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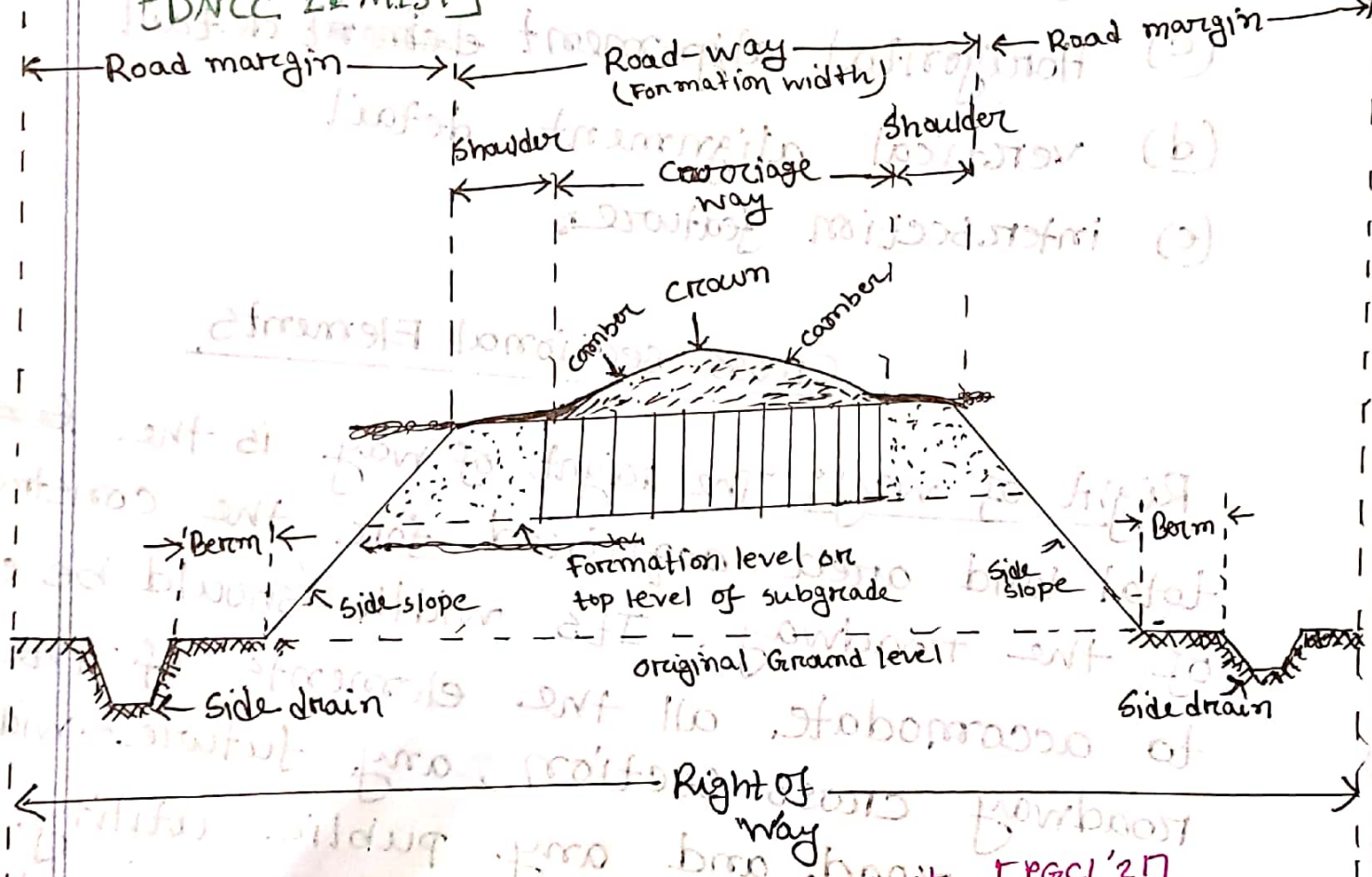
Q1: Sketch right of way and its different parts [ISTT'15] [MSc'17] [PSC] / Draw the X-section of two-way undivided roadway & two-way divided roadway [BREB-MIST'18] [DNCC 22 MIST]



What is camber, write two reasons to use it [PGCL'21]

* **Camber:** camber is the slope provided to the road surface at the transverse direction to drain off the rainwater out of the road surface.

Shape of camber may be parabolic or straight or

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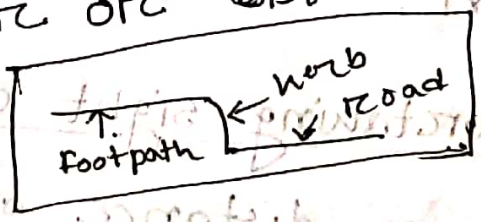
Shoulders: A road shoulder is a strip of land immediately adjacent to the traffic lane of a road not bordered by ~~kerbs~~ kerb.

Shoulders are provided along the road edge and is intended for accomodation of stopped vehicles, serve as emergency lane for vehicles

*** **Kerb (Titas '14) / Curb (in American English)**

A kerb is a vertical or sloping member provided along the edge of ~~carriage way~~ pavement to prevent vehicles from leaving the carriageway. kerb confirms the barrier between the carriageway and the shoulders or island or foothpath.



*** ~~Berm (AIST MSc)~~

~~The horizontal~~

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SSD formula:

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

where,
v in m/s

v = vehicle speed
t = reaction time (2.5 sec if not given)
g = 9.8 ms^{-2}
f = frictional coefficient (take 0.35 if not given)
n = gradient (%) [Ex: 2%, 4% gradient]
= ascending/upward grading (+)
= descending/downward grading (−)

*** brake efficiency দ্বারা প্রাপ্ত frictional coefficient কে আবার multiply করে।

Ex: f = 0.7 & braking efficiency = 50%
∴ revised, f = 0.7 × 0.5 = 0.35

*** vehicle speed kmph এ দেয়া থাকলে 0.278 দিয়ে সুত গুণেই m/s এ চলে আসবে। কিন্তু mph এ দেয়া থাকলে 0.447 দিয়ে সুত করলেই m/s এ চলে আসবে।

[BWDB'15]

MCQ: Grading descending হলে SSD কী হয়?

(a) more (b) less (c) same (d) None of this

$SSD = Vt + \frac{V^2}{2g(f \pm 0.01n)}$ [+ হবে, - হলে]

Q.2 Calculate the stopping sight distance for highway design speed is 50mph. Assume $f = 0.42$. Also assume reasonable values for other data items involved in calculation [BWDB'15] [WRGCL'14] [BWDB'13]

Soln: $SSD = Vt + \frac{V^2}{2gf}$

$= 22.35 \times 2.5 + \frac{(22.35)^2}{2 \times 9.8 \times 0.42}$

$= 116.56\ m$

$V = 50\ mph = (0.447 \times 50)\ m/s = 22.35\ m/s$

1 mile = 5280 ft

$\therefore 1\ mph = \frac{5280}{3600} = 1.467$

Or,

$SSD = 1.47Vt + \frac{V^2}{30f}$

$= 1.47 \times 50 \times 2.5 + \frac{50^2}{30 \times 0.42} = 382.16\ ft$

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Q3 Calculate safe SSD for design speed of 80kmph for two-way traffic on two-lane road. Assume $f = 0.25$ [Padma Bridge '15]

Soln: $SSD = vt + \frac{v^2}{2gf}$ | $v = 80$ kmph $= 0.278 \times 80 = 22.24$ m/s

$= 22.24 \times 2.5 + \frac{(22.24)^2}{2 \times 9.8 \times 0.25}$

$= 156.54$ m Ans

**যেখানে frictional coefficient এর পরিবর্তে deceleration rate দেয়া থাকলে তখন f এর পরিবর্তে $\frac{a}{g}$ ব্যবহার করা হয়। $\frac{a = m/s^2}{g = m/s^2} =$ unitless, f ও unitless

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

Q4: When $v = 50$ mph, reaction time $= 2.5$ sec, deceleration rate 20 ft/sec^2. SSD = ? [EGCB '20]

Soln: $SSD = vt + \frac{v^2}{2g \cdot \frac{a}{g}}$ | $a = 20$ ft/sec^2 $= \frac{20}{3.28}$ m/sec^2 $= 6.1$ m/s^2

$= 22.35 \times 2.5 + \frac{(22.35)^2}{2 \times 6.1}$ | $v = 50$ mph $= 50 \times 0.447 = 22.35$ m/s

$= 96.82$ m

Ans

$SSD = 1.47vt + \frac{v^2}{30xf} = 1.47 \times 50 \times 2.5 + \frac{50^2}{30 \times \frac{20}{32.2}}$

$= 317.917$ ft

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Q5. A car running at a speed of 60mph on a highway at an ascending gradient of 3%. If coefficient of friction is 0.37, $g = 32.2 ft/sec^2$. The driver of the car applied brake by seeing a obstacle 500 ft away from his car. calculate the car collision occur or not. (MSC'17)

Soln:

Stopping distance $= vt + \frac{v^2}{2g(f + \frac{n}{100})}$

$= 1.47 \times 60 \times 2.5 + \frac{(1.47 \times 60)^2}{2 \times 32.2 \times (0.37 + 0.01 \times 3)}$

$= 522.5 ft$ (collided)

$> 500 ft$

1 mile = 5280 ft

1 mph $= \frac{5280}{3600} = 1.47 ft/sec$

$g = 9.81 m/s^2$
$= 9.81 \times 3.28 ft/s^2$
$= 32.2 ft/sec^2$

+ for ascending

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Sun Mon Tue Wed Thu Fri Sat

* A driver moving at a speed of 65 mph on 3% downgrade section of a highway sights an overturning truck 800 ft away on the highway and applied the brake. The coefficient of friction is 0.29, acceleration due to gravity is 32.2 ft/s^2. What would be the final ~~sight~~ distance between the two stopped vehicles ?

[BPDB '23]

Soln:

$$S = vt + \frac{v^2}{2g(f-G)}$$

$$= 95.33 \times 2.5 + \frac{(95.33)^2}{2 \times 32.2 \left(\frac{11.2}{32.2} - 0.03\right)}$$

$$= 682.325 \text{ ft}$$

$\therefore$ distance between two vehicles

$= (800 - 682.325)$ ft

$= 117.675$ ft

$v = 65$ mph $= \frac{65 \times 5280}{3600} = 95.33$ ft/sec

$g = 32.2$ ft/sec^2

perception reaction time, $t = 2.5$ sec

(8) Initial velocity is 50kmph & final velocity after braking is 30kmph. Car is on a positive gradient hill of 3%. Frictional factor 0.5. Determine the braking distance. [DMTCL Line 55 2022]

Sol^no braking distance, $d_b = \frac{V_i^2 - V_f^2}{2g(G \pm f)}$

50kmph
= 13.89m/s
30kmph = 8.33m/s

$= \frac{(13.89)^2 - (8.33)^2}{2 \times 9.81 \times (0.5 + 0.03)}$

$= 11.88 \text{ m/s}$

Positive gradient
or +

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* Find the minimum sight distance to avoid head on collision of two cars approaching at 90kmph and 60kmph. Use frictional coefficient 0.7 & brake efficiency 50 percent in either case.

Soln: $SSD_1 = 0.278 \times 90 \times 2.5 + \frac{(0.278 \times 90)^2}{2 \times 9.81 \times 0.7 \times 0.5}$

$= 153.71 m$

$SSD_2 = 0.278 \times 60 \times 2.5 + \frac{(0.278 \times 60)^2}{2 \times 9.81 \times 0.2 \times 0.5}$

$= 82.216 m$

∴ minimum sight distance to avoid head on collision $= (153.71 + 82.216) m = 235.926 m$ A

* calculate SSD for $v = 50$ kmph for
(a) two-way traffic in a two ~~way~~ lane road
(b) two-way traffic in a single lane road
Use - $f = 0.37$, reaction time of driver, $t = 2.5$ sec

Soln: $SSD = 0.278 \times 50 \times 2.5 + \frac{(0.278 \times 50)^2}{2 \times 9.81 \times 0.37} = 61.4 m$

(a) SSD for two ~~way~~ lane two way traffic $= 61.4 m$
(b) SSD for single lane two way traffic $= (2 \times 61.4) m$
$= 122.8 m$
A

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* Find head light sight distance & intermediate sight distance for a design speed of 65kmph. Use $f = 0.36$

Soln: $SSD = 0.278 \times 65 \times 2.5 + \frac{(0.278 \times 65)^2}{2 \times 9.81 \times 0.36}$

$= 91.4\ m$

∴ Head light sight distance = 91.4 m

Intermediate sight distance = (2×91.4) m

$= 182.81\ m$ Ans

Q6] A car moving at 60kmph saw a crash in front of it. If the driver stopped the car 5m in front of the crash, find the distance it has travelled after seeing the crash [~~DESCO'15~~ DESCO'15]

Soln: $SSD = vt + \frac{v^2}{2gf}$

$= (16.68) \times 2.5 + \frac{(16.68)^2}{2 \times 9.81 \times 0.35}$

$= 82.22\ m$

$V = 60$ kmph
$= 0.278 \times 60$
$= 16.68$ m/s

$f = 0.35$ (if not given)

SSD ই অতিক্রান্ত দূরত্ব। 5m এর কোন কাজ নাই।

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Ex-01 A motorist travelling at 65 mi/h on an expressway intends to leave the expressway using an exit ramp with a max^m speed of 35 mi/h. At what point on the expressway should the motorist step on her brakes in order to reduce her speed to the maximum allowable on the ramp just before entering the ramp, if this section of expressway has a downgrade of 3%?

Soln:

$$D = \frac{v^2 - u^2}{2g(f - 0.01n)}$$

$$= \frac{(95.55)^2 - (51.45)^2}{2 \times 32.2 \times (0.35 - 0.01 \times 3)}$$

$$= 314.57 \text{ ft} \quad \underline{A}$$

$u = 35$ mph
$= 35 \times 1.47$
$= 51.45$ ft/sec
$f = 0.35$
$v_0 = 65$ mph
$= 95.55$ ft/sec

[illegible] brake [illegible], [illegible] point B distance [illegible] braking.

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Q22] A directional sign is to be given in a turnoff. The value of 85th percentile speed is 50mph. The turnoff is to be approached at 25 mph. The peception reaction time is 1.25sec & deceleration rate is 0.3g. Determine the minimum distance of the sign to be placed before the turnoff to have safe turning. [BWDB'16]

Soln $S = 1.47Vt + \frac{v^2 - u^2}{30 \cdot \frac{a}{g}}$

$= 1.47 \times 50 \times 1.25 + \frac{(50)^2 - (25)^2}{30 \cdot \frac{0.3g}{g}}$

$= 300.21$ ft Ans

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Horizontal Alignment Details

① Superelevation or cant or banking :

Q9 : Define superelevation [SGBMA] [ISTT'15] [MSc]

Soln: superelevation or cant is the transverse slope provided at horizontal curve to counteract the centrifugal force by raising the outer edge of the pavement with respect to the inner edge throughout the length of the horizontal curve.

Formula for superelevation:

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

if $e = 0$, (no superelevation)

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

if $f = 0$ (no friction)

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

v = vehicle speed

R = Radius of circular curve

super elevation rate $e = \tan\theta$ (banking angle)

Total superelevation = $e \times B$ → width of road

↙ rate of superelevation

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Q10 If $e = 0.10$ & $f = 0.15$, design ~~speed 100km~~ speed = 100kmph, determine radius of curvature [PGCB'20]

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

$\Rightarrow 0.10 + 0.15 = \frac{(0.278 \times 100)^2}{9.81 \times R}$

$\Rightarrow R = \frac{(0.278 \times 100)^2}{9.81 \times 0.25}$

$= 315.12 \text{ m}$ Ans

Q11 Determine the angle of banking of a road if $v = 90 \text{ km/hr}$, $R = 300$ ~~ft~~, $f_s = 0.17$ [MSc'18] [NPCBL'17]

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

$\Rightarrow e = \frac{(0.278 \times 90)^2}{9.81 \times 300} - 0.17$

$= 0.0427$

$e = \tan\theta = 0.0427$

$\therefore \theta = 2.45^\circ$ Ans

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Q12 Determine the safe radius of circular curve for the following condition where the symbol contains there usual meaning.
$V = 60$ mph, $e = 0.4$ ft/ft, $g = 32.2$ ft/sec^2
(PGCL'17)

Soln: $e = \frac{V^2}{gR}$

$\Rightarrow R = \frac{V^2}{eg}$

$= \frac{(60 \times 1.467)^2}{0.4 \times 32.2}$

$= 601.52$ m

Q13 If the radius of curvature is 400m & the speed of vehicle is 60kmph. Calculate the rate of superelevation [BWDB'14]

Soln: $e = \frac{V^2}{gR}$

$= \frac{(0.278 \times 60)^2}{9.81 \times 400}$

$= 0.071$ Ans

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Q[14] Calculate the maximum allowable speed on a horizontal curve of radius 200m for the data, ~~v = 80 kmph~~, $e_{max} = 0.07$, $f_{max} = 0.15$ [BUET]

Soln:

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

$$\Rightarrow 0.07 + 0.15 = \frac{v^2}{9.81 \times 200}$$

$$\Rightarrow 0.22 \times 9.81 \times 200 = v^2$$

$$\Rightarrow v = 20.77 \text{ m/s}$$

$$= \frac{20.77}{0.278} \text{ kmph}$$

$$= 74.73 \text{ kmph (Ans)}$$

Q[15] Determine the superelevation in inch for a 20ft wide road with a design speed of 50mph & degree of curvature = 7°. Take f = 0.14 [BUET]

Soln:

Some basic before starting the soln —

* $R = \frac{5730}{D}$ (in ft) [এটি American practice. এখানে 100ft Engineer's chain use করে। এই correlation থেকে আর 22.65 ।]

