"Transportation Engineering"

* **Transportation Engineering:** According to Institute of Transportation Engineering (ITE) - Transportation Engineering is the application of technology and scientific principles to the planning, functional design, operation and management of facilities for any mode of transportation in order to provide the safe, rapid, comfortable & economical movement of people and goods.

* **Mode of Transportation:**
  - Roadway / Highway
  - Railways.
  - waterways
  - Airways

* **Objectives of Highway planning:**
  - To provide a most suitable type of road, of maximum length, with the available funds.
  - To plan road system for future anticipated requirements by constructing new roads and improving the existing ones.
  - If road system cannot be constructed with available funds, phased programme may be planned.

* **Highway Surveys:** Before any highway alignment is finalised, various engineering surveys are required to be done -
  1. Map study.
  2. Reconnaissance surveys.
  3. preliminary surveys.
  4. Detailed survey.

* Alignment - [illegible]

Feeder Road A: Connecting upazilla headquarters of the region and with national highways.

Feeder Road B: Connecting major rural market/development centers with upazilla headquarters, growth center with RHD networks.

By-pass: A road passing around a town on its center to provide an alternative route for through traffic.

Distributor/Ring road: The road which is used to carry through traffic

Feeder/Collector road: A collector road is one intended for collecting and distributing the traffic to and from local road also providing access to arterial streets.

* What is road alignment? Write down the factors which affect road alignment.

Road Alignment: Establishing the centre line of the proposed road in plan on ground is called road alignment. In road alignment, horizontal control as well as vertical controls are to be exercised as both these controls play a vital role in road alignment.

Factors:

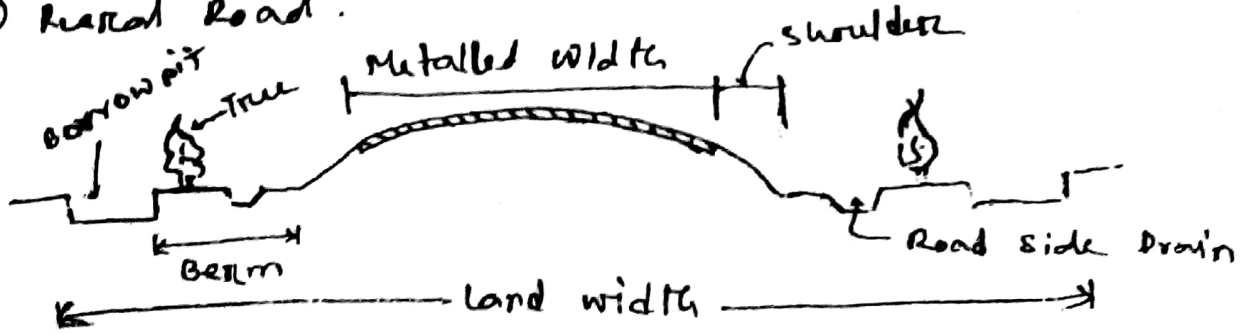
- Volume & type of traffic.
- Topographical features of the area.
- Floods in the area.
- Geological conditions.
- Existing right of way.
- River/railway crossing.
- Places of availability of construction materials and labour.

Roadway Types (function wise)

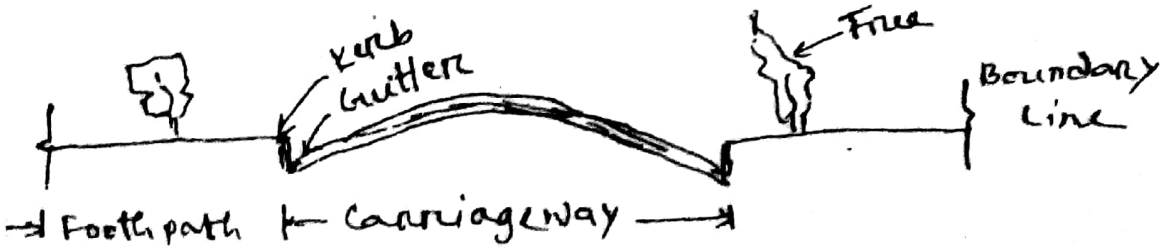
Sl No	Type	Definition	Ownership & Responsibility
1	National Highway	Connecting the capital with divisional HQs, port cities HQs and international highways.	RHD.
2.	Regional Highway	Interconnecting district headquarters of the region and with national highways.	RHD
3.	Zilla Road	Connecting upazila HQs with district HQs.	RHD
4.	Upazila Road	Connecting upazila HQs with growth centre.	LGED/LGI
5.	Union Road	Connecting union HQs with Upazila HQs & growth centre.	LGED/LGI
6.	Village Road	Connecting rural market/ development centre with union HQs.	

Classify Roads geographical/location wise (sectional view).

① Rural Road.



② Urban Road.



"Highway Geometrics"

* Define highway geometrics. What are the elements of highway geometrics.

Ans: Highway geometrics are the elements of a road which are visible to road users.

Elements: Gradient, super elevation, Camber, Road width, horizontal & vertical curves, sight distance, etc.

* Highway geometrics can be classified into 3 divisions-
  1. X-sectional elements (camber, super-elevation)
  2. Sight distance (SSD, OSD, ISD)
  3. Horizontal & vertical alignments.

* Write down the factors affecting co-efficient of friction.

Factors:
- Type of road surface - (bituminous/WBM/earth/cement concrete)
- pavement condition - (rough/smooth/wet/dry)
- Conditions of tyre.
- Brake efficiency.
- Tyre pressure.
- Load on tyres.
- Speed of the vehicle.
- Temperature of tyre & pavement.
- Type of skid.

Skid	Slip
Wheel slide without revolving is known as skidding.	Slipping occurs in driving wheels on wet road surface, sand, etc.
The distance travelled by wheel on road is greater than the circumferential movement of the wheel.	The distance travelled by wheel on road is less than the circumferential movement of the wheel.

* How skidding is occur?
  - When brakes are applied, wheel gets locked and still if vehicle moves ahead, longitudinal skidding takes place.
* Factors affecting Highway geometrics.
  - Topography, Design speed, Traffic factors, volume & capacity factors, Environmental factors.
* Define Design speed. Factors affecting design speed.
  - Design speed: The speed which can be allowed on a road without risking safety conditions. Design speed is dependent on the type, importance & surface conditions of the road.

  Factors: Road width, clearance requirements, sight distance, radius of horizontal curves, super-elevation, gradient, etc.

* 85th percentile speed: The speed below which 85 percent of all the vehicle travel, is used for determining the speed limits for traffic regulation.

* 15th percentile speed: The speed below which 15 percent of all the vehicle travel, is used for determining the speed limits for traffic regulation.

*Define Camber. Why excessive camber should not be provided?

- Camber / cross-slope: Transverse slope given to the road surface is called Camber. It is provided mainly to drain out rain water from the road surface. The camber is expressed as the slope of the line joining the crown with the edge of the carriageway.

Excessive Camber should not be provided because -

i) Most of the vehicles will tend to move along the centre line of the road and thus road capacity is affected.

2) Edges of the road wear out faster than the central part, because vehicles moving near edges put more load on the road edge.

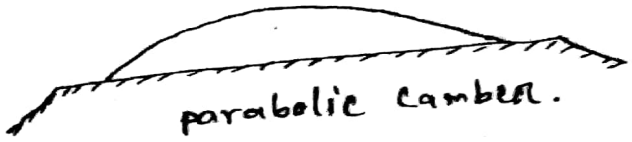
3) Because of tilt, high loaded vehicles may topple over easily.

4) Due to rapid flow of rain water, cross-rut may develop on the road surface.

5) During overtaking operation, vehicles tend to drag, causing uncomfortable conditions.

#Types of Camber:

i) parabolic Camber – This camber provides flatter profile at the middle which becomes steeper near edges.

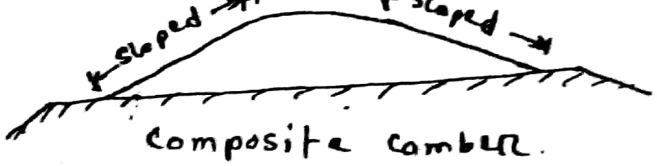


parabolic camber.

ii) straight sloped camber – When value of camber to be provided is very small as in the case of cement concrete road, straight sloped camber is preferred.

straight

iii) Composite Camber: In this camber, central part of the road is made parabolic & sloped straight near edges.



Composite camber.

*Recommended camber range for different road.

Road Type	Camber Range
Earth Road	1 in 25 (4%) to 1 in 33 (3%)
Gravel "	1 in 33 (3%) to 1 in 40 (2.5%)
WBM "	1 in 33 (3%) to 1 in 40 (2.5%)
Bituminous Surface	1 in 40 (2.5%) to 1 in 50 (2%)
Cement Concrete road	1 in 50 (2%) to 1 in 60 (1.7%)

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* Equation for providing camber:

For providing parabolic camber, following eqn is used to determine offsets from the horizontal line drawn through the crown.

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

Where, B = width of pavement.
n = camber (for 1 in 20, n = 20)
x = horizontal distance of offset point from centre of pavement
y = offset/ordinate of wooden baulk.

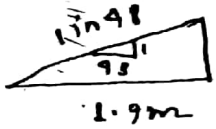
* The bituminous road has 3.8 m wide carriageway. Calculate the height of crown above the edges.

Soln: Let, provide camber 1 in 48 ~~:. 4 = 48~~

∴ Height of centre point above edge.

$$= \frac{3.8}{2} * \frac{1}{48} * 100$$

$$= 3.96 \text{ cm}$$



Ans

* Distinguish between camber & super-elevation.

Camber	Super-elevation
1. Transverse slope given to the road surface is called camber.	1. To reduce the tendency of the vehicle to topple, the outer edge of road pavement is raised with respect to the inner edge. This lateral inclination to the road surface is called super-elevation.
2. It is denoted by 1 in n.	2. It is denoted by e.
3. It is provided mainly to drain off rain water from the road surface.	3. It is provided mainly to reduce the tendency to topple.

* Carriageway width: The portion of the road surface which is used for traffic movement is known as carriage way. width of carriage way depends on the width of the traffic lane and number of traffic lanes.

According to IRC

Carriageway width (single lane) = $2 \cdot 44 + 2 * 0 \cdot 68$
↑ width of vehicle. ↑ clearance

* Shoulder: Shoulders are strips provided on both the sides of the carriage way. It acts as parking place for vehicles.

* Kerb: The dividing line between carriage way and shoulders is known as kerb.

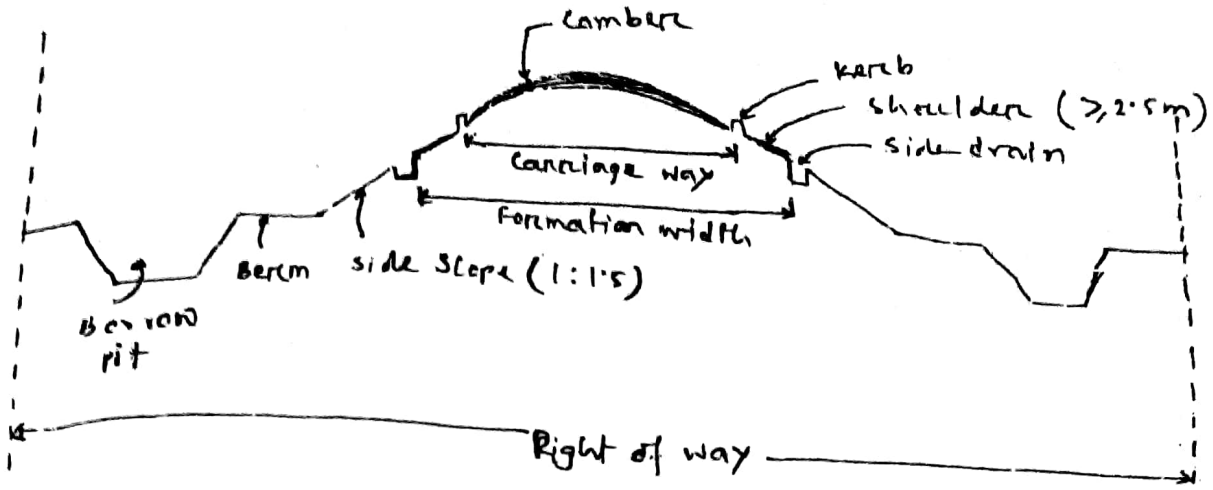
* Footpath/side walk: footpaths are provided along the kerb lines in urban roads. They

* parking lane: The lane provided along urban roads to allow kerb paking is called parking lane.

* Drive-ways: They are a sort of link roads which connect important highways with fuel-stations, service-stations, bank and commercial establishments.

* Right of way: Area to be acquired along the road alignment is called right of way.

* Draw the right of way of a pavement.



* Sight Distance: Sight distance is the actual length of road over which a driver sitting at a specified height in a vehicle can see objects either moving or stationary, on the road surface.

* Reaction time: It is the time in seconds which a driver can take from the instant the object is visible to him to the instant the brakes are effectively applied.

* Stopping sight distance: The distance travelled during reaction time (lag distance) and the distance travelled by the vehicle from the instant of effective application of brakes to the dead stop position of the vehicle (braking distance)

SSD = lag distance + Braking distance.

Equation for SSD:

* $SSD = vt + \frac{v^2}{2g\mu}$ [$\mu = 0.4$ ধরা হয়]

  where SSD in m, v in m/s.

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

  where, SSD in m, V in km/hr

Stopping distance at slopes:

* $SSD = vt + \frac{v^2}{2g(\mu \pm \frac{n}{100})}$

  where, SSD in m, v in m/s

  use (+) for ascending gradient, (−) for descending gradient.

* $SSD = 0.278Vt + \frac{V^2}{254(\mu \pm \frac{n}{100})}$

  where, SSD in m, V in km/hr.

Note: * Reaction time t যেখানে যা বলেনি সেখানে ২.৫ s ধরব.

* SSD for two way traffic on a single lane is twice of SSD for two way traffic on a two lane road.

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* Calculate the safe stopping sight distance for a design speed of 60 km/h for i) Two way traffic on a two lane road ii) Two way traffic on a single lane road iii) When grade is 3% ascending iv) When grade is 3% descending. Assume reaction time 2 sec & $\mu = 0.35$.

Soln: i) $SSD = 0.278 Vt + \frac{V^2}{254\mu}$

$= 0.278 * 60 * 2 + \frac{60^2}{254 * .35} = 73.85 m$ Ans

ii) SSD for two way traffic on a single lane

$= 2 *$ SSD for two way traffic on two lane

$= 2 * 73.85 = 147.7 m.$ Ans

iii) $SSD = 0.278 Vt + \frac{V^2}{254\left(\mu + \frac{n}{100}\right)}$ $[n = 3]$

$= 0.278 * 60 * 2 + \frac{60^2}{254\left(0.35 + \frac{3}{100}\right)}$

$= 70.66 m$ Ans

iv) $SSD = 0.278 * 60 * 2 + \frac{60^2}{254\left(0.35 - \frac{3}{100}\right)}$

$= 77.65 m$ Ans

* Calculate the minimum sight distance required to avoid a head on collision of two buses approaching from the opposite directions. The speed of both the buses is 70 kmph. Assume a total perception and brake reaction time of 2.5 s. co-efficient of friction is 0.4 and brake efficiency is 50%.

Brake efficiency

n: SSD for one bus $= 0.278Vt + \frac{V^2}{254(f \pm 0.5)}$

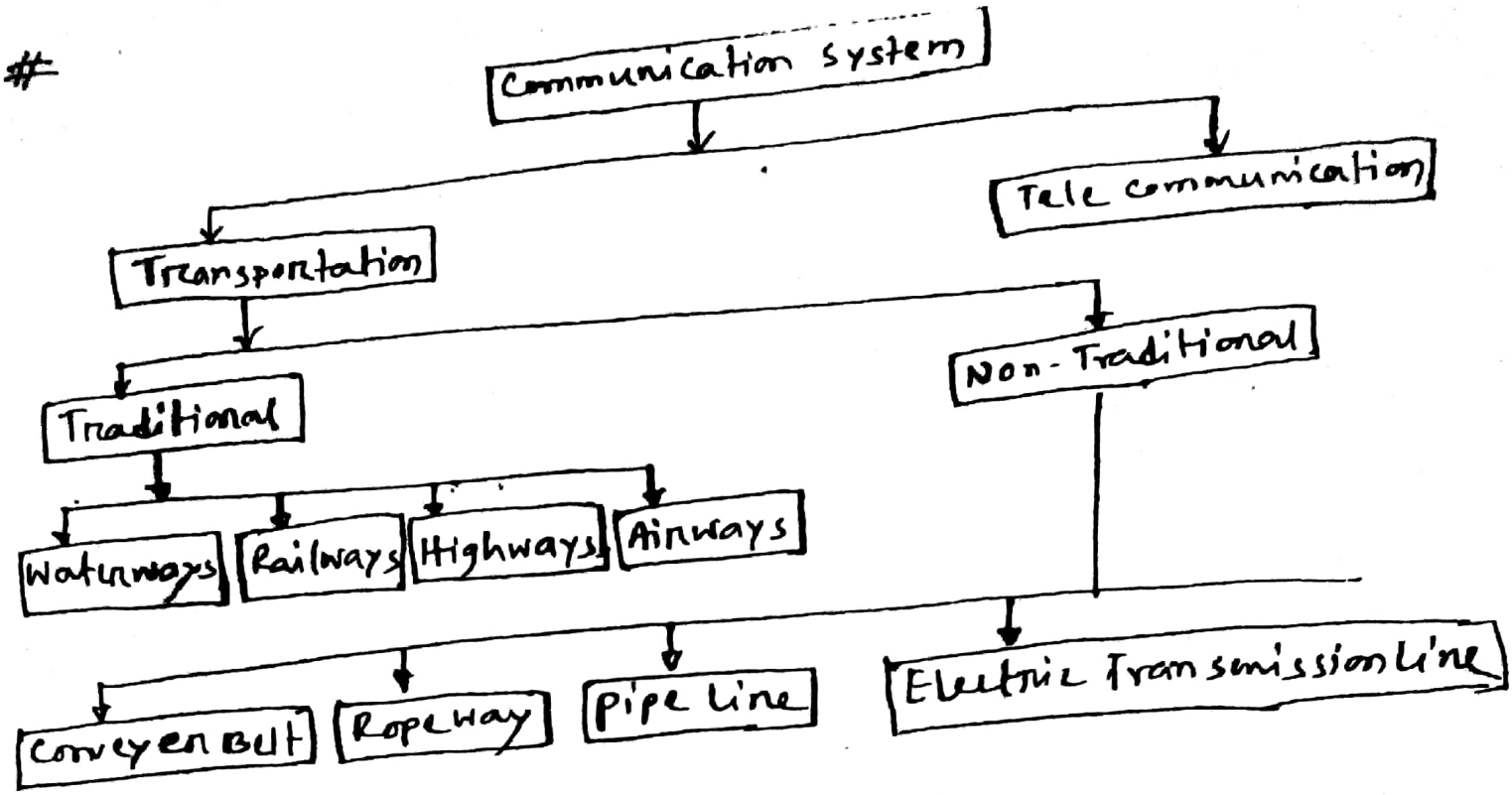
$= 0.278 * 70 * 2.5 + \frac{70^2}{254 * 0.4 * 0.5}$

$= 195.1\ m$

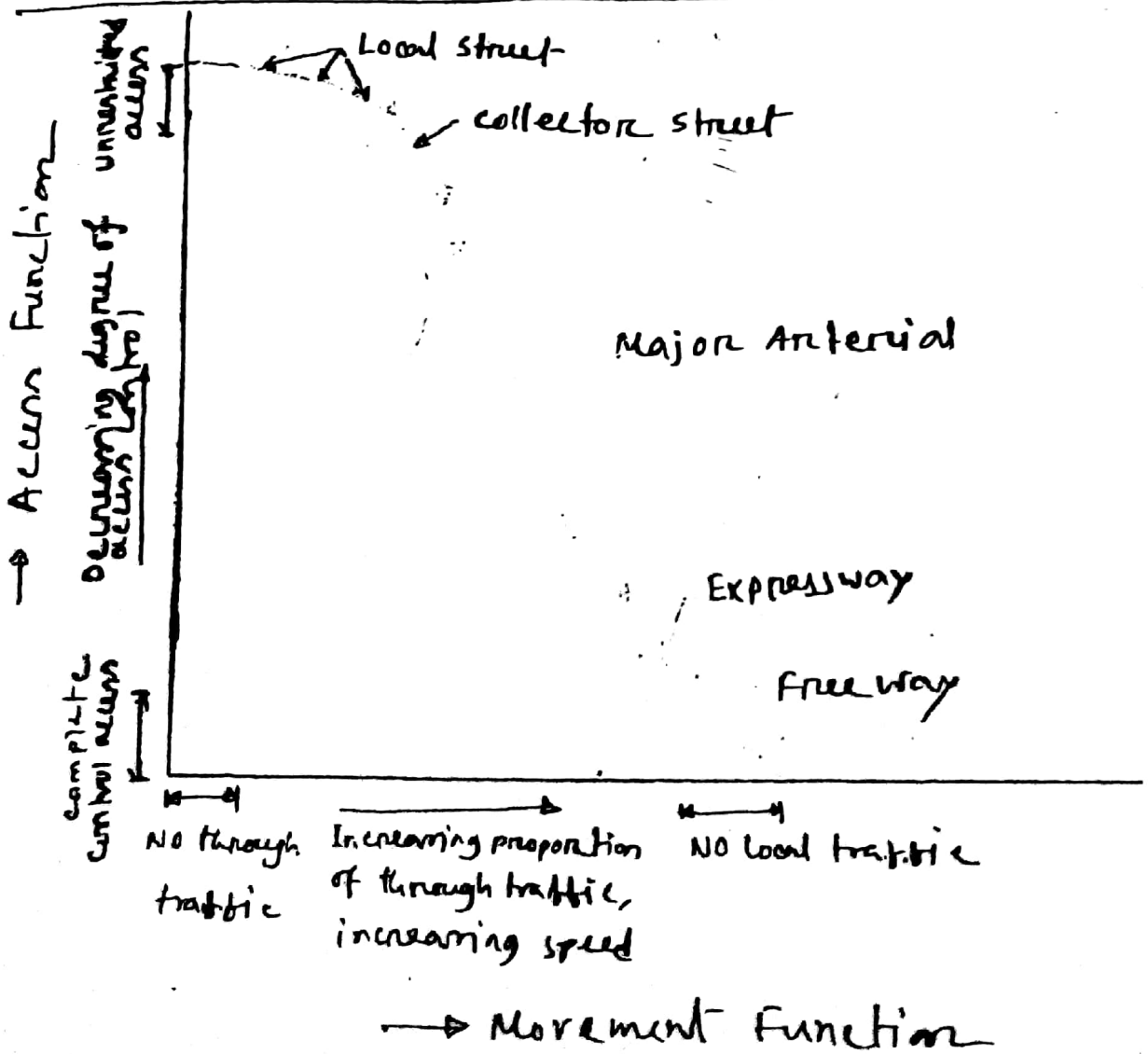
∴ SSD to avoid head on collision

$= 2 * 195.1 = 290.2\ m$ Ans

#



Draw schematic relationship between access and movement:



* **overtaking sight distance/ passing sight distance:** The distance visible to the driver of a vehicle intending to overtake another slow moving vehicle, without causing any accident to the traffic in the opposite direction, is called OSD or PSD.

