

Introduction

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P.E.

Carrying men & material from one place to another place is Transportation.

Def for Transportation :-

Application of technology and scientific principles to the planning, development, Operation and management of facilities for any mode of Transportation in order to provide safe, comfortable, convenient, economical and environmentally compatible movement of people & goods.

Developing process :-

- Planning
- Preliminary designing
- Detailed designing
- Construction
- Operation
- Planning

Modes of Transportation :

* Railways

- Surface
- Under ground

→ Elevated ways (e.g. metro rails)

* Road ways

* Air ways

* water ways

* Pipe lines (Tunnel ways)

* Road ways

Characteristics Of Road Transportation

- * low capital investment
- * flexible service
- * more freedom to users
- * various types of vehicles can travel
- * one & only door-to-door service
- * cheaper & fastest

Scope Of Highway Engineering :-

- Planning & Location
- Alignment & Geometric factors
- Pavement Design
- Construction materials & Equipments
- Traffic utility & control
- Economic feasibilities
- Environmental Impact & Assessment

Modern Classification Of Roads :

1. National Highways — Express Way
2. State Highways
3. Major District Roads
4. Minor District Roads
5. Other Roads (i) Village Roads

Classification Of Roads in Metropolitan City :

1. Arterial Roads
2. Sub Arterial Roads
3. Collector Streets
4. Local Streets

Classification Based on Weather Conditions :-

1. All Weather Roads

2. Fair Weather Roads

Classification Based on pavement :-

1. Paved Roads Bituminous Roads

2 Unpaved Roads

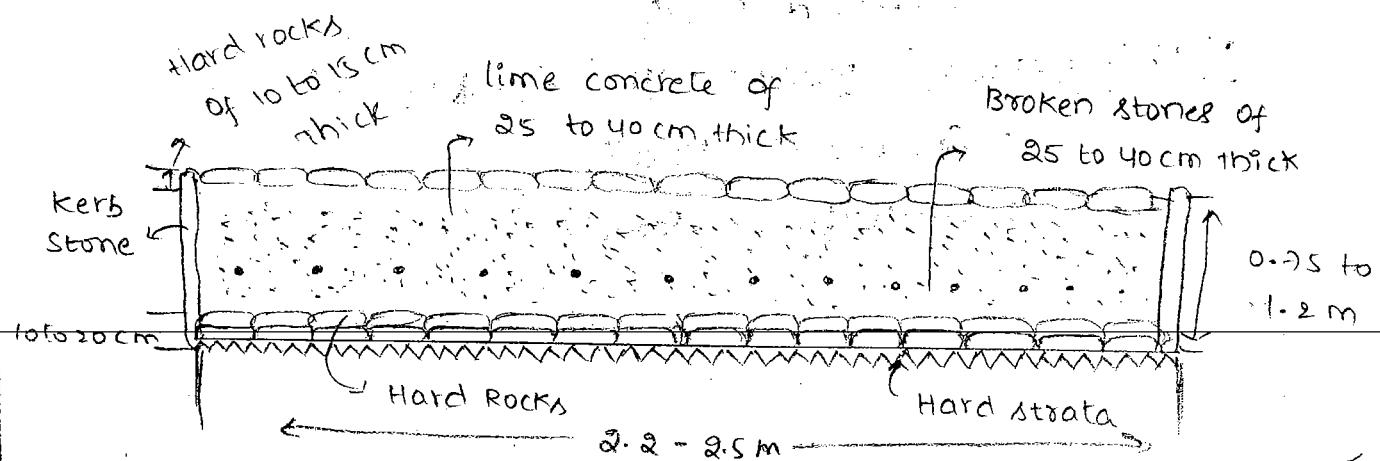
Classification Based on Surface :-

1. Surfaced Roads

2. Unsurfaced Roads

1. HIGHWAY PLANNING & DEVELOPMENT

Typical cross section of Roman Roads



→ There are Roman roads still working after 2000 yrs
this is because Scientific awareness of romans in
Olden days.

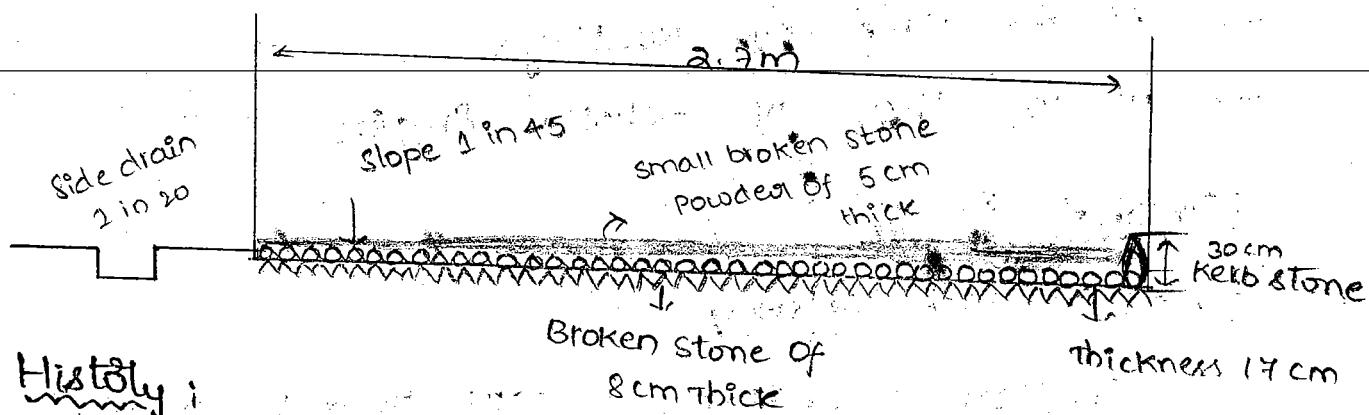
they followed 3 simple principles

1. they laid roads regardless of gradients
 2. upto a hard strata they trench & they remove loose soil
 3. They used to mix lime concrete and surfaced with Hard rocks even the vehicle wheel is hard to move.
- * Trench upto a Hard strata & remove loose soil
 - * Lay two layers of Hard rocks Of thickness 10-20 cm
 - * Fill broken stone Of thickness 25-40 cm
 - * Cover the broken stone with lime concrete of thickness 25 - 40 cm
 - * Surface the lime concrete with hard rocks of

10-15 cm

* Provide Kerb stones each sides of infrastructure to avoid percolation of water into it.

Tresaguet Construction :-



History :-

After Roman roads construction there is no other road construction was popular in any country.

At the time of Tresaguet Empire they initiated new road construction in France in 18th century.

- Stabilize the soil & compact.
- A layer of 8cm laid on the stabilized soil with broken stones.
- Broken stones are covered with 5cm layer thickness of small broken stones so that stone to stone gap is filled with broken stones.
- They maintain 1 in 45 slope to drain rain water.
- They covered the construction edges with 17cm Kerb stones.

→ they also provided side drains with slope of 1 in 20 to carry water from carriage way

The total height of the construction is 30 cm & the total width is 2.7 m

Highway Development in India : —

Highway Development in Ancient India :

- At the time of Harappa and Mohenjodaro
- At the time of Koutilya
- At the time of Ashoka Empire

Mughal Roads : —

Roads in 19th century : —

Jayakar Committee in 1927 to make a total plan of road pattern

Recommendations :

1. Capital Investment - govt 80% & people 20%
2. Extra tax on Petrol (Secondary Fund)
3. Semi Official Technical body → giving advices, giving standards like length of road, turnings width etc...
4. Research & Development panel

In 1929, second recommendation is implemented

In 1934, third recommendation is implemented

In 1950, fourth recommendation is implemented

Central Fund :

80% of government fund

- 20% of Taxes people who are using it

Indian Road Congress :- (I.R.C)

Established in 1934 - still working

Some specifications like maintenance, geometric designs, highway structure, traffic designs, structure designs etc...
Research materials like Bitumen & some powders

(C.R.R.I) Central Road Research Institute :

Established in 1950

Research Development be the main function of CRRI

National Highway act : -

Proposed in the year of 1956

It says the details

Highway Research Board H.R.B : -

Established in the year of 1973 Its only for highways

Motor Vehicle Act :

Established in 1939

Nagpur Road plan :

This is first road plan from 1943 - 1963

It is first 20 year road plan → design, Alignment, No. of routes

1951 - 1956

short road plans are → roads

First 5 year road plan

1956 - 1961

second 5 year road plan

For 100 sq km area the length of road should be

Second Road Plan :

Second 20 year Road plan established from 1961 - 1981

Third 5 year road plan from 1961 - 1966

Fourth 5 year road plan from 1969 - 1974

Per 100 sq km area, the road length should be 34.8 km
Around 1600 km Express way is proposed by second
20 year Road plan due to sudden increase in road
users

Lucknow Road plan

From 1981-2001 → Third 20 year Road plan

Per 100 sq km area the road length should be 46 km

This is the classification done by 3rd 20 year road plan

Primary classification : Express ways & National
Highways

Secondary classification : State Highways, major &
minor District Roads

Tertiary classification : Village Roads

Review of Highway Development in India after Independence :-

Before allotment of Jaykar committee, the length
of the road for 100 sq. km is 11.8 km

After allotment of Jaykar committee, the length of
road is increased according to 20 Year Road plan

1 st 20 year Road plan	- 16 km
2 nd 20 " "	- 34.8 km
3 rd 20 " "	- 46 km

This is due to the Mobility & population increment

Span of 1951-1981 → users of motor vehicle user
are 3,00,000 to 4,00,000

1951 - 81 → 5.4 Billion to 114 Billion → traffic tonnage
Passengers → 10 billion to 315 billion

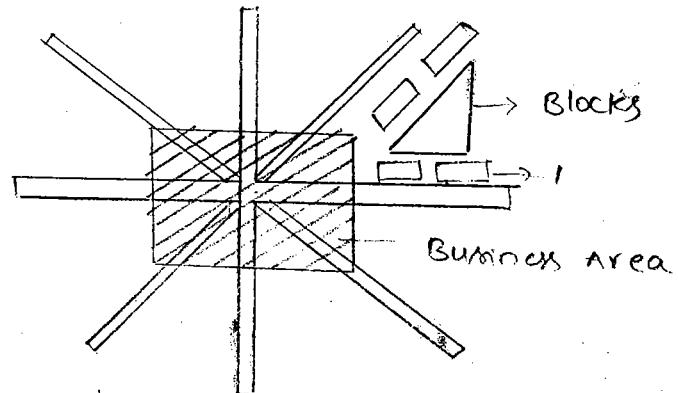
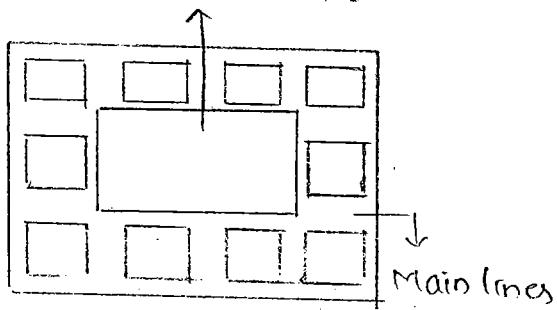
Necessity Of Highway planning :-

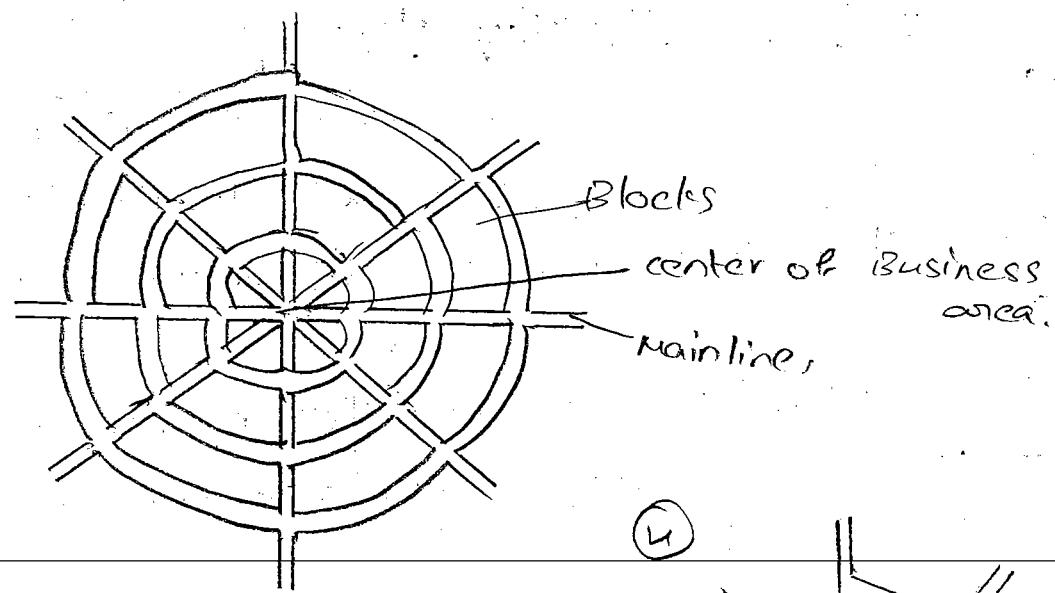
- To design safe and comfortable construction within low cost. The Economy of safe total project includes construction materials and equipment which are used for construction.
- To utilize the total road length upto design period
- To maintain day to day work progress in the planning period
- To use capital funds & construction materials in proper way.

Road Network patterns :-

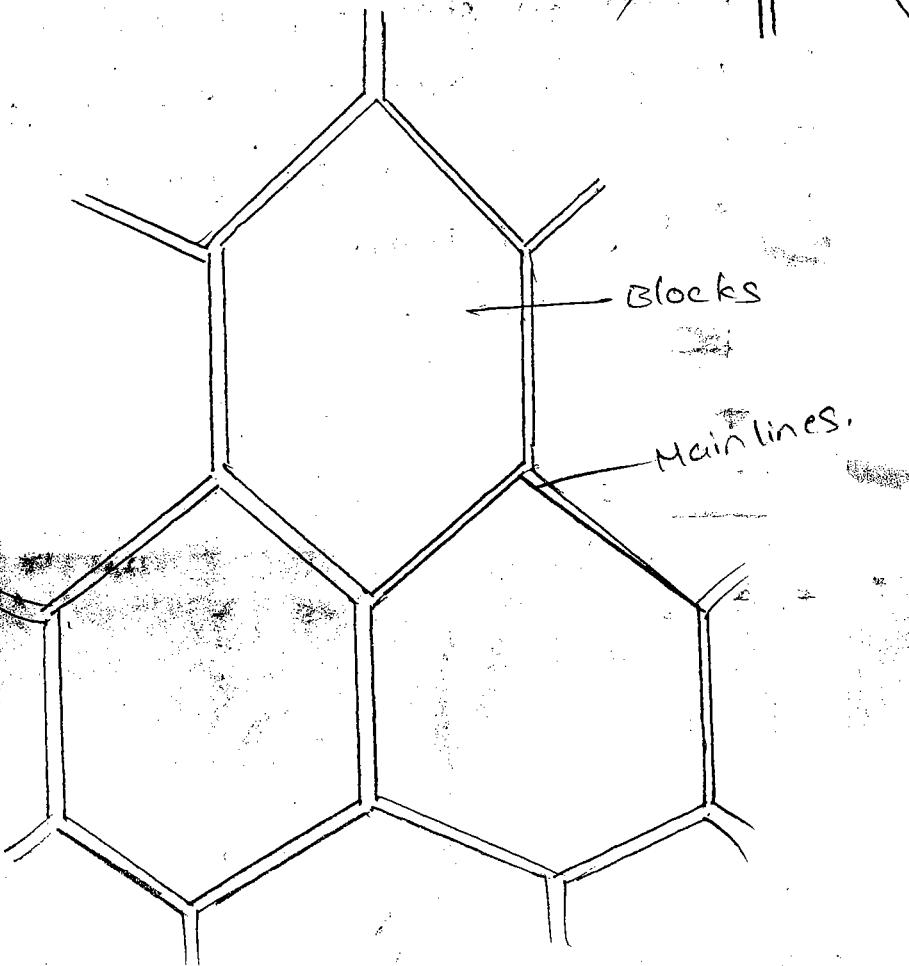
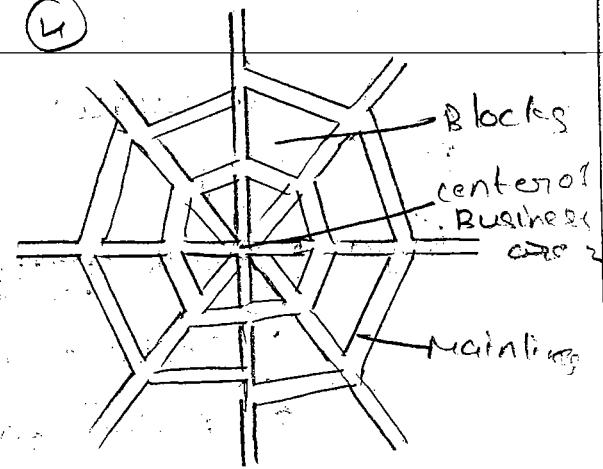
1. Rectangular & grid pattern
2. Radial (or) star and Block pattern
3. Radial (or) star and circle pattern
4. Radial (or) star and grid pattern
5. Hexagon pattern

Business Area





(4)



Planning Surveys :-

Any development program need to plan in a proper way to reach the maximum possible best construction planning is done with different surveys by collecting data required.

Here, Transportation route maps are generally country wide so that it need to be plan in detail way with accurate values.

Planning surveys first objective is

→ Assessment of Road length for an area → objective

1. Economical
2. Financial
3. Traffic surveys
4. Engineering surveys

It is not possible to design a road pattern to the whole country at a time so that it is divided in no. of Area plans.

Planning surveys that are conducted for determining Road length for an area are as above.

Economical Surveys :

- It includes population existing in the area
- Population distribution over an area
- Population growth rate and type of population growth
- Population forecasting in the future for future development.

Financial Surveys :

- It includes road taxes and revenue on Road transport.

→ Per capita Income

→ Employment rate.

Traffic Surveys :

→ Traffic volume studies

→ Peak hourly volume

→ Annual average daily traffic

→ Accident rate

→ Traffic signal timing & No. of conflicts points

Engineering Survey :

→ Geometric design

→ Pavement design

→ Type of pavement

→ Length of the Road

→ No. of cross drainage works

Highway Alignment :

The process of fixing of centre line of the Highway on the ground is called as Highway Alignment.

