \frac{80^2}{8\cancel{0}\times R} \Rightarrow R = 80 \text{ m}$$

The loss of tractive force due to turning of a vehicle on horizontal curve, $P = T(1-\cos\alpha)$

T = Tractive force on vehicle.

α = Turning angle

1) $\Rightarrow \frac{T(1-\cos\alpha)}{P}$

$\Rightarrow T(1-\cos 45^\circ)$

$\Rightarrow 0\cdot292T$

2) $T(1-\cos 30)$

$= 0\cdot133\cancel{8}T$

3) $T(1-\cos 90)$

$= T.$

UNIT - XI

Verticle curves:-

Verticle curves are classified into two types

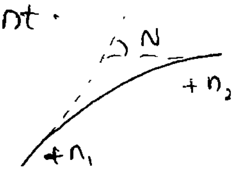
1) Summit (or) crest curve

2) Valley (or) Sag curve.

Summit curves:-

Summit curves are formed in any one of the following combination.

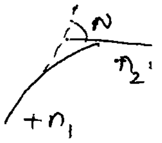
1. A upgradient meeting with another upgradient.



2. Upgradient generally denoted with 'N' $\cong n_1 - n_2$

3. 'N' is deviation angle or deflection angle.

4. Angle at the intersection of two gradients



2. A upgradient meeting with level surface $N = n_1$

3. A upgradient meeting with down gradient

$N = n_1 - (-n_2)$

$= n_1 + n_2$

4. A down gradient meeting with another down gradient

$$N = -n_1 - (-n_2)$$

$$N = n_2 - n_1$$

The maximum deviation angle is found in third case.

Factors considered for design of summit curve:-

1. When a vehicle moving on a summit curve the centrifugal force will act upward direction therefore there is no problem of discomfort to the passengers.

2. provide adequate sight distance i.e., stopping sight distance and OSD

3. Length of the summit curve:-

1. SSD:-

a) L > SSD (S)

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

N = deviation angle or deflection angle

S = stopping sight distance

H = Height of high level of driver = 1.2 m

h = height of object = 0.15 m

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

b) L < SSD (S)

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

H = 1.2 m

h = 0.15 m

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

2. Over taking sight distance (OSD):-

a. L > OSD (S):-

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

$H = h = 1.2m$

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

b. L < OSD

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

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

Note:-

1. Simple parabolic curve is used as a summit curve

2. The radius of simple parabolic curve, $R = L/N$

P.g NO:- 35

1. $S = 120\ m$

$H = 1.5m$

$h = 0.15\ m$

$N = 0.09$

$L > SD\ (S)$

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

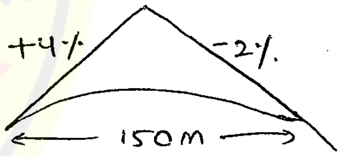
$$= \frac{0.09(120)^2}{(\sqrt{2\times1.5}+\sqrt{2\times0.15})^2}$$

$$\simeq 249.35m$$

$L \simeq 250\ m$ (Hence satisfied)

$\therefore (L > SD)$

4.



$N = +4-(-2) = 6\%$

$6\% \longrightarrow 150\ m$

$4\% \longrightarrow ?$

$$\Rightarrow \frac{4\times150}{6} = 100\ m$$

At 100m, get a highest point

5. Raising gradient $= +\frac{1}{50}$

downward gradient $= -\frac{1}{100}$

$$N = \frac{1}{50} - \left(-\frac{1}{100}\right)$$

$$= 3\%$$

Given $1\% \longrightarrow 100$ m

$3\% \longrightarrow$ ~~3~~ ?

$$\Rightarrow \frac{3 \times 100}{1} = 300 \text{ m}$$

7. Raising gradient $= +\frac{1}{25}$

falling gradient $= -\frac{1}{25}$

$$N = \frac{1}{25} - \left(-\frac{1}{25}\right)$$

$$= 0.08$$

Given OSD = 300 m

consider, L > OSD

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

$$= \frac{0.08\,(300)}{9.6}$$

$$L = 750 \text{ m}$$

10. Raising gradient $= +3\%$

Falling gradient $= -5\%$

$$N = 3 - (-5)$$

$$= 8\%$$

$$= 0.08$$

consider L > SSD

$$L = \frac{NS^2}{4.4} = \frac{0.08\,(128)^2}{4.4}$$

$$= 298 \text{ m}$$

6. Raising gradient $= +\frac{1}{25}$

Falling gradient $= -\frac{1}{50}$

$$N = \frac{1}{25} - \left(-\frac{1}{50}\right)$$

$$= 0.06$$

Given SSD = 100 m

consider L > SSD

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

let $H = 1.2$ $h = 0.15$

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

$$L = \frac{0.06 \times 100^2}{4.4} = 136.4 \text{ m}$$

$\therefore$ Hence satisfied.

8. Raising gradient $= +\frac{1}{50}$

Falling gradient $= -\frac{1}{25}$

$$N = \frac{-1}{25} - \left(\frac{1}{50}\right)$$

$$= \left|-\left(\frac{1}{25} + \frac{1}{50}\right)\right|$$

$$= |-\cancel{0.0}6\%|$$

$$= \cancel{0.0}6\%$$

Given $0.3\% \longrightarrow 20$ m

$\cancel{0.0}6\% \longrightarrow x$ m

$$x = \frac{20 \times \cancel{0.0}6}{0.3}$$

$$= 400 \text{ m}$$

11. Raising gradient $= \frac{1}{100}$

Falling gradient $= \frac{-1}{50}$

$$N = \frac{1}{100} - \left(\frac{-1}{50}\right)$$

$$= 0.03$$

Given OSD = 500 m

consider $L > OSD$

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

$$= \frac{0.03\,(500)^2}{9.6}$$

$$L = 781 \text{ m}$$

UNIT – XII

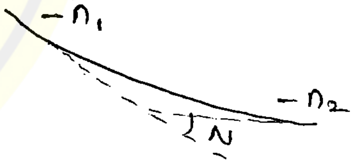
Valley curve (or) sag curve:-

Valley curves are formed in any one of the followin combinations.

1. A down gradient meeting with another downgradient

$$N = -n_1 - (-n_2)$$

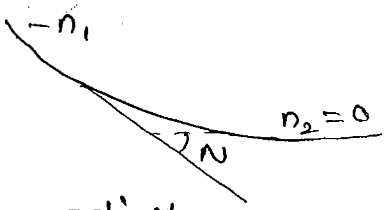
$$N = n_2 - n_1$$



2. A down gradient meeting with level surface.

$$N = |-n_1 - 0|$$

$$N = n_1$$

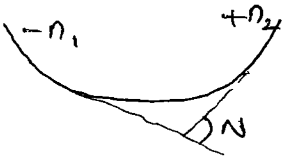


3. A down gradient meeting with up gradient

$$N = |-n_1 - n_2|$$

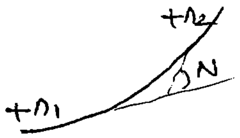
$$= |-(n_1 + n_2)|$$

$$N = n_1 + n_2$$



4. A upgradient meeting with another upgradient

$N = n_1 - n_2$



Note:-

The maximum deviation angle is obserbed in the third case.

Factors considered for design of valley curve:-

1. When a vehicle moving on valley curve the centrifugal force will act downward direction therefore it is discomfort to the passengers. Hence considered the impact free moment of vehicles at the design speed.
2. Availability of stopping sight distance under head lights during night time.
3. OSD is prohibited in valley curve.
4. SSD is taken as Head light sight distance.

Length:-

1. By considering rate of change of centrifugal acceleration.

$$L = 2\left(\frac{Nv^3}{c}\right)^{1/2}$$

N = Deflection angle

v = speed of vehicle in m/sec

c = Rate of change of centrifugal acceleration in m/s^3.