P.T.O

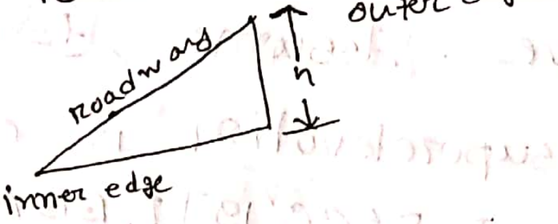
** matric system (m) এ 30m long chord হিসেবে ধরা হয়।

$$R\,(\text{in } m) = \frac{1719}{D}$$

D = degree of curve

superelevation এর rate

~~[illegible]~~ e দ্বারা প্রকাশ করা হয়। superelevation হচ্ছে কোন রাস্তার ~~[illegible]~~ যার দ্বারা superelevation হচ্ছে কোন রাস্তার width জুড়ে outer edge এর সাথে inner edge এর ~~relat~~ relative height এর পার্থক্য বোঝায়।



$$h = \frac{Bv^2}{gR}$$

Soln:

Superelevation, $e = \frac{v^2}{gR} - f$

$$= \frac{(73.35)^2}{32.2 \times 818.57} - 0.14$$

$$= 0.204 - 0.14$$

$$= 0.064$$

$R = \frac{5730}{7}$

$= 818.57\ ft$

$v = 50\ mph$

$= 50 \times 1.467$

$= 73.35\ ft/sec$

∴ height of superelevation $= 0.064 \times 20$

$= 1.28\ ft$

$= 15.4\ inch$ Ans

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Q16] An existing horizontal curve on a highway has a radius of 465ft, which restricts the posted speed limit on this section of the road to only 61.5% of the design speed of the highway. If the curve is to be improved so that its posted speed will be design speed of the highway, determine the minimum radius of the new curve. Assume, $f = 0.16$ and the rate of superelevation is 0.08 for both the case. [DSCC'19] [BBAD'18]

Soln:

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

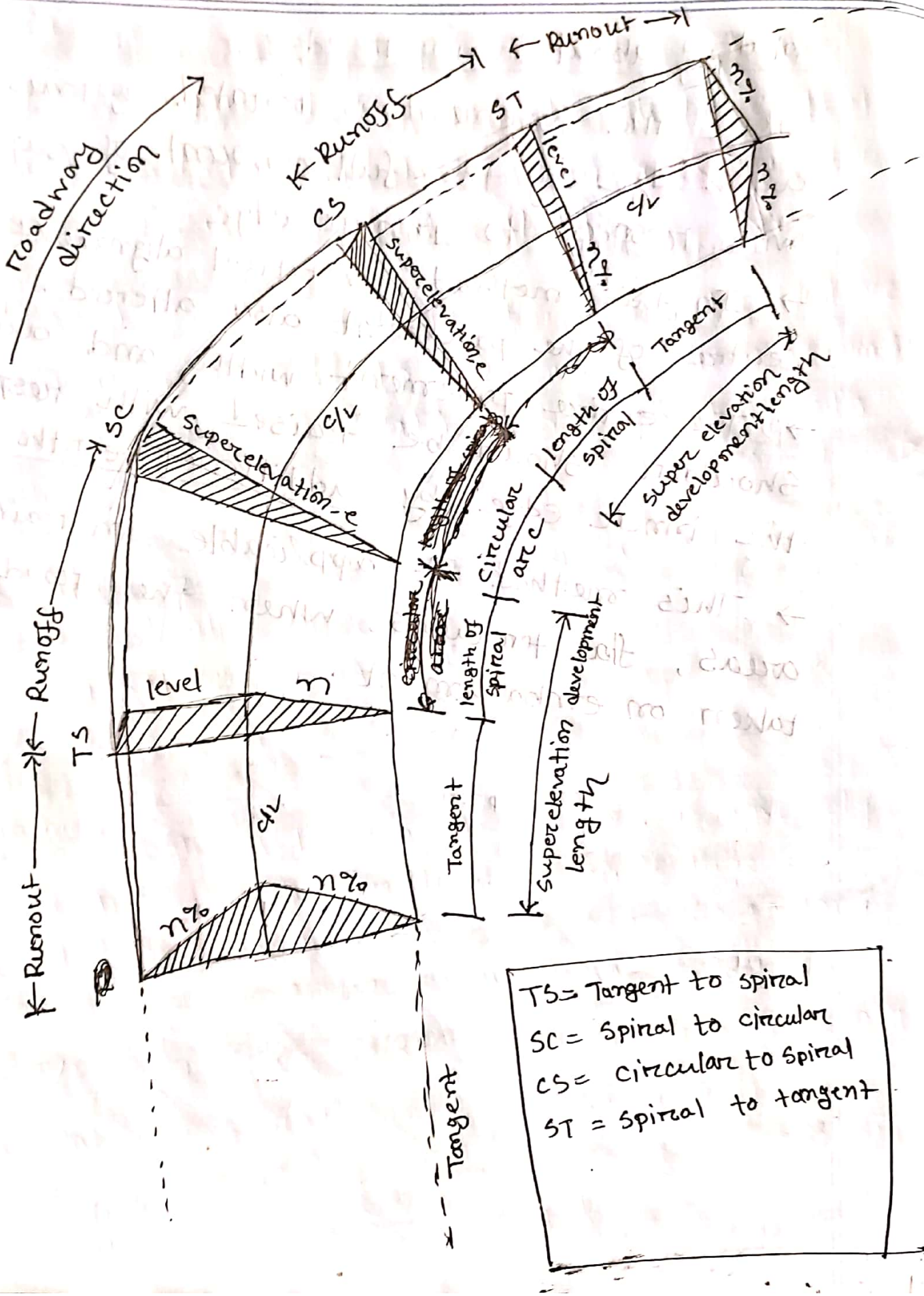
$$\Rightarrow v = \sqrt{gR(e+f)} = \sqrt{32.2 \times 465 \times (0.08+0.16)}$$

$$= 59.95 \text{ ft/sec}$$

$$\therefore \text{Design speed} = \frac{59.95}{0.615} = 97.5 \text{ ft/sec}$$

$\therefore$ Radius of curvature for 97.5ft/sec speed, $R = \frac{v^2}{g(e+f)} = \frac{(97.5)^2}{32.2(0.08+0.16)}$

$$= 1230 \text{ ft}$$ Ans


Runout
Runoff
ST
CS
Roadway direction
level
n%
c/l
Superelevation
Tangent
SC
Superelevation-e
Runoff
TS
level
n
c/l
n%
n%
Runout
Tangent
Length of spiral
Circular arc
Length of spiral
Tangent
Super elevation development length
Superelevation development length
TS = Tangent to spiral
SC = Spiral to circular
CS = Circular to spiral
ST = Spiral to tangent

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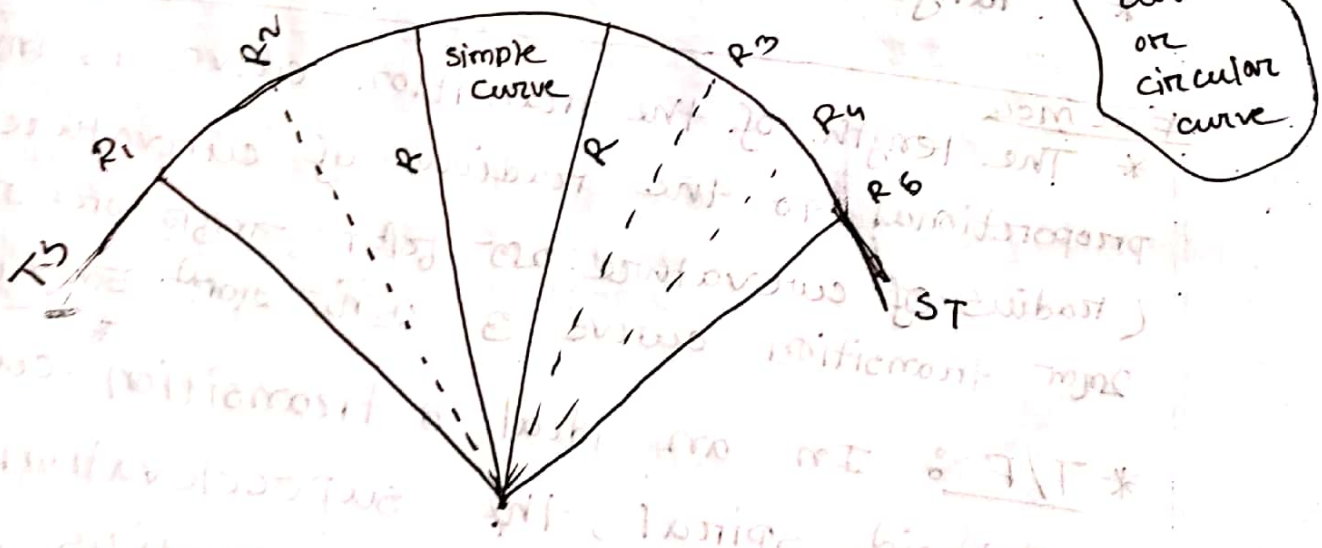
Tangent : straight line

*** **Spiral / Transition curve :** To avoid a sudden change from a tangent with infinite radius (straight line ত্ব হেতু) to a circular curve of relatively small radius, a curve with radii ~~varying~~ varying from infinite to the ~~circular~~ radius of circular curve is placed between the circular curve and the tangent. Such a curve is known as a spiral or transition curve.



simple curve or circular curve

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~~Runoff~~

Runout: Runout length is the distance that is required to transition from normal crown to zero superelevation (flat)

Runoff length: Runoff length is the distance that is required to transition from ~~normal crown to~~ zero (flat) superelevation to full superelevation

* circular curve portion ও সর্বত্র full superelevation থাকে।
* spiral curve ও runoff
* Tangent ও Runout

For MCQ

* The length of the transition curve is inversely proportional to the radius of curvature. (radius of curvature বড় হলে transition curve ও ছোট হবে। ছোট হলে বড় হবে।)

* **T/F:** In an ideal transition curve with a clothoid spiral, the superelevation is directly proportional to the radius (PSCL'17)

Ans: False ($e = \frac{v^2}{gR} \therefore e \propto \frac{1}{R}$)

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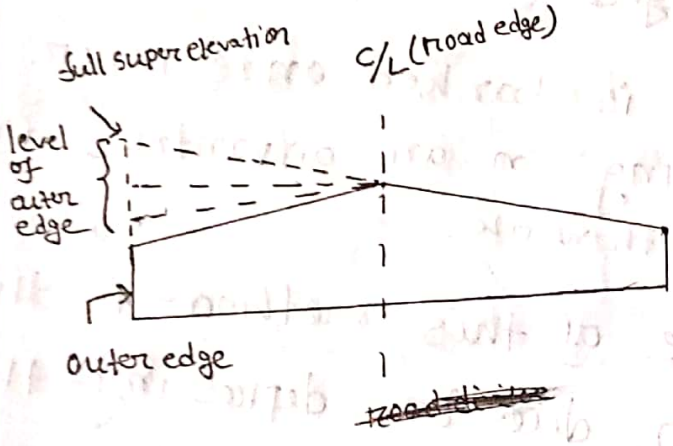
Attainment of Superelevation:

The attainment of superelevation may be split up into two parts:

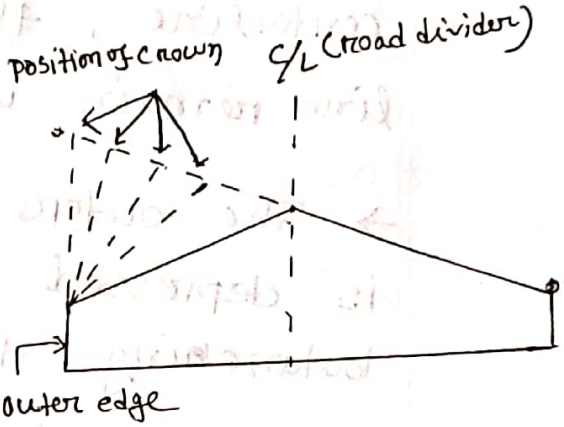
(I) Elimination of crown of the cambered section

(II) Rotation of pavement to attain full superelevation

Elimination of crown:

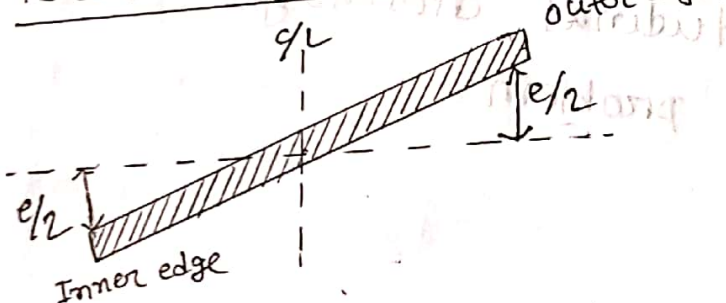


(a) outer edge rotated about the crown

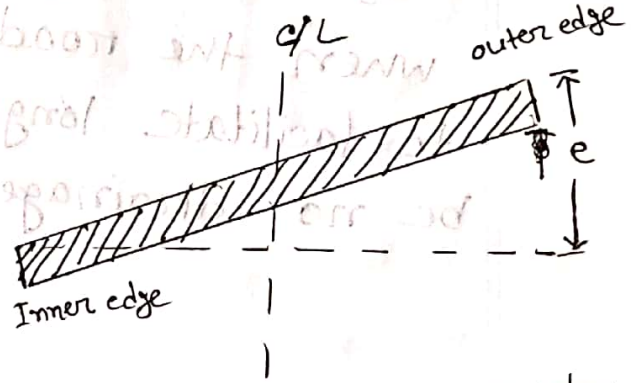


(b) crown shifted outwards

Rotation of Pavement:



(a) rotating about center line



(a) rotating about inner edge

e = amount of superelevation

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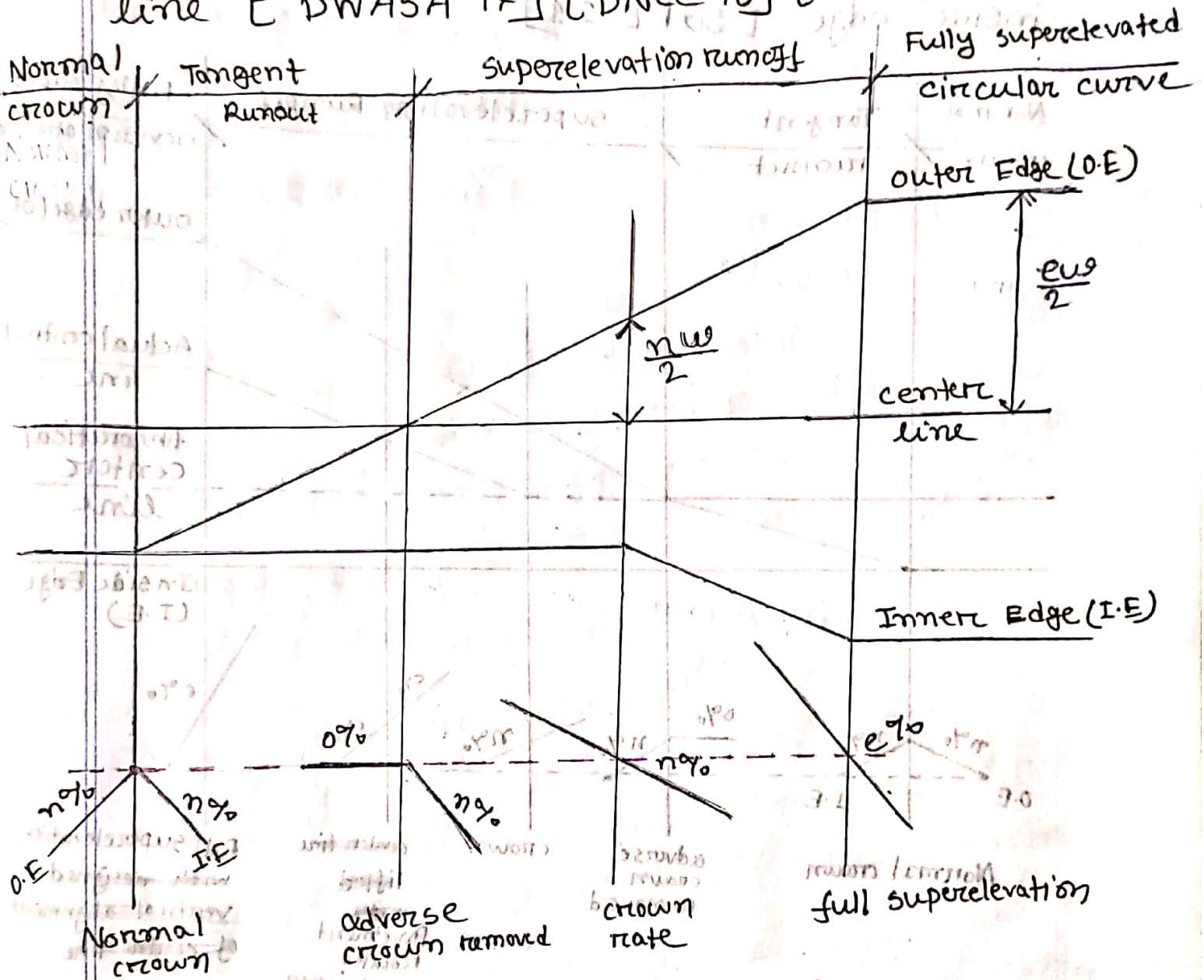
***Q17: Diagram of attaining superelevation of crowned road revolved around center line [DWASA'17] [DNCC'16] [MSc'18] [DTCA'18]