Requirements of good Alignment :

Maximum possible shortest route

It should be safe enough throughout the route

It should be economical

The Route should be flexible and comfortable

Factors Influencing Highway Alignment :

1. Obligatory points

4. Economy

2. Traffic

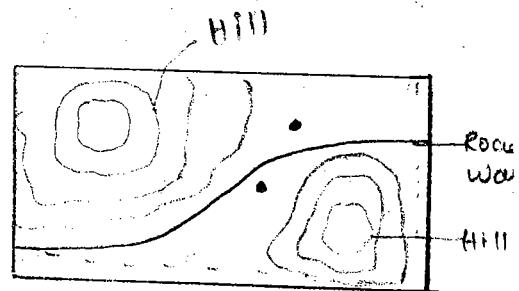
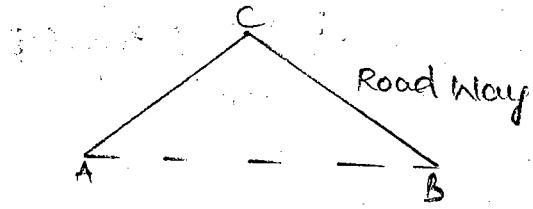
5. Other requirements

3. Geometric design

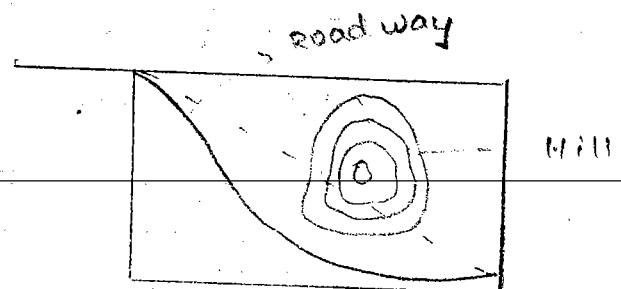
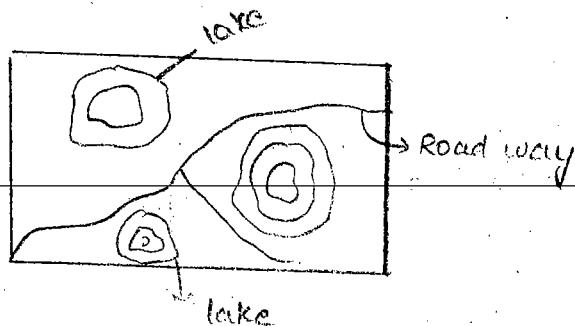
(Drainage conditions)

Obligately points :

Points to be added to the route



Points to be avoided from the route



Traffic :

Traffic is a factor of Alignment

Geometric Design :

Economy :

Cost Estimation

Factors Influencing Hilly Area Alignment :

1. Soil should be strength enough
2. Proper drainage conditions
3. Residual length

Engineering survey for Highway Alignment :

1. Map study
2. Reconnaissance survey
3. Preliminary survey
4. Final location survey

Drawing & Reports :

Key maps

Index maps

Locations

Cross drainage works

Intersection points

Levellings

Contour maps

Water Bodies

Cross section of pavements.

Route maps of Diff Roads
Land Acquisition plans

Ans questions:

1. Necessity of highway planning & Design
2. Explain Nagpur, Bombay & Lucknow Road plan
3. What is Highway Alignment & Explain factors influencing Highway alignment,
4. What are the planning surveys ,
5. Explain Engineering surveys with Drawings & Reports ,
6. classification of Roads

10/12/18

Geometric Design Of Highway

Factors of Geometric Design :

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1. cross section Elements
2. Sight distances
3. Horizontal Alignment
4. Vertical Alignment
5. Intersections

Design & Control factors :

1. Designer speed

2. Topography
3. Traffic
4. Design hourly volume
5. Environmental aspects

① Cross sectional Elements :

- a. Road surface characteristics (a) Pavement surface characteristics
 - a) Pavement unevenness - Bump Indicator
 - b) Friction
 - c) Lightening Effect
 - d) Surface Drainage conditions.

Pavement unevenness

For Expressways & National Highways Pavement unevenness shouldn't cross 1500 m²/km.

For Major District Roads & minor District Roads it shouldn't cross 3500 m²/km

For Rural Roads it shouldn't cross 4500 m²/km

With the Help of Bump indicated equipment we generally test the pavement unevenness

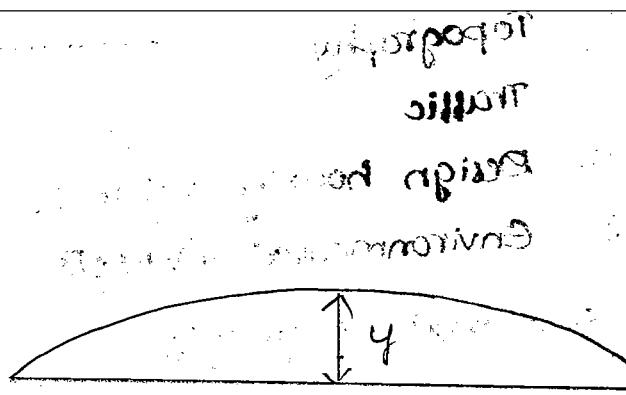
Friction:

As per IRC the friction limit for longitudinal pavement at turnings is 0.35 to 0.40.

Friction limit per National Highways, Express ways is in between 0.10 to 0.11

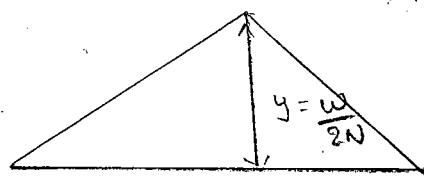
2. Camber:

Main function of camber is to drain out the rain water itself

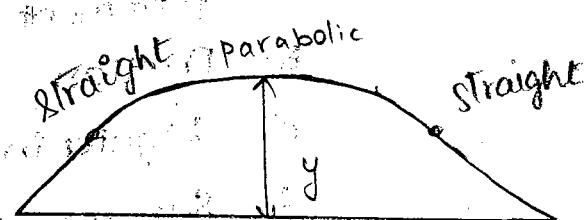


$$y = \frac{w x^2}{2N}$$

parabolic camber



straight camber



straight & parabolic

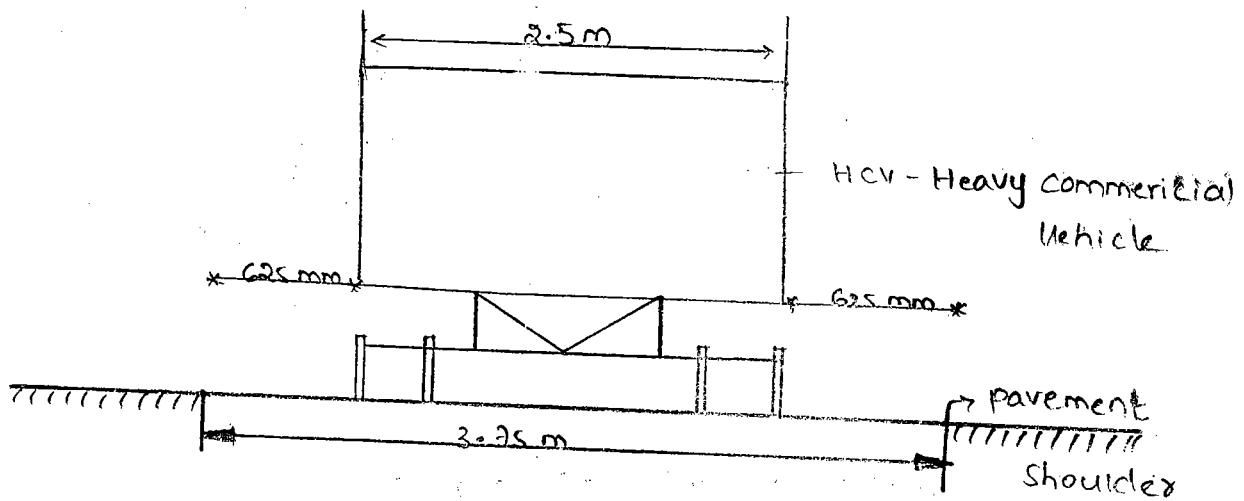
Camber of 2.5 is generally provided for rainfall more

than 1000 mm

A camber of 2.1 generally provided for the rainfall less than 1000 mm

Type of pavement	Type of Rainfall area	
	Heavy Rainfall	Low Rainfall
1. cement concrete (or) High type Bituminous Roads	1 in 50 2.1.	1 in 60 1.9.1.
2. thin Bituminous pavements	1 in 40 2.5.1.	1 in 50 2.1.
3. water bound macadam roads	1 in 33 3.1.	1 in 40 2.5.1.
4. Earth Roads	1 in 25 4.1.	1 in 33 3.1.

3. Width of Pavement (or) carriage way :
 Single Lane Pavement for HCV (Heavy Commercial Vehicle) :

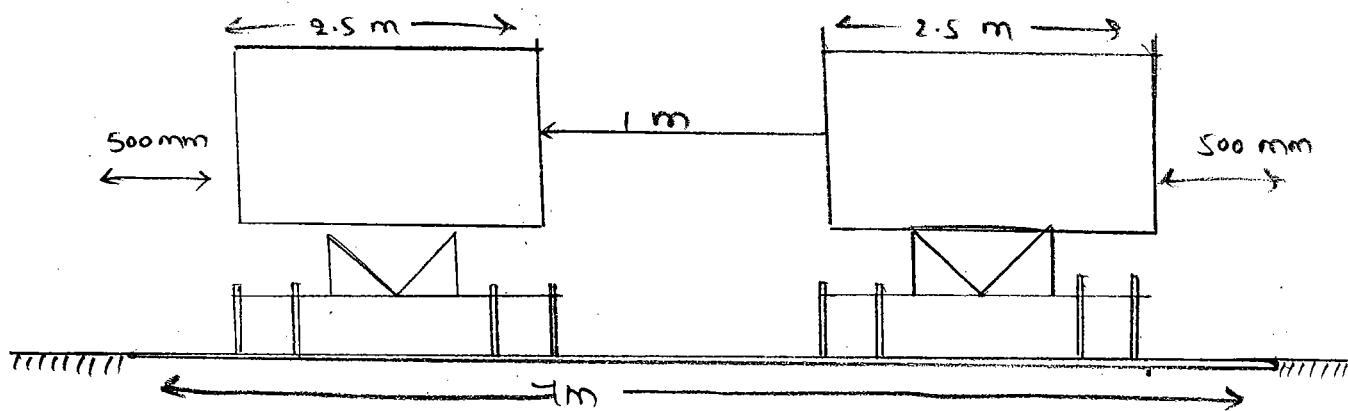


Width of pavement :

→ Width of pavement for single lane is 3.75 m
 Extra width of 0.25 can be added for the safe & comfortable movement of vehicles.

No. of lanes	Width of pavement
Single lane	3.75
Double lane without raised kerb	7
Double lane with raised kerb	7.5
Multi lane	3.5 (per lane)
Intermediate lane (Urban Roads)	5.5

Double Lane Carriage way:



Traffic separators (or) Median:

Functions:

- To segregate the Traffic
- To channelize the Traffic
- To avoid glare from the opposite vehicles
- To maintain beauty to the pavement

A Median of 8-14 m is generally desired for all types of pavements

But If the land is less the median width is restricted to 6m

- * For rural Highways median width should be 9-12 m
- * It is restricted upto 5m
- * For National Highways median width should be 10-15 m
A 4m way is allowed for right (OR) left turnings at the pavement.
- * It may be extended upto 7.5 m
- * A Median of 5-8 m is provided for intersectional areas
- * For Express ways median width should be 10-15 cms
- * For future developments it may be developed upto 18 m

5. Kerbs :

a. Low Kerb (OR) Mounted Kerb

- It is levelled at a height of 100 mm from the pavement level
- But there is allowance of traffic in the kerb like slow moving, overtaking vehicles

b. Semi Barrier Kerb :

- This is located 150 mm from the pavement level
- This is maximum design for pedestrians.

c. Barrier Kerb :

- Levelled at a height of 200 mm from pavement level
- These are only for pedestrians

6. Road Markings :-

- | | |
|----------------------------|---------------------|
| → Shoulders | → Bus Bays |
| → Guard Rails | → Lay Bays |
| → Foot path (OR) walk ways | → Frontage Bays |
| → Drive ways | → Embankment slopes |
| → Parking Lanes | |
| → Cycle Lanes | |

Formation Width :-

Addition of carriage way, medians, foot paths, kerbs and shoulders except side drains is known as formation width.

Right Of Way :-

The total land acquired for the construction of road when kept to it yet to start.

Formation width for Roads :-

- * the width of formation for arterial routes ranges from 50 to 60 m
- * Sub-Arterial Routes the width of formation ranges from 30 - 40 m
- * For collector streets width of formation ranges from 20 to 30 m
- * For Local streets Range of formation width is 10-20 m

Width of Formation for Rural Roads :-

- * For Express ways width of formation is 60 m
- * For National Highways formation width is 45 m
- * For state Highways width of formation is 40 m
- * For major & minor District roads width of formation ranges from 25 - 35 m
- * For other roads width of formation is 15 - 25 m.

Formation width based on No. of lanes :

Cross - section of Pavement :

Wearing course

25 to 50 mm

Binding course

50 to 100 mm

Base course

100 to 300 mm

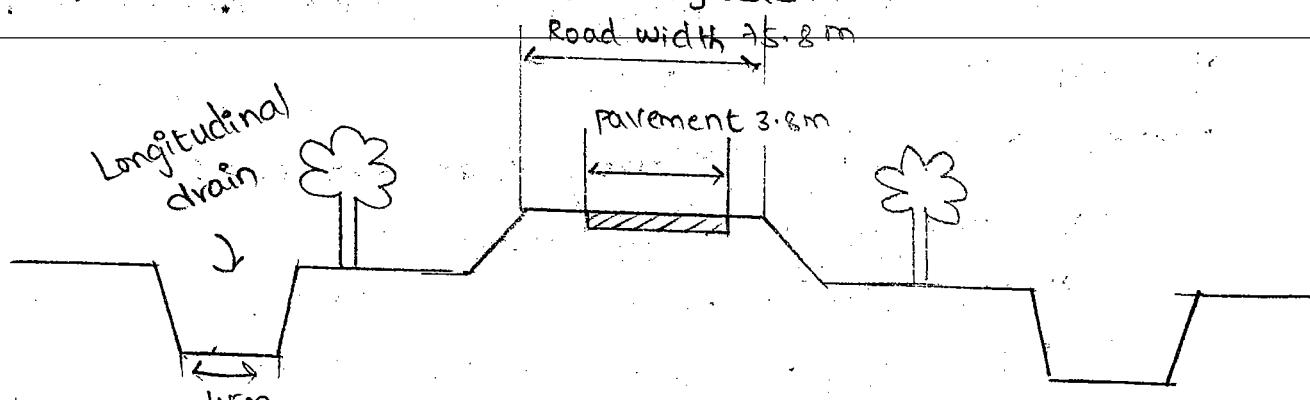
Sub course

100 to 300 mm

Compacted subgrade

150 to 300 mm

Natural subgrade



Land width 18 (or) 21 m

→ spoil bank → Road width → 10m

→ 3.8 pavements →
1.5m

cls of MDR in cutting in Rural Areas

①

(2) Sight distance :
 The visible distance for the driver ahead when a vehicle is moving in a path. The type of sight distances are

1. Stopping sight distance S.S.D
2. Intermediate sight distance I.S.D
3. Overtaking sight distance O.S.D

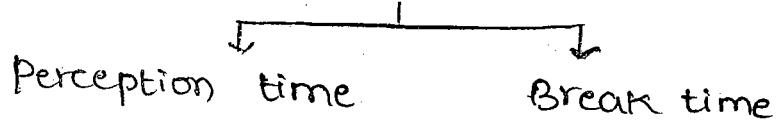
Stopping sight distance :

The min distance visible to the driver ahead to stop at any instant of time

Factors Influencing Stopping sight distance :

1. Reaction time of the driver
2. Speed of the vehicle
3. Efficiency of brakes
4. Gradients
5. Friction

Reaction time of the driver :



PIEV : Perception - sense
 Intellection
 Emotion
 Volition

$$\begin{aligned} \text{S.S.D} &= \text{Lag distance} + \text{Break distance} \\ &= (9\% t) + \frac{v^2}{2g(f + \frac{n}{100})} \end{aligned}$$

$f \rightarrow$ friction
 $n \rightarrow$ slope

Al-

Vehicle carrying a speed of 90 kmph with friction 0.35 and slope of 2.1. Vehicle is travelling from Hill position to Toe position. Lag time is 3 sec find out S.S.D

$$\text{Given, } V = 90 \text{ kmph}$$

$$= 90 \times \frac{5}{18}$$

$$= 25 \text{ m/s}$$

$$F = 0.35$$

$$N = 2.1 = \frac{2}{100} = 0.02$$

$$\text{Lag time} = 3 \text{ sec}$$

$$\begin{aligned} \text{S.S.D} &= \text{Lag distance} + \text{Break distance} \\ &= (V \times t) + \frac{V^2}{2g(f + \frac{n}{100})} \\ &= (25 \times 3) + \frac{(25)^2}{2 \times 9.81 (0.35 + 0.02)} \end{aligned}$$

$$\text{S.S.D} = 171.5 \text{ m}$$

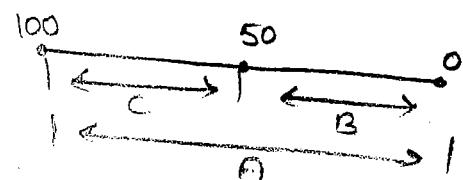
2.

A vehicle is moving with speed of 100 kmph. Later reduces to 50 kmph. Friction is 0.35, $N = 2.1$. Find out the lag distance.

Al-

$$\text{Given } V_1 = 100 \text{ kmph} =$$

$$C = A - B$$



$$\begin{aligned} D_{AB} &= \frac{V_A^2}{2g(f + \frac{n}{100})} - \frac{V_B^2}{2g(f + \frac{n}{100})} \\ &= \frac{(100 \times \frac{5}{18})^2}{2 \times 9.81 (0.35 + 0.02)} - \frac{(50 \times \frac{5}{18})^2}{2 \times 9.81 (0.35 + 0.02)} \\ &= 106.29 - 26.5726 \end{aligned}$$

$$\cancel{106.29 - 26.5726}$$

$$= 79.7 \approx 80 \text{ m}$$

3. vehicle with a speed 80 kmph having a friction 0.35, travelling from hill top to toe. S.S.D is 260 m. Find out lag time

$$V = 80 \times \frac{S}{18} = 22.22$$

$$F = 0.35$$

$$S.S.D = 260$$

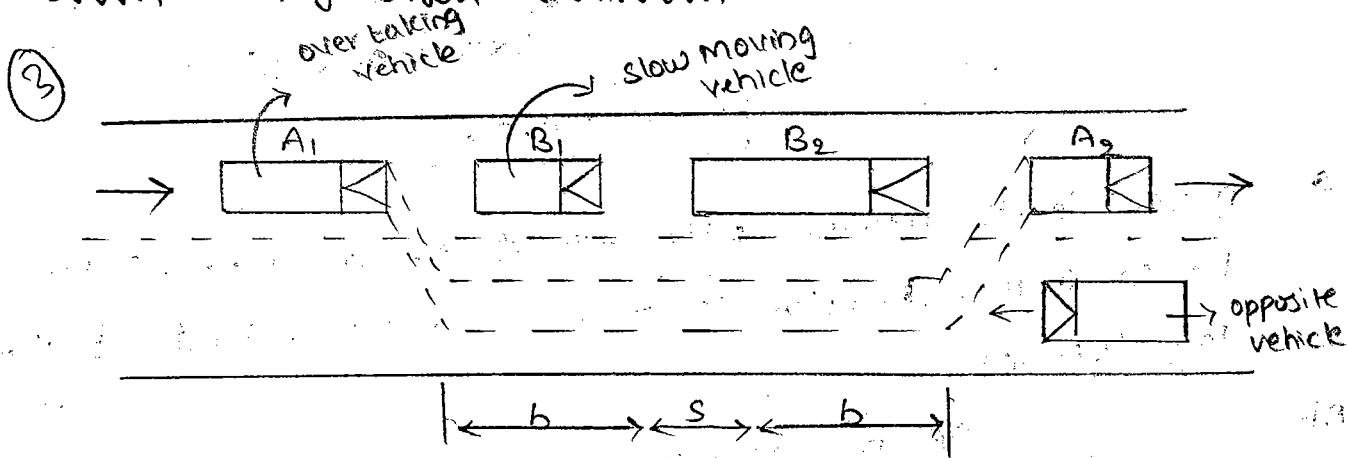
$$N = 3.1 = 0.03$$

$$S.S.D = 22.22 \times t + \frac{(22.22)^2}{2 \times 9.81 (0.35 - 0.03)}$$

$$260 = 22.22 \times t + 78.63$$

$$t = 8.16 \text{ sec}$$

Overtaking sight distance :-



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

$$d_1 = v_b \times t \quad v_b \rightarrow$$

$$d_2 = 2s + b = 2s + v_b \times t$$

$$s = 0.7 v_b + b$$

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

$$d_3 = v \cdot T$$

↓
Opp. vehicle
Speed

s → space

b → width of vehicle

Def:

the min distance visible to the driver to overtake slow moving vehicle ahead (Say free). This is also known as Safe Overtaking Distance.