$c = 0.6\, m/sec^3$.

$$L = 2\left(\frac{Nv^3}{c}\right)^{1/2} \qquad v \text{ in kmph.}$$

$$L = 0.38\,(NV^3)^{1/2}$$

2. HLSD = SSD

a. L > HLSD (s)

$$L = \frac{NS^2}{(2h_1 + 2S\tan\alpha)}$$

$$L = \frac{NS^2}{(1.5 + 0.035S)}$$

S = SSD

h_1 = height of head light above the road surface

h_1 = 0.75m generally

α = Head of light angle

$\alpha = 1°$

(b) L < HLSD

$$L = \left(2S - \frac{2h_1 + 2S\tan\alpha}{N}\right)$$

$$L = 2S - \frac{1.5 + 0.035S}{N}$$

→ The best shape of valley curve is cubic parabola.

→ the minimum radius of valley curve $R = \frac{L}{N}$

Impact Factor (I):-

The ratio of centrifugal force to the weight of vehicle

$$I = \frac{P}{W}$$

$$I = \frac{1.6NV^2}{L}$$

$N = \phi$

v in kmph

L in m.

P.g No:- 38

3. $n_1 = -0.04$ $n_2 = +0.025$

$N = |-0.04 - 0.025|$

$N = 0.065$

(i) L > HLSD

$$L = \frac{NS^2}{(1.5 + 0.035S)} = \frac{0.065 \times 100^2}{(1.5 + 0.035 \times 100)} = 130\text{m} > 100\text{m (HLSD)}$$

2. $c = 0.6\ m/sec^3$ $n_1 = -0.04$ $n_2 = +0.05$

$N = -n_1 + 0.05$

$= |-0.09|$

$N = 0.09$

(i) comfort condition :-

$L = 0.38 (Nv^3)^{1/2}$

$= 0.38 (0.09 \times 100^3)^{1/2}$

$L = 114m$

(ii) HLSD = 180 m

a. L > HLSD

$$L = \frac{NS^2}{(1.5 + 0.035S)}$$

$$= \frac{0.09 \times 180^2}{(1.5 + 0.035 \times 180)}$$

$L = 373.84m$

Take max. of these two L values

(iii) calculate impact factor for above values (I) :-

$$I = \frac{1.6\ Nv^2}{L}$$

$$= \frac{1.6 \times 0.09 \times 100^2}{373.84}$$

$I = 3.85$

UNIT - I

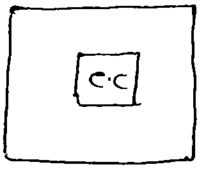
HIGHWAY PLANNING

The classification based on location and function by Nagpur Road plan is as follows.

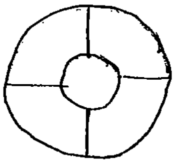
1. National Highway
2. SH
3. MDR
4. ODR
5. VR

1. Rectangular or block pattern is adopted in the city of chandigarh.

2. Radial and circular pattern is similar to the road network of cannaught place in New Delhi.



3. Master plan is the final development of road in urban areas by taking into consideration of future expansion and requirements.



4. First 20 years road plan is Nagpur road plan (1943 – 1963).

5. Second 20 years road plan is Bombay road plan (1961-81

6. Third 20 years road plan is lucknow road plan (1981-2001

→ Jayakar comittee as suggested three recommondations.

a. collect central Road Fund (CRF)

b. Formation of IRC

c. Formation of Indian Motor vehicle Act.

IRC 1934:-

For specifications, standardization and Recommendation on materials, design and construction of road and bridges.

CRRI (1950):-

Research in various aspects of highway Engineering.

Saturation system (or) Maximum utility system:-

It is useful in deciding the best road system based on alternative proposals.

In this system the optimum road length is calculated based on maximum utility per unit length of the road.

The factors considered are

a. population

b. Agricultural and Industrial productivity.

Three new roads P, Q, and R planned in a given area based on principle of maximum utility. the order of priority for these three roads should be

Road	Length	No. of villages with population			utility
		<2000	2000-5000	>5000	
P	20	8	6	1	8×0.5+6×1+1×2 = 12 unit
Q	28	19	8	4	19×0.5+8×1+4×2 = 25.
R	12	7	5	2	7×0.5+5×1+2×2 =12.5 units
Sol:- weightage factor		$\boxed{0.5}$	$\boxed{1}$	$\boxed{2}$	

Less population less weightage factor

$$P = \frac{12}{20} = 0.6 \quad \underline{III}$$

$$Q = \frac{25.5}{28} = 0.91 \quad \underline{II}$$

$$R = \frac{12.5}{12} = 1.04 \quad I$$

} Utility per unit length.

UNIT – XIII

HIGHWAY MATERIALS

Based on structural behaviour

1. Flexible pavement (or) Bituminous pavement (or) Black top road
2. Rigid pavement (or) cement concrete pavement (or) white top road

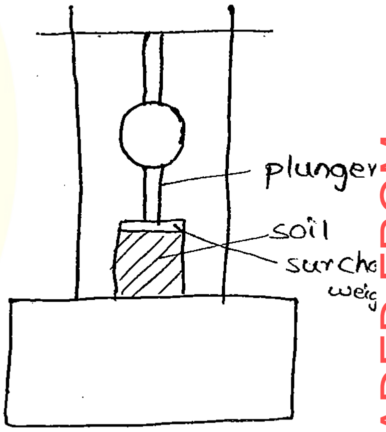
Sub grade soil characteristics :-

CBR Test :-

It is an emprical method by considering physical properties and strength parameters of sub grade soil for desig of flexible pavement.

CBR percentage is calculated at 2.5 mm and 5.0 mm penetration.

Time	penetration mm	proving ring reading	Load kg.
1 min	1.25	x_1	y_1
2 min	2.5	x_2	y_2
3 min	3.75	x_3	y_3
4 min	5.0	x_4	y_4
5 min	6.25	x_5	y_5



$$\text{CBR \%} = \frac{\text{Load carried by soil specimen at given penetration}}{\text{Load carried by aggregates at the same penetration}} \times 100$$

$$\text{(i) CBR \% @ 2.5 mm} = \frac{\text{Load carried by soil specimen @ 2.5 mm}}{\text{Load carried by aggregates @ 2.5 mm}} \times 100$$

$$= \frac{y_2}{1370} \times 100$$

Load carried by aggregates @ 2.5 mm penetration = 1370 kgs.

(ii) CBR % @ 5.0 mm $= \frac{y_4}{2055} \times 100$

Load carried by aggregates @ 5.0 mm penetration = 2055 kgs.

CBR % 2.5 mm > CBR % 5.0 mm

→ The maximum these two values is actual CBR % of subgrade soil.

Area of plunger (A) = 19.6 cm^2

pressure created by plunger = P

$$\text{Load} = \frac{P}{A}$$

As the CBR value increases the required thickness of pavement will be decreases.

Ex:-) the following test results were obtained by CBR test on subgrade soil. Then CBR of soil is.

penetration	2.5	5.0
Load	55	78

A) CBR @ 2.5 mm $= \frac{55}{1370} \times 100$

$= 4.01\%$

CBR @ 5.0 mm $= \frac{78}{2055} \times 100$

$= 3.79\%$

$$\boxed{\text{CBR of soil} = 4.01\%}$$

→ The function of surcharge weights is to (equal distribution of load) (or) simulate the effect of flexible pavements.

Plate bearing test:-

This test is used to find a) modulus of subgrade reaction (K) b) Modulus of elasticity of soil (E).

Modulus of subgrade reaction (K):-

75 cm ϕ plate is used in this test.

The pressure sustained for unit deformation of subgrade soil.

$$K = \frac{\text{pressure}}{\text{Deformation (or) settlement}} = \frac{kg}{cm^2/cm} = \frac{kg}{cm^3}$$

a. 0·7 kg/cm² (P) to settlement.

Standard pressure 0·7 kg/cm² and standard settlement 1·25 mm are considered for this experiment.