w = width of the pavement

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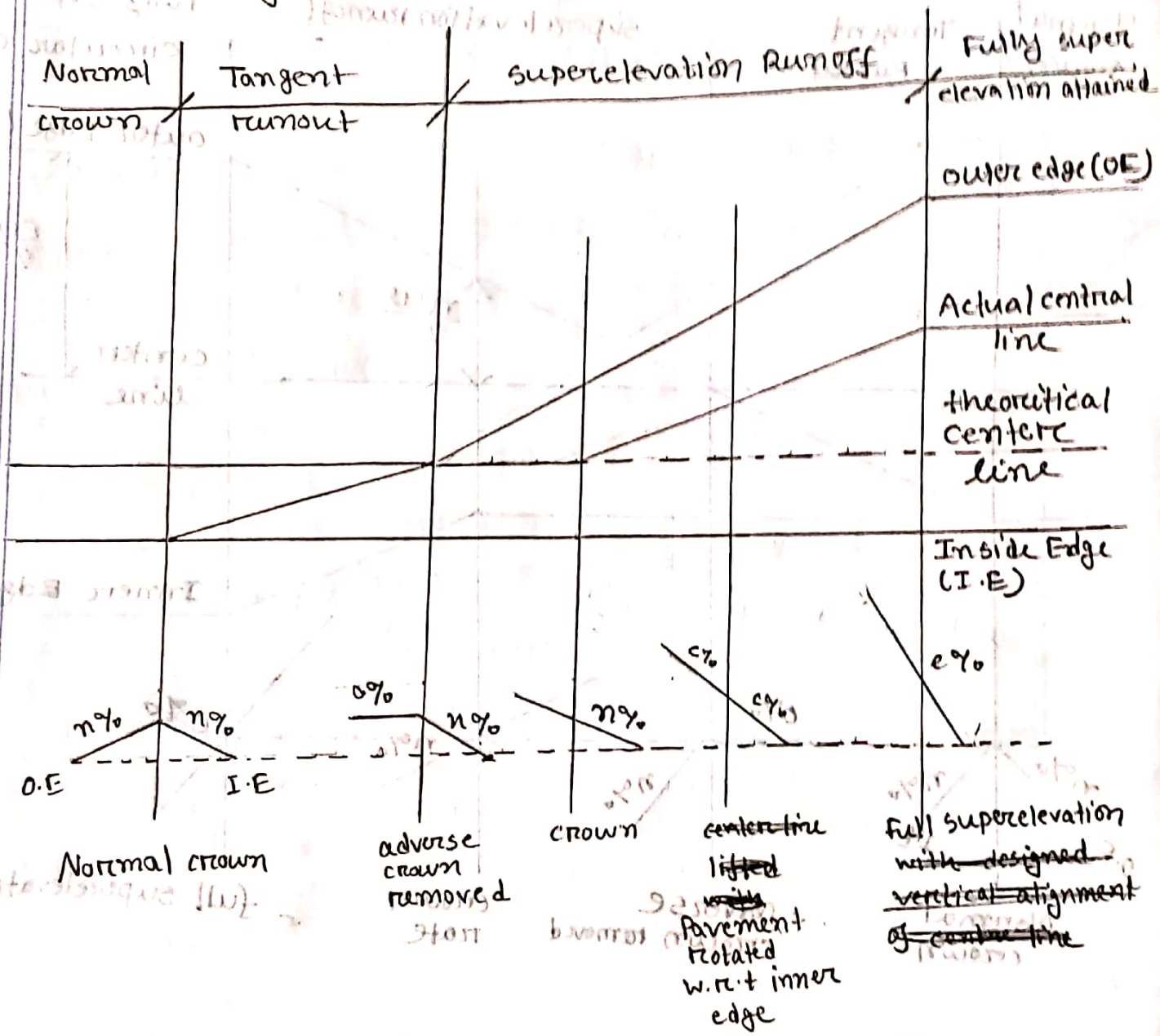
*** Q18. Diagram of attaining supereleveation of crowned pavement revolved about inside edge [SQFL'21]



Q20: A crest vertical curve is to be designed to join a +3% grade with a −2% grade at a section of a two-lane highway. Determine the minimum length of the curve if the design speed of the highway is 60mph, S<L and deceleration rate for braking is 11.2 ft/sec² [SGFL'21]

Soln: The worst case for minimum sight distance would be due to 3% grade.

যেকোনো ক্ষেত্রে কিন্তু বিবেচনায় নয় বরং যেই grade এর মান বড় সেটিই use করতে হবে। এবং SSD এর formula সবসময় ই $vt + \frac{v^2}{2g(f-G)}$ হবে। এখানে ascending / descending বিবেচ্য না। কারণ গাড়ি বিপরীত দিক থেকে এলেই ascending হয়ে যাবে descending এবং vice-versa. আমাদের তাই সবসময় worst case অর্থাৎ descending ক্ষেত্রে বিবেচনায় নিয়ে G এর মান ধনাত্মক নিয়ে SSD বের করতে হবে। কারণ SSD বেশি curve length বড় করে curve design করতে হবে। সব vertical curve এর জন্য এই নিয়ম।

P.T.O

$vt + \frac{v^2}{2g(\frac{a}{g}-G)}$ $f = \frac{a}{g}$

$SSD = 1.47vt + \frac{v^2}{30(\frac{a}{g}-\frac{G}{100})}$ | ft এর ক্ষেত্রে formula

$= 1.47 \times 60 \times 2.5 + \frac{(60)^2}{30(\frac{11.2}{32.2} - 0.03)}$

$= 598.1$ ft

∵ $S < L$

∴ minimum length of vertical curve,

$L_{min} = \frac{AS^2}{2158}$ | Assuming, driver height = 3.5ft, object height = 2ft

$= \frac{5 \times (598.1)^2}{2158}$ | $A = 3\% - (-2\%) = 5\%$

$= 828.8$ ft Ans

Q21] A circular curve with 4% gradient. Length of circular curve is 1250ft. Determine maximum safe speed if $S < L$. Given P/R time 2.5sec [MSc'13]

Soln: $S < L$

∴ $L_{min} = \frac{AS^2}{2158}$

$\Rightarrow 1250 = \frac{4 \times S^2}{2158} \Rightarrow S = \sqrt{\frac{1250 \times 2158}{4}}$

$= 821.2$ ft

$\Rightarrow$

এই formula থেকে V এর মান সরাসরি mph এ বের হবে। কারণ এই formula তে V mph এ input দিলাম

Sub:

$$\therefore SSD = 1.47Vt + \frac{V^2}{30\left(\frac{a}{g} - \frac{G}{100}\right)}$$

Take,
$a = 11.2$ ft/sec²
or,
take, $t = 0.25$

$$821.2 = 1.47 \times 2.5 \times V + \frac{V^2}{30\left(\frac{11.2}{32.2} - \frac{4}{100}\right)}$$

$$\Rightarrow 821.2 = 3.675V + 0.11V^2$$

$\therefore$ ~~V = 71.03 ft/sec~~ $V = 71.3$ mph

~~= 48.5 mph~~ use 70 mph

Ans.

Sub: Traffic Engineering

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Spot Speed Studies:

(বারবার প্রশ্ন এসেছে, গুরুত্বপূর্ণ exam এর জন্য)

⇒ Spot speed studies are conducted to estimate the distribution of speeds & of vehicles in a stream of traffic at a particular location on a highway.

(রাস্তার কোনো একটি point এ বিভিন্ন vehicle এর speed এর range কেমন হবে তা বের করা হয়, যেমন vehicle গুলো speed 20mph থেকে 60mph এর মধ্যে, কোন vehicle এর কতো speed)

⇒ Spot speed is the instantaneous speed of vehicle at a specific location.

T/F* The speed of a vehicle, instantaneous at the moment of passing a point, is the design speed. (False)

Sample size for spot speed studies:

Minimum number of sample size/observation required for spot speed studies,

$$N = \frac{z^2 \sigma^2}{d^2} = \left(\frac{z\sigma}{d}\right)^2$$

N = minimum sample size

z = Number of standard deviations corresponding to the required confidence level
(z = 1.96 for 95% confidence level)

σ = Standard deviation (mph)

*** σ^2 = variance

(SD এর square করলে variance).

d = limit of acceptable error in average speed.

***Q23 An engineer checking the speed characteristics. Confidence level is 95% and acceptable speed limit is 1 kmph. Speed variance is ~~30~~ 25 kmph. He collected a total of 130 spot speed. Has the engineer meet the requirement? [BWDB'16] [BWDB'18] [DESCO'15] [BUET MSc'18]

Sol^{n}:

$$N = \frac{z^2\sigma^2}{d^2}$$

$$= \frac{(1.96)^2 \times 25}{1^2}$$

$$= 96.04 < 130$$

Given,
σ^2 = 25 kmph
z = 1.96 [for 95% confidence level]
d = 1 kmph

∴ The Engineer met the requirements.

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* As part of a class project, a group of students collected a total of 120 spot speed samples at a location and determined from this data that the standard ~~deviation~~ deviation of the speed was ± 6 mi/h. If the project required that the confidence level be 95% and the limit of acceptable error was ± 1.5 mi/h, determine whether these students satisfied the project requirement.

Soln: required sample $N = \left(\frac{z\sigma}{d}\right)^2$

$= \left(\frac{1.96 \times 6}{1.5}\right)^2$

$= 61.45 < 120$

∴ collected sample > required sample

∴ (ok)

* Enoscope is used to find spot speed

[BWDB'16]

[এই related অংশের মধ্যে volume study topic এর- আগের page এ লেখা আছে।]

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Time mean speed (TMS): Time mean speed is ~~the arith~~ defined as the average speed of all the vehicles passing a point on a highway over some specified time period.

→ এর আরেক নাম spot speed বা arithmetic mean.

$$TMS = \frac{\sum_{i=1}^{n} v_i}{n}$$

Space mean speed (SMS): It is defined as the average speed of all the vehicles occupying a given section of a highway over some specified time period.

→ এর আরেক নাম spot speed বা harmonic mean.

$$SMS = \frac{n}{\sum_{i=1}^{n} \left(\frac{1}{v_i}\right)}$$

* TMS is always higher than SMS

$$TMS = SMS + \frac{\sigma^2}{SMS}$$ | σ^2 = variance

Q24] Speed of four vehicles on a two lane highway are 20km/hr, 35km/hr, 40 km/hr and 45km/hr calculate the time mean speed and space mean speed. Length of section is 300m. [Titas'18]

Soln: $TMS = \frac{20+35+40+45}{4} = 35 \text{ km/hr}$

$SMS = \frac{4}{\frac{1}{20}+\frac{1}{35}+\frac{1}{40}+\frac{1}{45}} = 31.79 \text{ km/hr}$

Q25] Time required by four vehicles for travelling 1km were 1.6, 1.2, 1.5 & 1.7 min respectively. Find TMS & SMS [PGCL'17]

Soln: $TMS = \frac{\frac{1}{1.6}+\frac{1}{1.2}+\frac{1}{1.5}+\frac{1}{1.7}}{4} = 0.628 \text{ km/min}$

$= 40 \text{ km/hr}$

$= 40.7 \text{ km/hr}$

$SMS = \frac{4}{\frac{1}{\frac{1}{1.6}}+\frac{1}{\frac{1}{1.2}}+\frac{1}{\frac{1}{1.5}}+\frac{1}{\frac{1}{1.7}}}$

$= \frac{4}{1.6+1.2+1.5+1.7} = 0.667 \text{ km/min}$

$= 40 \text{ km/hr}$

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Flow: Flow (q) is the equivalent hourly rate at which vehicles pass a point on a highway during a time period less than 1 hour.

[1 ঘন্টার কম সময়ের traffic কে 1 ঘন্টায় রূপান্তর convert করা]

It can be determined by,

$$q = \frac{n \times 3600}{T} \text{ veh/h}$$

n = vehicle number

T = Time in seconds

Density: ~~Desity~~ Density (k) is the number of vehicles travelling over a unit length of highway at an instant in time.

Its unit is veh/mile or veh/km

As unit length is taken as 1 mile or 1 km

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Speed - flow - density relationship :

Flow = speed × density

↘ q = ↓ v × ↙ k

flow এর আলোচনা volume 3 এবং 22 ।

[Q27] Draw the typical fundamental diagram of speed vs density, flow vs density, speed vs flow [SGFL'17] [NHA'19] [MSC]

Or,
show theoritical relationship among flow, density, speed [BWDB'19] [DTCA'18]

Soln: we know,

$q = v \times k$ —(i)

where, q = flow ; v = speed ; k = density

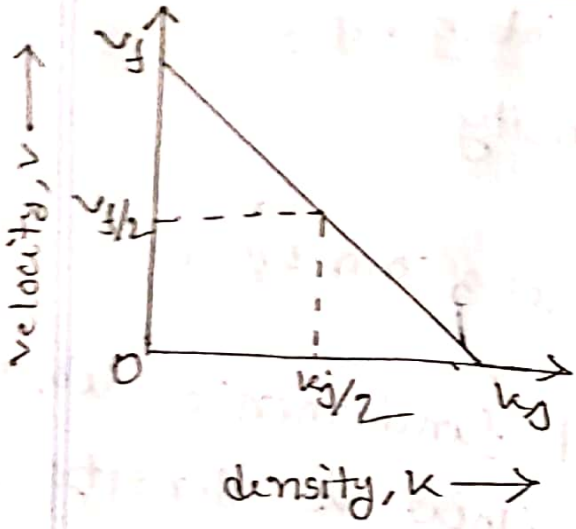
Again, $v = A - Bk$ —(ii) ***

where, $A = v_f$ = free flow speed

$B = \frac{v_f}{k_j}$; k_j = jam density

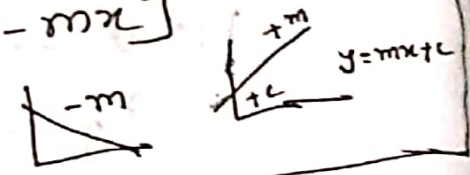
$\therefore v = v_f - \frac{v_f}{k_j} \cdot k$ ***

start marked formula এবং প্রশ্নের ধরণ



Q $v = A - Bk$

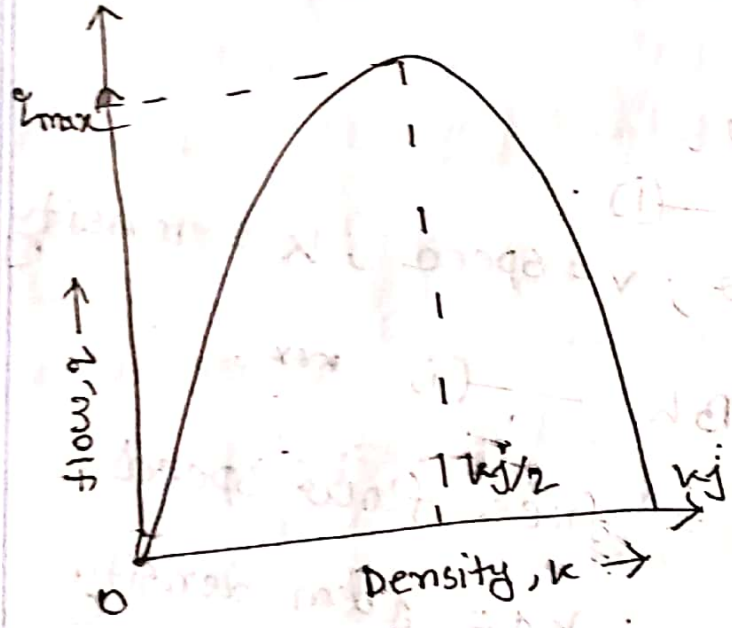
$y = c - mx$



From eqn (i) & (ii),

$q = kv = Ak - Bk^2$ —(iii)

$\Rightarrow$ $q = v_f \cdot k - \frac{v_f}{k_j} \cdot k^2$ ***



From eqn (ii) →

$$k = \frac{A}{B} - \frac{v}{B}$$

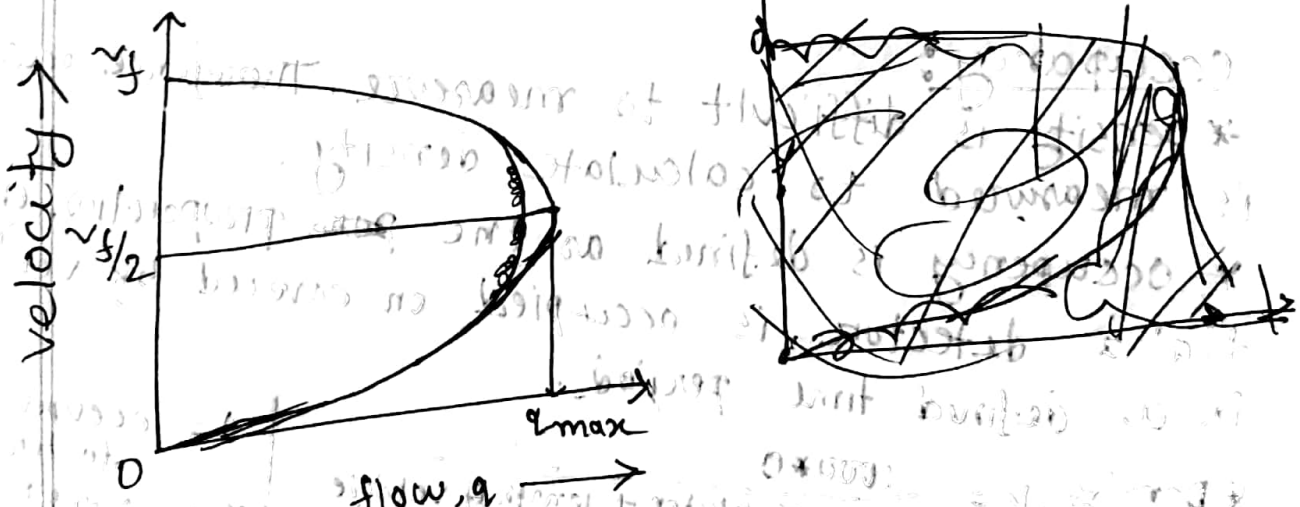
Now, from eqn (i),

$$q = v\left(\frac{A}{B} - \frac{v}{B}\right)$$

$$q = \frac{A}{B}v - \frac{v^2}{B} \quad \text{—(iv)}$$

$$\Rightarrow q = \frac{v_f}{\frac{v_f}{k_j}}v - \frac{v^2}{\frac{v_f}{k_j}}$$

$$\Rightarrow \boxed{q = k_j \cdot v - \frac{k_j}{v_f} \cdot v^2}$$



* [illegible] formula [illegible]

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~~$q_{max} = v_{max} * k_{max}$~~

From figure-2 & figure-3 we can see

maxm flow occurs at $k_j/2$ & $v_f/2$

$$\therefore q_{max} = \frac{k_j}{2} \times \frac{v_f}{2}$$

$$\boxed{q_{max} = \frac{v_f k_j}{4}}$$

maxm flow / capacity

Date: / /

Sun Mon Tue Wed Thu Fri Sat

* Determine the theoretical capacity of road if design speed is ~~700~~ 70 kmph, total reaction time 2 seconds and average length of the vehicle as 8m.

