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 compatable movement of people & goods.

Developing process :—

→ Planning
→ Priliminary designing
→ Detailed designing
→ Construction
→ Operation
→ Planning

Modes of Transportation :

* Railways
  → Surface
  → underground
  → Elevated ways Eg: metro rails
* Road ways
* Air ways
* water ways
* Pipe lines (Tunnel ways)
* Roap 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 & Assesment

Modern Classification Of Roads :

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

Classification Of Roads in Metropolitian 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

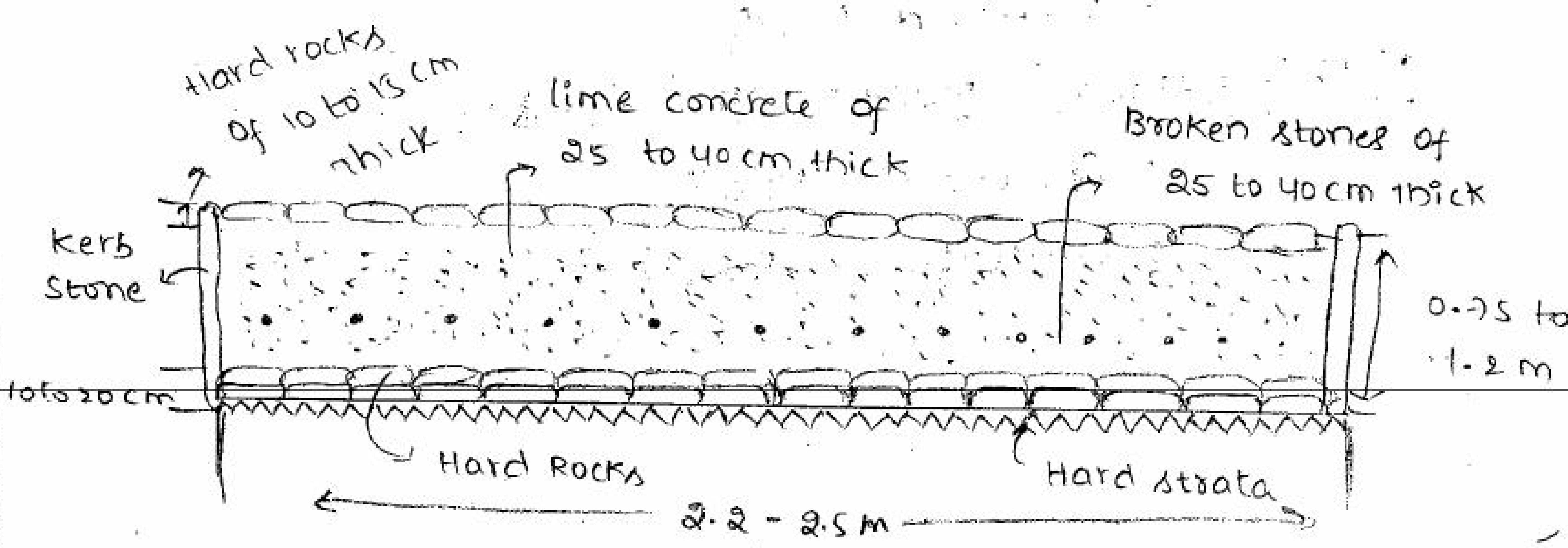
Classification Based on Surface :—

1. Surfaced Roads

2. Unsurfaced Roads

1. HIGHWAY PLANNING & DEVELOPMENT

Im 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

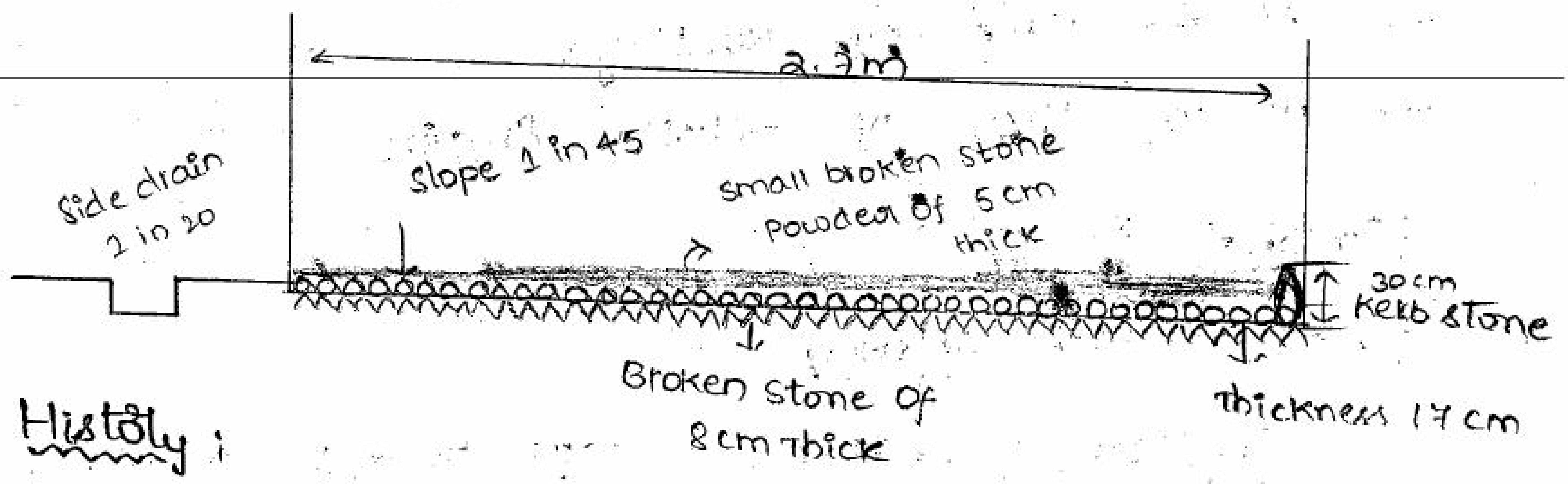
1. they laid roads regardless of gradients
2. upto a hard strata they trench & they remove loose soil
3. They used to mix lime concrete and surfaced with Hard rocks even the vehicle wheel is hard to move.

* 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 intiated 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 maintaine 1 in 45 slope to drain rain water

→ They covered the construction Edges with 17 cm 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

Moughal Roads :—

Roads in 19th century :—

Jayakar Commitee in 1927 to make a total o/p of Road pattern

Recommendations :

1. Capital Investment gov 80 % & people 20 %
2. Extra tax on petrol (secondary fund)
3. Semi official Technical body → gaving advices, giving standards } IRC
4. Research & Development panel like length of Road, turnings width etc ...

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 :— (IRC)

Established in 1934 — still working

Some specifications like maintainance, Geometric designs, Highway structure, Traffic designs, structure designs etc... Research materials like Bitumen & some powders

2M

(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 decla

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 → Road of 100 sqm length of Road
First 5 year road plane

1956 - 1961 second 5 year road plane

For 100 sq km area the length of road should be [illegible]

[illegible] Road Plan :

Second 20 year Road plan Establis. 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

Teritary classificate : Village Roads

Review of Highway Development in India after Independence :—

Before allotment of Jaykar commitee, the length of the road to 100 sq. km is 11.8 km

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

1st 20 year Road plan – 16 km

2nd 20 " " – 34.8 km

3rd 20 " " " – 46 km

This is due to the Mobility & population Increment

Span of 1951 - 1981 → users of motor vehicle users are 3,00,000 to 40,00,000

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.

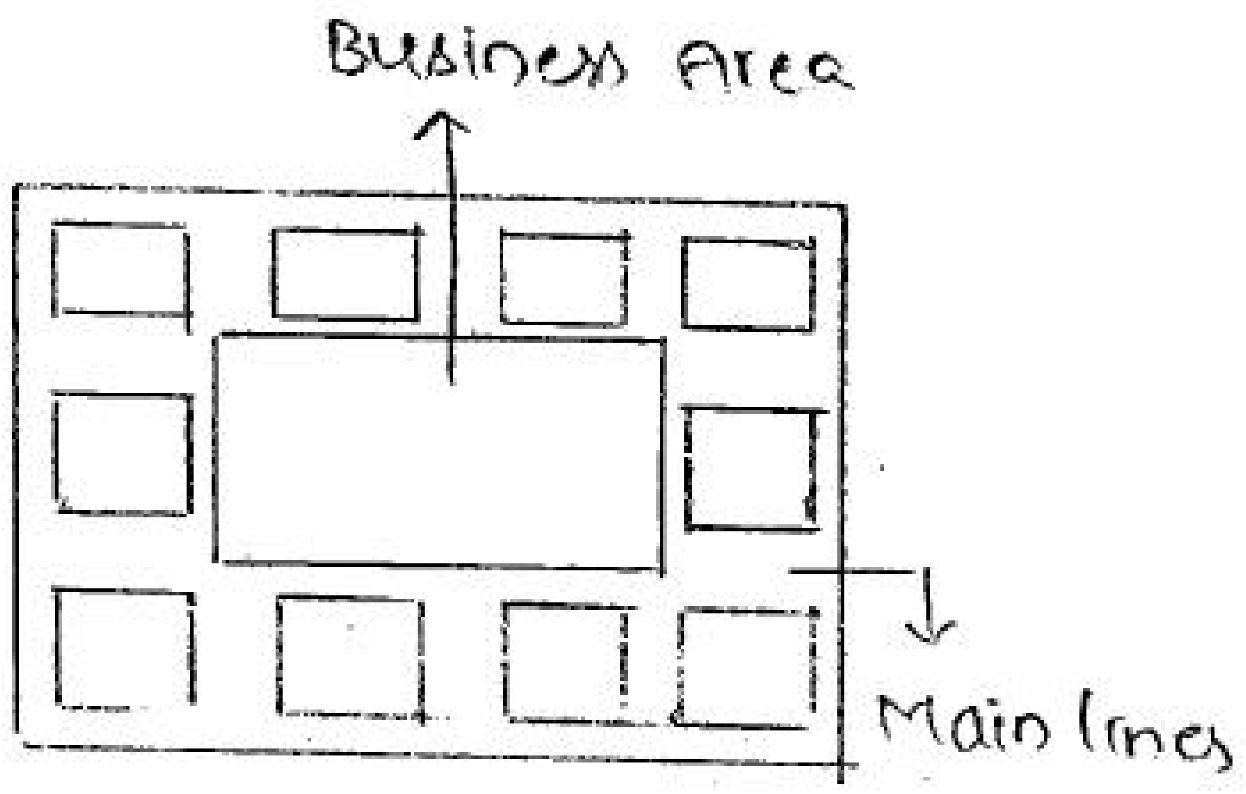
→ To utilize the total road length upto design period

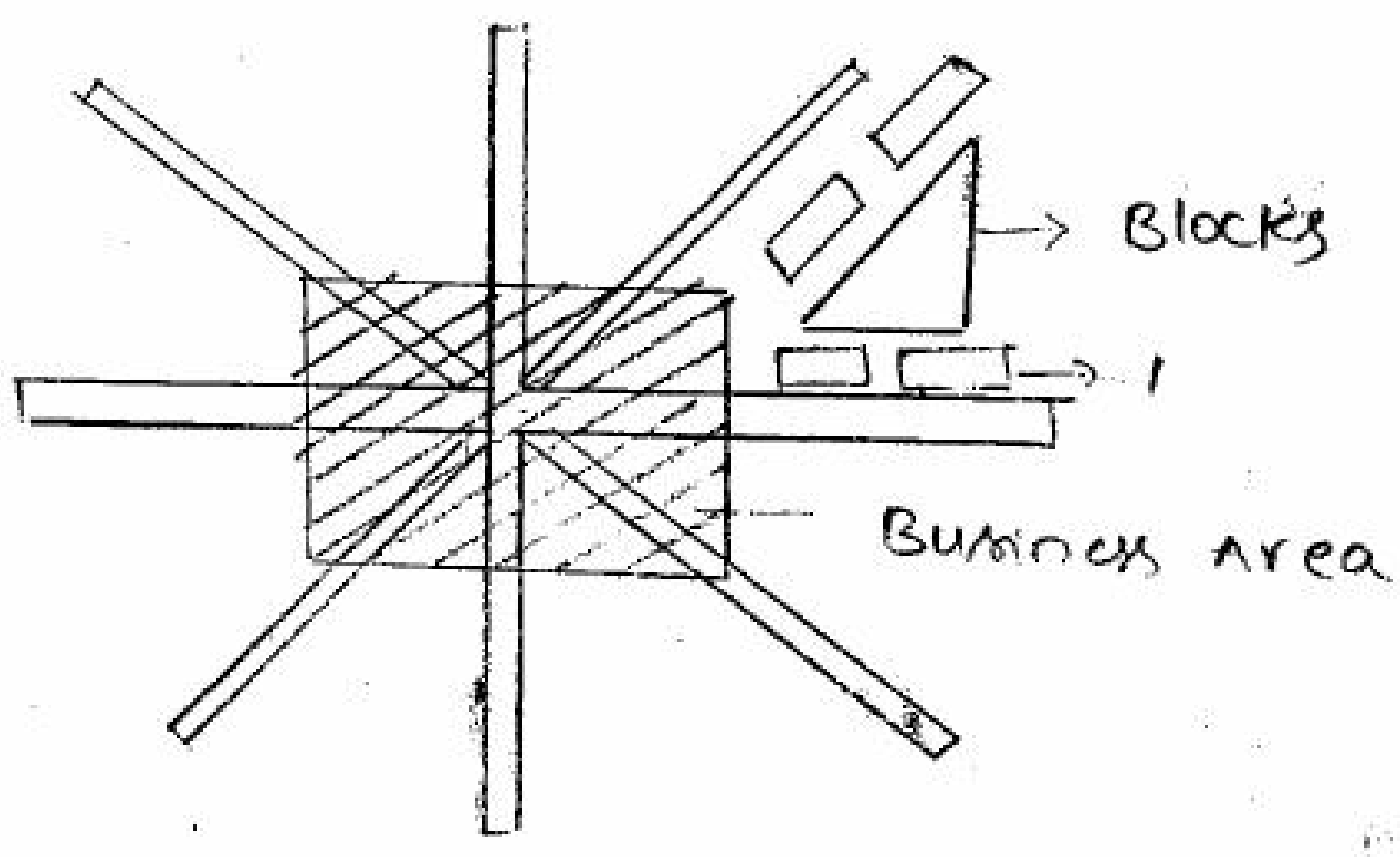
→ To maintain day to day work progress in the planning period

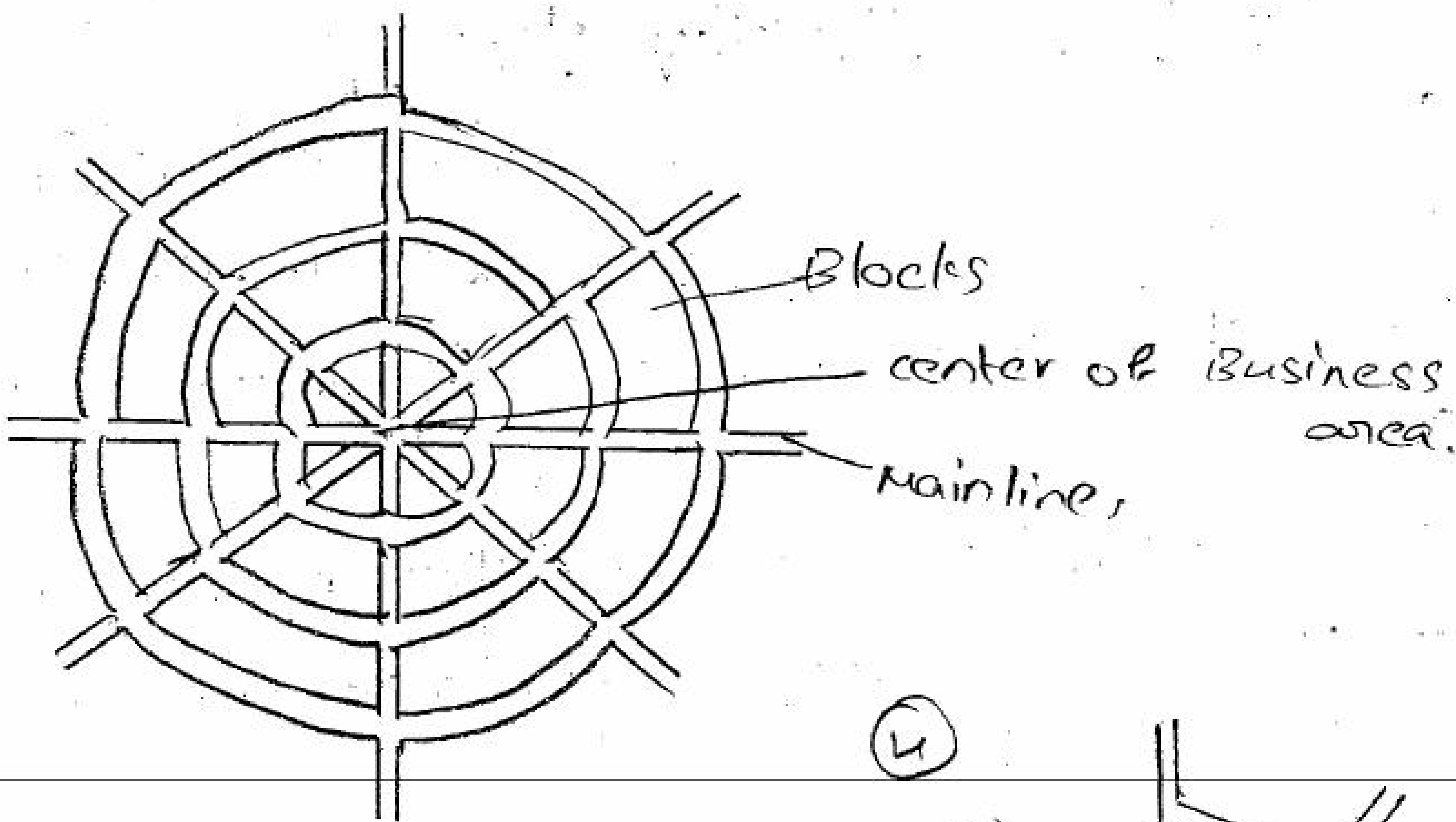
→ To use capital funds & construction materials in proper way.

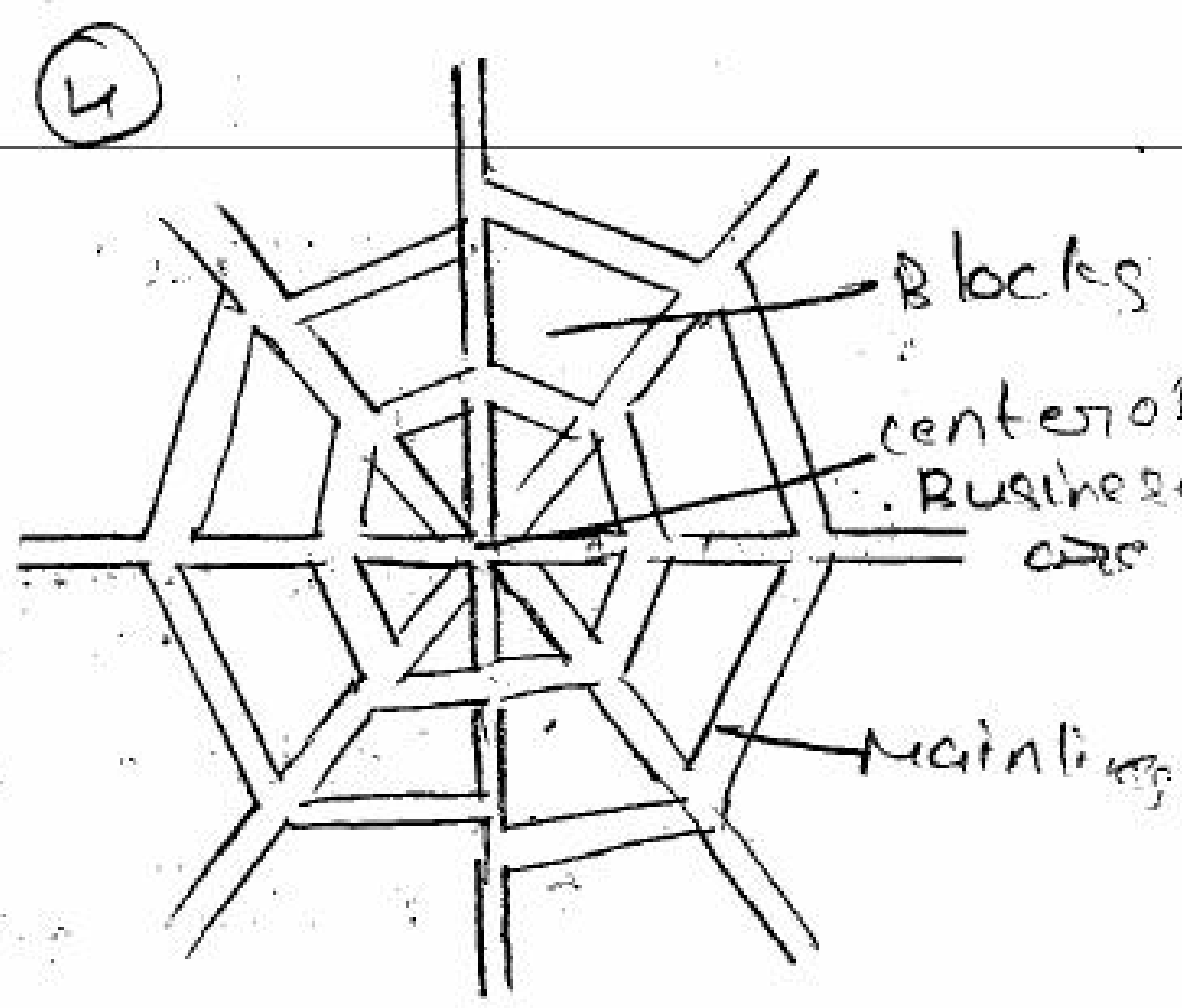
Road Network patterns :-

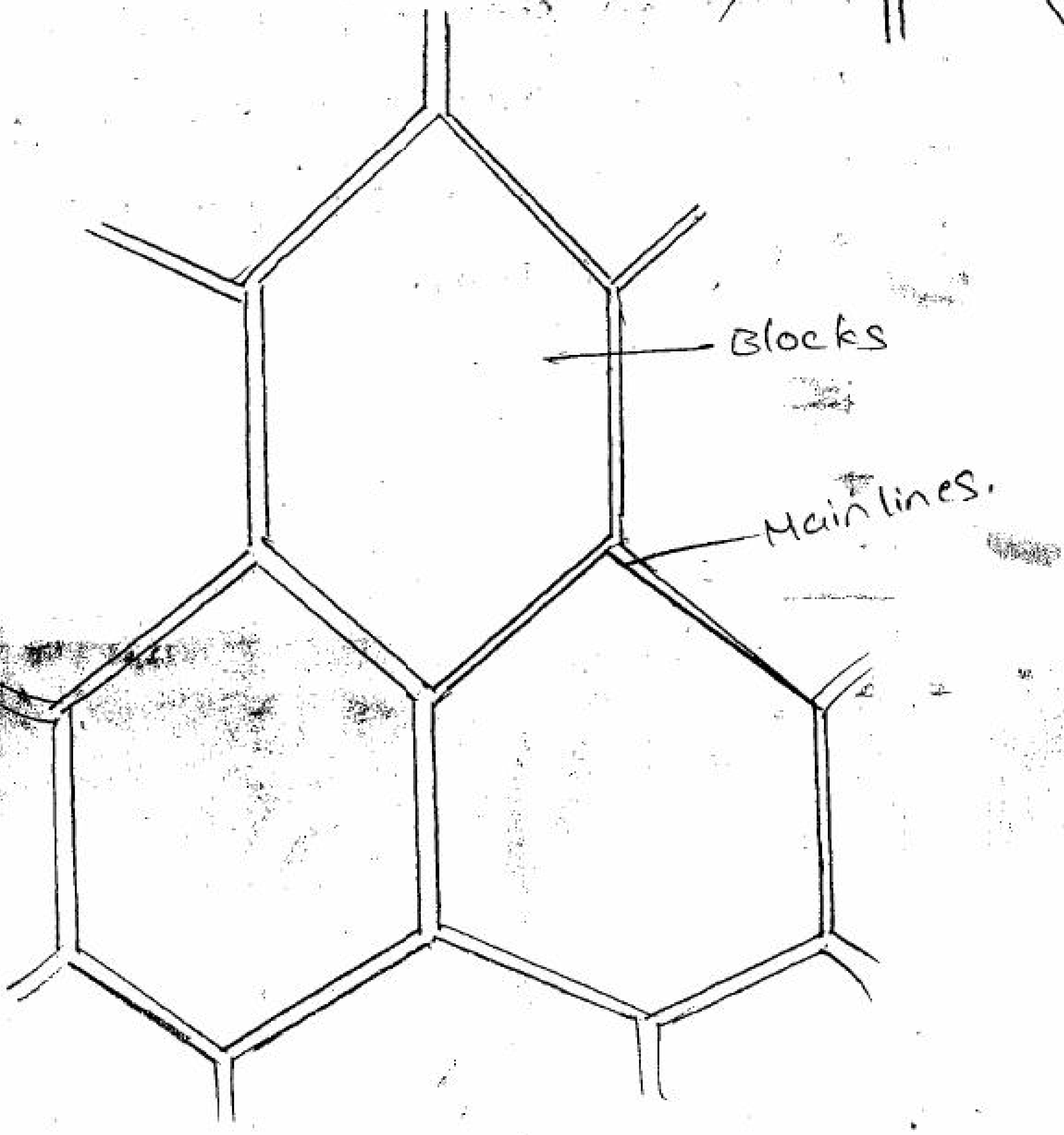
1. Rectangular & grid pattern
2. Radial (or) star and Block pattern
3. Radial (or) star and circle pattern
4. Radial (or) star and grid pattern
5. Hexagon pattern






Blocks
center of Business
area.
Mainlines


4
Blocks
center of
Business
Mainlines


Blocks
Mainlines.