If smaller size of the plate 30 cm ϕ plate is used to find K value then the relation is K corresponding to 75cm ϕ is equal to K corresponding to 30 cm ϕ × 0·5

$$K_{75}\ cm\ \phi = K_{30\ cm\ \phi} \times 0{\cdot}5$$

The modulus of subgrade reaction (K) is used in design of rigid pavement i.e., C.C. pavement.

Modulus of elasticity of subgrade soil:-(E)

$$E = \frac{1{\cdot}18\ pa}{\delta}$$

where

P = pressure or stress in kg/cm²

a = Radius of plate in cm

δ = Deformation or settlement in cm

E = kg/cm².

EX:- Modulus of ~~Elasticity~~ subgrade reaction using 30 cm ϕ plate is 200 N/cm³ the value of same using standard plate will be.

A) $K_{75\ cm\ \phi} = K_{30\ cm\ \phi} \times 0.5$

$= 200 \times 0.5$

$= 100\ N/cm^3$

EX:-) A plate load test conducted with a 75 cm ϕ plate on soil sub grade given a deflection of 2.5 mm under a stress of 800 N/cm². The modulus of elasticity of subgrade soil in KN/cm² is

A) $\delta = 2.5\ mm = 0.25 cm$

$a = \frac{75\ cm\ \phi}{2} = 37.5\ cm$

$P = 800\ N/cm^2$

$E = \frac{1.18\ pa}{\delta} = \frac{1.18 \times 800 \times 37.5}{0.25}$

$= 141600\ N/cm^2$

$E = 141.6\ KN/cm^2$

Marshall stability test

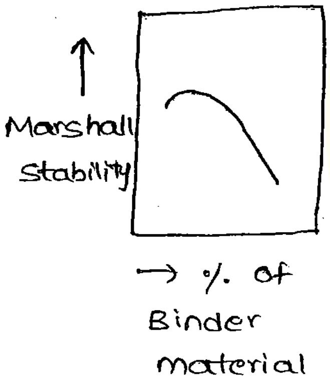
1. This test is used for hot mix process for design of bituminous mixes scientifically.

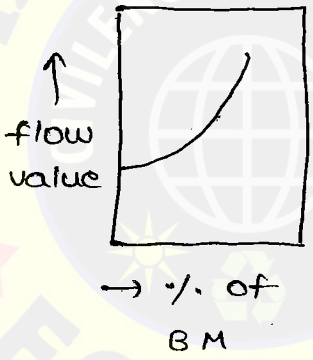
2. The optimum binder content for the given type of aggregates is the average of the binder content corresponding to maximum stability, max bulk density and percent air voids. 3 to 5.

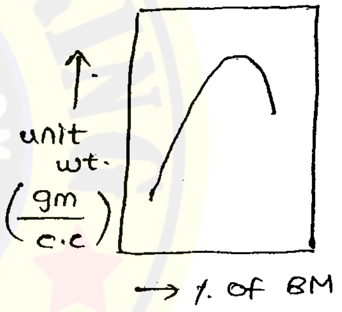
3. The material used for bituminous construction are coarse aggregate and fine aggregate filler material and binder materi

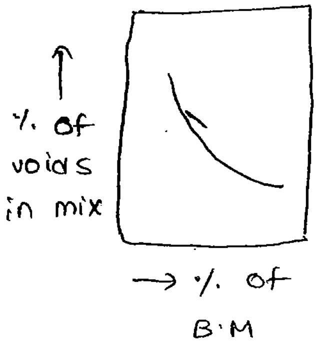
*

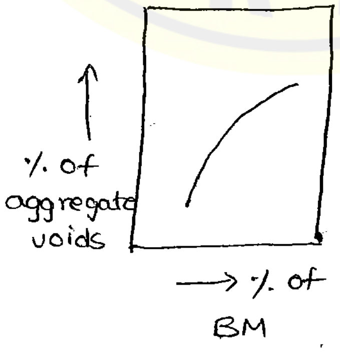
The graphs for different parameters of marshall stability test are as follows.











4. The theoritical sp.gravity of the mix $= \frac{100}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_4}{G_4}}$

where, w_1 = % weight of coarse aggregate.

G_1 = sp. gravity of coarse aggregate.

W_2 = % weight of fine aggregate

G_2 = sp. gravity of fine aggregate.

W_3 = % weight of filler material.

G_3 = sp. gravity of filler material

W_4 = % weight of binder material

G_4 = sp. gravity of binder material.

5. percentage of volume of air voids (V_a) = $\frac{G_t - G_m}{G_m} \times 100$ %

where, G_t = theoretical unit wt. of mix.

G_m = measured unit wt. of mix

6. volume of binder material (V_b) = $\frac{W_b}{G_b} \times G_M$ %

where, W_b = % weight of binder material

G_b = sp. gravity of binder material

G_M = Measured unit weight.

7. voids in mineral aggregates (VMA) = $V_a + V_b$ %

8. voids filled with binder material (VFB) = $\frac{V_b}{VMA} \times 100$

Ex:- In the marshall method of mix design the coarse aggregates, fine aggregates filler material and bitumen having respective sp. gravities 2.62, 2.72, 2.7 and 1.02 are mixed in the ratio of 55, 34.6, 4.8 and 5.6%. The theoretical sp. gravity of the mix is?

A. Theoretical sp. gravity = $$\frac{100}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_4}{G_4}}$$

$$= \frac{100}{\frac{55}{2.62} + \frac{34.6}{2.72} + \frac{4.8}{2.7} + \frac{5.6}{1.02}}$$

$$= 2.44$$

Ex:- The specific gravities and weight of different materia used for preparation of Marshall mould are given belo The volume and weight of marshall mould are 475 cm³ and 1100 gm respectively. Find voids filled with bitume

A.

	A_1	A_2	A_3	A_4	Bitumen	
wt. (gm)	825	1200	325	150	100	⇒26 g
Sp. gravity	2.63	2.51	2.46	2.43	$\boxed{1.05} \rightarrow G_b$	

A. Theoretical sp. gravity

$$= \frac{100}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_4}{G_4} + \frac{W_5}{G_5}}$$

$$= \frac{100}{\frac{825}{2.63} + \frac{1200}{2.51} + \frac{325}{2.46} + \frac{150}{2.43} + \frac{1\cdot}{1\cdot}}$$

$$A_1\,\% \Rightarrow \frac{825 \times 100}{2600} = 31.7\,\%$$

$$A_2\,\% \Rightarrow \frac{1200 \times 100}{2600} = 46.15\,\%$$

$$A_3\,\% \Rightarrow \frac{325 \times 100}{2600} = 12.5\,\%$$

$$A_4\,\% \Rightarrow \frac{150 \times 100}{2600} = 5.7\,\%$$

$$\text{bitumen} \Rightarrow \frac{100 \times 100}{2600} = 3.8\,\% \Rightarrow W_b$$

Theoretical ~~unit~~ sp. gravity

$$= \frac{100}{\frac{31.7}{2.63} + \frac{46.15}{2.51} + \frac{12.5}{2.46} + \frac{5.7}{2.43} + \frac{3}{1\cdot}}$$

$$= \frac{100}{12 + 18.38 + 5.08 + 2.34 + 3.61}$$

$$= \frac{100}{41.41}$$

$$= 2.41$$

Theoretical unit weight $(G_t) = 2.4\ gm/c.c$

$$G_M = \frac{1100}{475} = 2.31$$

% of voids $(V_a) = \frac{G_t - G_M}{G_M} \times 100$

$$= \frac{2.4 - 2.31}{2.31} \times 100$$

$$= 3.89\ \%$$

volume of binder bitumen $(V_b) = \frac{W_b}{G_b} \times G_M$

$$= \frac{3.8}{1.05} \times 2.31$$

$$= 8.36$$

voids in mineral aggregates $= 3.89 + 8.36 \quad (V_a + V_b)$

$$= 12.26\ \%$$

voids filled with binder material $= \frac{V_b}{VMA}$

$$= \frac{8.36}{12.26} \times 100$$

$$= 68.24\ \%$$

Ex:- A bitumen mixer contain 60% coarse aggregate, 35% fine aggregate, 5% bitumen. Find unit wt. of the mixer after compaction with 7% air voids. sp. gravity of coarse aggregate 2.72, sp. gravity of fine aggregate 2.66, sp. gravity of bitumen 1.0.