Soln:

$$SSD = vt + \frac{v^2}{2g}$$

$$= 19.44 \times 2 + \frac{(19.44)^2}{2 \times 9.81}$$

$$= 58.14\ m$$

$v = 70$ kmph $= \frac{70 \times 1000}{3600} = 19.44$ m/s

$\therefore$ Road capacity $= \frac{1000V}{S}$ — in kmph

$$= \frac{19.44}{(58.14 + 8)\ m}$$

$$= \frac{1000 \times 70}{58.14 + 8}$$

$$= 1058.36\ \text{veh/hr}$$

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Q26 Four vehicles travelling at constant speed on a two-lane highway between sections x & y (280m) apart. An observer at point x observes the four vehicles passing point x during a period of 15sec. The speed of the vehicles are 88, 80, 90 & 72 kmph respectively. Calculate flow, density, time mean speed & space mean speed of the vehicle. [PGCL'17] [DESCO'16]

1 mile = 5280ft

Soln: Flow, $q = \frac{n \times 3600}{T} = \frac{4 \times 3600}{15} = 960$ veh/hr

density, $k = \frac{4}{280} \times 1000 = 14.3$ veh/km

$TMS = \frac{88+80+90+72}{4} = 82.5$ km/hr

$SMS = \frac{4}{\frac{1}{88}+\frac{1}{80}+\frac{1}{90}+\frac{1}{72}} = 81.86$ km/hr

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* A study of freeway flow at a particular site has resulted in the following speed-density relationship as follows :

$$u = 57.5\,(1 - 0.008k)$$

where u in mph & k in veh/mile

determine : (a) free flow speed (b) jam density (c) speed-flow relationship (d) the flow-density relationship (e) maximum flow (i.e. capacity)

Soln : General speed-density relationship is, $u = u_f - \left(\frac{u_f}{k_j}\right) * k$

where, u_f = free flow speed

k_j = jam density

Given relationship, $u = 57.5(1 - 0.008k)$

$$u = 57.5 - 0.46k$$

$\therefore$ free flow speed, $u_f = 57.5$ mile/hr

$$u_f/k_j = 0.46$$

$$\therefore k_j = \frac{u_f}{0.46} = \frac{57.5}{0.46} = 125 \text{ veh/mile}$$

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$\therefore$ jam density = 125 veh/mile

(c) Speed – flow relationship

$$q = k_j \cdot u - \frac{k_j}{u_f} \cdot u^2$$

$$\therefore q = 125u - \left(\frac{125}{52.5}\right)u^2$$

$$\therefore q = 125u - 2.174u^2 \quad \text{Ans}$$

Or,

$$u = 52.5 - 0.46k$$

substituting $k = q/u$ produces

$$u = 52.5 - 0.46\frac{q}{u}$$

$$\Rightarrow 0.46\frac{q}{u} = 52.5 - u$$

$$\Rightarrow q = 125u - 2.174u^2 \quad \text{Ans}$$

(d) Flow – density relationship

$$q = u_f k - \frac{u_f}{k_j} k^2$$

$$= 52.5k - 0.46k^2 \quad \text{Ans}$$

(e) Maximum flow/capacity - $q_{max} = \frac{k_j \cdot u_f}{4}$

$$= \frac{125 * 52.5}{4}$$

$$= 1796 \text{ veh/hr} \quad \text{Ans}$$

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Q27 In speed-density relationship, $v_s = 65\left(1 - \frac{k}{110}\right)$ where, v_s in km/hr & k in veh/km.

Determine

(i) Flow-density & flow-speed relationship

(ii) free flow speed, jam density & capacity.

[DESCO'16]

Soln:

(ii) General speed-density relationship,

$$v_s = v_f - \frac{v_f}{k_j} * k \quad \text{—(i)}$$

where, v_f = free flow speed

k_j = jam density

Given relationship, $v_s = 65\left(1 - \frac{k}{100}\right)$

$$\Rightarrow v_s = 65 - \frac{65}{100}k \quad \text{—(ii)}$$

from eqn (i) & (ii),

free flow speed, $v_f = 65$ kmph

jam density, $k_j = 100$ veh/km

Capacity, $q_{max} = \frac{v_f * k_j}{4}$

$= \frac{65 \times 100}{4} = 1625$ veh/hr

Ans

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(i) Flow - density relationship,

$q = 65k - \frac{65}{100}k^2$ Am [from eqn (ii)]

flow - speed relationship,

from eqn (ii),

$v_s = 65 - \frac{65}{100}k$

substituting, $k = \frac{q}{v_s}$ produces

$v_s = 65 - \frac{65}{100} \times \frac{q}{v_s}$ [$\because q = vk$]

$\Rightarrow \frac{65}{100} \times \frac{q}{v_s} = 65 - v_s$

$\Rightarrow q = 65 \times \frac{100}{65} \times v_s - \frac{100}{65} \times v_s^2$

$\Rightarrow q = 100v_s - \frac{100}{65}v_s^2$ Am

* Flow-density relationship [মনে রাখতে হবে]
* Flow-speed relationship given relationship থেকে v_f আর k_j মানের সহজে পরিবর্তন করতে আর k থেকে v বানাতে। [shortcut]

* Design speed is 90/15/20/85 percentile speed. [MSc'19]

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Q28 Draw Flow–density relation curve. Estimate the mean velocity at point where the density is 175 veh/mile & flow is 10,000 veh/hr [EGCB'20] [DPDC'20] [JGTDSL'21]

Soln: See Q27 for flow-density curve.

We know,

$$q = vk$$

$$\therefore v = \frac{q}{k} = \frac{10,000}{175} = 57.14 \text{ mile/hr}$$

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*** T/F ⇒ Level of service 'E' indicates approaching unstable flow condition. (PSCB)

Ans: ~~False~~ True

DMTCL '22

* Spot speed data were collected at a section of highway during 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. [DMTCL'22]

$u_1 = 35.5$ mph
$s_1 = 7.5$ mph
$n_1 = 250$

$u_2 = 38.7$ mph
$s_2 = 7.4$ mph
$n_2 = 280$

Sol^n

$$s_d = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = \sqrt{\frac{(7.5)^2}{250} + \frac{(7.4)^2}{280}}$$

s_d (Std. deviation)

$$= 0.65 \text{ mph}$$

$$Z = \frac{|u_1 - u_2|}{s_d} = \frac{|35.5 - 38.7|}{0.65} = 4.923$$

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

$\therefore Z > Z_{critical}$

$\therefore$ Difference in mean speeds is significant.

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Volume Study :

Annual Average Daily Traffic (AADT) : It is the average 24-hr traffic volume at a given location over a full 365-days.

[এক বছরে Traffic volume নির্ণয় করা হয় 365 দিন ধরে]

Average Daily Traffic (ADT) : It is the average 24-hr volume at a given location for some period of time less than a year.

For this, minimum x days count is done to include the daily variation like on ~~Saturday~~ Friday (শুক্রবার) & Sunday.
(সাপ্তাহিক ছুটির দিন)

~~Design~~

Peak Hour Volume (PHV) : is the maximum number of vehicles that pass a point on a highway during a period of 1 hour.

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Peak-Hour Factor (PHF) :

$$PHF = \frac{\text{Volume during peak hour}}{4 \times \text{volume during peak 15 min within peak hour}}$$

$4 \times 15 = 60 = 1\,hr$

স্বাভাবিক ভাবেই বোঝা যায়, PHF এর মান 1 থেকে ছোট হবে, কারণ peak 15 min এই সর্বোচ্চ traffic volume হবে। সেটিকে 4 দ্বারা গুণ করলে সুনিশ্চিত ভাবেই peak hour volume থেকে বেশিই হবে।

Design Hourly Volume (DHV) :

$$DHV = \frac{\text{Peak Hour Volume (PHV)}}{PHF}$$

এখানে Design volume, peak volume এর চেয়ে বেশিই হবে, এটাই স্বাভাবিক। কারণ Design করার সময় peak এর চেয়েও বেশিই নিয়ে আমরা।

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*** The table below shows 15 min volume counts during the peak hour on an approach of an intersection. Determine the design hourly volume of the approach.

Time	Volume
6:00 - 6:15 PM	375
6:15 - 6:30 PM	380
6:30 - 6:45 PM	412
6:45 - 7:00 PM	390

Soln:

(a) Peak hour volume = 375 + 380 + 412 + 390
= 1557

Volume during peak 15 min = 412

∴ Peak hour factor (PHF) = $\frac{1557}{4 \times 412}$
= 0.945

∴ Design Hourly Volume (DHV) = $\frac{1557}{0.945}$
= 1648

(4 x 15 = 60 min = 1 hr)

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এটা just PCU কী বোঝার জন্য, এখানকার math বা কিছু exam এ আসবে না।

Passenger Car Unit (PCU):

রাস্তায় চলাচলকারী বিভিন্ন যানবাহনের size, speed, acceleration এবং অন্যান্য বিভিন্ন ধরনের characteristics বিভিন্ন রকম। তাই road এর traffic volume আর capacity নির্ণয়ের সুবিধার জন্য বিভিন্ন ধরনের vehicle কে Passenger car এর equivalent এ convert করে হিসাব করা হয়। এই ইউনিটকে PCU বলে।

যেমন:

	PCU
1 Bus (≤ 24 Passenger)	1.25
1 Bus (> 24 Passenger)	2–3
1 Truck	2
1 motorcycle	0.33

etc.

* **Example:**

For the following traffic composition –

Passenger car	= 50%	
Busses (25 passenger)	= 5%	PCU = 2.5
Heavy vehicles	= 42%	PCU = 3
motorcycle	= 3%	PCU = 0.33

Determine the equivalent passenger car unit if

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the total number of vehicles passing is 8500.

Soln: No of passenger cars = $8500 * \frac{50}{100} = 4250$

Busses = $8500 * \frac{5}{100} = 425$

heavy vehicles = $8500 * \frac{42}{100} = 3570$

motorcycle = $8500 * \frac{3}{100} = 255$

Total Equivalent Passenger cars (PCE)

$= 4250 * 1 + 425 * 2.5 + 3570 * 3 + 255 * 0.33$

$= 16107$

PCE = Passenger Car Equivalent

(20) Find ADT [PGCB'19]

vehicle type	Design Hourly volume (DHV)	PCU
Car	35	1
BUS	23	2
Truck	56	3
cycle	34	0.5

Hourly expasion factor (HEF) = 42

Soln: ADT = $(35*1 + 23*2 + 56*3 + 34*0.5) * 42$

$= 11152$ Ans.

P.T.O

DHV হইলো 1 ঘণ্টার হিসাব
ADT হইলো 24 ঘণ্টার হিসাব।
সেজন্য DHV থেকে ADT বের করতে Expasion factor দ্বারা গুণ করা হয়েছে।

Here ADT = 11172 is measured in terms of ~~equivalent~~ Passenger cars unit (PCU)

<u>Calculation of DHV from ADT:</u>

Design Hourly volume, <u>DHV = ADT * k</u>

*k হইলো 24 ঘণ্টার volume ADT কে 1 ঘণ্টার volume DHV তে convert করার factor

~~k = 0.1~~ k = 0.1 [for urban area]
= 0.15 [for rural area]

DHV যদি কোনো নির্দিষ্ট দিকে / এক lane এ বের করতে বলে ~~(...)~~ তখন তাকে বলে Directional Design Hour Volume (DDHV). যেমন সকালের দিকে ঢাকা আইতে চাপ বেশি থাকে গাজীপুর থেকে, আবার বিকেলে বা সন্ধ্যায় ঢাকা থেকে গাজীপুর যাইতে চাপ বেশি থাকে।

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DDHV = ADT * k * D

where D = directional factor

= 0.55 (urban road)

= ~~0.50 to 0.80~~ (rural roads)

= 0.60 to 0.80

(30) For an urban highway with an ADT of 20,000 vehicle/day. Determine Design Hourly volume (DHV) for the peak direction of flow. ~~Assume k = 0.10 & D = 0.60~~ [BWDB'13]

Soln: DHV at peak direction = ~~20000~~ X

= DHV * k * D

= 20,000 * 0.1 * 0.55

= ~~1200 veh/hr~~

= 1100 veh/hr Ans

(31) In a four lane two way road, the ADT is 4000 and commercial vehicle is 45%. Determine the number of commercial vehicle of one way road. [BIFPCL'15] [BCIC'16]

Soln: ADT = $\frac{1}{2}$ X 4000 * 0.45 = 900

(one-way)

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Traffic volume Forecasting :

* Design data is required for the improvement of two-way highway with current traffic 3000 veh/day in both directions. The improved road with a design life of 20 years, annual growth rate of traffic is 8% & construction period is 5 years, k = 12%, D = 55%

$\therefore$ Future ADT = $3000 * (1 + 0.08)^{25}$ → (20+5)

= 20546 veh/day

Design Hourly volume in one direction

= 20546 * 0.12 * .55

= ~~1356 veh/day~~

= 1356 veh/hr

[Design Data সাধারণত DHV এর উপর আগ্রহ হয়]

ADT = Average Daily Traffic

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Time headway (h_t) : কোন রাস্তার lane এর একটি নির্দিষ্ট point এ একের পর এক দুইটি vehicle এর মধ্যবর্তী সময় পরিমাপ।

কোন রাস্তায় চলাচল করা দুইটি vehicle এর মধ্যবর্তী সময় পরিমাপ। unit = sec/veh

$$\text{Traffic volume, } q \text{ (veh/hr)} = \frac{1}{\text{time headway (hr/veh)}}$$

Space headway (h_s) : রাস্তার একটি নির্দিষ্ট lane এ চলাচল দুইটি গাড়ির মধ্যকার দূরত্ব।

unit = m/veh, ~~mile/veh~~, ft/veh

$$\text{Density per lane, } k \text{ (veh/mile)} = \frac{1}{\text{space headway (mile/veh)}}$$

$$\text{space mean speed, } v_s = \text{flow } (q) \times \text{space headway } (h_s)$$

$$v_s = q \times h_s$$

$$= \frac{\text{veh}}{\text{hr}} \times \frac{\text{mile}}{\text{veh}}$$

$$= \text{mile/hr}$$

$$\text{space headway, } h_t = v_s \times h_t$$

$$= \frac{\text{mile}}{\text{hr}} \times \frac{\text{hr}}{\text{veh}} = \frac{\text{mile}}{\text{veh}} = \frac{5280 \times \text{ft}}{\text{veh}}$$

* Max^m capacity of a road is 2500 veh/hr. ~~Calculate~~ & jam density is 400 veh/km. Find minimum time headway & minimum space headway.

Sol^n: Minimum time headway,

$$h_t = \frac{1}{q_{max}} \text{ hr}$$

$$= \frac{3600}{2500} \text{ sec}$$

$$= 1.44 \text{ sec}$$

jam density তে গেলে গাড়ি flow করতে পারবে, space headway মানে কেমন? অর্থাৎ সর্বোচ্চ density মানের free flow করতে পারে vehicle টির density কত? respect এ হবে space headway.

Max^m free flow density $= \frac{kj}{2} = \frac{400}{2} = 200$ veh/km

$\therefore$ minimum space headway $= \frac{1}{200}$ km/veh

$$= \frac{1000}{200} \text{ m/veh}$$

$$= 5 \text{ m/veh}$$

Ans

* Determine traffic flow, density and velocity if time headway 3.8 sec and average spacing 200ft. [DTCA 2022]

Ans: Traffic flow = $\frac{3600}{3.8}$ = 947 veh/hr

Traffic density = $\frac{5280}{200}$ = 26 veh/mile

[1 mile = 5280ft]

$v = q/k$ velocity = $\frac{947}{26}$ = 36.42 mi/hr

* Determine the mean speed at density 100 veh/mile, capacity 1849 veh/hr and jam density 118 veh/mile.

Soln: We know, $q = \frac{v_f * k_j}{4}$

$\Rightarrow 1849 = \frac{v_f * 118}{4}$

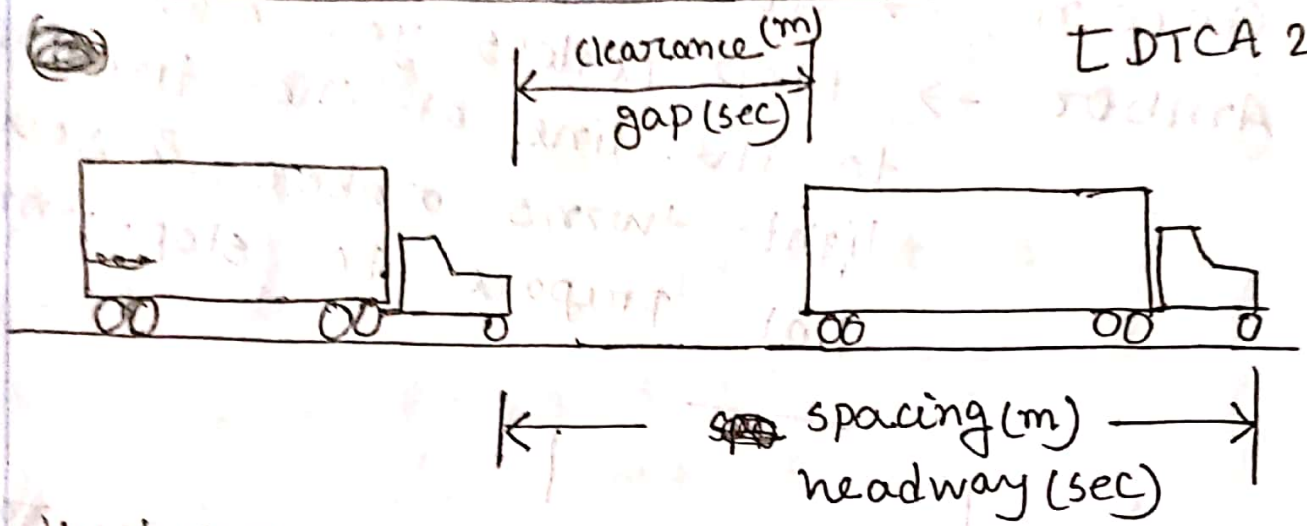
$\therefore v_f = 62.68$ mi/hr

↓ free flow velocity

$\therefore$ Mean velocity, $v = v_f - \frac{v_f}{k_j} k$

$= 62.68 - \frac{62.68}{118} \times 100 = 9.56$ mi/hr

[DTCA 2022]



Headway: Headway is the time elapses between the arrival of the leading vehicle and the following vehicle at the designated test point.