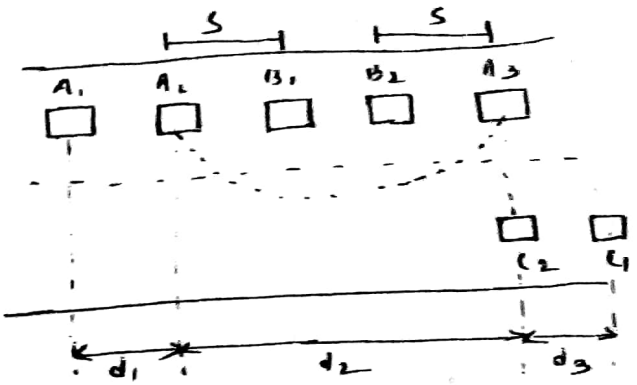
* **Equation for overtaking sight distance:**

Reaction time = t

Design speed = v

Speed of overtaken vehicle = v_b

Time taken for overtaking = T



clearance distance before and after overtaking,

$$S = 0.69 v_b + 6.1$$

$d_1 = v_b t$ ——— ①

$d_2 = v_b T + 2S$ ——— ②

$d_3 = vT$ ——— ③

Let, acceleration = f m/s²

For vehicle A

$$d_2 = v_b T + \frac{1}{2} f T^2$$

$$\Rightarrow v_b T + 2S = v_b T + \frac{1}{2} f T^2$$

$$\Rightarrow T = \sqrt{\frac{4S}{f}}$$

$\therefore$ OSD or PSD $= v_b t + v_b T + 2S + vT$

$= d_1 + d_2 + d_3 = 0.278 v_b t + 0.278 v_b T + 2S + 0.278 vT$

Note:

* Minimum length of overtaking zone = 3 * OSD.
* Max^m/desirable " " " = 5 * OSD.
* OSD for one way traffic = $d_1 + d_2$
* যদি overtaken vehicle -এর speed যেহেতু design speed থেকে 16 km/hr কম ধরা হয়েছে।

* The speeds of overtaking and overtaken vehicles are 80 and 65 km/hr on a two way traffic road. If the acceleration of overtaking vehicle is 3.6 km/hr per second. Calculate -

1. safe overtaking sight distance.
2. Minimum length of overtaking zone.

Soln:

$f = 3.6$ km/hr per second $= 1$ m/s^2

$S = 0.69 V_b + 6.1$ [V_b in m/s]

$= 0.69 * \frac{65 * 1000}{3600} + 6.1$

$= 18.56$ m

$T = \sqrt{\frac{4S}{f}} = \sqrt{\frac{4 * 18.56}{1}} = 8.6$ sec.

$\therefore d_1 = 0.278 V_b t$ [let, $t = 2$ sec]

$= 0.278 * 65 * 2 =$ [illegible] m

$d_2 = .278 V_b T + 2S$

$= 0.278 * 65 * 8.6 + 2 * 18.56$

$= 192.52$ m

$d_3 = 0.278 V T$

$= 0.278 * 80 * 8.6 = 191.26$ m

1. $OSD = d_1 + d_2 + d_3 = 419$ m.

2. Minimum length of overtaking zone $= 3 OSD$

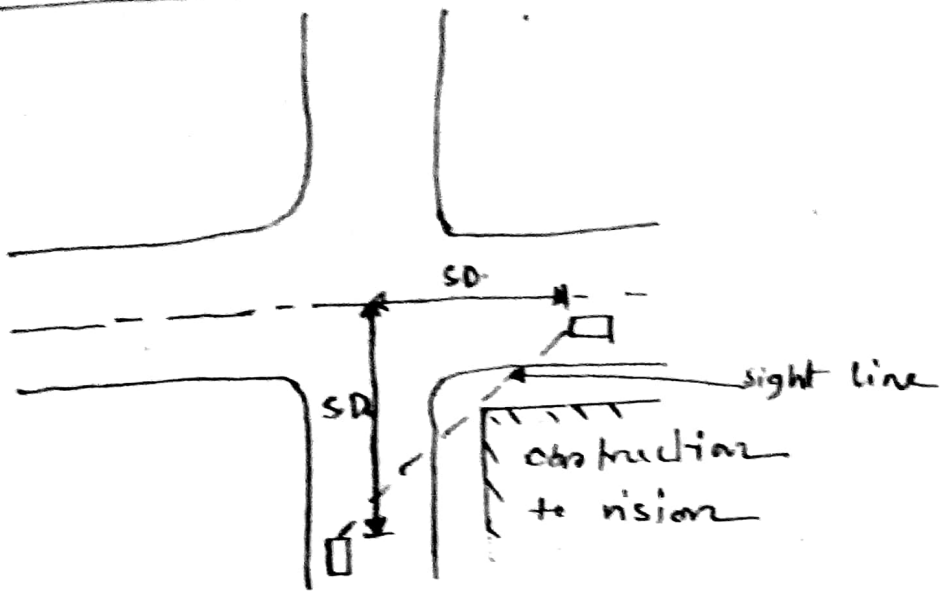
$= 3 * 419 = 1257$ m

3. Max^m/desirable " " $= 5 * OSD$

$= 2095$ m

Ans

* Sight distance at intersection:



* Super elevation/cant: To reduce the tendency of the vehicle to topple, the outer edge of the road pavement is raised with respect to the inner edge. This lateral inclination to the road surface is known as super elevation / cant. It is denoted by e.

* The value of super elevation, e depends on —

i) speed of the vehicles on the curves.

ii) Radius of the horizontal curve

iii) Friction between tyre and road surface.

Note:

* Maxm super-elevation $\leq$ 1 in 15 (6.7%)

* Minimum " = camber

* Equation for super-elevation:

$$e + f = \frac{V^2}{127R}$$; where V is in km/hr.

Here, the value of co-efficient of friction, $f = 0.15$
Radius of curvature = R.

For slippery road, $f = 0$.

$$e = \frac{V^2}{127R} = \frac{(0.75V)^2}{127R}$$ [super elevation 75% balance করার জন্য]

* Design steps for superelevation:

1. Calc. e for 75% when $f = 0$

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

2. If value of e is less than 1 in 15 (6.7%), the value of e is provided. If e is more than 6.7%, then go step 3 & 4.

3. Calc. f.

$$f = \frac{V^2}{127R} - e$$ [$e = 0.067$ ধরে নিতে হবে]

then $f \leq 0.15$, the value of e is safe.

If $f > 0.15$, find the restricted speed.

4. Calculate the allowable speed as —

$$e + f = 0.067 + 0.15 = 0.22$$

$$\therefore 0.22 = \frac{V_a^2}{127R} \rightarrow V_a = ?$$

*Note: যদি R-এর মান না দেওয়া থাকে D° curve দেয়া থাকে, then

$$R = \frac{1719}{D}$$

* Determine the rate of superelevation from the following data -

i) Speed of vehicle 90 kmph ii) Radius of curvature = 25 m.

iii) Neglect co-efficient of friction

Soln: $e + \mu = \frac{(0.75V)^2}{127R}$ $[\mu = 0]$

$\Rightarrow e = \frac{(0.75 * 90)^2}{127 * 25} = 1.44 = 1 \text{ in } 0.69 > 1 \text{ in } 15$

→ Rate of superelevation বের করতে বলাতে আমরা [illegible] করব।

Not OK

Calculate μ: take, $e = 6.7\% = 0.067$

$\therefore e + \mu = \frac{V^2}{127R} \Rightarrow \mu = \frac{90^2}{127 * 25} - 0.067$

$= 2.48 > 0.15$

Not OK

Calculate Allowable speed V_a:

$e + \mu = \frac{V_a^2}{127 * R} \Rightarrow 0.067 + 0.15 = \frac{V_a^2}{127 * 25}$

$\Rightarrow V_a = 26.25$ km/hr

* A two lane road with design speed of 90 kmph has horizontal curve of radius 500m. If the pavement is rotated about the centre line and width of pavement at curve is 7.5 m, design -

i) Rate of super-elevation for mixed traffic.

ii) The rise of outer edge from the centre of pavement.

Soln:

(i) $e = \frac{(0.75 * 90)^2}{127 * 500} = 0.0717 > 0.067$ $[\mu = 0]$

So, use 1 in 15 ~~Spee~~ super-elevation.

Scanned by CamScanner

(ii) Here, $B = 7.5$, $B/2 = 3.75$

$\therefore$ Rise of outer edge from centre $= B/2 + e$

$= 3.75 + \frac{1}{15} = 0.25$ m Ans

* Calculate safe radius of road curve when design speed 80 km/hr & $f = 0.12$, $e = 002$?

soln: $e + f = \frac{V^2}{127R} \Rightarrow R = \frac{80^2}{127(0.02+0.12)}$

$= 360$ m Ans

* Determine the super elevation for 20' wide road whose radius of curve 300', $f = 0.14$, $v = 90$ mph

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

$\Rightarrow e = \frac{145^2}{127 \times 91.46} - 0.14$

$= 1.47$

$= 1$ in $0.6 > 1$ in 15 not ok

$\therefore E = e \times B = \frac{1}{15} \times 6.1 = 0.406$ m Ans.

$V = (90 \times 1.61) = 145$ Km/hr

$R = \frac{300}{3.28} = 91.46$ m

$B = 20' = 6.1$ m

* Determine the super-elevation in inch for a 20' wide road with a design speed of 50 mph and degree of curvature 7°. $f = 0.14$

soln:

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

$\Rightarrow e = \frac{80.5^2}{127 \times 245.57} - 0.14$

$= 0.068 > 0.067$.

$\therefore E = 0.067 \times 6.1 = 0.406$ m

$\simeq 16''$ Ans.

$V = 50 \times 1.61 = 80.5$ Km/hr.

$R = \frac{1719}{D} = \frac{1719}{7} = 245.57$ m

$B = 20' = 6.1$ m

* Why extra width / extra widening of road is required at horizontal curve?

Ans: 1) Drivers have a tendency to keep away from the edge of the carriage way, while driving on curves.

2) While negotiating a horizontal curve the front steering wheels are turned and more space is occupied by the vehicle.

3) Rear wheel do not trace the same path as the front steering wheel.

4) At start of the curves, drivers have a tendency to follow outer edge.

* Two types of widening is considered -

1) psychological widening (W_s)

$$W_s = \frac{V}{9.5\sqrt{R}} \quad ; V \text{ is in Km/hr.}$$

2) Mechanical widening -

$$W_m = \frac{nl^2}{2R} \quad ;$$

n = no. of lane
l = length of longest vehicle.
R = Radius of the curve.
V = Design speed in Km/hr.

* Note:

- Total extra widening, $W_e = W_s + W_m$ which is not more than 0.6m, if longer use 0.6m.

* Calculate the extra widening required for a pavement of width 7m on a horizontal curve of radius 200m if the longest wheel base of vehicle expected on road is 6.1m. Design speed is 80 Km/hr. Compare the values obtained with IRC recommendation.

Soln: Here, pavement width = 7m.

$\therefore$ Nos of lane $= \frac{7}{3.8} = 2$

$l = 6.1\,m,\ v = 80\ Km/hr,\ R = 200m$

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

$$= \frac{80}{9.5\sqrt{200}} + \frac{2*6.1^2}{2*200} = 0.781\,m > 0.6\,m.$$

So, provide 0.6m Ans

* Find the total width of the pavement on a horizontal curve for a new state highway with a ruling maximum radius. Design speed 80 Km/hr. width of road 7.0 m and wheel base is 6.1 m.

Soln: No. of lane, $n = \frac{7}{3.8} = 2$

$$R_{(ruling)} = \frac{(V+16)^2}{27.5} = \frac{96^2}{27.5} = 335.13\,m$$

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

$$= \frac{80}{9.5\sqrt{335}} + \frac{2*6.1^2}{2*335} = 0.571\,m.$$

$\therefore$ Total width $= 7 + 0.571 = 7.571\,m$

* What is transition curve? objectives of it?
– surveying note.

* Gradient: The rate of rise or fall of road surface along its length with respect to horizontal distance is termed as gradient. It is expressed as 1 in x (one unit vertical to x units horizontal).

* Vertical Curve: When two different or contrary gradients meet, they form a curve in vertical plane known as vertical curve.

Two types –

i) Summit curves

ii) Valley curves.

Summit curve: The vertical curve having convexity upwards is called a summit curve.

* Length of summit curve for SSD:

(i) When L > SSD

$$L = \frac{NS^2}{\left(\sqrt{2H} + \sqrt{2h}\right)^2} = \frac{NS^2}{4.4}$$

H = driver's eye height above road surface in m
↳ normally H = 1.20 m

h = Hight of obstruction in m → use 0.15 m

S = SSD in m, L = Length of summit curve.

N = Angle of deviation in tangents.

(ii) When $L < SSD$

$$L = 2S - \frac{4.4}{N} \quad [H = 1.20\,m,\ h = 0.15\,m]$$

* Length of summit curve for OSD and ISD:

(i) When $L > OSD$ or ISD

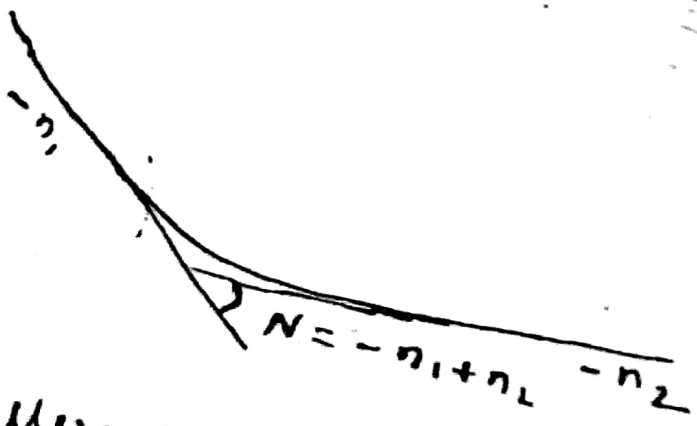
$$L = \frac{NS^2}{9.6} \quad [H = h = 1.20\,m]$$

Here,
S = OSD in m

(ii) When $L < OSD$ or ISD

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

* Valley curves: A vertical curve having concavity upwards or convexity downwards is called a valley curve.



* Length of valley curve:

$$L = 0.378\sqrt{NV^3}$$

* Head light sight distance:

(i) When $L > SSD$

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

(ii) When $L < SSD$

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

* A vertical summit curve is formed at the intersection of two gradients +1% and -4%. Design the length of summit curve to provide a SSD for a design speed of 100 kmph. Assume other data.

Soln:

Assume, $t = 2.5$ sec, $\mu = 0.4$, $V = 100$ km/hr

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

$$= 0.278 * 100 * 2.5 + \frac{100^2}{254 * 0.4} = 168 m$$

Here, $N = 0.01 - (-0.04) = 0.05$

Take, $L > SSD$.

$$\therefore L = \frac{NS^2}{4.4} = \frac{0.05 * 168^2}{4.4} = 320.73 m$$

Ans

* An ascending gradient of 1 in 80 meets a descending gradient of 1 in 100. A summit curve is to be designed for a speed of 100 kmph so as to have an OSD of 500m.

Soln:

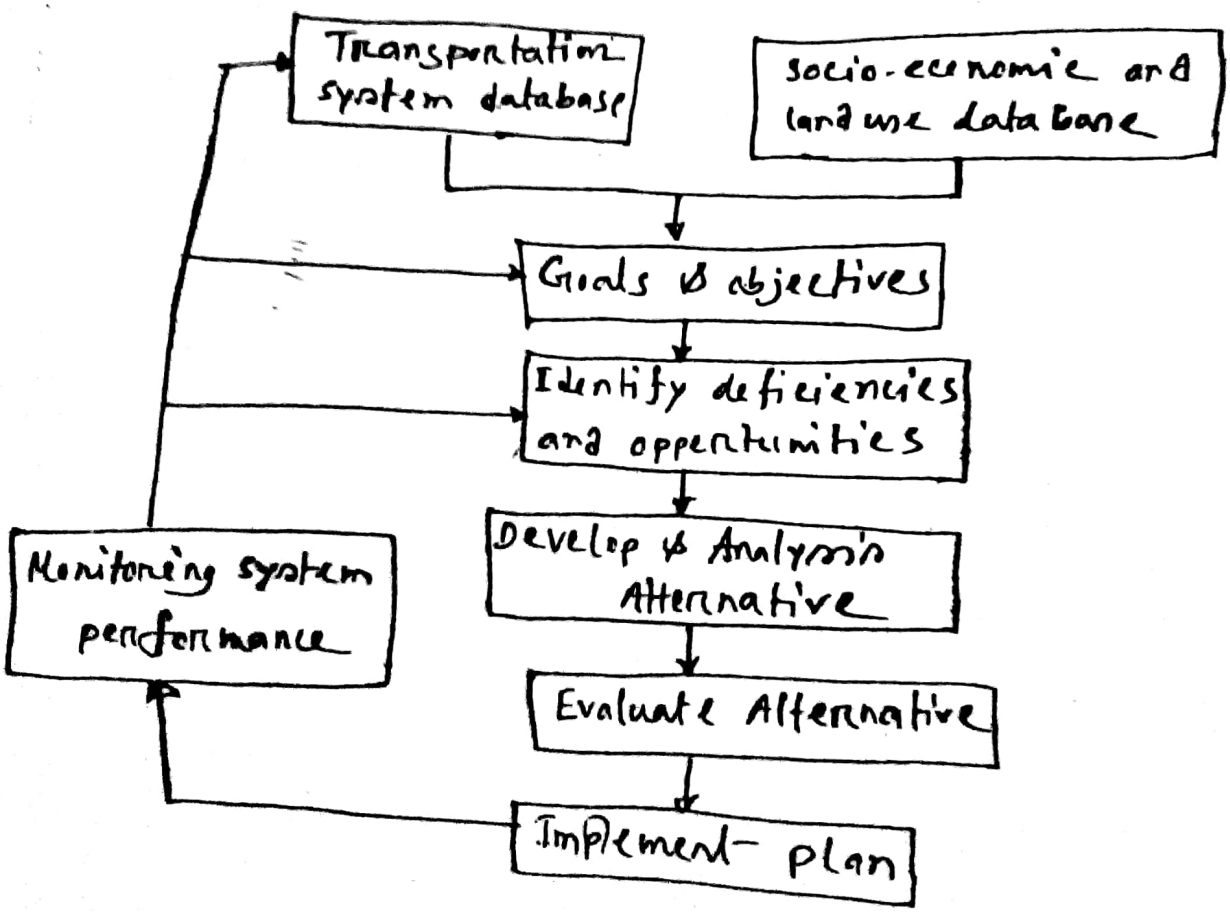
$$N = \frac{1}{80} - \left(-\frac{1}{100}\right) = \frac{9}{400}$$

take, $L > OSD$

$$L = \frac{NS^2}{9.6} = \frac{9 * 500^2}{400 * 9.6} = 586\ m$$

Ans

Basic elements of transportation planning:



Traffic Capacity (with respect to space Headway):

$$c = \frac{1000V}{s} \quad ; V \text{ in Km/hr}$$

s = Avg. c/c spacing of vehicles in m

$$s = SSD + L$$

$$= 0.278Vt + \frac{V^2}{254\mu} + L$$

L = Length of vehicle
$\mu = 0.9$

Traffic Capacity with respect to time Headway:

$$s = Vt$$

$$\Rightarrow t = s/V \quad ; \quad s = L + 0.278Vt$$

$$\therefore c = \frac{3600}{t}$$

c = Capacity.

* Calculate the theoretical maximum traffic capacity for a traffic lane at speed of 80 km/hr. Avg. length of the vehicle may be assumed as 6m.

Soln:

$$c = \frac{1000V}{s} \quad ; \quad s = SSD + L$$

$$= 0.278 * 80 * 2.5 + \frac{80^2}{254 * 0.4} + 6$$

$$= 124.6 \text{ m}$$

$$\therefore c = \frac{1000 * 80}{124.6} = 642 \text{ vehicles/hr.}$$

* Determine the theoretical capacity of four lane national highway per hour. The speed of vehicle is 60 km/hr. c/c spacing of vehicle is 4m.

Soln:

$$c = \frac{1000V}{s} * n$$

$$= \frac{1000 * 60}{4} * 4 = 60,000 \text{ vehicle/hr}$$

Ans

* Determine theoretical capacity of road if design speed 100 km/hr with reaction distance 2m and avg. length of vehicle is 6m?

Soln:

Here, $s = 2 + l = 8\,m$

$$C = \frac{1000V}{s} = \frac{1000 * 100}{8} = 12500 \text{ vehicles/hr/lane}$$

Ans

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"Aggregate & Bituminous materials"

Tests for Road aggregate:

① Los-angle's abrasion test ② Aggregate crushing value (ACV) test ③ Aggregate impact value (AIV) test ④ Elongation Index test ⑤ Flakiness Index test ⑥ Angularity Number test ⑦ Bitumen affinity or stripping test.

Tests for Sand:

(1) Fineness modulus test (2) specific gravity & absorption test ③ Moisture content test ④ silica content test ⑤ salinity test ⑥ Mica test.

*__Bitumen__: Bitumen can be defined as a non-crystalline solid or viscous material having adhesive properties.

*What are the processes for refining bitumen?

1. Distillation process – Crude petroleum - এর থেকে এবং bitumen পাওয়া যায়,

2. Solvent extraction process → solvent (propane)

3. Cracking process → Gasoline/motor fuel পাওয়া

short note:

1. straight run bitumen: Bitumen which has been distilled to a definite viscosity/penetration without further treatment is known as straight run bitumen. It is produced by distillation process.

2. Air Blown Bitumen: special properties can be developed in semi solid bitumen by blowing air through hot residue. In making air blown bitumen, the regular distillation is discontinued at some point while the residue is still liquid. The residue is then put in a tank called a converter and air is blown through it.

3. Cut-backs: It is defined as a bitumen whose viscosity has been reduced by the addition of a volatile diluent, such as gasoline/Naphtha, kerosene and high boiling-light oils.

* properties of bituminous materials:

According to Mr. F. N. Hveem -

1. Consistency
2. Durability/resistance to weathering.
3. Rate of curing.
4. Resistance to water action.

Tests on Bitumen:

1. Specific gravity test:

$$\text{Sp. gr.} = \frac{\text{wt of sample}}{\text{wt of water to the same volume of sample}}$$

$$= \frac{C-A}{(B-A)-(D-C)}$$

Here,
A = wt of dry & clean pycnometer
B = wt of pycnometer + water
C = wt of pycnometer + bitumen.
D = wt of pycnometer + bitumen + water.

* Sp. gr. of pure bitumen = 1·03 ~ 1·06
* Sp. gr. of tare = 1·10 ~ 1·25

objective: Sp. gr. is used to convert weight of bitumen to volume or vice-versa.

2. penetration test: This test is used to determine the hardness or softness of the bitumen. The test is performed by allowing a needle of standard (50mm length, 1mm dimension, loaded by 100 gms to penetrate vertically in the bitumen at 25°c for a period of 5 seconds.

* Penetration: 0 ~ 49 | 50 ~ 149 | 150 ~ 249 | > 250
Difference: 2 | 4 | 6 | 8

* penetration value must round to nearest full number.
* Angle of needle 8·7° ~ 9·7°

3. Softening point test (Ring & Ball Method): softening point gives an idea of the temperature susceptibility of bitumen. Higher the softening point, lower will be the temperature susceptibility. Softening point of bitumen lies between 35°c to 70°c.