A. theoritical sp. gravity of the mix $= \frac{100}{\frac{60}{2.72} + \frac{35}{2.66} + \frac{5}{1.0}}$

$$= 2.48$$

theoretical unit wt. of the mix $(G_t) = 2.48\ gm/cc$

$$V_a = \frac{G_t - G_M}{G_M} \times 100$$

$$7 = \frac{2.48 - G_M}{G_M} \times 100$$

$$7G_m + \overset{100}{G_M} = 248$$

$$G_M = \frac{248}{107}$$

$$G_M = 2.32 \text{ gm/cm}^3.$$

* Tests on aggregate :-

1. Crushing test :- (strength)

$$\text{Crushing value of aggregate} = \frac{\text{Powder wt.}}{\text{Initial wt. of aggregate}} \times 1c$$

→ A total load of 40 tons @ 4 tons/min is applied fo 25 to 10 mm size of aggregate and 10 tons at the rate of 1 ton/min is applied for below.

→ Base coarse of cement concrete road should not exceed 45% and surface coarses should not exceed 30%.

2. Impact test :-

Impact test is used for toughness of aggregates

Resistance to sudden application of loads is toughness

→ 13.5 to 14 kg weight of hammer, height of fall of hammer 38 cm and 15 blows

→ For base coarses of cement concrete road should note exceed 45% and surface coarse should not exceed 30%.

→ The aggregate crushing and Impact value are simila closing the within limits are majority of aggregates. But in case of fine grained highly siliceous aggregates the Impact values are higher than crushing value.

3. Abrassion test :-

Abrassion test is used for Hardness of aggregates. Rubbing action between two materials is known as Abrassion.

Abrassive charge in the form of steel balls used in this test.

a. Los angeles abrassion
b. Dorry abrassion
c. Deval abrassion

A B C D	grade of aggregate	5 kg	500 rpm
E F G	grade of aggregate	10 kg	1000 rpm

→ The maximum value of abrassion for surface coarses both for bituminous and cement concrete road is 30%.

→ Surface coarse of WBM is 40%.

→ Attrition means the rubbing action between same materials.

→ The deval abrassion test is used for finding abrassion value of aggregates without using steel balls.

4. Shape test :-

The shape test are

1) Flakiness index
2) Elongation index
3) Angularity number.

Flakiness index :-

The percentage weight of aggregate whose least dimension or thickness is less than 0.6 times mean dimension of aggregates.

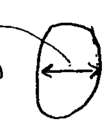
1. passing weight of aggregates is considered
2. Then Flakiness Index (FI) = $\frac{\text{Total passing wt. of aggre}}{\text{Total wt. of aggregates}} \times$
3. It is not applicable to below 6.3 mm size of aggregate
4. Thickness gauge is used.

Size of aggregate (mm):-

63-50 mm, 50-40, 40-31.5, 31.5-20, 20-16, 16-12·

12.5-10, 10-6.3.

width of the (63-50 mm) is $\frac{0.6\,(63+50)}{2} = 33.9$ mm



width of the (50-40 mm) is $\frac{0.6\,(50+40)}{2} = 27$ mm

Elongation Index:-

The percentage weight of aggregate whose greater dimension or length is greater than 1.8 times the mean dimension of aggregate.

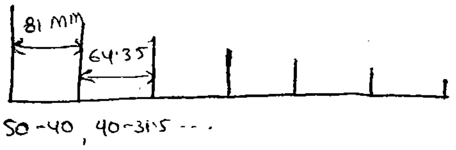
Retained weight of aggregates is considered.

Elongation index = $\frac{\text{Total retained weight of aggregates}}{\text{Total weight of aggregates}} \times 100$

It is not applicable to below 6.3 mm size of aggrega

→ Length gauge is used.

size of aggregate starting with 50-40 mm, 40-31.5 mm...



Size of apperture = $\frac{1.8\,(50+40)}{2}$ = 81 mm

size of apperture = $\frac{1.8\,(40+31.5)}{2}$ = 64.35 mm

EX:- In a 500 gm sample of coarse aggregates there are 100 gm flaki particles and 80gm elongated particles. what are the flakiness and elongation Indices in total is?

[✓ a) 40%] b) 36% c) 18% d) 4%

A)
$$\left.\begin{array}{l} F\,I = \frac{100}{500} \times 100 = 20\% \\[2em] E\cdot I = \frac{80}{400} \times 100 = 20\% \end{array}\right\} 40\%$$

Note:- In flakiness index there are 100 particles are passed out of 500. the remaining 400 particles are used for Elongation Index.

Angularity number:-

It denotes the void content of single size of aggregates in excess of that is obtained with spherical size of aggregates. It ranges from 0-11

$$\text{Angularity Number} = 67 - \frac{100W}{Ca}$$

w = weight of aggregate

c = weight of water

a = sp. gravity of aggregates

5. Water absorption test:-

It measures the porosity of the aggregate. water absorption should be < 0.6% designated for bituminous road surface.

The sp. gravity of the aggregates used for road construction ranges from 2.5 to 3.0

6. soundness test:-

It is used for resistance to weathering action. Sodium sulphate and Magnesium sulphate solutions are used for this experiment. The average loss of weight after 10 cycle should not exceed 12% when tested with sodium sulphate and 18% when tested with Magnesium sulphate.

7. stripping value of aggregates:-

IRC as specified the maximum stripping value 5% for the aggregates used for bituminous construction.

Silica a common mineral of Igneous rocks having greater attraction with water than bituminous binder material

Types of binder material used for bituminous construction:-

1. Bitumen :-

It is a hydro carbon obtain by fractional distillation of petroleum. It is soluble in carbon-di-sulphide and carbo tetra chloride.

2. Tar :-

It is obtain by destructive distillation of coal and wood in absence of air. It is soluble in toluene and free carbon content is more.

Road Tar, RT - 1 having low viscosity

RT - 2

:

RT - 5 having high viscosity

3. Asphalt :-

The natural available bitumen is called Asphalt. Bitumen contains certain minerals that is Asphalt. Bitumen, Tar, Asphalt are used for Hot mix process.

4. Cut back bitumen:-

When bitumen mixed with volatile diluent (or) Solvent. that is called cut back bitumen

Types of cut back bitumen:-

1. Rapid curing cut back bitumen: (RC)

When bitumen is mixed with petroleum distillate such as naptha (or) gasolene

2. Medium curing cutback bitumen:- (MC)

Bitumen is mixed with kerosene (or) Light diesel oil.

3. slope curing cut back bitumen:- (SC)

When bitumen is mixed with high boiling point gas oils.

→ These are used in surface dressing bitumen macadam and soil bitumen stabilization.

5. Emulsions:-

Bitumen is suspended in a finely divided condition in water medium and stabilized with Emulsifier

The methodes used for preparation of Emulsions

1. colloid mill method or High speed Mixer method.

Emulsions are used for maintainance and patch repair works. It also used in soil stabilization in desert areas.

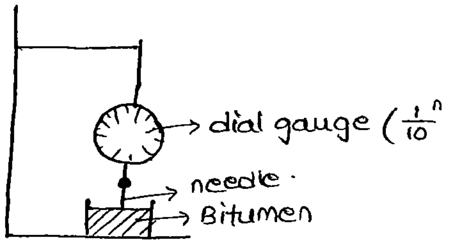
Above two materials are used for cold mix process.

Ex:- RC 1, MC 1, SC 1 indicates three different cutback bitumen having same viscosity.