Spacing: spacing is the physical distance in m or ft between the front bumper of the leading vehicle and the front bumper of the following vehicle.

Gap: Gap is a measure of the time between the rear bumper of the leading vehicle and the front bumper of the second vehicle.

Clearance: same as gap but with respect to time (sec)

* Difference between Lane occupency & density.

[DTCA '2022]

Soln: **Density:** Defined as the number of vehicles occupying a given length of highway or lane expressed as vehicles/km or veh/mile

Occupancy:

* Density is difficult to measure. Therefore occupancy is measured to calculate density.
* occupency is defined as the ~~part~~ proportion of time that a detector is occupied or covered by vehicles in a defined time period.

* Density, $k = \frac{1000 * O}{\text{length of detector (m)} + \text{length of vehicle (m)}}$

O = occupency factor

* m ও ft এর মধ্যে সম্পর্ক 1 ft = 0.3048 m, 1 m = 3.281 ft, 1000 m = 1 km

Exc: 15 min analysis, occupency factor = 0.20, length of vehicle 8.5 m and length of detector 0.91 m ∴ Density = $\frac{1000 * 0.20}{8.5 + 0.91} = 21.2$ veh/km

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Accident studies :

Type-1

The number of all crashes recorded at an intersection in a year was 23, and the average 24-hr volume entering from all approaches was 6500. Determine the crash rate per million entering vehicles.

ADT

Soln : Crash rate per million vehicles

$$= \frac{23 \times 1{,}000{,}000}{6500 \times 365}$$

(6500 = ADT, 365 ← yearly traffic)

$$= 9.69 \text{ crashes/million vehicles}$$

Type-2

Crash rate per 100 million vehicle mile

* vehicle এর সাথে mile এ সম্পর্ক।

(33) It is observed that 40 traffic crashes occured on a 12.5 mile long section of highway in one year. The ADT on the section was 5000 vehicles

(a) Determine the rate of total crashes per ~~100~~

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100 million vehicle-miles. (3)

(b) Determine the rate of fatal crashes per 100 million vehicle-miles if 5% of the crashes involves fatalities. [BWDB'16] [DPDC'19]

Soln:

(a) rate of total crashes $= \dfrac{40 \times 100{,}000{,}000}{\frac{17.5}{\text{mile}} \times \frac{5000}{\text{ADT}} \times \frac{365}{\text{year}}}$ (100 million)

$= 125.24$ crashes/100 million veh-mile

(b) rate of fatal crashes $= 125.24 \times 0.05$

$= 6.26$ crashes/100 million veh-mile

100 million = 100×10^6

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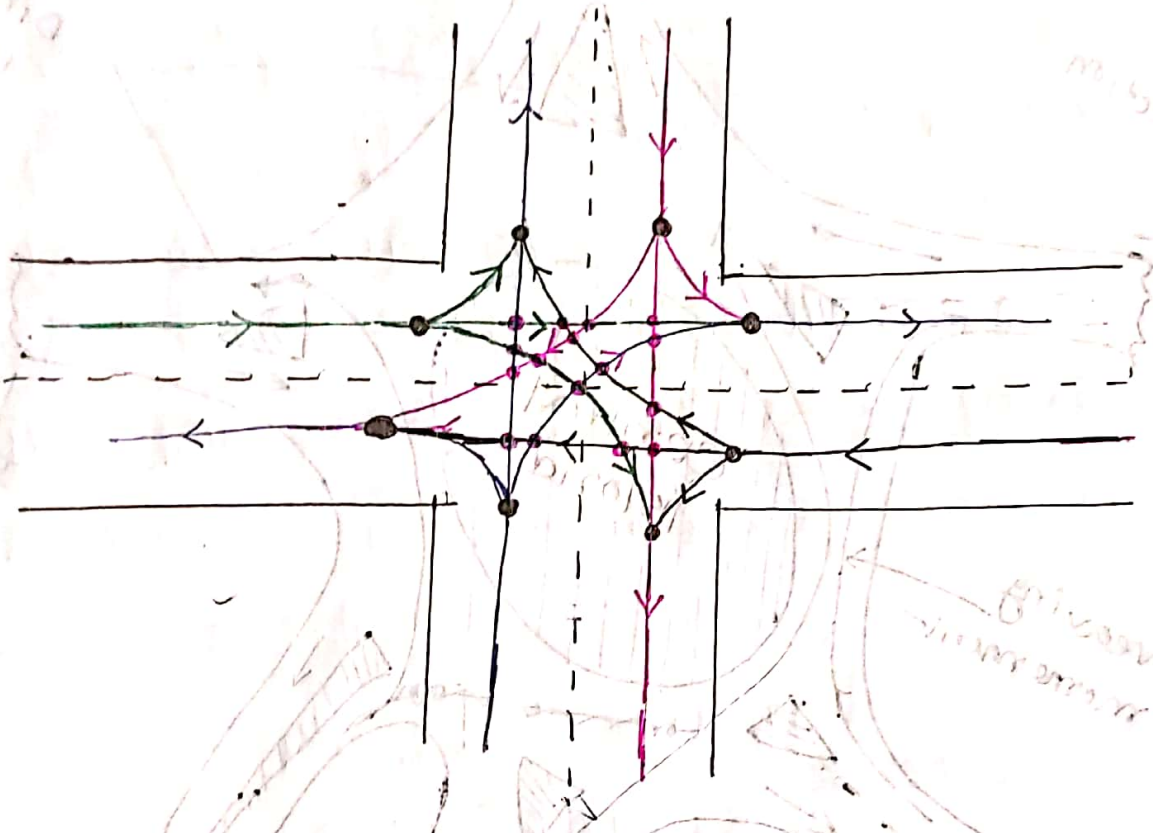
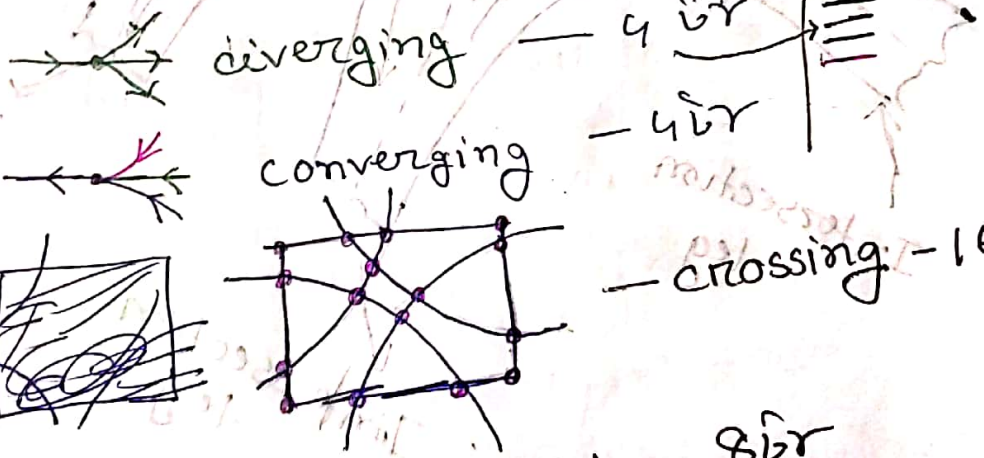
Potential conflict Points at four legged at-grade intersection





diverging — 4 Nos

converging — 4 Nos

crossing - 16 Nos

Padestrain conflict - 8 Nos

Total = 4+4+16+8 = 32*** conflicts

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Traffic Signal Design

Signal sequence : Green → Amber → Red

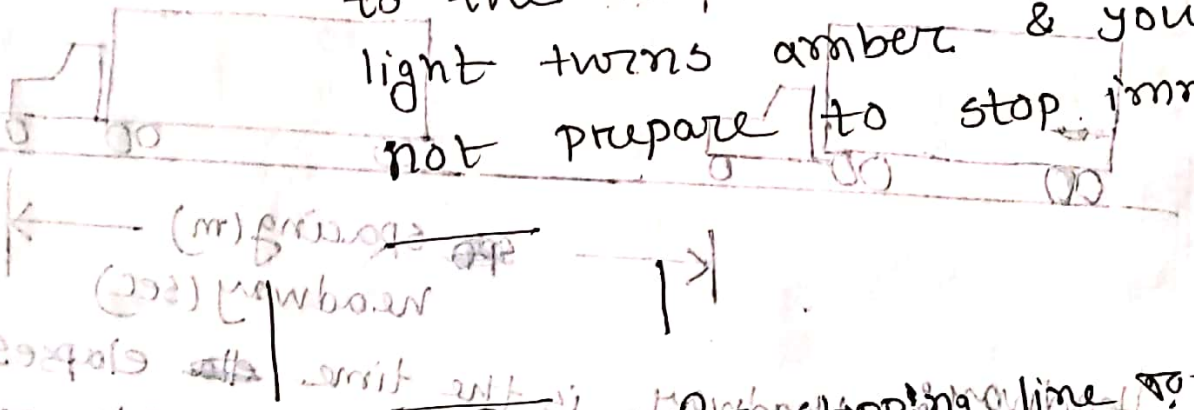
---- Amber ← Green ← Red & Amber

Red → stop

Red & Amber → prepare to go

Green → GO

Amber → stop unless you are too close to the line at the time the light turns amber & you are not prepare to stop immediately.



Cycle length (C) : It is the time in seconds that it takes a signal to complete a full cycle of indication i.e. interval between two successive green time.

Lost time:

(i) **Startup lost time:** occurs when a signal indication turn from red to green, drivers in the queue do not instantly start moving; there is an initial lag due to perception-reaction process.

(ii) **Clearance lost time:** time lost due to intersection clearance (All red - সময়ে দুইদিকেই চলাচল বন্ধ থাকে)

Total lost time, $T_L = t_{sl} + t_{cl}$

t_{st} = startup lost time

t_{cl} = clearance lost time

Effective green time: Actual time available for vehicles to cross the intersection.

Effective green time, $g_i = G_i + y_i - t_L$

~~g_i = ef~~

G_i = Actual green interval (time)

y_i = Yellow / Amber interval (আসলে এই সময়েও technically intersection pass করা যায়)

T_L = total lost time

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Capacity of a lane:

[cycle time এর মধ্যে সর্বোচ্চ গাড়ি চলাচল করে]

capacity of a lane = green ratio × max^m traffic volume

$$\text{max}^m \text{ traffic volume}, q_{max} = \frac{1}{\text{saturation headway (hr/veh)}}$$

$$= \frac{3600}{\text{saturation headway (sec/veh)}}$$

* saturation headway = রাস্তায় সর্বোচ্চ ধারণক্ষমতাতে দুইটি গাড়ির মধ্যবর্তী দূরত্ব।

$$\text{* green ratio} = \frac{\text{effective green time}}{\text{cycle length}} = \frac{g_i}{C}$$

$$\therefore \text{capacity of a lane} = \frac{g_i}{C} \times \frac{3600}{h_t \text{(sec)}}$$

unit = veh/hr/lane

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(Q37) Cycle time of an intersection is 60sec. Green time is 27sec. corresponding yellow time is 4sec. If the saturation headway is 2.4 sec./veh, the startup lost time is 2sec & clearance time is 1sec, find the capacity of movement per lane [MSc'18] [NHA'19]

Soln:

effective green time, $g_i = 27 + 4 - (2+1)$

$= 28$sec

$\therefore$ capacity per lane $= \frac{g_i}{C} \times \frac{3600}{h_t}$

$= \frac{28}{60} \times \frac{3600}{2.4}$

$= 700$ veh/hr/lane

Ans

* Determine the minimum yellow interval at an intersection whose width is 40ft. Maximum allowable speed on the approach roads is 30mph. Assume average length of vehicle is 20ft.

Soln: $Y_{min} = 1 + \frac{40+20}{30 \times 1.47} + \frac{30 \times 1.47}{2 \times 11.2}$

$= 4.3$sec Ans:

Take,
perception reaction time = 1sec
deceleration rate = 11.2 ft/sec^2

* What should be the minimum red clearance interval for this section? [NESCO'21]

Soln: $R_{min} = \frac{40+20}{30 \times 1.47} = 1.36$ sec

$s = vt$

$\therefore t_{interval} = \frac{s}{v}$

1.47 for mph to ft/sec

* A signalized intersection approach has three lanes with no exclusive left or right turning lanes. The approach has a 40sec green out of of a 75-second cycle. The yellow plus all-red intervals for phase total 4sec. If the start-up lost time is 2.3s/phase, the clearance lost time is 1.1sec/phase and the saturation headway is 2.48sec/veh under prevailing conditions. calculate the capacity of the intersection.

[BIWTA'23]

Soln°

$$\text{capacity} = \frac{40+4-2.3-1.1}{75} \times \frac{3600}{2.48}$$

$$= 785.806 \text{ veh/hr/lane}$$

Total capacity = $785.806 \times 3 = 2357.42$ veh/hr

Find the saturation flow and total lost (initial & final) time if 48sec is green plus amber time and flow at 6s interval is 2, 4, 4, 3, 4, 3, 4, 2 .

SGFL 2023

Soln: average flow at 6sec interval

$$= \frac{4+4+3+4+3+4}{6} = 3.67$$

$$\therefore \text{ Saturation flow} = \frac{3.67}{6}$$

$$= 0.612 \text{ veh/sec}$$

$$= 2203 \text{ veh/hr}$$

$$\text{Initial lost time, } I_1 = t_i - \frac{n_i}{s}$$

$$= 6 - \frac{2}{0.612} = 2.732 \text{sec}$$

$$\text{Final lost time, } I_2 = t_f - \frac{n_f}{s}$$

$$= 6 - \frac{2}{0.612} = 2.73 \text{sec}$$

Ans

(30) Determine the total inter-green time for a 2 face traffic signal having cycle time, $C = 66S$, Green time for NS direction, $G_{NS} = 24S$, for EW direction, $G_{EW} = 27S$. [PGCL'17]

Ans: Total intergreen time = $66 - (24+27)$
$= 15sec$

A

* T/F cycle time is obtained by adding the loss time with effective green time [BWDB'16] [PGCB'17]

Ans: True

$G_{NS} = g_{NS} + l - a$

g_{NS} ↙ effective green; l → loss time

cycle time = $G_{NS} + G_{EW} + \sum$ Intergreen (NS + EW)

Sub :

Traffic signs :

(40) Sign shape for (i) Mandatory sign (ii) Cautionary sign (iii) Information or guide sign [GTCL'16]

or,

Draw signs : (i) Warning (ii) Mandatory (iii) Information [Titas'18]

Ans:

(i) Mandatory sign:

→ usually circular in shape with red border, white background

→ Special mandatory sign

(a) Stop: octagonal, red background, white border

(b) Yield/Giveway: triangular pointing downward

STOP

YIELD/Give way

Height Limit

8 For mandatory sign, which shape is used? [MSc'12] Δ/□/○

Speed limit

U-turn Prohibited

Right turn prohibited

Mandatory / regulatory signs

Right hand curve

Hair pin bend

Reverse Bend

Narrow Road Ahead

Narrow Bridge Ahead

School Ahead

Warning / Cautionary signs

Warning signs

→ equilateral triangle or dimond shape

Sub :

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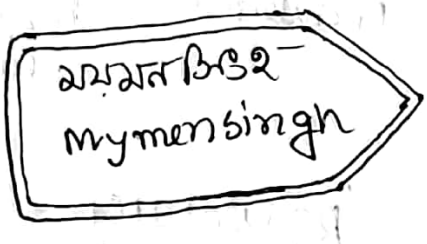
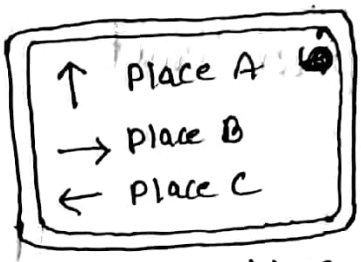
* Informatory / Guide signs :

→ Rectangular in shape

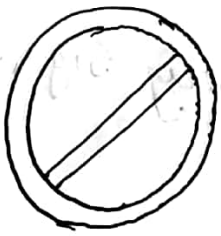




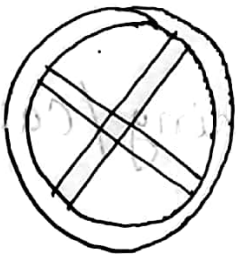
Destination

Q(41) Draw the following road signals:
(i) No parking (ii) Roundabout (iii) No stopping
(iv) Prohibited right turn [DWASA '14]

Soln :



No parking



No stopping

Prohibited Right turn

← Roundabout

Sub :

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Q.42 What is BRT? [Titas '21] Write down the six points/characteristics of BRT [Titas'21] [RRI'15] [MSc'13]

Ans: Bus Rapid Transit (BRT) is a high-quality bus-based transit system that delivers fast, comfortable & cost effective services at metro-level capacities. It does this through the provision of dedicated lanes with busways and iconic stations typically aligned to the center of the road, off-board fare collection & fast and frequent operations.

Six points/characteristics of BRT:

(1) **Dedicated Right-of-Way:** Bus only lanes make for faster travel and ensure that buses are not delayed by mixed traffic congestion.

(2) **Busway ~~Alignment~~ Alignment:** A median (segregated) alignment of bus-only lane keeps buses away from busy curb-side conflicts, where cars and trucks are parking, standing and turning.

(3) Off-boared fare collection: Fare payment at the station, instead of on board the bus, eliminates the delay caused by passengers paying on board.

(4) Intersection treatment: Prohibiting turns for traffic across the bus lane reduces delays caused to buses by turning traffic. Bus priority will often be provided at signalized intersections to reduce delays by extending green ~~time~~ phase or reducing the red phase in the required direction compared to the normal sequence.