* softening point $\leq 80°c$ → use water
" " $> 80°c$ → use G

* Two bitumen having softening point 35°c & 45°c. Then bitumen with 35°c more susceptible and 45°c less susceptible.

4. Fire & Flash point test:

Flash point: It is the lowest temperature at which the vapours of a bituminous material momentarily take fire in the form of a flash, under specific conditions of the test. Flash should not be less than 175°c.

Fire point: It is the lowest temperature at which bituminous material gets ignited and burns under specific conditions of test. Fire point $\geq 320°c$

Corrected Flash/Fire point $= F + 0.06(760 - p)$
" " " $= C + 0.03(760 - p)$

F = observed Flash/fire point in °F (nearest 5°F)
C = " " " in °c (" 2°c)
p = Barometric pressure, mm Hg.

5. Loss on Heating test:

- To remove volatile substances from bitumen and to obtain hardened bitumen.

$$\text{Loss on heating} = \frac{A-B}{A'} * 100 = \%\ (2 \text{ decimal})$$

where,
A = Wt of can + bitumen (before heat)
B = Wt of can + bitumen (after heat)
A' = initial wt of bitumen (50gm)

* Road -এর জন্য ব্যবহৃত bitumen - এর loss 1% -এর বেশি হওয়া উচিত না।

6. Solubility test:

- pure bitumen is fully soluble in carbon disulphide & Carbon tetrachloride.
- 2g bitumen - কে 100 mL CCl_4 -এ মিশিয়ে filter paper -এর সাহায্যে insoluble bitumen আলাদা করা।

$$\% \text{ of insoluble material} = \frac{B-A}{A'} * 100\% \quad \begin{cases} <1\% \sim 0.00 \\ >1\% \sim 0.0 \end{cases}$$

$$\% \text{ of soluble} = 100 - \% \text{ of insoluble.}$$

where,
A = Wt of filter paper dry at 120°c
B = " " " + insoluble bitumen.
A' = Wt of sample (2g)

7. Ductility test: Ductility is the distance in cm that a standard briquette of bitumen will stretch before breaking.

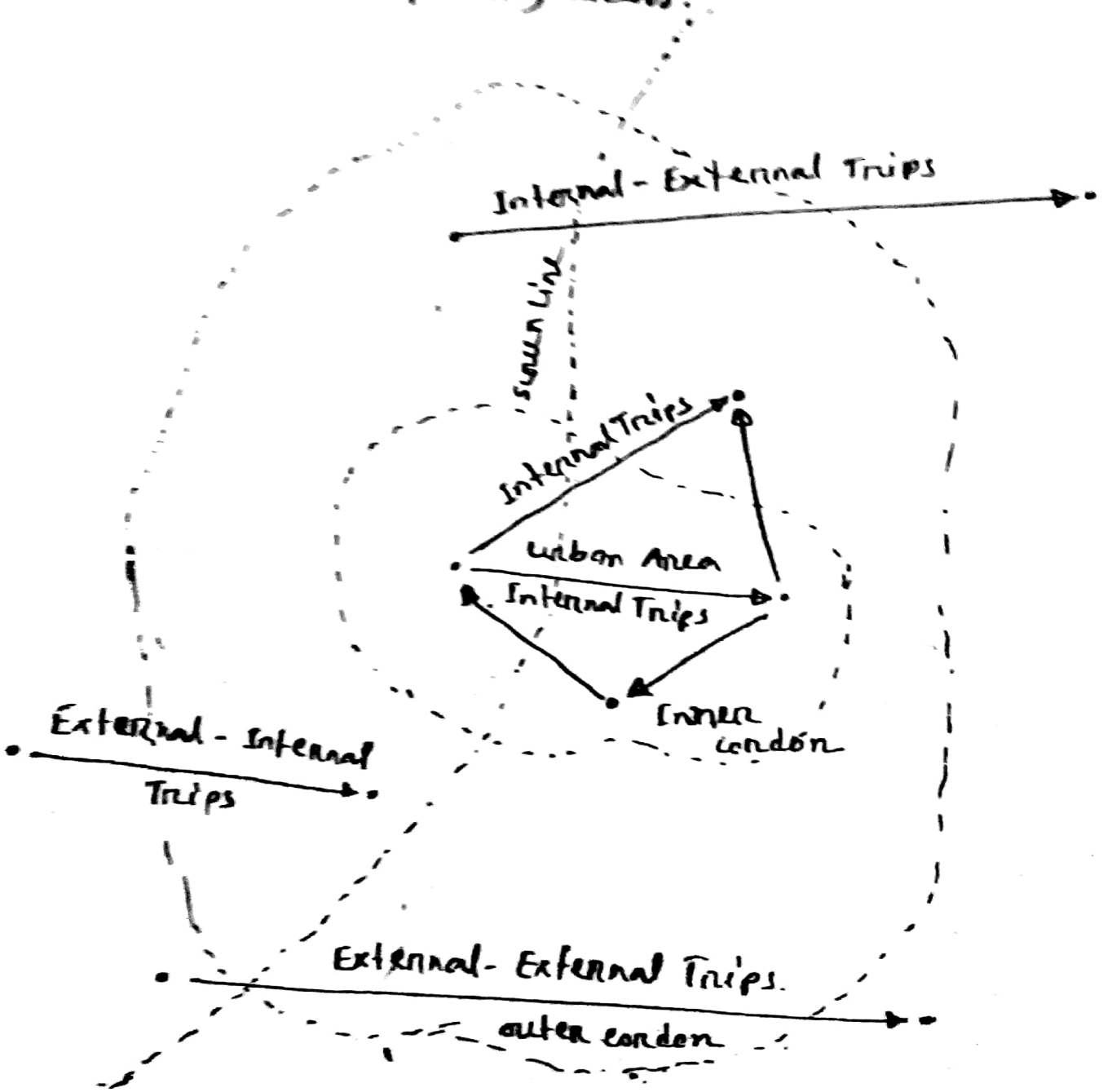
* Ductility of bitumen varies 5 ~ 100 cm.
* For Road, Ductility > 50 cm.
* The test is done at 25°C & the rate of pull applied is 5 cm/min.

8. Spot test: 2g bitumen-কে 10 cm^3 naphtha-তে solution filter paper-এ 1st drop (after 1 hr) এবং 2nd drop (after 24 hrs) দেওয়ার পর যদি color change uniform হয় তাহলে color uncracked bitumen হয় acceptable.

* What do you mean by 80/100 of bitumen?

Ans: 80/100 means that the bitumen having penetration value of 80 and the needle will sink by distance of 0.8 in the bitumen at 25°C, provided load at 100 gm during 5 sec.

Explain diagrammatically the basic movement to categorize travel pattern in planning areas.



* Tests on Bitumen / Asphaltic materials:

① penetration test ② Ductility test ③ softening point test ④ specific gravity test ⑤ Flash & Fire point test ⑥ Loss on heating test. ⑦ Water content test ⑧ solubility test.

* Road tar: Tar is a by-product of the destructive distillation of coal. It can be obtained from many organic substances also.

* Composition of Tar:

- Liquid oil → Tar (4)
- Middle oil → Light Road Tar (3)
- Heavy oil → Heavy Road Tar (2)
- pitch → pitch (1)

* Comparison between bitumen & Tar.

Bitumen	Tar
1. produced from crude petroleum	1. produced by destructive distillation of coal.
2. Less susceptible to temperature	2. More susceptible to temperature.
3. Costly.	3. Cheaper.
4. Setting time is less than tar.	4. Setting time is more than bitumen.
5. useful for road construction.	5. useful for roofing materials.
6. Bitumen does not have any toxicity.	6. Tar possesses phenol which is toxic.

"Traffic Engineering"

* Traffic Engineering: Traffic engineering is the science of -

- measuring traffic & travel.
- the study of basic laws relating to traffic flow and generation.
- and application of this knowledge to the professional practice.

of planning, designing and operating traffic systems to achieve safe, efficient and convenient movement of persons and goods.

* Why traffic engineering is essential now-a-days?

Ans: - Increased urbanization process.
- Difficulties in expanding roadway facilities within build-up areas.
- Congestion become chronic in everywhere.
- Increased air pollution
- Increased accident numbers.
- Road network become longer.

Therefore, there is a need to maximize the utilization of existing facilities by better traffic management and control measures.

* Causes of Congestion:

External (geometric) Factors:

+ Road intersections + Railway crossing.
+ Inconsistent Roadway width.
+ poor turning radius. + Bus stops
+ scattered parking. + Frequent side roads enter.

poor roadway environment:

- poor road discipline
- speed Breakers
- poor sight distance.
- poor lighting.
- poor drainage facilities.

Internal (traffic) Factors:

- Heterogeneous traffic stream.
- High volume of traffic (demand > capacity)

* Traffic Engineering tools:

- To control vehicular movements -

1) Road signals/ signs/ markings.
2) Road divider/ canalization / islands.
3) Bus lay-by
4) speed breakers.
5) segregated bus lane
6) Grade separation.
7) On/ off street parking
8) Terminals.
9) side walk
10) cross walk
11) Underpass and overpass.

* Stimulus → সংজ্ঞা

* Write down the components of road-traffic system?

Ans: Four components

1) Road 2) Vehicles 3) Road users 4) Environment.

* What is PIEV time?

Ans: The total time required to perceive and complete a reaction to a stimulus is the sum of the times necessary for perception, identification, emotion and violation. This total reaction time is called PIEV time.

perception – involves seeing the stimuli

Indentification – involves identification and understanding the stimuli.

Emotion – involves decision making process.

violation – involves execution of the decision.

PIEV Time:
- Rural Road → 2.5 sec
- Urban " → 2.25 ~ 2.5 sec.

* A driver was driving a car with speed 60 kmph. After a turning, he saw a child at 60m distance from car. perception & identification time 1.5 s, Emotion time 0.5 sec, violation time 1 s. He applied break with a deceleration of 2 m/s². Now, find that whether the driver was able to save the child from accident.

Soln: Speed = 60 kmph = 16.67 m/s

For perception & identification & emotion

$$s_1 = vt$$
$$= 16.67 * (1.5 + .5) = 33.34 \text{ m}$$

For violation

~~$v^2 = u^2 - 2as$ [v=0]~~

~~$\Rightarrow s = \frac{(16.67)^2}{2*2}$ =~~

$$s_2 = ut - \frac{1}{2}at^2 = 16.67 * 1 - \frac{1}{2} * 2 * 1$$
$$= 15.67 \text{ m}.$$

$\therefore s = s_1 + s_2 = 49 \text{ m} < 60 \text{ m}.$

so, the child will be saved.

* Transportation - Land use cycle:

* vicious - through

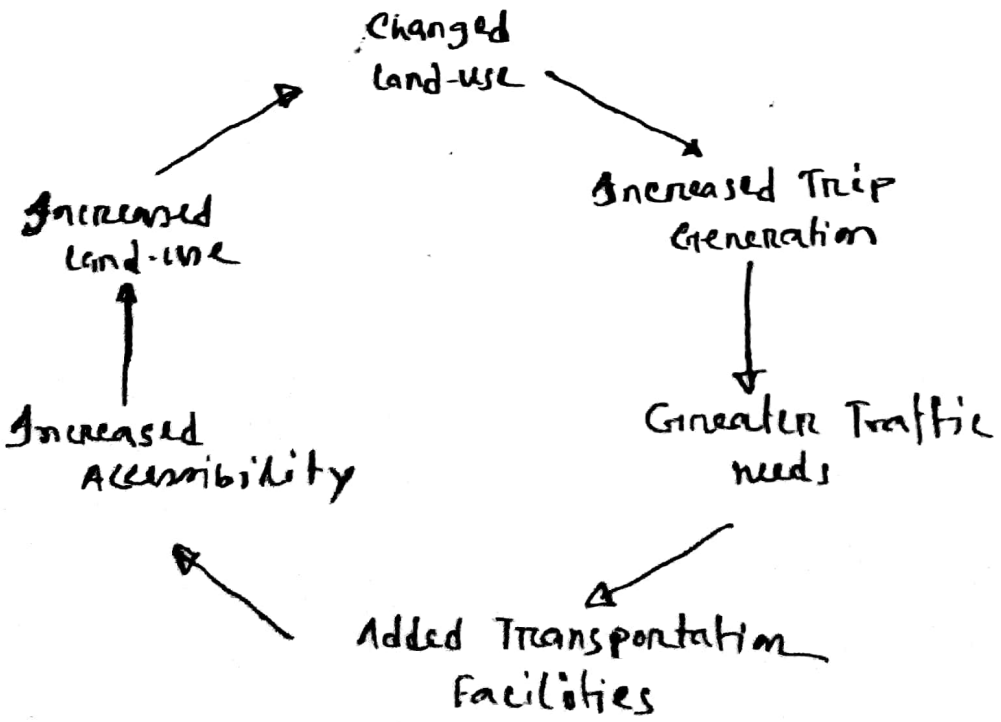


Fig: Transportation - Landuse cycle.

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"Traffic Control Devices"

Traffic control devices include all —

- Signs
- Markings
- Signals.

* **Objectives:**
  - to regulate
  - to warn
  - to guide traffic movements
  - to ensure safe and efficient travel pattern.

* Types of signs according to their function:

Ans:

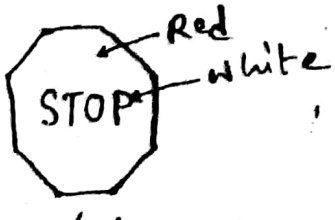
① Mandatory signs (shall follow)
  - Regulatory sign
  - ~~Also~~ prohibitory sign
  - Special mandatory sign.

CL-16

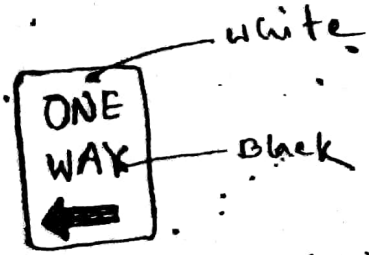
② Warning or Cautionary signs (should follow)

③ Informatory or Guide signs (may follow)

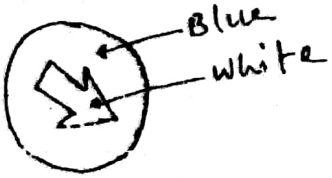
Regulatory:



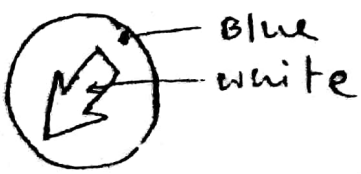
Slow/stop



One way traffic

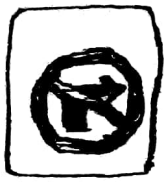


Keep Right



Keep Left

Prohibitory:



No Right turn

No left turn

No U-turn

No left or U-turn

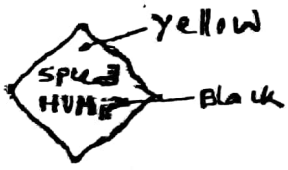
No Trucks

No parking

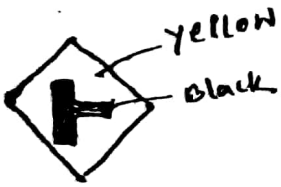
No pedestrian Crossing

No Horn

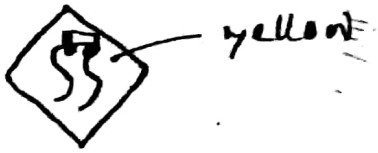
Warning:



Road Hump



Side Road



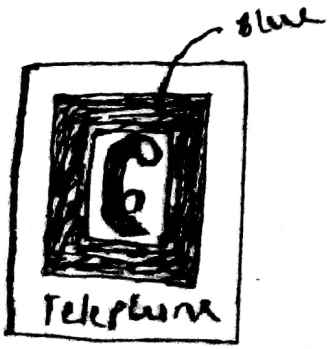
Zigzag Road

U-Turn

School

Level Crossing.

Information:



Telephone Booth

Hospital.

* Height of Sign:
post height is measured from the pavement surface.

- Open Area – 1.5 m
- Build-up Area – 2.1 m

* Traffic Signal: It is a physical device which is used to control traffic movement at the junction.

* Signal sequence:

Green → Amber → Red → Red/Amber

* Amber period/clearance time (a): Times required to allow vehicles to clear the junction. Amber period is usually 3 sec, 3~6 sec for high speed junction.

* Inter Green period (I): The time from the end of the green period to the ~~gen~~ phase losing right-of-way to the beginning of the green period of the phase gaining right-of-way. $I = a + \text{all-red}$

* Lost time: The time which is effectively lost to traffic movement in a phase because of starting delays and the falling-off discharge rate during the amber period.

* Effective green time: It is the sum of the green period and the amber period less the lost time for a particular phase.

$$g = G + a - L$$

* Saturation flow (s): The maximum rate of discharge for a particular approach.

* Cycle time:

$$C = \Sigma G + \Sigma I$$

* Green period:

$$G = g + LI + LF$$

- LF → Final lost time
- LI → Initial lost time
- g → Effective green time

* Total lost time/cycle:

$$L = \Sigma \text{all red} + \Sigma \text{lost time}$$

$$= \Sigma (I - a) + \Sigma (L_I + L_F)$$

* Flow ratio:

$$F.R = \frac{\text{Actual Flow Rate}}{\text{saturated Flow Rate}}$$

* An urban secondary road,
  - with 50 ft pavement width.
  - having a reflectance of 10%.
  - Carries a maximum of 1000 vph at night time in both directions.

* Design lighting system of the road considering sodium light source with mounting of 40 ft and a maintenance factor of 0.8. Draw the lighting layout.

Soln: i) Actual Average Illumination (AAI):

Avg recommended illumination = 0.8 L/ft² [Table-1]

Adjustment factor for surface reflectance = 1 [Table-2]

$\therefore$ AAI = 0.8 × 1 = 0.8 L/ft²

Mob: 01742940304

(ii) Lumen output of light source:

Taking Efficiency of light = 100 lumens/watt

wattage = 150 watts.

∴ Lumen output = source efficiency x wattage

= 100 x 150 = 15,000 Lumen.

From figure-1; for ratio width and height

$= \frac{50}{40} = 1.25$; $C_u = 0.35$

∴ Effective C_u = 0.35 * maintenance factor

= 0.35 * 0.8 = 0.28

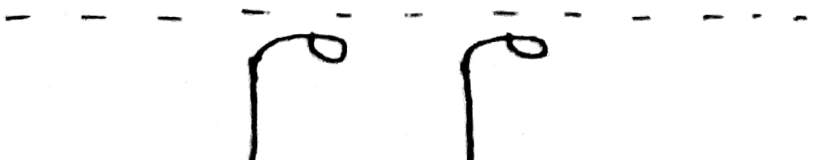
∴ AAI = (lumen output x C_u)/(spacing x width of pavement)

=) Spacing = $\frac{15000 * 0.28}{0.8 * 50}$ = 105 ft.

proposed lighting layout:

Spacing = 105 ft, Mountain Height = 40 ft.

overhang = 10 ft



* Speed: It is the rate of movement of traffic or specified component of traffic and is expressed in Kmph.

* Time-mean speed: It is the average of the speed measurements at one point in space over a period of time. It is denoted by V_t.

* Space-mean speed: It is the average of speed measurements at an instant of time over a space. It is denoted by V_s.

* Operating Speed: The highest overall speed permitted to the driver is called operating speed.

* Free flow speed: The speed at which drivers face no restriction in driving and can maintain desired speed.

* Safe speed → 85th percentile speed.

* Design speed → 98th percentile speed.

* Median speed → 50th percentile speed.

* Speed limits → Upper limit 85th percentile speed
lower limit 15th percentile speed

* Flow: It is the number of vehicles passing a specified point during a stated period of time. It is denoted by q and expressed in vehicles/hr.

* Concentration (K): ~~It is usually expressed~~
It is the number of vehicles passing present in a stated length of road at an instant. It is usually expressed in vehicles per kilometer length of road per lane.

* Space Headway (s): It is the distance between the fronts of successive vehicles. It is measured in meters.
* Time Headway (h): It is the time interval between the passages of the fronts of successive vehicles at a specified point. It is measured in seconds.
* The following travel times were observed for 4 vehicles traversing a 1 mile segment of highway:

vehicle	Time (min)
1	1.6
2	1.2
3	1.5
4	1.7

Calculate the space and time mean speed of the vehicles.

Soln:

$$\text{Time-mean Speed} = \left(\frac{1}{1.6} + \frac{1}{1.2} + \frac{1}{1.5} + \frac{1}{1.7}\right)/4$$

$$= 0.678 \text{ miles/min} = 40.7 \text{ mph.}$$

$$\text{Space mean Speed} = 4^{(1+1+1+1)} / (1.6+1.2+1.5+1.7)$$

$$= 0.667 \text{ miles/min} = 40 \text{ mph}$$

Ans

* Types & uses of traffic signals.

Types: i) Traffic control signals 2) pedestrian signals
3) specific traffic signals.

uses:
- to provide an orderly movement of traffic.
- to reduce the number of accidents.
- to control speed of the vehicles.
- to direct traffic on different routes.

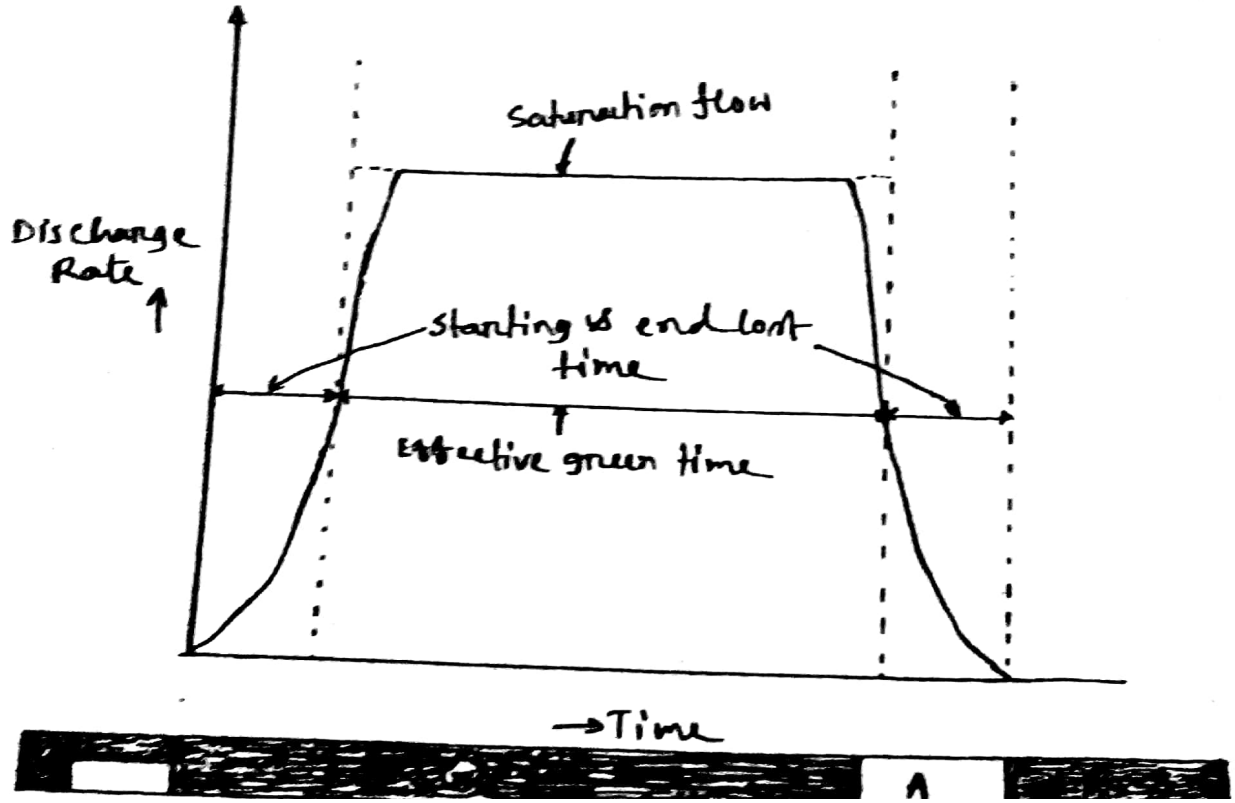
* Three cars travel over a 65m section at constant speed of 18 m/s, 19 m/s & 22 m/s. Compute TMS & SMS?