Factors influencing the O.S.D:

Speed of overtaking vehicle

Speed of overtaken vehicle

Distance from overtaking vehicle to overtaken vehicle

Reaction time of the driver

Speed of opposite vehicle

Gadients

Fiction

③

1. Design speed is 90 kmph, vehicle speed is 72 kmph,
Acceleration 1.32. Find out O.S.D, Lag time $t = 2$ sec

AI-

Given, $V_b = 72 \text{ kmph} = 72 \times \frac{5}{18} = 20$

$$d_1 = 20 \times 2 = 40$$

$$\begin{aligned} d_2 &= 2s + b \\ &= 2 \times 20 + V_b \times T \\ &= 2 \times 20 + 20 \times 1.32 \\ &= 495.68 \end{aligned}$$

$$\begin{aligned} d_3 &= 90 \times \frac{5}{18} \times 1.32 \\ &= 194.6 \end{aligned}$$

$$\begin{aligned} T &= \sqrt{\frac{4s}{a}} \\ &= \sqrt{\frac{4 \times 20}{1.32}} \end{aligned}$$

$$T = 7.784$$

$$\text{O.S.D} = 430.28 \text{ m} = d_1 + d_2 + d_3$$

2. Find out O.S.D for vehicle with design speed 96 kmph
Assume the req data?

Given data,

(3)

$$\text{Design speed} = 96 \text{ kmph}$$

$$\begin{aligned}\text{Vehicle speed } V_b &= \text{Design speed} - 16 \\ &= 96 - 16\end{aligned}$$

$$= 80 \text{ kmph i.e } 22.22$$

Assumed data are a & t

$$t = 2 \text{ sec}$$

$$a = 1.32 \text{ m/sec}^2$$

$$d_1 = V_b \times t \Rightarrow d_1 = 80 \left(\frac{5}{18}\right) \times 2 \\ = 100.44.44$$

$$d_2 = 2s + b V_b \times T$$

$$s = 0.7 V_b + 6$$

$$s = 0.7 \times 80 + \left(\frac{5}{18}\right) + 6$$

$$s = 21.554$$

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

$$= \sqrt{\frac{4 \times 21.554}{1.32}}$$

$$T = 8.081$$

$$\therefore d_2 = 2 \times 21.554 + 22.22 \times 8.081 \\ = 222.667$$

$$d_3 = V \cdot T$$

$$= 96 \left(\frac{5}{18}\right) \times 8.081$$

$$= 149.55 \cdot 215.49$$

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

$$= 100.44.44 + 222.667 + 215.49$$

$$= \underline{\underline{480.059}}$$

3. calculate O.S.D for vehicle speed 72 kmph with
 $A = 5 \text{ kmph/sec}$. Find out O.S.D. opp vehicle speed

Given $v_b = 72 \text{ km/hr}$ Formulae $V = 80 \text{ kmph}$

$V = 80 \text{ kmph}$

(3) $A = 5 \text{ kmph/sec}$

Assume $t = 2 \text{ sec}$

$d_1 = v_b * t$

$= 72 * 2 = 144 \text{ m}$

$d_2 = 2s + b = 2s + v_b * T$

$s = 0.2v_b * t$

$s = 0.2 * 72 * 2 = 28.8 \text{ m}$

$d_2 = 2s + b = 2s + v_b * T$

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

$d_3 = V * T$

$T = 7.6649$

$d_2 = 2 * 20.4 + \frac{72}{80} * 7.6649$

$d_2 = 653.492 - 592.69$

$d_3 = V * T$

$= 80 * 7.6649$

≈ 613.192

$d_1 + d_2 + d_3 = O.S.D \Rightarrow O.S.D = 1349.87$

$O.S.D \approx 1350 \text{ kmph}$

4. Calculate O.S.D for double lane without traffic separated.
 Designed speed is 100 kmph

Given,

Design Speed = 100 kmph

$$V = 100 \times \frac{s}{18} = 27.78 \text{ m}$$

Vehicle Speed = Design Speed - 16
 $= 100 - 16 = 84 \text{ kmph}$

$\therefore v_h = 23.32 \text{ m}$

Assumed data is

$$a = 1.32 \text{ m/sec}^2$$

$$t = \text{sec}$$

$$d_1 = v_b \times t = 23.32 \times 2 \\ = 46.66$$

$$d_2 = 2s + v_b \times t$$

$$s = 0.7 v_b + 6$$

$$s = 22.331$$

$$T = \sqrt{\frac{4 \times s}{a}} = \sqrt{\frac{22.331 \times 4}{1.32}}$$

$$T = 8.2265$$

$$d_2 = 2(22.331) + 23.33 \times 8.2265$$

$$d_2 = 236.6162$$

$$d_3 = v \times T \\ = 27.77 \times 8.2265$$

$$d_3 = 228.449$$

$$\text{O.S.D} = 46.66 + 236.6162 + 228.449$$

$$\text{O.S.D} \approx 520 \text{ m}$$

5. find out 't' value for O.S.D 1200 m with vehicle speed 80 kmph, A is 5 kmph /sec, opposite vehicle speed 85 kmph

AI-

$$\text{O.S.D} = d_1 + d_2 + d_3$$

$$d_1 = v_b \times t \\ = 80 t$$

$$d_2 = 2s + v_b \times t$$

$$s = 0.2 v_b + c$$

$$s = 22$$

$$d_2 = 2 \times 22 + 80 \times t \\ = 680 + 80t$$

$$d_3 = v \times t = 85 \times t \\ = 85t$$

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

$$= \sqrt{\frac{14.4 \times 22}{5}} = 7.959$$

$$O.S.D = 80t + 680 \cdot 719 + 676.515$$

$$1200 = 80t + 1357.305$$

$$\therefore t = -1.966$$

$$t \approx 2 \text{ sec}$$

Intermediate sight distance :

$$I.S.D = 2 \times S.S.D$$

the minimum distance for two vehicles while they are travelling in a same lane with same speed.

(3)

Horizontal Alignment : —

process of fixing of a central line for path is Alignment

Horizontal Alignment is an alignment with ground level.

Sometimes, alignment may changes its direction from one path to another path.

So, there is a need of Horizontal curve

In general straight paths are having 0 & 0 radius whereas curved paths having some degree & radius while the path is changing its alignment to curved path the geometric design changes here with a degree and radius

Equation for centrifugal force $P = \frac{WV^2}{R}$

P = Centrifugal force

W = Weight of vehicle

V = Speed of vehicle in m/sec

g = Acceleration due to gravity = 9.81 m/sec²

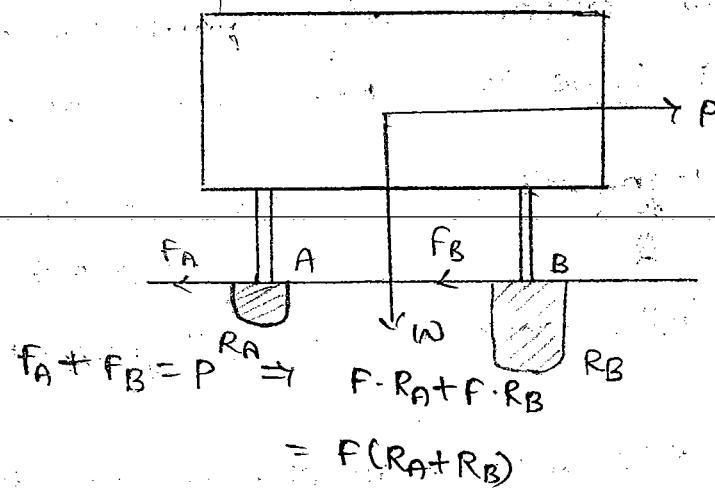
R = Radius of Arc

there are 2 effects act in vehicle moving in horizontal curve.

1. Over turning Effect

2. Transverse Skidding Effect

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



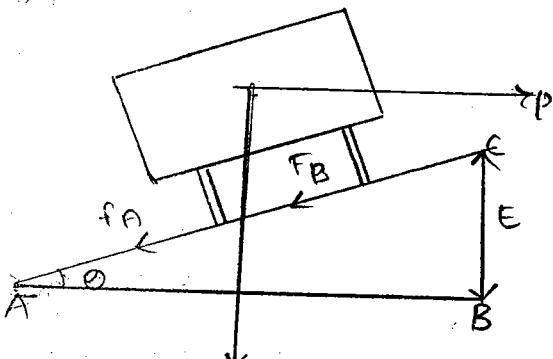
$$\frac{P}{W} = f$$

Super Elevation :-

6

The rise given to the outer edge with respect to inner edge is known as super Elevation.

$$\frac{CB}{AB} = \tan\theta = e$$



Forces acting on the vehicle are
Centrifugal force,

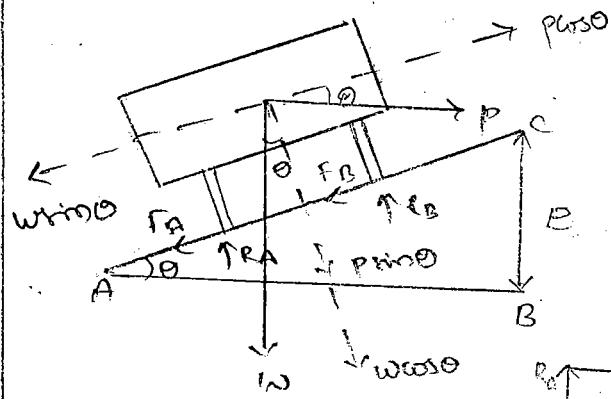
$$P = \frac{WV^2}{9r} \text{ at } 59.0 \text{ m}$$

Over turning Effect

$$\frac{P}{W} = \frac{V^2}{g r}$$

$\sqrt{2}$

Transverse Skidding Effect, $\frac{P}{W} = f$



forces on Right hand side =

Forces on Left Hand side

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

$$= W_{\text{fixed}} + F(R_A + R_B)$$

$$R_A + R_B = p \sin \theta + w \cos \theta$$

$$P_{\text{cos}\theta} = w \sin \theta + F_r (\rho \sin \theta + w \cos \theta)$$

$$P_{\text{base}} = f P_{\text{time}} = w \sin \theta + f w \cos \theta$$

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

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

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

If Tang is small & friction also neglected

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

$$\frac{P}{\omega} = e + f$$

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

$$e + f = \frac{\left(\frac{V}{18}\right)^2}{9.81R}$$

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

e = rate of super elevation

f = coefficient of lateral friction = 0.15 - 0.20

V = vehicle speed in $\frac{\text{m}}{\text{sec}}$

R = radius of curve in 'm'

1. calculate a) Rate of super elevation and b) friction if no super elevation is given.

The vehicle speed is 50 kmph, Radius is 100m, coefficient of friction 0.15

Al-

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

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

$$e = 0.0468$$

- b) In this case $e = 0$.

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

$$0 + f = \frac{(50)^2}{127 \times 100}$$

$$f = 0.1968$$

2. Find out Radius of the curve for a vehicle speed 60 kmph

Al-

let,

coefficient of friction = 0.15

$$e = 0.05$$

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

$$0.05 + 0.15 = \frac{(60)^2}{127 R}$$

$$\underline{\underline{R = 141.73 \text{ m}}}$$

3. If the super elevation is 7.1. & f is 15.1, then actual speed of the vehicle is $e+f = \frac{v^2}{127 R}$

Ans

$$\text{Given } e = 0.07$$

$$f = 0.15$$

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

$$\frac{v^2}{127 R} = 0.22$$

$$\underline{\underline{v = 5.28 \sqrt{R}}} \text{ (or) } v = \sqrt{27.94 R}$$

4. calculate actual speed of vehicle & Radius if $f=0.15$ and $e=0.06$

Ans

$$\text{Given } e = 0.06, f = 0.15$$

$$0.06 + 0.15 = \frac{v^2}{127 R}$$

$$v^2 = 26.67 R$$

$$v = \sqrt{26.67 R}$$

i) Normal speed of vehicle is 50 kmph

$$\underline{\underline{R = 93.73 \text{ m}}}$$

ii) Actual speed, $v = \sqrt{26.67 R}$

$$v = 49.97 \text{ m/sec}$$

Note:

- If negative super elevation occurs, then equation is as follows

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

1. Find out negative super elevation value for $f = 0.4$ & speed of vehicle is 60 kmph, $R = 100m$

At

(2)

Given, $f = 0.4, V = 60, R = 100$

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

$$0.4 - e = \frac{60^2}{127 \times 100}$$

$$0.4 - \frac{60^2}{127 \times 100} = e$$

$$e = 0.1165$$

Q.

b) If $f = 0.15$

$$0.15 - e = \frac{60^2}{127 \times 100}$$

$$e = -0.133$$

Radius of Horizontal curve :-

there are 2 types of Radius with conditions

1. Ruling Radius
2. Absolute min. Radius

For ruling Radius equation is as follows:

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

$$R_{\text{Ruling}} = \frac{V^2}{127(e+f)}$$

$$R_{\text{min}} = \frac{V^2}{127(e+f)}$$

- b) calculate Ruling and Min Absolute Radius for vehicle Speed 60 kmph as Absolute Min speed and 96 is the design speed. f is 0.15, e is 0.07

At

Given $V_1 = 60$

$$V = 96$$

$$F = 0.15$$

$$e = -0.07$$

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

$$= \frac{96^2}{127(0.07+0.15)} = 329.84$$

$$\text{Absolute min Radius, } R = \frac{V^2}{127(e+f)}$$

$$= \frac{60^2}{127(0.07+0.15)} = 128.84$$

Note:

Vehicle speed is restricted to 70 kmph on an average and Radius of super elevation increases when vehicle speed is increased

1) Super elevation & friction are more than 7% and 15% then speed is restricted upto 40 kmph. and R value must be more.

2. At A Two lane road with design speed 80 kmph of radius 480 mts. Design rate of super elevation? Find out rise of outer edge w.r.t inner edge. Width of pavement at horizontal curve = 7.5 mts

Given, $V = \text{Design speed} = 80 \text{ kmph}$

$$\text{Radius } r = 480 \text{ mts}$$

We know that, $e+f = \frac{V^2}{127R} \times$

$$e+0.15 = \frac{80^2}{127 \times 480}$$

$$e = \times$$

Super Elevation is generally designed for 75% of design speed

$$\frac{\pi^2}{127R} = \frac{(0.75V)^2}{127R} = \frac{V^2}{225R}$$

$$\therefore e = \frac{80^2}{225 \times 480} \Rightarrow e = 0.059$$

the RSE given to the outer edge w.r.t inner edge =

Rate Of super Elevation \propto Width Of pavement

$$= e \propto W$$

$$= 0.059 \times 7.5$$

$$= 0.4425$$

3. Design rate of super elevation of horizontal curve of radius 500 mts and speed 100 kmph

Al-

②

Given data,

$$\text{Speed } V = 100 \text{ kmph}$$

$$\text{Radius } r = 500 \text{ mts}$$

$$e = \frac{V^2}{225R} = \frac{(100)^2}{225(500)}$$

$$e = 0.088$$

Note: As for the above value obtained 9.1. is not allowed so take 7.1. of rate of super elevation
7.1. of rate of super elevation is maximum

From the Super elevation equation $e + f = \frac{V^2}{127R}$

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

$$f = \frac{100^2}{127(500)} - 0.07$$

$$f = 0.087$$

The Designed Super Elevation of $e = 0.07$ & friction

$f = 9.1.$ is safe.

4. Design speed is 80 kmph, Radius 200 mts. coefficient of lateral friction 0.15
- calculate super Elevation
 - calculate maximum allowable speed for max of super Elevation?

A1.

Given data,

$$\text{Design speed } v = 80 \text{ kmph}$$

$$R = 200 \text{ mts}$$

$$F = 0.15 \text{ mts}$$

a) For super Elevation $e = \frac{v^2}{225R}$

$$e = \frac{(80)^2}{225(200)}$$

$$e = 0.142$$

If e is not allowable only ≈ 1 . of e is allowable
so e is 0.142 is rounded for ≈ 1 .