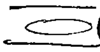
Tests on Binder Material :-

1. penetration test :-

It is used to find softness or Hardness of binder material.



Intial reading	Final reading	D/f
0	80	80
81	160	79



0 - 80 grade ⇒ Hard

80 - 225 grade ⇒ Medium

> 225 grade ⇒ soft

Ex:- A 45 indicates the penetration value of binder materi lies between 40-50 and binder material is extractec from Assam refineries.

S 25 indicates the binder material having penetration value ranges from 20 - 30 and binder material is extracted from other sources.

→ The standard test temperature is 25°c. The shape of tip of the needle is conical.

2. Ductility Test :-

Improving the physical interlocking of aggregates. Briquette mould is used for conducting test. Minimum cros section of the Briquette mould is 10 mm x 10 mm. This mould is fixed at one end and other end is pulled under a pressure of 50 mm/min.

→ The ductility value should not be less than 50cm for bituminous construction.

3. Viscosity test :-

Inverse of fluidity is known as viscosity. It is expressed in terms of seconds. It is measure by finding the time taken by 50ml of the sample passing through specified orifice at a given temperature. Orifice viscometer is used for Tar and cut back bitumen.

Capillary tube viscometer is used for bitumen.

4. Specific gravity :-

The specific gravity of pure bitumen ranges from 0.97 to 1.02.

The specific gravity of tar ranges from 1.1 - 1.25.

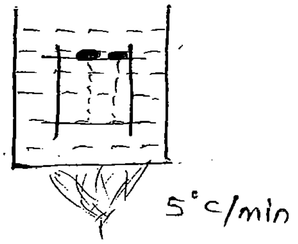
→ It measures the quality of binder material.

→ In case the binder material contains certain impurities the specific gravity will be higher.

→ pycnometer method and balance method are used for finding specific gravity.

5. Softening point :-

The minimum temperature where the binder material having certain degree of softness.



→ Ring and Ball apparatus is used

→ When water heats ; the ball fall down and touches the bottom plate. Note the temperature. That temperature is a softening point.

→ For material softening point is above 80°c, glycerine is used as heating medium.

6. Flash and Fire point test:-

The lowest temperature where the vapour of substance catches the fire in the form of flash. The instrumen used to conduct the test is pensky martens (or) closed cu and open cup are used for this test.

→ It will restrict the mixing temperature and application temperature well within the limits.

P.Q No:- 48

29. 1.8 Mean dimension for elongated test

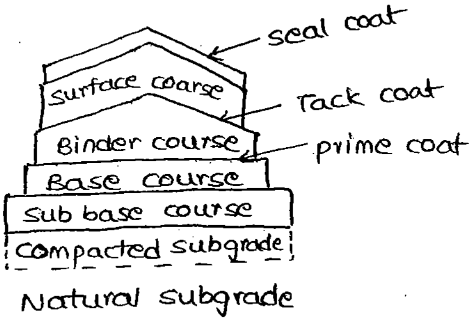
$$1.8\left(\frac{50+40}{2}\right)$$

$$= 81\ mm$$

2-11-2014

UNIT - 14

PAVEMENT DESIGN



Cross of a flexible pavement :-

The estimated traffic at the end of design life of pavement

$$A = P(1+r)^{x+n}$$

where,

P = at present traffic.

r = annual rate of growth of traffic.

x = time required for construction of road

n = design life of the pavement.

$$\text{contact pressure} = \frac{\text{wheel load}}{\text{contact area}}$$

$$\text{Rigidity factor} = \frac{\text{contact pressure}}{\text{tyre pressure.}}$$

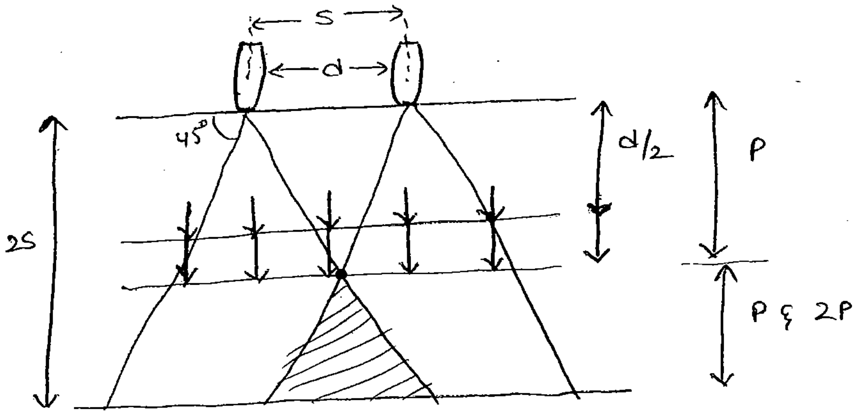
R.F = 1, for tyre pressure is 7 kg/cm^2

R.F > 1, for tyre pressure is low, < 7 kg/cm^2

R.F < 1, for high tyre pressure > 7 kg/cm^2

Equivalent single wheel load (ESWL) :-

Multiple wheel load are converted to Equivalent single wheel load and this value is used for design of pavements.



d = clear distance between two wheels

s = centre to centre distance between two wheels.

→ upto d/2 each wheel load be acting independently. after this point the stresses induced due to each whee load begins to overlap.

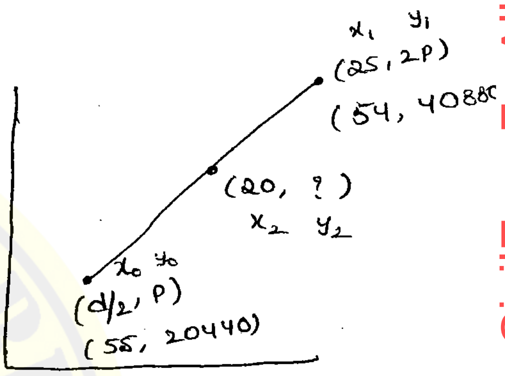
→ At any depth greater than '2s' is considered to be equivalent to a single wheel load of magnitude 2×p

P.g NO:- 54

1. d = 11 cm

S = 27 cm

P = 20440 N



$$\frac{\log y_1 - \log y_0}{\log x_1 - \log x_0} = \frac{\log y_2 - \log y_0}{\log x_2 - \log x_0}$$

$$\frac{\log(40880) - \log(20440)}{\log(54) - \log(5.5)} = \frac{\log y_2 - \log(20440)}{\log(20) - \log(5.5)}$$

$$0.30 = \frac{\log y_2 - 4.31}{0.56}$$

$$\log y_2 = 0.168 + 4.31$$

$$y_2 = 30190 \text{ N}$$

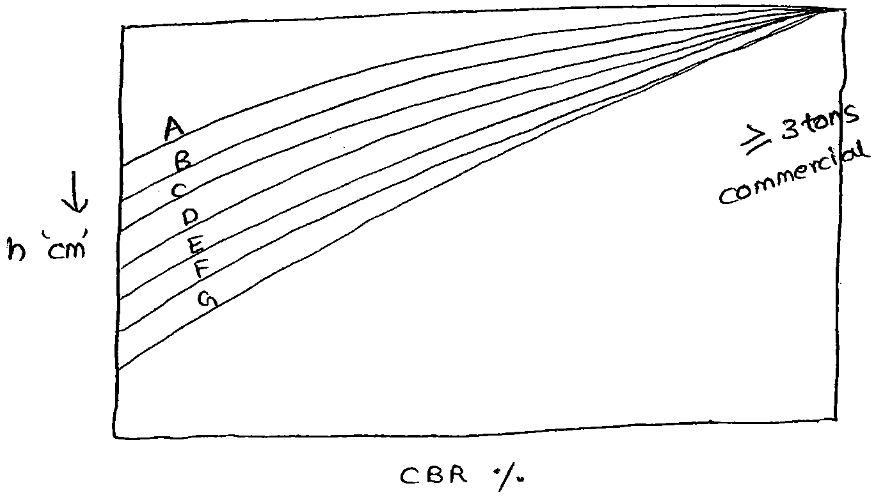
Design of flexible pavement:-

It transmit the load to the lower layers by grain to grain structure.