Soln:

$$TMS = \frac{18+19+22}{3} = 19.67 \text{ m/s}.$$ Ans

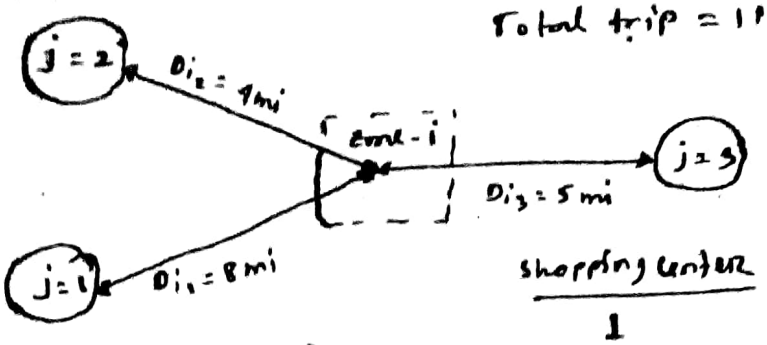
$$SMS = \frac{65+65+65}{\frac{65}{18}+\frac{65}{19}+\frac{65}{22}} = 19.52 \text{ m/s}$$ Ans

Illustration of saturation flow and lost times at traffic signals:



* Determine the total no. of trip for the following figure—

Total trip = 110



Shopping center	Floor space (thousand ft²)
1	184
2	215
3	86

Soln:

$$\text{Trips from zone } i \text{ to zone-1} = \frac{\frac{A_1}{(D_{i1})^2}}{\frac{A_1}{(D_{i1})^2} + \frac{A_2}{(D_{i2})^2} + \frac{A_3}{(D_{i3})^2}} \times 110$$

$$= \frac{\frac{184}{8^2}}{\frac{184}{8^2} + \frac{215}{4^2} + \frac{86}{5^2}} \times 110 \simeq 16$$

$$\text{Trips from zone } i \text{ to zone-2} = \frac{\frac{215}{4^2}}{\frac{184}{8^2} + \frac{215}{4^2} + \frac{86}{5^2}} \times 110$$

$$= 75$$

Trips from zone-i to zone-3 = 19

Ans.

* Gravity model for trip distribution:

$$T_{ij} = \frac{\frac{A_j}{(D_{ij})^n}}{\sum_{j=1}^{m} \frac{A_j}{(D_{ij})^n}} \times P_i$$

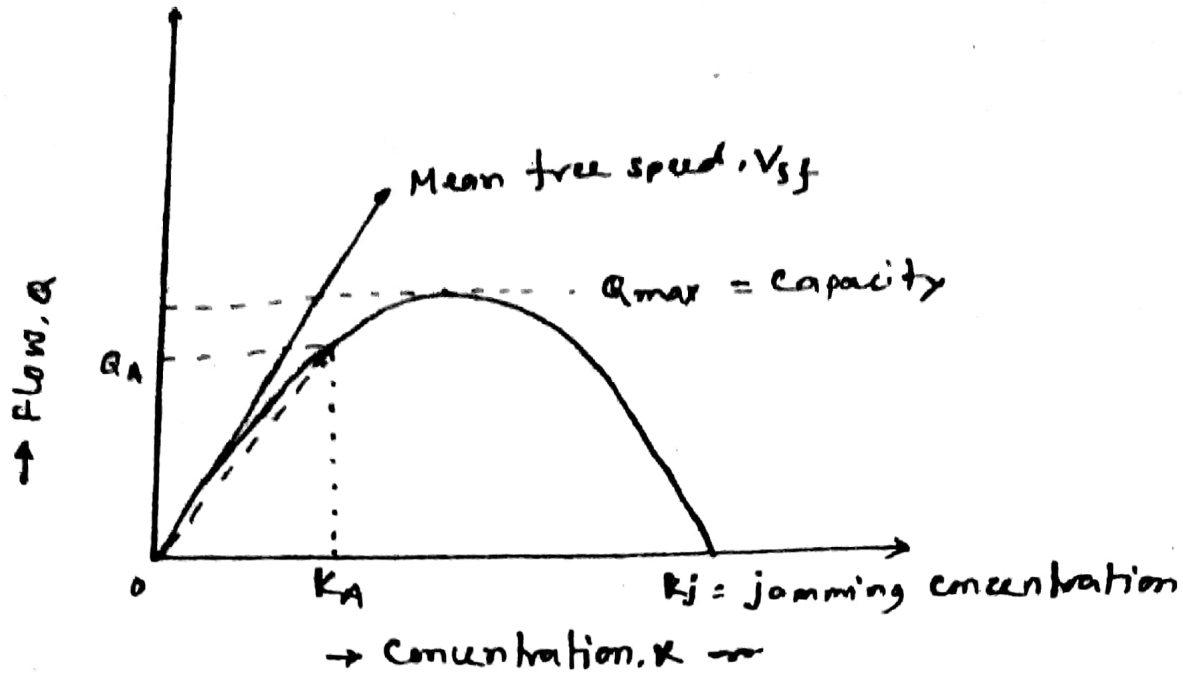
where, P_i = total no. of trip

T_{ij} = trips from zone i to zone j

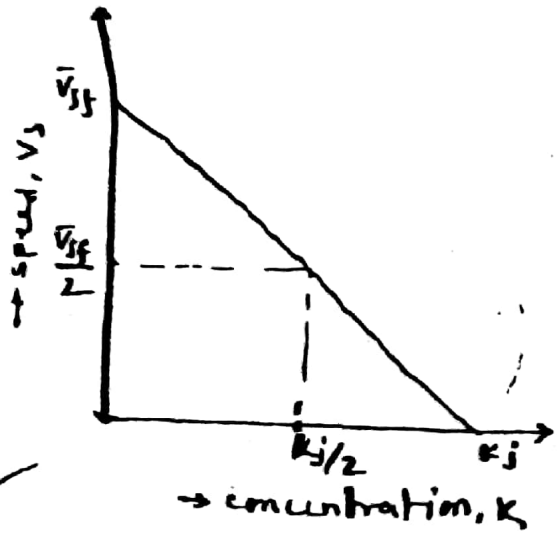
A_j = Total attraction at zone j

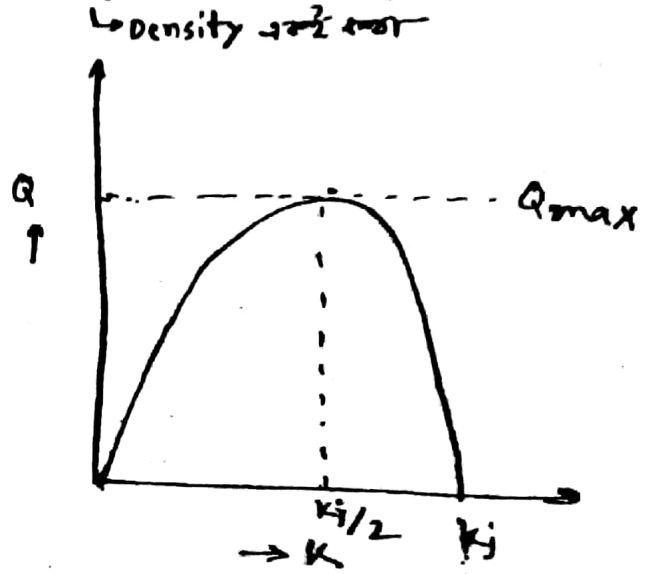
D_{ij} = Distance between zone i & j

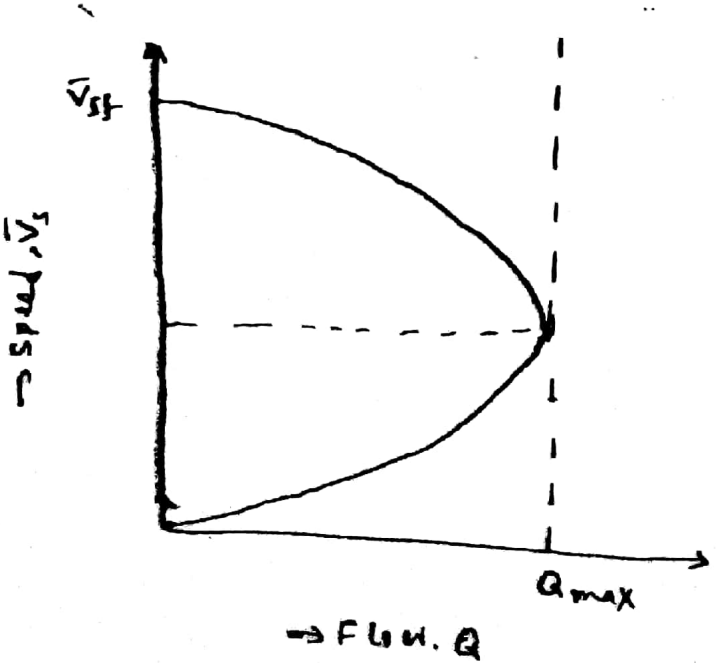
* Fundamental diagram of traffic flow:



* Draw speed - Flow - concentration curve.







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"Flexible pavement"

* **pavement**: A road pavement is a structure of super-imposed layers of selected and processed materials that is placed on the basement soil or subgrade.

* **Function of pavement**: The main structural function of a pavement is to support the wheel loads applied to the carriageway and distribute them to the underlying subgrade.

* **Flexible pavement**: A flexible pavement is those which may consist of a relatively thin wearing surface built over a base course and subbase course and they rest upon the compacted subgrade.

* **Structural components of a Flexible pavement:**

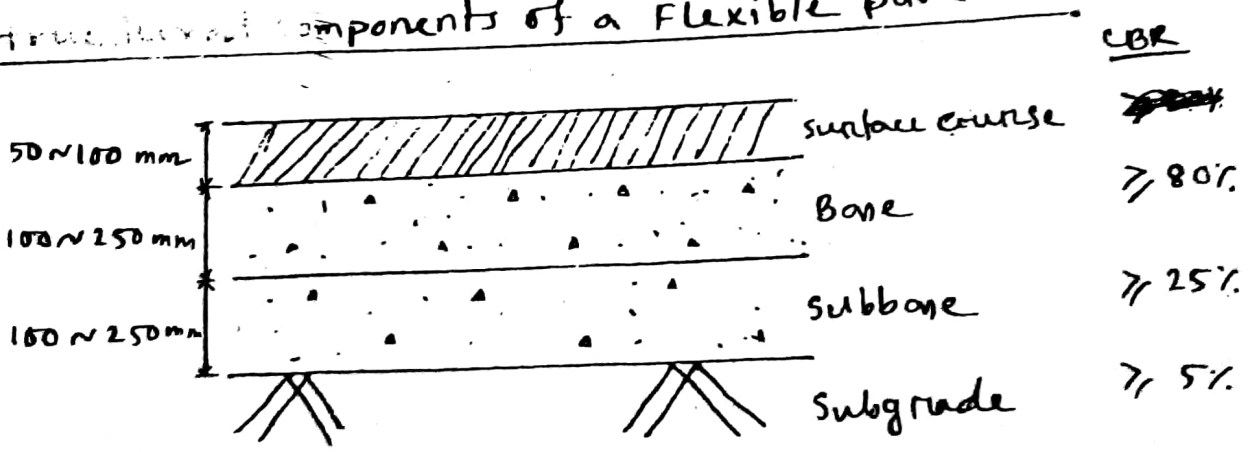


Fig: Schematic of a flexible pavement (section)

Subgrade:

* In our country, Base 2-types.
  - Base type 1 - stone chips.
  - Base type 2 - Brick chips.

* If CBR of subgrade ≥ 25%, then no subbase is required.

* If CBR of subgrade is less than 5%, then it is needed to improve subgrade (CBR of 8%)

Subgrade: It is the foundation layer which supports all the load coming onto the pavement. Natural soil, Sandy soil are preferable for subgrade.

Improved Subgrade: A layer of imported material between the Subgrade and Subbase is used for improving subgrade. It comprises silt and silty sand with a CBR value ≥ 8% when compacted at suitable moisture content.

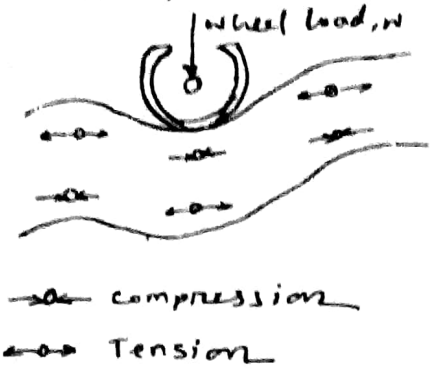
Subbase: It is located immediately above the subgrade and consists of material of a superior quality to that which is used for subgrade construction. When quality of subgrade material meets the requirements of subbase material, the subbase component may be omitted. It distributes loads to the subgrade.

Base: It is located above subbase and usually consists of granular materials such as crushed stone, gravel, brick chips and sand. It distributes stresses created by wheel loads acting on the wearing surface.

Surface course: It is the uppermost layer of the pavement. It is normally consists of bituminous surface dressing. It provides safe, smooth and stable riding surface.

- dressing → stone chips + binder

* Schematic of tennile and compressive stress in pavement structure and draw wheel load distribution diagram in flexible pavement.



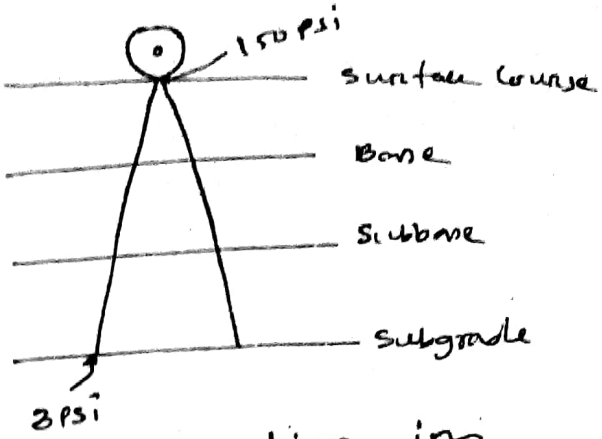


Fig: Load distribution in flexible pavement.

* Load distribution in Rigid & Flexible pavement.

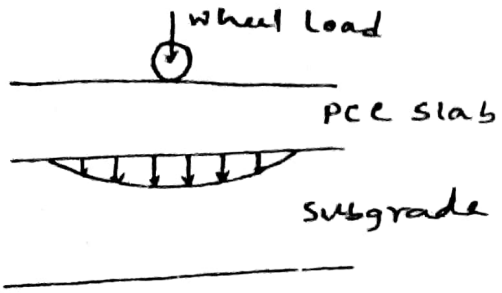


Fig: Rigid pavement.

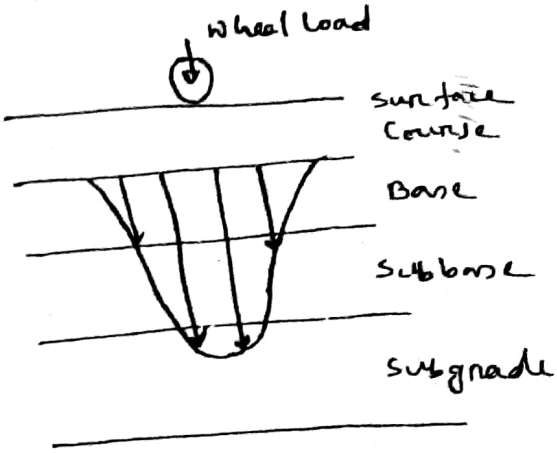


Fig: Flexible pavement.

* choice of pavement type:

- Amount & type of traffic
- Subgrade soil condition
- Cost of materials, construction and maintenance charges.
- Anticipated life of pavement.
- Available finance.

Flexible pavement	Rigid pavement.
1. It consists of a series of layers with the highest quality materials at or near the surface.	1. It consists of one course portland cement concrete slab of relatively high bending resistance.
2. Low initial cost.	2. High initial cost.
3. High maintenance cost	3. Low maintenance cost.
4. Lower life time. (10...	4. Longer life time (40 yrs)
5. Flexible pavement is not impervious.	5. Rigid pavement is practically imperious.
6. It distributes load in small area.	6. It distributes load in large area.
7. Stage construction is not possible	7. Stage construction easily possible.

* Some important definition

Design traffic number (DTN): It is the average daily number of equivalent ...le-axle load applications expected for the lane ...ring the design period.

Initial Daily Traffic (IDT): The average daily number of vehicles expected during the first year following the opening of the finished roadway to traffic. This is called initial daily traffic.

Equivalent Single Axle Load (ESAL): The traffic characteristics are determined in terms of the number of repetitions of an 18,000 lb single axle load applied to the pavement on two sets of dual tires. This is usually referred to as the ESAL.

Serviceability: It is defined as the ability of a pave-ment to serve the traffic for which it was designed.

present serviceability Rating (PSR): It is a number of grades given to a pavement section based on the ability of that pavement to serve its intended traffic. Rating range 0 to 5. 5 for excellent pavement.

Initial serviceability Index (P_i): It is the serviceability index immediately after the construction of the pavement.

Terminal serviceability Index (P_t): It is the minimum acceptable value before resurfacing or reconstruction is necessary.

Structural Number (SN): The SN is defined as an index number derived from an analysis of traffic, road-bed soil conditions and regional factor that may be conver-ted to thickness of various flexible pavement layers through the use of suitable layer co-efficients.

$$SN = a_1D_1 + a_2D_2 + a_3D_3$$

Resilient Modulus: The resilient modulus is equivalent to elastic modulus of the materials in the pavement structure. It is well known that most paving materials are not elastic and experience some permanent defor-mation after each load. If the load is small compa-red to the strength of the material and is repeated for a large number of times, the deformation under each load is nearly recoverable and considered as elastic.

The elastic modulus based on the recoverable strain under repeated loads is called the resilient modulus, MR.

$$M_R = \frac{\sigma_d}{\varepsilon_r}$$

σ_d → Deviator stress.

ε_r → recoverable strain

characteristics of a pavement:

① Structurally sound.
② Thick to distribute load.
③ Hard wearing surface.
④ Dust-proof.
⑤ Good riding quality.
⑥ Low friction.
⑦ Adequate rough to prevent skidding.
⑧ impervious.
⑨ Long life.

Factors affecting pavement design:

① Design Life

② Reliability: probability that any type of distress will remain below or within the permissible level during the design life.

③ Traffic factors – Wheel load, impact, position of wheel on pavement.

④ Climatic factors: Rainfall, frost action, temperature.

⑤ Road Geometry – Horizontal & vertical curves.

⑥ Subgrade strength & drainage.

⑦ Materials properties for structural design.

Specification: A set of requirements that to be satisfied by the materials.

* If the traffic using the pavement grows at an annual rate of 4 percent. Determine the design ESAL for 20 yrs. design period.

Soln: Design ESAL $= \left[\frac{(1+r)^n - 1}{r}\right] * ESAL$

$= \frac{(1+0.04)^{20} - 1}{0.04} * 78900 = 2349000$ Ans

*ESAL = No. of vehicles * Factors.

* Flexible pavement Design Method:

① AASHTO Design Method.

② Asphalt Institute Method.

AASHTO Design Method:

(a) Find Reliability, R [Table]

(b) Overall standard deviation [Table]

(c) ESAL (given) or $W_{18} = D_D \times D_L * W_{18}$ → the cumulative two direction 18 kips ESAL

→ Lane distribution factors

→ Directional distribution factor.

(d) Effective Roadbed soil resilient modulus, M_R (Subgrade)

$M_R = 1500\ CBR$

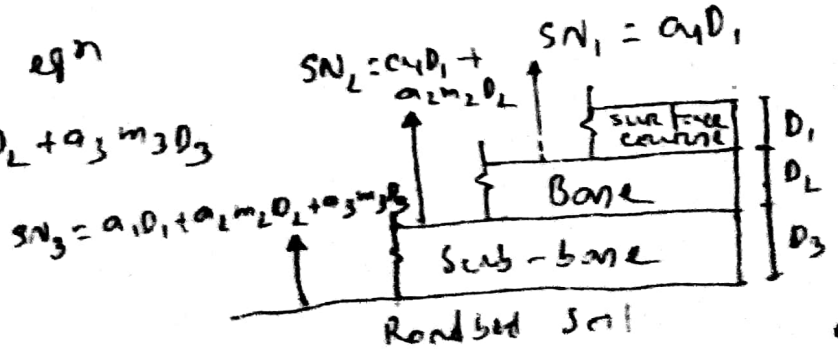
(e) Design serviceability loss, $\Delta PSI = P_i - P_t$

(f) Find layer co-efficient a_1, a_2, a_3 [Table]

(g) Find drainage co-efficient m_2, m_3 [Table]

(h) Find D_1, D_2, D_3 from eqn

$SN = a_1 D_1 + a_2 m_2 D_2 + a_3 m_3 D_3$



i) $SN_1 = a_1 D_1 \Rightarrow D_1 = \frac{SN_1}{a_1}$

ii) $SN_2 = a_1 D_1 + a_2 m_2 D_2$

$\Rightarrow D_2 = (SN_2 - SN_1)/a_2 m_2$

iii) $SN_3 = SN_2 + a_3 m_3 D_3$

$\Rightarrow D_3 = (SN_3 - SN_2)/a_3 m_3$

Ans

Asphalt Institute Method: The Asphalt Institute thickness design manual includes design charts for the following six type of pavement structure and three sets of environmental conditions based on the mean annual air temperature (45°F, 60°F & 75°F)

1) Full depth asphalt concrete with an asphaltic concrete for both the surface and the base.
2) Emulsified asphalt mix (type-1) constructed with semi processed, crusher run aggregates and an asphaltic emulsion.
3) Emulsified asphalt mix (type-2) made with processed, dense graded aggregates and an asphaltic emulsion.
4) Emulsified asphalt mix (type-3) made with sands and silty sands and asphaltic emulsion.
5) Asphalt concrete over an untreated aggregate base with a thickness of 6 inch.
6) Asphalt concrete over an untreated aggregate base with a thickness of 12 inch.

* **Stage Construction**: Stage construction of a pavement structure involves construction in steps at specified time to meet the increase in traffic. This method of construction is usually used when adequate fund are not available to construct the pavement and when traffic growth rates are expected to be higher in the future.

n_1 = Design ESAL for the 1st stage.

n_2 = " " " " 2nd "

N_1 = Adjusted design ESAL for stage-1

N_2 = " " " " stage-2

If D_1 = proportion of the life of the pavement expended (damage) at the end of stage-1

$$D_1 = \frac{n_1}{N_1} \Rightarrow 0.6 = \frac{n_1}{N_1} \Rightarrow N_1 = 1.67\, n_1$$ ← h_1 এর জন্য ব্যবহার

$$1 - D_1 = \frac{n_2}{N_2} \Rightarrow 0.4 = \frac{n_2}{N_1} \Rightarrow N_2 = 2.5\, n_2$$ ← h_2 এর জন্য ব্যবহার।

* A full depth asphalt concrete pavement is to be constructed in two stages. Design period is 20 yrs. The 2nd stage will be constructed 10 yrs after the 1st stage. If the ESAL on the design lane during the 1st year is 60,000 & the growth rate for all vehicles is 5%, determine the asphalt thickness for the 1st and 2nd stages of construction if the subgrade resilient modulus is 15000 lb/in² and a MAAT (Mean Annual Air Temp.) of the area is 60°F.