(5) Platform-level boarding: The station should be at level with the bus for quick and easy boarding. This also makes it fully accessible for wheelchairs, disabled passengers, strollers and carts with minimum delays.

Sub:

(6) <u>High capacity vehicles:</u> High-capacity vehicles such as articulated or even bi-articulated buses may be used, typically with multiple doors for fast entry and exit. Double-decker buses or guided buses may also be used.

Road Types:

(1) <u>Arterial Roads</u>: Highways, expressways, urban main roads

(2) <u>Collector Roads</u>: major and minor roads that connect local roads and streets with arterials

(3) <u>Local roads</u>: Provide limited mobility and are the primary access to residential areas, business, farms and other local areas

Arterial Road এ mobility (গতি) বেশি কিন্তু বাড়িঘর, অফিস আদালত এবং অন্যান্য লোকাল এরিয়ায় সরাসরি access কম। কিন্তু local road এ বেশি।

BGDCL - [illegible]

Sub :

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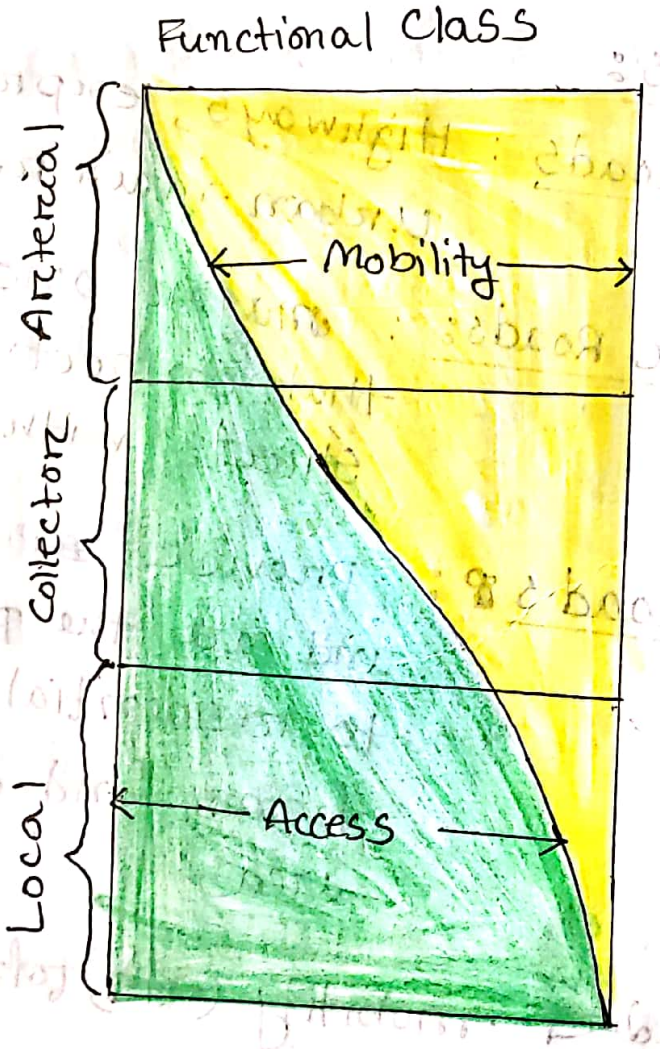
Q43 Draw the schematic Relationship between access and mobility function of streets [PGCB'15] [MSc'17] [DNCC'16] [BIWTA'19] [BGDCL'21] [DESCO'22] [Petrobangla 22]

Or,

Accessibility movement diagram for local, collector & Arterial road [BIWTA'19]

Soln:



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Q46 A new office building is expected to add 800 pedestrains to a 15ft sidewalk during the pick 10 minute period. The sidewalk already has a flow of 1400 pedestrains during the peak period. Around 3ft width of the sidewalk is used for light posts and other observations. Determine the net flow rate and characterize the quality of flow. [BIWTA'19] [PGCL'17] [BWDB'16] [PGCL'14]

Soln: Pedestrain flow rate

$$= \frac{\left(\frac{1400+800}{10}\right) \text{ped/min}}{(15-3)\,\text{ft}}$$

$$= \frac{220}{12} \text{ ped/min/ft}$$

$$= 18.33 \text{ ped/min/ft}$$

Level of Service (LOS)	Flow Rate (ped/min/ft)
D	10-15
E	15-23

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LOS D : Provides reasonably fluid flow, but friction and interaction between pedestrains is likely.
Crossing or reverse flow movement face a high probability of conflicts.

LOS E : pedestrains environment is unsuitable. All pedestrains restricts their normal walking speed. Volume approaches the limit of walkway capacity.

LOS F : Breadown, fully stopped

LOS D : Poor pedestrain conditions exist

LOS E : Pedestrain environment is unsuitable

From math,
flow rate = 18.33 ped/min/ft

∴ Level of service (LOS) = E

~~Poor pedestrain condition exist~~

Pedestrain environment is ~~unstab~~ unsuitable.

Level of service = D
Pedestrain environment is fully saturated condition

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Mode-Choice : Logit Model

Mode-choice এর মধ্যে bus, car, auto কীভাবে যাবে সেটার probability বের করা হয়, এজন্য logit model use করা হয়।

যেমন auto তে যাওয়ার probability,

$$P_{auto} = \frac{e^{u(auto)}}{e^{u(auto)} + e^{u(bus)} + e^{u(car)}}$$

এখানে, u এর মান হবে utility of respected vehicles

Example:

Utility function of road user travelling from sub-urban to CBD of Newyork city using mode auto and bus are given below:

$U_{auto} = -0.06 - 0.07$ (auto travel time)
$- 0.105$ (parking cost) $+ 0.00001$ (HH income)

$U_{bus} = -0.07$ (bus travel time) $- 0.12$ (bus waiting time) $- 0.56$ (bus fee)

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Variable	Auto	Bus
travel time(min)	40	60
bus headway (min)	–	20
Parking cost ($)	8	–
Bus fare ($)	–	2
Annual HH income($)	8000	8000

① Compute probability of each mode of transportation.

② If bus number is doubled, what is the probability of chosing bus for trip?

(similar math in DTCA'19)

Ans: $u_{(auto)} = -0.06 - 0.07 \times 40 - 0.105 \times 8 + 0.00001 \times 8000$

$= -3.62$

$u_{(bus)} = -0.07 \times 60 - 0.12 \times 10 - 0.66 \times 2$ ↗ waiting time = headway/2

$= -6.72$

Probability of auto, $P_{auto} = \frac{e^{u(auto)}}{e^{u(auto)} + e^{u(bus)}} = \frac{e^{-3.62}}{e^{-3.62} + e^{-6.72}}$

$= 0.957$

Probability of bus, $P_{bus} = \frac{e^{-6.72}}{e^{-3.62} + e^{-6.72}} = 0.043$

or, $1 - 0.957 = 0.043$

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(b) For doubling the number of buses,

waiting time
~~headway~~ = 5 (আগের মতোই)

$$\therefore U_{bus} = -0.07 \times 60 - 0.12 \times 5 - 0.66 \times 2$$

$$= -6.12$$

$$\therefore P_{bus} = \frac{e^{-6.12}}{e^{-6.12} + e^{-3.62}}$$

$$= 0.076 \quad \text{Ans:}$$

~~(c) volume~~

(c) value of time for bus.

$$VOT = \frac{\text{travel time coefficient}}{\text{bus fare coefficient}}$$

$$= \frac{0.07}{0.66}$$

$$= 0.106 \text{ dollar/min}$$

$$= 6.36 \text{ dollar/hr}$$

Date : / /

Sun Mon Tue Wed Thu Fri Sat

* Determine the ~~share~~ percentage increase in using Mass Transit which would result from doubling the private auto's out-of-pocket cost.

Utility function: $u_k = A_k - 0.05T_a - 0.04T_w - 0.03T_r - 0.014C$

Parameter	Private auto	Mass Transit
T_a = access time (min)	5	10
T_w = waiting time (min)	0	15
T_r = riding time (min)	25	40
C = out-of-pocket cost (Tk)	150	100
Calibration constant A_k	-0.01	-0.07

Soln:

$u_{auto} = -0.01 - 0.05\times5 - 0.04\times0 - 0.03\times25 - 0.014\times150$

$= -3.11$

$u_{MRT} = -0.07 - 0.05\times10 - 0.04\times15 - 0.03\times40 - 0.014\times100$

$= -3.77$

$\therefore$ Mass Transit share $= \dfrac{e^{-3.77}}{e^{-3.77} + e^{-3.11}} \times 100\%$

$= 34.07\%$

~~If out of cost~~

If out of pocket cost is doubled for auto,

$u_{auto} = -0.01 - 0.05\times5 - 0.04\times0 - 0.03\times25 - 0.014\times300$

$= -5.21$

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∴ New Mass transit share $= \frac{e^{-3.77}}{e^{-3.77} + e^{-5.21}} \times 100\%$

$= 80.845\%$

ঘ.

∴ % increase in using Mass Transit

$= \frac{80.845 - 34.07}{34.07} \times 100\%$

$= 137.3\%$

* প্রশ্নে যদি বলাতো % of shift from auto to MRT তবে, হবে -

$\frac{P_{auto} - P_{auto(new)}}{P_{auto}} \times 100\%$

∴ New auto share $= (100 - 80.845)\%$

$= 19.155\%$

∴ % of shift from auto to MRT

$65.93 = \frac{(100 - 34.07) - 19.155}{65.93} \times 100\%$

$= 70.946\%$

auto হতে MRT তে 70.946% মানুষ shift করছে।

Date : / /

Sun | Mon | Tue | Wed | Thu | Fri | Sat

* If utilities of Auto, Bus & walking are 0.47, −1.525 & −2.5 respectively, determine their mode share probabilities using basic logit model. [Petro bangla '22]

$$P_{auto} = \frac{e^{0.47}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.842$$

$$P_{Bus} = \frac{e^{-1.525}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.1145$$

$$P_{walking} = \frac{e^{-2.5}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.0432$$

$$P_{auto} = \frac{e^{auto}}{e^{auto} + e^{bus} + e^{walk}}$$

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Highway Materials

Sub-grade Soil:

The supporting soil beneath pavement and its special under courses is called sub-grade.

GOP
* The top of ground on which the foundation of a road rests is called subgrade [WRGCL'14]

* subgrade materials used generally is soil [BCIC'16]

* T/F The upper part of the ground is called sub-grade (True) [BPDB'15]

California Bearing Ratio (CBR) Test:

CBR test was developed by the California Division of Highway as a method of classifying and evaluating soil-sub grade and base course materials for flexible pavements.

* CBR test is required for evaluate subgrade [BPDB'13]

→ CBR দ্বারা subgrade এর strength evaluate করা হয় এবং CBR অনুযায়ী subgrade এবং base course এর thickness নির্ণয় করা হয়।

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→ CBR test is an empirical formula/test that has been used to determine the material properties for pavement design

*** → CBR test is a penetration test that compares the bearing capacity of a material with that of a well-graded crushed stone.

*** → Thus a high quality crushed stone material should have a CBR @ 100%

*** → CBR test is usually done for the particles of size less than 19mm (or 3/4 inch)

→ For CBR test, size of standard penetration piston is 50mm (2 inch)

→ ∴ Area = $\pi \times (\frac{50}{2})^2 = 19.62\ cm^2$ ($3.14 inch^2$)

→ Penetration rate is 1.25mm (0.05") per minute

*** → The ratio at 2.5mm (0.1 inch) penetration is used as CBR [এটাই 2 Point এর CBR]

→ Sometimes CBR for 5mm (or 0.2 inch) penetration also used.

Sub :

~~Pressure or unit load of sample for~~
~~CBR (%)~~

$$CBR = \frac{\text{Pressure (unit load) of sample for 2.5mm or 5mm Penetration}}{\text{standard unit load / pressure for that penetration}} \times 100$$

standard pressure,

$P_{2.5mm}$ = 1000 psi (6.9 MPa)

P_{5mm} = 1500 psi (10.3 MPa)

kg unit ও রূপ করে,

$P_{2.5mm}$ = 1370 kg $\left(\frac{1370}{19.62} = 70\,kg/cm^2 \right)$

$P_{5.00mm}$ = 2055 kg $\left(\frac{2055}{19.62} = 105\,kg/cm^2 \right)$

*** Normally $CBR_{2.5mm} > CBR_{5mm}$
(CBR reported is higher of the two value)

If $CBR_{5mm} > CBR_{2.5m}$, test is to be repeated for checking. If it again gives the same result, the higher value is reported as CBR value

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*MCQ

If the pressure carried by a CBR specimen at 2.5mm penetration is 3.5 N/mm^2, the CBR of the soil is _____ (BWBB'20)

[A] 10% [B] 35% [C] 50% [D] 70%

Soln: $CBR_{2.5mm} = \frac{3.5}{6.9} \times 100 \approx 50\%$

**calculate CBR value for 400 lb & 2-sinch penetration.

Ans: $CBR_{2.5mm} = \frac{400}{1370 \times 2.204} \times 100 \approx 13\%$

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(52) What is CBR? Why CBR is calculated for 2.5mm? [Padma Bridge '15]

Ans:

CBR test is a penetration test that compares the bearing capacity of a material with that of a well-graded crushed stones. CBR value is usually recored for 2.5mm penetration.

CBR values is calculated for 2.5mm penetration because it gives the highest value. It also provide the most accurate value so that we can ascertain about soil bearing capacity. Due to the surface irregularities, lower penetration than 2.5mm don't give accurate result. Sometimes CBR is calculated for 5mm penetration. When 5mm penetration gives higher value than 2.5mm penetration than 5mm penetration value is used.

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(53) What is CBR value? How is it performed?
[Rajuk '14] [54BMA]

Ans: Test procedure:

(1) The laboratory CBR apparatus consists of a mould 150mm dia with a base plate and a collar, a loading frame & dial gauges for measuring penetration values & the expansion on soaking.

(2) The specimen in the mould is soaked in water for four days and the swelling and water absorption values are noted.

(3) Load is applied on the sample by a standard plunger with dia. of 50 mm at the rate of 1.25mm/min. A load penetration curve is drawn.

(4) The pressure on standard crushed stones are 1000psi (6.3MPa) & 1500psi (10.3MPa) at 2.5mm & 5.0mm penetration respectively.

(5) CBR = $\frac{\text{Pressure of sample for 2.5mm or 5.00 mm penetration}}{\text{standard pressure for that penetration}} \times 100$

(6) Normally $CBR_{2.5mm} > CBR_{5.00mm}$. CBR is reported as the higher of the two values.

(7) If CBR for 5mm penetration is higher than the test should be repeated. If it gives the higher value again, then 5 mm penetration is taken.

Q(54) Difference between soaked (wet) & unsoaked (Dry) CBR. [MIST MSc '17]

Ans: When we perform the CBR test in soaked condition, we try to simulate the worst conditions in the field and to achieve this condition the soil specimen is kept submerged in water for about 4 days before testing.

When CBR test is conducted in unsoaked condition, we try to simulate the normal field conditions, so the moulding water

content is equal to the equilibrium water content which the soil is likely to attain after the construction of the pavement.

Remember: Always Dry CBR > Wet CBR

[Q55] What is improved subgrade? why it is provided in Bangladesh [CPGCBL'15] [53 BMA]

Ans: সড়কের কোন স্থানে subgrade এর উপরস্থ মাটি (low bearing capacity soil) কে অপসারণ করে বালি দিয়ে ভরাট করে compact করে bearing capacity i.e. CBR value বাড়ানো হয়। তাকেই improved subgrade (ISG).

Improved subgrade এর main element: Sand (বালি) যার FM 0.8 (local sand)

~~*** CBR values~~

*** Minimum CBR values for subgrades

Subgrade = 4% (LGED), 5% (RHD)

Improved subgrade = 8% (LGED, RHD)

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Aggregates :

Different tests of aggregate —

(i) Aggregate crushing value (ACV) test

***→ to determine strength

→ Higher the ACV value weaker the aggregate

→ ACV test is not suitable for testing the aggregates with ACV value higher than 30. In that case 10% finer value (TFV) is recommended

→ 10% Fines value (TFV) test is suitable for both strong and weak aggregate

→ According to RHD, minimum ACV value is less than 25% for wearing course & less than 30% for base course.

→ ACV value shouldn't be greater than 36% for sub-base.

ACV ৩% বেশি - base course ≤ 30% ; wearing course ≤ 25%
ACV ৩% বেশি - base course ≤ 35% ; wearing course ≤ 30%

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(ii) Los Angeles Abrassion test :

→ This test is carried out to evaluate the hardness properties of aggregate

→ The principle of Los Angeles Abrassion (LAA) test is to find the percentage of wearing in aggregate.

→ ~~LAA~~ LAA value should be less than 30% for wearing course & less than 35% for base course.

(iii) Aggregate Impact value (AIV) test :

→ This test is carried out to evaluate the toughness of aggregate

→ AIV value of aggregate used in wearing course shouldn't exceed 30%.

(iv) Soundness test (durability test)

→ Soundness test is done to evaluate the resistance of aggregates to weathering action.

→ Aggregates are soaked in sodium sulphate (Na_2SO_4)

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or magnesium sulphate ($MgSO_4$) for 16-18hrs and than oven dried.

→ This process or cycle continues for 5 times.

→ For good quality aggregate, loss in weight after 5 cycle with Na_2SO_4 solution should not be more than 10%

(v) Flakiness Index test:

→ For good aggregate flakiness index shall not exceed 30%

→ The flakiness index is defined as the percentage by weight of aggregate particles whose least dimension is less than 0.6 times their mean size.

(vi) Flat & Elongated particles (Elongation Index):

→ The elongation index of an aggregate is defined as the percentage by weight of particles whose greatest dimension is 1.8 times their mean dimension.

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→ A flat and elongated particle is defined as one that has its maximum dimension five times greater than its minimum dimension (not length). [ASTM D4791]

(vi) Angularity Number

(vii) Bulk specific gravity and water absorption:

→ for wearing & base course materials, water absorption capacity shall not be more than 2%

(viii) Coating & stripping test:

→ Determines bitumen adhesion capacity of Aggregates.