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

$$0.07 + 0.15 = \frac{80^2}{127 \times 200}$$

$$f = 0.181$$

b) $V_A = \sqrt{28R}$

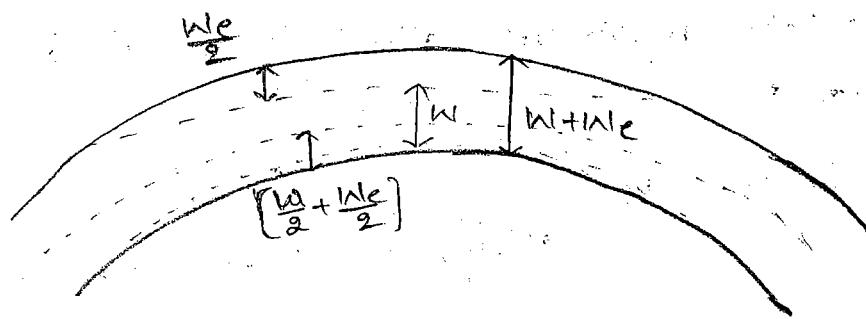
$$V_A = \sqrt{28 \times 200} \Rightarrow V_A = 74.83$$

L $V_A \approx 75 \text{ kmph}$

Except 75 kmph the vehicle don't move than ≈ 75 kmph.

so, Allowable speed limit is 60 - 70 kmph

* Extra Widening Of pavements on horizontal curves :-



Consider

Design Extra widening for two lane pavement. consider
extra widening is from center line of pavement to inner
edge

$$W_e = 3.5$$

$$\frac{W}{2} + \frac{W_e}{2} \Rightarrow \frac{7}{2} + \frac{3.5}{2} \\ \Rightarrow 5.25 \text{ m}$$

Design Extra widening from centre line to outer Edge for
4 lane pavement

for 4 lane pavement there is a median

$$\text{Width of pavement } W = 14$$

$$\text{Width of Extra widening } W_e = 2$$

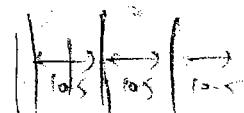
$$\frac{W}{2} + \frac{W_e}{2} = \frac{7}{2} + \frac{3.5}{2} \\ = 5.25 \text{ m}$$

Calculate
23 mts
lanes

centre line to outer edge for pavement width

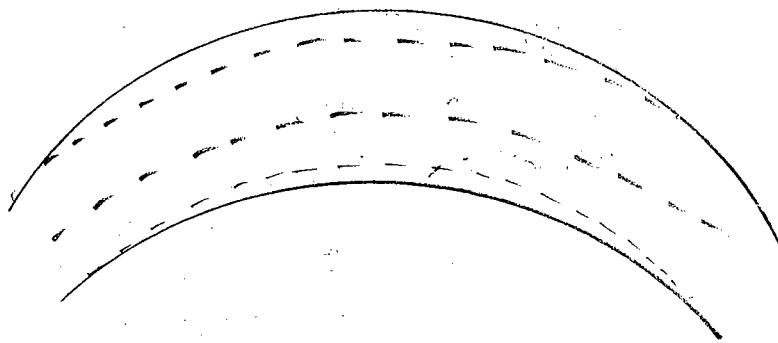
$$= \frac{10.5}{2} + \frac{3.5}{2}$$

$$= 7 \text{ m}$$



21 mts \Rightarrow 6 lanes

Widening Of Pavements on sharp curves :-



Addition of Mechanical widening & psychological widening is known as Widening of Pavements on sharp curves.

$$W_m + W_{p.s} = \frac{nl^2}{2R} + \frac{v}{9.5\sqrt{R}}$$

$n \rightarrow$ No. of Traffic lanes

$l \rightarrow$ length of wheel base

$R \rightarrow$ Radius

$v \rightarrow$ Design speed

- Calculate the extra widening reqd for pavement of width 7m, Radius 200m, wheel base is 6.5 m, design speed 65 kmph

$$l = 6.5 \text{ m}, R = 200 \text{ m}, n = 2 \text{ lanes } (\because 7 \text{ m}) \\ v = 65 \text{ kmph}$$

$$\begin{aligned} W_m + W_{p.s} &= \frac{nl^2}{2R} + \frac{v}{9.5\sqrt{R}} \\ &= \frac{2 \times 6.5^2}{2 \times 200} + \frac{65}{9.5 \times \sqrt{200}} \\ &= 0.728 \text{ m} \end{aligned}$$

- Find the total width of pavement on a horizontal curve for a new national highway to be aligned along a rolling terrain with curving minimum radius. Assume necessary data

Assumed data,

$$v = \text{Design speed} = 80 \text{ kmph}$$

$$e = 7\text{°l.}$$

pavement width $w = 7\text{m}$, $n = 2$
wheel base: $L = 6\text{m}$ (6.0 - 6.5 constant value)

$$f = 15\text{°l.}$$

$$\begin{aligned} R_{\text{ruling}} &= \frac{V^2}{127(e+f)} \\ &= \frac{80^2}{127(0.07+0.15)} \end{aligned}$$

$$= 229.06$$

$$R_{\text{ruling}} \approx 230\text{ m}$$

$$\begin{aligned} W_m + w_{ps} &= \frac{nL^2}{2R} + \frac{V}{9.5\sqrt{R}} \\ &= \frac{2(6)^2}{2 \times 230} + \frac{80}{9.5\sqrt{230}} \\ &= 0.7117 \approx 0.712 \end{aligned}$$

$$\begin{aligned} \text{Total pavement width on curve} &= 7 + 0.712 \\ &= 7.712\text{ m} \end{aligned}$$

3. Find out the extra widening of pavement for a National Highway with Rolling Terrain for minimum Radius. Assume all the data.

Assume data,

$$V = 80\text{ kmph}$$

$$e = 7\text{°l.}, f = 15\text{°l.}$$

$$w = 7\text{m}, n = 2$$

$$\text{Wheel base } l = 6\text{m}$$

$$\begin{aligned} R_{\min} &= \frac{V^2}{127(e+f)} \\ &= \frac{70^2}{127(0.07+0.15)} \quad (8) \end{aligned}$$

$$\begin{aligned} R_{\min} &= 175.37 \\ &\approx 175\text{ m} \end{aligned}$$

$$\begin{aligned} \text{Vehicle speed} &= \text{Design speed} - 15 \\ &= 80 - 10 \\ &= 70 \end{aligned}$$

$$\begin{aligned} 80 - 15 &= 70 \\ &= \frac{65^2}{127(0.07+0.15)} \end{aligned}$$

$$\begin{aligned} R_{\min} &\approx 152\text{ m} \\ &\approx 160\text{ m} \end{aligned}$$

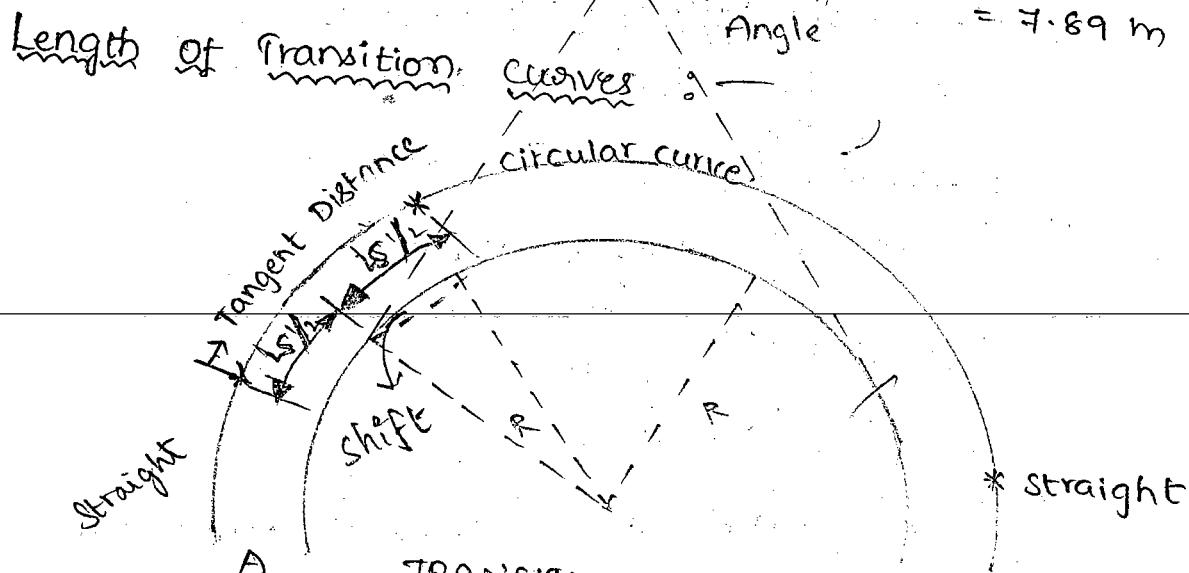
$$W_m + W_{ps} = \frac{\eta e^2}{2R} + \frac{N^2}{9.5\sqrt{R}}$$

$$= \frac{2(6)^2}{2 \times 160} + \frac{80}{9.5\sqrt{160}}$$

$$= 0.89 \text{ m}$$

(3×10^{-3})

Total Pavement width on curve = $7 + 0.89$
Deflection Angle = 7.89 m



TRANSITION CURVE IN HORIZONTAL ALIGNMENT

Transition curve is a curve connects a straight path to a circular path. For finding out length of transition curve we need to know rate of centrifugal acceleration

$$C = \frac{80}{(75+v)}$$

units : m/s^2

$C \rightarrow$ rate of centrifugal acceleration

$v \rightarrow$ vehicle speed

L_s = length of transition curve

$$= \frac{v^3}{C \cdot R} \text{ in kmph}$$

$$L_s = 0.0215 \frac{v^3}{C \cdot R} \text{ in msec}$$

Rate of Introduction of Super Elevation :-

For Plane & Rolling Terrain $L_s = 2.7 \frac{v^2}{R}$

For Mountain & Steep Terrain $L_s = \frac{v^2}{R}$

$$\text{Shift } s = \frac{L_s^2}{24fR}$$

Design speed $V = 65 \text{ kmph}$
Normal

$$R = 220 \text{ m}$$

Pavement Width + Extra Widening = 7.5 m

Allowable rate of introduct of super

elevation = 1 in 150

$$= 0.006$$

a. length of transition curve

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

$$c = 0.57 \text{ ml sec}$$

The limits for rate of centrifugal acceleration
is 0.5 to 0.8

Our value is 0.57. \therefore It is adopted or

$$L_s = 0.0215 \cdot \frac{V^3}{C \cdot R}$$
$$= 0.0215 \times \frac{65^3}{0.57 \times 220}$$
$$= 47.08$$

$$e = \frac{V^2}{225R} \Rightarrow e = 0.085$$

Adopt $0.07 = e$

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

$$f = \frac{65^2}{127 \times 220} - 0.07$$

$$f = 0.0812$$

Width of pavement = 7.5 m
 the Rise of outer edge w.r.t center line = $\frac{0.07 \times 7.5}{2} = 0.2625$

Rate of Super Elevation

$$L_s = ex[B + W_e] \times N$$

$$W_e = \frac{n e^2}{2R} + \frac{v}{9.5 \sqrt{R}}$$

$$= \frac{2 \times 7.5^2}{2 \times 220} + \frac{65}{9.5 \sqrt{220}}$$

$$W_e = 0.70.$$

Length of Transition curve

Rate of introduction of super elevation
 ↓

$$L_s = ex[B + W_e] \times N$$

$$= 0.07 \times [7.5 + 0.70] \times \frac{150}{50}$$

$$= 86.1 \text{ m}$$

length of Transition curve

Rate of centrifugal acceleration

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

$$= \frac{0.0215 \times 65^3}{0.57 \times 220}$$

$$= 47.08 \text{ m}$$

Consider pavement located at Rolling Terrain
length of transition curve

IRC for Rolling Terrain

$$L_s = \frac{2.7 v^2}{R} = \frac{2.7 \times 65^2}{220} = 51.8$$

Adopt the length of transition curve 86.3 m

$$\begin{aligned} \text{Shift } s &= \frac{\frac{L_s^2}{24R}}{24 \times 220} \\ &= \frac{86.1^2}{24 \times 220} \\ &= 1.40 \end{aligned}$$

- a) Super Elevation
- b) Extra Widening
- c) Length of transition curve

Assume, $V = \text{Design speed} = 80 \text{ kmph}$

Pavement as 2 Lane $\Rightarrow B = 3.5 + 3.5$

$$B = 7 \text{ m}$$

$$N = 1 \text{ in } 150 = \text{slope}$$

Length of wheel base $L = 6 \text{ m}$

- a) Super elevation

$$L_s = ex[B + W_e] \times N$$

$$e = \frac{v^2}{225R} \Rightarrow e = 0.129 = \frac{80^2}{225 \times 1220}$$

$$e = 0.07 \rightarrow \because \text{above is } 12.1. \text{ Can't take}$$

Rise of outer edge w.r.t centre line of pavement

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

$$(b) E = \frac{B \times B}{2} = 0.245 \text{ m}$$

Extra widening of Pavement $W_e = \frac{n \cdot L^2}{2R} + \frac{v}{9.5 \sqrt{R}}$

$$\begin{aligned} W_e &= \frac{2 \times (6)^2}{2 \times 220} + \frac{80}{9.5 \sqrt{220}} \\ &= 0.731 \text{ m} \end{aligned}$$

Total width of pavement = $7 + 0.73 = 7.73 \text{ m}$

Length of Transition curve

Rate of introduction of super elevation

$$L_s = \frac{v}{g} [B + W_e] \times N$$

$$L_s = 0.07 \times [7 + 0.73] \times 150$$

$$L_s = 81.165 \text{ m}$$

(b)

Extra widening

$$\text{Rate of centrifugal acceleration } c = \frac{80}{75 + v}$$

$$c = 0.516 \text{ m/sec}^2$$

Length of Transition curve

Rate of centrifugal acceleration

$$L_s = \frac{0.0215 v^3}{c R}$$

$$L_s = \frac{0.0215 \times 80^3}{0.516 \times 220} = 96.96 \text{ m}$$

Length of transition curve

IRC for Rolling Terrain

$$L_s = \frac{2.7 \times v^2}{R} = \frac{2.7 \times 80^2}{220}$$

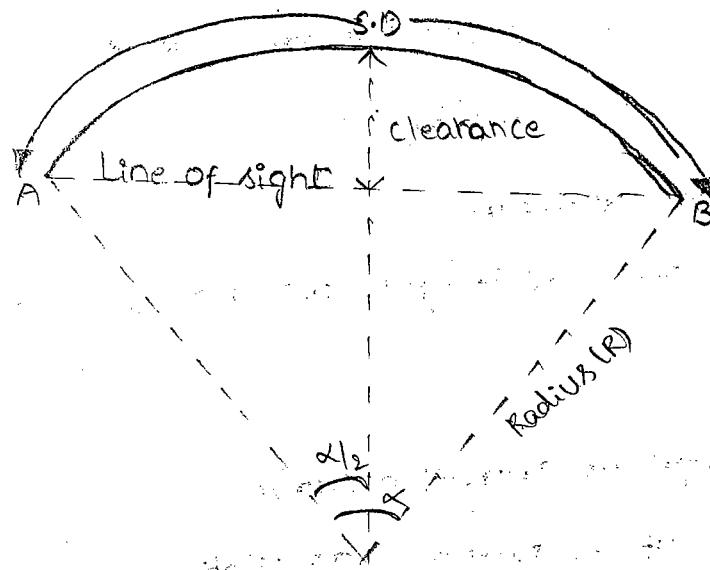
$$= 78.5 \text{ m}$$

Adopt the length of transition curve be 96 m

$$\begin{aligned} \text{Shift } \delta &= \frac{L_s^2}{24 R} \\ &= \frac{96.96^2}{24 \times 220} = 1.78 \end{aligned}$$

↓
Consider higher
length of transit
curve

Set Back distance :



Case i:

When $L_c > S$

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

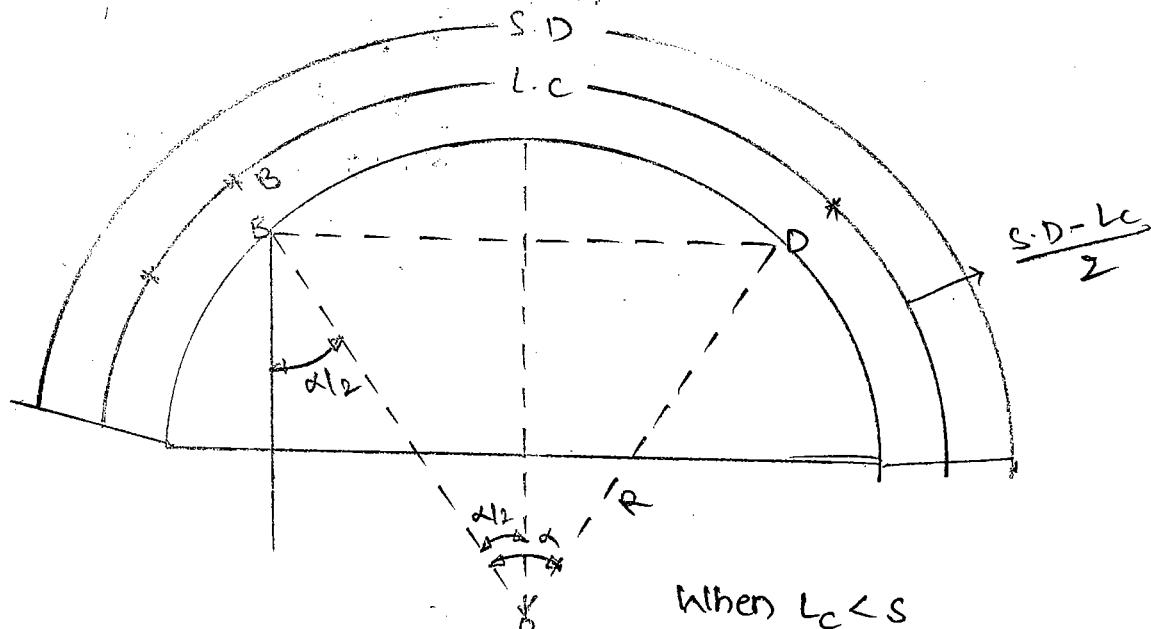
$$\text{Radius} = \frac{180}{2\pi} \left(\frac{S}{R} \right) \text{ degrees}$$

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

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

$B \rightarrow$ width of pavement

$$\frac{\alpha}{2} = \frac{180 S}{2\pi(R-d)} \text{ degrees}$$



When $L_c < S$

$$\frac{\alpha}{2} = \frac{180 L_c}{2\pi(R-d)} \text{ degrees}$$

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

1. The two lane pavement with Radius 250 m width 7.6 m minimum sight distance 240 m. Assume length of curve is greater than sight distance. Determine set back distance

AH

Given,

$$R = 250 \text{ m}$$

$$\text{No. of lanes} = 2$$

$$\text{Width} = 7.6 \text{ m}$$

$$S.D = 240 \text{ m}$$

Given $L_c > S$

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

$$\frac{\alpha}{2} = \frac{240}{2 \times 250} \Rightarrow \frac{\alpha}{2} = 0.48 \Rightarrow \alpha = 0.96$$

$$d = \frac{B}{4} = \frac{7.6}{4} \Rightarrow d = 1.9$$

$$\frac{\alpha}{2} = \frac{180 \times 240}{2\pi(250 - 1.9)} = \frac{180 \times s}{2\pi(R-d)}$$

$$\therefore \frac{\alpha}{2} = 27.7$$

$$m' = 250 - (250 - 1.9) \cos(27.7) = R - (R-d) \cos \frac{\alpha}{2}$$

$$m' = 30.33$$

2. Two lane pavement width 250 m^{radius}. Total length of curve is 240 m. Sight distance is 340 m. Distance b/w centre line of pavement to the centre line of inner curve is 1.95 m. Determine set back

AH

Given,

$$R = 250 \text{ m}, n = 2, R > L_c$$

$$L_c = 240 \text{ m}$$

$$s = 340$$

$$d = 1.95 \text{ m}$$

$$L_c < s$$

\therefore case ii,

$$\frac{\alpha}{2} = \frac{180 \times L_c}{2\pi(250-d)}$$

$$= \frac{180 \times 240}{2\pi(250 - 1.95)}$$

$$\therefore \frac{\alpha}{2} = 27.71$$

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

$$= 250 - (250 - 1.95) \cos(27.71) + \left(\frac{340 - 240}{2} \right) \sin(27.71)$$

$$= 30.39 + .23 \cdot 24$$

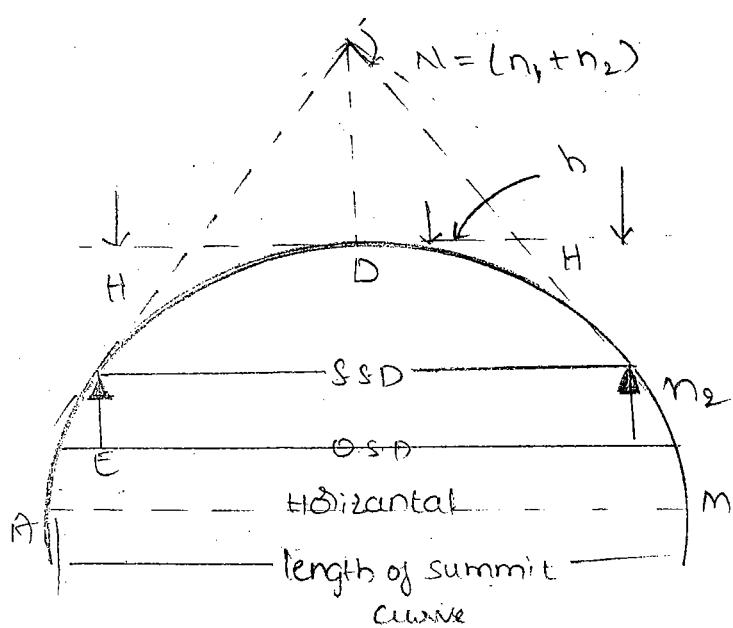
$$= 53.63 \text{ m}$$

$$\underline{\underline{M \approx 54 \text{ m}}}$$

There are

length of the summit curve :

$$Y = ax^2 \quad (a = \frac{N}{2L})$$



Length of summit curve for S.S.D:

Two cases are to be considered in deciding length

- When length of curve is greater than S.S.D ($L > S.S.D$)
- When length of curve is less than S.S.D ($L < S.S.D$)

$$a) L > S.S.D$$

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

$$L = \frac{Ns^2}{4 \cdot 4}$$

$$b) L < S.S.D$$

$$\begin{aligned} L &= 2s - \frac{(\sqrt{2}H + \sqrt{2}h)^2}{N} \\ &= 2s - \frac{4 \cdot 4}{N} \end{aligned}$$

When $H = 1.2$, $h = 1.5$ m then length of curve $L =$

$$L = 2s - \frac{4 \cdot 4}{N}$$

$L \rightarrow$ length of summit curve

$s \rightarrow$ stopping sight distance

$N \rightarrow$ Deviation angle

$H \rightarrow$ Height of Eye level of drivers above road

$A \rightarrow$ Height of subject above Pavement Surface

Way surface

Length of summit curve for O.S.D (0) Intermediate S.D

- a) When length of curve is greater than O.S.D (0) $\frac{1}{8} \cdot S \cdot D$ ($L > O.S.D$)
 b) when length of curve is less than O.S.D (0) $\frac{1}{8} \cdot S \cdot D$ ($L < O.S.D$)

(a) $L > O.S.D (0)$ I.S.D

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

$$L = \frac{N S^2}{8H^2}$$

When $H = 1.2 \text{ m}$

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

(b) $L < O.S.D (0)$ I.S.D

$$L = 2S - \frac{8H}{N}$$

If $H = 1.2 \text{ m}$

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

1. A vertical summit curve is formed at intersect of two gradients $+3.8\%$ -5.0% . Design the length of summit curve to provide a stopping sight distance. For $V = 80 \text{ kmph}$
 Assume the required data?