It reflect the deformation of the lower layers on to the surface of pavements.

Aggregate Interlocking property is major criteria for design of flexible pavement.

C.B.R. method for design of flexible pavement:-



≥ 3 tons commercial veh/day

A — 10 - 15

B — 15 - 45

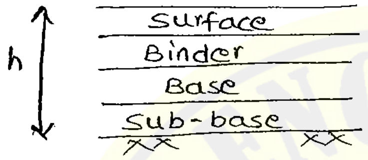
C — 45 - 150

D — 150 - 450

E — 450 - 1500

F — 1500 - 4500

G — Above 4500



IRC - 37 used for design of flexible pavements.

IRC - 37 - 1984 it is applicable to design traffic upto 30 million standard Axles.

IRC 37 - 2001 it is applicable to design traffic upto 150 million standard Axles.

The design traffic is considered in terms of cumulative no. of standard Axles i.e., denoted with N

$$N = \frac{365 \times A \times [(1+r)^n - 1] \times D \times F}{r}$$

where

A = initial traffic in the year of completion of road construction.

r = annual rate of growth of traffic.

D = lane distribution factor

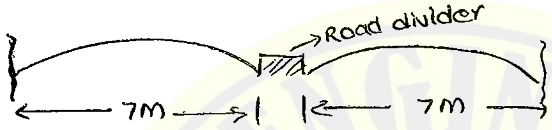
F = vehicle damage factor.

→ The lane distribution factor corresponding to the lane which is carrying maximum traffic.

1. For single lane road, lane distribution factor is 1
2. For two lane single carriage way is 7m, lane distribution factor is 0·75
3. Four lane single carriage way is 14m, lane distribution factor is 0·40

In above three cases the traffic moving in both the directions is considered.

4. Dual carriage way :-
   a. Dual two lane carriage way, lane distribution factor 0·7



   b. Dual three lane carriage way is 0·60
   c. Dual four lane carriage way is 0·45

In above case the traffic moving in one direction is considered.

Vehicle damage Factor (F) :-

Initial traffic volume (CV/day)	Terrain	
	plain	Mountaineous
0 – 150	1·5	0·5
150 – 1500	3·5	1·5
>1500	4·5	2·5

By using 'N' value and CBR (%) of subgrade soil refers the tables in IRC 37 – 2001.

1. Sub grade construction should have dry density greater than or equal to 1·75 gm/cm³.

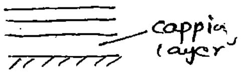
2. C.B.R of sub grade soil is calculated atleast for 3 samples for each type of soil.

3. The permissible maximum variation with in the C.B.R. values from the three specimens is as follows.

C.B.R (%)	Max. variation
upto 5	± 1
5 - 10	± 2
11 - 30	± 3
31 above	± 5

4. If variation is more than above values the design CBR value should be the average of atleast six samples.

5. If CBR value of the sub grade is less than 2%. A capping layer of thickness 150mm should be provided in addition to sub base course.



6. A blanket course of thickness 225 mm should be provided on the expansive soil sub grade as a sub-base course.

7. The top 50 cm of sub grade is important for the design.

8. The CBR test should be performed on remoulded soil (disturbed soil) with static compaction

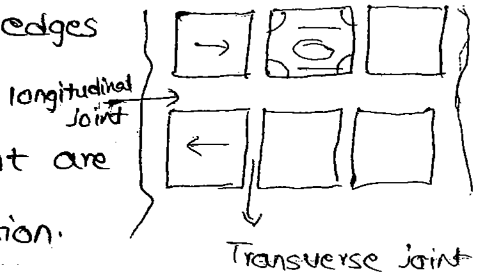
Design of Rigid pavement :-

1. The flexural strength of concrete is major criteria for design of rigid pavement.

2. The minimum characteristic compressive strength 280 kg/cm^2. min. F.S = 40 kg/cm^2 considered for design.

3. The critical load positions are interior, edges and corner locations.

4. The stresses caused in the rigid pavement are due to wheel load, temperature and friction.



Wester ghaurds stress equation due to wheel load:-

1. $$S_i = \frac{0.316\,P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right)+1.069\right]$$

where

S_i = wheel load stress at interior location in kg/cm²

P = wheel load in kgs.

h = Thickness of pavement in cms.

l = radius of relative stiffness in cm.

b = radius of resisting section in cm.

E = young modulus of concrete kg/cm²

K = modulus of sub grade reaction in kg/cm³

μ = poission ratio of concrete.

$$l = \left[\frac{E\,h^3}{12K(1-\mu^2)}\right]^{1/4}$$

$$b = \sqrt{1.6a^2+h^2} - 0.675h \quad \text{when } \frac{a}{h} < 1.724$$

$$b = a \qquad \frac{a}{h} > 1.724$$

a = radius of wheel load distribution in cm.

2. $$S_e = \frac{0.572\,P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right)+0.359\right]$$

where

S_e = wheel load stress at edge location in kg/cm²

3. $$S_c = \frac{3P}{h^2}\left[1-\left(\frac{a\sqrt{2}}{l}\right)^{0.6}\right]$$

where

S_c = wheel load stress at corner location in kg/cm².

II. Temperature (or) warping stresses :-

1. $$S_{t(i)} = \frac{E \cdot e \cdot t}{2}\left[\frac{C_x + \mu C_y}{1 - \mu^2}\right]$$

where

e = thermal expansion of concrete per °C

t = temperature difference b/w top and bottom surfaces

C_x and C_y = warping stress coefficient

l_x = length of pavement section

l_y = width of pavement section

$$\left.\begin{aligned} C_x &= \frac{L_x}{l} \\ C_y &= \frac{L_y}{l} \end{aligned}\right] \text{Design chart.}$$

2. $$\left.\begin{aligned} S_{t(e)} &= \frac{C_x \cdot E \cdot e \cdot t}{2} \\ &\text{(or)} \\ S_{t(e)} &= \frac{C_y \cdot E \cdot e \cdot t}{2} \end{aligned}\right] \longrightarrow \text{Max. of two is considered.}$$

3. $$S_{t(c)} = \frac{E \cdot e \cdot t}{3(1-\mu)} \times \sqrt{\frac{a}{l}}$$

III. Frictional stress :-

1. $$S_f = \frac{WLf}{2\times10^4}$$

where

W = unit weight of concrete in kg/m³

L = Length of pavement section

f = coefficient of subgrade restraint

Critical combination of stresses :-

1. critical combination of stresses at edges and interior locations when pavement is ~~considered~~ constructed in summ

$$= W \cdot S + T \cdot S - F \cdot S$$

Interior $= S_i + S_{t(i)} - S_{(f)}$

edge $= S_e + S_{t(e)} - S_f$

2. Critical combination of stresses at interior and edge location when pavement is constructed in winter

$$= WS + TS + FS$$

3. critical combination of stresses at corner location

$$= W \cdot S + T \cdot S$$

Ex:- calculate the radius of relative stiffness in cm for following data. $E = 3 \times 10^5$ kg/cm^2, $h = 18$ cm, $\mu = 0.15$ $K = 6$ kg/cm^3, $a = 15$cm.

A. $$l = \left[\frac{E h^3}{12k(1-\mu^2)}\right]^{1/4}$$

$$l = \left[\frac{3 \times 10^5 \times 18^3}{12 \times 6 (1 - 0.15^2)}\right]^{1/4}$$

$$l = 70.61 \text{ cm}$$

$\frac{a}{h} = \frac{15}{18} = 0.83$. So $\frac{a}{h} < 1.724$ then

$$b = \sqrt{1.6a^2 + h^2} - 0.675h$$

$$= \sqrt{1.6 \times 15^2 + 18^2} - 0.675 \times 18$$

$$b = 14 \text{ cm}.$$

P.g NO:- 60

3. $S_i = 210\ N/mm^2$; $S_t = 90\ N/mm^2$; $S_f = 10\ N/mm^2$

combination in summer $= WS + TS - FS$

$= 210 + 90 - 10$

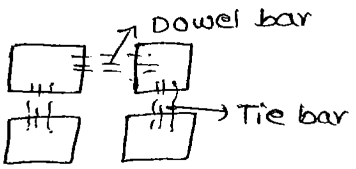
$= 290\ N/mm^2$.