Planning Surveys :-

Any development programm 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, Transpotation route maps are generally country wide so that it need to be plan in detail way with accurate values.

Planning surveys first objective is

→ Assesment 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

→ [redacted] growth rate and type of population growth

→ [redacted] forecasting in the future for future development.

Financial surveys :

→ It includes road taxes and revenue on Road Transport.

→ percaptia Income

→ Employment rate.

Traffic surveys :

→ Traffic volume studies
→ peak hourly volume
→ Annual average daily Trabbic
→ 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 drianage works

Highway Alignment :

the processing 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

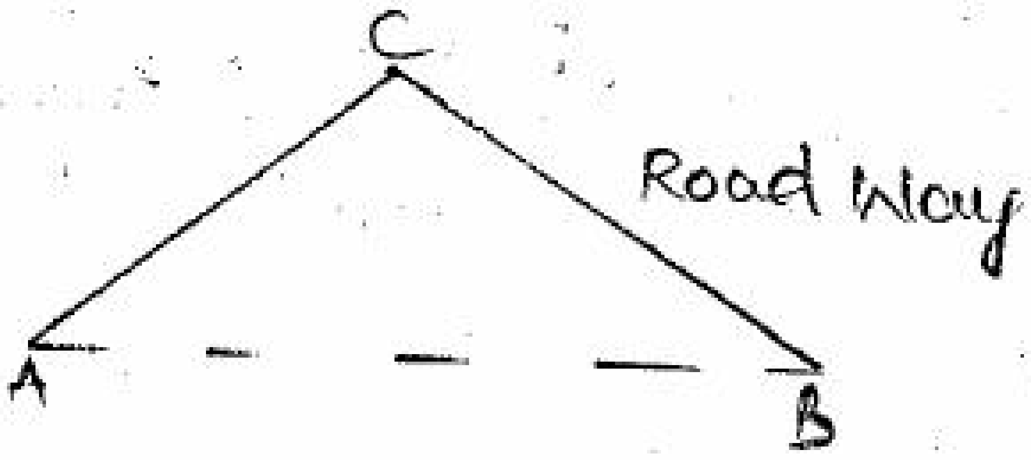
The Route should be Flexible and comfortable

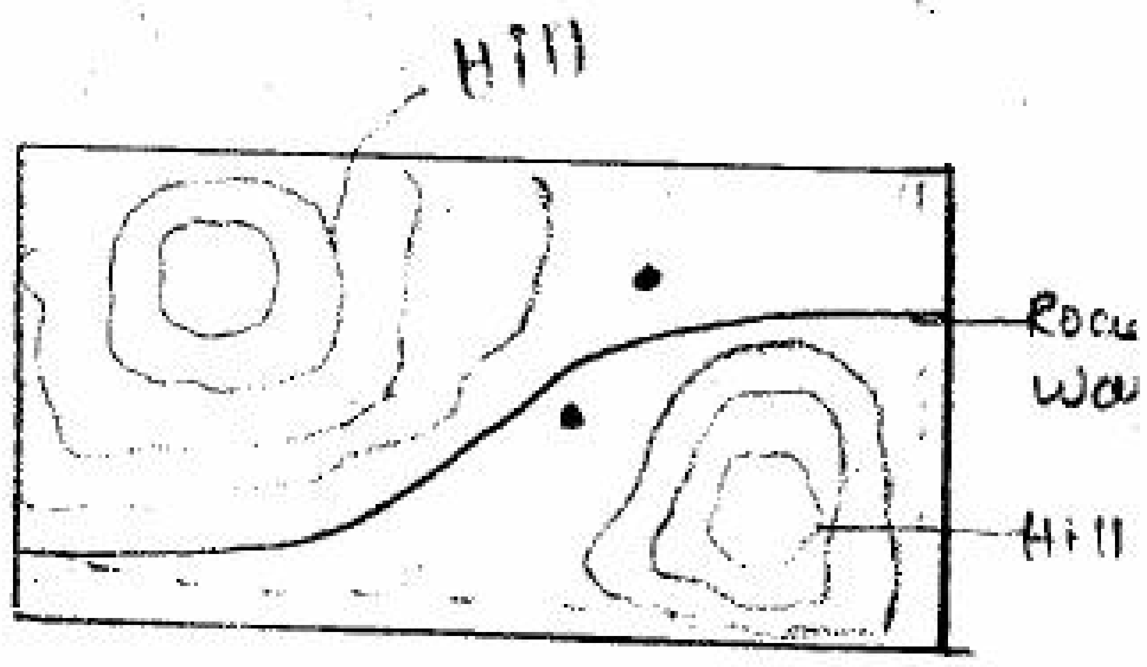
Factors Influencing Highway Alignment :

1. Obligatoly points
2. Traffic
3. Geometric design
4. Economy
5. Other requirements (Drainage conditions)

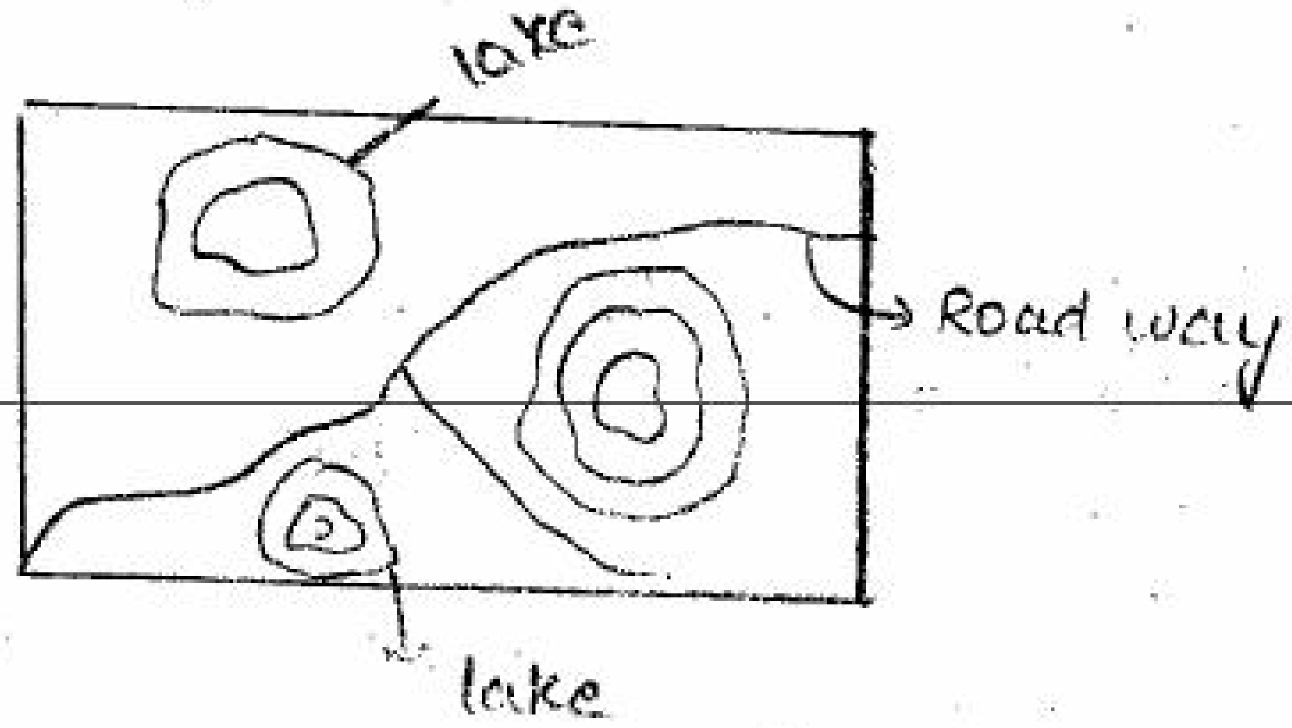
Obligatory points :

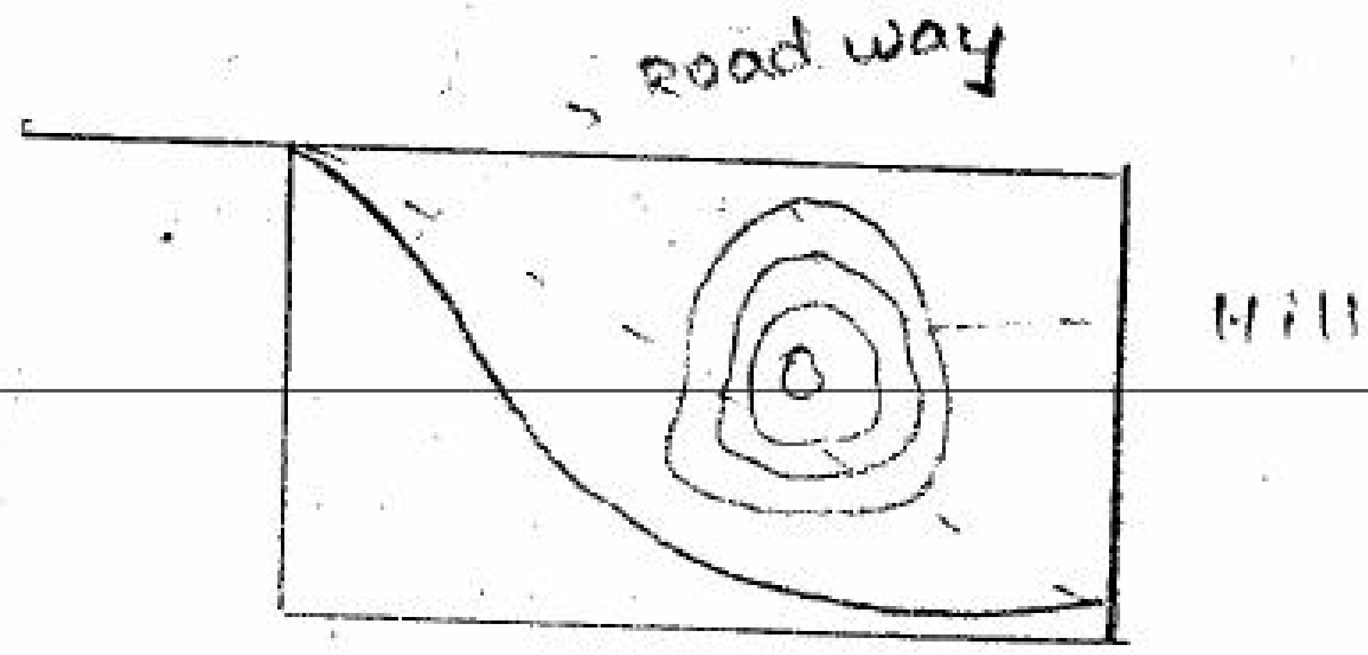
Points to be added to the route





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 Drianage conditions
3. Residual length

Engineering survey for Highway Alignment :

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

Drawing & Reports :

- Key maps
- Index maps
- Locations
- Cross Drianage works
- Intersection points
- Levellings
- Contour maps
- water Bodies
- Cross section of pavements.
- Route maps of Diff Roads
- Land Acquisition plants

AD questions :

1. Necessity of Highway Planning & Design
2. Explain Nagpur, Bombay & Lucknow Road plans
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 :

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

Design & control Factors :

1. Design speed
2. Topography
3. Traffic
4. Design hourly volume
5. Environmental Aspects

(1) Cross sectional Elements :

1. Road surface characterstics (or) Pavement surface characterstics
   a) Pavement uneveness – Bump Indicator
   b) Friction
   c) Lightening Effect
   d) Surface Drianage conditions.

Pavement uneveness

For Express ways & National Highways pavement uneveness shouldn't cross 1500 m/km.

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

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

With the Help of Bump Indicator Equipment we generally test the pavement unevenness

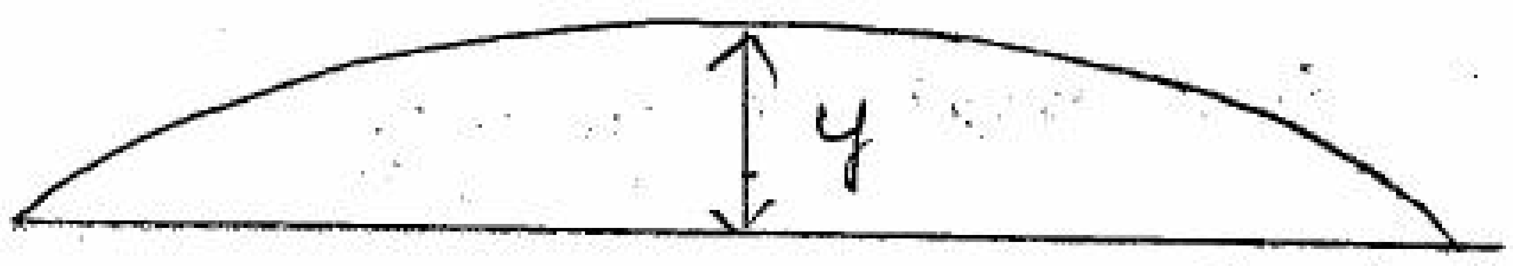
Friction :

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

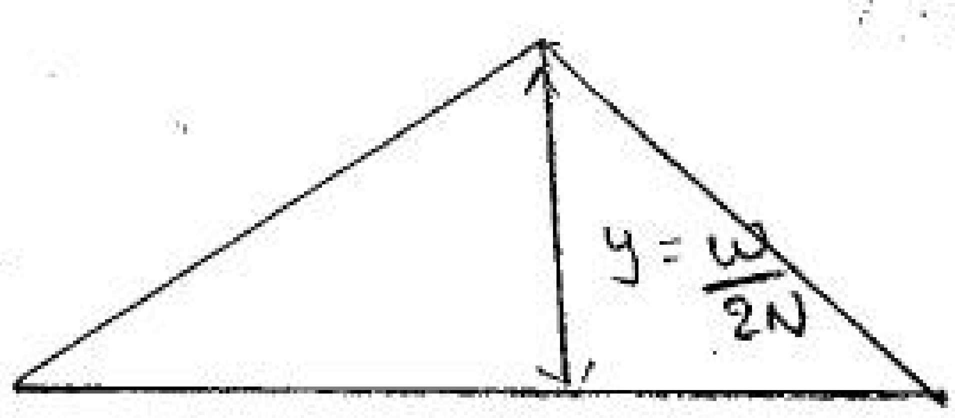
Friction limit per National Highways, Express ways is in between 0.10 to 0.11

2. Camber :

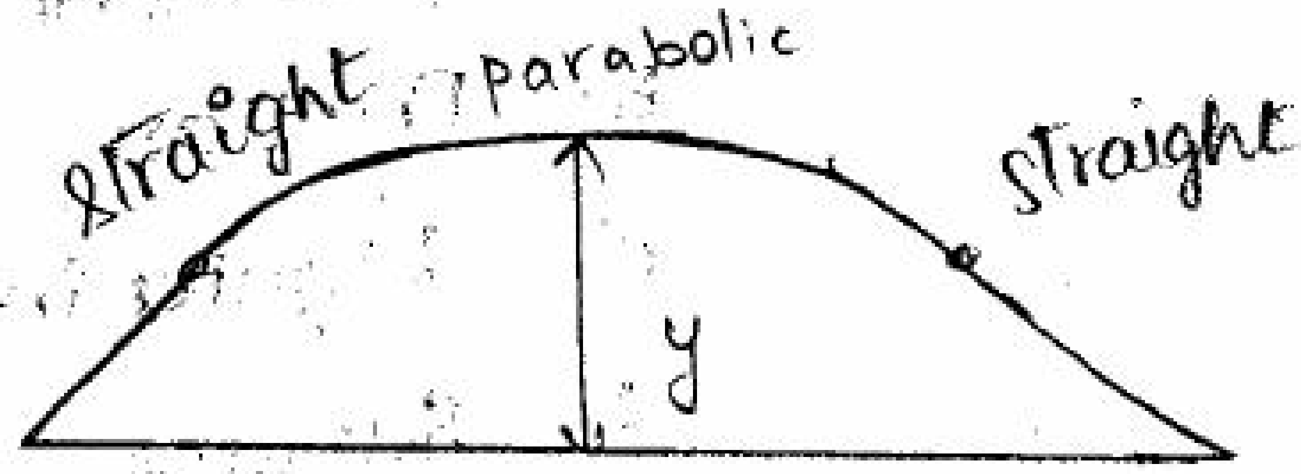
Main function of camber is drain out the rain water itself



$y = \frac{2x^2}{wN}$ parabolic camber



Straight camber



Straight & parabolic

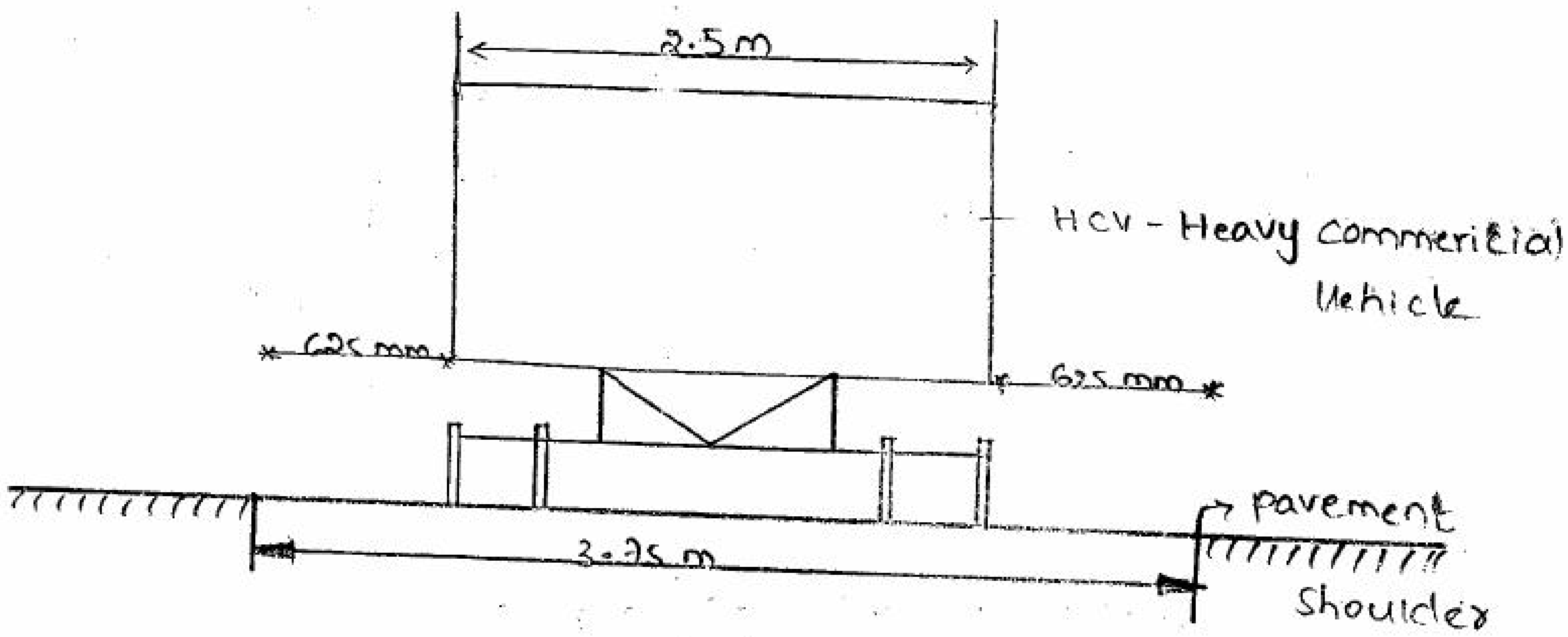
Chamber of 2.5 is generally provided for rainfall more ~~Generally~~ than 1000 ml.

A chamber of 2% 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 in 60	1.7 %
2.	thin Bituminous pavements	1 in 40	2.5 %	1 in 50	2 %
3.	water bound mecdam roads	1 in 33	3 %	1 in 40	2.5 %
4.	Earth Roads	1 in 25	4 %	1 in 33	3 %

3. Width of pavement (or) carriage way :

Single Lane pavement for HCV (Heavy commercial vehicle) :



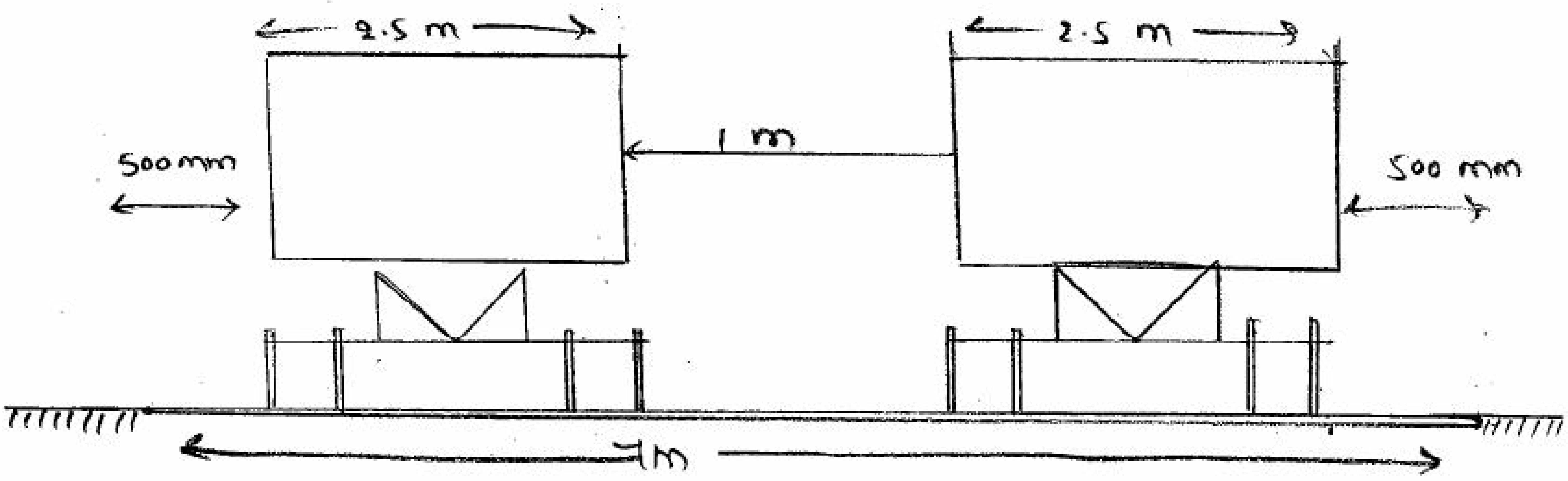
Width of pavement :

→ Width of pavement for single lane is 3.75 m

Extra width of 0.25 can be added for the safe & comfortable moment 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 :-



4, Traffic separators (or) Median :-

Functions :

→ To segragate 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

* Fo rural Highways median width should be 9-12 m
* It is restricted upto 5m
* Fo National Highways median width should be 10-15 m
A 4m way is allowed fo right (o) left turnings at the pavement.
* It may be extended upto 7.5 m
* A Median of 5-8 m is provided fo Intersectional Areas
* Fo Express ways Median width should be 10-15 cms
* Fo Future developments it may be developed upto 18 m

5. Kerbs :

1. Low Kerb (o) 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, over taking vehicles

2. Semi Barrier kerb :
→ This is located 150 mm from the pavement level
→ This is maximum design fo pedestrains.

3. Barrier kerb :
→ Levelled at a Height of 200 mm from pavement level
→ these are only fo pedestrains

6. Road Markings :-
→ Shoulders
→ Guard Rails
→ Foot path (o) walk ways
→ Drive ways
→ Parking Lanes
→ Cycle Lanes
→ Bus Bays
→ Lay Bays
→ Frontage ways
→ Embankment slopes
→

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 ~~yet 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