→ For good quality aggregates, minimum 95% coating should be retained.

** For both AIV & ACV (& also 10% finer test) test -

(i) In dry aggregate condition → oven dry for 4 hours before testing

(ii) For soaked aggregate condition → immersed the aggregate for 24 hrs.

(dry, wet condition test over 2 hr)

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*** Previous MCQs & T/Fs

(i) TFV (10% Finer value) gives a measure of the resistance of aggregate of crushing force weak & strong aggregate (T/F) [SGFL'17]

Ans: True

(ii) AIV, TFV, soundness, brittleness etc tests are of bitumen contents (T/F) [BUET]

Ans: False

(iii) (GAP)
percentage of wear aggregate is determined by Los Angeles Abrassion value [BPDB'15]

(GAP)
(iv) The aggregate abrassion value (AAV) of good aggregate should be less than 30% [47 BMA]

(T/F)
(v) ACV test is done for weaker aggregate particles [PGCB'15] [BWDB'16]

Ans: False [ACV কম হলে strong aggregate, ACV 30% এর বেশি হলে weak]

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(6)(vi) T/F

The aggregate sample for AIV test has to be oven dried for 24hrs [PGCB '15] [GWDB '15]

Ans: False [4hrs oven dry তাপ 22°]

(vii) T/F

Los Angeles abrcassion test is usually performed on fine aggregates.

Ans: False [এই test টি coarser aggregate এর জন্য তার 22°]

(viii) According to RHD specifications, ACV for wearing course is less than 25% [MES]

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Some properties of Bitumen :

→ It is soluble in carbon disulphate

→ It is insoluble in water

→ Its specific gravity is between 1.02 to 0.97

→ Unit weight of bitume is 1040 kg/m3

Different Tests of Bitumen: (Viva)

(1) Viscosity test
(2) Ductility test
(3) Penetration test
(4) Softening point test
(5) Flash & fire point
(6) Specific gravity
(7) Solubility
(8) Float test
(9) Loss on heating test
(10) Water content test

Penetration test:

→ Determines hardness or softness of bitumen.

*** The test is normally carried out at 25°C

→ It measures the distance a standard blunt pointed needle (1.00mm dia, 50mm length) will vertically penetrate a sample of material at 25°C, the load being 100g and time of

(needle wt + imposed weight = 100g)

application of load being 5secs

→ The unit of penetration is 1/10mm.

→ Grading of Bitumen is done using this penetration test.

(viva) → A 80/100 grade bitumen indicates that its penetration value lies between 8mm & 10mm when standard penetration test is done.

→ similarly 60/70 grade means 6mm to 7mm penetration

→ common grades of ~~penet~~ Bitumens are 80/100, 60/70, 30/40

(Viva) → commonly used bitumens in Bangladesh are 80/100 grade & 60/70 grade

→ In warmer regions (Gulf countries), lower penetration grade (30/40) is preferred to avoid softening. (কারণ এর সবচেয়ে hard)

viva → রাস্তার সর্বোচ্চ surface coating এ 60/70 grade bitumen ব্যবহার করা হয়, কারণ উচ্চ তাপমাত্রায় গলে, তবে নিচের দিকের layer যেমন primecoat, tack coat এ 80/100 bitumen ব্যবহার করা হয়।

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viva → কীতপ্রতিরোধ যেকোন মাত্রা 30/40 কিম্বা 60/70 গ্রেডের বিটুমেন ব্যবহার করা হয় তা সুনিশ্চিত করতে যে brittleness তাড়াতে কিংবা রাস্তায় crack হতে পারে আর ~~কিন্তু~~ উচ্চ তাপমাত্রাতে 80/100 বা এর উপরের grade এর bitumen ব্যবহার করলে তা সহজে কিংবা bitumen bleeding হতে পারে।

~~*** BUET MSC~~

*** BUET MSC '2021 (MCQ)

Which of the following represent the hardest grade of bitumen?

(i) 60/70 (ii) 100/120 (iii) 30/40 (iv) 80/100

Softening Point test

→ Softening point is the temperature at which bitumen attains a particular degree of softness under standardised test conditions.

→ Usually determined by ring & ball test.

→ Hard grade (i.e. 30/40) bitumen has higher softening point, soft grade bitumen has lower softening point.

Sub :

→ Higher the softening ~~value~~ point, lower the temperature susceptibility & is preffered in warm climates.

Viva* → Description about softening point test of bitumen [NWPGCL-Viva]

প্রথমে bitumen গরম করে brass (পিতল) ring এ ঢেলে নিতে হবে। ~~~~ তাপ দেয়ার সময় খেয়াল রাখতে হবে তাপমাত্রা যেন কোনোভাবেই 90°C এর বেশি না হয় এবং 30 মিনিটের বেশি তাপ দেয়া না হয়, বিটুমিন ঠান্ডা হয়ে শক্ত হয়ে গেলে একটি বিকারের মধ্যে পানি ঢেলে ring holder এর মধ্যে দিতে রাখতে হবে। এর উপর steel এর বল ~~~~ এরকম দুইটি হবে যার ওজন 3.5g। ring holder এ ring ball assembly থাকতে হবে। পানিতে অবশ্যই 100°C এর তাপমাত্রা মাপার জন্য থার্মোমিটার ও রাখতে হবে। ring থেকে 25mm নিচে থাকবে base plate.

~~শুরুতে পানির তাপমাত্রা~~ শুরুতে পানির তাপমাত্রা থাকবে 5°C। এই তাপমাত্রা অন্তত 15 minute যাবত বহাল থাকবে। ~~এরপর~~ পানিতে তাপ বাড়াতে হবে। প্রতি মিনিটে 5°c rate এ তাপমাত্রা বাড়ানো, যেই তাপমাত্রায় bitumen গলে গিয়ে steel ball এর ওজনে

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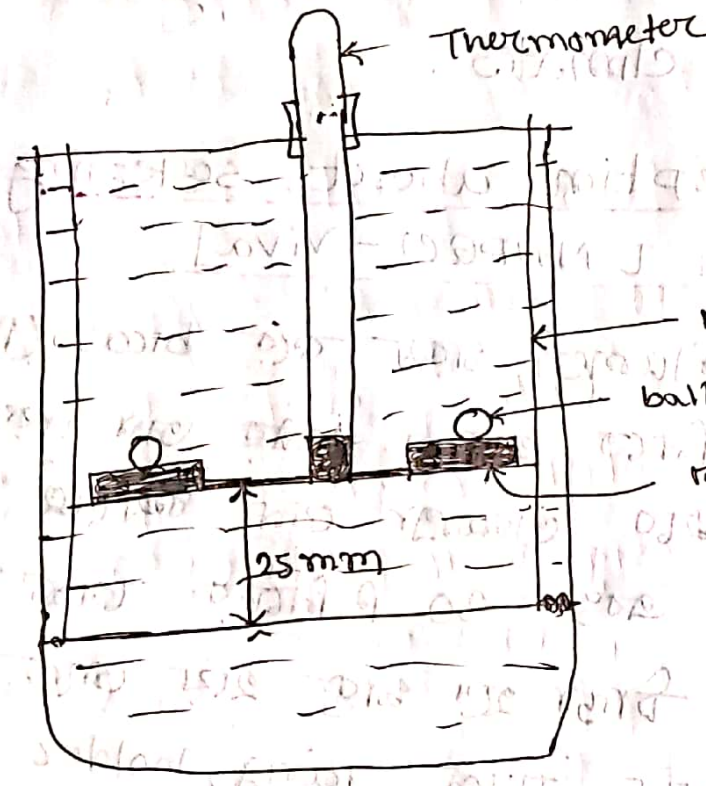
জন্য 25mm নিচে bottom plate এ রিং-
পরে সেই bitumen এর softening point.



* বিভিন্ন bitumen এর softening point 80°C
এর উপরে সেগুলোর জন্যে বাতাস থেকে
glycerol (গ্লিসারল) use করতে হয়।

Example :

According to RHD, softening point of different grade bitumens —

grade	softening point min	softening point Max
60/70	48°C	56°C
80/100	45°C	52°C

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Flash Point & Fire Point of Bitumen : [BEPZA'19] [CTG Port'15]

→ These are primarily safety tests.

→ For These tests cleveland open cup apparatus is used.

→ The flash point is the lowest temperature (in °C) at which the application of a test flame causes the vapours from bitumen to catch fire momentarily in the form of a flash.

→ The fire point is the lowest temperature in ~~degrees~~ (°C) at which the application of the test flame causes the bitumen to ignite and burn for at least 5secs under specified conditions of test.

→ According to RHD, flash point of 60/70, 80/100 grade bitumen is 250°C

→ In order to eliminate fire hazards during heating, mixing or application, it is necessary to restrict the process well below these critical temperature (At least 50°C below flash point)

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Los on Heating:

Los on heating to 163°C for 5hr is 0.2% of wt. for 60/70 grade, 0.5% for 80/100 grade

Viva question:

বাংলাদেশের কোথায় Bitumen produce হয়?

ERL (Eastern Refinery Ltd) এবং ~~recent~~ Bashundhara Bitumen Plant (November, 2020 সালে first production) বিস্তারিত প্রশ্নের উত্তর জানতে হবে।

Marshall mix design:

1. Objectives:

→ Sufficient bitumen to ensure a durable pavement against weathering & abrasive actions.

→ Sufficient strength to resist shear deformation under traffic at higher temperature

→ Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic.

→ Sufficient flexibility to avoid premature cracking due to repeated bending by traffic

→ sufficient flexibility at low temperature to prevent shrinkage cracks.

→ sufficient workability to permits easy placement with segregation.

2. Constituents of a mix

(1) coarse aggregate (max^m size 25mm for base coarse, 20mm for wearing coarse according to RHD. But normally max^m size of 20mm is mostly preferred)

(2) Fine aggregate

(3) Filler [aggregate passing #200 (0.075mm) sieve]

(4) Bitumen [total weight ए 4-6% base coarse ए, 5-7% wearing coarse ए RHD]

***For evaluation of performance of Bituminous mixes, flow test & stability test are performed.

Q.5x Draw the marshall qualitative curve [BPDB 15] [BWDB '14] [MSc '13] [DESCO '13] [PGCB '18] [WRGCL 14] [PGCB '15] [BIFPCL '21] [GTCL '22] [KPDCL '21]

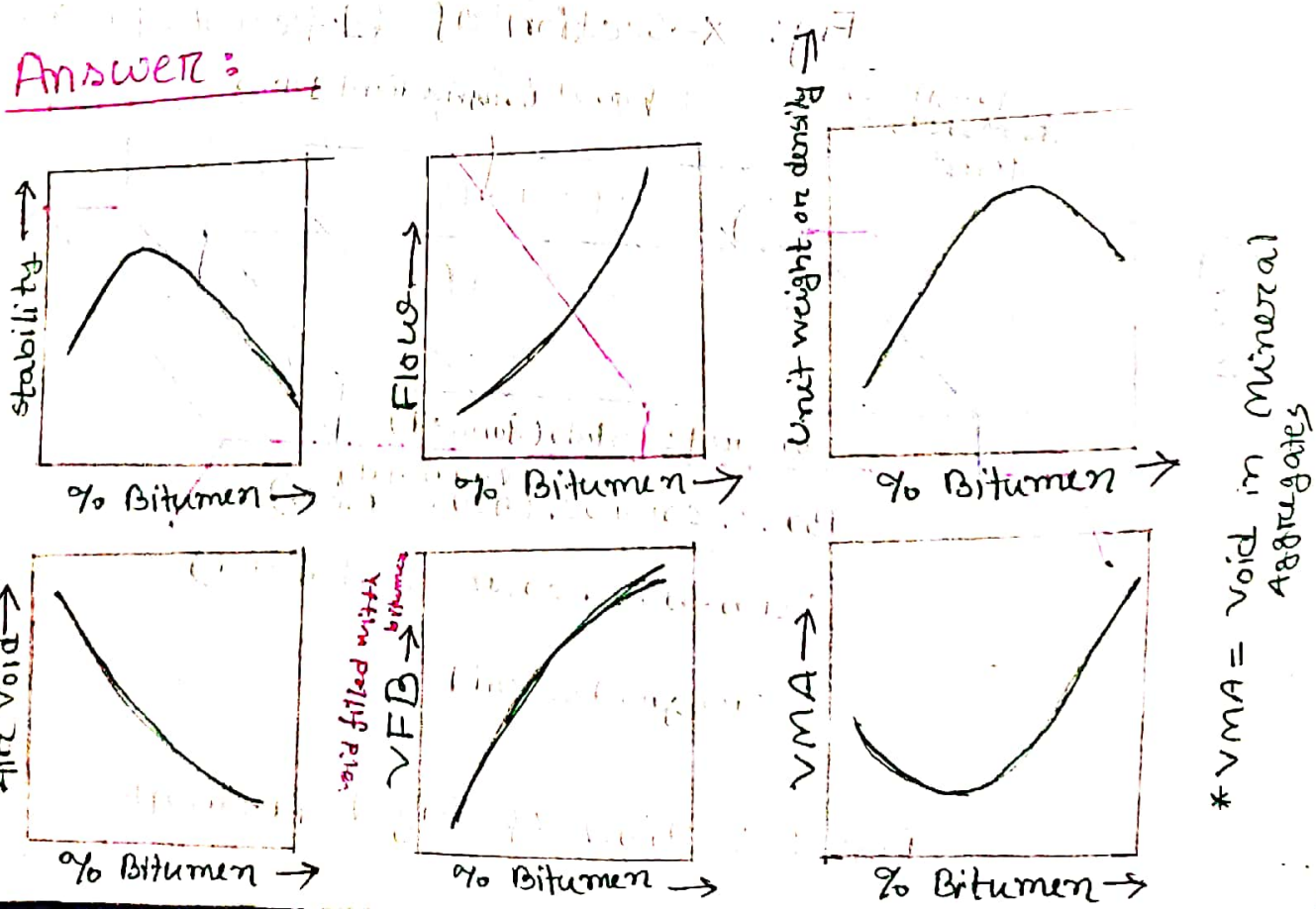
OR

Draw percentage of AC (Asphalt content) vs Air void, & flow, & VMA (MSc '11)

OR

In hot mix design, draw percentage of void, unit weight & stability against percentage of AC

Answer:



* Write down the names of the 4 polymers used for bitumen modifications [DNCC'22]

→ Styrene-butadiene-styrene (SBS)
→ Styrene-butadiene-rubber (SBR)
→ Ethylene-vinyl-acetate (EVA)
→ Ethylene-glycidyl-acrylate (EGA)

Pavement Design

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Q5 Draw the cross-section of flexible & rigid pavement [BD-China'16] [RRL'15] [DWASA'19] [MSC'19] [BEPZA'16] [WRGCL'14] [EGGB'20] [BWDB'13] [DWASA'21]

DNCC'20

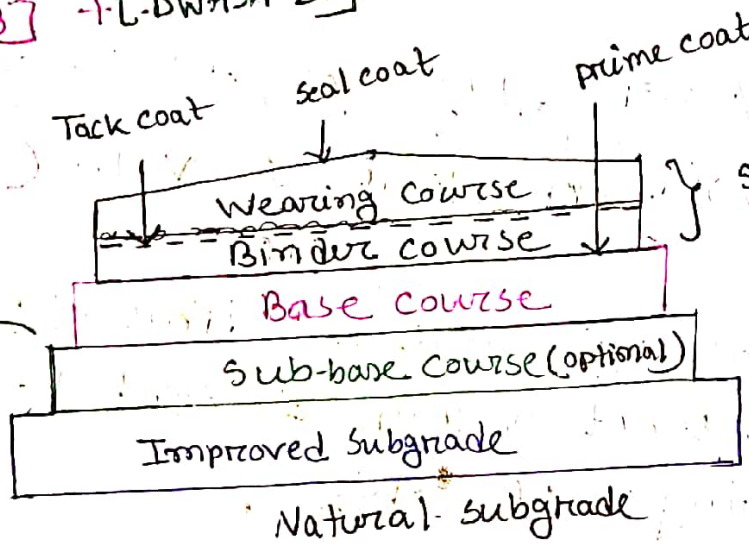


Fig: X-section of flexible pavement

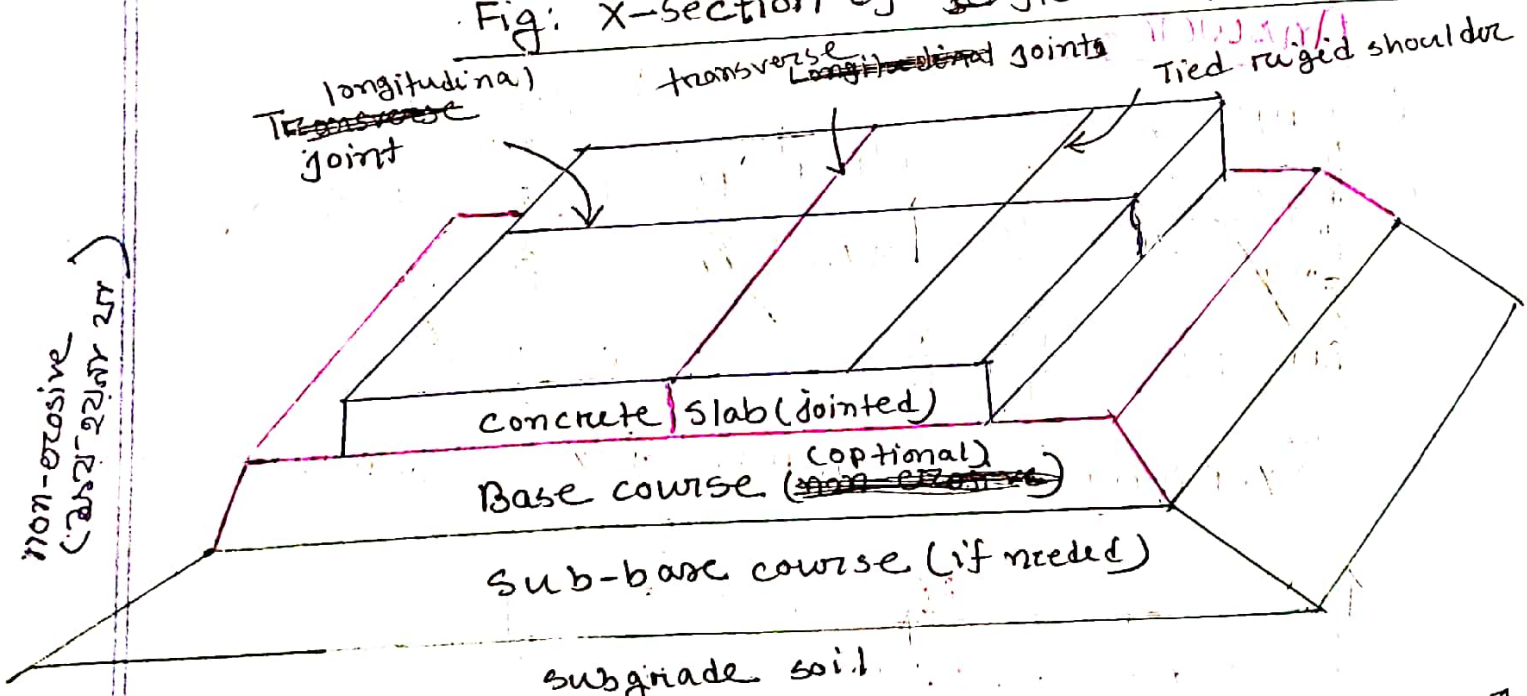


Fig: X-section of Rigid Pavement

* Describe pavement surface characteristics [RPGCL'22]

⇒ ~~For safe and comfortable driving, four aspects of the pavement surface are important:~~

~~(1) Section:~~

(1) It should be structurally sound to withstand the heavy loads imposed on it.