Ans

Given data, $V = 80 \text{ kmph}$

$$n_1 = +3$$

$$n_2 = -5.0$$

$L > S.S.D$

Determination of safe S.S.D

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

$$f = 0.35$$

$$t = 2 \text{ sec}$$

$$V = 80 \text{ kmph}$$

$$S.S.D = 0.278(0.80)(2) + \frac{80^2}{254(0.35)}$$

$$S.S.D = 116.47 \text{ m}$$

- (b) Determination of length of summit curve

Deviation angle (N) $= n_1 - n_2$

$$= n_1 + n_2 = \frac{3+5}{100} = 0.08$$

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

$$= \frac{0.08(116.47)^2}{4.4}$$

$$\therefore L = 246.64 \text{ m}$$

2. The vertical summit curve with gradients +2, -4 %. Design speed 80 Kmph. Determine length of summit curve

A-

Given data,

$$n_1 = 2, n_2 = -4$$

$$V = 80 \text{ Kmph}, f = 0.35$$

$$t = 2 \text{ sec}$$

$$\text{S.S.D} : 0.278 V t + \frac{V^2}{254 f}$$

$$= 0.278 \times 80 \times 2 + \frac{80^2}{254 \times 0.35}$$

$$= 116.47 \text{ m}$$

- b) Determination of Length of summit curve

$$L > \text{S.S.D}$$

$$L < \text{S.S.D}$$

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

$$\therefore L = \frac{0.08(116.47)^2}{4.4}$$

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

$$N = n_1 - n_2$$

$$= 2 + 4$$

$$N = 6 = 0.06 \text{ ft.}$$

$$L = 184.98 \text{ m}$$

$$= 2(116.47) - \frac{4.4}{0.06}$$

$$L = 159.60 \text{ m}$$

- B. Gradients of 1 in 100 & 1 in 200 ascending & descending respectively. A summit curve is to be designed for speed of 80 Kmph to have an O.S.D. 490 m.

A)-

Given Data,

$$n_1 = \frac{1}{100} = 0.01$$

$$n_2 = \frac{1}{200} = 0.005$$

$$S = 490$$

$$N = 0.01 + 0.005$$

$$= 0.015$$

$$L \geq 0.8 \cdot D$$

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

$$= \frac{0.015(470)^2}{9.6}$$

$$L = 345.15 \text{ m}$$

$$L \leq 0.8 \cdot D$$

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

$$= 2(470) - \frac{9.6}{0.015}$$

$$L = 300 \text{ m}$$

4. A vertical summit curve with gradients +1150 & -1150 S.S.D & O.S.D are 180 & 640 m. length & vertical curve restricted to 300 m if possible calculate the length of summit curve needed to fulfil the requirements of a) S.S.D b) O.S.D

A1-

Given data

$$n_1 = \frac{1}{50} = 0.02, n_2 = -\frac{1}{80} = -0.0125, t = 2, v = 80$$

$$N = 0.02 + 0.0125 \\ = 0.0325$$

$$F = 0.35 \\ S = 180$$

$$\begin{aligned} S.S.D &= 0.278vt + \frac{v^2}{254F} \\ &= 0.278 \times 80 \times 2 + \frac{80^2}{254 \times 0.35} \\ S.S.D &= 116.47 \text{ m} \end{aligned}$$

a) $L > S.S.D$

$$L = \frac{Ns^2}{4.4} = \frac{0.0325 \times 180^2}{4.4}$$

$$L = 239.3$$

$$L \approx 240 \text{ m}$$

b) $L \leq O.S.D$

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

$$L = 2(640) - \frac{9.6}{0.0325}$$

$$L = 985 \text{ m}$$

Not allowable

$$I.S.D = 2(S.S.D) = 2 \times 180 = 360 \text{ m}$$

$L > I.S.D$

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

$$= \frac{0.0325(360)^2}{9.6}$$

$$L \approx 440 \text{ m}$$

5- A vertical summit curve with gradients $+1/60$, $-1/100$
 S.S.D & O.S.D are 180 & 420m. the min 'n' length is 150m &
 Max of length 500m. find out 1. S.S.D 2. O.S.D & 3. I.S.D
 length of summit curves for safe condition

At-

Given,

$$n_1 = \frac{1}{60} = 0.016, \quad n_2 = -\frac{1}{100} = -0.01$$

$$N = 0.0266$$

$$\text{S.S.D} = 180, \quad \text{O.S.D} = 420 \text{ m}$$

$$L > \text{O.S.D}$$

$$L < \text{S.S.D}$$

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

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

$$= \frac{0.0266(420)^2}{9.6}$$

$$= 2(420) - \frac{9.6}{0.0266}$$

$$= 638.4 \text{ m}$$

$$L = 479.09 \text{ m}$$

$$\text{I.S.D} = 2(\text{S.S.D})$$

∴ It is allowable

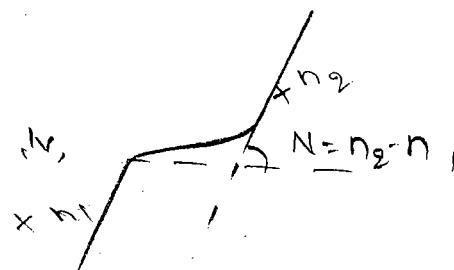
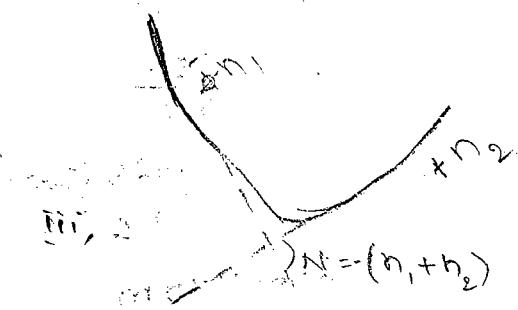
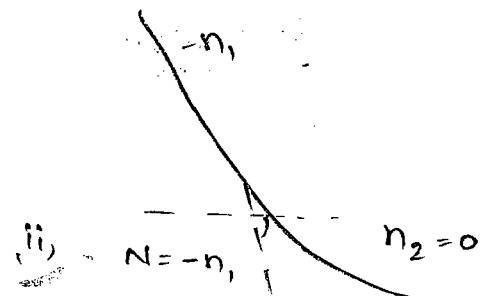
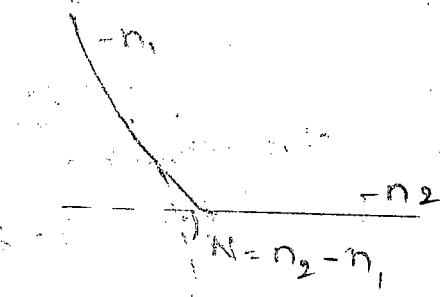
$$= 2 \times 180$$

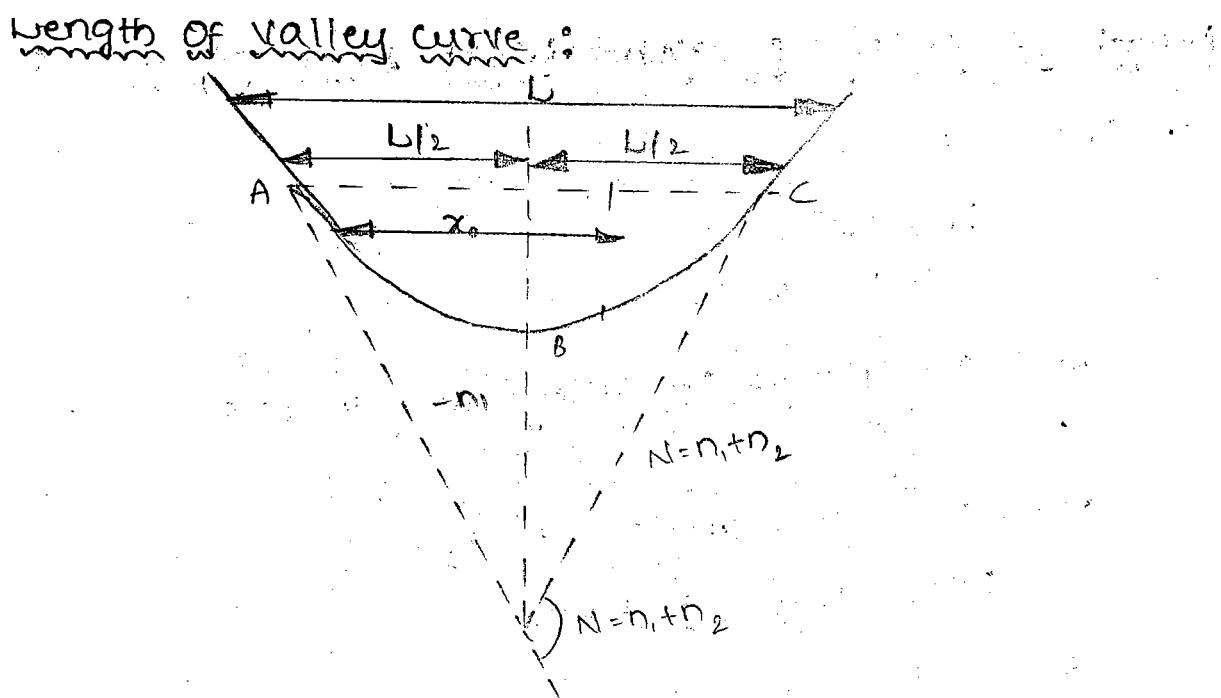
$$= 360 \text{ m}$$

$$L = \frac{Ns^2}{9.6} = \frac{0.0266 \times 360^2}{9.6}$$

$$L = 351 \text{ m}$$

Valley curves :





a) Length of Transition Curve

$$L_s = \frac{V^3}{CR}$$

$$\text{Value of } R \text{ at length } (s) = \frac{L_s}{N} = \frac{L}{2N}$$

$$L_s = \frac{V^3}{CR_s} \times N \Rightarrow L_s^2 = \frac{NV^3}{C}$$

$$L_s = \left(\frac{NV^3}{C} \right)^{1/2} \rightarrow ①$$

$$L = 2L_s = 2 \left(\frac{NV^3}{C} \right)^{1/2} \rightarrow ②$$

$$V \text{ kmph} = \frac{V}{36} \text{ m/s}$$

$$L_s^2 = \frac{NV^3}{0.6 \pi 36}$$

$$L_s = 0.19 [NV^3]^{1/2}$$

$$L = 2L_s = [0.38 (NV^3)^{1/3}]$$

$$\begin{aligned} \text{Total length of valley curve is } L &= 2 \left(\frac{NV^3}{C} \right)^{1/2} \\ &= 0.3 [NV]^2 \end{aligned}$$

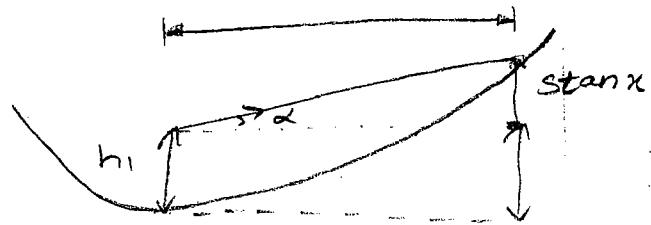
$V \rightarrow$ Design speed, kmph

$$\text{Min Radius } (R) = \frac{L_s}{N} = \frac{L}{2N}$$

Length of Valley for Head light sight distance :

(i) $L > S.S.D$

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



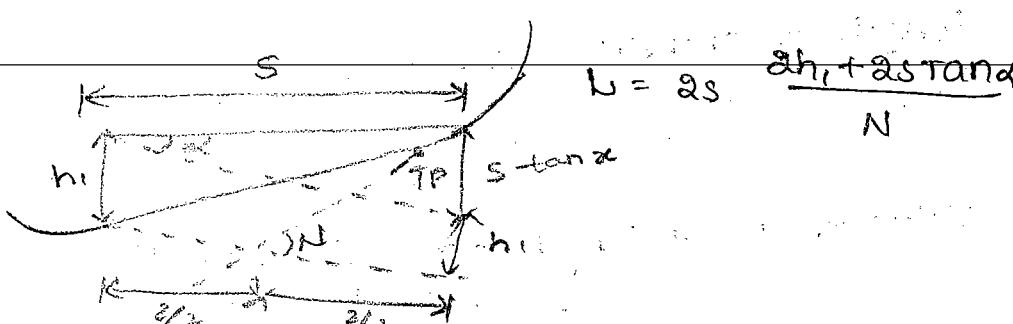
$L \rightarrow$ Total length of Valley curve $m(L > s)$

$s \rightarrow$ S.S.D

$N \rightarrow$ Deviation angle $= (n_1 + n_2)$

With slope $-n_1$ & $+n_2$

(ii) $L < S.S.D$



1. A Valley curve is descending grade of 1 in 30 meeting & ascending grade of 1 in 35 design the length of valley curve to fulfill both comfort & head light sight condition for $V = 80$ kmph. Assume allowable rate of change of centrifugal acceleration 6 m/s^3

A1-

Given, $V = 80 \text{ kmph} = 80 \times \frac{5}{18} = 22.2 \text{ m/s}$

$$n_1 = -\frac{1}{30}, n_2 = +\frac{1}{35}$$

Condition for comfort by valley curve

$$\begin{aligned} L &= 2 \left[f \frac{N N^3}{C} \right]^{1/2} \\ &= 2 \left[0.0049 \left(\frac{22.2}{6} \right)^3 \right]^{1/2} \\ &= 18.56 \text{ m} \end{aligned}$$

$$\begin{aligned} N &= -(n_1 + n_2) \\ &= -\left(-\frac{1}{30} + \frac{1}{35} \right) \\ &= 0.0049 \end{aligned}$$

Valley length for Head light sight distance

Assumed values are $t = 2 \text{ sec}$, $f = 0.35$

$$S.S.D = Vt + \frac{V^2}{2af}$$

$$= 22.2(2) + \frac{22.2^2}{2(9.81)(0.35)}$$

$$S.S.D = 116.16 \text{ m}$$

$$N > S.S.D \Rightarrow L = \frac{Ns^2}{1.5 + 0.035s}$$

$$= \frac{0.0049(116.16)^2}{1.5 + 0.035(116.16)}$$

$$\underline{\underline{L = 11.27 \text{ m}}}$$

-:- TRAFFIC ENGINEERING :-:-

Vehicular characteristics

Road user characteristics :

- Mental
- Physical
- Psychological
- Environmental

Vehicular characteristics :

- Width of vehicle ≤ 2.5
- Length of vehicle ≤ 6
- Loads on vehicle
- Height of vehicle
- Speed of vehicle

Important Efficiency of Brakes

1. A vehicle with ^{Initial} speed 30 kmph applied brakes and it stops after length of 5.8m. Find out Resistance

Al-

Given

$$\text{Initial speed} = 30 \text{ kmph}$$

$$= 30 \times \frac{5}{18}$$

$$= 8.33 \text{ m/sec}$$

length Braking distance $L = \frac{u^2}{2gf}$

$$f = \frac{u^2}{2gL}$$

$$= \frac{8.33^2}{2 \times 9.81 \times 5.8}$$

$$\underline{f = 0.609}$$

2. Vehicle with Initial speed 40 kmph with Braking time 1.8 sec
Find out Resistance?

Al-

Given,

Initial speed = 40 kmph

$$= 40 \times \frac{5}{18} \Rightarrow 11.11 \text{ msec}$$

Braking time = 1.8 sec

From the Eq's of Retardation $v = u + at$

$$v = 0, u = 11.11, t = 1.8$$

$$a = -\frac{u}{t}$$

$$= -\frac{11.11}{1.8} \Rightarrow a = -6.17 \text{ msec}^2$$

(-) denotes Retardation.

3.

Fric

Friction $F = ma$

$$F = m \cdot F$$

$$W \cdot F = \frac{m}{g} \cdot a$$

$$f = \frac{a}{g} = \frac{6.17}{9.81}$$

$$\underline{f = 0.62}$$

3. A vehicle with speed 40 kmph Breaking distance 12.2 having avg speed Resistance 0.5. Determine the Efficiency of Brakes
Al-

$$u = 40 \times \frac{5}{18} = 11.11 \text{ msec}$$

$$L = 12.2 \text{ m}$$

$$f = 0.50$$

$$f' = \frac{u^2}{2gL}$$

$$f' = \frac{11 \cdot 11^2}{2 \times 9.81 \times 12.2}$$

$$f' = 0.515$$

$$\epsilon = \frac{f'}{f} \times 100$$

$$\epsilon = \frac{0.515}{0.70}$$

$$= 73.5214$$

4. A vehicle with breaking time 1.2 sec & skid resistance length 6m. Find out the skid resistance.

Ans-

Given,

$$\text{Breaking time} = 1.2 \text{ sec} = t$$

$$\text{Skid distance } s = 6 \text{ m}$$

From the Eq's of acceleration and Retardation

$$V = U + at$$

$$as \leq u = -at$$

$$V^2 = U^2 = 2as$$

$$V = 0, -U^2 = 2as$$

$$s = \frac{-U^2}{2a}$$

$$s = \frac{-(-at)^2}{2a}$$

$$s = \frac{-at^2}{2}$$

$$a = -\frac{2s}{t^2} \Rightarrow a = -\frac{2 \times 6}{1.2^2}$$

$$a = -8.33 \text{ m/sec}^2$$

$$F = ma$$

$$f = \frac{a}{g} = \frac{8.33}{9.81}$$

$$f = 0.84$$

Traffic Engineering studies :

Traffic Volume studies

spot speed studies

Speed & Delay studies

Traffic volume studies : traffic coverage unit time

The unit of Traffic volume is P.C.U

Type of Vehicle	P.C.U Factor
Bike	0.35
Car, auto	1
Tractor	3
Bus, Heavy loaded	3
Truck	3

Annual Average Daily Traffic :

Avg Daily Traffic (ADT)

Avg Hourly Volume (Avg H.V.)