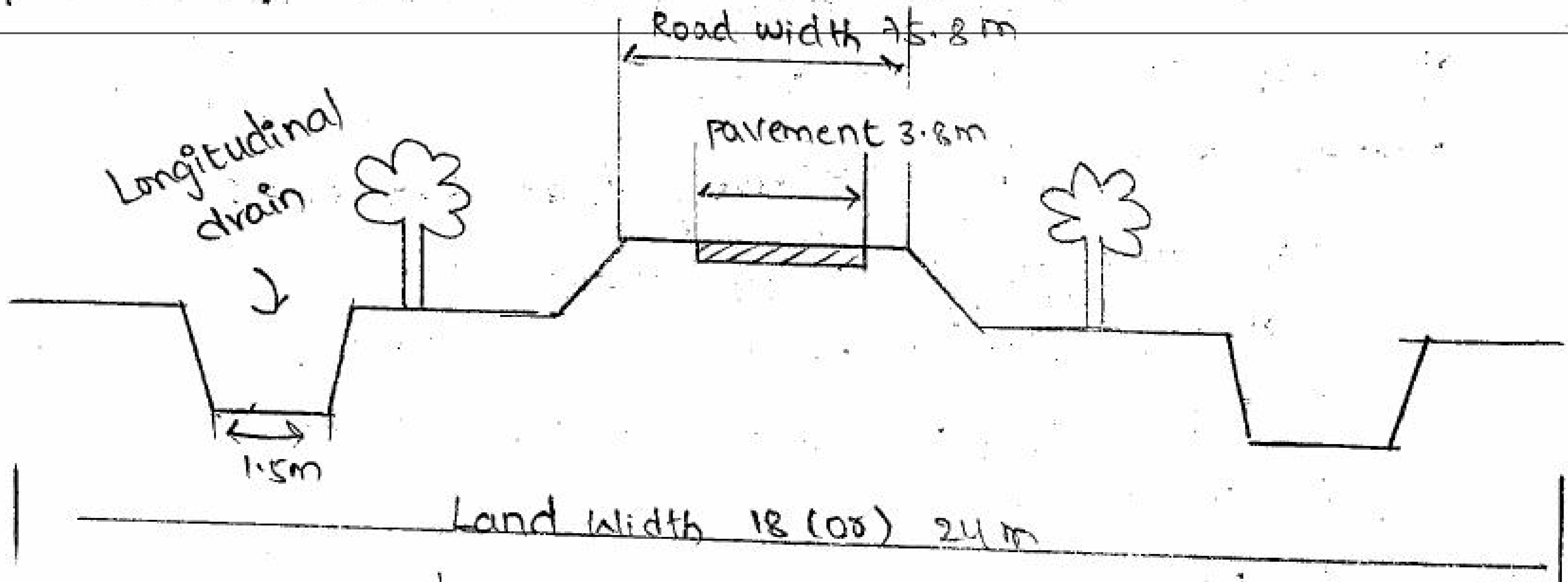
Width of Formation for Rural Roads :-

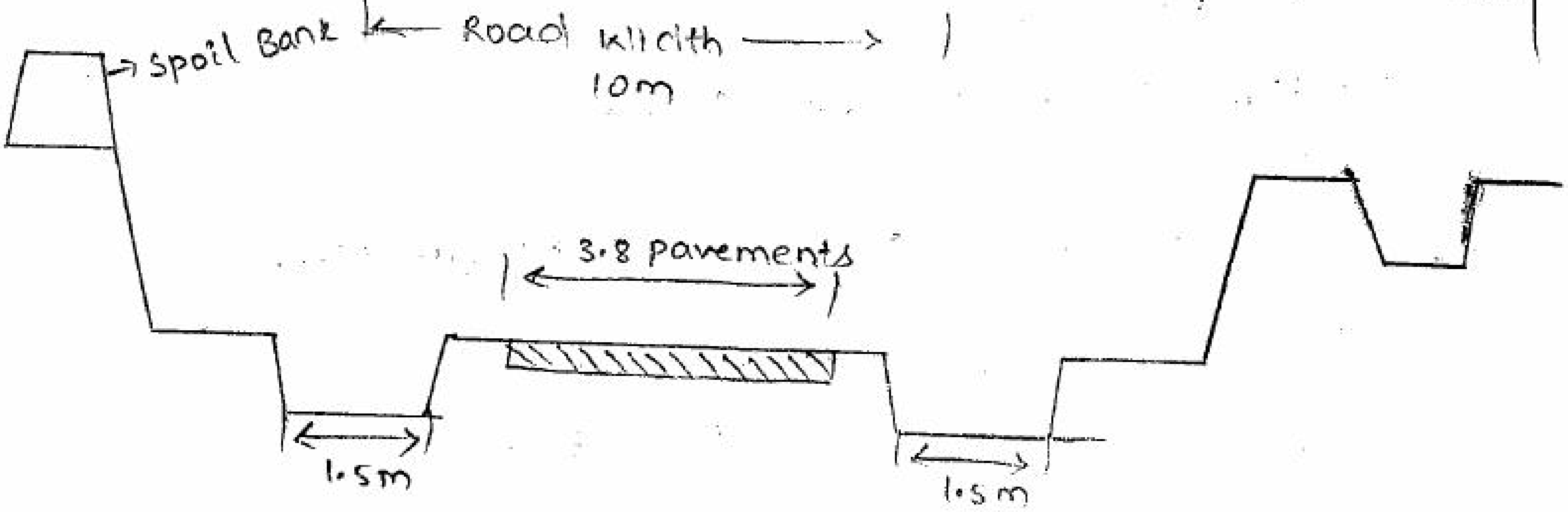
* For Express ways width of Formation is 60 m
* For National Highways Formation width is 45 m
* For State Highways width of formation is 40 m
* For major & minor District roads width of Formation ranges from 25 - 35 m
* For Other roads width of formation is 15- 25 m

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	





C/s of MDR in cutting in Rural Areas

(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 :

- Perception time
- Break time

PIEV :

- Perception - sense
- Intellection
- Emotion
- Volition

$$S.S.D = \text{Lag distance} + \text{Break distance}$$

$$= (v * t) + \frac{v^2}{2g\left(f + \frac{n}{100}\right)}$$

$f \rightarrow$ friction

$n \rightarrow$ slope

1. Vehicle carrying a speed of 90 kmph with friction 0.35 and slope of 2%. Vehicle is travelling from Hill position to Toe position. Lag time is 3 sec find out S.S.D

A1-

Given, $V = 90$ kmph

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

$= 25$ m/s

$F = 0.35$

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

Lag time $= 3$ sec

S.S.D = Lag distance + Break distance

$= (v \times t) + \frac{v^2}{2g(f - \frac{n}{100})}$

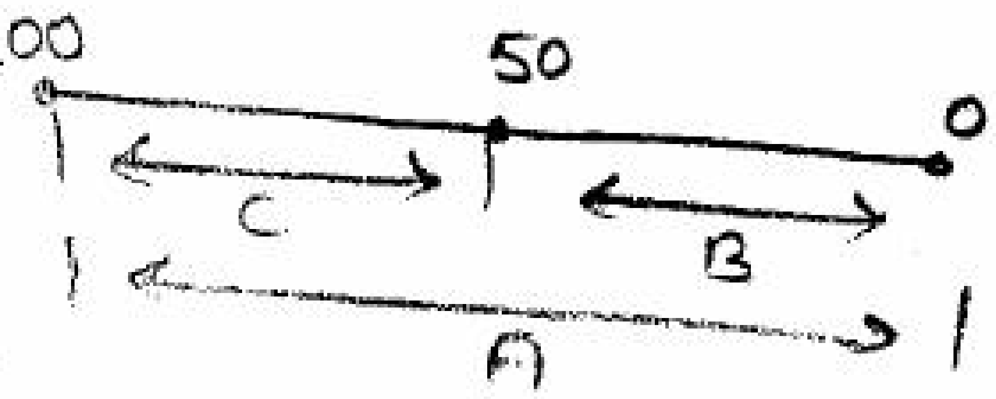
$= (25 \times 3) + \frac{(25)^2}{2 \times 9.81(0.35 - 0.02)}$

S.S.D = 171.5 m

2. A vehicle is moving with speed of 100 kmph. Later reduced to 50 kmph. Friction is 0.35, N = 2%. Find out the lag distance.

A1-

Given $v_1 = 100$ kmph =



C = A − B

$D_A = \frac{v_A^2}{2g(f + \frac{n}{100})} - \frac{v_B^2}{2g(f + \frac{n}{100})}$

$= \frac{(100 \times \frac{5}{18})^2}{2 \times 9.81(0.35 + 0.02)} - \frac{(50 \times \frac{5}{18})^2}{2 \times 9.81(0.35 + 0.02)}$

= ~~7.2594~~

$= 106.29 - 26.5726$

$= 79.7 \sim 80$ 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

$$v = 80 \times \frac{5}{18} = 22.22$$

$$f = 0.35$$

$$S.S.D = 260$$

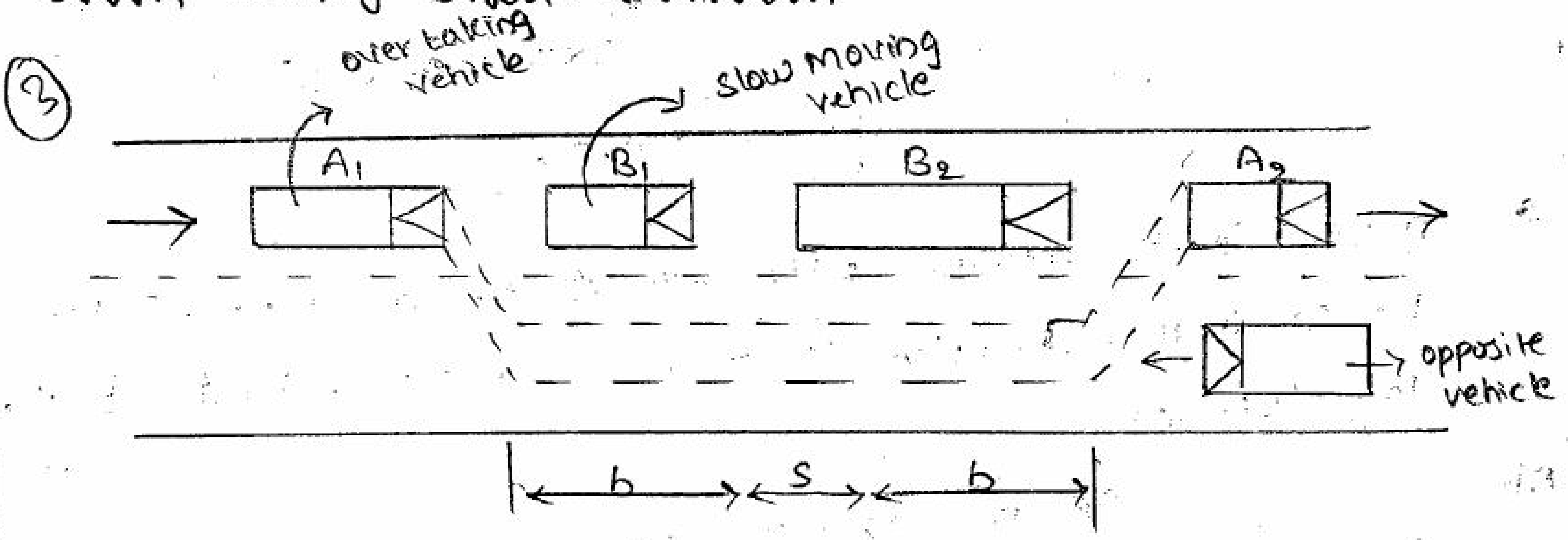
$$N = 3\% = 0.03$$

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

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

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

Over taking Sight Distance :—



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

$$d_1 = v_b * t \qquad v_b \rightarrow$$

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

$$s = 0.7 v_b + 6$$

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

$$d_3 = V \cdot T$$ (V → 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~~
- Gradients
- Friction

(3)

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

A1- Given, $V_b = 72$ kmph $= 72 \times \frac{5}{18} = 20$.

$d_1 = 20 \times 2 = 40$

$d_2 = 2S + b$, $S = 0.7 V_b + 6$

$= 2 \times 20 + V_b \times T$

$= 0.7 \times 20 + 6$

$\boxed{S = 20}$

$= 2 \times 20 + 20 \times 7.784$

$= 195.68$

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

$= \sqrt{\frac{4 \times 20}{1.32}}$

$\boxed{T = 7.784}$

$d_3 = 90 \times \frac{5}{18} \times 7.784$

$= 194.6$

O.S.D = 430.28m = $d_1 + d_2 + d_3$

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

Given data,

(3)

Design speed = 96 kmph

vehicle speed V_b = Design speed − 16

= 96 − 16

= 80 kmph i.e 22.22

Assumed datas are a & t

t = 2 sec

$a = 1.32\ m/sec^2$

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

= ~~100~~ 44.44

$d_2 = 2S + V_b \times T$

$S = 0.7 V_b + 6$

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

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

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

S = 21.554

T = 8.081

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

= 222.667

$d_3 = V \cdot T$

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

= ~~179.55~~ 215.49

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

= 44.44 + 222.667 + ~~179.55~~ 215.49

= 482.059

3. calculate OSD for vehicle speed 72 kmph with A = 5 kmph/sec. Find out O.S.D. Opp vehicle speed V = 80 kmph

A) Given $V_b = 72$ km/hr

$V = 80$ kmph

(3) $A = 5$ kmph/sec

Assume $t = 2$ sec

$d_1 = V_b * t$

$= 72 \times 2 = 144$ m

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

$S = 0.2 V_b ~~*~~ 6$

$\therefore S = 20.4$

$T = \sqrt{\frac{14.4 S}{A}} = \sqrt{\frac{14.4 \times 20.4}{5}}$

$T = 7.6649$

$d_2 = 2 \times 20.4 + \overset{72}{~~80~~} \times 7.6649$

$d_2 = ~~653.492~~$ 592.67

$d_3 = V \cdot T$

$= 80 \times 7.6649$

$= 613.192$

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

O.S.D ~ 1350 kmph

Formulae

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

$d_1 = V_b * t$

$d_2 = 2S + b$

$= 2S + V_b \times T$

$S = 0.2 V_b + 6$

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

$d_3 = V \cdot T$

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

Given,

Design speed = 100 kmph

$V = 100 \times \frac{5}{18} = 27.77$ m

vehicle speed = Design speed − 16

$= 100 - 16 = 84$ kmph

$\therefore V_b = 23.33$ m

Assumed data is

$a = 1.32\ m/sec^2$

$t = sec$

$d_1 = V_b \times t = 23.22 \times 2$

$= 46.66$

$d_2 = 2S + V_b \times T$

$S = 0.7 V_b * 6$

$S = 22.331$

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

$T = 8.2265$

$d_2 = 2(22.331) + 23.33 * 8.2265$

$d_2 = 236.6162$

$d_3 = V * T$

$= 27.77 \times 8.2265$

$d_3 = 228.449$

$O.S.D = 46.66 + 236.6162 + 228.449$

$O.SD \simeq 520\ m$

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

A:-

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

$d_1 = V_b \times t$

$= 80t$

$d_2 = 2S + V_b * T$

$S = 0.2 V_b + 6$

$S = 22$

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

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

$d_2 = 2 \times 22 + 80 \times 7.959$

$= 680.7919$

$d_3 = V * T = 85 * 7.959 = 676.515$

$$O.S.D = 80t + 680.719 + 676.515$$

$$1200 = 80t + 1357.305$$

$$\therefore t = -1.966$$

$$t \simeq 2\ sec$$

Intermdiate sight distance :

$$I.S.D = 2 * S.S.D$$

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

(3) Horizantal Allignment :— Processing of Fixing of a central line for path is Allignment

Horizantal Allignment is an allignment with ground level.

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

So, there is a need of Horizantal curve

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

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

P = centrifugal force

W = Weight of vehicle

V = speed of vehicle in m/sec

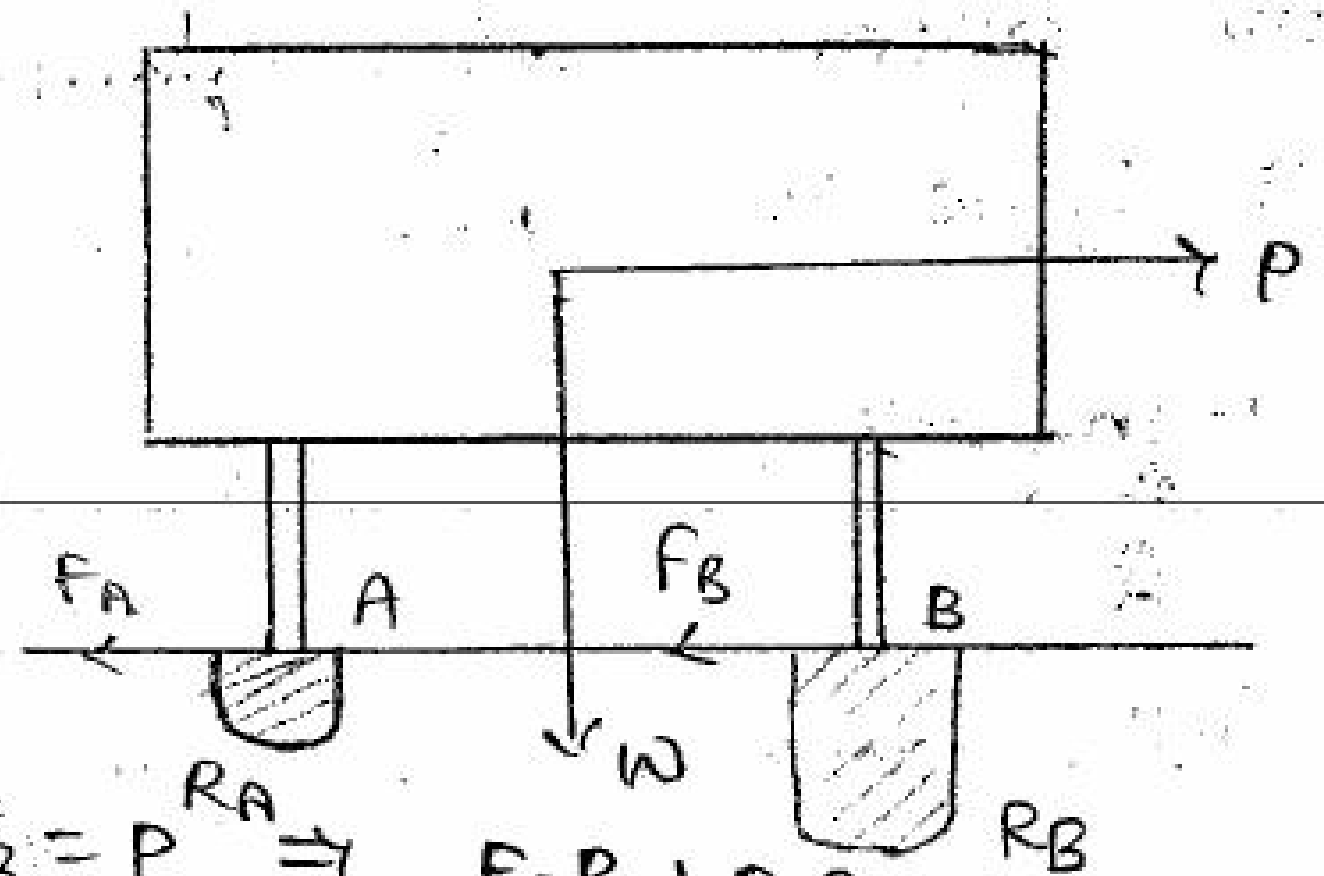
g = Accelation due to gravity = 9.81 m/sec^2

R = Radius of Arc

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

1. Over Turning Effect
2. Transverse Skidding Effect

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



$$f_A + f_B = P \Rightarrow F \cdot R_A + F \cdot R_B$$

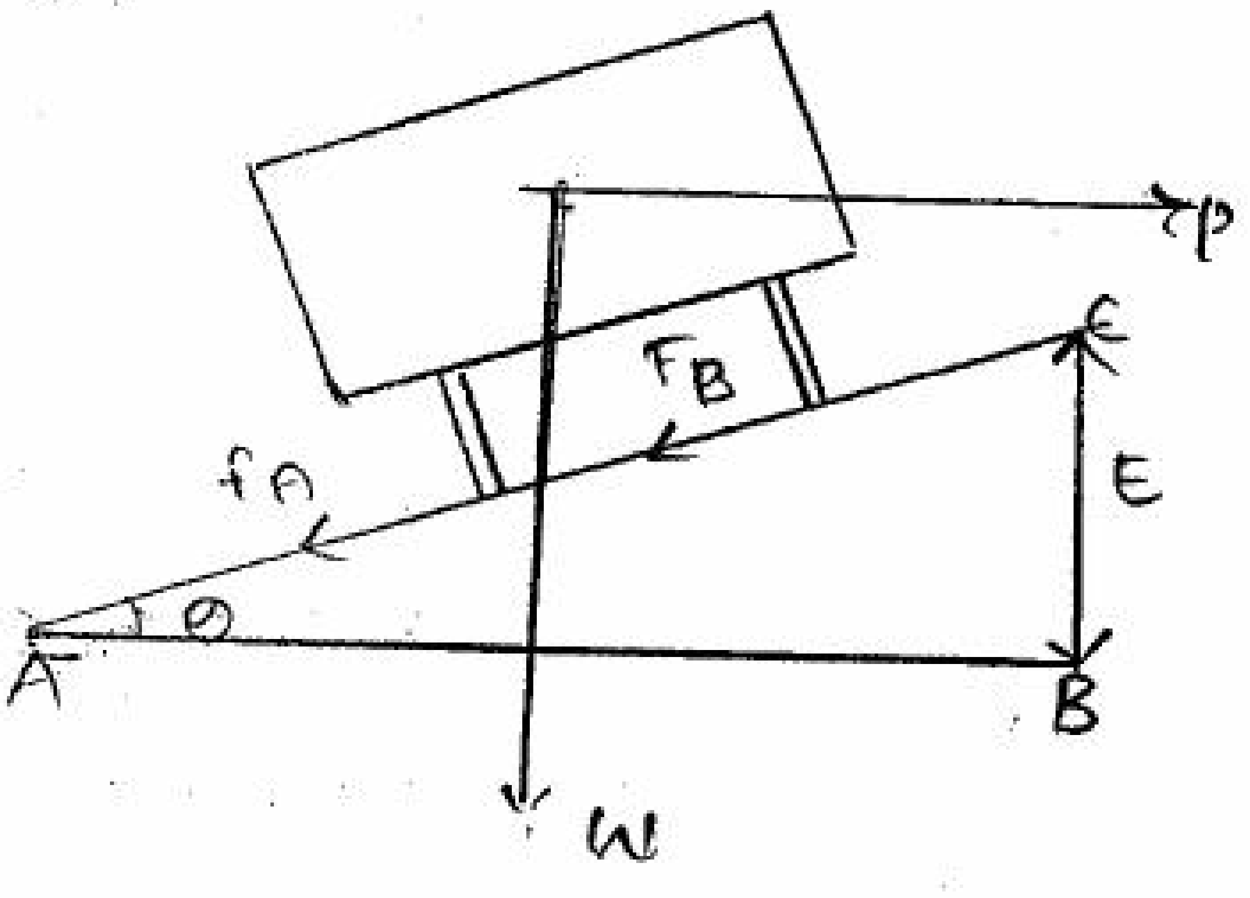
$$= F(R_A + R_B)$$

$$P = FW$$

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

Super Elevation :-

(2) The rise given to the outer edge with respect to Inner Edge is known as super Elevation.



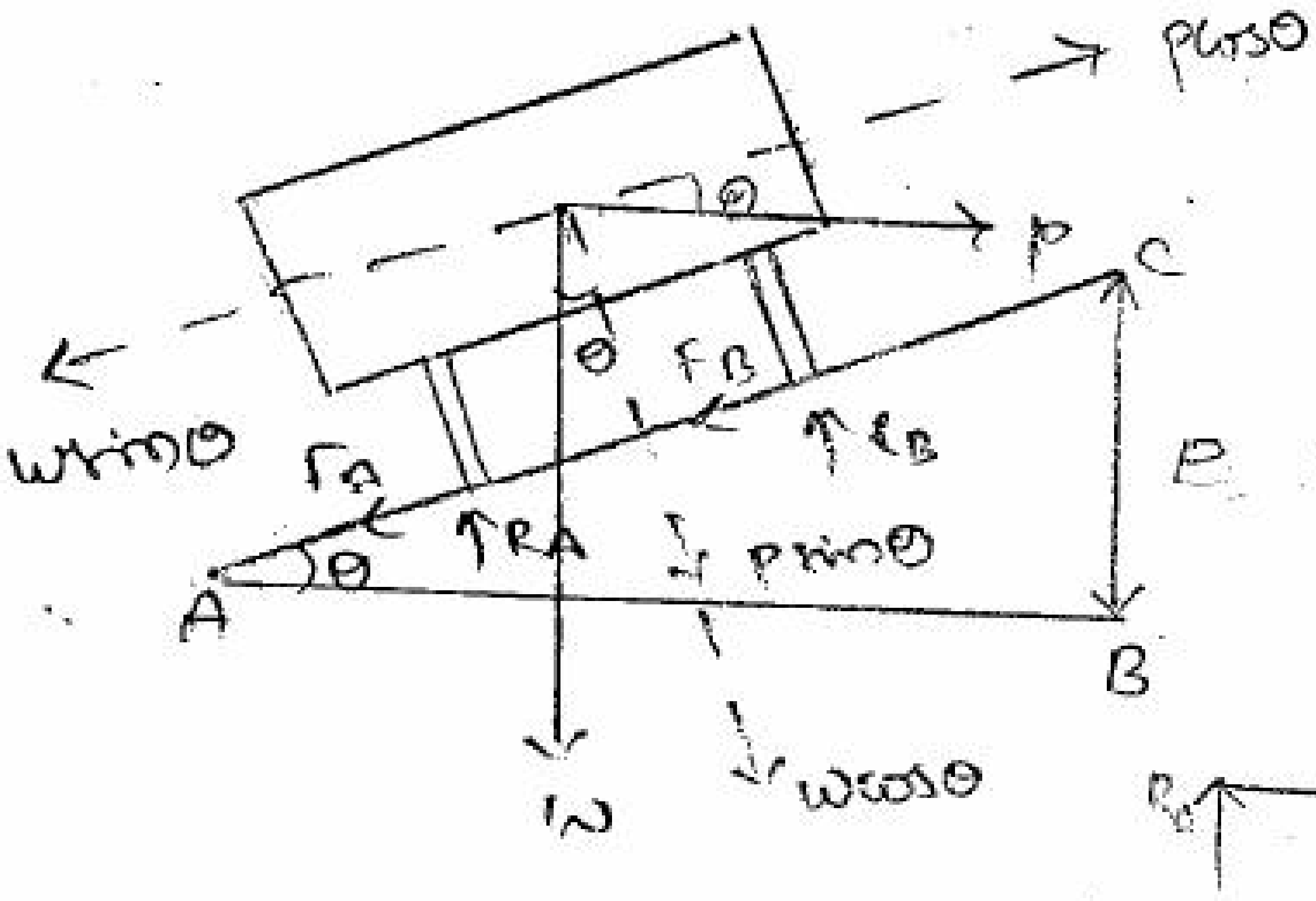
$$\frac{CB}{AB} = \tan\theta = e$$

Forces acting on the vehicle are centrifugal force,

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

Over turning Effect, $\frac{P}{W} = \frac{v^2}{gr}$

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



Forces on Right Hand side = Forces on Left Hand side

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

$$= W\sin\theta + f(R_A + R_B)$$

R_A W R_B

$R_A + R_B = W$

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

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

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

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

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

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

If $\tan\theta$ is small & Friction also neglected

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

$$\frac{F}{W} = e + f$$

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

$$e + f = \frac{\left(\frac{5}{18}\right)^2 v^2}{9.81R}$$

max^m cl.