Joints in Rigid pavement :-

Reinforcement is provided only at joints.

Longitudinal joints — Tie bars

Transverse joints — Dowel bar



Types of Transverse joints :

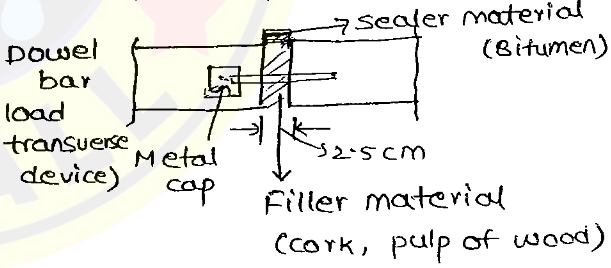
1. Expansion joint

2. contraction joint.

Expansion joint :-

These are provided to allow the expansion of pavement due to raise in temperature with respect to construction temperature.

2.5 cm gap is provided as expansion joint



Spacing of expansion joint

$$L_e = \frac{\delta'}{e(t_2 - t_1)}$$

where

δ' = Max. expansion of slab $= \frac{1}{2}$ of the gap provided

$\delta' = \frac{2.5}{2} = 1.25$ cm

e = thermal expansion of concrete for °c

t_2 = Max. temp in °c

t_1 = Construction temp in °c.

EX:- The width of expansion joint is 20 mm in c.c. pavemen the laying temperature is 20°c and maximum temp. in summ 60°c. Thermal expansion of concrete 10×10^{-6} per °c. The spacin of expansion joint should be

A. $L_e = \frac{\delta}{e(t_2-t_1)}$ $\delta = \frac{20}{2} = 10$ mm

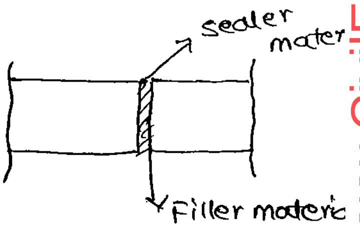
$= \frac{10}{10\times10^{-6}(60^\circ-20^\circ)}$

$= 25000$ mm

$L_e = 25$ m

Contraction joint:-

The contraction joints are provided to allow the contraction of concrete due to fall in temperature with respect to construction temperature.



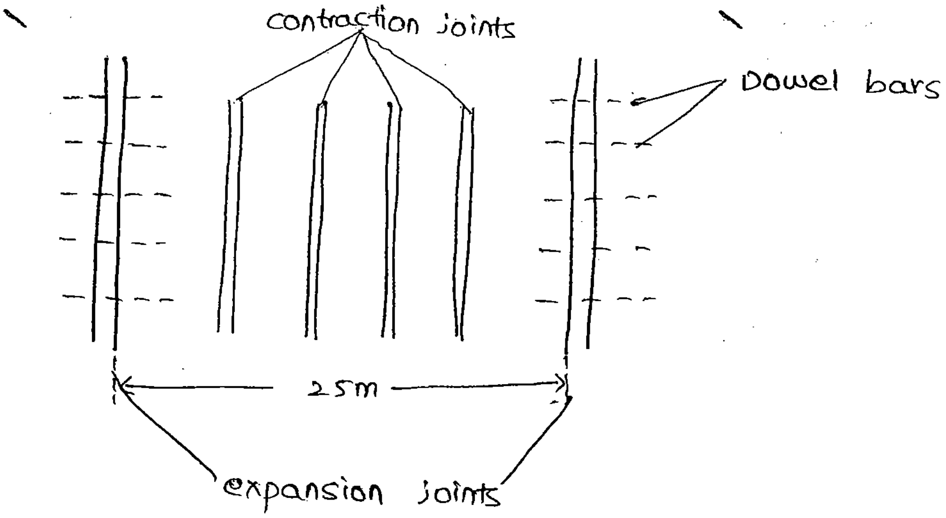
The spacing of contraction joint $L_c = \frac{2S_c}{wf} \times 10^4$

where

S_c = Allowable stress in tension in c.c. kg/cm^2

w = Unit wt. of concrete in kg/m^3

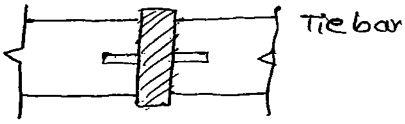
f = coefficient of subgrade restraint.



Longitudinal joint :-

1. The longitudinal joints are required width of pavement is more than 4.5m

2. The area of reinforcement (tie bars) for 1m length of joint $A_s = \frac{Bhfw}{S_s \times 100}$



where

B = width of pavement from edge of pavement to longitudinal joint.

$B = \frac{\text{width of pavement}}{2}$

h = thickness of pavement in cm.

f = coefficient of subgrade restraint.

w = unit wt. of concrete in kg/m^3

S_s = working tensile stress in steel in kg/cm^2

Length of the tie bar $(L_t) = \frac{d \times S_s}{2 \times S_b}$

where

d = Dia of the tie bar in cm

S_b = permissible bond stress of concrete in kg/cm^2

IRC-58 is used for design of Rigid pavement.

IRC-58 design of Rigid pavements for highways.

1. Legal axial loads in India
2. single axial - 10.2T
3. Tandom axial - 9T
4. Tridem axial - 24T

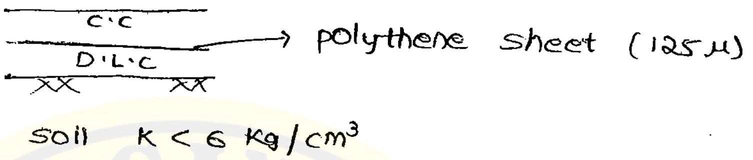
cumulative no. of standard axle during design period of pavement $C = \frac{365 A [(1+r)^n - 1]}{r}$

where, A = initial no. of ~~standard~~ axles ~~during design~~ perd

r = annual rate of growth of traffic.

n = Design life of pavement.

5. If 'k' value of subgrade is less than 6 kg/cm³, the cement concrete payment should not construct directly o the subgrade soil. A drying lean concrete (DLC) has a su base course is recommonded for construction of cement concrete pavement.



6. A separation membrane of minimum thickness is 125μ is recommonded to reduce the friction b/w a D.L.C. layer and cement concrete layer.

7. Recommonded dowel ~~has~~ bars has based on slab thickne

Slab thickness	Dia (cm)	Length (mm)	spacing
20	25	500	250
25	25	500	300
30	32	500	300
35	32	500	300

Ex:- If the load warping (nothing but temperature) and friction stresses in a cement concrete pavement 290, 90, 10 N/mm². The critical combination of stresses during summer mid da

A. W.S + T.S − F.S

290 + 90 − 10

$= \overset{370}{\cancel{290}}$ N/mm²

UNIT - 17

HIGHWAY CONSTRUCTION & MAINTAINANCE

Maintaince of construction and bitumen pavement:-

The various types of bitumen construction are

1. prime coat (Tack coat)
2. Surface dressing and seal coat
3. Grouted (or) penetration type of construction.
   - i) penetration macadam
   - ii) Buit up spray grout.
4. pre - mix methods
   - i) bituminous bond macadam (BBM)
   - ii) carpet
   - iii) bituminous concrete
   - iv) Sheet asphalt (or) Rolled asphalt
   - v) plastic Asphalt.

Prime coat:-

1. The main object plug in the voids of the forces surface and bonding the existing pavement.
2. Medium curing and slow curing and cut back bitumen are suitable.