Peak Hourly Volume

Spot Speed Studies :

Traffic Volume characteristics;

Variation in volume

* Avg volume

* Avg volume per day

* Variation in traffic

* Distribution of Traffic

* Annual Avg daily Traffic

A.D.T for Adjustment of count station volume :

Daily factor D.F.

1 day Avg & for 24 hrs

24 hr count at any particular day

Seasonal factor S.F

Avg 24 hr traffic volume for 12 months

24 hr traffic vol count for specific month

the 24 hr traffic vol b/w any station on a specific day
in a particular Month A.D.T = Traffic vol. \propto D.F \propto S.F
count

Computation Of Annual Avg Daily Traffic

$$\begin{aligned} \text{A.A.D.T} &= \text{A.D.T} \times \text{D.T} \times \text{S.U.T} \times \text{S.T} \\ &= \text{A.D.T} \times \text{D.F} \times \text{W.F} \propto \text{S.F} \end{aligned}$$

Spot Speed Studies :

$$V_s = \frac{3.6 d n}{\sum_{i=1}^n t_i}$$

$V_s \rightarrow$ spot mean speed kmph

$d \rightarrow$ length of road (on distance considered)

$n \rightarrow$ No. of individual vehicle observations

$t_i \rightarrow$ observed travelled time for 1st vehicle to travel the distance

Time Mean speed is calculated from the Eq

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

Uses Of Spot Speed Studies :

- For Traffic Regulations & control
- Design (iii) Redesign of various Geometric elements
- To decide the design speed
- To estimate the accident studies & preventive measures
- Study of Traffic capacity
- To find out the speed trends
- To compare the behaviours of divergent vehicles

Factors Effecting Spot Speed studies:

- | | |
|------------------|-------------------------------------|
| Pavement width | Summit & Valley curves |
| Horizontal curve | pavement unevenness |
| Sight distance | Intersections |
| Gradients | Traffic conditions |
| | Characteristics of driver & vehicle |

Measurement of spot Speed studies:

Vehicle speed $v = \frac{d}{t}$ (m/sec)

Equipments used to measure spot speed studies

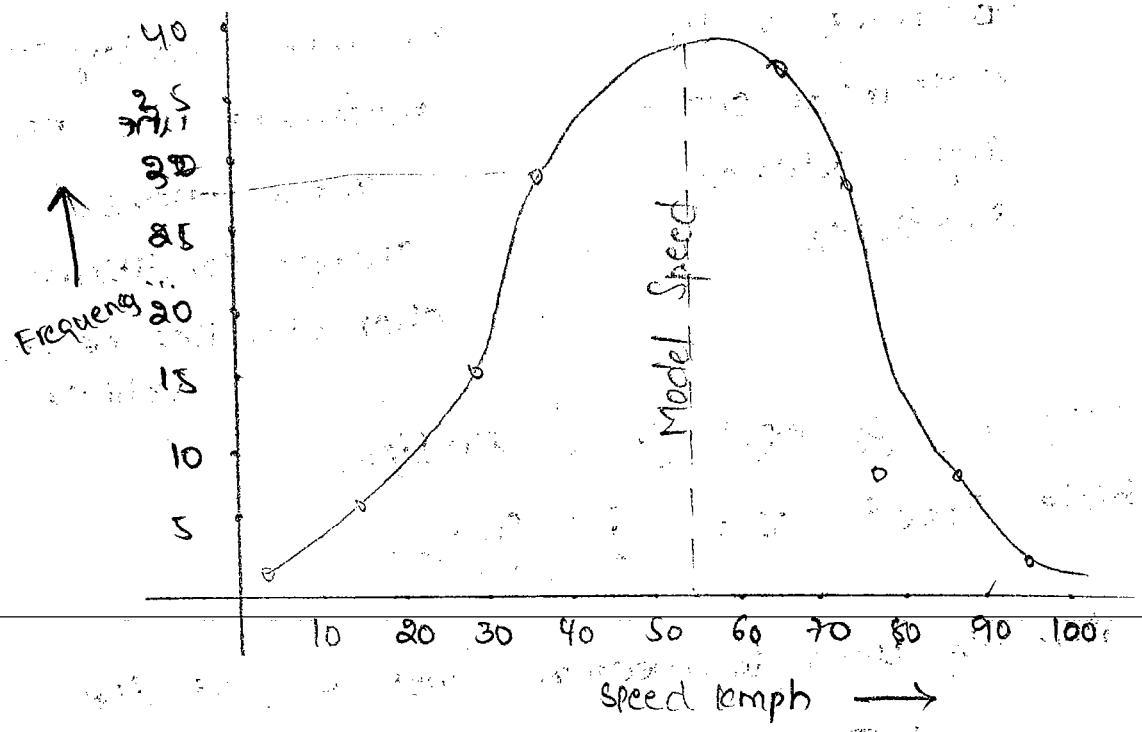
1. Traffic Recorder
2. Electronic meter
3. Photo Electric meter
4. Photographic Methods
5. Radar speed meter

Presentation of spot Speed studies:

Frequency Distribution diagram

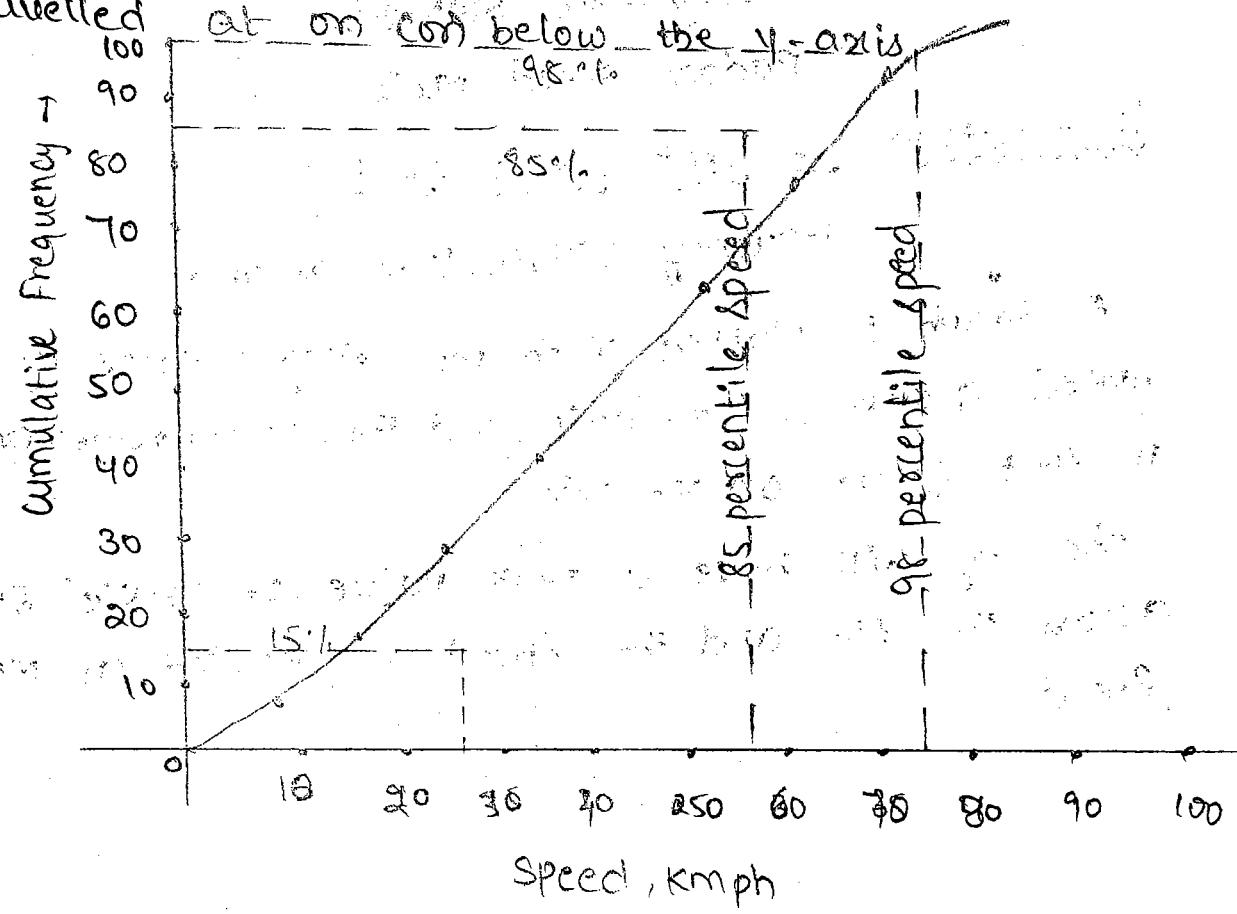
A Graph is plotted with the Avg values of each speed group on x-axis and the Percentage of vehicle in that group on y-axis.

The dig will have a peak value of travel speed across the slc and the speed is denoted as modal speed



Cumulative Speed Distribution diagram:

Graph plotted with the avg values of each speed group on the x-axis & cumulative %'s of vehicles travelled



Speed & Delay studies

The main objective of speed & delay studies is to find out running speeds of vehicles & fluctuations in vehicle speeds

Methods of conducting speed & delay studies

1. Floating car or Riding check method
2. License Plate (or) Vehicle No. method
3. Interview Technique
4. Elevated observations
5. Photographic Technique

1. Floating car method:

The floating car method is done by manually with the help of fast vehicle over a given rate.

$$\text{The Avg Journey time} : T = \frac{t_a + n_y}{q}$$

$$q = \frac{n_a + n_y}{t_a + t_w}$$

→ For Floating car only

$q \rightarrow$ Flow of Vehicles

$n_a \rightarrow$ Avg No. of vehicles

$n_y \rightarrow$ Avg No. of overtaking vehicles

$t_a \rightarrow$ Avg Journey time opposite to the stream

$t_w \rightarrow$ Avg Journey time in the direction of stream

2. License plate (or) Vehicle No. method:

In this Method Observers are stationed at the entrance and exit of the test stream

The timing and distance covered is noted manually

Origin and Destination Studies :

Applications :

- To know capacity of existing routes
- To establish design standards for roads, bridges, canals, railways, airways
- To locate express ways on major routes
- To establish types of vehicles
- To locate the new bridge as per traffic demands

Methods of conducting origin & destination studies

Road side method

License plate method

Written post card method.

Tag on car method

Home interview

Parking studies :

Types of parking :

On street parking

Off street parking

Accident studies :

Causes of accidents :

1. Road users
2. Vehicles
3. Traffic
4. Visibility & climatic conditions
5. Geometric elements
6. Efficiency of brakes
7. Condition of road

Accident Analysis :

Analysis of Initial speed from skid distance :

$$V_1 = \sqrt{V_2^2 + 2gfs}$$

$$V_1 = \sqrt{V_2^2 + 254fs}$$

Accident type -

↳ collision of moving vehicle with parked vehicle

Before Collision : $V_1^2 = V_2^2 + 2gfs,$

At Collision :

$$V_2 = \frac{W_A + W_B}{W_A} V_3 + agfs,$$

After Collision :

$$V_1 = \sqrt{254f \left[S_2 \left(\frac{W_A + W_B}{W_A} \right)^2 + S_1 \right]}$$

$W_A \rightarrow$ weight of moving vehicle

$W_B \rightarrow$ weight of parked vehicle

$f \rightarrow$ friction

$S_1 \rightarrow$ skid distance before collision

$S_2 \rightarrow$ skid distance after collision for both
the vehicles are together

Initial
 $V_1 \rightarrow$ vehicle speed

$V_2 \rightarrow$ initial speed
before collision

$V_3 \rightarrow$ speed after
collision

- Vehicle of weight 2 tonnes, skid distance before collision is 40m. Parked vehicle weight 1 tonne. Skid distance after collision 12 m. Friction 0.5. Compute vehicle speeds

Given:

Weight $w_A = 2$ tonnes

$S_1 = 40$ m

$w_B = 1$

$S_2 = 12$ m

$f = 0.5$

After collision:

$$\frac{W_A + W_B}{2g} [V_3^2 - V_4^2] = (W_A + W_B) \cdot F \cdot S_2$$

$$\frac{W_A + W_B}{2g} [V_3^2 - V_4^2] = (W_A + W_B) \cdot F \cdot S_2$$

($V_4 = 0$)

$$V_3^2 - 0 = 2g F S_2$$

$$V_3 = \sqrt{2g F S_2}$$

$$V_3 = \sqrt{2 \times 9.81 \times 0.5 \times 12}$$

$$V_3 = 10.84 \text{ m/sec}$$

At collision:

$$\frac{W_A V_2}{g} = \left[\frac{W_A + W_B}{g} \right] V_3$$

$$V_2 = \left[\frac{W_A + W_B}{W_A} \right] V_3$$

$$V_2 = \left[\frac{2+1}{2} \right] \times 10.84$$

$$V_2 = 16.26 \text{ m/sec.}$$

Before collision:

$$\frac{W_A}{2g} [V_1^2 - V_2^2] = W_A \cdot f \cdot S_1$$

$$V_1^2 - V_2^2 = 2g F S_1$$

$$V_1 = \sqrt{2g F S_1 + V_2^2}$$

$$= \sqrt{2 \times 9.81 \times 0.5 \times 40 + (16.26)^2}$$

$$V_1 = 25.82 \text{ m/sec}$$

i.e. 92.26 Km/h

Another method:

$$\text{After collision: } V_t = \sqrt{254 f_1 [s_2 \left(\frac{w_A + w_B}{w_A} \right)^2 + s_1]}$$

$$= \sqrt{254 \times 0.5 [12 \left(\frac{2+1}{2} \right)^2 + 40]}$$

$$= 92.24 \text{ kmph}$$

Traffic Signals:

At intersection there are so many complex cases. lot of damage property and people. To facilitate intime travel we need to fixed traffic signals at intersections.

There are so many methods for fixing signals system. In general traffic signals time varying queuelength

Single signal system:

Tri cycle method:

(i) The 15 minutes traffic count 'n₁' and 'n₂' on road 1 and 2 will be noted during the design peaks hour flow.

Some suitable tricycle 'c' is assumed and cycles in 15 min. 15×60 seconds.

$$\text{The cycle period} = \frac{50 \times 60}{c}$$

Assuming an Average time head way 2.5 sec.

'G₁' and 'G₂' are green periods for Road 1 & 2.

$$G_1 = \frac{2.5 \times n_1 \times 9}{900} \quad \text{and} \quad G_2 = \frac{2.5 \times n_2 \times 4}{900}$$

Then the Amber period A_1 and A_2 are either calculated (or) observed so that cycle length $C_i = G_1 + G_2 + A_1 + A_2$.

Ex 1: The 15min traffic count on cross roads 1, 2 during peak hours observes an 178 and 142 no. of vehicles per hour. If Amber coins are 3 and 2 sec. Design signal timing by tricycle method assume average headway 2.5 sec during green face?

Given data:

$$n_1 = 178 \quad A_1 = 2 \text{ sec} \quad \text{headway} = 2.5 \text{ sec}$$

$$n_2 = 142 \quad A_2 = 3 \text{ sec} \quad \text{Assume a tricycle } c_i = 50 \text{ sec}$$

$$\text{No. of cycles in 15 min} = \frac{15 \times 60}{50} = 18 \text{ sec}$$

Green time for Road 1: $G_1 = \frac{2.5 \times 178 \times 50}{900}$

$$= 24.72 \text{ sec}$$

Green time for Road 2: $G_2 = \frac{2.5 \times 142 \times 50}{900}$

$$= 19.72 \text{ sec}$$

$$\text{Total cycle length } C_i = G_1 + G_2 + A_1 + A_2$$

$$= 24.72 + 19.72 + 2 + 3$$

$$= 49.44 \text{ sec.}$$

This is lower than the assumed tricycle of 50 sec. another lower cycle length may be

Trail 2:

$$n_1 = 178 \quad A_1 = 2 \text{ sec} \quad \text{head way} = 2.5 \text{ sec}$$

$$n_2 = 142 \quad A_2 = 3 \text{ sec} \quad C_1 = 40 \text{ sec}$$

$$C_1 = \frac{50 \times 15}{40} = 22.5 \text{ sec.}$$

$$G_1 = \frac{2.5 \times 178 \times 40}{900} = 19.7 \text{ sec}$$

$$G_L = \frac{2.5 \times 142 \times 40}{900} = 15.7 \text{ sec}$$

$$\text{Total cycle length } G = G_1 + G_L + A_1 + A_2$$

$$= 40.4 \text{ sec.}$$

Trail 3:

$$n_1 = 178 \quad A_1 = 2 \text{ sec} \quad \text{head way} = 2.5 \text{ sec}$$

$$n_2 = 142 \quad A_2 = 3 \text{ sec} \quad C_1 = 45 \text{ sec}$$

$$C_1 = \frac{15 \times 60}{45} = 20 \text{ sec}$$

$$G_1 = \frac{2.5 \times 178 \times 45}{900} = 22.25 \text{ sec}$$

$$G_L = \frac{2.5 \times 142 \times 45}{900} = 17.75 \text{ sec}$$

$$\text{Total cycle length } G = G_1 + G_L + A_1 + A_2$$

$$= 45 \text{ sec.}$$

Hence ok.

2. Approximate method based on pedestrian procedure.

- (i) Based on pedestrian walking speed 1.2 m/sec to the road way width of each road the minimum time for the pedestrian to cross each road is calculated
 - (ii) Total pedestrian crossing time should not less than 7 seconds.
 - (iii) The Amber period is 2 to 4 seconds

Ex 1: An isolated traffic signal with pedestrian induction with road (i) 18m and road (ii) 12m, traffic volume 275 & 225 approximate speed 55 kmph, pedestrian speed 1.2m/sec during the timings of two way traffic design pedestrian signals by appropriate method.

Given date _____ Month _____ Year _____

Width of road (W) = 18m

width of road (2) 5129

— traffic volume (v) = 245

$$(ii) = 225$$

Pedestrian Speed = 1.2 m/sec

At 1st. approx. Speed = 55 mph.

(i) Design of two way traffic Signals

pt pedestrian crossing for road i = $\frac{18}{1.2} = 15 \text{ sec}$

$$L = \text{arc length} = \frac{14}{1.2} = 10.83$$

Adding 7 seconds per initial walk period that should be minimum red time per road (i) for 1 min

$$R_a = 15 + 7 = 22 \text{ sec}$$

$$R_b = 10 + 7 = 17 \text{ sec}$$

Minimum green time for Road (b) = 3

$$= 22 - 3 \Rightarrow 19 \text{ sec}$$

Minimum green time for Road (a) = 3

$$= 17 - 3 = 14 \text{ sec}$$

Using the relationship

$$\frac{G_a}{G_b} = \frac{N_a}{N_b}$$

$$\therefore G_a = \frac{N_a}{N_b} \times G_b$$

$$= \frac{275}{225} \times 19 \Rightarrow 23.22 \text{ sec.}$$

Total cycle length $G_a + G_b + A_1 + A_2$

$$= 23.22 + 19 + 3 + 3$$

$$\approx 48.2 \text{ sec}$$

An additional period of $50 - 48.2 = 1.8 \text{ sec}$.