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

e = rate of super elevation

f = coeffcient of lateral friction = 0.15 - 0.20

V = vehicle speed in kmph

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, coeffcient of friction 0.15

A/-

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

A/- let,

coeffcient of friction = 0.15

$$e = 0.05$$

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

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

$$R = 141.73\ m$$

3. If the super elevation is 7% & f is 15%, then actual speed of the vehicle is $e+f = \frac{v^2}{127R}$

Ans-

Given $e = 0.07$

$f = 0.15$

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

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

$$v^2 = 5.28\sqrt{R} \quad (\text{or}) \quad v = \sqrt{27.94R}$$

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

Ans-

Given $e = 0.06$, $f = 0.15$

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

$$v^2 = 26.67R$$

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

(i) Normal speed of vehicle is 50 kmph

$$R = 93.73\ m$$

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

$$v = 49.99\ \text{kmph}$$

Note:

5. If negitive super elevation allows then Equation is as follows

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

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

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

(2)

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

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

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

$$e = 0.1165$$

2. 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 Radient
2. Absolute min Radius

For ruling Radius equation is as follows:

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

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

$$R_{min} = \frac{V_1^2}{127(e+f)}$$

1. calculate Rulling 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

A- Given $V_1 = 60$

$V = 96$

$F = 0.15$

$E = 0.07$

Ruling Radius, $R = \frac{v^2}{127(e+f)}$

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

Absolute min Radius, $R = \frac{v_1^2}{127(e+f)}$

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

$= 128.84$

Note :

1. vehicle speed is restricted to 70 kmph on an average and Radius of super elevation increases when vehicle speed is Increased

If super elevation & Friction are more than 7% and 15% then speed is restricted upto 40 kmph. and R value must be more.

2. 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 = Design speed = 80 kmph

Radius r = 480 mts

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

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

$e =$

Super Elevation is generally designed for 75% of design speed

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

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

the Rise given to the outer edge w.r.t Inner Edge =

Rate of super elevation * width of pavement

$= e * W$

$= 0.059 * 7.5$

$= 0.4425$

3. Design rate of super elevation of Horizontal Curve of radius 500 mts and speed 100 kmph

A- Given data,

(2) Speed $v = 100$ kmph

Radius $r = 500$ mts

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

$$e = 0.088$$

Note: As for the above value obtained 9%. is not allowed so take 7% of rate of super elevation

∴ 7% 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 $f = 9\%$ is safe.

4. Design speed is 80 kmph ; Radius 200 mts . coefficient of lateral friction 0.15 a) calculate super Elevation
b) calculate maximum allowable speed for max of super Elevation ?

A1. Given data,

Design speed $V = 80$ Kmph

$R = 200$ mts

$F = 0.15$ mts

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

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

$e = 0.142$

14 % of e is not allowable only 7 % of e is allowable so e is 0.142 is rounded for 7 %.

b)

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

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

$f = 0.181$

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

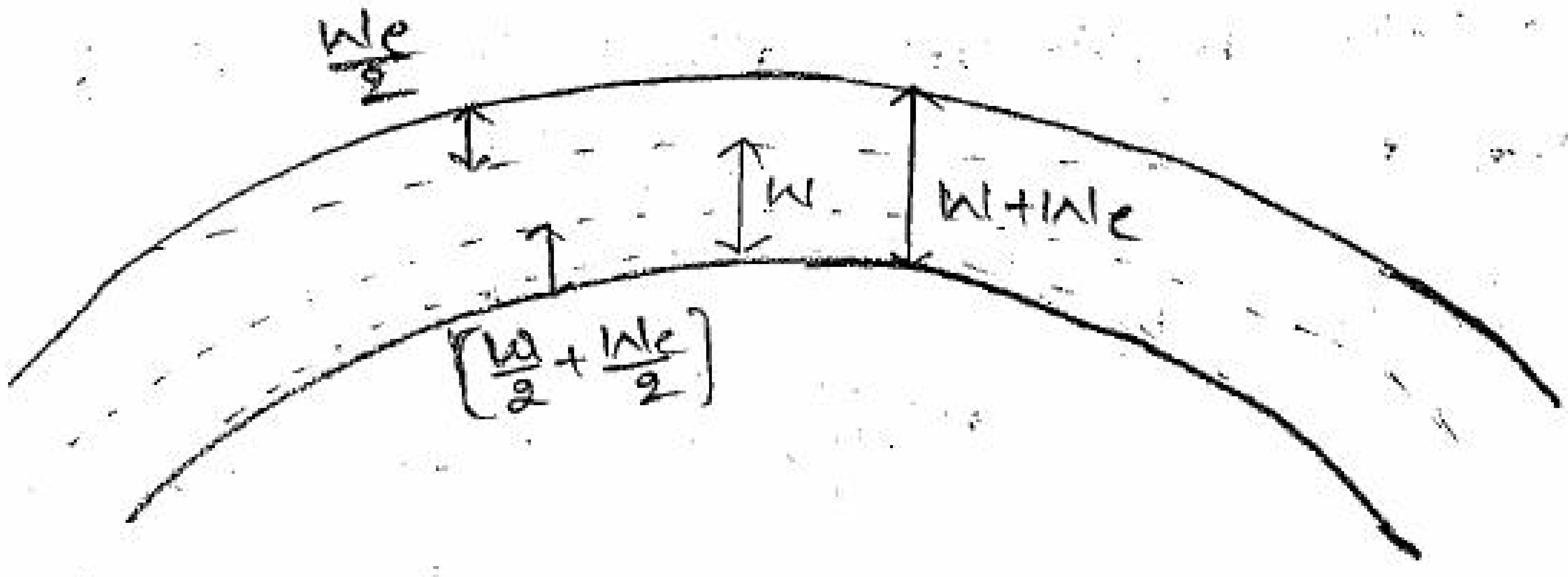
$V_A = \sqrt{28 \times 200} \Rightarrow V_A = 74.83$.

$V_A \sim 75$ 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

$$W_e = 3.5$$

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

$$\Rightarrow 5.25 \, m$$

Design Extra Widening from centre line to Outer Edge for 4 lane pavement

For 4 lane pavement there is a Median

Width of pavement $W = 14$

Width of Extra Widening $W_e = 2$

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

$$= 5.25 \, m$$

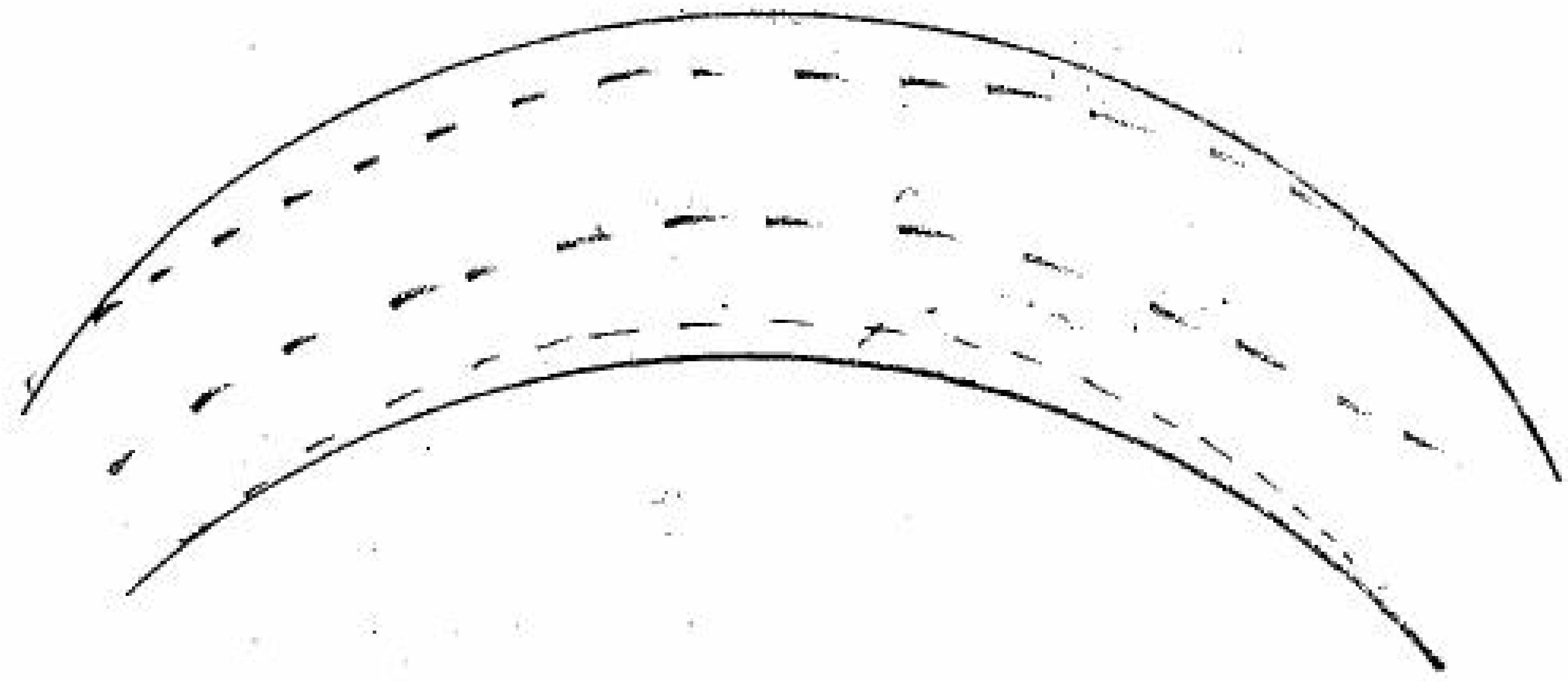
Calculate centre line to outer edge for pavement width 23 mts

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

$$= 7 \, m$$

21 mts ⇒ 6 lanes

Widening of pavements on sharp curves :-



Addition of Mechanical widening & pshycological 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 → No. of Traffic lanes

l → length of wheel Base

R → Radius

V → Design speed

1. Calculate the extra widening req for pavement of width 7m, Radius 200 m, wheel Base is 6.5 m, design speed 65 kmph

$l = 6.5$ m, $R = 200$ m, $n = 2$ lanes ($\because$ 7 m) (lane $l = 7$)

$V = 65$

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

$$= \frac{2 \times 6.5^2}{2 \times 200} + \frac{65}{9.5 \times \sqrt{200}}$$

$= 0.695$ m

2. Find the total width of pavement on a Horizantal curve for a new national Highway to be aligned along a rolling Terrain with ruling minimum Radius. Assume Necessary data

A:- Assumed data,

V = Design speed = 80 kmph

$e = 7\%$

Pavement width $w = 7m$, $n = 2$

wheel base : $l = 6m$ (6.0 – 6.5 constant value)

$f = 15\%$

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

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

$$= 229.06$$

$$R_{ruling} \sim 230\ m$$

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

$$= \frac{2(6)^2}{2\times230} + \frac{80}{9.5\sqrt{230}}$$

$$= 0.7117 \sim 0.712$$

Total pavement width on curve $= 7 + 0.712$

$= 7.712\ m$

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

Assume data,

$V = 80\ kmph$

$e = 7\%$, $f = 15\%$

$w = 7m$, $n = 2$

wheel base $l = 6m$

Vehicle speed = Design speed – 10

$= 80 - 10$

$= 70$

$$R_{min} = \frac{V_1^2}{127(e+f)}$$

$$= \frac{70^2}{127(0.07+0.15)}$$

$$R_{min} = 175.37$$

$$\sim 175\ m$$

(or)

$80 - 15 = 70$

$$= \frac{65^2}{127(0.07+0.15)}$$

$R_{min} \simeq 152\ m$

$\simeq 160\ m$

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

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

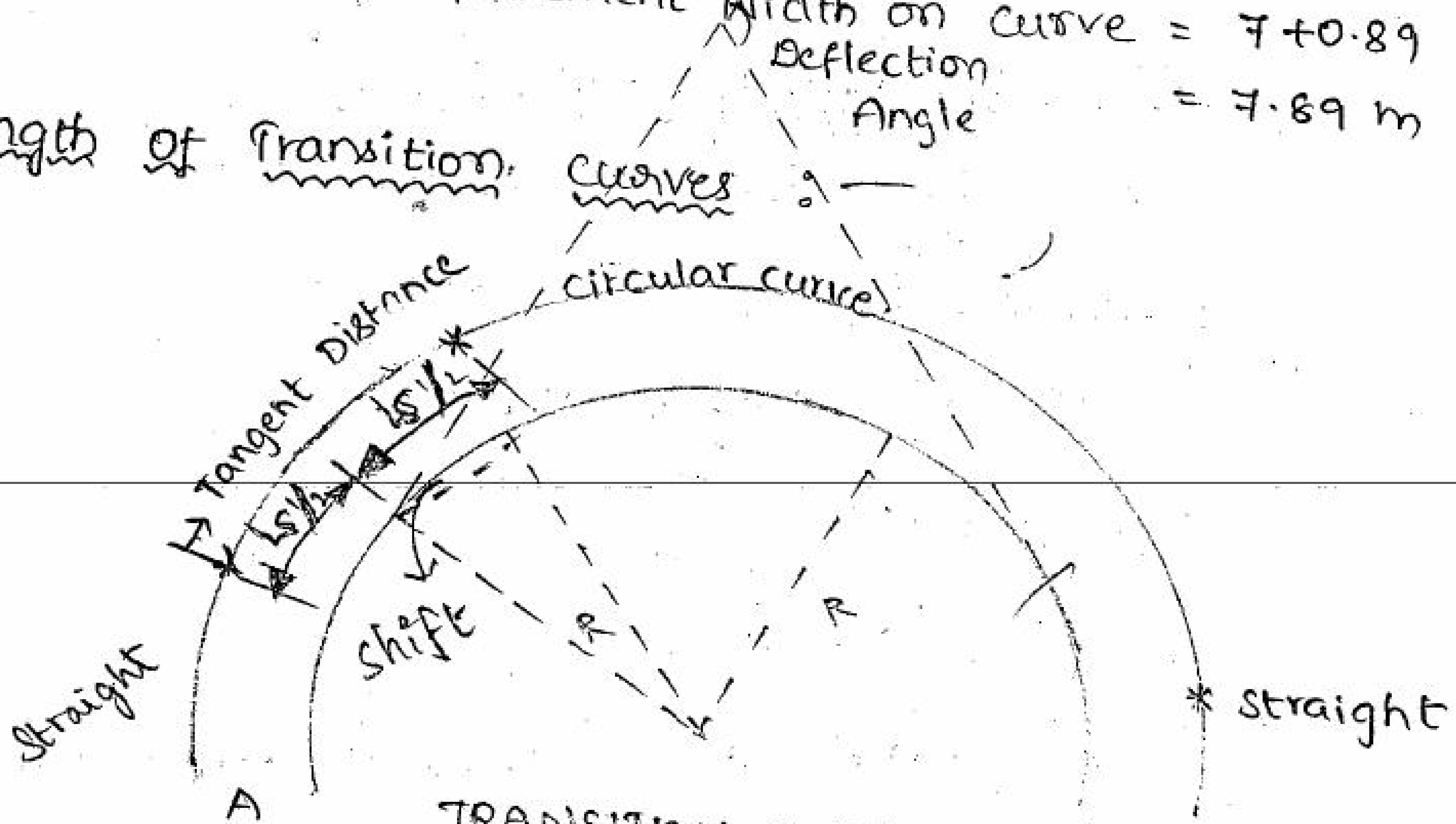
$$= 0.89\ m$$

Total pavement width on curve = 7 + 0.89

= 7.89 m

$(c = 3 \times 10^8)$

Length of Transition Curves :—



TRANSITION CURVE IN HORIZANTAL ALIGINMENT

Transistion 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 accerlation

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

$C \rightarrow$ rate of centrifugal accerlatio

$V \rightarrow$ Vehicle speed

Units : m/s^3

L_s = length of Transition curve

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

$$L_s = 0.0215 \frac{V^3}{C \cdot R} \quad \text{in m/sec}$$

Rate of Introduction of Super Elevation :—

For plane & Rolling Terrain $L_s = 2.7 \frac{V^2}{R}$

For Mountain & steep Terrain $L_s = \frac{V^2}{R}$

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

Design speed $v = 65$ kmph

(ii) Normal

$R = 220$ m

Pavement Width + ExtraWidening $= 7.5$ m

Allowable rate of Introduct of super elevation $= 1$ in 150

$= 0.006$

a. length of Transition curve

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

$$\boxed{C = 0.57 \ m/sec^3}$$

The limits for rate of centrifugal accerlation is 0.5 to 0.8

Our value is 0.57 ∴ It is adopted

$$L_s = 0.0215 \frac{V^3}{C \cdot R}$$

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

$$= 47.08$$

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

Adopt $0.07 = e$

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

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

$$\boxed{f = 0.0812}$$

Width of pavement = 7.5 m

the Rise of outer Edge w.r.t center line $= \frac{0.07 \times 7.5}{2}$

$= 0.2625$

Rise of edge = W×e

Rate of Super Elevation

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

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

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

$$W_e = 0.70.$$

Length of Transition curve

Rate of Introduction of super elevation

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

$$= 0.07 \times [7.5 + 0.70] \times 150$$

$$= 86.1 \text{ m}$$

length of Transition curve

Rate of centrifugal accerlation

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

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

$$= 47.08 \text{ m}$$

Consider pavement located at Rolling Terrain

length of Transition curve

IRC for Rolling Terrain

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

Adopt the length of Transition curve 86.1 m

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

$$= \frac{86.1^2}{24 \times 220}$$

$$= 1.40$$

a) super Elevation

b) Extra Widening

c) Length of Transition curve

Assume, V = Design speed = 80 kmph

Pavement as 2 lane ⇒ $B = 3.5 + 3.5$

$B = 7 m$

$N = 1$ in 150 = slope

Length of wheel Base $l = 6m$

a) Super elevation

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

$$e = \frac{V^2}{225R} \Rightarrow e = 0.129 = \frac{80^2}{225 \times (220)}$$

$e = 0.07$ → ∵ above is 12% can't take

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

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

(or) $$E = \frac{e \times B}{2} = 0.245 \, m$$

Extra widening of Pavement $W_e = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$

$$W_e = \frac{2 \times (6)^2}{2 \times 220} + \frac{80}{9.5\sqrt{220}}$$

$$= 0.731 \, m$$

Total width of pavement $= 7 + 0.73 = 7.73 \, m$

Length of Transition curve: Rate of Introduction of super elevation

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

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

$L_s = 81.165\ m$

(b) Extra widening

Rate of centrifugal accerlation $C = \frac{80}{75+V}$

$C = 0.516\ m/sec^3$

Length of Transition curve: Rate of centrifugal accerlation

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

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

Length of Transition curve: IRC for Rolling Terrain

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

$= 78.5\ m$

Adopt the length of Transition curve be 96 m

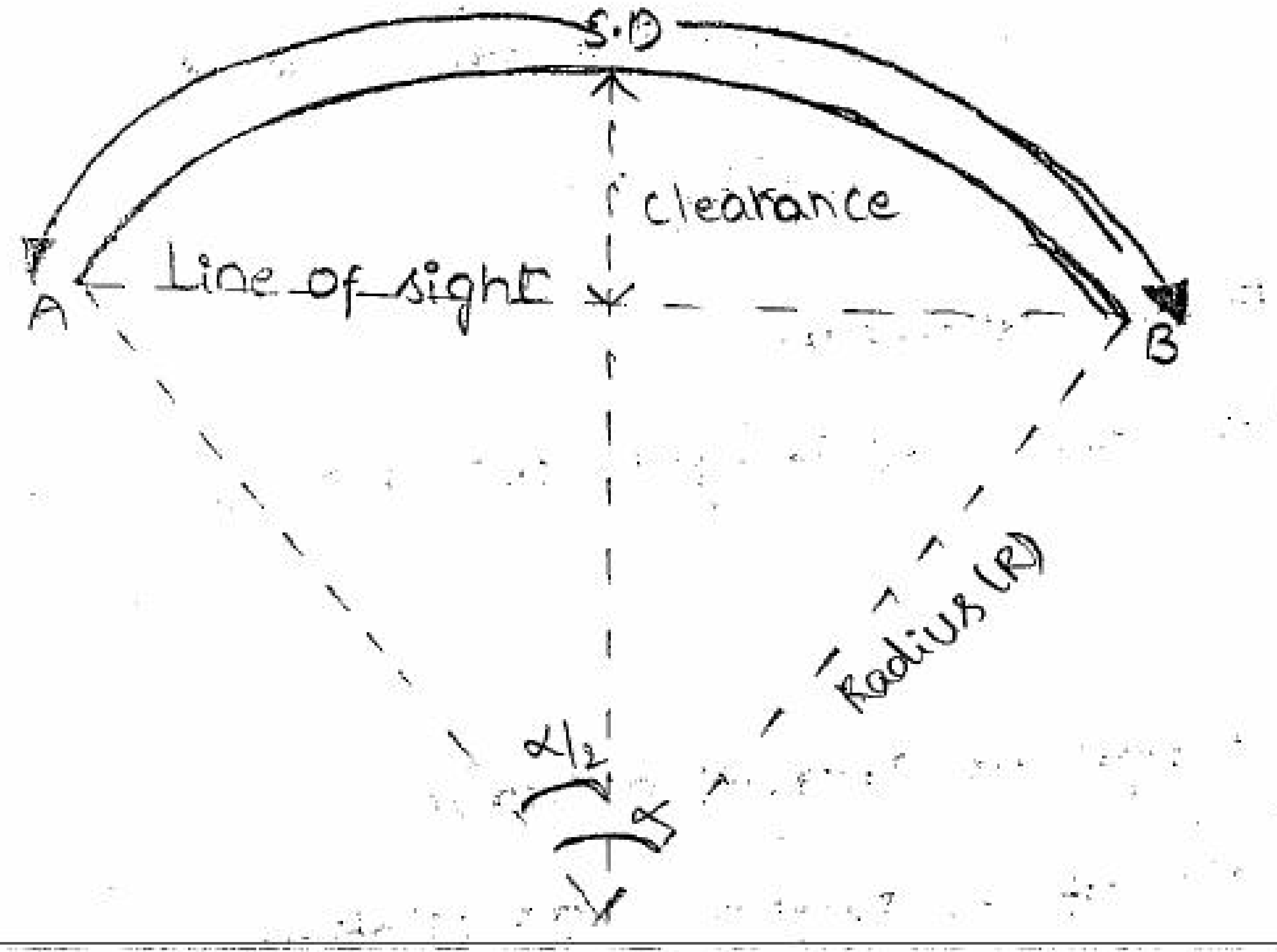
↓ consider highes length of Transit curve

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

$= \frac{96.96^2}{24 \times 220} = 1.78$

e

Set Back distance :



case i :

When $L_c > S$

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

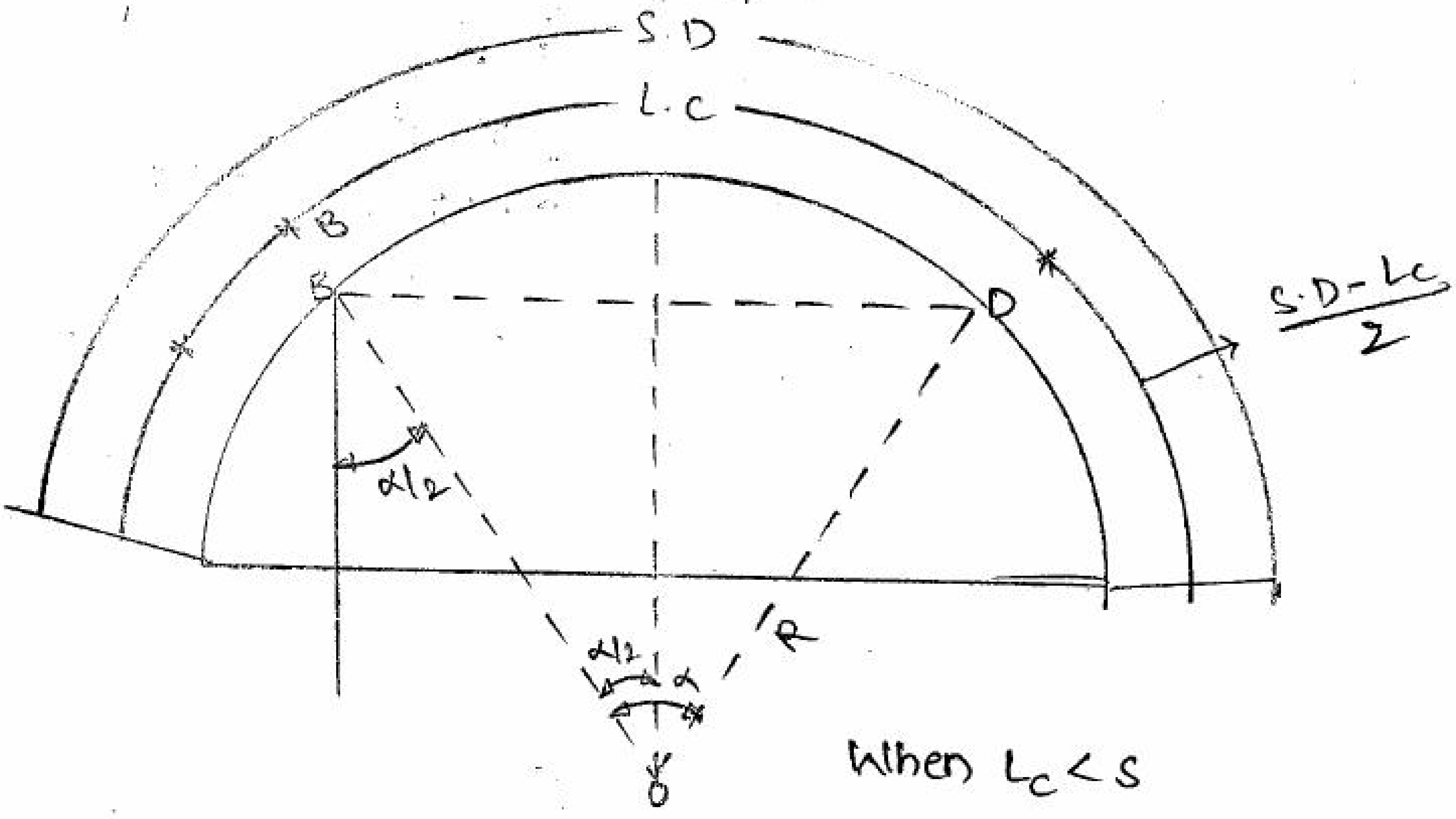
$$\text{Radius} = \frac{180}{2\pi}\left(\frac{S}{R}\right) \text{ degrees}$$