Note: যদি দেয়া resilient modulus থেকে না হয় তাহলে CBR value থেকে হলেও M_R বের করা যায়; CBR থেকে না হলে Subgrade-এর CBR (5%) ধরে নিতে।

$M_R = 1500\ CBR$.

Sol^n: Growth factor for 10 yrs $= \frac{(1+r)^n - 1}{r}$

$= \frac{(1+0.05)^{10} - 1}{0.05} = 12.58$

Growth factor for 20 yrs $= \frac{(1+0.05)^{20} - 1}{0.05} = 33.06$

$n_1 = 60,000 * 12.58 = 754800$

$n_2 = 60,000 * (33.06 - 12.58) = 1228800$

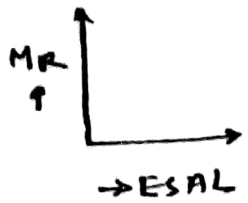
$N_1 = 1.67\, n_1 = 1260516$

$N_2 = 2.5\, n_2 = 3072000$

From graph

$h_1 = 7.5''$

$h_2 = 9.5''$



$\therefore h_3 = 9.5 - 7.5 = 2''$

* A full depth HMA (Hot mixed Asphalt) pavement with a subgrade resilient modulus of 10,000 psi will be constructed in 2 stages. The 1st stage is 5 yrs with 150000 ESAL repetitions and the 2nd stage is 15 yrs with 850000 ESAL repetitions. Limiting the damage ratio to 0.6 at the end of stage-1. Determine the thickness of HMA required for the 1st 5 yrs and the thickness of overlay required to accommodate the additional traffic expected during the next 15 yrs.

Sol^n: $n_1 = 150000$, $n_2 = 850000$

$N_1 = 1.67\, n_1 = 250500$

$N_2 = 2.5\, n_2 = 2125000$

From graph

$h_1 = 6.5''$

$h_2 = 9.5''$

$\therefore$ Thickness of overlay $= 9.5 - 6.5$

$= 3''$

Ans

* Seal coats:

- seal coats are usually single application of asphaltic material that may or may not contain aggregate.
- Seal coats are applied as a final step in the construction of many types of bituminous wearing surfaces.
- The primary purpose of seal coats is to waterproof or seal the surface.
- A seal coat usually consists of a single application of bituminous material that is covered by a light spreading of fine aggregates or sand.

Types of seal coats:

i) Fog seal (Emulsified Asphalt with no aggregate is sprayed at a rate of 0.1 to 0.2 gal/yd^2)

ii) Slurry seal (Emulsified Asphalt + Fine Aggregate + Mineral Filler + water)

iii) Aggregate seal (Asphalt spray + Covering aggregate and rolling the aggregate into the asphalt).

* prime Coat: A prime coat is an application of liquid bituminous material to a previously untreated base or wearing surface. prime coats are mainly used to -

- provide a waterproof surface on the base.
- Fill capillary voids in the base.
- facilitate the bonding of loose mineral particles.
- Facilitate the adhesion of surface treatment to the base.

* Tack Coats: A tack coat is a thin layer of asphaltic material sprayed over an old pavement. The purpose of a tack coat is to provide adhesion between the existing surface and the new bituminous wearing surface. Quantity of bituminous material ranging from 0.05 to 0.10 gal/yd^2.

* pavement distress: The term pavement distress refers to the condition of a pavement in terms of its general appearance. A distressed pavement may be fractured, distorted or disintegrated.

(A) Surface defects:

① Fatty surface ② Smooth surface
③ streaking ④ Hungry surface.

causes:
- Excessive Binder
- Less Binder
- Heavy prime coat, tack coat.
- polishing of aggregate

Treatment
- Removal of affected Area.
- Resurfacing.
- Application of slurry, fog seal.

(B) Cracks:

① Hair-Line ② Alligator crack (কুমিরের চামড়ার মত)
③ Longitudinal cracks ④ Shrinkage crack ⑤ Edge crack.

causes:
- Less Binder
- Improper Compaction
- Repeted Load.
- Shrinkage of bitumen.

Treatment
- Application of low viscosity bitumen.
- slurry seal.
- Fog seal.

(a) Deformation

(1) Slippage – Cause: • Unusual thrust of wheels
• Insufficient tack or prime coat.

Treatment: • Removal of surface layer around the affected area.

(2) Rutting – (Channel like way) Causes: • Heavy channelised traffic.
• Inadequate compaction.

Treatment: • Filling with premix dense graded patching material after a tack coat and compacting to the desired level.

(3) Corrugation – (undulation) Causes: • Lack of stability in the mix.
• Faulty laying of surface course.

Treatment: • cutting of high spots with blade and filling of low spots.
• Spreading of sand bituminous premix and rolled.

(b) Disintegration:

(1) Stripping – (separation of bitumen & aggregate) Causes: • Inadequate mix composition.
• Due to continuous contact of water.

Treatment: • spreading and compacting hot coarse sand.

(2) pot-hole – (ગાબડાં) Causes: • Insufficient bitumen content.
• Improper compaction.

Treatment: • pot-holes are filled with premix dense-graded patching.

* Requirement of Bituminous mixes:

stability, durability, workability & skid resistance.

* Write a short note on water-bound Macadam (WBM) road.

Ans: Water-bound macadam is a layer composed of broken-stone fragments that are bound together by stone dust and water applied during construction which is compacted by a heavy roller or a vibratory compactor. The thickness of WBM ranging from 3 ~ 12 inch.

Broken-stone fragments are bound together by stone dust and water, no binding materials are used. For this reason, it is called WBM.

* Construction Method of WBM:

- preparation of Subgrade.
- spreading and rolling.
- Application of screening & rolling.
- Application of water & wet rolling.
- Curing & application of second course.
- Surface checking.

* What is screening?

Ans: The materials used to fill the surface voids in the compacted layer is called screening.

Grading requirements -

opening		passing
3/8"	—	100
#4	—	85-100
#100	—	10-30

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* Comparison between BRTA & BRTC.

BRTA	BRTC
- Bangladesh road transport Authority - Service: * Driving license * vehicle registration * set traffic rules & regulations. - Established in 1988	- Bangladesh Road Transport Corporation. - service: * provide public transport service.

* Why structural design of pavement is a complex one?

Ans: Traffic loading pattern -
- is repetitive in nature
- causes stresses of wide varying intensities
- forecast is very difficult.

pavement is greatly influenced by -
- Shrinkage - crack of slab due to temperature change
- swelling of roadbed soil due to moisture change.
- pumping - loss of roadbed material with water.
- Stripping - break of bonding between aggregates.

* Load Equivalency:

Generalized fourth power approximation

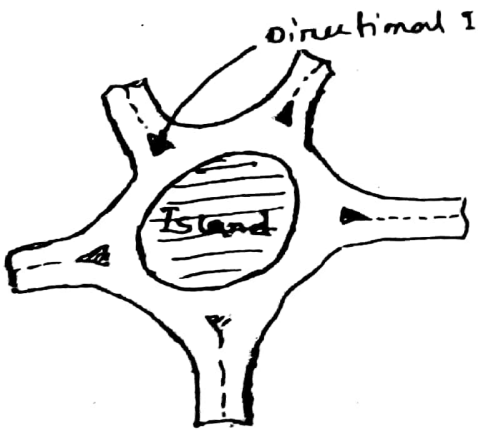
$\left(\frac{\text{Load}}{18000\text{lb}}\right)^4$ = relative damage factor.

- Tee (T)
- Wye (Y)
- Cross (X)
- skewed
- Staggered
- Roundabout

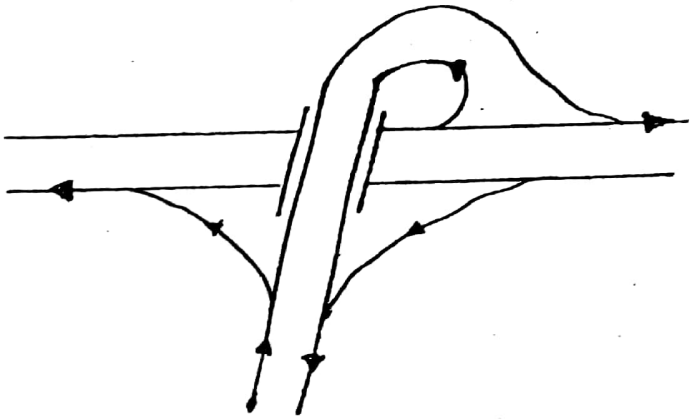
Grade separated interchange:

- Trumpet
- Diamond
- Clover-leaf
- Roundabout / rotary.

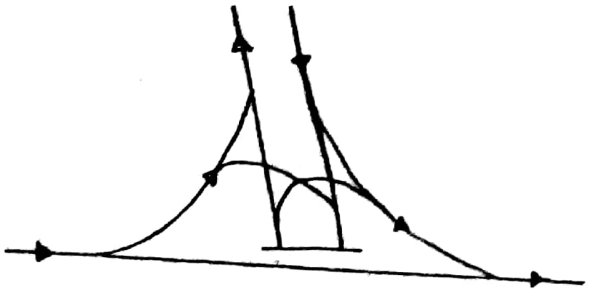
Draw figure of grade separated interchange:

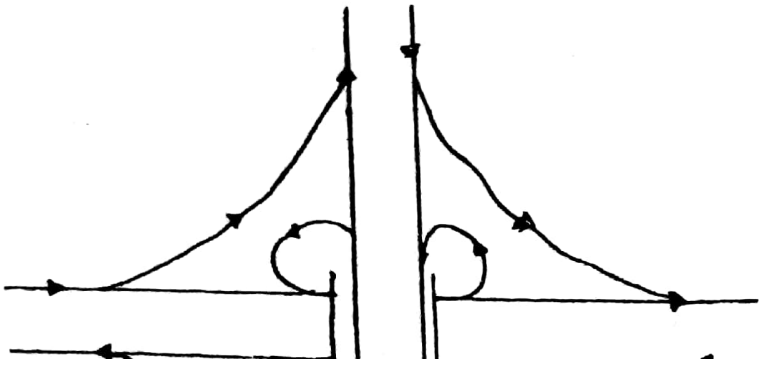


Roundabout / Rotary



Tee / Trumpet.





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"Rigid pavement"

Rigid pavements are normally constructed of portland cement concrete and may or may not have a base course between the subgrade and the concrete surface. Thickness ranges from 6 to 13 inch.

* Write down the components & section of rigid pavement.

Components: - subgrade
- Base Course (it is not considered to be a load carrying member).
- portland cement concrete slab.

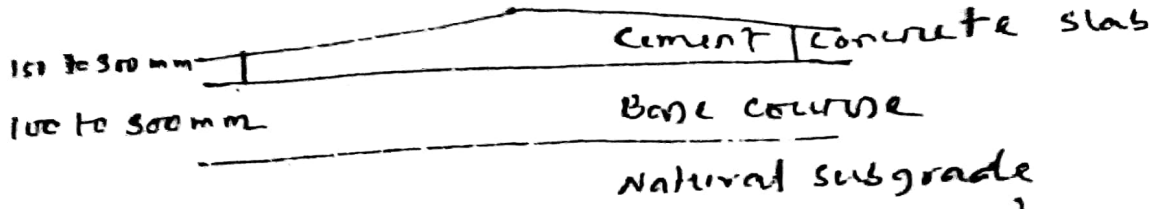


Fig: section of a Rigid pavement.

* Why Base Course is used in Rigid pavement?

Ans: - control of pumping.
- control of frost action
- Drainage
- control of shrink & swell of subgrade.

* Types of Rigid pavement:

1) plain concrete pavement - no temperature steel or dowels for load transfer, used for low volume highways, joints are provided ~~after~~ at relatively shorter distances (10 to 20 ft) to reduce the amount of cracking.

2) Simply reinforced concrete pavement - Dowel bar is used for load transfer, joints are placed at larger distance (30 to 100 ft), Temperature steel is also used throughout the slab.

3) Continuously reinforced concrete pavement - Have no transverse joints, High percentage of steel (0.6 percent of x-sectional area of slab), Contain tie bars across the longitudinal joints.

* Materials of Rigid pavement:

Ans: portland cement, coarse aggregate, Fine aggregate and water.

* Temperature steel:

- It is provided in the form of bar mat or wire mesh consisting of longitudinal and transverse steel wires welded at regular intervals.
- Mesh is usually placed 3" below the slab surface.
- Minimum x-sectional area of steel
  - x-sectional area of longitudinal steel should be at least 0.1 percent of x-sectional area of slab.
  - Longitudinal wires should not be less than NO.2 gauge (6.593 mm), Spacing 6 inch maximum.
  - Transverse wire should not be less than NO. 4 gauge spacing 12 In maximum.

* Dowel bars:

- Dowel bars are used mainly as load-transfer mechanisms across joints.
- Dia 1 to 1.5 inch, Lengths 2 to 3 ft.
- spacing 1 ft across the width of slab.

* Tie Bars:

- Tie bars are used to tie two sections of pavement together.
- diameter $\frac{3}{4}$ inch, spacing 3 ft.

* Why joints are provided in rigid pavement?

Ans: Different types of joints are placed in concrete pavements to limit the stresses induced by temperature changes and to facilitate proper bonding of two adjacent sections of pavement when there is a time lapse between their constructions.

* Types of joints:

1) Expansion joints:

- When concrete pavement is subjected to an increase in temperature, it will expand, i.e. increase the length of slab.
- joint width $\frac{3}{4}$ ~ 1 inch.

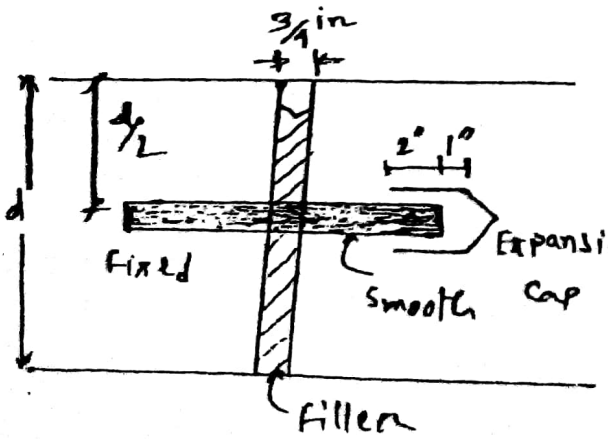


Fig: Expansion joint.

- Filler materials are cork, rubber, bituminous materials.
- An expansion cap is placed to provide a space for dowel to occupy during expansion.

2) Contraction Joints:

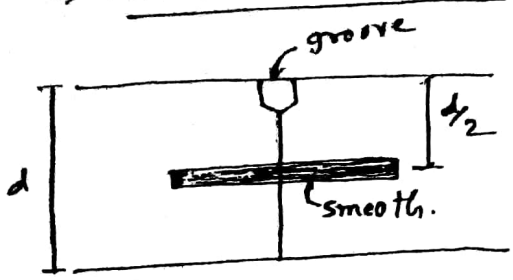


Fig: Contraction joint.

- When concrete pavement is subjected to decrease in temp., the slab will contract and induce tensile stresses in the pavement.
- Contraction joint are provided transversely in order to release some of the tensile stresses that are so induced.
- Spacing of joint is ~100 ft.
- Groove width 3/16 or 1/4 in width and groove is filled with rubber and rubber asphalt compounds.

3) Hinge joints:

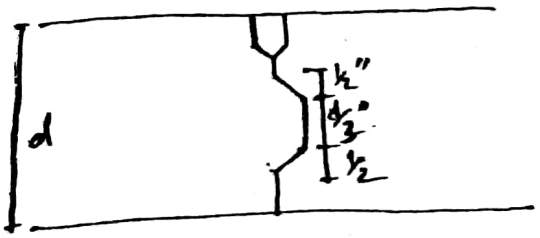


Fig: Hinge joint.

- Hinge joints are mainly used to reduce cracking along the center line of highway pavements.

4) Construction joint:

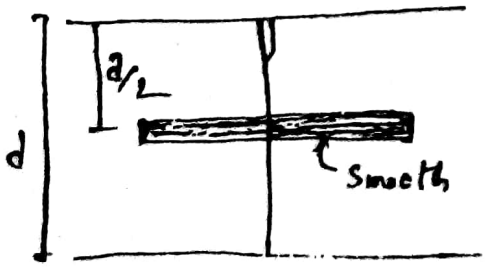


Fig: Construction Joint.

- Construction joints are placed transversely across the pavement width to provide suitable transition between concrete laid at different times.
- Expansion joint can be used in lieu of construction joint when construction joint falls near the expansion joint.

5) Longitudinal Joints: A longitudinal joint in a concrete pavement is a joint running continuously the length of the pavement.

* Joint Fillers: A material which is used for filling the joint is known as fillers.

Materials: - soft wood free from knot.
- Cork
- Bituminous materials.
- Impregnated fiber boards.

* Sealers: The material which is used for sealing the joint is known as sealer.

Sealing Compounds: - straight-run asphalt.
- Air-blown asphalt.
- Rubber asphalt.

* primer: It is used to the sides of the concrete surface and sealing compounds. Composition of primer: 66% - 200 penetration asphalt, 14% - light creosote oil, and 20% - solvent naptha.

* pumping of Rigid pavement: pumping is the discharge of water and subgrade material through joints, cracks, and along the pavement edge. It is primarily caused by the repeated deflection of the pavement slab in the presence of accumulated water beneath it.

* Advantages & disadvantages of cement concrete Roads.
or
What types of pavement is suitable for BD? why?
↳ বাংলায় Ans এর advantage.

Advantages: cement concrete roads prove cheaper than bituminous roads. Because -

- Maintenance cost is negligible.
- Their life span is very large.
- They are not slippery when wet.
- They can deal with very heavy traffic.

Disadvantages:

- Initial cost is comparatively high.
- 28 days curing is required.
- It is not possible to adopt stage construction programme in these roads.
- Lots of joints is to be provided which proves additional places of weakness.

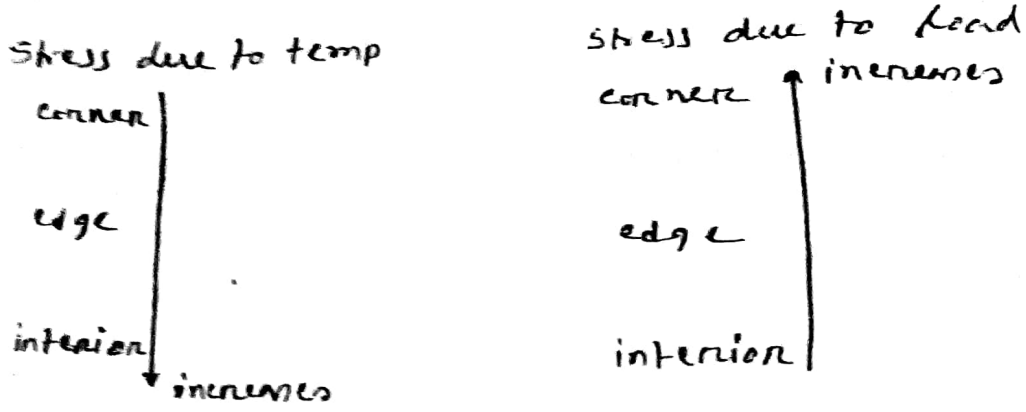
* What is modulus of subgrade reaction? factors on which it depends.

Ans: The modulus of subgrade reaction is the stress (lb/in²) that will cause an inch deflection of the underlying soil.

Factors:

- Density
- Moisture
- Soil texture
- other factors that influence the strength of soils.

* stresses in concrete pavement:



* Rigid pavement design methods:
  - AASHTO Design Method
  - portland cement Association Method

AASHTO Design Method:
- Effective modulus of subgrade reaction, K
- Concrete modulus of rupture, S_c
- load-transfer co-efficient, J
- Drainage co-efficient, C_d
- Reliability, R & Standard deviation, S_o.
- Traffic load applications, $W_{18} = D_0 D_L \hat{W}_{18}$
- serviceability loss

* Draw a concrete pavement with steel & joints.

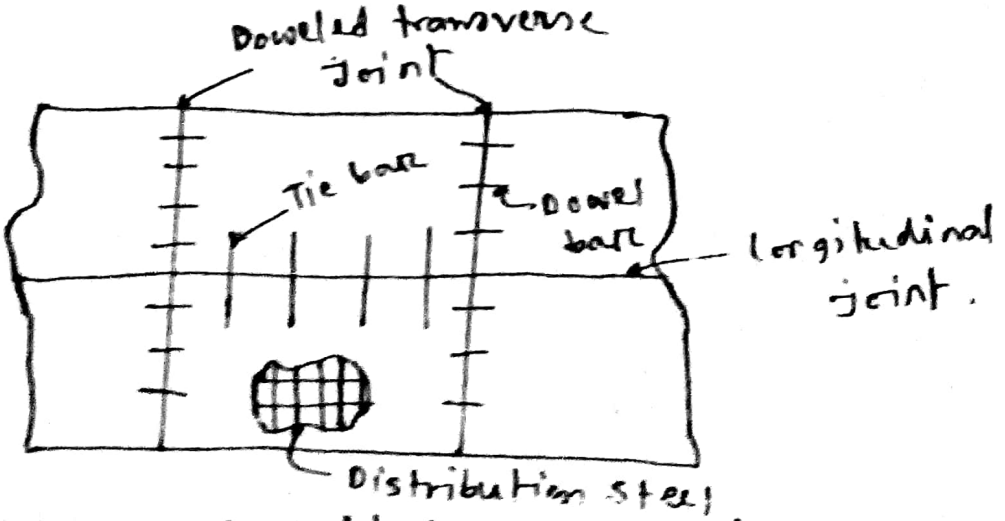


Fig: steel & joints in concrete pavements.

* **Concrete stress:**

$$\sigma_c = \frac{\gamma_c L f_a}{2}$$

where,
σ_c = stress in the concrete
γ_c = Unit wt of concrete.
L = Length of the slab
f_a = co-efficient of friction about 1.5.

* A concrete pavement with a joint spacing of 25 ft and a co-efficient of friction of 1.5. Determine the stress in concrete due to friction.

Solⁿ: Here, $\gamma_c = 150$ pcf, $L = 25$ ft, $f_a = 1.5$

$$\sigma_c = \frac{\gamma_c L f_a}{2} = \frac{150 \times 25 \times 1.5}{2} = 2812.5 \text{ psf}$$
$$= 19.5 \text{ psi}$$

Ans:

* The tensile stress of concrete ranges from $3\sqrt{f_c'}$ to $5\sqrt{f_c'}$, f_c' is the compressive strength of concrete.
If. $f_c' = 3000$ psi, then tensile stress is 164 ~ 274 psi.

* **Joint spacing** (কতদূর পর পর joint হবে)

$$\Delta L = CL(\alpha_t \Delta T + \varepsilon)$$

where,
ΔL = Joint opening caused by temp. & shrinkage.
α_t = co-efficient of thermal expansion
ε = shrinkage co-efficient of concrete.
L = Joint spacing or slab length.