So divide $1.8/2 = 0.9 \text{ sec}$

length of each of the two phases

$$G_a = 23.2 + 0.9 = 24.1 \text{ sec}$$

$$G_b = 9 + 0.9 = 9.9 \text{ sec}$$

$$R_a = G_b + A_b$$

$$= 9 + 3 = 12 \text{ sec}$$

$$R_b = G_a + A_a$$

$$= 24.1 + 3 = 27.1 \text{ sec}$$

$$= G_a + G_b + A_a + A_b$$

Final cycle length

$$= 50 \text{ sec}$$

2. A cross road (a) and (b) traffic volume is 700 and 400
approximate speed 50 and 30 road width 14m & 10m
pedestrian speed 1.2 m/sec design (i) 2 way traffic signals
(ii) pedestrian signal.

Given data

Road (a) = 14m

Road (b) = 10m

$$\eta_a = 700 \text{ and } N_b = 400$$

$$\text{pedestrian crossing road (a)} = \frac{14}{1.2} = 11.6 \text{ sec}$$

$$\text{pedestrian crossing road (b)} = \frac{10}{1.2} = 8.3 \text{ sec}$$

adding 7 second per initial walk period

$$R_a = 11.6 + 7 = 18.6 \text{ sec}$$

$$R_b = 8.3 + 7 = 15.3 \text{ sec} \equiv 16$$

green time for Road (b) = $19 - 3$

Intersection cycle length $\equiv 16 \text{ sec}$

green time for Road (a) $= 16 - 3$

$\equiv 13 \text{ sec}$

length of intersection $\equiv 0.6 \text{ sec}$

all together intersection cycle length $\equiv 16 + 0.6 = 16.6 \text{ sec}$

using Relation

$$\frac{G_a}{G_b} = \frac{N_a}{N_b}$$

$$G_a = \frac{N_a}{N_b} \times G_b \implies \frac{400}{400} \times 16 \implies 28 \text{ sec}$$

$$\text{Total cycle length} = G_a + G_b + A_b + A_a$$

$$= 28 + 16 + 3 + 3$$

$$= 50 \text{ sec}$$

3. Webster Method of traffic signal

Assumption:- Traffic Volume 160 PCU per 0.3m

Equations:-

$$y_1 = \frac{q_1}{s_1} \quad \text{and} \quad y_2 = \frac{q_2}{s_2} \quad C_0 = \frac{1.5L + 5}{1 - y}$$

$$\therefore y = y_1 + y_2$$

L = Total lost time for cycle $= 2N + R$

N = No. of faces

R = All red time are red & Amber time

S. & S = saturation

$$G_1 = \frac{y_1}{Y} [C_0 - L] \quad \text{and} \quad G_2 = \frac{y_2}{Y} [C_0 - L]$$

G_1 and G_2 are green time periods

Ex:1: An cross roads, A & B 400 & 250 pcu with saturation force 1250 & 1000 pcu all red time required pedestrian crossing time 12 sec. design two way traffic signal with Webster method.

Given data

$$R = 12 \text{ sec}$$

$$S_1 = 1250$$

$$S_2 = 1000$$

$$q_1 = 400 \text{ pcu/sec} \quad q_2 = 250 \text{ pcu/sec}$$

$$y_1 = \frac{q_1}{S_1} = \frac{400}{1250} = 0.32$$

$$y_2 = \frac{q_2}{S_2} = \frac{250}{1000} = 0.25$$

$$y = y_1 + y_2 \Rightarrow 0.32 + 0.25 = 0.57 \text{ sec}$$

$$C_0 = \frac{1.5(L+5)}{1-y} = \frac{1.5 \times 60 + 5}{1 - 0.57} = 67.5 \text{ sec}$$

$$L = 2A + R \Rightarrow 2 \times 24 + 12 \Rightarrow 60 \text{ sec}$$

out

$$G_1 = \frac{y_1}{Y} [C_0 - L]$$

$$= \frac{0.32}{0.57} [67.5 - 60] \text{ sec} \rightarrow 16 \text{ sec}$$

same for G_2 and total time 116 sec

for the additional 10% loss in condition which has been experienced
in the last 10 years. This is largely due to the
increased number of visitors to the park,
and to the effects of heavy grazing.

Plantation in disturbed areas

Let us now look at what has been done

soil erosion prevention work



Plantation work in disturbed areas



4. Design of road intersections: (or) classification of roads.

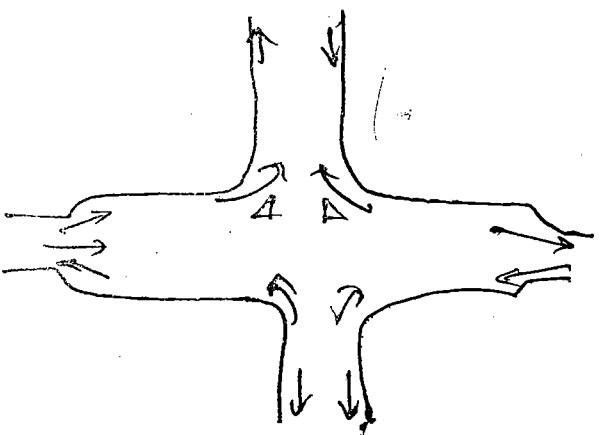
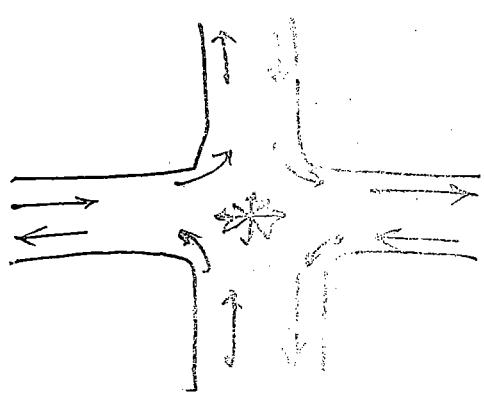
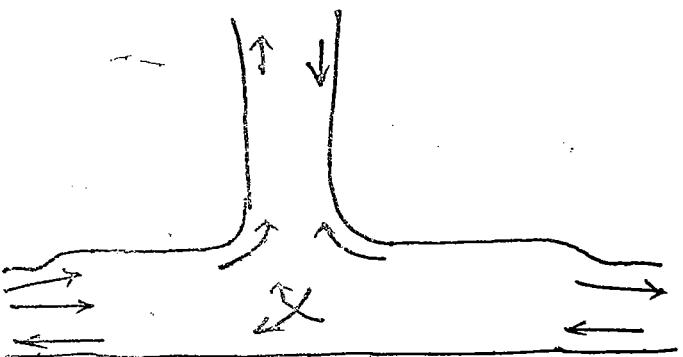
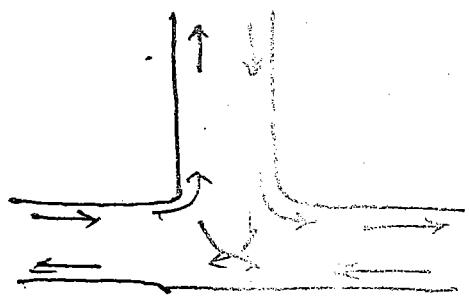
There are 2 types:

- They are 1. Intersection at grade
- 2. Grade separated with junction.

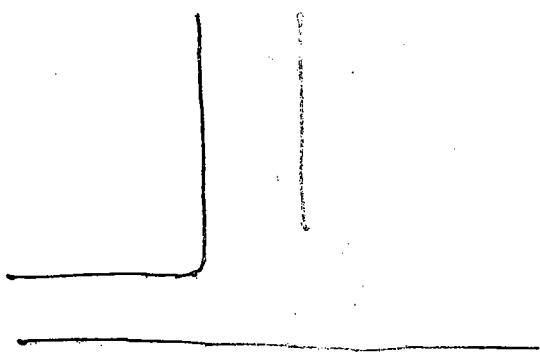
1. Intersection at grade:

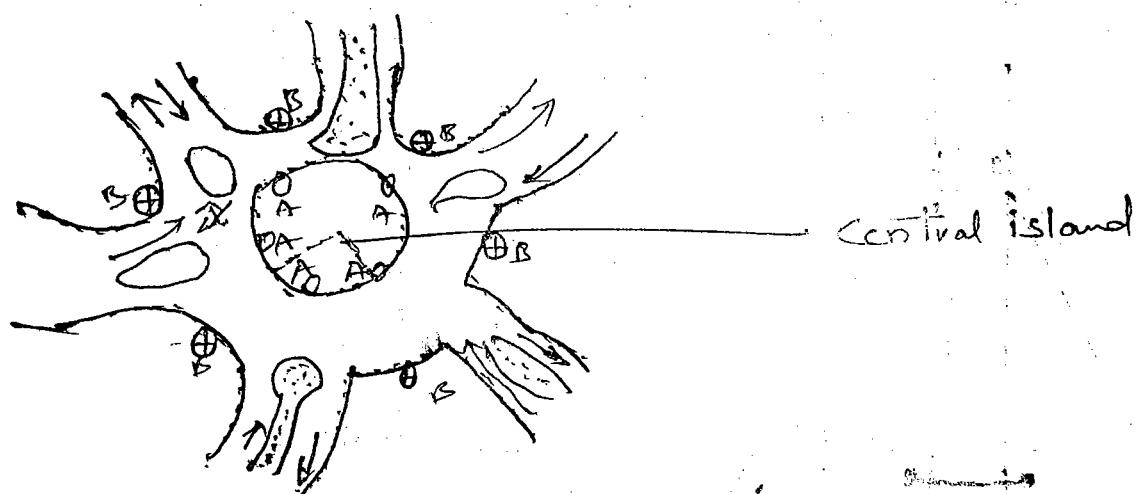
There are again 4 types. They are:

1. Unchannelised intersection:

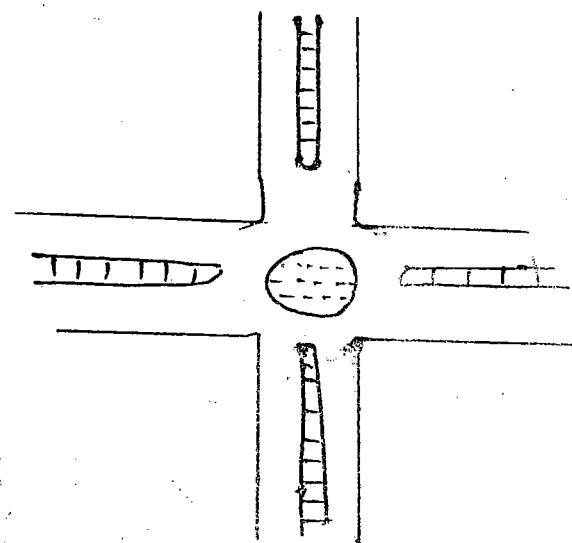


2. Channelised intersection:

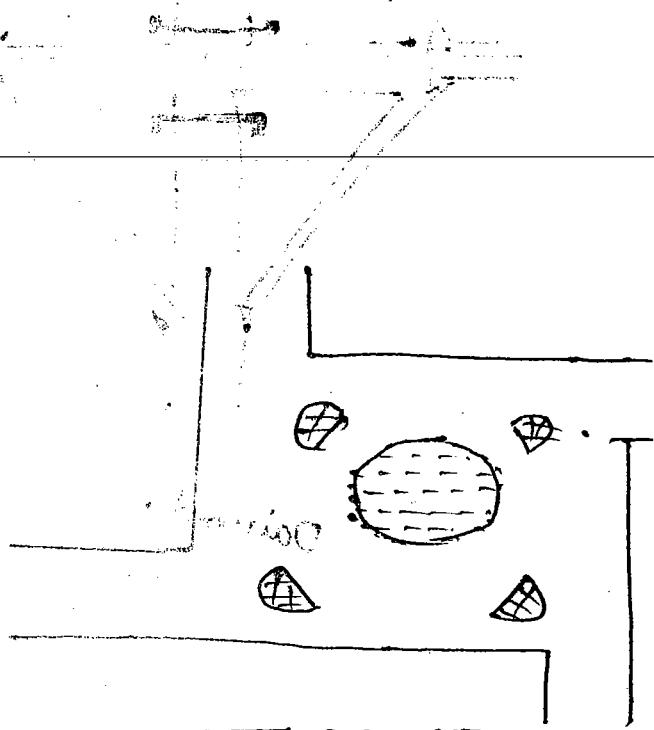




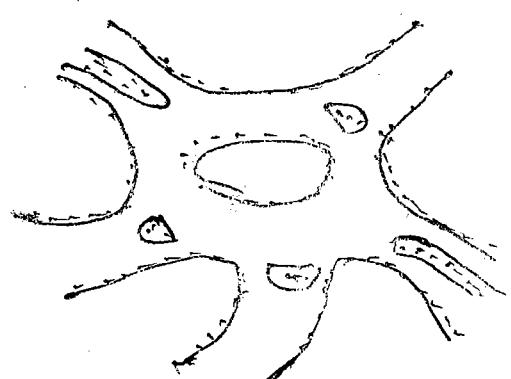
A typical rotary intersection



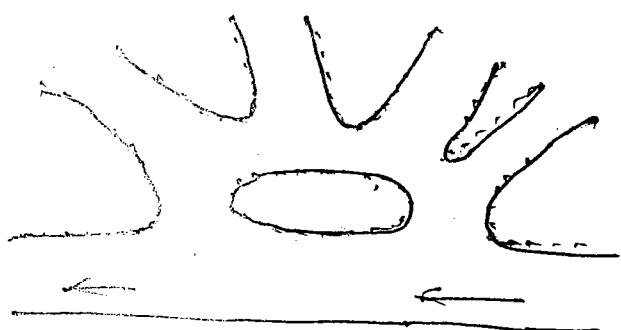
circular



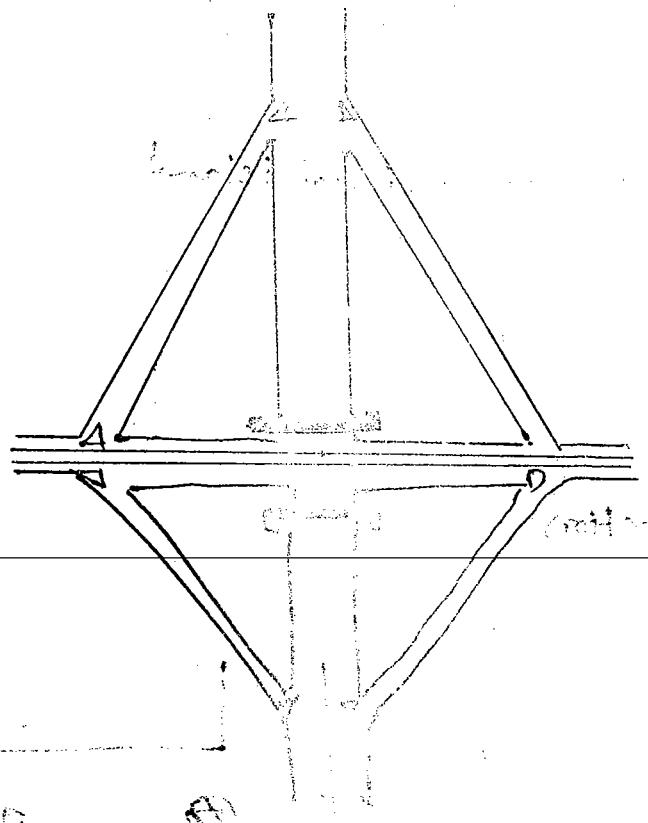
TURBINE



Elliptical

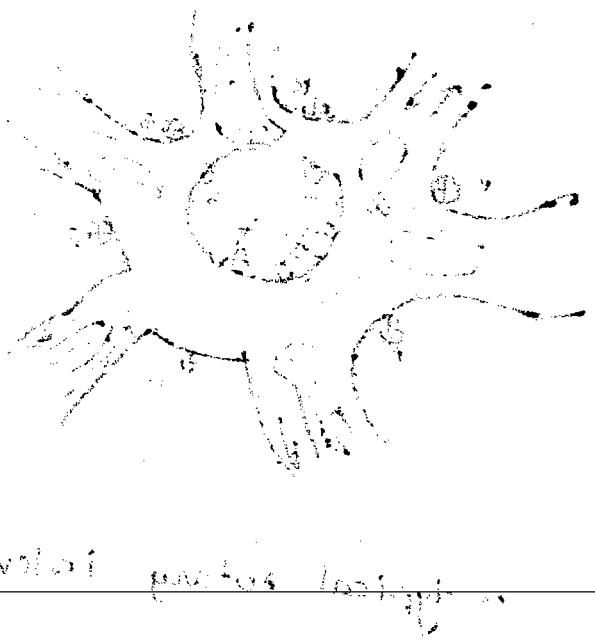


tangential



Diamond

Triangle



Irregular

Irregular shapes

Polygon

Irregular



loses

4 - HIGHWAY MATERIALS

Components of the Highway and Materials used :

1. Embankment
2. Sub grade
3. Pavement layers

Materials for Highway Embankment :

(Not useful) → fly ash, Locally available Materials (useful)

Biodegradable waste, Granular soil (useful)
(Not useful)

Materials in Highway cutting :

Granular soil

Characteristics & properties with Important Laboratory Tests
on the following highway materials :-

1. Soil
2. Stone Aggs
3. Bituminous Binders
4. Bituminous Mixes
5. Portland cement & cement concrete

Soil :

Desirable Properties of Soil

- Stability
- Incompressibility
- Strength
- Volumetric changes
- Drainage conditions
- Ease of Compaction

Index Properties Of Soil

1. Grain size Distribution
2. Liquid limit
3. Plastic limit

Soil Classification

	Sand			Silt			Clay		
Giravell	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine
	2.0*	0.6*	0.2		0.06	0.02	0.0006	0.002	0.00006

Soil classification methods

1. Textural soil classification
2. Bernsties Descriptive classification
3. Casagrande classification
4. Unified soil classification - BIS soil classification
Bureau of Indian Standards
5. U.S Public Road Administration classification
6. Highway Research Board classification
7. Federal Aviation Administration classification (F.A.A)
8. Civil Aeronatic Administration classification
9. Compaction classification

Sub grade Soil strength :

Factors on which the strength characteristic of soil depends

1. Soil type
2. Moisture content
3. Dry density
4. Internal structure of soil

5. Type and mode of ^{of stress} Application of soil

Columbs and Esphirical Law :

$$SR = C + \sigma \tan \phi$$

SR \Rightarrow Shearing Resistance

C \Rightarrow Cohesion per unit area

ϕ \Rightarrow Angle of Internal Friction

σ \Rightarrow Normal stress

Evaluation of soil strength :

1. Shear Test

2. Bearing Test

3. Penetration Test

Shear Test :

\rightarrow Direct shear test

\rightarrow Tri axial compression test

Bearing Test and Penetration Test :

California Bearing Ratio (CBR)

Direct shear Test :

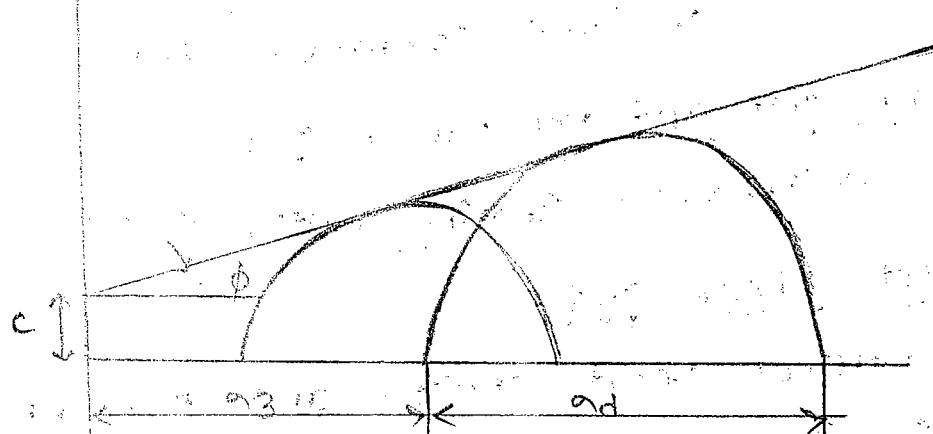
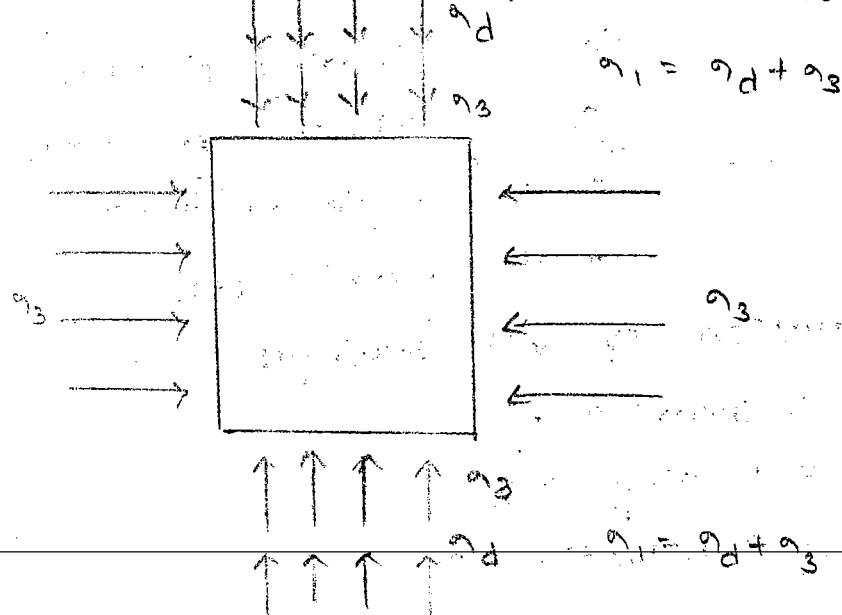
A vertical load applied and horizontal pull caused to produce certain rate of horizontal displacement at maximum horizontal force at failure measured for different values of normal load.