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

B → Width of pavement

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

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



When $L_c < S$

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

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

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

A:- Given,

$R = 250$ mm

No. of lanes = 2

Width = 7.6 m

S.D = 240 m

Given $L_c > S$

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

$\frac{\alpha}{2} = \frac{240}{2 \times 250} \Rightarrow \frac{\alpha}{2} = 0.48 \Rightarrow \alpha = 0.96$ (struck through)

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

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

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

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

$m' = 30.33$

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

A:- Given,

$R = 250$ m, $n = 2$

$L_c = 240$ m

$S = 340$

$d = 1.95$ m

$L_c < S$

$\therefore$ case ii,

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

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

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

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

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

$$= 30.39 + 23.24$$

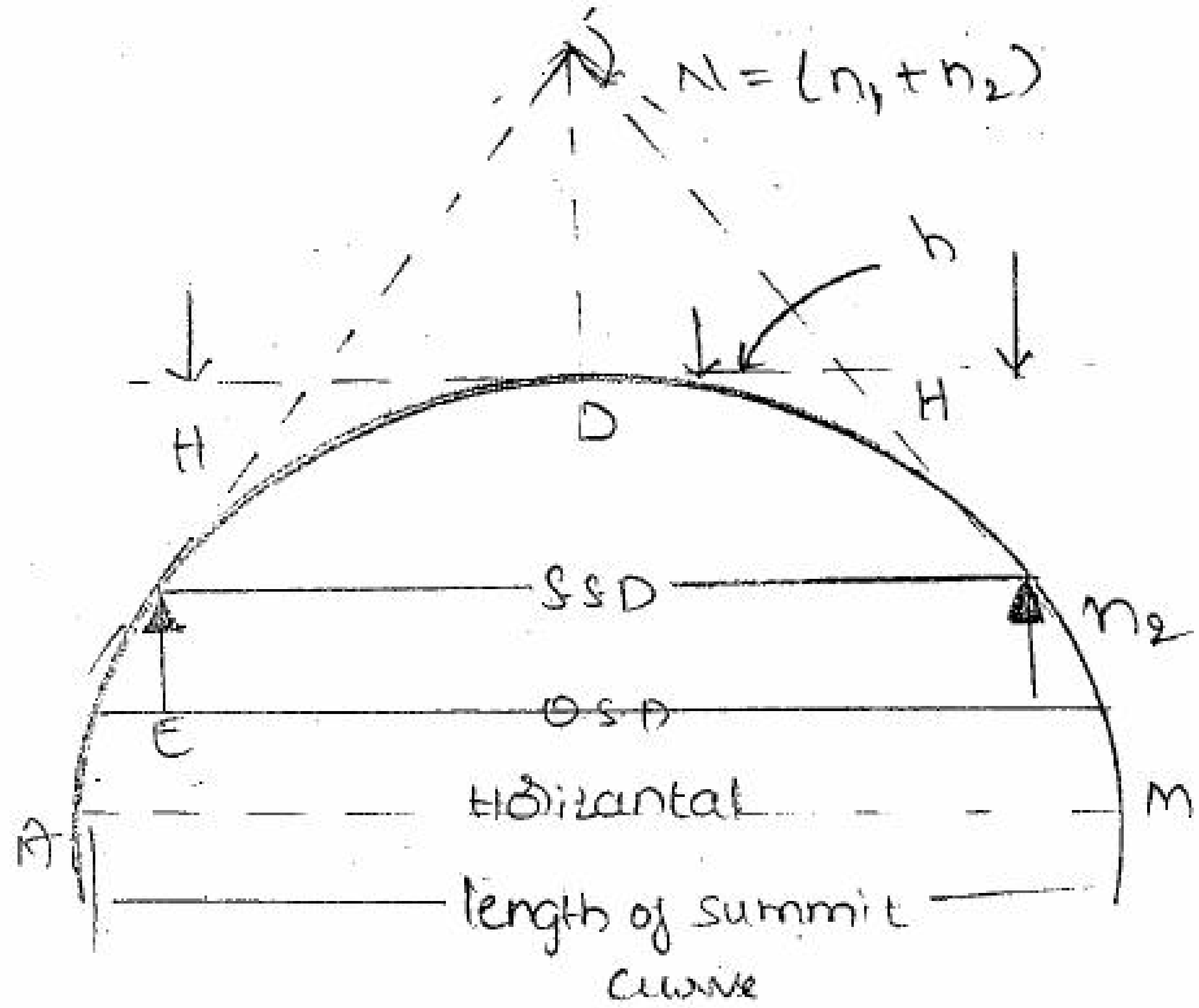
$$= 53.63\ m$$

$$M \sim 54\,m$$

There are

Length of the summit curve :

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



Length of summit curve for S.S.D:

Two cases are to be considered in deciding length

(a) When length of curve is greater than SSD ($L > SSD$)

(b) When length of curve is less than S.S.D ($L < S.S.D$)

a) $L > S.S.D$

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

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

b) $L < S.S.D$

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

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

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

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

L → length of summit curve

S → stopping sight distance

N → Deviation angle

H → Height of Eye level of driver above road way surface

h → Height of subject above pavement surface

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

a) When length of curve is greater than O.S.D (or) I.S.D $(L > OSD)$

b) when length of curve is less than O.S.D (or) I.S.D $(L < OSD)$

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

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

If $h = H$

$$L = \frac{NS^2}{8H}$$

When $H = 1.2\,m$

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

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

If $h = H$

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

If $H = 1.2\,m$

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

---

1. A vertical summit curve is formed at Intersect of two gradients +3 & -5.0 %. Design the length of summit Curve to provide a stopping sight distance. For $V = 80$ kmph Assume the required data ?

A: Given data, $V = 80$ kmph

$n_1 = +3$

$n_2 = -5.0$

$L > SSD$

Determination of safe S.S.D

$$S.S.D = 0.278Vt + \frac{V^2}{254f}$$

$f = 0.35$

$t = 2$ sec

$V = 80$ kmph

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

$S.S.D = 116.47\,m$

(b) Determination of length of summit curve

Deviation angle $(N) = n_1 - n_2$

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

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

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

$$\therefore L = 246.64\,m$$

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

A- Given data, $n_1 = 2, n_2 = -4$

$V = 80$ Kmph, $f = 0.35$

$t = 2$ sec

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

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

$$= 116.47\,m$$

b, Determination of Length of summit curve

$L > S.S.D$ $L < S.S.D$

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

$N = n_1 - n_2$

$= 2+4$

$N = 6 = 0.06\%$.

$$\therefore L = \frac{0.06(116.47)^2}{4.4}$$

$L = 184.98\,m$

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

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

$L = 159.60\,m$

3. 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 470 m.

A- Given Data, $n_1 = \frac{1}{100} = 0.01$

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

$S = 470$

$N = 0.01 + 0.005$

$= 0.015$

$L > O.S.D$

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

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

$$L = 345.15\ m$$

$L < O.S.D$

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

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

$$L = 300\ m$$

4. A vertical summit curve with gradients +1/50 & -1/80 S.S.D & O.S.D are 180 & 640 m. length & vertical curve restricted to 500 m If possible calculate the length of summit curve needed to fulfil the requirements of a) S.S.D b) O.S.D

A/- Given data

$$n_1 = \frac{1}{50} = 0.02,\ n_2 = -\frac{1}{80} = -0.0125,\ t = 2,\ V = 80,\ f = 0.35,\ S = 180$$

$$N = 0.02 + 0.0125 = 0.0325$$

$$S.S.D = 0.278\,Vt + \frac{V^2}{254 f}$$

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

$$S.S.D = 116.47\ m$$

a) $L > S.S.D$

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

$$L = 239.31$$

$$L \sim 240\ m$$

b) $L < O.S.D$

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

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

$$L = 985\ m$$

Not allowable

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

$L > I.S.D$

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

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

$$L \sim 440\ m$$

It is all[illegible]

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

A:- Given,

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

$$N = 0.0266$$

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

$L > O.S.D$

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

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

$$= 638.4\ m$$

$L < O.S.D$

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

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

$$L = 479.09\ m$$

∴ It is allowable

$$I.S.D = 2(S.S.D)$$

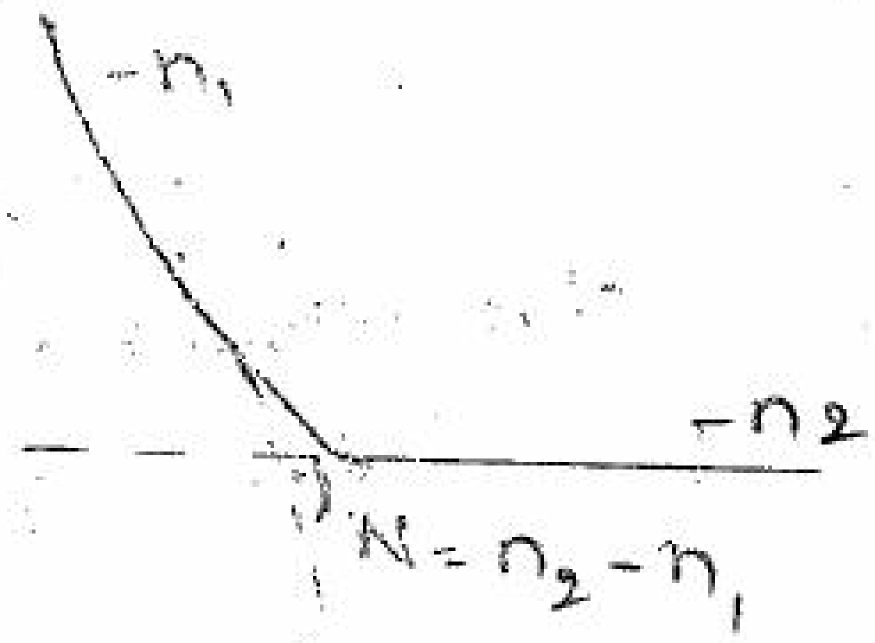
$$= 2 \times 180$$

$$= 360\ m$$

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

$$L = 351\ m$$

Valley curves :

i,


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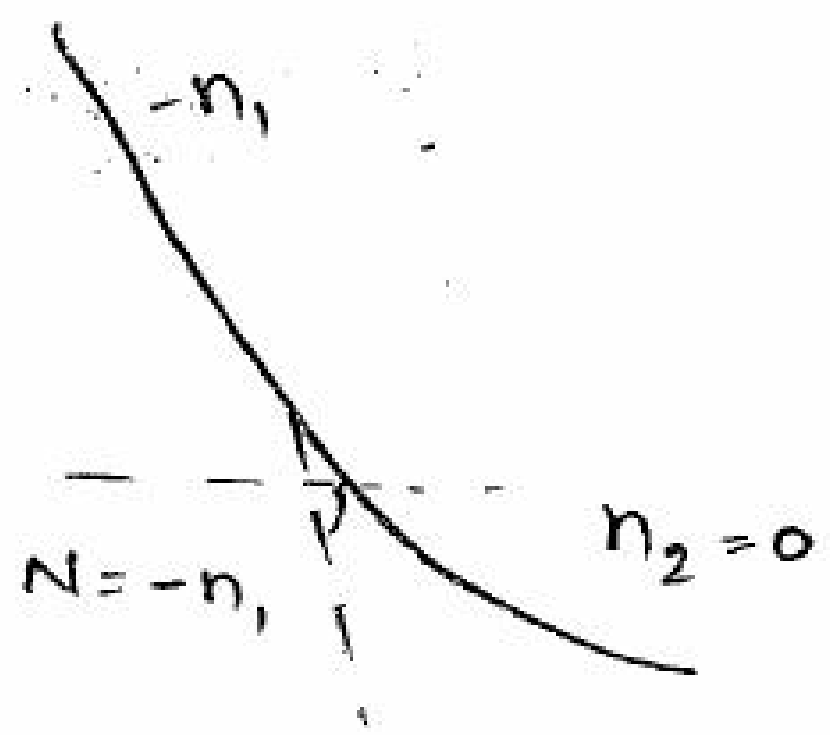

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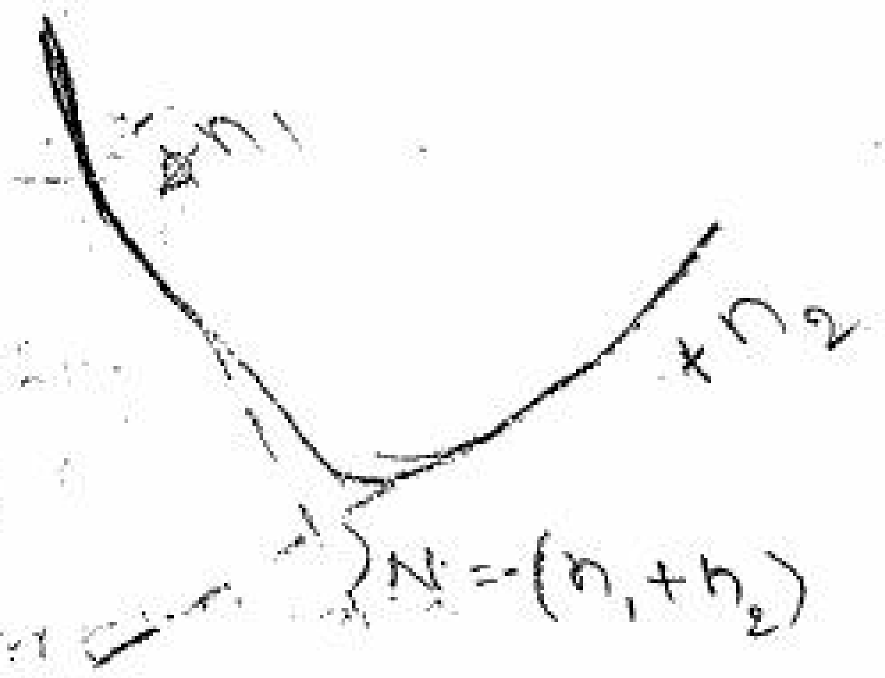

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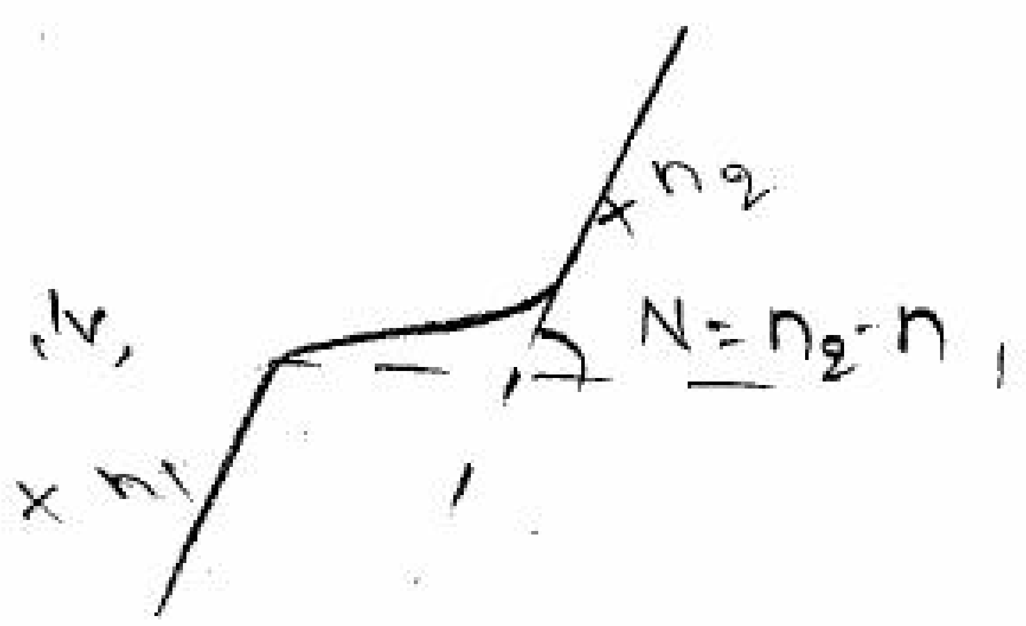
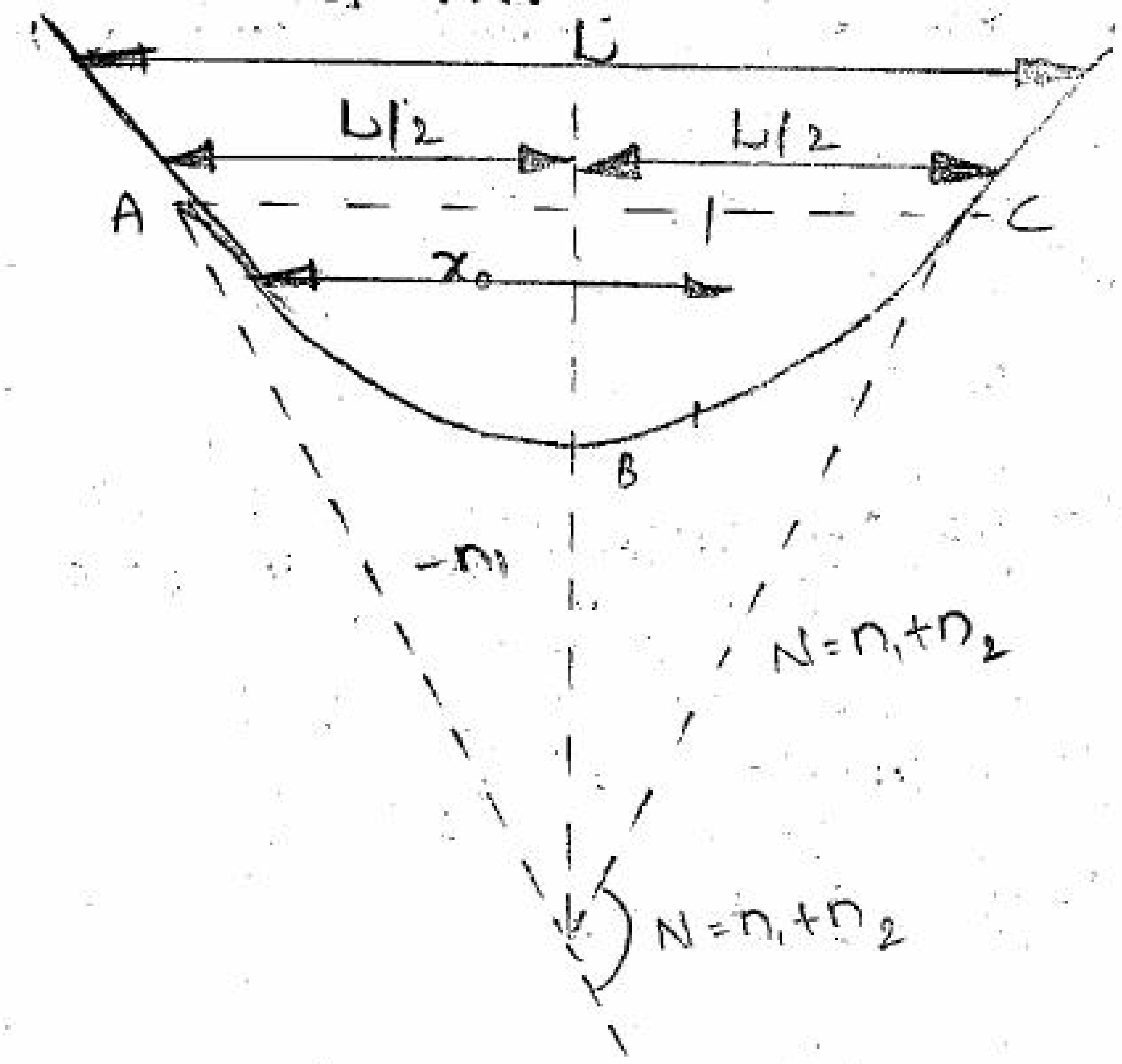


Length of valley curve :



a) length of Transition curve

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

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

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

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

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

$$V_{Kmph} = \frac{V}{3.6}\ m/s$$

$$L_s^2 = \frac{NV^3}{0.6 \times 3.6}$$

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

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

Total length of valley curve is $L = 2\left[\frac{NV^3}{C}\right]^{1/2}$

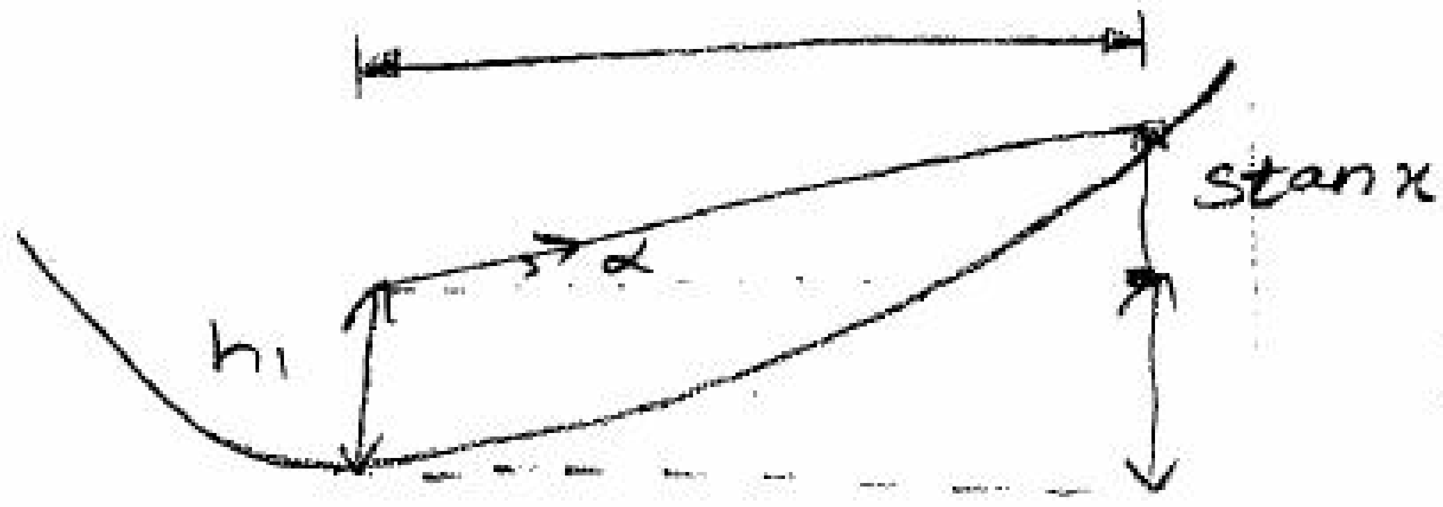
$$= 0.3\,[NV]^{1/2}$$

$V \rightarrow$ Design speed, Kmph

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

Length of valley for Head Light sight distance :

(i) L > S.S.D



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

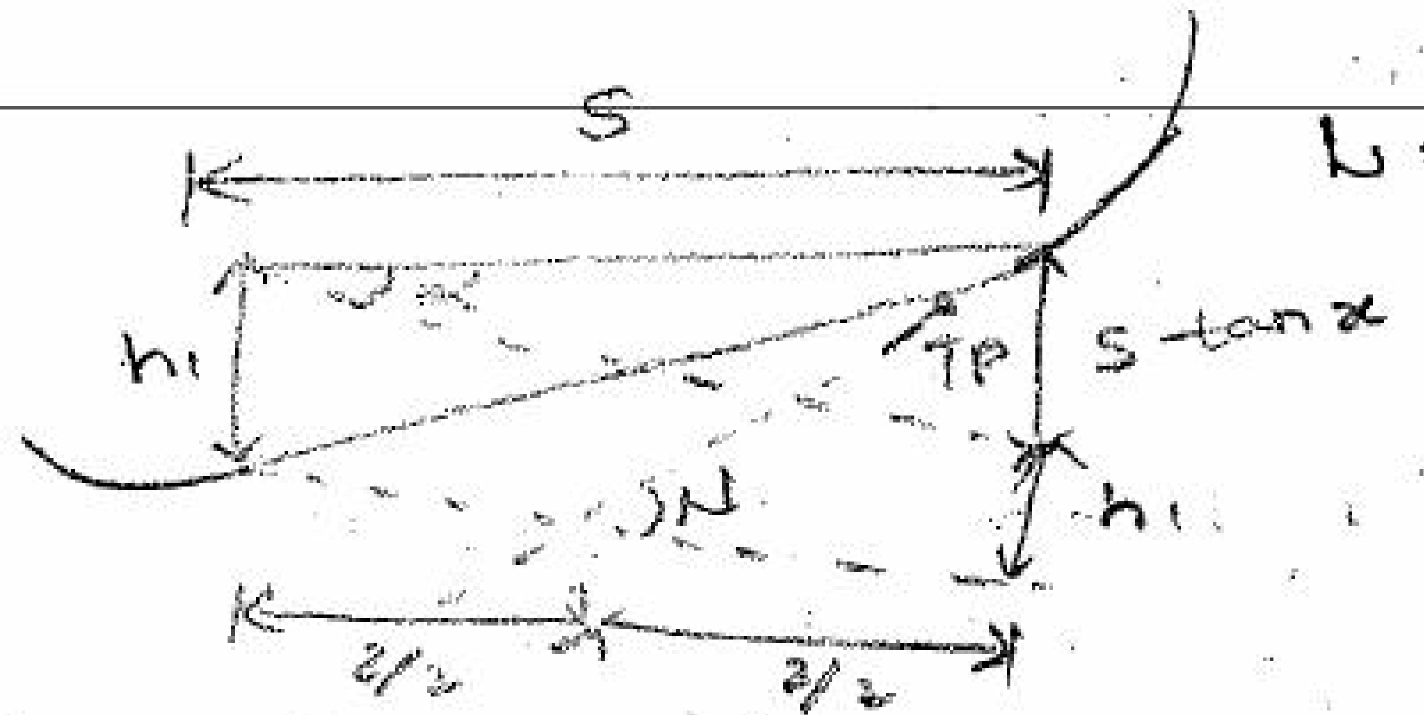
L → Total length of valley curve m(L>S)

S → S.S.D

N → Deviation angle = (n_1+n_2)

With slope $-n_1$ & $+n_2$

ii) L < S.S.D



$$L = 2S \quad \frac{2h_1+2S\tan\alpha}{N}$$

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 accerlation 6 m/s³

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

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

Condition for comfort by valley curve

$$L = 2\left[\frac{NV^3}{C}\right]^{1/2}$$

$N = -(n_1+n_2)$

$= -\left(-\frac{1}{30}+\frac{1}{35}\right)$

$= 0.0047$

$$= 2\left[\frac{0.0047\,(22.2)^3}{0.6}\right]^{1/2}$$

$= 18.56$ m

Valley length for Head light sight distance

Assumed values are $t = 2$ sec, $f = 0.35$

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

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

$$S.S.D = 116.16\ m$$

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

$$= \frac{0.0047(116.16)^2}{1.5 + 0.035(116.16)}$$

$$L = 11.27\ m$$

TRAFFIC ENGINEERING

Vehicular characteristics

Road user characteristics:

Mental

Physical

Pschyological

Environmental

Vehicular characteristics:

Width of vehicle < 2.5

Length of Vehicles ≤ 6

Loads on Vehicle

Weight 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

A- Given

Initial speed = 30 kmph

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

$= 8.33$ m/sec

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

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

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

$$f = 0.609$$

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

A:- Given,

Initial speed = 40 kmph

$= 40 \times \frac{5}{18} \Rightarrow 11.11$ m/sec

Braking time = 1.8 sec

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

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

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

$$= -\frac{11.11}{1.8} \Rightarrow a = -6.17 \text{ m/sec}^2$$

(-) denotes Retardation.