ΔT = Temperature change
c = Adjusted factor due to slab-subbase friction (0.65 for stabilized base, 0.80 for granular base).

* $\Delta T = 60°F$, $\alpha_t = 5.5 * 10^{-6}/°F$, $\varepsilon = 1 * 10^{-4}$, $c = 0.65$ and the allowable joint openings for undoweled and doweled joints are 0.05 & 0.25 in. Detⁿ the max^m allowable joint spacing / slab length.

Soln:

$$\Delta L = cL(\alpha_t \Delta T + \varepsilon)$$

$$\Rightarrow L = \frac{\Delta L}{c(\alpha_t \Delta T + \varepsilon)} = \frac{\Delta L}{0.65(5.5*10^{-6} * 60 + 1*10^{-4})} = \frac{\Delta L}{0.00028}$$

For undowled joint, $L = \frac{0.05}{.00028} = 178.6 \text{ in} = 14.9 \text{ ft}$.

For dowled joint, $L = \frac{0.25}{.00028} = 892.9 \text{ in} = 74.4 \text{ ft}$.

Ans

* Reinforcement for distribution steel:

$$A_s = \frac{\gamma_c L h f_a}{2 f_s}$$

where, A_s = Area of steel required per width.
f_s = Allowable stress in steel.

* Determine the wire fabric required for a two-lane concrete pavement, 8 in thick, 60 ft long and 24 ft wide with a longitudinal joint at the centre.

Soln: Note: $f_a = 1.5$ for AH-25,

$\gamma_c = 150$ pcf, $h = 8$ in $= \frac{8}{12}$ ft, $L = 60$ ft, $L_T = 24$ ft.

$f_s = 43000$ psi $= 6.192 \times 10^6$ psf.

$\therefore$ Longitudinal direction steel, $A_s = \frac{\gamma_c h L f_a}{2 f_s}$

$= \frac{150 \times \frac{8}{12} \times 60 \times 1.5}{2 \times 6.192 \times 10^6} = 7.27 \times 10^{-4}$ ft^2/ft

$= 0.105$ in^2/ft.

$\therefore$ Transverse steel, $A_s = \frac{\gamma_c h L_T f_a}{2 f_s}$

$= \frac{150 \times \frac{8}{12} \times 24 \times 1.5}{2 \times 6.192 \times 10^6} = 2.91 \times 10^{-4}$ ft^2/ft

$= 0.042$ in^2/ft.

Use 6 x 12 - W5.5 x W4.5 with x-sectional area 0.11 in^2 for longitudinal wire, 0.045 in^2 for transverse wire.

* Tie Bars:

$$A_s = \frac{\gamma_c h L' f_a}{f_s}$$

where, L' = distance from the longitudinal joint to the free edge where no tie bar exits.

$$t = \frac{1}{2}\left(\frac{f_s d}{u}\right)$$

where, t = length of tie bar

u = Allowable bond stress (350 psi)

d = Dia of bar.

* Determine the diameter, spacing and length of the tie bars required for a two lane concrete pavement, 8 in thick, 60 ft long, 24 ft wide, with a longitudinal joint at the center.

Soln: Let, $f_s = 27,000$ psi

$L' = 12$ ft $= 144$ in

$$A_s = \frac{r_c h L' f_a}{f_s} = \frac{0.0868 \times 8 \times 144 \times 1.5}{27000} = 0.00556 \text{ in}^2/\text{in}$$

(150 lb/ft³)

use #4. Spacing $= \frac{0.20}{0.00556} = 36$ in

(Area #4 bar)

$$\therefore t = \frac{1}{2}\left(\frac{f_s d}{\mu}\right) = \frac{1}{2} \times \frac{27000 \times 0.5}{350} = 19.3 \text{ in}$$

$\therefore 19.3 + 3 = 24''$ (increase by 3")

$\therefore$ Dia 0.5 in (#4 bars), spacing = 36", Length 24" Ans

The headway of a bus stop

$$h_m = 2t_d/60.$$

where, h_m = Minimum headway between buses (min)

t_d = Average dwell time

~~Dwell~~ Dwell time, $t_d = P_a \times t_a + P_b \times t_b + t_{oc}$

where, P_a = passengers/bus during peak 15 mins (Alighting)

t_a = passenger alighting time (sec/person)

P_b = Boarding passenger/bus during peak 15 mins

t_b = passenger boarding time (sec/person)

t_{oc} = Door opening & closing time.

* Alighting → ~~fast~~
* Boarding → ~~less~~

passenger volume during peak 15 mins (person),

$$P_{15} = \frac{P}{4(PHF)}$$

where, PHF = peak hour factor

P = passenger during peak hour (person)

The frequency of service,

$$f = \frac{n}{N}$$

where, f = frequency required (bus/hr)

n = Demand for service (passenger/hr)

N = max^m number of passengers/bus.

The passenger capacity of a bus,

$$c_t = c_a + \alpha * c_b$$

where, c_t = total passenger capacity / vehicle

c_a = vehicle seating capacity.

c_b = vehicle standing capacity.

α = Fraction of c_b allowed.

peak hour demand,

$$R_e = \frac{60 c_t}{h_m} = \frac{60(c_a + \alpha * c_b)}{h_m}$$

Round - trip travel, $t_R = \frac{d}{v_c}$

where, t_R = Round trip travel (hr)
d = Distance of a round trip (mi or km)
v_c = Avg. vehicle speed / commercial speed (mph or km/h)

* A bus system needs to be set up between the KUET and BUET, a distance of 8.5 mi. The operating time is 30 min. It has been estimated that the peak hour demand is 400 passenger/hr and 45 seater buses are available, which can safely accomodate 20 standees. Design the basic system and determine fleet size, assuming that the policy headway is 30 min and that the minimum terminal time is 7.5 min, which may be revised if necessary?

Soln: Here, t_o = 30min, policy headway = 30 min
Terminal time = 7.5 min, R_c = 400

operating speed = $\frac{L}{t_o} = \frac{8.5}{\frac{30}{60}} = 17$ mph

Headway, $h_{min} = \frac{60 C_t}{R_c} = \frac{60(c_a + \alpha c_b)}{R_c}$ [$c_t, \alpha = 1$]

$= \frac{60(45 + 1 \times 20)}{400} \simeq 10$ min Ans.

Cycle time, $T = 2(t_o + t_t) = 2(30 + 7.5) = 75$ min

Fleet size, $N_f = \frac{T}{h_{min}} = \frac{75}{10} = 7.5 \simeq 8$ vehicle Ans.

Revised cycle time, $T' = N_f * h = 8 \times 10 = 80$ min Ans.

Revised terminal time, $t_t' = (T' - 2t_o)/2 = \frac{80 - 2 \times 30}{2} = 10$ min

Commercial speed, $v_c = \frac{d}{t_R} = \frac{2L}{t_R}$

$= \frac{2 \times 8.5}{\frac{80}{60}} = 12.75$ mph

Ans.

Test-1: Determination of Aggregate impact value (AIV)

- Relative measure of resistance due to sudden load (shock or impact).
- Standard value ≤ 30%
- 19 mm sieve passing, 10 mm sieve retained aggregate is tested.
- Done by Aggregate impact machine (45 ~ 60 kg)

Aggregate impact value = $B/A * 100\%$ (result should be Whole Number)

$$\Downarrow$$

$$A - (B+C) < 1\text{gm}$$

where,

A = Initial wt of sample

B = 2.36 mm sieve passing

C = 2.36 mm sieve retained.

Test-2: Aggregate crushing value test (ACV)

- Allowable limit ≤ 30%

  Subbase — ≤ 38%

  Base type-2 — ≤ 35% (Brick chips)

  Base type-1 — ≤ 30% (Stone chips)

- Aggregate 19 mm sieve passing, 10 mm sieve retained.

$$ACV = B/A * 100\% \text{ (result whole number)}$$

$$\Downarrow$$

$$A - (B+C) < 10\text{g}$$

Where, A, B, C are the same as above test.

Test-3: Ten (10) percent Fines value test.

- 10% fine ... load ... ten percent fines value.
- According to RHD, 10% Fines value

surfacing ≥ 150 KN

Base type-1 ≥ 125 KN

Base-type-2 ≥ 90 KN

Subbase ≥ 75 KN

* percent (%) Fines, $y = \frac{B}{A} * 100\%$.

Where, A = Initial wt of sample

B = passing wt of sample

* Force required for ten p... fines, $= \frac{14x}{y+4}$

where,

- x = The maximum force for 20mm penetration.
- penetration value -
  1) 15 mm for rounded / partially rounded aggregate
  2) 20 mm for normal crushed aggregate.
  3) 24 mm for honeycombed aggregate.

- Fines values are always within 7.5 to 12.5%.
- When force ≥ 100, round nearest 10.
- " " < 100, round nearest 5.

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Test-4: Flakiness Index test. { ← Flaky aggregate.

- The aggregates are termed as flaky when their smallest dimension is less than 0.6 of their nominal size.

Smallest dimension < 0.6 × nominal size

- A metal thickness gauge is used for this test.

Calculation: Sample wt = 2000 gm (let), 5% of wt = 100 gm

passing (mm)		Retained (mm)	Wt Retained (gm) (sieve retained)	passing (gm) (gauge passing)
63	—	50	0	0
50	—	37.5	0	0
37.5	—	28	31.1	0
28	—	20	405.7	190
20	—	14	1081.4	317.6
14	—	10	370.5	86.1
10	—	6.3	104.3	16.4
			$M_2 = 1961.9$ gm	$M_3 = 610.1$ gm

বাকি, এর < 100 gm

$$\therefore \text{Flakiness Index} = \frac{M_3}{M_2} \times 100\%$$

$$= 31.1\%, \simeq 31\%.$$

Ans

- Allowable limit ≤ 25%.

- Nominal size $= \frac{63 + 50}{2} = 56.5$ mm ≈ 50.0 mm.

Test - 5: Elongation Index test.

- The aggregate are termed as elongated when their greatest dimension is more than 1.8 times of their nominal size.

  Longest dimension > 1.8 * Nominal size

- A metal length gauge is used.

Calculation: Sample wt = 2000 gm (Let).

5% of sample = $\frac{5}{100} * 2000 = 100$ gm — sieve-এ retained gauge-এ retained.

passing (mm)		Retained (mm)		Wt Retained (gm)		Retained (gm)	
50	—	37.5	—	0	—	0	
37.5	—	28	—	0	—	0	
28	—	20	—	667	—	135.4	
20	—	14	—	1172.5	—	365.3	
14	—	10	—	137.8	—	61.2	
10	—	6.3	—	(19.4)	—	-	যাদের, প্রত্যেক <100 gm
				$M_2 = 1977.3$ gm		$M_3 = 521.7$ gm	

$\therefore$ Elongation Index = $\frac{M_3}{M_2} * 100$

$\simeq 28\%$

Ans

- Nominal size = $\frac{50 + 37.5}{2} = 43.75$ mm
- Allowable limit $\leq 25\%$

Test-5: Determination of Angularity number

$$\text{Angularity Number} = 67 - \frac{100M}{CG_s}$$

Where,

M = Mean mass of aggregate in cylinder, gm

C = Mass of water required to fill the cylinder, gm

G_s = Specific gravity of aggregate.

* Determine the angularity number if 10 cm x 30 cm cylinder filled with aggregate? Unit wt of water and aggregate are 1000 kg/m³, 1500 kg/m³. $G_s = 2.8$.

Soln: Here, volume of cylinder, $V = \pi * 0.1^2 * 0.3$
$= 9.42 * 10^{-3}\ m^3$

$\therefore M = 1500 * 9.42 * 10^{-3} = 14.14$ kg.

$C = 1000 * 9.42 * 10^{-3} = 9.42$ kg.

$$\therefore \text{Angularity Number} = 67 - \frac{100M}{CG_s}$$

$$= 67 - \frac{100 * 14.14}{9.42 * 2.8}$$

$$= 13.4 \quad \text{Ans}$$

* Calculate the Angularity Number (AN) of aggregate if Relative density of aggregate = 2.8, Mass of water required to fill the cylinder = 2500 gms, Mass of cylinder filled with compacted aggregate = 5150 gms, Mass of cylinder = 1100 gms.

Soln: Here, C = 2500 gms, $G_s = 2.8$, M = 5150 − 1100 = 4050 gms

$$\therefore AN = 67 - \frac{100M}{CG_s} \Rightarrow AN = 67 - \frac{100 \times 4050}{2500 \times 2.8} = 9.1 \quad \text{Ans}$$

=

Test-6: The California Bearing Ratio (CBR) test.

- To determine the potential strength of sub-grade, sub-base and base course materials for use in road and airfield pavements.

Apparatus:

i) CBR Mold ⇒ Dia - 6", Ht - 7"

ii) Spacer Disk ⇒ Dia - $5\frac{15}{16}$", Ht - 2.416"

iii) Rammer: Load = 5.5 lb (12")
Load = 10 lb (18")

iv) Surcharge wt - 2.27 kg

v) penetration piston: Area - 1935 mm^2 ($3in^2$)
Dia - 49.63 mm.

vi) Filter paper

Materials:

- All materials (sample) passing 19 mm sieve is retained on 4.75 mm sieve. If some sample retained on 19 mm sieve then replace it by soil passing 19 mm is retained 4.75 mm.

Test:

1) Standared proctor test - 25 blows / layer

2) Modified proctor test - For roads on which heavy vehicles move.

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procedure:

1) Compaction test এর জন্য sample তৈরি করতে হবে।

2) Soil sample - এর সাথে কিছু পরিমান পানি মিক্সাতে হবে।

3) 5 layer - এ sample - কে compact করতে হবে। প্রতি layer এ 56 blows.

4) Compaction - এর পরে sample collect করে oven - এ ৫ 24 hrs রেখে dry sample - এর ওজন নিতে হবে।

5) 5 টা mold তৈরি করে এগুলোর জন্য বিভিন্ন পরিমান water এর প্রয়োজন (8%, 10%, 12%, 14%, 16%).

6) Optimum moisture content and maximum dry density বের করব compaction curve থেকে।

7) এই OMC দিয়ে 5kg soil কে পুনরায় mix করতে হবে।

8) Three mold was prepared 10, 30 & 65 blows/layer. Total 5 layer - এ compact করতে হবে।

9) Mold এর soil sample - এর ওজন নিতে হবে।

10) Swelling disk & Surcharge disk were placed on the mold and then the mold was placed into the soaking tank.

11) Initial reading of swelling, reading after 24, 48, 72 & 96 hrs were taken.

12) Then the mold is prepared for penetration test.

13) Dial gauge reading is taken & reported in mm.

14) The CBR value is calculated then.

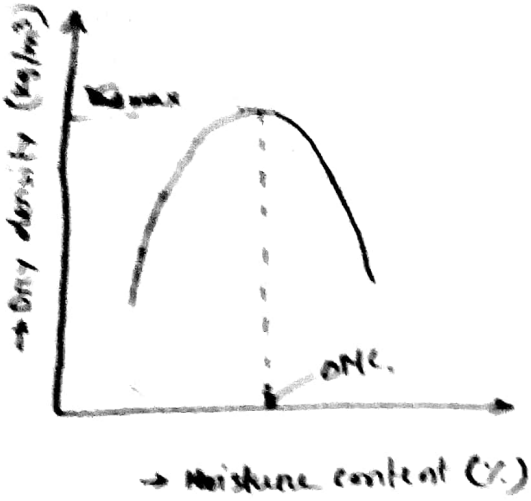


Fig: Compaction Curve

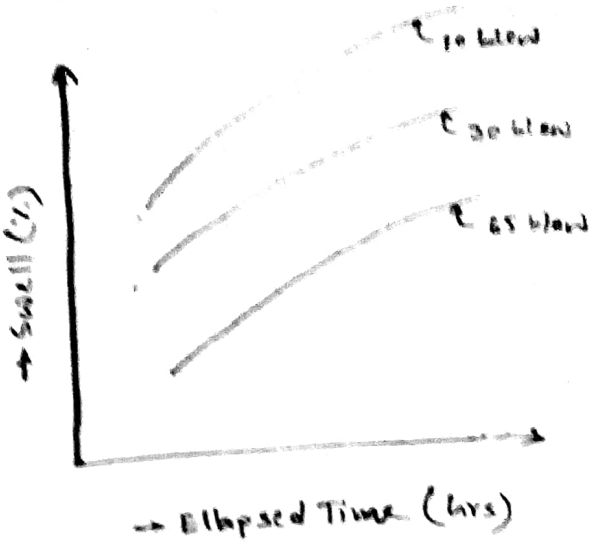


Fig: Swell Vs ellapsed time.

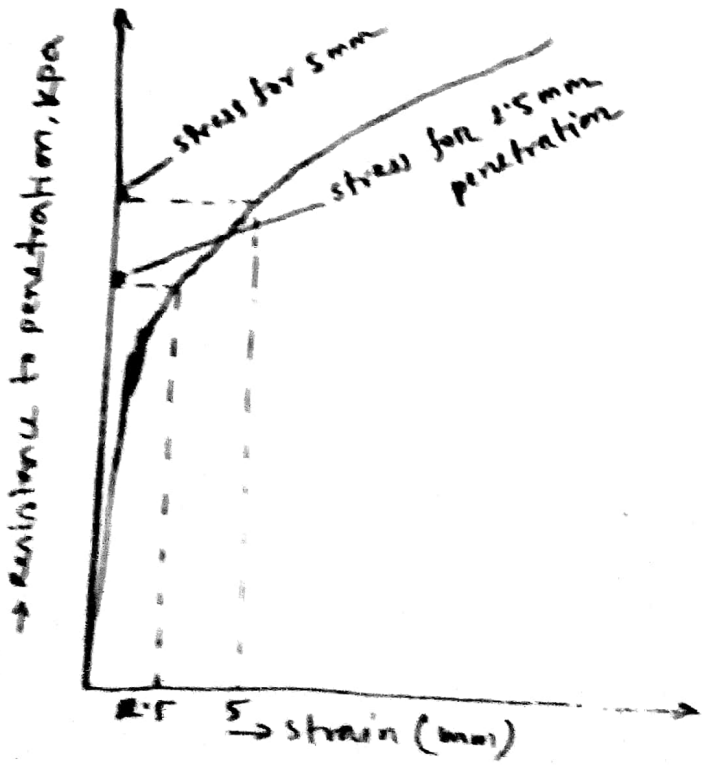
* Swell (%) = $\frac{B - A}{(\text{Ht of sample with spacer disc} - \text{Ht of spacer disc})} \times 100\%$

where, A = Initial reading.

B = Reading after 24, 48, 72, 96 hrs.

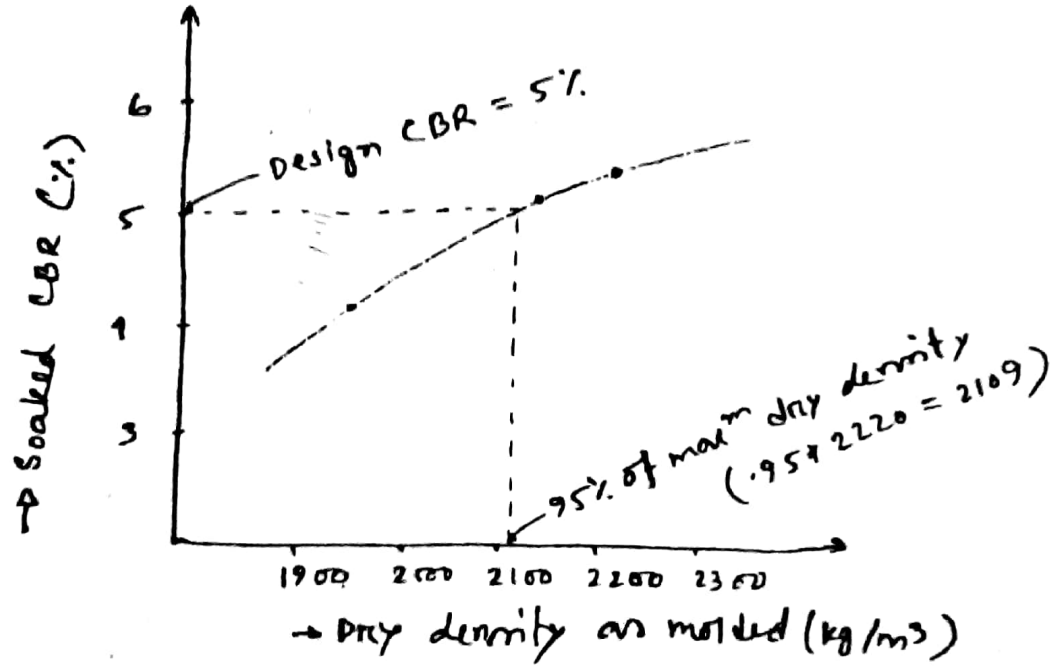
* Height is in mm.

* Stress - Strain Diagram:



From graph (Stress Vs Strain) $\frac{225}{6.9 \times 10^3} \times 100 = 3.26\%$

* 10, 30 & 65 blows এর সাথে 3টি CBR value পাওয়া যাবে, আর 5 kg sample এর জন্য আমরা dry density as molded বিবেচনা করি। তারপর তৈরি soaked CBR Vs dry density as molded plot করতে হবে। Then 95% of max^m dry density বরাবর offset টেনে design CBR বের করতে হবে।



CBR: It is the ratio of the force per unit area required to penetrate a soil mass, to the force required for a similar penetration of a standard crushed rock material.

$$CBR = \frac{\text{Corrected load} \leftarrow \text{(from stress Vs strain graph)}}{\text{Standard load}} \times 100\%$$

Test - 7: Marshall Method of mix design.

- To determine the optimum bitumen content (OBC) for designing the road pavement.

% of C.A. & F.A with respect to Filler Content

Filler	Coarse Aggregate	Fine Aggregate
4%	———	
5%	———	
6%	———	
7%	———	
8%	———	

Sample preparation: For filler 8%

Asphalt = 4.5%, 4.5% of 1300 gm = 58.5 gm

Wt of aggregate = 1300 − 58.5 = 1241.5 gm

	passing (in)		Retained (in)		% by weight		weight (gm)
C.A. − 52%	3/4	———	1/2	———	5	———	.955 * .52 * .05 * 1300 = 32.28 gm
	1/2	———	3/8	———	32	———	.955 * .52 * .32 * 1300 = 206.58 gm
	3/8	———	#4	———	37	———	.955 * .52 * .37 * 1300 = 239.86 gm
	#4	———	#10	———	26	———	.955 * .52 * .26 * 1300 = 167.85 gm
F.A − 40%	#10	———	#40	———	32	———	.955 * .40 * .32 * 1300 = 158.91 gm
	#40	———	#80	———	44	———	.955 * .40 * .44 * 1300 = 218.5 gm
	#80	———	#200	———	24	———	.955 * .40 * .24 * 1300 = 119.18 gm
Filler				———	8	———	.955 * .08 * 1300 = 99.32 gm
							Σ = 1241.48 gm

(100 − 4.5 = 95.5%)

ESAL	Traffic	Tamping (No)
$\leq 10^4$	Light	35
$10^4 \sim 10^6$	Medium	50
$> 10^6$	Heavy	75

* Stability: Stability of the test is the maximum load resistance in lb (Newton) that the standard test specimen will develop at 60°c when tested.

* Flow value: The flow value is the movement or strain in unit of $\frac{1}{100}$ in (0.25 mm) occurring in the specimen between no load and maximum load during stability test.