Tacke coat:-

1. It is application of bituminous material over existing pavement surface.
2. High viscous material like bitumen is suitable
3. Surface dressing:-

It is a thin various course of pavement to protect base course.

Seal coat :-

(1) It is a impervious layer provided on the top of the surface of the pavement.

ii) It will seal the surface not to enter the rain water

iii) It will develop the skid resultant texture.

Penetration macadam:-

1. It is used as a base course (or) binder course

2. If bitumen penetrated entire depth of compacted aggregate then it is called full grout.

3. If binder material penetrated half of depth of the compacted aggregate then it is called semi-grout.

Built up spray grout :-

It is used for strengthening of existing bituminous pavement.

Total compacted thickness of 75 mm is provided.

Pre mix method:-

Nothing but hot mix process.

Advantages:-

1. It is possible to coat each particle of aggregate with binder material.

2. The quantity of binder material is less when compare t penetration macadam.

3. Strength of the mix is more.

a. BBM :-

1. It is considered to be superior than other base course like WBM with respect to low dispersion characteristics and durability.

b. carpet :-

The course aggregate of soils 12.5 to 10 mm mixed with binder materials like bitumen (or) far used as a surface course.

Bituminous concrete:-

1. It is also known as dense graded bituminous construction
2. It is a combination of coarse aggregate, fine aggregate, filler materials and bitumen.
3. Marshal stability method is used for design.

Sheet (or) Rolled Asphalt :-

It consists of course to fine sand mixed with binder material used as a dense layer.

plastic Asphalt :-

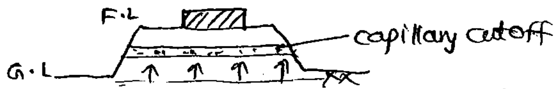
It is a combination of fine aggregate, Filler material and binder material. It is suitable for bridge deck slab for absorbing vibrations and has a property of self yielding of cracks with out leading.

Maintanance of Roads:-

1. Alligator cracking (or) Map cracking is most common type of failures occur in flexible pavements.
2. This occurs due to swelling and shrinkage of subgrade soil and weakness of base course.
3. Reflection cracking is observed in bituminous overlay over C.C. pavement.

↓ addition of thickness of pavement existing.

4. Mud jacking is remedial measure for mud pumping
5. Benkleman beam, deflection beams are reflection studies used for design of flexible over lay over the flexible pavement.
6. Scaling in cement concrete pavement indicates overall detoriation of concrete.
7. Capillary ~~set~~ cut off is constructed to decrease the capillary rise of ground water.



8. The combination of aggregates screening and Binding material is called W.B.M.

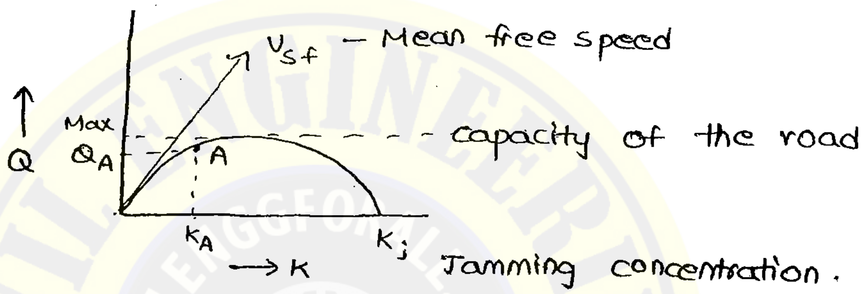
Traffic flow:-

Traffic flow theory is consult with three characteristics of road traffic i.e., speed (space V_s means speed, (c flo and concentration (k))

Concentration (k):-

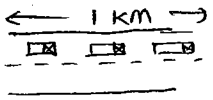
Concentration is also known as density. It is the no of vehicles present in 1 km length of the road, it is expres interms of vehicles/km.

Relation between traffic flow and concentration:-



1. The theoritical max. density is called Jamming concentrati
2. If vehicles are packed from end to end and avg. length of the vehicle is 5m then Jamming concentration is k_j

$$K_j = \frac{1000}{5} = 200 \text{ veh/km}$$



3. When vehicles are packed from end to end the flow (Q) is zero.
4. As a concentration increase, flow also increases and reached to max. which is equal to capacity of road.
5. The slope of line joining the origin 'O' to the point 'A' on the curve indicates the space mean speed.

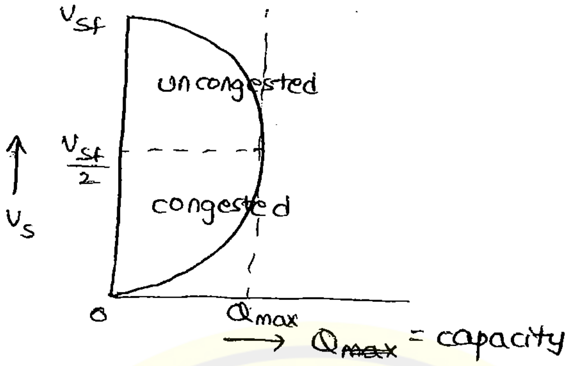
$$V_s = \frac{Q_A}{K_A} \quad (\text{or}) \quad \frac{Q}{A}$$

$$Q = V_s \cdot A$$

6. The slope of the line tangential to the curve drawn at origin 'o' represents the mean free speed.

7. The relation is given as $Q = V_{sf}\left[k - \frac{k^2}{k_j}\right]$

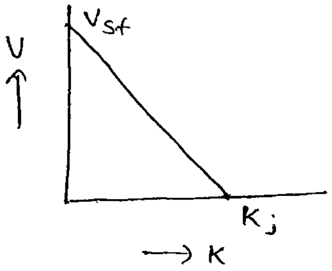
Relation between speed and traffic flow:-



1. When speed is zero. The flow (Q) also zero.
2. when flow is zero, the speed is max. corresponding to mean free-speed (V_{sf})
3. As the flow increases the speed decreases and the flow is reached to the max. corresponding to capacity of the road.
4. The speed corresponding to max. flow is $V_{sf}/2$. The relation between these two

$$Q = k_j\left[k_s - \frac{V_s^2}{V_{sf}}\right]$$

Relation b/w speed and concentration:-



1. when concentration is zero, the speed is max. corresponding to mean free speed (V_{sf})
2. when speed is zero, the concentration is max. corresponding to jamming concentration (K).

The relation b/w these two is given as

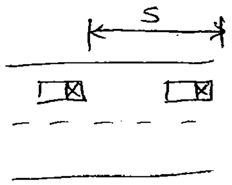
$$V_s = V_{sf}\left[1 - \frac{k}{k_j}\right]$$

Note:-

$$Q = Q_{max}$$

$$V_s = V_{sf}$$

$$k = k_j$$



$$Q = V_s \times k \quad , \quad Q_{max} = \frac{V_{sf} \times k_j}{4}$$

$$V_s = \frac{Q}{k}$$

concentration (k) is reciprocal of space head way 's'.

$$V_s = \frac{Q \times s}{1000}$$

where

s = space head way in 'm'.

If time head way 'h' then the relation is

$$s = \frac{h}{3600} \times V_s \times 1000 \quad , \quad h = sec$$

Ex:- The speed density relation ship on a given section of the road is given has $V_s = 70 - 0.7\,k$ then find capacity of the road.

A. This equation in the form of $V_s = V_{sf}\left(1 - \frac{k}{k_j}\right)$

compare these two equations

$$V_s = 70\left(1 - \frac{0.7}{70}k\right)$$

$$V_s = V_{sf}\left(1 - \frac{k}{k_j}\right)$$

$$V_{sf} = 70 \text{ kmph} \qquad k_j = \frac{70}{0.7}$$

Then capacity of the road $Q_{max} = V_{sf} \times k_j$

$$= 70 \times \frac{70}{0.7} \times \frac{1}{4}$$

$$= 1750 \text{ veh/hr}$$