Friction $F = ma$

$F = W.f$

$$W.f = \frac{W}{g} . a$$

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

$$f = 0.62$$

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

A:-

$$u = 40 \times \frac{5}{18} = 11.11 \text{ m/s}$$

$L = 12.2$m

$f = 0.70$

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

$$f' = \frac{11.11^2}{2*9.81*12.2}$$

$$f' = 0.515$$

$$\mathcal{E} = \frac{f'}{f} * 100$$

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

$$= 73.5714$$

4\. A vehicle with Breaking time 1.2 sec & skid ~~resistance~~ length 6m. Find out the skid ~~length~~ Resistance?

A/- Given,

Breaking time = 1.2 sec = t

Skip distance $s = 6 m$

From the Eq's of acceleration and Retardation

$$v = u + at$$

$$u = -at$$

$$v^2 - u^2 = 2as$$

$$v = 0, \quad -u^2 = 2as$$

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

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

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

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

$$a = -8.33 \ m^2/sec^2$$

~~F = ma~~

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

$$f = 0.84$$

Traffic Enigeneering studies :

Traffic Volume studies

Spot Speed studies

Speed & Delay studies

Traffic volume studies : (Traffic tonnage / 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 Truck	3

Annual Average Daily Traffic :

Avg Daily Traffic (hr)

Avg Hourly volume (or) (Day)

Peak Hourly volume

Spot Speed studies :

Traffic volume characterstics :

* Variation in volume (traffic)
* 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 DF ↓

$$\frac{\text{7 day Avg \& for 24 hrs}}{\text{24 hr count at any particular day}}$$

Seasonal Factor S.F

$$\frac{\text{Avg 24 hr traffic volume for 12 months}}{\text{24 hr Traffic vol count for specific month}}$$

the 24 hr Traffic vol for any station on a specific day in a particular Month A.D.T = Traffic vol count * D.F * S.F

Competition Of Annual Avg Daily Traffic

$$A.A.D.T = A.D.T * D.T * W.T * S.T$$

$$= A.D.T * D.F * W.F * S.F$$

Spot Speed studies :

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

V_s → spacemean speed kmph

d → length of Road (or) distance considered

n → No. of Individual Vehicle observations

t_i → 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 (or) Redesign of Various Geometric elements

To decide the design speed

To estimate the accident studies & preventive measur

~~study~~ of Traffic capacity

To Find out the speed trends

To compare the behaviours of divergent vehicles

Factors Effecting Spot Speed Studies:

Pavement width
Horizantal curve
Sight distance
Gradients
Summit & valley curves
pavement uneveness
Intersections
Traffic conditions
Characteristics of driver & vehicle

Measurement of Spot Speed Studies:

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

ph

Equipments used to measure spot speed studies

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

d)

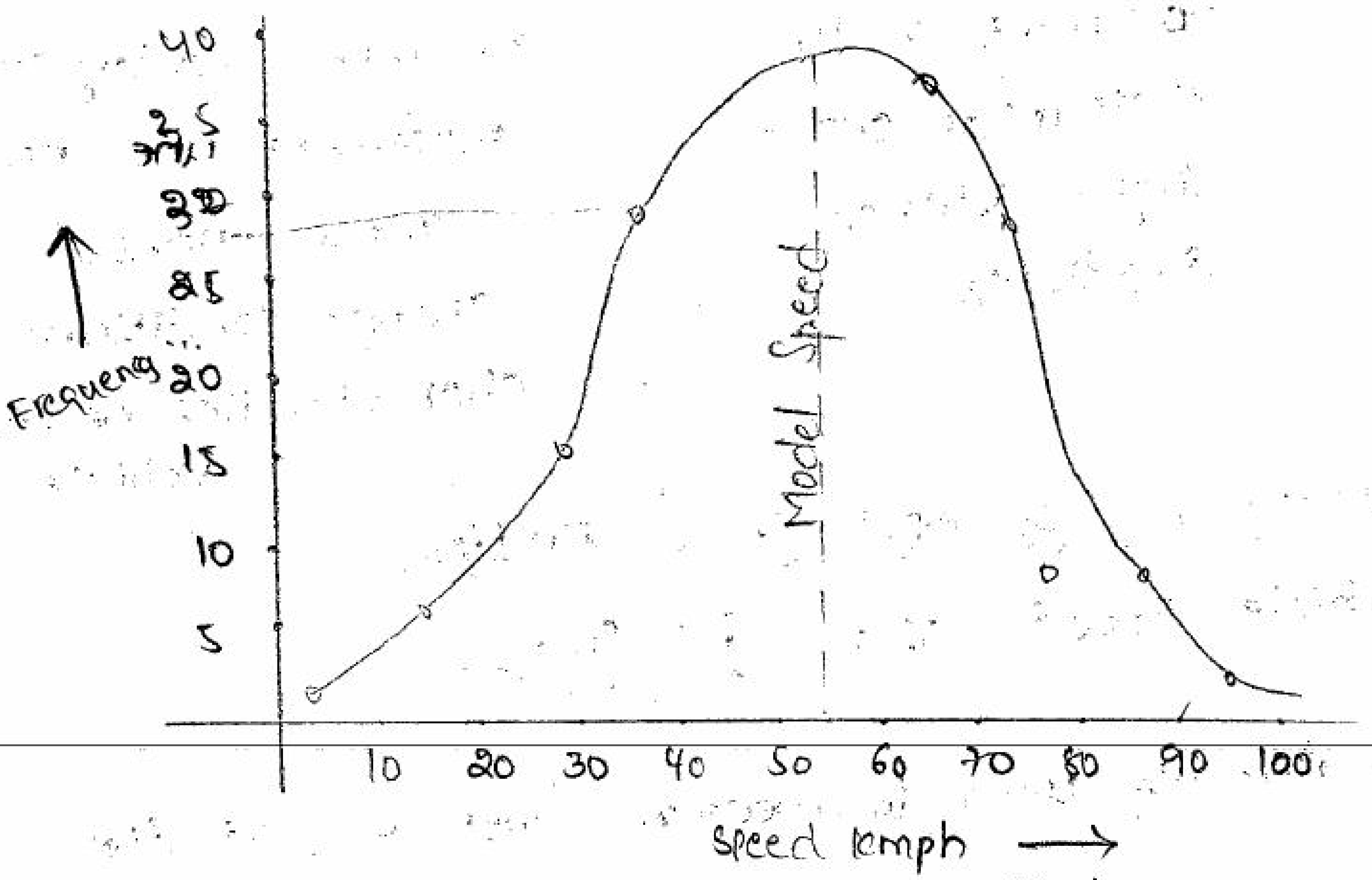
Presentation of Spot Speed Studies:

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.

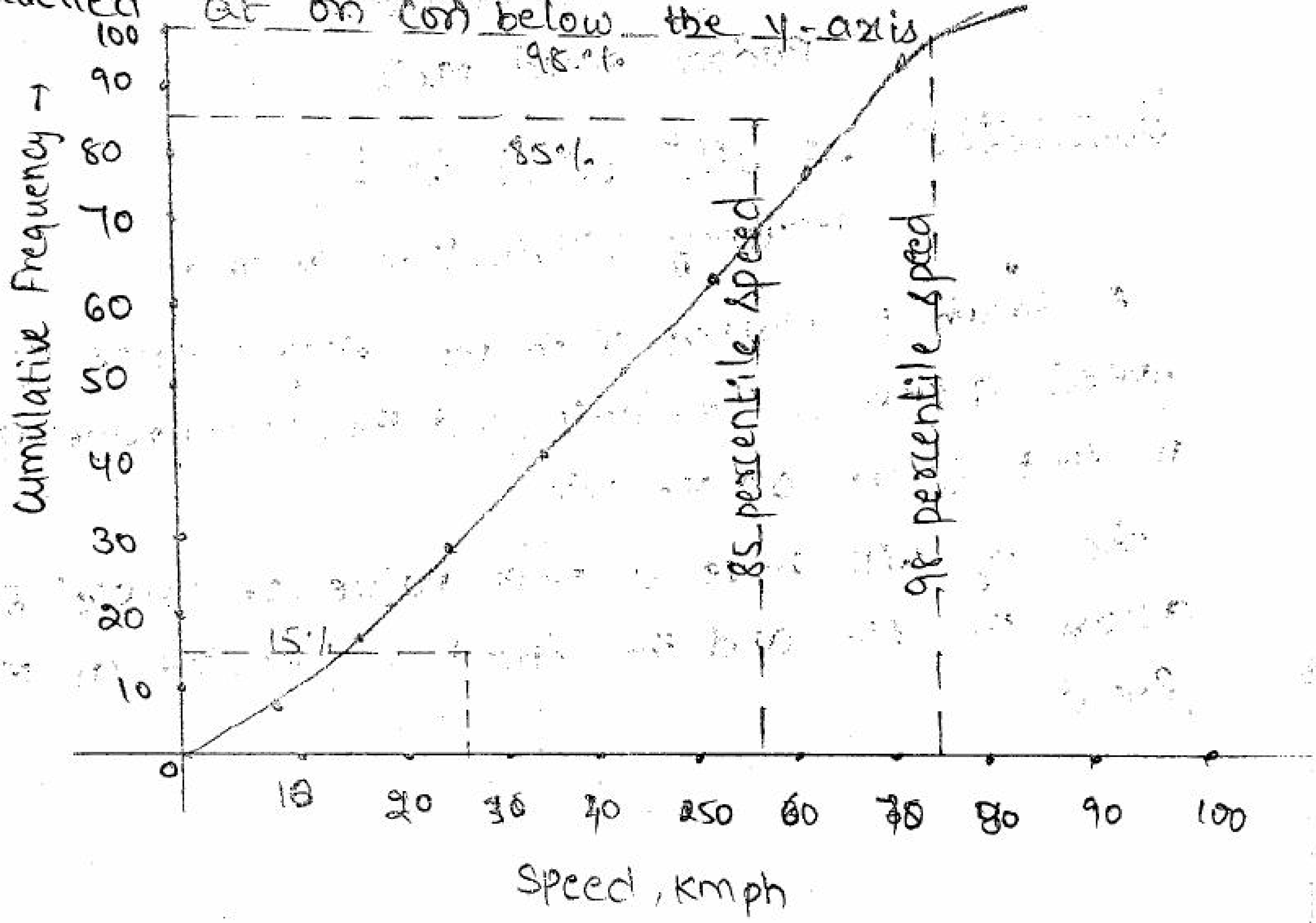
The dig will have a peak value of Travel speed across the s/c and the speed is denoted as model speed

e)



Cumulative speed Distribution diagram:

Graph plotted with the avg values of each speed group on the x-axis & cumulative %'s of vehicles travelled at on (or) below the y-axis



Speed & Delay studies

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

Methods of conducting speed & delay studies

1. Floating car (or) Riding check method
2. Liscense 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 test vehicle over a given route

The Avg Journey time $\bar{t} = t_w - \frac{n_y}{q}$ → For Floating car only

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

q → Flow of vehicles
n_a → Avg No. of vehicles
n_y → Avg No. of over taking vehicles
t_a → Avg Journey time opposi to the stream
t_w → Avg Journey time in the direction of stream

2. Liscense 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, Calvarts, Railways, Airways
→ To locate Express ways (or) 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 :

i. Collision of moving vehicle with parked vehicle

Before collision : $V_1^2 = V_2^2 + 2gfS_1$

At collision :

$$V_2 = \frac{W_A + W_B}{W_A} V_3^2 + 2gfS_1$$

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

$V_1 \rightarrow$ Intial vehicle speed

$V_2 \rightarrow$ Intial speed before collision

$V_3 \rightarrow$ Speed after collision

$V_4 = 0$

1. Vehicle of weight 2 Tonnes skid distance before collision is 40m. Parked vehicle weight 1 Tonn. skid distance after collision 12 m. Friction 0.5. Compute vehicle speeds

Given

Weight W_A = 2 Tonns

$S_1 = 40$ m

$W_B = 1$

$S_2 = 12$m

$f = 0.5$

After collision:

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

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

$(\because V_4=0)$

$$V_3^2 - 0 = 2gfS_2$$

$$V_3 = \sqrt{2gfS_2}$$

$$\therefore V_3 = \sqrt{2*9.81*0.5*12}$$

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

At collision:

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

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

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

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

Before collision:

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

$$V_1^2 - V_2^2 = 2gfS_1$$

$$V_1 = \sqrt{2gfS_1 + V_2^2}$$

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

$$V_1 = 25.62 \text{ m/sec}$$

i.e. 92.26 Kmph

Another method:

After collision: $V_1 = \sqrt{254 f_1 \left[S_2 \left(\frac{W_A + W_B}{W_A} \right)^2 + S_1 \right]}$

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

$= 92.24$ kmph

Traffic Signals:-

At intersection there are so many complex coins causes lot of damage property and people. To facilitat 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 quelengt.

Single signal system:

1. Tri cycle method:

(i) The 15 minutes traffic count n_1 and n_2 on road 1 and 2 will be noted during the design peaks hour flow.

Some suitable tricycle 'C_1' is assumed and cyles in 15 min, 15×60 seconds.

The cycle period $= \frac{50 \times 60}{C_1}$

Assuming an Average time head way 2.5 sec.

'G_1' and G_2 are green periods for Road 1 & 2.

$G_1 = \frac{2.5 \times n_1 \times C_1}{900}$ and $G_2 = \frac{2.5 \times n_2 \times C_1}{900}$

Then the Amber period A_1 and A_2 are either calculated (or) observed. So that cycle length

$C_1 = G_1 + G_2 + A_1 + A_2$.

Ex 1: The 15min traffic count on cross roads 1, & 2 during peak hours observes an 178 and 142 to vechile per 1 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:

Trail 1

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

$n_2 = 142$ $\quad A_2 = 3$ sec $\quad$ Assume a tricycle $C_1 = 50$sec

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

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

$= 24.72$ sec

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

$= 19.72$ sec

Total cycle length $C_1 = G_1 + G_2 + A_1 + A_2$

$= 24.72 + 19.72 + 2 + 3$

$= 49.44$ sec.

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

Trail 2:

$n_1 = 178$ $A_1 = 2$ sec head way = 2.5 sec

$n_2 = 142$ $A_2 = 3$ sec $C_1 = 40$ sec

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

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

$$G_2 = \frac{2.5 \times 142 \times 40}{900} = 15.7 \text{ sec}$$

Total cycle Length $C = G_1 + G_2 + A_1 + A_2$

$= 40.4$ sec.

Trail 3:

$n_1 = 178$ $A_1 = 2$ sec head way = 2.5 sec

$n_2 = 142$ $A_2 = 3$ sec $C_1 = 45$ sec

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

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

$$G_2 = \frac{2.5 \times 142 \times 45}{900} = 17.75 \text{ sec}$$

Total cycle Length $C = G_1 + G_2 + A_1 + A_2$

$= 45$ 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 pedestrial indigation with road (i) 18 m and road (ii) 12 m traffic volume 275 & 225 approximate speed 55 kmph, pedestrian speed 1.2 m/sec during the timings of two way traffic design pedestrain signals by approximate method.

Given data

Width of road (i) = 18 m

width of road (2) = 12 m

traffic volume (i) = 275

(ii) = 225

pedestrain speed = 1.2 m/sec

approximate speed = 55 kmph.

(i) design of two way traffic signals

pedestrian crossing for road (i) = $\frac{18}{1.2}$ = 15 sec

" " " road (ii) = $\frac{12}{1.2}$ = 10. sec

Adding 7 seconds per initial wait period that should be minimum red time per road (i)

$R_a = 15 + 7 = 22$ sec

$R_b = 10 + 7 = 17$ sec

Minimum green time for Road (b) = 3

= 22 − 3 ⟹ 19 sec

Minimum green time for Road (a) = 3

= 17 − 3 = 14 sec

Using the relationship

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

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

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

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

= 23.22 + 19 + 3 + 3

= 48.2 sec

A additional period of 50 − 48.2 = 1.8 sec.

So divide 1.8/2 = 0.9 sec.

Finilized $G_a = 23.2 + 0.9 = 24.1$ sec

$G_b = 19 + 0.9 = 19.9$ sec

$R_a = G_b + A_b$

$= 20 + 3 = 23$ sec

$R_b = G_a + A_a$

$= 3 + 24 = 27$ sec

Final cycle length $= G_a + G_b + A_a + A_b$

$= 50$ 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 1.2m/sec design (i) 2 way traffic signals (ii) pedestrian signal.

Given data

Road (a) = 14m

Road (b) = 10m

$n_a = 700$ and $N_b = 400$

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

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

adding 7 second per initial walk period

$R_a = 11.6 + 7 = 18.6$ sec

$R_b = 8.3 + 7 = 15.3$ sec $\cong 16$

green time for Road (b) = 19 − 3

= 16 sec

green time for Road (a) = 16 − 3

≅ 15 sec

Using Relation

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

$$G_a = \frac{N_a}{N_b} \times G_b \Rightarrow \frac{700}{400} \times 16 \Rightarrow 28 \text{ sec}$$

Total cycle Length = $G_a + G_b + A_b + A_a$

= 28 + 16 + 3 + 3

= 50 sec

3. <u>Webster</u> <u>method</u> <u>of traffic</u> signal

Assumption:- Traffic Volume 160 PCU per 0.3m

Equations:-

$$y_1 = \frac{q_1}{S_1} \quad \text{and} \quad y_2 = \frac{q_2}{S_2} \qquad C_o = \frac{1.5L + 5}{1 - Y}$$

$\therefore Y = y_1 + y_2$

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

N = no. of faces

R = All red time are red & Amber time

S_1 & S_2 = Saturation

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

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

$R = 12$ sec

$S_1 = 1250$ $S_2 = 1000$

$q_1 = 400$ $q_2 = 250$

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

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

$Y = y_1 + y_2 \Rightarrow 0.32 + 0.25$

$= 0.57$

$C_0 = \frac{1.5L + 5}{1 - Y} = \frac{1.5 \times 60 + 5}{1 - 0.57} = 67.5$

$L = 2N + R \Rightarrow 2 \times 24 + 12 \Rightarrow 60$ sec

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

$= \frac{0.32}{0.57}[67.5 - 16]$

doubt

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

These are 2 types:

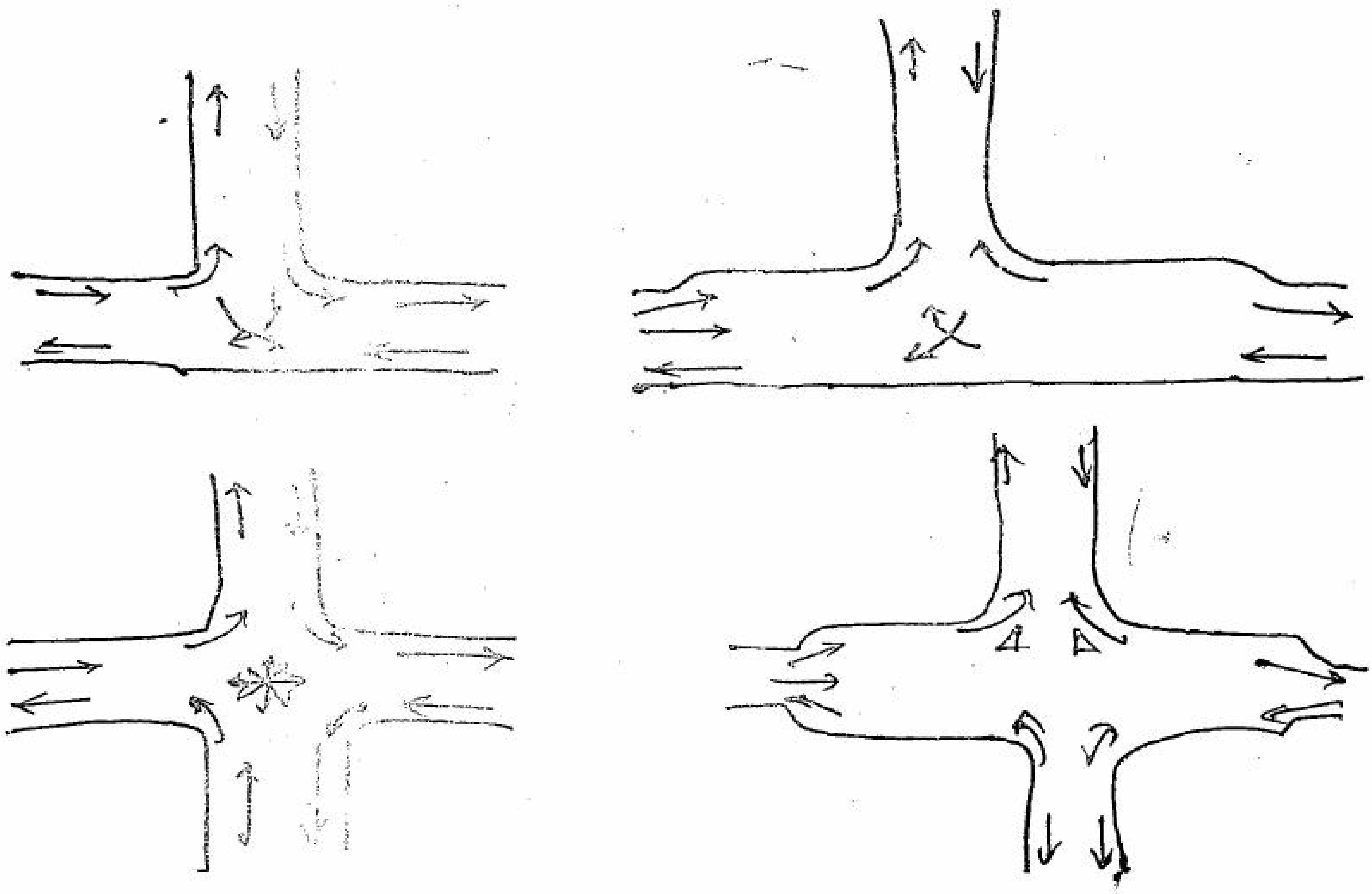
They are 1. Intersection at grade &

2. Grade seperated with intestion.

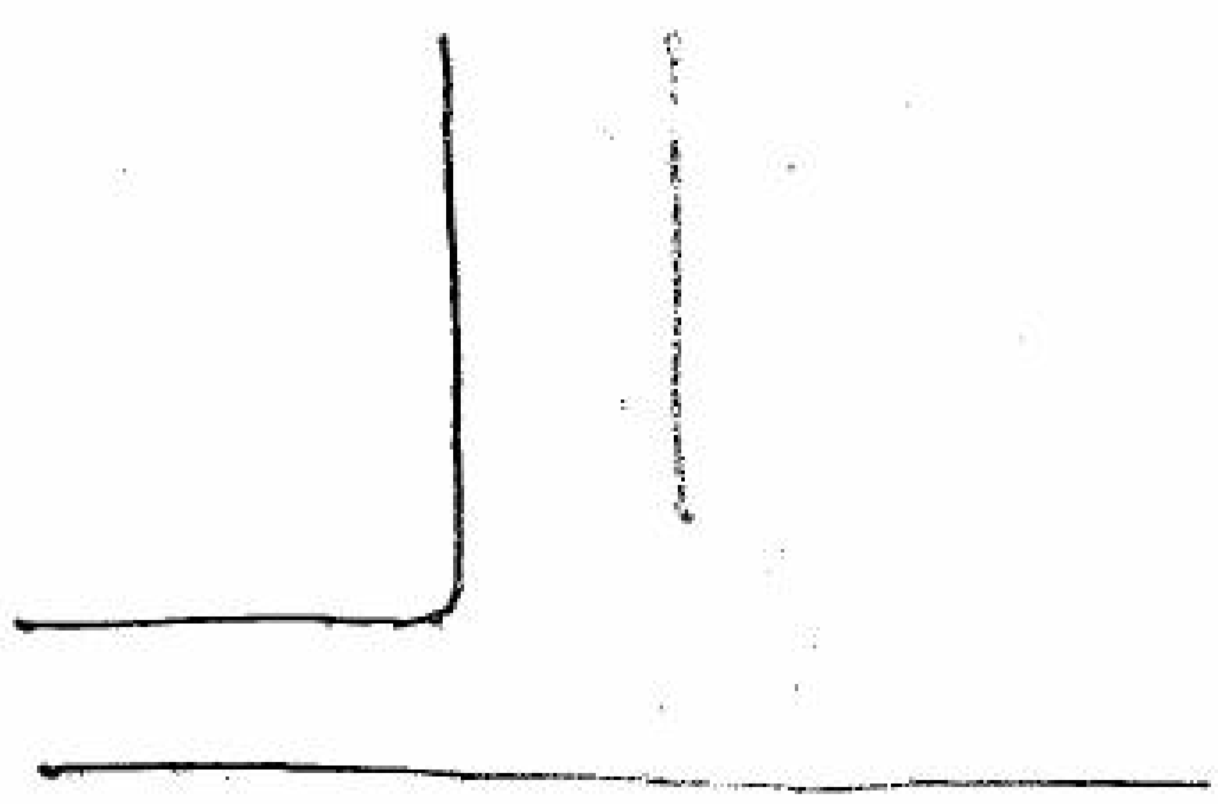
1. Intersection at grade:

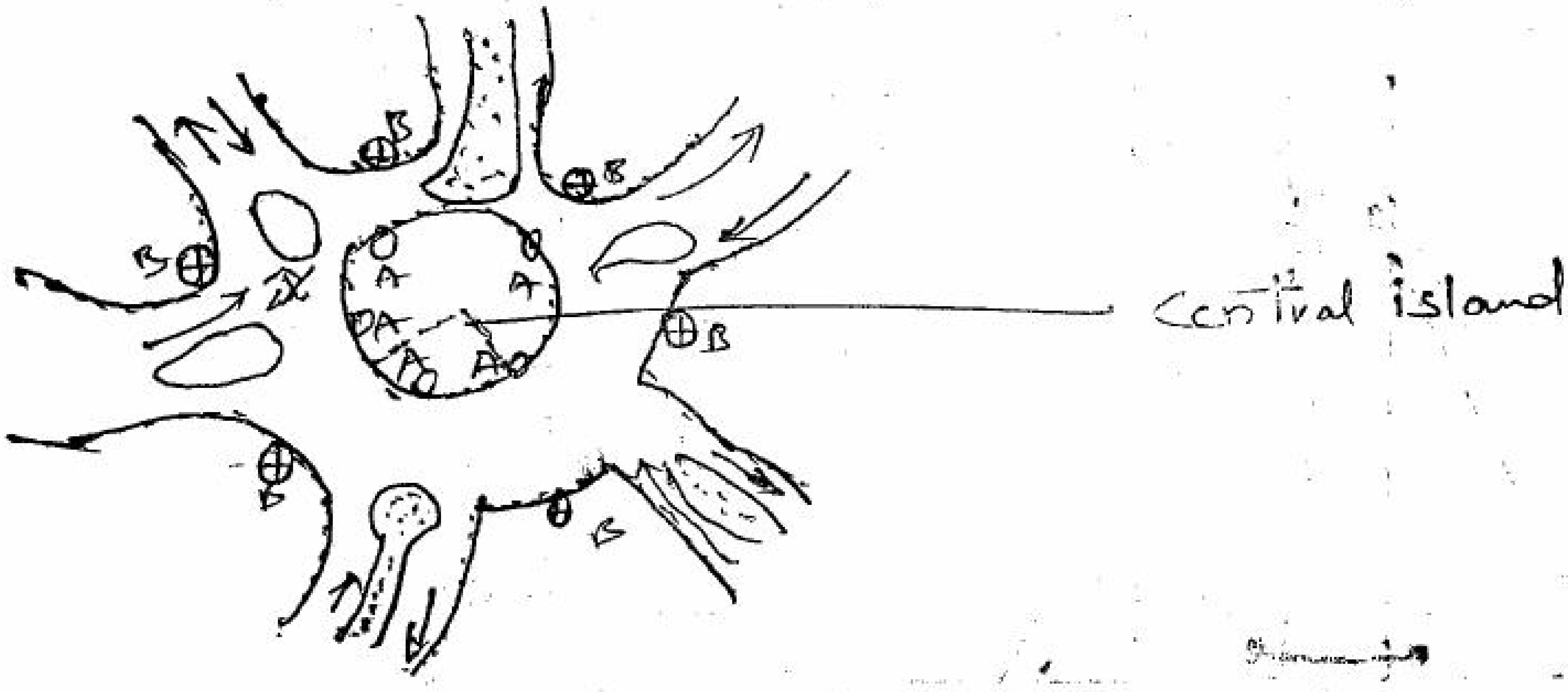
There are again 4 types. They are.

1. Un channelised intersection:

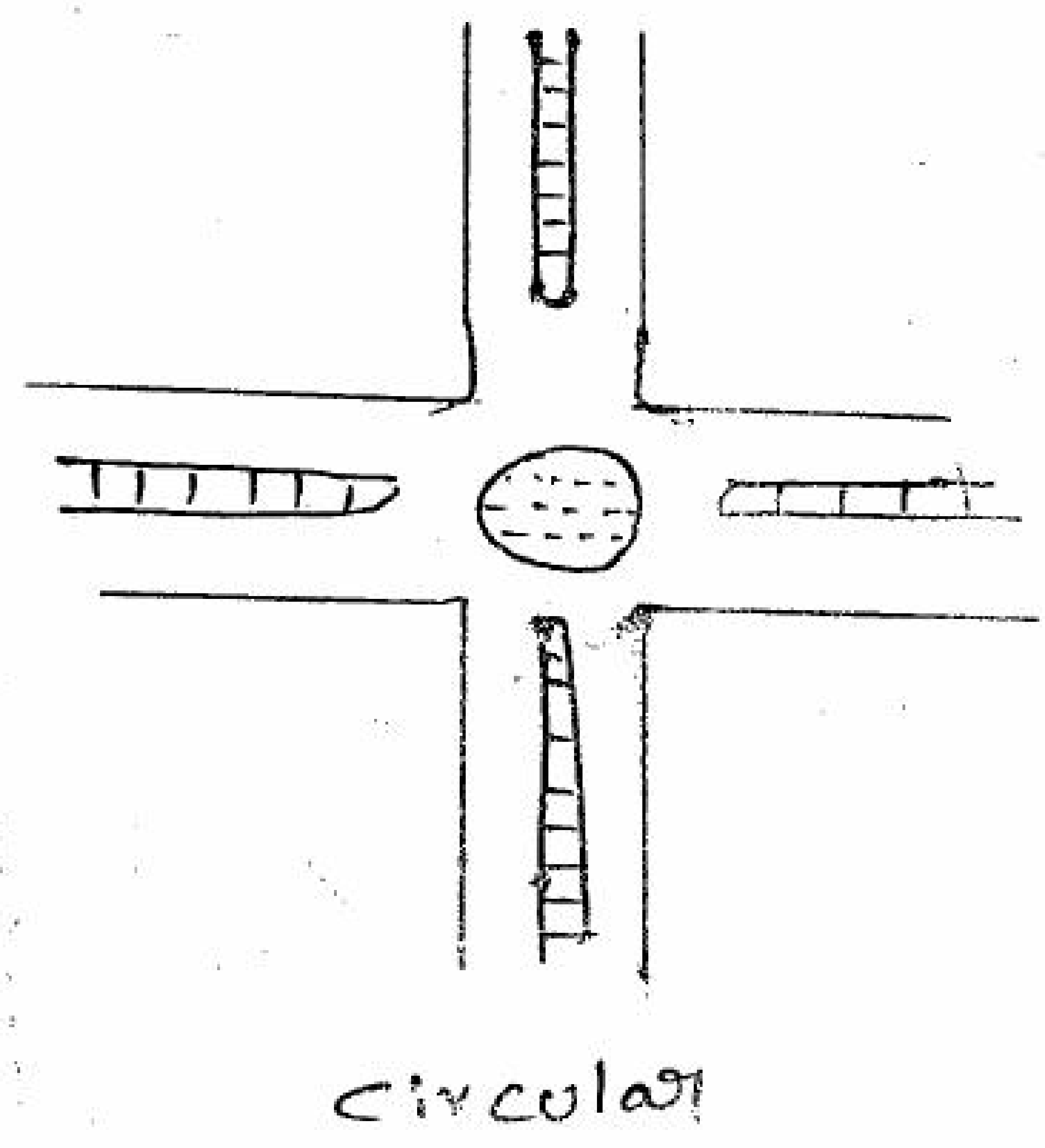


2. Channelised Intersection:

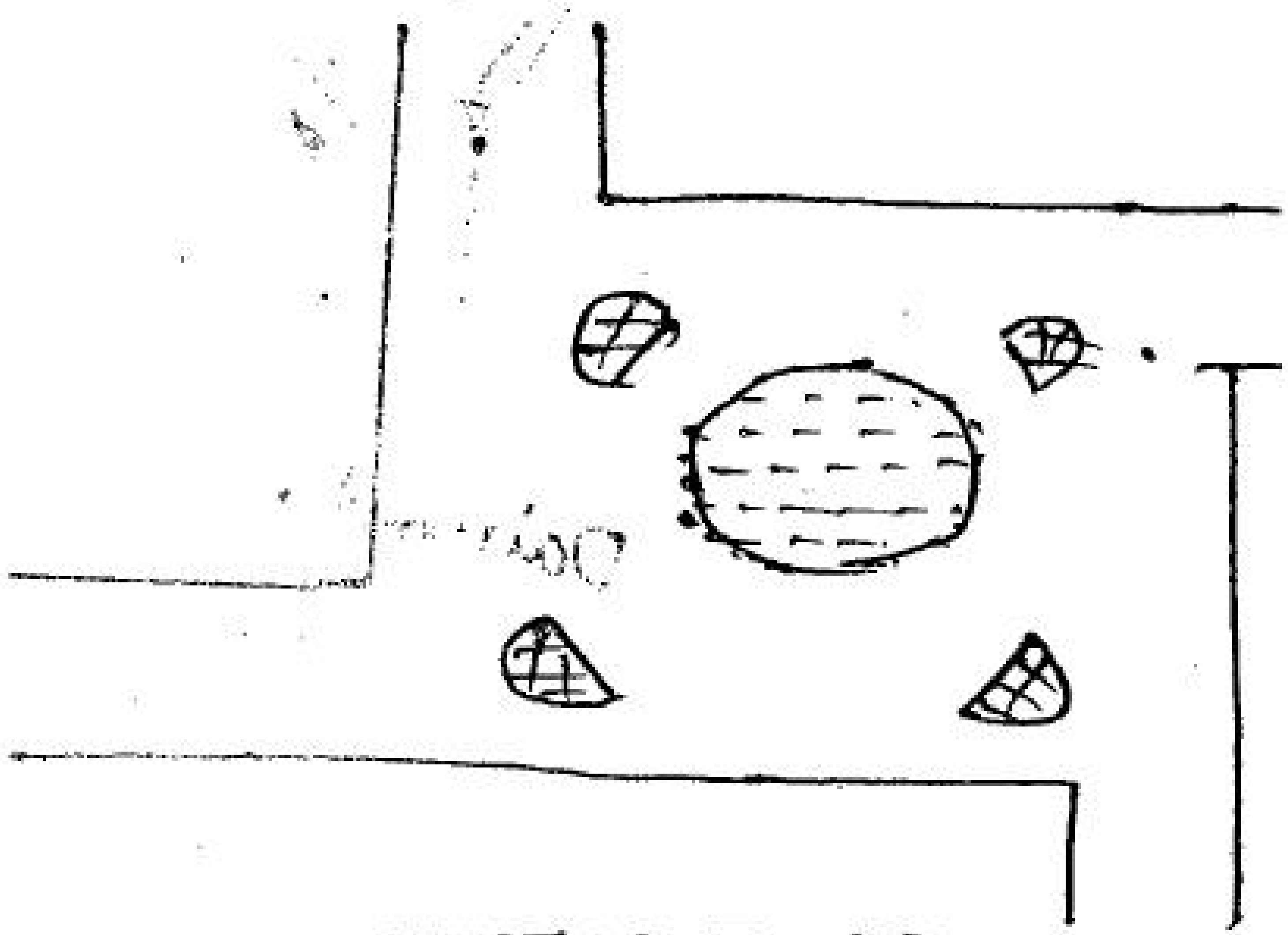




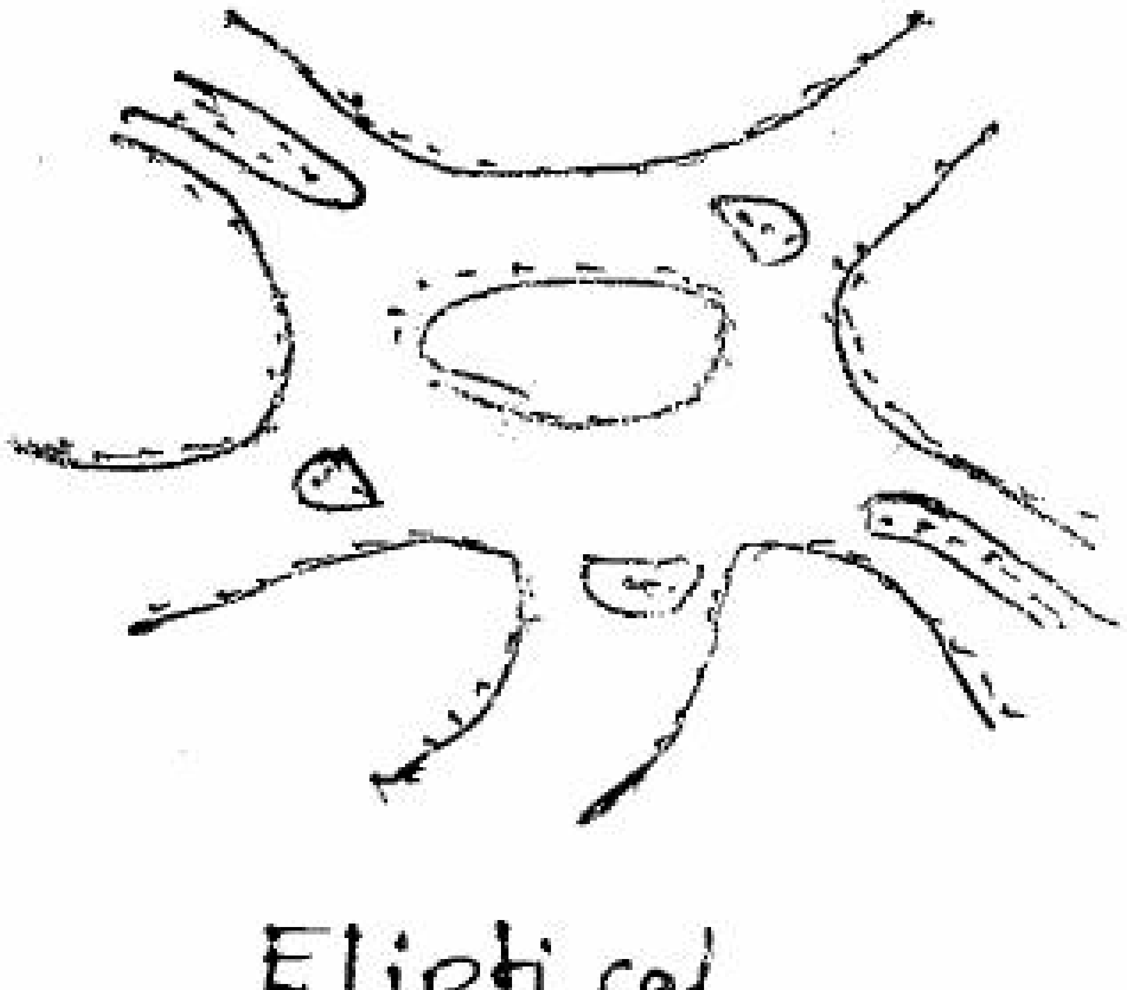
A typical rotary intersection



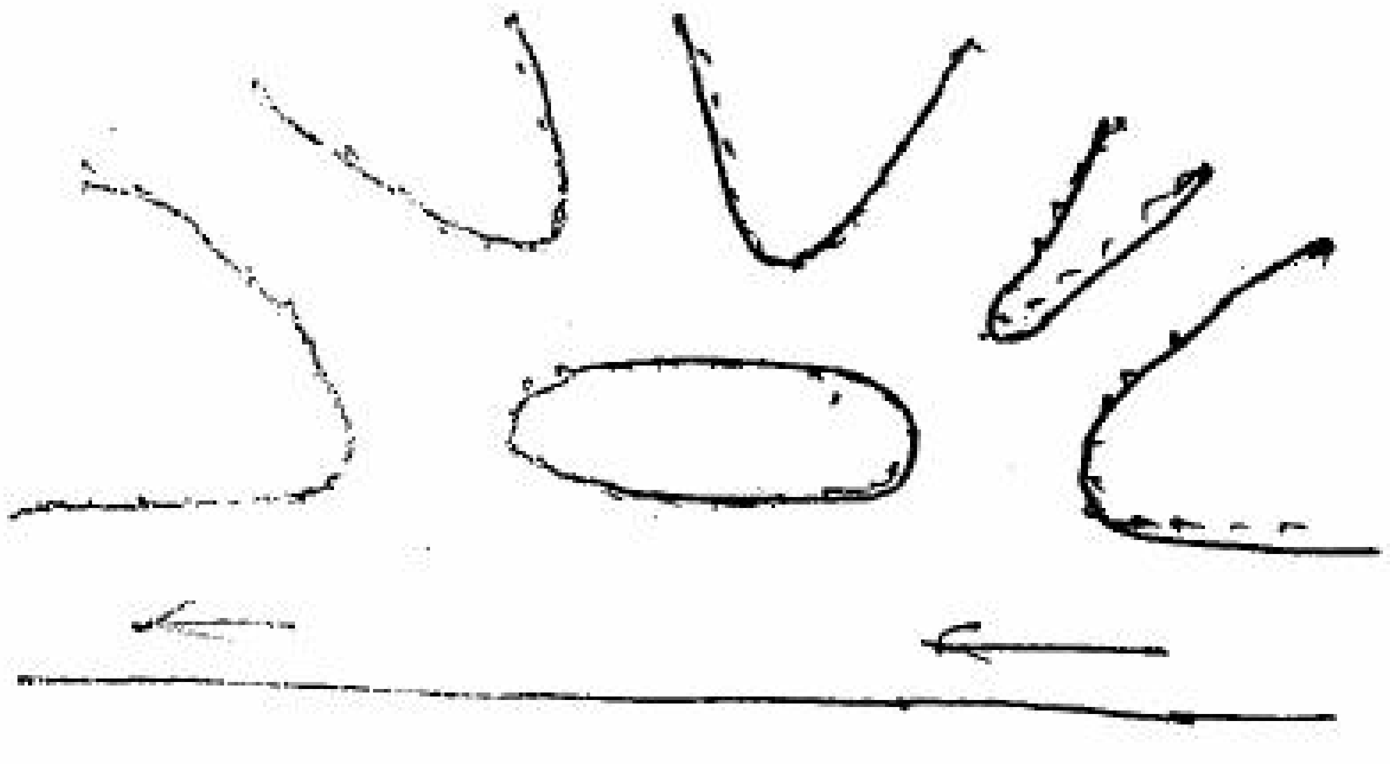
circular



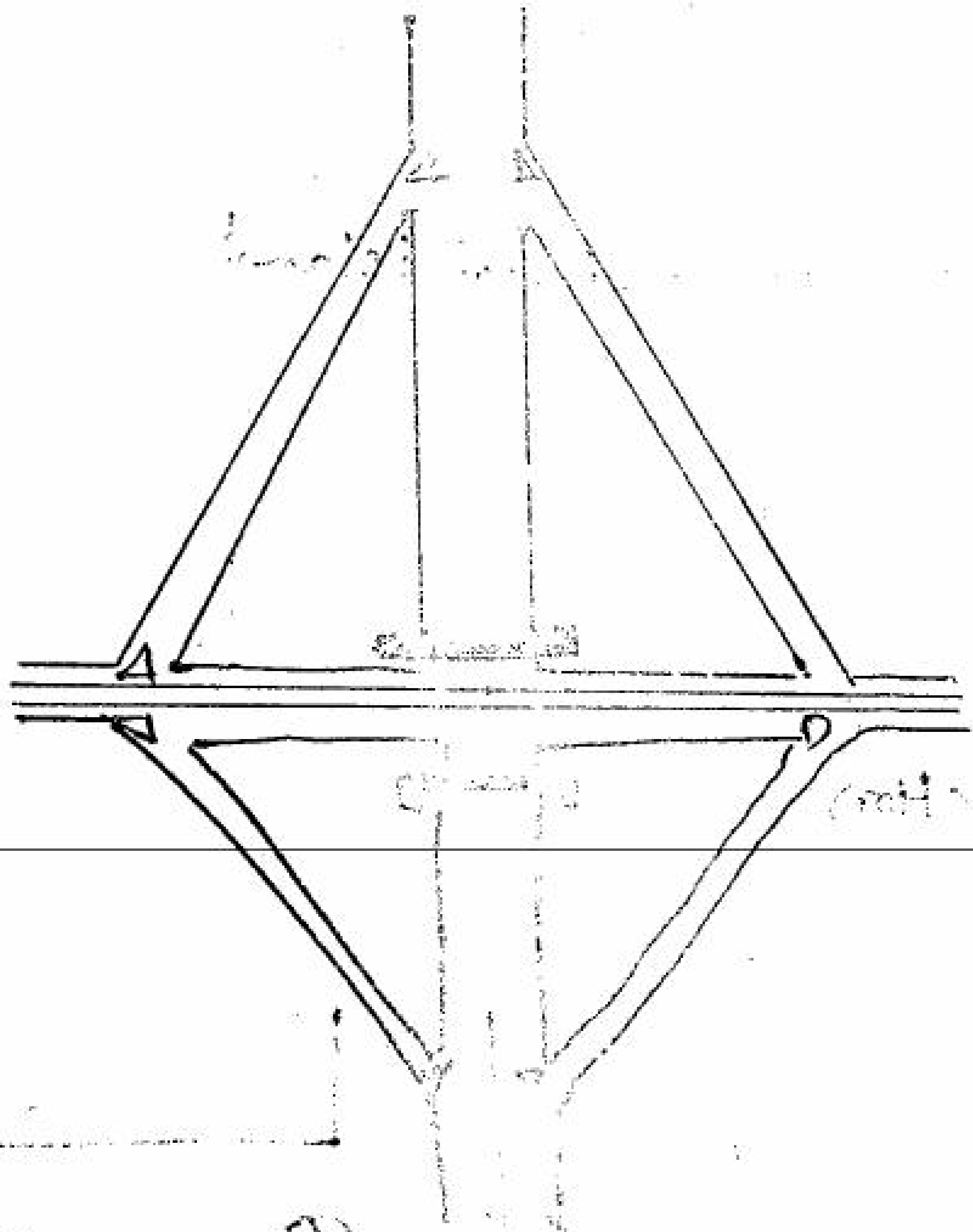
TURBINE



Eliptical



Tangent.



Daimond.