* According to RHD - Bitumen range for marshall test is (4.0 ~ 6.5)%.

- Bulk specific Gravity, $G_1 = \frac{W_a}{W_a - W_w}$

where, W_a = wt of test specimen in air
W_w = " " " suspended in water

- Unit wt = $(G * 62.4)$ lb/ft^3

- Theoretical max^m specific gravity

$$G_t = \frac{100}{\frac{W_1}{g_1} + \frac{W_2}{g_2} + \frac{W_3}{g_3} + \frac{W_4}{g_4}}$$

where,

Sp gr. of C.A $g_1 = 2.60$
Sp. gr. of F.A $g_2 = 2.65$
Sp gr. of Filler, $g_3 = 2.80$
Sp. gr. of Asphalt, $g_4 = 1.0$

$W_1 = .955 * 5.2$
$W_2 = .955 * 40$
$W_3 = .955 * 8$
$W_4 = 4.5$

* Determine VMA & VFA for the following data.

$W_a = 3041.2$ gm, $W_W = 1713.2$ gm, $W_5 = 56\%$, $W_6 = 30\%$,

$W_7 = 7\%$, $g_1 = 2.61$, $g_2 = 2.69$, $g_3 = 3.10$.

Soln:

Bulk sp. gr. of mixture, $G_1 = \dfrac{W_a}{W_a - W_W} = 2.29$

Here, $W_4 = (100 - 56 - 30 - 7) = 7\%$.

∴ Sp. gr. of mineral aggregate, $G_a = G\left(1 - \dfrac{W_4}{100}\right)$

$= 2.29\left(1 - \dfrac{7}{100}\right) = 2.13$

Theoretical max^m sp. gr. of mineral aggregate.

$$G_{ta} = \frac{W_5 + W_6 + W_7}{\frac{W_5}{g_1} + \frac{W_6}{g_2} + \frac{W_7}{g_3}}$$

$$= \frac{93}{\frac{56}{2.61} + \frac{30}{2.69} + \frac{7}{3.10}} = 2.67.$$

∴ VMA (%) $= \dfrac{G_{ta} - G_a}{G_{ta}} \times 100 = 20.22\%$.

∴ VFA (%) $= \dfrac{VMA - V_a}{VMA} \times 100$ | $V_a = 3.79\%$.

$= 81.26\%$

Ans

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Traffic volume Study

* **Volume/Flow:** The total number of vehicles that pass over a given point or section of a lane or roadway during a given time interval.

* **Rate of flow:** The equivalent hourly rate at which vehicles pass over a given point or section of a lane or roadway during a given time interval less than 1 hr, usually 15 min.

* **Average daily Traffic (ADT):** The volume during a given time period (greater than 1 day but less than 1 year) divided by the number of days in that time period and expressed in terms of veh/day or vpd.

* **Average annual daily traffic (AADT):** It is the total yearly volume divided by the number of days in a year and expressed in terms of veh/day.

Factor Approach to determine ADT & AADT:

a. Hourly expansion factors, $HEF = \frac{\text{total 24-hr volume}}{\text{vol. for particular hr.}}$

These factors are used to expand counts of durations shorter than 24-hr to 24-hr vol.

b. Daily expansion factors, $DEF = \frac{\text{Avg. total weekly vol.}}{\text{Avg. vol. for particular day}}$

These factors are used to determine weekly volume from counts of 24-hr duration.

c. Monthly expansion factors, $MEF = \frac{AADT}{\text{ADT for particular month}}$

These factors are used to determine AADT from the ADT for a given month.

* A traffic engineer urgently needs to determine AADT on a rural primary road that has the volume distribution characteristics shown below. The engineer collected data shown below on a thursday during the month of may.

Hour	volume	HEF
7 – 8 am	400	28.99
8 – 9 am	535	22.05
9 – 10 am	650	18.8
10 – 11 am	710	17.11
11 – 12 pm	650	18.52

DEF = 7.727 for thursday

MEF = 1.395 for May

Soln: 24-hr vol. $= \frac{400 \times 28.99 + 535 \times 22.05 + 650 \times 18.8 + 710 \times 17.11 + 650 \times 18.52}{5}$

$= 11960$

Total 7-day vol. $= 11960 \times 7.727 = 92415$

$\therefore$ ADT (Avg. 24-hr vol^{m}) $= \frac{92415}{7} = 13202$

$\therefore$ AADT $= 13202 \times 1.395 = 18417$

* For an urban highway with an ADT of 20000 vehicle/day, determine DHV (Design hour vol^{m}) for the peak direction of flow.

Ans

Soln:

JOB-13

DHV = ADT × D × K

= 20000 × 0.55 × 0.1

= 1100 veh/hr

Ans:

ADT = 20000 veh/day

Directional distribution factor,

D = 55% to 80%.

for urban road, D = 55%

K = 10%.

Note: Directional Design hour volume = AADT × D × K

* spot speed data were collected at a section of highway during and utility maintenance work. The speed characteristics are given below. Determine whether there was any significant difference between the average speed at the 95% confidence level.

$u_1 = 35.5$ mph, $u_2 = 38.7$ mph, $S_1 = 7.5$ mph, $S_2 = 7.4$ mph

$n_1 = 250$, $n_2 = 280$

Soln:

$$S_d = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} = 0.65 \text{ mph}$$

$Z_{critical} = 1.96$ at 95% confidence level

$$Z = |u_1 - u_2| / S_d$$

$$= \frac{|35.5 - 38.7|}{0.65} = 4.92$$

As $Z > Z_{critical}$, it can be concluded that the difference in mean speeds is significant at 95% confidence level.

* ESAL Calculation:

Axle load ①	Avg ②	EWLF ③	No of axle in design period ④	ESAL ③×④
14-18	16	$(16/18)^9$	8.09×10^6	5.02×10^6
18-22	20	$(20/18)^9$	1.407×10^6	2.14×10^6
22-26	24	$(24/18)^9$	6.2×10^6	1.96×10^7
26-30	28	$(28/18)^9$	3.01×10^5	1.76×10^6

Total no. of ESAL, $\Sigma = 2.85 \times 10^7$

* Standard axle: Axle used for design & all other axle will convert to that axle.

Standard axle load = 18 kip (80kN)

* An engineer is checking the speed characteristics. Confidence level 90%, acceptable limit 1 Km/h and 130 spot speed variance 25 (Km/hr). Has the engineer meet the entire requirement?

Soln:

$$N = Z^2 \times \frac{S}{e^2}$$

$$= 1.64^2 \times \frac{25}{1^2}$$

$$= 67 < 130$$

$Z = 1.64$ for 90% confidence level from graph

$S = 25$ km/hr

$e = 1$ km/hr

So. Engineer meets the requirement Ans:

confidence level	Z
90%	1.64
95%	1.96
98%	2.33
99%	2.58

* Two-lane two-way highway street having ADT 4000. If the commercial vehicle is 45% and loads 27K. Then calculate ESAL for commercial vehicle in one direction.

Soln:

ESAL for commercial vehicle $= \left\{\left(\frac{27}{18}\right)^4 * 0.45 \times ADT\right\} / 2$

$= 4556.$

Ans.

* Determine the total cost of highway transportation and unit cost of transportation if annual cost of highway is 20000 tk annual cost of vehicle operation (single vehicle) is 4000 tk with total vehicle 100 nos on the road per year also length of highway is 1000 km?

Soln. Total cost, $A = B + CN$

$= 20000 + 4000 \times 100$

$= 420000$ tk. Ans.

unit cost $= \frac{A}{NL}$

$= \frac{420000}{100 \times 1000}$

$= 4.2$ tk/km/vehicle/year Ans.

* Mode split Models: Mode split models predict the number of travelers who will choose one mode over others for making a particular trip. Also called individual choice model / mode choice model.

The utility of individual modes –

$$U_{auto} = 1 - 0.1(TT_{auto}) - 0.05\ (TC_{auto})$$

$$U_{bus} = -0.1\ (TT_{bus}) - 0.05\ (TC_{bus})$$

$$U_{walk} = -0.5 - 0.1\ (TT_{walk})$$

Where,

TT = travel time by mode in minutes.

TC = travel cost by mode in dollars.

The probability of individual t choosing mode i by Logit model –

$$P_{it} = \frac{e^{U_{it}}}{\sum_{\text{All } j} e^{U_{jt}}}$$

Where, P_{it} = probability of individual t choosing mode i

U_{it} = Utility of mode i to individual t

U_{jt} = " " " j to " t

* There are 1000 trips being made between zones i & j. Three modes are available to make their trip. Find the utility of the individual modes. Travel time for auto 5 mins, for bus 15 mins, for walking 20 mins. Costs for auto & bus are $0.60, $0.50. Also find the probabilities for the mode.

Soln:

$$U_{auto} = 1 - 0.1\,(TT_{auto}) - 0.05\,(TC_{auto})$$

$$= 1 - 0.1 \times 5 - 0.05 \times 0.60$$

$$= 0.47$$

$$U_{bus} = -0.1\,(TT_{bus}) - 0.05\,(TC_{bus})$$

$$= -0.1 \times 15 - 0.05 \times 0.5$$

$$= -1.525$$

$$U_{walk} = -.5 - 0.1\,(TT_{walk})$$

$$= -0.5 - 0.1 \times 20$$

$$= -2.5$$

$$P_{auto} = \frac{e^{0.47}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.842$$ → means 84.2% people use auto.

$$P_{bus} = \frac{e^{-1.525}}{e^{.47} + e^{-1.525} + e^{-2.5}} = 0.115$$

$$P_{walk} = \frac{e^{-2.5}}{e^{.47} + e^{-1.525} + e^{2.5}} = 0.043$$

Trips made by auto = 842

Trips made by bus = 115

Trips made by walk = 43

Gravity model

* Given, no of trips = 33

Shopping center	Floor space	distance (km)
1	184 ft² × 1000	8
2	215 ft² × 1000	4
3	86000 ft²	5

Soln:- Trips from zone i to shopping center 1

$$= \frac{\frac{184000}{8^2}}{\frac{184000}{8^2} + \frac{215000}{4^2} + \frac{86000}{5^2}} \times 33$$

$$\simeq 4.8 \simeq 5 \text{ trips}$$

Trips from zone i to shopping center 2 $= \frac{\frac{215}{4^2}}{\frac{184}{8^2} + \frac{215}{4^2} + \frac{86}{5^2}} \times 33$

$$= 22.45 \simeq 22 \text{ trips}$$

Trips from zone i to shopping center 3 $= \frac{\frac{86}{5^2}}{\frac{184}{8^2} + \frac{215}{4^2} + \frac{86}{5^2}} \times 33$

$$\simeq 6 \text{ trips}$$

Any.

* What is the purpose of zebra-crossing?

Ans: Zebra crossings are the marking on the road with alternatively black & white strips.

- These markings warn drivers that there may be pedestrians on the roads.
- These markings tell drivers that they must give way to pedestrian on the crossing.

DB-12/

* A directional sign is needed. Highway turn-off 85th percentile speed is 50 mph, vehicle turn at design speed is 25 mph, can travel at 50 mph during perception and reaction time, during perception and reaction time is 1.5 sec to read & understand the sign and deaccelerate and on breaking at 0.3 g. What is the minimum distance the direction sign should be placed in advance of the turn off?

BUET-16

Soln:

$$S = 1.47\,Vt + \frac{v^2 - u^2}{30f}$$

$$= 1.47 * 50 * 1.5 + \frac{50^2 - 25^2}{30 * .3}$$

$$= 318.58 \text{ ft}$$

* The utility values for bus, car & walk 2.3, 2.1, −3.4 respectively. Using logit model, find the mode share percentage.

Soln:

DUET-16

$$\%\ \text{bus} = \frac{e^{2.3}}{e^{2.3} + e^{2.1} + e^{-3.4}} = .5488$$

$$= 54.88\%$$

$$\%\ \text{Car} = \frac{e^{2.1}}{e^{2.3} + e^{2.1} + e^{-3.4}} = .4493$$

$$= 44.93\%$$

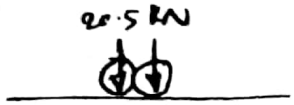
$$\%\ \text{Walk} = \frac{e^{-3.4}}{e^{2.3} + e^{2.1} + e^{-3.4}} = 8$$

$$= 0.18\%$$

Ans.

* Two close wheels imparted 20.5 KN load each on road. The pressure was determined as 0.7 MPa. If the two wheel is replaced by a single wheel of same property, find out the imparted effective diameter on soil (by considering circular imparted effect) by single wheel.

Soln:



Total load = 20.5 + 20.5
= 41 KN

Pg-CB-18

$$\text{Area} = \frac{P}{\text{stress}}$$

$$\Rightarrow \frac{\pi}{4} D^2 = \frac{41 \times 10^3}{.7 \times 10^6} \Rightarrow D = 0.27 \text{ m}$$

Md. Miraz Gazi
Roll: 1201032

"Railway Engineering"

Rail Gauges:

* **Gauge of a Track:** The gauge of a railway track is defined as the clear minimum perpendicular distance between the inner faces of the two rails.

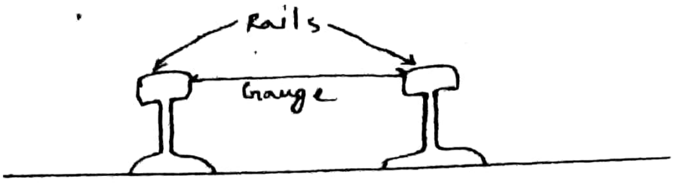


Fig: Gauge

* **Types of gauge:**

1) Broad Gauge – width 1676 mm to 1524 mm
2) Standard Gauge – width 1435 mm to 1451 mm.
3) Metre Gauge – width 1067 mm, 1000 mm & 915 mm.
4) Narrow Gauge – width 762 mm & 610 mm

* If gauge in a country is not uniform, what problems arises?

Ans: **problems:**

1) Difficulties to passengers – need to change train.
2) Difficulties for sending goods – train change-এর সময় অতিরিক্ত labour লাগে, platform লাগে, সময় বেশি, মালের ক্ষতি হয়।
3) Difficulty in war – gauge uniform না হলে army এক স্থান থেকে অন্য স্থানে দ্রুত সময়ে নেওয়া যায় না।
4) Equipment at station – যেখানে gauge change হয় সেখানে— Platform, sanitary arrangement, clock, ticket office লাগে।

Factors affecting choice of a gauge:

① Traffic Condition ② cost of track ③ Nature of terrain
④ speed of movement ⑤ Development of poor Area.

Rail: Rails are similare to steel girders which spread the high pressure Load imposed by the train wheels into the ground.

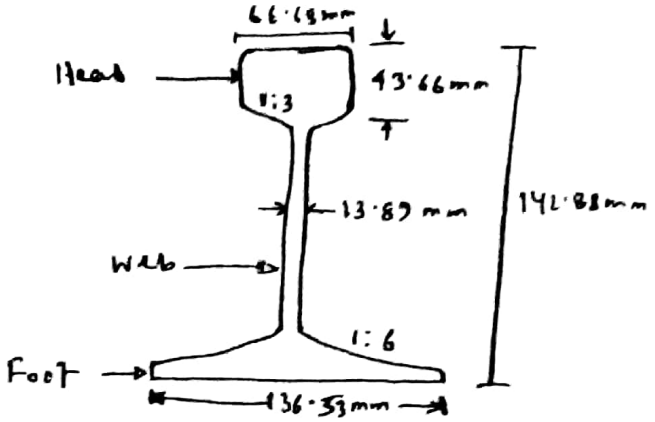
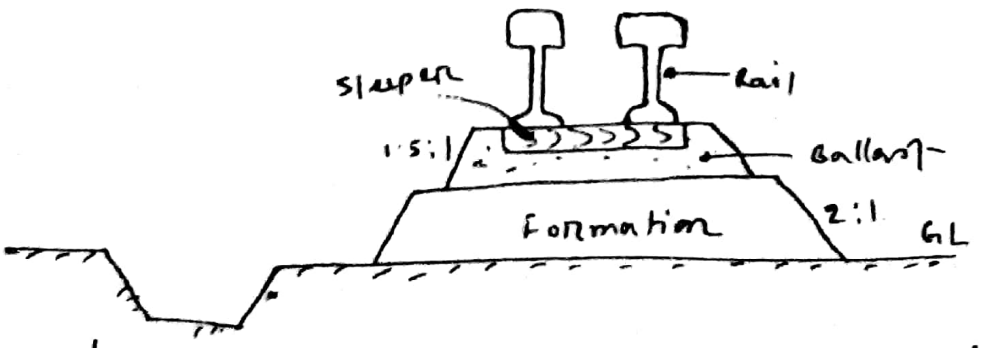


Fig: Flat footed Rail

Function of a rail:

- provide a continuous & level surface.
- serve as a lateral guide for the wheels.
- to transmit load to the sleepers.
- to reduce pressure on ballast and formation.

permanent way (Railway track): The finished or completed track of a railway line is commonly known as the permanent way.



- Air void, $V(\%) = \frac{G_t - G}{G_t} * 100\%$
- specific gravity of mineral aggregate

$$G_a = G\left(1 - \frac{w_4}{100}\right)$$

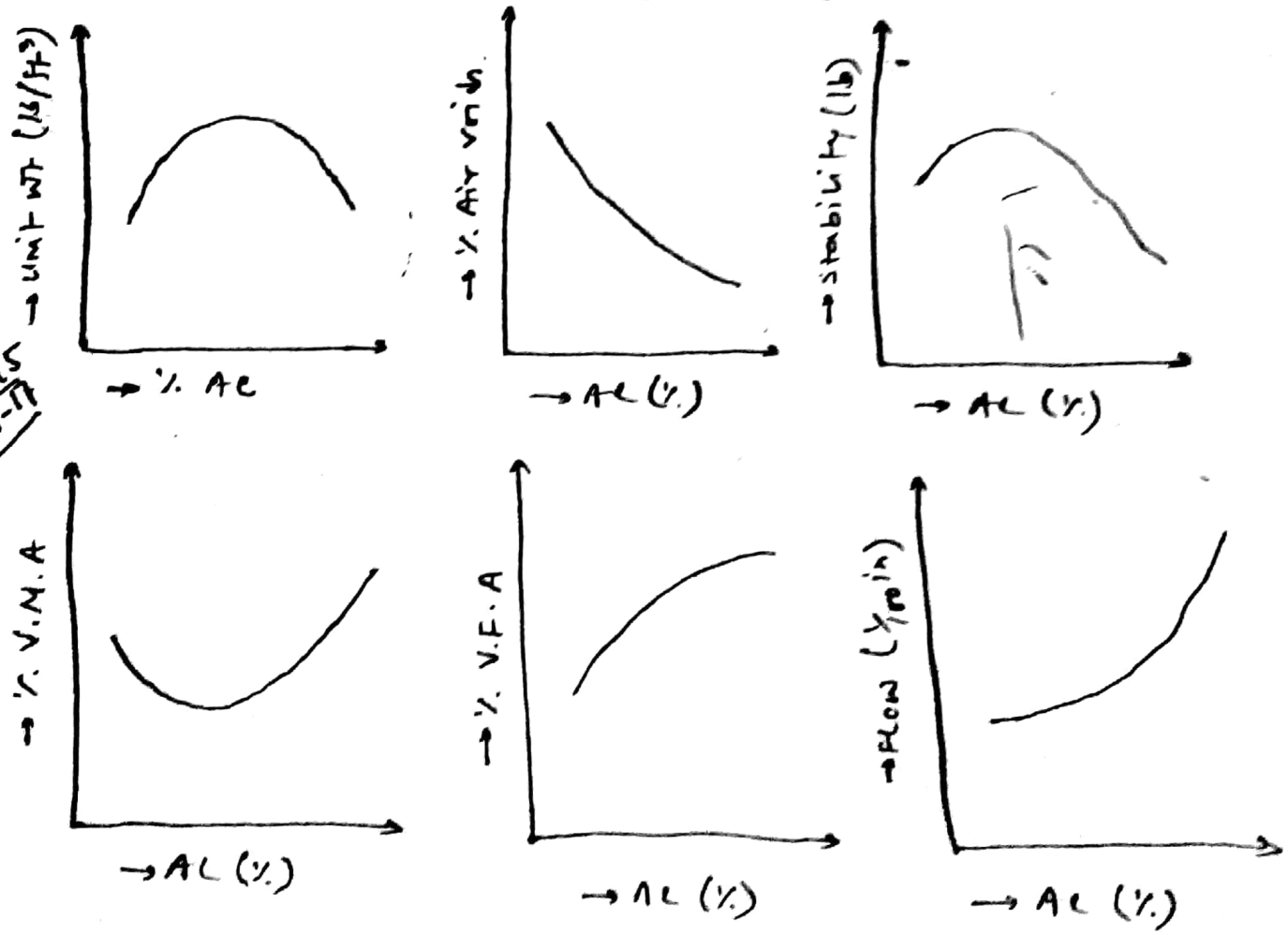
- Theoretical maximum sp. gr. of mineral agg.

$$G_{ta} = \frac{100}{\frac{w_5}{g_1} + \frac{w_6}{g_2} + \frac{w_7}{g_3}}$$

where, $w_5 = 52$, $w_6 = 40$, $w_7 = 8$.

- voids in mineral aggregate, $V.M.A(\%) = \frac{G_{ta} - G_a}{G_{ta}} * 100$
- voids filled with Asphalt, $V.F.A(\%) = \frac{V.M.A - V}{V.M.A} * 100$.

* Draw the qualitative diagram of marshall test.



ICE-15
D.WASA-IT

Fig: Test property curve by Marshall Method.

Test of aggregate:

1. Sp. gr. test
2. Unit wt test.
3. Water absorption test.
4. Flakiness index test.
5. Elongation index test.
6. Impact value test.
7. Abrasion test
8. Sieve Analysis.
9. Crushing strength test.
11. Durability test.

Design property of aggregate:

1. Strength
2. Shape and texture
3. Grading
4. porosity
5. Durability
6. Crushing property

* Determine the suitable rail section for a locomotive to carry axle load of 22.5 tonnes.

Soln:

Axle load of locomotive in tonnes = 512.06 × Wt. of rail in tonnes.

$\Rightarrow$ Wt. of rail in tonnes = $\frac{22.50}{512.06}$

= 0.04394 tonnes

= 43.94 kg

Add 5% for rail wear.

∴ Total = 43.94 + 5% of 43.94

= 43.94 + 2.20

= 46.14 kg Ans.

Force in a rail per degree change of temperature, P:

$$P = E A \alpha$$

where,

E = Modulus of elasticity of steel

= 2×10^6 kg/cm²

A = cross sectional area of rail

= 66.15 cm² for 52 kg/m rail.