The values of maximum shear stress applied for the different vertical stresses are computed and plotted on a graph.

The values of cohesion and angle of internal friction are found either from graph (or) by using columbs equation

Tri axial compression test : \rightarrow load (or) stress is applied on multi directions \rightarrow its value

Tri axial test is accurate compared to direct shear Test



$$\sigma_1 = [\sigma_d + \sigma_3]$$

Mohr's circle envelope from tri-axial test results

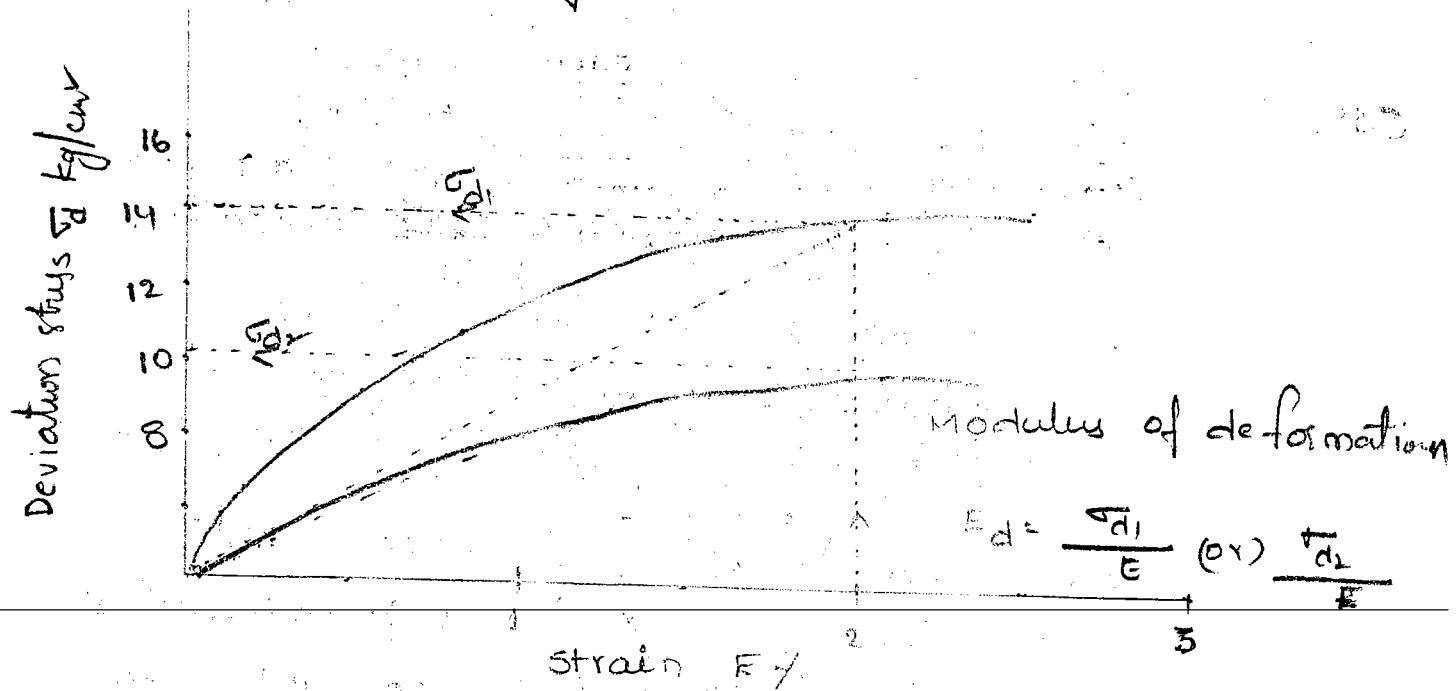
Correction for area of cross section :

$$\text{Volume} = A_0 l_0 = A_1 l_1 = A_1 (l_0 - \Delta)$$

$$\sigma_d = \frac{P_1}{A_1} = \frac{P_1 l_1}{A_0 l_0} = \frac{P_1}{A_0} \left[\frac{l_0 - \Delta}{l_0} \right]$$

$$\sigma_d = \frac{P_1}{A_0} [1 - \delta]$$

Stress strain diagram from triaxial compression test



california bearing ratio:

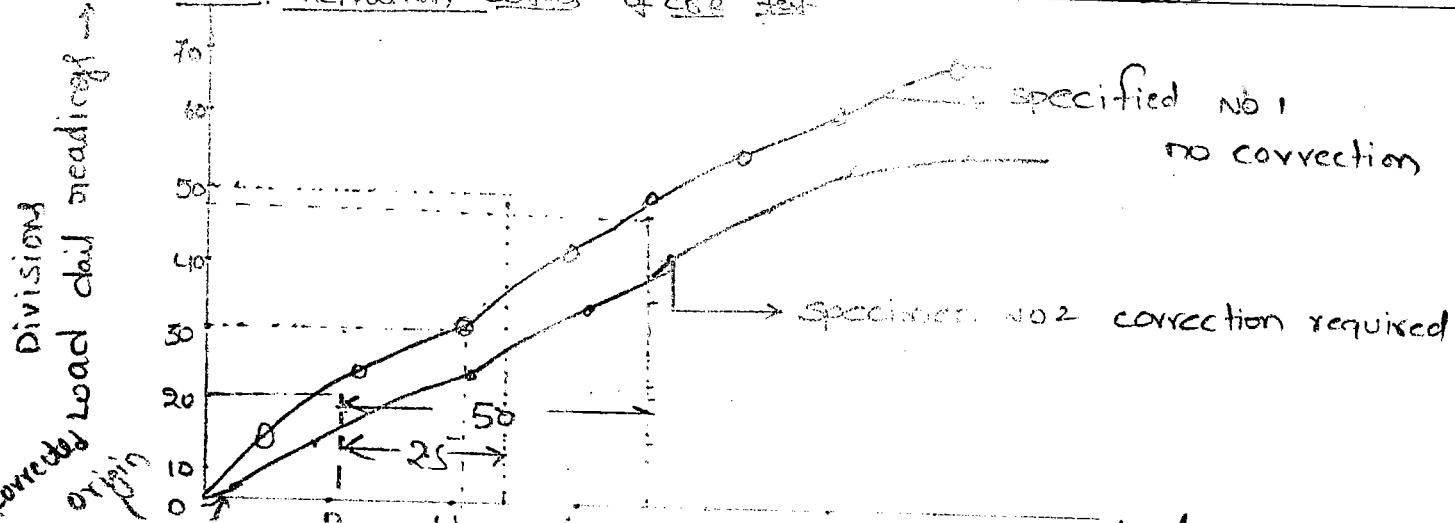
The basic principle in CBR test a cylindrical plumb of 50mm diameter to penetrate into the soil specimen at a rate of 1.25 mm/min.

The loads are applied for 2.5 mm & 5 mm deformation of the plumb into soil are recorded.

The standard load given below may directly be used in CBR.

Penetration in mm	standard load in kg	unit standard load kg/cm²
2.5	1570	70
5.0	2055	105

load penetration curves of cbr test

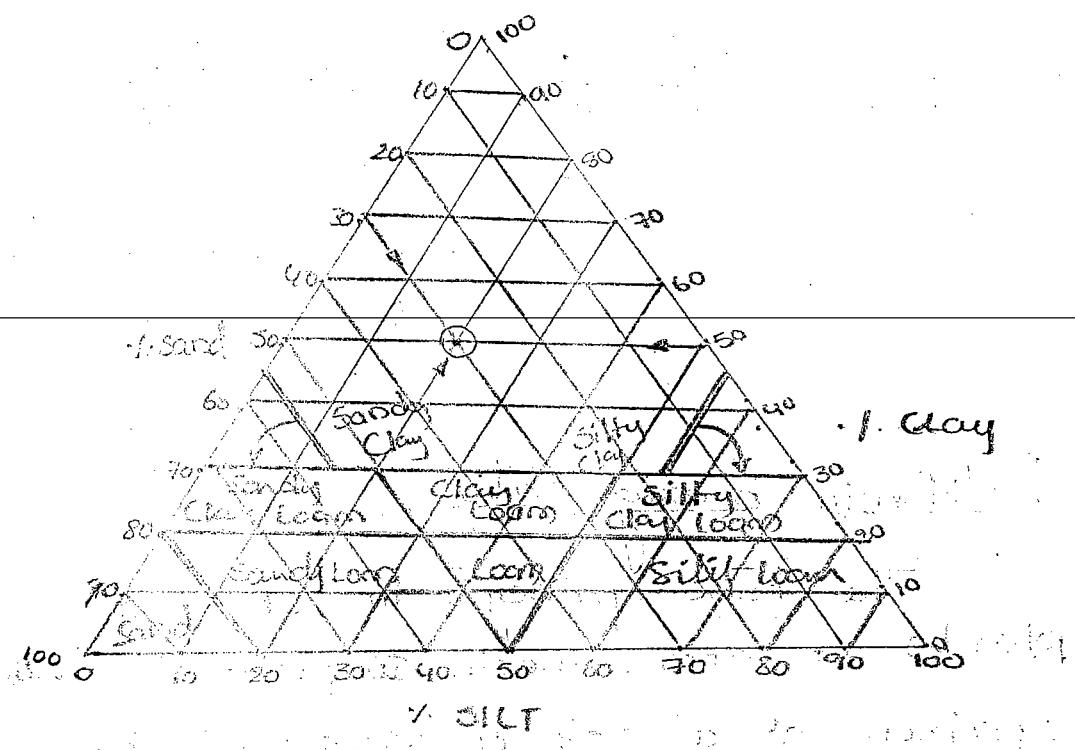


The CBR value calculated using the relation

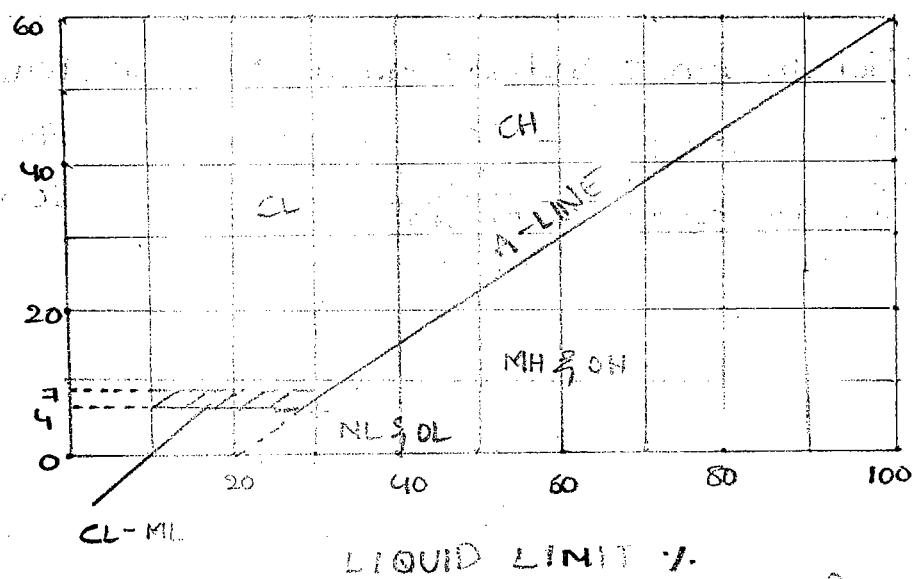
$\text{CBR} \cdot \%$

[Load (or) pressure sustained by the specimen at 2.5 (or) 5.0 mm penetration]

$\left[\frac{\text{load (or) pressure sustained by aggregate}}{\text{at the corresponding penetration level}} \right] \times 100$



TEXTURAL SOIL CLASSIFICATION CHART



Plasticity chart for Unified soil classification system

Plate bearing Test : only load application

diff is penetration

Introduction
Experimental
set up

EBR

Penetration & load
jacks, application
3 circular disks

We won't count
void ratio

Plate bearing

Load application

Soil settlement (1.95) mm

In this we count void
ratio

Stone Agg's :

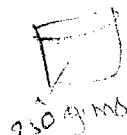
Desirable properties for stone agg's :

1. Resistance to Impact
2. Resistance to Abrasion and Adhesion
3. Req shape
4. Resistance to weathering
5. Resistance to compressive loads

Lab Tests on Agg's :

1. Impact Test
2. Los Angeles Abrasion Test
3. Devels Attrition Test
4. Crushing value (or) compression test
5. Specific gravity
6. Shape Test (Elongation and Flakiness Index)

Impact Test:



Sample damp with water + load
Ag -> W₁

2.56 mm dia. Agg will come out that powder as W₂ W₁ × 100

W₂ / W₁ = % of

Abrasion Attrition

↓ Failure of Agg's ↓

deep failure

surface failure

6 spherical balls → load

Hydraulic box used → agg be filled in box → then we apply load by spherical balls → switch on supply ^{and rotate} → those balls hit the agg → deep failure will occur

Danveils → same as above but we take 2 moulds

Crushing

→ 3 spherical ball

2 kg of agg → take the mould with agg on UTM → gap should be leave in the mould →

Sp Gravity

→ Take agg weight → w_1

→ weighing bucket will be fill with agg & put it into water

→ then again check the weight of agg → w_2

→ clear the agg and expose to the sun → w_3

→ then put the agg into oven → w_4

By using water Absorb, sp. gravity, bulk density formulae we measure

shape:

All sizes are arranged in order

1 kg of brick lime are put on 63 seive

then that agg will pass through flaky scale & elongated scale.

Weight of passed agg

$\times 100\%$

1 kg of Agg's weight

In elongated → we pass the agg along length wise

Labaratory Tests on Bitumen

Penetration Test

Viscosity Test

Ductility Test

Softening Point

Specific Gravity

Flash & Fire

Laggs on Heating Test

Solubility Test

Penetration Test :

Consider a bitumen sample and heat the sample by using penetration level we identify Grade & softness of bitumen.

Procedure :

Take a panet & add sand to it & stir it well, then it becomes soft.

Take a penetration mould (5 cm of height) and fill this bitumen into mould & leave some 5mm space cool it for 50 min in water bath.

Fix into a penetration dial gauge.

Penetration time will be 10 sec.

This dial gauge shows reading to be the penetration value multiply the value by 10² because the needle value is $\frac{1}{10}$.

Viscosity Test :

Need : How much of Agg will be added to bitumen also known by this viscosity method.

Ductility Test :

Due to this ductility test we know how much of materials add to the bitumen to convert the bitumen into liquid state.

→ Take a bitumen into mould and put in water bath

softening point :

If we add agg to Bitumen how can it ease to allow +

At what temp Bitumen convert into semi liquid state

Initial weight of Bit = w_1

At water bath = w_2

Dry condition of Bitumen = w_3

Bituminous Paving Mixes :

We add some mixtures to Bitumen (only 2-8%)

The major diff b/w Thar & Bitumen is

If we heat the Thar it will release much amount of carbon

It reacts with O to form CO which is Harmful

like wise If we heat the Bitumen it will also release carbon but it will be less as compared to Thar

→ We adding some extra materials like plastic to Bitumen.

Tire powder are mixed with soil and added to the Foundation (2%) It gives some more strength

Notes 1

Requirement of the lower layers of flexible pavement :

F

Type of pavements

Flexible Eg: Bituminous Roads

Rigid Eg: cement concrete Roads

* If the soil is weak or there is any water problem on the ground we need this Bituminous pavement to the inner layers. (also add lime & geopolymers)

Constituents of Bituminous mixes

Bitumen

Aggs

Filler (Hydrated lime, stone dust) It pass on

Bituminous Binder

mix

75 seive

Desirable properties of Bituminous mix:

Adequate Stability To stable from water fishes, Earth quakes etc...

Adequate Flexibility Easy to move on any direction (or) may

Adequate Resistance Water percolation

Adjustment with Temperature variation

Durability life span

* Posses some amount of voids

Skid Resistance (To provide friction

Workability by adding Agg)

Requirements of Design mix:

Stability

Flexibility

Voids

Durability

It is in liquid state
voids are helpful to move the Bitumen
out If there is no voids in it the Bitum
flows out of pavemen

5. DESIGN OF HIGHWAY PAVEMENTS

Types of Pavements :

- a) Flexible pavement (Bituminous pavement)
- b) Rigid Pavement (Cement concrete pavements)

Factors

Engineering design of pavement :

a) Flexible pavements :

- a) Wheel Load (passenger wl + gravitational + vehicle load)
- b) Subgrade soil
- c) Climatic conditions

d) Pavement material mix proportion in each layer

e) Damage & Environmental factors

→ Design of flexible pavements consists of 2 parts:

i) Mix design of materials

ii) Thickness design of pavement directly proportional to traffic load

→ Mix design of wheel loads:

 a) Traffic loads (depends on speed)

 b) Wheel load & contact pressure → Type of Tyre

 c) Equivalent single wheel load Design of Tyre
 Age of Tyre

It is designed in the single wheel load replacement of the dual wheel assembly which will cause the same magnitude of vertical deflection with same compressive strength.

Flexible pavements :

Flexible pavements have negligible flexural strength and it relies rather flexibility in their structural action.

If the pavement layers are distressed the total
Pavement will deteriorate early