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

Characterstics & properties with Important Labratory Tests on the following Highway Materials :—

1. Soil
2. Stone Agg's
3. Bituminous Binders
4. Bituminous Mixes
5. Portland cement & cement concrete

Soil :

Desirable Properties for 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

Gravel	Sand			Silt			Clay		
	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fin

Boundaries (left to right): 2.0, 0.6, 0.2, 0.06, 0.02, 0.006, 0.002, 0.0006, 0.000

Soil classification methods

1. Textural soil classification
2. Burmister Descriptive classification
3. Casagrande classification
4. Unified soil classification – BIS soil classificati
   [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 characterstic of soil depenc

1. Soil type
2. Moisture content
3. Dry density
4. Internal structure of soil
5. Type and mode of stress Application of soil

Columbs and Empherical Law :

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

SR ⇒ shearing Resistance
C ⇒ Cohesion per unit area
ϕ ⇒ Angle of Internal Friction
σ ⇒ Normal stress

Evaluation of soil strength :

1. Shear Test
2. Bearing Test
3. Penetration Test

Shear Test :

→ Direct shear test
→ Tri axial compression test

Bearing Test and Penetration Test :

California Bearing ratio (CBR)

Direct shear Test :

A vertical Load applied and horizantal pull caused to produce certain rate of Horizantal displaceme

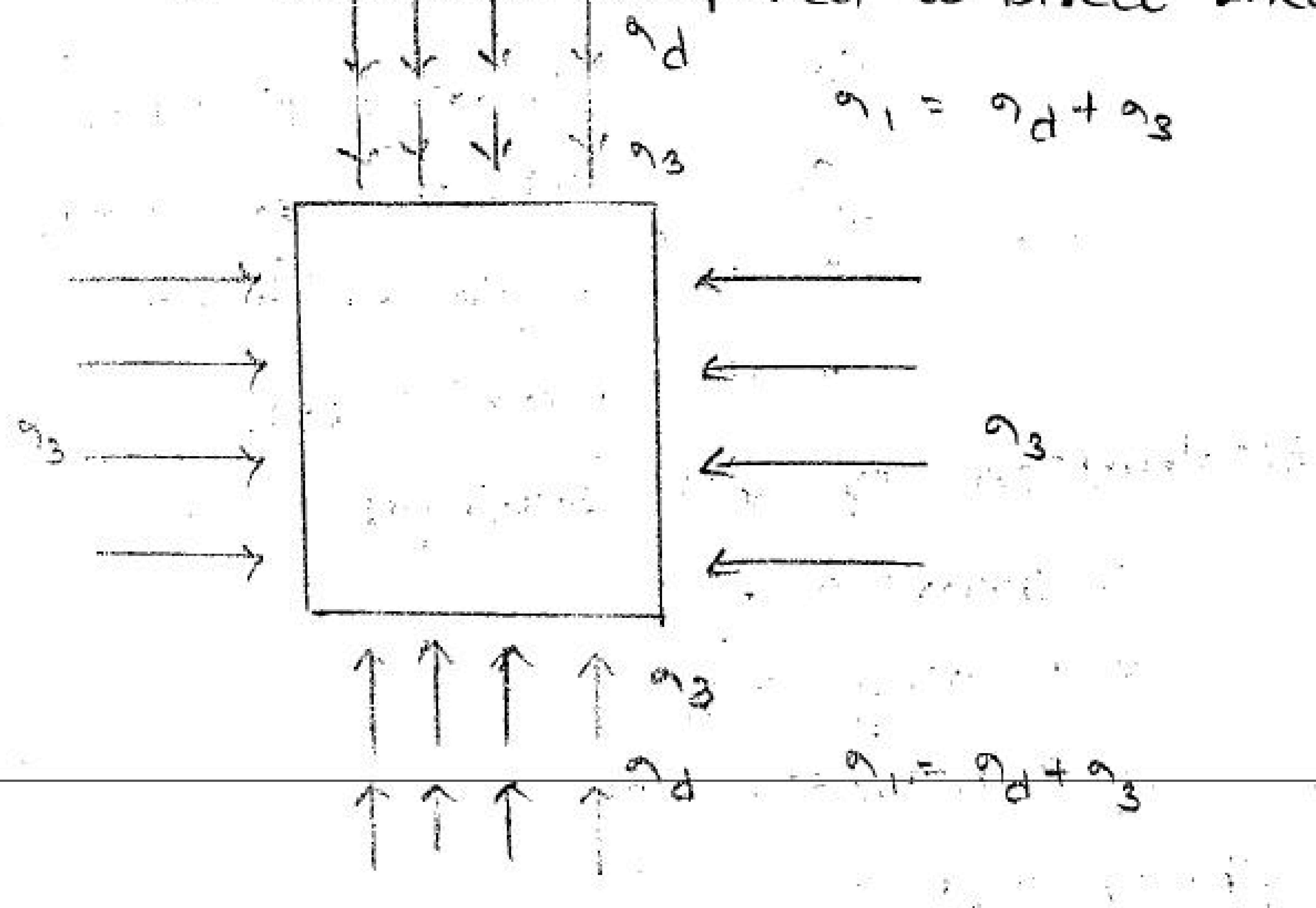
The maximum Horizantal Force at failure measured for different values of Normal load

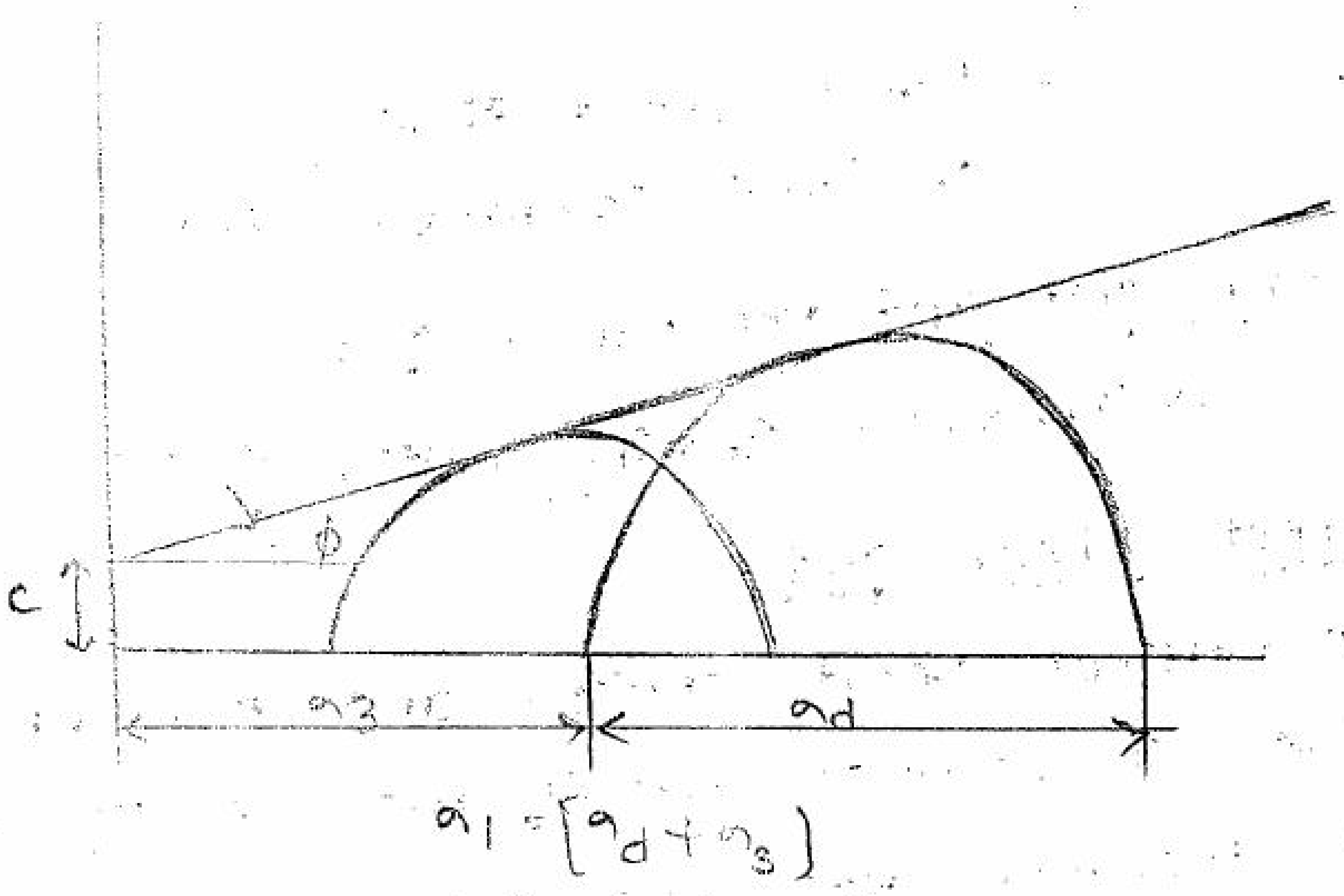
The values of maximum shear stress applied for the different vertical stresses are computed and plotted on a graph

The values of cohesion and angle of Internal friction are found Either from graph (or) by using columbs Equation

Tri axial compression Test : load (or) stress is applied on multi directions → Its solu...

Tri axial Test is accurate compared to Direct shear Test





Mohrs circle envelope from Tri axial Test results

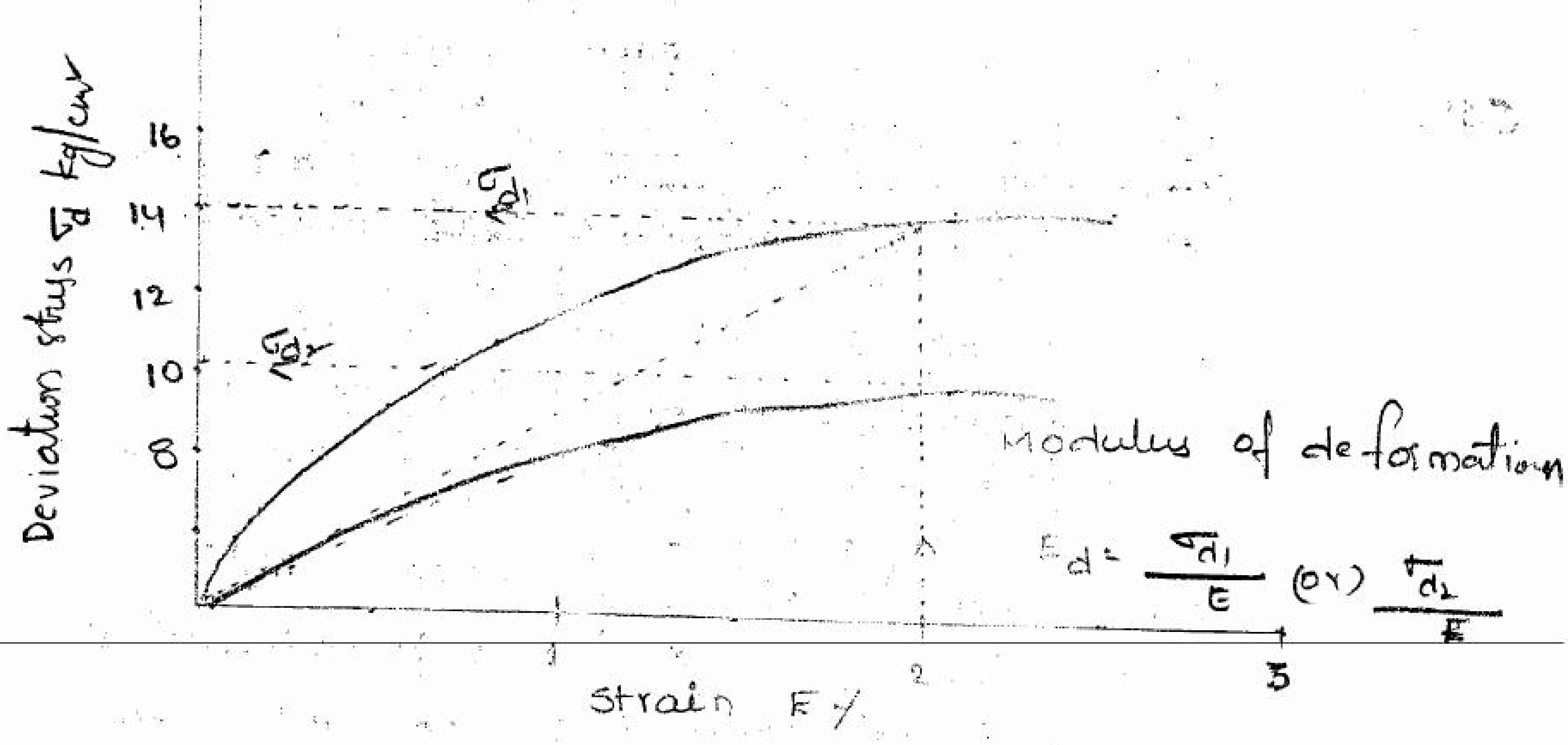
Correction for Area of cross section :

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

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

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

Stress strain diagram from triaxial compression test



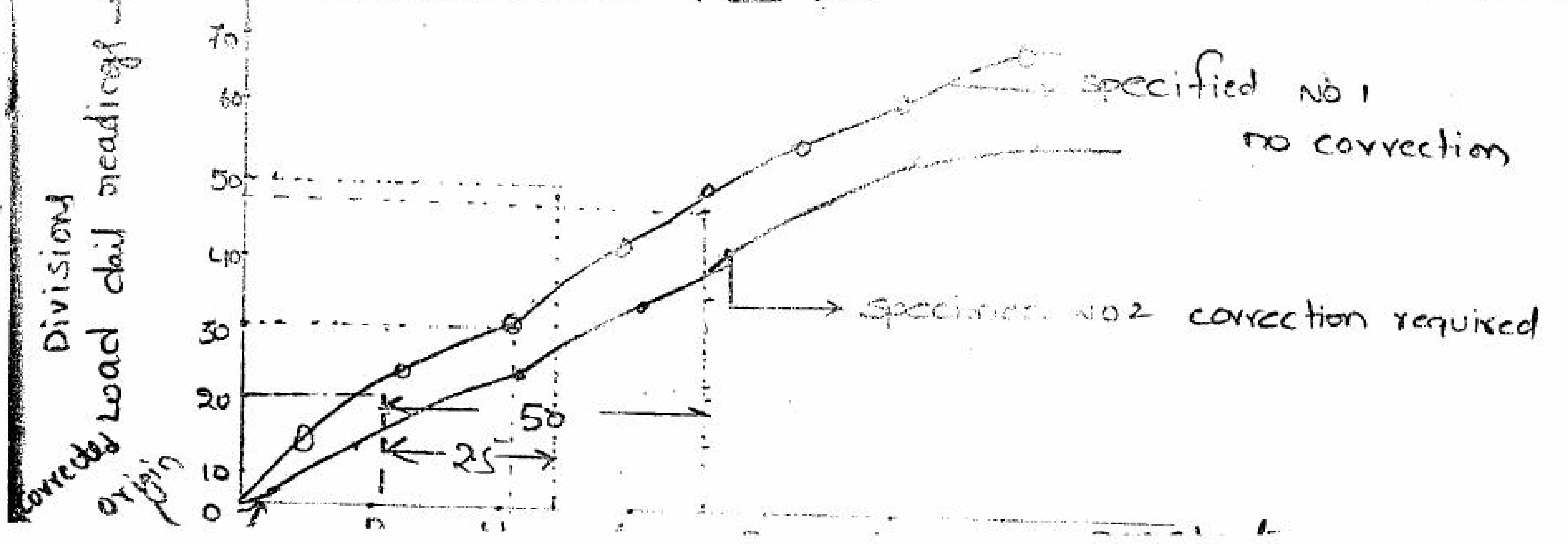
California bearing ratio:

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

The Loads are required for 2.5mm & 5mm deformation of the plumber into soil are recorded. The standard Load given by below may directly use in CBR.

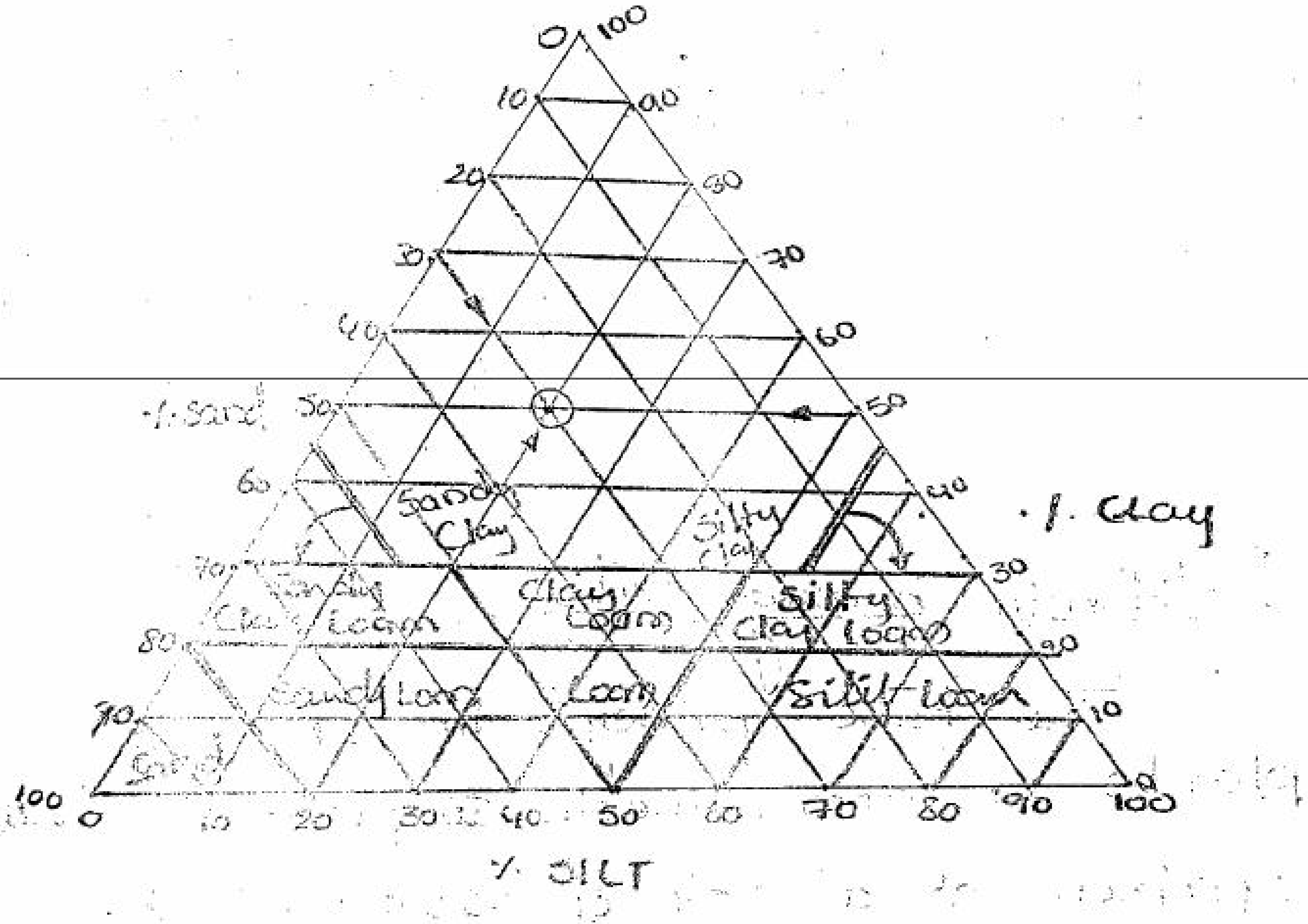
Penetration in mm	standard Load in kg	unit standard Load kg/c
2.5	1370	70
5.0	2055	105

Load penetration curve of CBR test

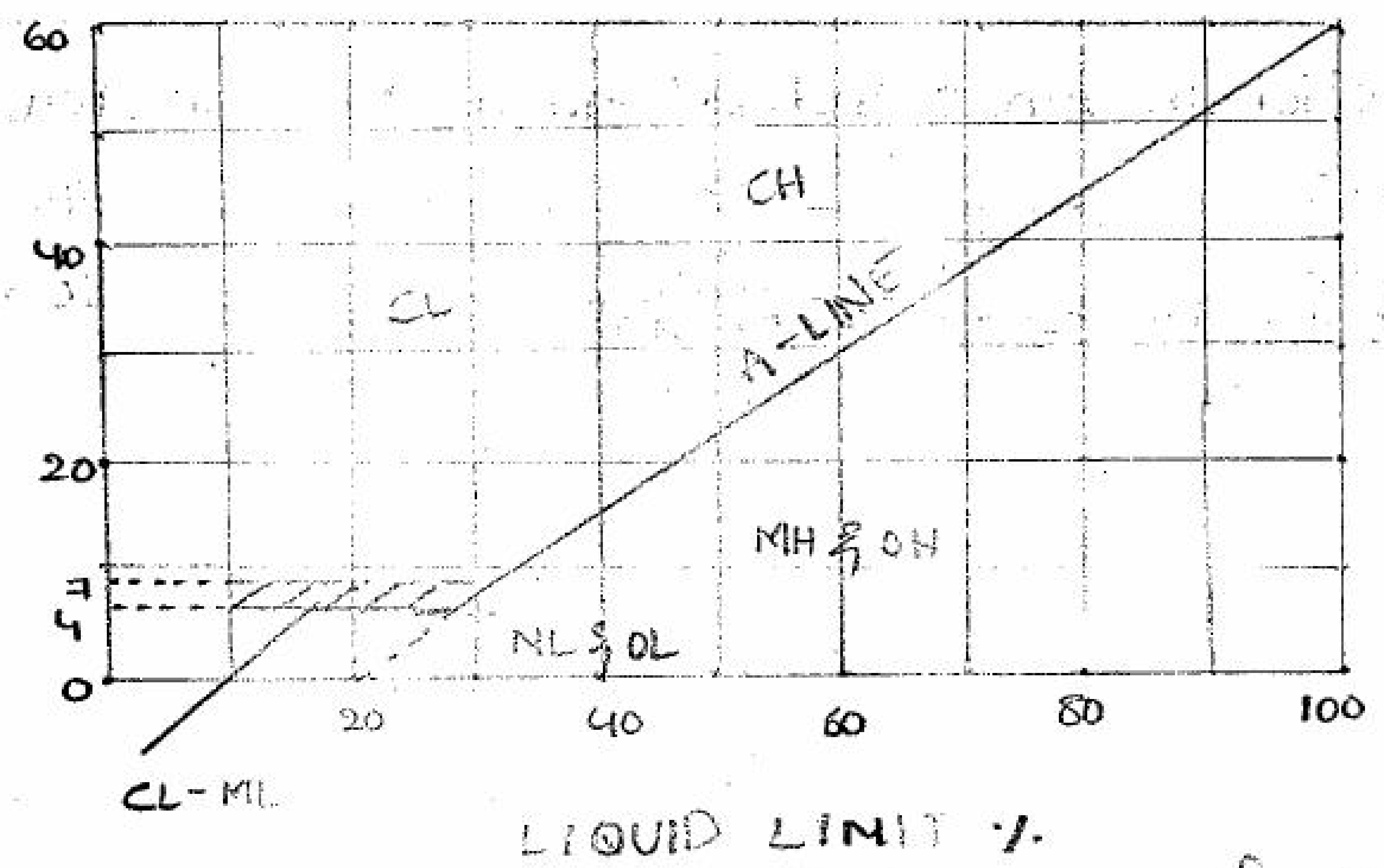


The CBR value calculated using the relation

CBR % = [Load (or) pressure sustained by the specimen at 2.5 (or) 5.0 mm penetration] / [Load (or) pressure sustained by aggregate at the corresponding penetration level] × 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

CBR	Plate Bearing
1. Penetration & load application	load application
Jacks, 3 circular disks,	Soil settlement (1.75) mm
We won't count void ratio	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 Wheathering
5. Resistance to compressive loads

Lab Tests on Agg's :

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

Impact Test :

250 gms

... same with ... load

Ag → w_1

2... Agg → w_2

2.36 mm ... sieved ... will come out → that powder as w_2

pass ... % of

$w_2 / w_1 \times 100$

Abrasion ——— Attrition

failure of Agg's

↓ deep failure

↓ surface failure

6 spherical Balls → load

cylindric Box used → Agg be filled in Box → then we apply load by spherical Balls → switch on supply and rotate → those Balls so revolve Hit the Agg → Deep failure will occur

Devals → same as above but we take 2 moulds

→ spherical balls

Crushing

2 kg of Agg → Fill 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

→ clean the Agg and expose to the sun → w_3

→ then put the Agg into oven → w_4

By using water Abso, sp. Gravity, Bulk density formulas we measure

Shape:

All sieves are arranged in order

1 kg of Agg's (min) are put on 63 seive

then that Agg's will pass through Flaky scale & Elongated scale

$$\frac{\text{Weight of passed Agg}}{\text{1 kg of Agg's weight}} \times 100\%$$

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
Loss 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 panel and add Bitumen to it & stirr it well, Ha
It becomes soft
Take a penetration mould (5 cm of height) and fill this Bitumen into mould & leave above 5mm space
Cool it to 30 min in water bath
Fix into a penetration dial guage
Penetration time will be 10 sec
This dial guage shows reading to be the Penetration valu
multiply the value by 10 because the needle value be 1/10

Viscosity Test :

Need : How much of Agg will be add 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 < 8%)

The major diff b/w Thar & Bitumen is

If we heat the thar it will release much amount of carbon contents

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 (S.I.) It gives some more strength

Notes I

Requirement Of the Lower Layers Of Flexible pavement :

F

Types 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 [illegible] the Inner layers. (also add lime & Geo polymers)

Consitutents of Bituminous mixes

- Bitumen
- Aggs
- Filler (Hydrated lime, stone dust) It pass on 75 seive
- Bituminous Binder mix

Desirable properties of Bituminous mix:

- Adequate stability — To stable from water forces, Earth quakes etc...
- Adequate Flexibility — Easy to move on any direction (or) way
- Adequate Resistance — water percolation
- Adjustment with temperature variation
- Durability — life span
- *** posses some amount of voids
- Skid Resistance (To provide friction by adding Agg)
- Workability

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

Requirements of Design Mix:

- Stability
- Flexibility
- Voids
- Durability

5. DESIGN OF HIGHWAY PAVEMENTS

Types of pavements :

1. Flexible pavement (Bituminous pavement)
2. Rigid pavement (Cement concrete paven

Factors influencing design of pavement :

a) Flexible pavements :

1. Wheel Load (passenger wt + gravitational force + vehicle load)
2. Subgrade soil
3. Climatic conditions
4. Pavement material mix proportion in each layer
5. Drainage & Environmental factors

→ Design of flexible pavements consists of 2 parts : (If friction ↑ amount of agg also ↑)

1. Mix design of materials
2. Thickness design of pavement directly proportional to Traffic load

→ Magnitude of wheel loads : (depends on speed)

1. Traffic loads
2. Wheel load & contact pressure → Type of tyre, Design of tyre, Age of tyre
3. Equivalent single wheel load

↓

It is defined as 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 have rather Flexibility in their structural action

If the pavement layers are destressed the Total Pavement will deteuriate Easily