α = Co-efficient of expansion of steel

= 1.2×10^{-5} /°C

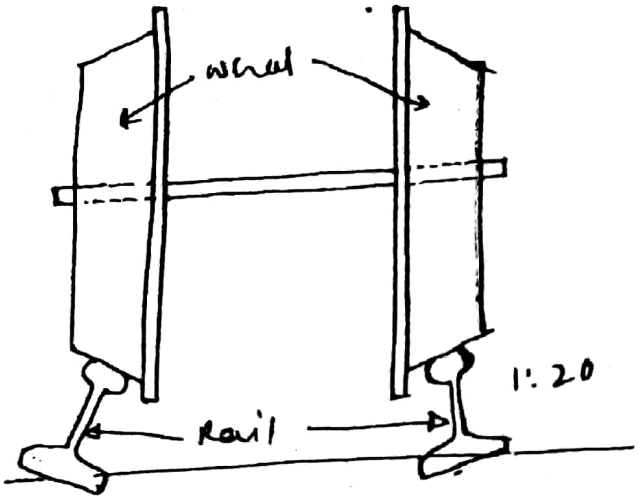
∴ $P = 2 \times 10^6 \times 65.15 \times 1.2 \times 10^{-5}$

= 1587.6 kg/°C

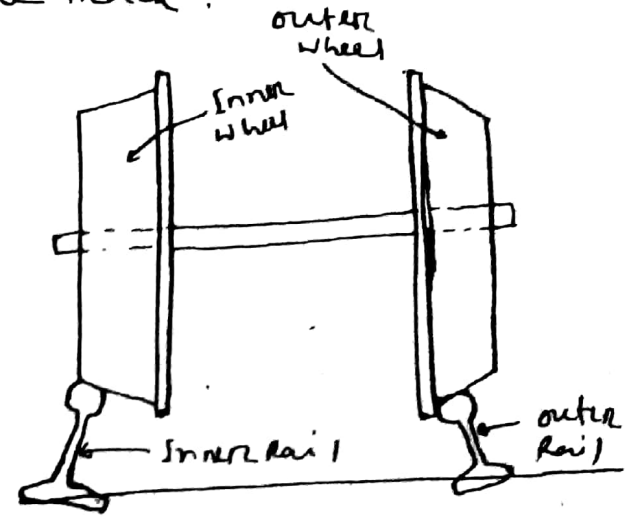
= 1.6 ton/°C

Ans.

Coning of Wheels: The act of providing an outward slope of 1 in 20 to treads of wheel is known as coning of wheel. It is mainly done to maintain the vehicle in central position with respect to the track.



a) Behaviour of wheels on level track.



b) Behaviour of wheels on curves.

Sleeper: Sleepers are those which support the rail and maintain the gauge of the track correctly.

2 Types —

① Longitudinal sleeper

② Transverse sleeper.

* Find out the number of sleepers for rails of 12.8 m length with sleeper density as $(n+3)$

Soln: Nos of sleeper $= n+3 = 12.8+3 = 15.8 \simeq 16$ Nos

Ans.

Sleeper density:

For B.G. $= n+7$

For M.G. $= n+3$

Ballast: The material placed in between the sleepers and the top of the formation is known as ballast.

Depth of Ballast:

$$\text{Depth of ballast, } D = \frac{S-B}{2}$$

S = sleeper spacing
B = width of sleepers.

Expansion Gap of rail:

$$e = L\alpha t.$$

where, e = expansion gap in mm
L = length of rail in mm
t = change in temp. (°c)
α = co-efficient of expansion of steel
$= 1.2 \times 10^{-5}$ /°c

* Calculate the width of actual expansion gap to be provided for a rail of 12.80 m length maximum rail temperature is 70°c and the temp. at the time of linking is 40°c.

Soln: $e = L\alpha t$

$= 12.8 \times 10^3 \times 1.2 \times 10^{-5} \times 30$

$= 9.61 \text{ mm} \simeq 10 \text{ mm}$.

$L = 12.8 \text{ m} = 12.8 \times 10^3 \text{ mm}$
$\alpha = 1.2 \times 10^{-5}$ /°c
$t = 70 - 40 = 30$°c

∴ Actual expansion gap = 10 mm

Ans.

* Calculate the materials required per unit length of track. Given that, rail length = 12.80 m, sleeper density (n+3).

Soln:

① Number of Rail per km:

$$\text{Nos. of rail per km} = \frac{1000}{\text{length of rail}} \times 2$$

$$= \frac{1000}{12.8} \times 2 \simeq 157 \text{ Nos.}$$

Wt. of rails per km = No. of rails x length of Rail x Wt of rail per metre.

Let, Wt of rail = 45 kg/m

$$\therefore \text{Wt of rail/km} = 157 \times 12.8 \times 45$$

$$= 90432 \text{ kg.}$$

② Nos. of Sleepers:

$$\text{Nos. of Sleeper/km} = \frac{\text{No. of rails/km}}{2} \times (n+3)$$

$$= \frac{157}{2} (12.8+3)$$

$$\simeq 1241 \text{ Nos.}$$

③ Nos. of fish-plates /km of track:

Rail-ের joint সংখ্যা

$$= 2 \times \text{No. of rails/km of track}$$

$$= 2 \times 157 = 314$$

④ Nos. of fish-bolts /km of track:

fish plate-এ ৪ (4) টি bolt হয়।

$$= 4 \times 157 = 628$$

⑤ No. of bearing plates /km of track:

Sleeper এর নিচে Rail-এর fish plate থাকে।

$$= 2 \times \text{No. of sleepers/km of track}$$

$$= 2 \times 1241 = 2482$$

⑥ Nos of dog-spikes/km of track:

= 4 × Nos. of sleepers/km of track

= 4 × 1241 = 4964

Ans.

Diversion:

$$l = \sqrt{p^2 + 4rd - d^2} + q/2$$

$$t = \frac{rd}{l - q/2 + p}$$

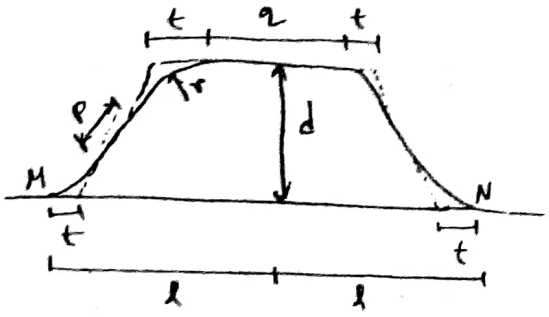


Fig: Diversion

Total diversion length

$$= 2\left(4t + p + q/2\right)$$

where, l = length of half diversion

t = length of tangent

r = radius of curves.

p = length of straight between curves.

q = straight portion of diversion

d = max^m distance of diversion from the alignment.

* A B.G. main line is to be diverted in case of an emergency for carrying out long duration repair works. If the diversion is to be kept at a distance 15m away from the main track, calculate 1) the length of diversion along the original alignment and 2) the total diversion length along the curve. Assume, radius of curve 450m, length of straight between curve as 30.5m and straight portion of diversion as 30m.

Soln:

1) $l = \sqrt{p^2 + 4rd - d^2} + q/2$

$= 181.50$ m

$p = 30.5$m
$r = 450$ m
$d = 15$m
$q = 30$m

∴ Length of diversion along original alignment $= 2l$

$= 363$m Ans.

2) $t = \frac{\gamma d}{1 - \frac{q}{2} + P} = \frac{4.50 \times 15}{181.5 - \frac{30}{2} + 30.5} = 34.26\ m$

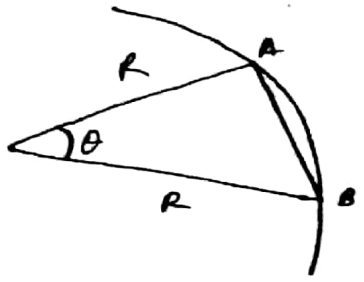
Total length of diversion $= 2\left(4t + P + \frac{q}{2}\right)$

$= 2\left(4 \times 34.26 + 30.5 + \frac{30}{2}\right)$

$= 365.08\ m$ Ans.

#Degree of curve:

$R = \frac{1719}{\theta}$ in m.



* The vertical curves are provided at the junction of grades when the algebraic difference between the grades is equal to or more than 4 mm/m or 0.40%.

* A rising grade of 1 in 100 meets a rising grade of 1 in 200. Will it be necessary to provide the vertical curve?

Soln: Rising grade 1 in 100 = 10 mm/m

" " 1 in 200 = 5 mm/m

∴ Algebraic difference = (10 - 5)

= 5 mm/m > 4 mm

So, Vertical curve will have to be provided.

Transition Curve:

$$Y = \frac{x^3}{6RL}$$

where,

Y = perpendicular offset of transition curve at a distance x from starting of the curve.

X = Distance of any point on the tangent from starting of the curve

R = Radius of circular curve.

L = Total length of transition curve.

Length of transition curve:

(1) $L = 7.20e$

(2) $L = 0.073 D \times V_{max}$

(3) $L = 0.073e \times V_{max}$

} → Take the maximum one.

where,

L = Length of transition curve in m

e = Actual super-elevation / cant in cm

D = Cant deficiency for maximum speed in cm

V_{max} = max^m speed in km/h

Shift:

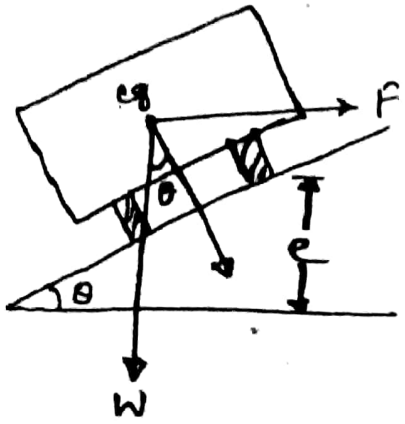
$$\text{Shift, } S = \frac{L}{24R}$$

where,

L = Length of transition curve

R = Radius of circular curve.

Super-elevation / Cant:



W = Wt. of train
v = velocity of train, m/s
f = centrifugal force
g = acceleration due to gravity
R = Radius of curvature, m
G = Gauge of the track, m
θ = Angle of inclination
e = Super-elevation

The centrifugal force, $f = \frac{Wv^2}{gR}$

$$\tan\theta = \frac{\text{Super-elevation}}{\text{Gauge}} = \frac{e}{G}$$

Again, $$\tan\theta = \frac{\text{centrifugal force}}{\text{weight}}$$

$$\therefore \frac{e}{G} = \frac{F}{W}$$

$$\Rightarrow e = \frac{Wv^2}{gR \times W} \times G$$

$$\therefore e = \frac{Gv^2}{gR}$$

For B.G., G = 1.676 m
For M.G, G = 1.0 m
For N.G, G = 0.762 m

Check for speed of trains on curves:

For B.G. and M.G., $V = 4.4\sqrt{R-70}$

For N.G., $V = 3.6\sqrt{R-6}$

Where,

V = max^m speed in km/h

R = Radius of curve in m

* A transition curve is to be used to join the ends of a 3.94° circular curve with the straight. The length of the transition curve is 120 m. Work out the shift and offsets at every 30 m interval.

Soln: $R = \frac{1719}{3.94} = 437$ m

$S = \frac{L}{24R} = \frac{120}{24 \times 437} = 1.37$ m

offset at 30 m, $Y_1 = \frac{x^3}{6RL} = \frac{30^3}{6 \times 437 \times 120} = 0.0858$ m

" " 60 m, $Y_2 = \frac{60^3}{6 \times 437 \times 120} = 0.6865$ m

" " 90 m, $Y_3 = \frac{90^3}{6 \times 437 \times 120} = 2.317$ m

" " 120 m, $Y_4 = \frac{120^3}{6 \times 437 \times 120} = 5.492$ m

* Find out the length of transition curve for a B.G. curve of three degree, having a cant of 10 cm. The maximum permissible speed on the curve is 80 Kmph and allowable cant deficiency is 75 mm.

Soln: Here, $e = 10\,cm$, $D = 7.5\,cm$, $V_{max} = 80\,Km/h$

(1) $L = 7.2e = 7.2 \times 10 = 72\,m$

(2) $L = 0.073\,D \times V_{max}$

$= 0.073 \times 7.5 \times 80 = 43.80\,m$

(3) $L = 0.073\,e \times V_{max}$

$= 0.073 \times 10 \times 80 = 58.40\,m$

$\therefore$ Length of transition curve $= 72\,m$ Ans.

* A 6° curve branches off from a 3° main curve in an opposite direction in the layout of a B.G. yard. If the speed on the branch line is restricted to 35 km/h, determine the speed restriction on the main line. Assume, permissible deficiency in cant as 75 mm.

Soln: $R = \frac{1719}{6} \simeq 287\,m$ for branch line

$G = 1.676\,m$ for B.G., $V = 35\,Km/h = 9.72\,m/s$

Super-elevation for branchline $= \frac{GV^2}{gR}$

$= \frac{1.676 \times 9.72^2}{9.81 \times 287}$

$= 0.05624\,m$

$= 5.624\,cm$

$\therefore$ Negative super-elevation $= 5.624 - 7.5$

$= -1.876\,cm$

Max^m S.E. can be given on main line = 1·876 cm

Theoretical S.E. on main line = 7·5 + 1·876

= 9·376 cm

$\therefore e = \frac{GV^2}{gR}$

$\Rightarrow 0.09376 = \frac{1.676 \times V^2}{9.81 \times 573}$

$R = \frac{1719}{3}$ = 573 m for main line

$\Rightarrow V = 17.73$ m/s = 63·83 km/h

Ans.

* Work out the maximum speed of a train on a B.G. track having a curvature of three degrees and cant of 10 cm. Assume, allowable cant deficiency as 75 mm.

Soln: $R = \frac{1719}{3} = 573$ m, $G = 1.676$ m

Theoretical super-elevation = cant + deficiency

= 10 + 7·5

= 17·5 cm = 0·175 m

$\therefore S.E. = \frac{GV^2}{gR}$

$\Rightarrow V = \sqrt{\frac{0.175 \times 9.8 \times 573}{1.676}}$ = 24·21 m/s

= 87·15 km/h.

Check:

$V = 4.4\sqrt{R - 70}$

$= 4.4\sqrt{573 - 70}$

= 98·68 km/h

$\therefore$ Max^m permissible speed = 87·15 km/h

Ans.

* What should be the equilibrium cant on a M.G. curve of five degrees for an average speed of 60 km/h? Also find out the maximum permissible speed allowing the maxm cant deficiency.

Soln: G = 1.0 m for M.G. V = 60 km/h = 16.67 m/s.

$$R = \frac{1719}{5} = 343.80 \text{ m}$$

$$SE = \frac{GV^2}{gR} = \frac{1 \times (16.67)^2}{9.8 \times 343.8} = 0.0825 \text{ m}$$ Ans

∴ Theoretical cant = 0.0825 + 0.075
= 0.1575 m

$$SE = \frac{GV^2}{gR}$$

$$\Rightarrow V = \sqrt{\frac{0.1575 \times 9.8 \times 343.8}{1}}$$

= 23.04 m/s = 82.93 km/h.

Check:

$$V = 4.4\sqrt{R - 70}$$

$$= 4.4\sqrt{343.8 - 70} = 72.81 \text{ km/h}$$

∴ Maxm permissible speed 72.81 km/h Ans.

* What should be the equilibrium cant on a B.G. curve of two degrees for an speed of 80 km/h? If the max^m permissible speed of train 100 km/h, then is the train safe on its movement? cant deficiency = 75 mm.

Soln: G = 1.676 m, v = 80 km/h = 22.22 m/s

$$R = \frac{1719}{2} = 859.5 \text{ m}$$

$$\therefore SE = \frac{GV^2}{9R} = \frac{1.676 \times 22.22^2}{9.81 \times 859.5} = 0.098 \text{ m}$$ Ans:

$\therefore$ Theoretical S.E = 0.098 + 0.075
= 0.173 m

$$\therefore S.E. = \frac{GV^2}{9R}$$

$$\Rightarrow V = \sqrt{\frac{0.173 \times 9.81 \times 859.5}{1.676}} = 29.5 \text{ m/s}$$

= 106.2 km/h > 100 km/h.

So, the train is safe on its movement. Ans.

* If the ruling gradient is 1 in 200 on a particular section of B.G. and if a curve of 4 degrees is situated on this ruling gradient, what should be the actual ruling gradient?

Soln: Let, grade compensation on B.G. = 0.04% /°c of curve.

$\therefore$ Compesation allowed = 0.04 × 4 = 0.16%

1 in 200 = 0.5% → $\left(\frac{1}{200} \times 100\right)$

Actual gradient = 0.5 − 0.16 = 0.34%

= 1 in 294 → $\left(\frac{1}{.34} \times 100\right)$

Ans.

widening gauge on curves:

$$d = \frac{(B+L)^2 \times 125}{R}$$

$$L = 2\sqrt{(D+h)h}$$

where, d = Extra width of gauge in mm
B = Rigid wheel base in m
L = Lap of flange in m
R = Radius of curve in m
D = Dia of wheel in mm
h = Depth of wheel flange below rail in mm

* The wheel base is 4.724 m of a vehicle moving on a B.G. The diameter of wheels is 1524 mm and the flange project 32 mm below top of rail. Determine the extra width of flange if radius of curve is 168 m.

Soln:

$$L = 2\sqrt{(D+h)h} = 2\sqrt{(1524+32)32} = 446 \text{ mm} \simeq 45 \text{ cm}$$

$\therefore B+L = 4.724 + 0.45 = 5.174$ m.

$$\therefore d = \frac{(B+L)^2 \times 125}{R} = \frac{5.174^2 \times 125}{168} \simeq 20 \text{ mm}$$

Ans

Locomotive: It is a machine which transfers the chemical energy of a fuel into the mechanical energy of motion.

* Resistance due to friction & wave action = $0.0016W + 0.00008WV$
* Resistance due to curve:
  - For B.G.: Curve resistance = $0.0004W \times$ degree of curve
  - For M.G.: Curve resistance = $0.0003W \times$ degree of curve
  - For N.G.: Curve resistance = $0.0002W \times$ degree of curve.
* Resistance due to gradient = $\frac{1}{\text{rate of grade}} \times W$

Where, W = weight of train

* Resistance due to speed of the train = $0.00006\ V^2 W$

V = speed in km/h

* Workout a gradient for a broad gauge railway line such that the grade resistance together with curve resistance due to a curve of four degrees shall be equal to the resistance due to a rauling gradient of 1 in 150.

Soln: Let, W = Wt of train

1 in x = required gradient.

Grade resistance = $\frac{1}{x} \times W$

Resistance due to rauling gradient = $\frac{1}{150} \times W$

Curve resistance of 4° = $(0.0004 \times 4 \times W)$

↓ grade compensation - 0.04% / ° of curve

Hence,

$$\frac{1}{x} \times W + 0.0004 \times 4 \times W = \frac{1}{150} \times W$$

$\Rightarrow x \simeq 200$

∴ Required gradient 1 : 200 Ans.

* Calculate the steepest gradient on a straight track from the following data -

Nos. of wagons = 26, Wt of one wagon = 20 tonnes.

Rolling resistance of wagon = 2 kg / tonne.

speed of train = 50 km/h, Wt of locomotive with tender = 180 tonnes, Tractive effort of locomotive = 15 tonnes, Rolling resistance of locomotive = 3 kg/tonnes.

velocity resistance = $0.0016 v^2$ kg / tonne Wt of train

where v is the velocity in km/h.

Soln:

Total wt of train = Wt of locomotive with tender + Wt of wagon

= 180 + (26 × 20)

= 700 tonnes.

Rolling resistance of wagon = $(2 \times 20) \times 26$

$= 1040$ kg

" " of locomotive = 3×180

$= 540$ kg

∴ Total rolling resistance = $1040 + 540$

$= 1580$ kg

$= 1.58$ tonnes.

velocity resistance = $0.0016 \times 50^2 \times 7.50$

$= 2800$ kg

$= 2.8$ tonnes.

Let, steepest gradient = 1 in x

Train resistance = Rolling resistance + Resistance due to speed + Resistance due to gradient

$= 1.58 + 2.8 + \frac{1}{x} \times 750$

$= 4.38 + \frac{750}{x}$

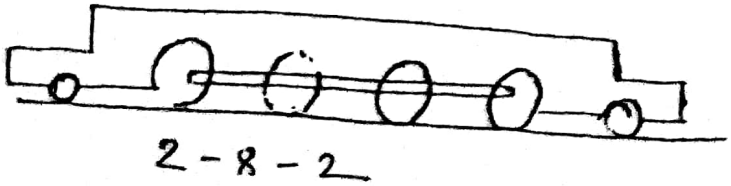
Hence, $4.38 + \frac{750}{x} = 15$

$\Rightarrow x = 66$

∴ steepest gradient 1 in 66

Ans.

* A locomotive shown in fig. is required to haul a train at 80 km/h. The axle load of the driving wheels of the engine is 22.50 tonnes. The train is to run on a straight level track. Find the maximum permissible train load that the engine can pull. If the train climbs a gradient of 1 in 200, how much of the speed should be reduced?



2-8-2

Soln: Let, 1 pairs of wheel (figure)

Hauling capacity of locomotive = $\frac{1}{6}$ times the load on driving wheels.

∴ Hauling capacity of locomotive = $\frac{1}{6} \times 4 \times 22.5$

= 15 tonnes.

Train resistance = resistance due to friction & wave action + resistance due to speed

$$0.0016W + 0.00008 \cdot WV + 0.0000006\, V^2 W$$

$$\therefore 0.0016W + 0.00008\, WV + 0.0000006\, V^2 W = 15$$

$$0.0016W + 0.00008W \times 80 + 0.0000006 \times 80^2 \times W = 15$$

$$\therefore W = 12.67 \text{ tonnes} \quad \underline{\text{Ans.}}$$

Again,

$$0.0016W + 0.00008WV + 0.0000006\, V^2 W + \frac{1}{200} \times W = 15$$

$$\Rightarrow 0.0016 \times 12.67 + 0.00008V \times 12.67 + 0.0000006\, V^2 \times 12.67 + \frac{1}{200} \times 12.67 = 15$$

$$\Rightarrow V = 48.12 \text{ km/h}.$$

∴ Reduction in speed = 80 − 48.12

= 31.88 km/h

Ans.

* What would be the further reduction in speed if the train has to negotiate a 4° curve on the rising gradient?

Soln: Above math +

$$0.0016W + 0.00008\, WV + 0.0000006\, V^2 W + \frac{1}{200} \times W + 0.0004W \times 4^\circ = 15$$

$$0.0016 \times 12.67 + 0.00008V \times 12.67 + 0.0000006\, V^2 \times 12.67 + \frac{12.67}{200} + 0.0004 \times 12.67 \times 4 = 15$$

$$\Rightarrow V = 35.85 \text{ km/h}.$$

∴ Further reduction = $(48.12 - 35.85) = 12.27$ km/h

Ans.

* What will be the compensated gradient of a B.G. track which having 2° curvature on a rising gradient of 1 in 200?

Soln: Let, Wt of train = W

Hence,

$$\cdot 0004 W \times 2 + \frac{1}{x} \times W = \frac{1}{200} \times W$$

$$\Rightarrow x \simeq 239$$

∴ Compensated gradient 1 in 239 Ans.

* Calculate the maximum permissible train load that can be pulled by a locomotive with four pairs of driving wheels with an axle load of 28.42 t each on a B.G. track with a ruling gradient of 1 in 200 and a maximum curvature of 3°, travelling at a speed of 48.3 km/h. Take the co-efficient of friction = 0.2.

Soln: Let,

Hauling capacity of locomotive = $\frac{1}{5}$ × Load on driving wheel

$$= \frac{1}{5} \times 4 \times 28.42$$

$$= 22.736 \text{ t}.$$

we get,

$$\cdot 0016 W + 0.00008 WV + \cdot 0000006 WV^2 + \frac{1}{20} \times W + \cdot 0004 W \times 3 = 22.736$$

$$\Rightarrow \cdot 0016 \times W + \cdot 00008 W \times 48.3 + \cdot 0000006 W \times 48.3^2 + \frac{W}{200} + 1.2 \times 10^{-3} W = 22.736$$

$$\Rightarrow W = 1740.39 \text{ t}$$

Ans.