(2) It should have sufficient thickness and composition such that the vehicle loads are distributed to a safe value on the embankment on which it rests.

(3) The surface of the pavement should have a texture and adequate roughness to provide skidding resistance.

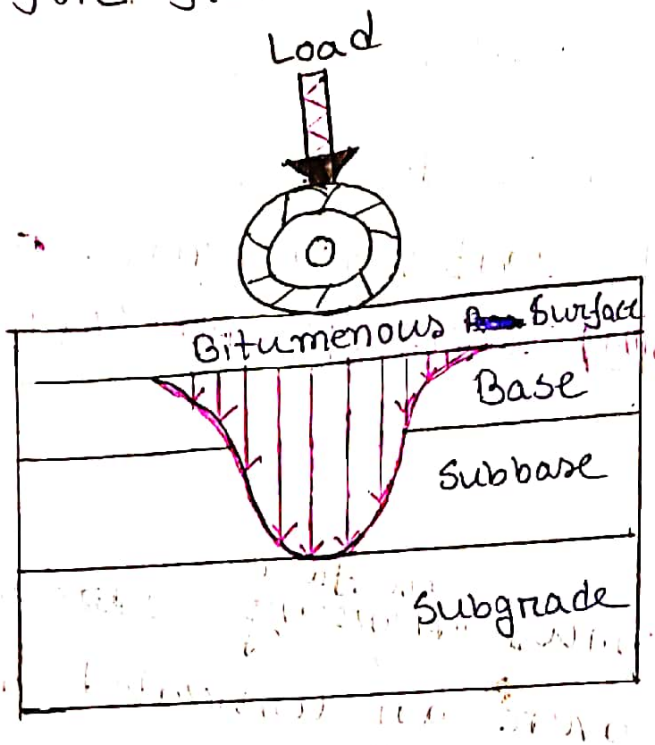
(4) The surface should not produce excessive level of sound from moving vehicles.

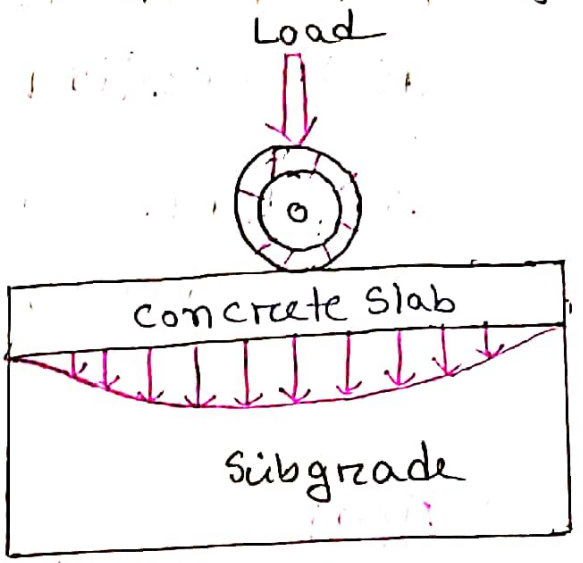
(5) The surface must not be uneven for smooth and faster speed. An unevenness index value less than 1500 mm/km is considered good.

(6) It is necessary that the road surface should be visible at night and shouldn't glare at day time.

(7) The pavement surface should be absolutely impermeable to prevent seepage of water into pavement layer. (8) Must have a good drainage system.

Q:55 Draw typical load transmission curve for flexible and Rigid pavement [Rajulin]





*** Flexible pavement is named flexible because it transfer the load applied on it through particles contact by distributing it through its layers. The load is distributed from top to bottom upto subgrade.

These types of pavements are called "flexible" since the total pavement structure "bends" or "deflects" due to traffic loads.

*** Rigid pavements as the name says are like rigid slab placed on earth which takes load by itself through its strength & rigidity.

* HMA = Hot Mix Asphalt

→ The main difference between flexible and rigid pavement is their load distribution.

Q.60 Write down the differences among Prime coat, tack coat, seal coat. [53 BIMA] [GTCL-'16] [DPDC'15] [NISCT]

Ans:

Prime Coat:

→ when a bituminous surface course is to be placed over an untreated and compacted base course (layer), (say, water bound macadam), the base is generally given a single light application of a liquid bituminous material called a prime coat.

→ It serves to promote adhesion or bond between base and wearing course.

→ It also make base course impermeable

→ the suitable materials for this purpose is cut-back bitumen or tar of low viscosity.

single - upper layer
light - lower bitumen ans - (cutback bitumen)

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Tack Coat:

→ Tack coat is a thin layer of asphaltic material sprayed over an ~~existing~~ old pavement to facilitate the bonding of the old layer and new layer.

→ It is also applied between two bituminous layers i.e. binder course and wearing course of road pavement.

→ The purpose of tack coat is to ensure adhesion between two bituminous layers.

→ Generally emulsified bitumen and 120/150, 150/200 or higher grade bitumens are used in tack coat.

Seal Coat :

→ Seal coat is a very thin surface treatment which is either applied as final step in the construction of certain bituminous surfaces or to existing bituminous surfaces which have cracked or oxidized over a number of years and have commenced to ~~deterior~~ deteriorate.

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→ The purpose of seal coat is to water proof or seal the surfaces and thereby prevent its deterioration from moisture and air oxidation.

→ Refined coal tar is usually used for seal coat as it has excellet resistance to UV rays, petrochemicals oils etc.

* Water Bound Macadam (WBM):

Water Bound Macadam is the most commonly used road construction procedure for over more than 190 years. This is pioneered by Scottish Engineer John Loudon A McAdam.

In this method, pavement base course made of crushed stones or brick aggregates mechanically interlocked by rolling and the voids filled with screening (filler) and binding material with the assistance of water.

Nowadays WBM is used as a sub-base or base

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~~Surface~~ course

* Screening : ~~4.75mm এর চেয়ে~~ coarse aggregate এর যে particle 12.5mm এর চেয়ে ছোট তাদেরকে

* Binding material : Surki (ইটের গুড়া) use করা হয়।

Q61 Write down the factors affecting pavement /road design [RRI'14] [RRI'15] [MSC'17] [GIC'16]

Ans:
Factors affecting the design of pavement

(1) Design wheel load
   → static load on wheels
   → contact pressure
   → Load Repetition

(2) Sub-grade soil
   → Thickness of pavement required
   → stress strain behavior under load
   → moisture variation

(3) Climate factor
   → Rainfall

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(4) Pavement component materials

(5) Environmental factor
→ Height of embankment & its details

(6) Traffic characteristics

(7) Required X-sectional elements of the alignment
(shoulder এর প্রস্থ কতটুকু হবে, median divider এর প্রস্থ কতটুকু)

MCQ

The way to reduce pavement layer thickness by improving subgrade : [BWDB'16]

T/F

The layer of road foundation just above the existing ground level is wearing course [BWDB'16] [DPDC'15]

Ans: False

* A pavement is classified as flexible or rigid pavement based on its

(a) wearing course (b) base course (c) sub-base

(d) sub-grade

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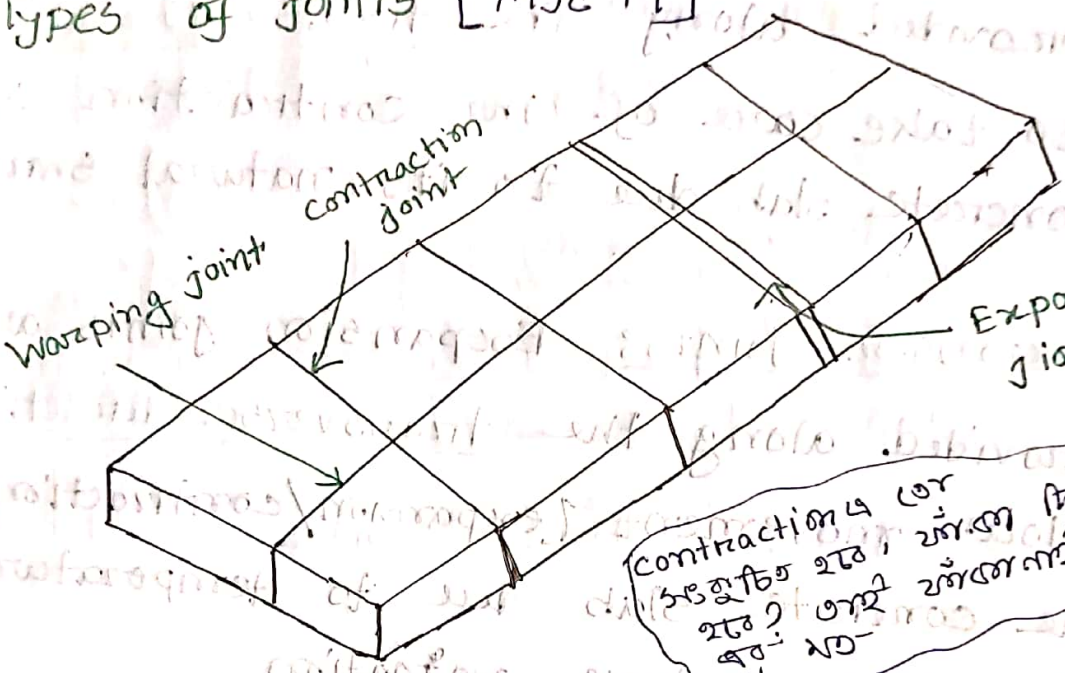
*** Q62 Why joints are used in rigid pavement? Types of joints [MSc '14]



contraction এর সংজ্ঞা কি? এবং কেন হয়? এবং expansion joint বলতে কি বুঝায়?

Ans:

Joints are provided in concrete pavements to control transverse & longitudinal cracking that occurs due to restrained deformations caused by moisture and temperature variations in the slab.

Joints help to release stresses due to temperature variation, subgrade moisture variation, shrinkage of concrete etc.

Various types of joints in concrete pavement and their functions are described below —

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Contraction joint: Contraction joints are provided along the transverse direction to take care of the contraction of concrete slab due to its natural shrinkage.

Expansion Joints: Expansion joints are also provided along the transverse direction to allow movement (expansion/contraction) of the concrete slab due to temperature and subgrade moisture variation.

Warping Joint: Warping joints are provided along the longitudinal direction to prevent warping of the concrete slab due to temperature and subgrade moisture variation. It is also called longitudinal joints.

(Shrinkage এর জন্য / বাঁকা হলে warping)

Construction joint: Construction joints are provided whenever the construction work stop temporarily. The joint direction could be either along the transverse or longitudinal direction. [এটা আগের ঢালাই পরের ঢালাই এর মধ্যে সংযোগ: [adhesion or interlocking এর জন্য থাকে। visible না]

T = transverse
T = Tie
but placed in Longitudinal joints

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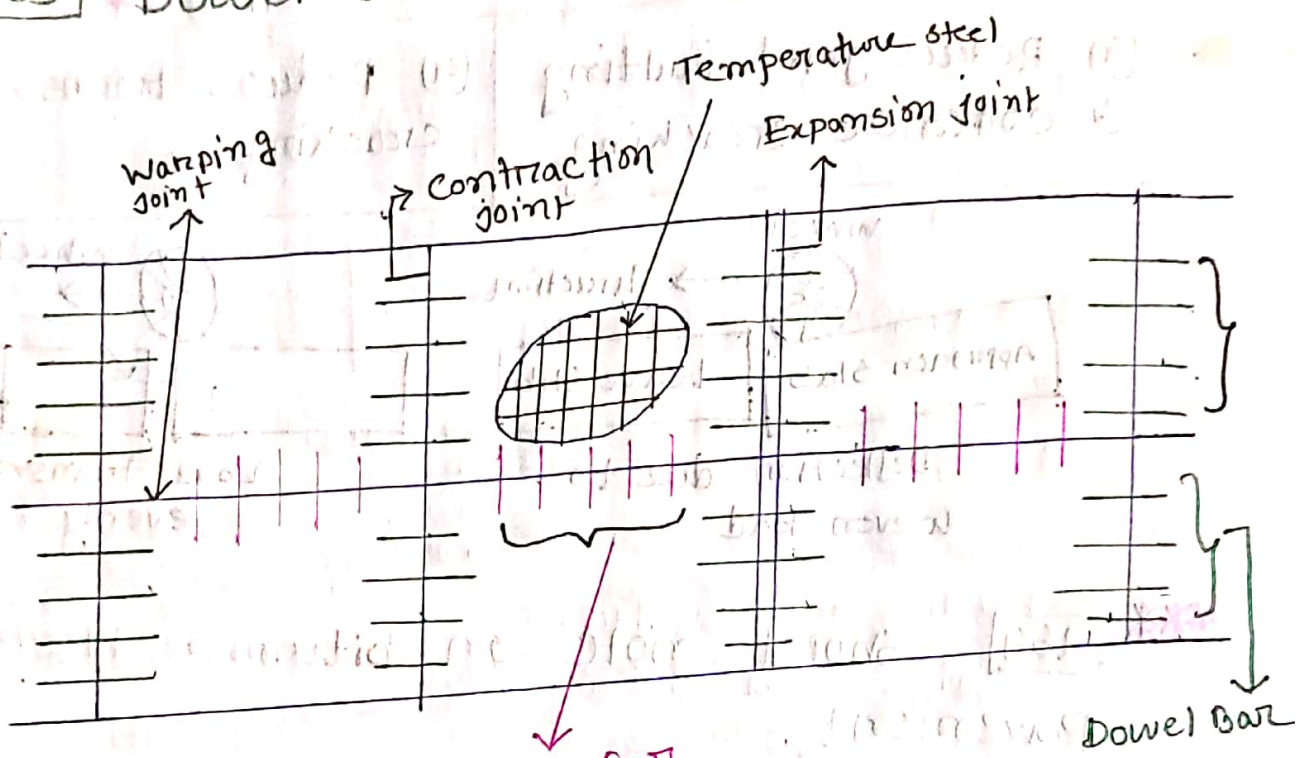
*** **Q.63** Dowel Bar vs Tie Bar [52BMA]



Dowel Bar	Tie Bar
(1) Placed accross transverse joints at the mid depth of the slab	(1) Placed accross logitudinal joints at the mid-depth of the slab
(2) They take part in wheel load transfer from one slab to adjacent slab	(2) They are not designed as load transferring device
(3) They are placed accross transverse joints of concrete pavement to allow movement due to expansion & contraction	(3) They are used for holding faces of rigid slabs in contact to prevent separation & differential deflections.

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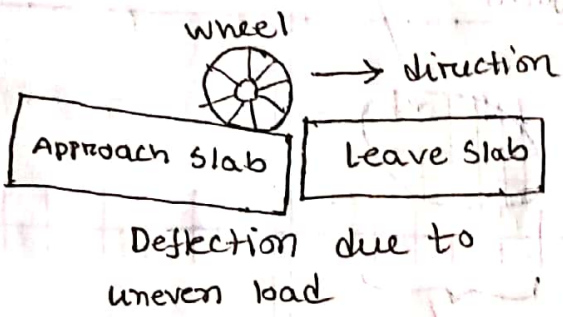
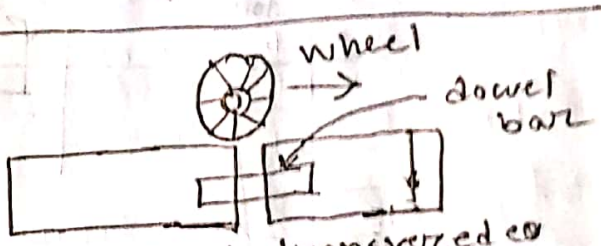
Dowel Bar	Tie Bar
(4) Reduce joint faulting & corner cracking	(4) Reduce transverse cracking



Deflection due to uneven load



Load transferred evenly

*** [Q64] Short note on bitumen bleeding on pavement.

~~Ans: Bitumen bleeding occurs w~~

Ans: Bleeding occurs in bituminous pavement when a film of asphalt binder appears on road surface. It usually creates a shiny, glass like reflecting surface that can become sticky when dry & slippery when wet. Therefore skid resistance reduces. Insufficient air void is a cause of bleeding in which there is insufficient room for asphalt to expand in hot weather and it forces its way to expand to pavement ~~structure~~ surface. Too much ~~of~~ asphalt binder in

bituminous material is also a common cause of bleeding.

Bleeding is an irreversible process. So the amount of asphalt binder on pavement surface increases with time.

Minor bleeding can often be corrected by applying coarse sand to blot up (শুষে নেয়) the excess asphalt binder.

Major bleeding can be corrected by cutting off excess asphalt with a motor grader or removing it with a heater planer.

Surface dressing : (সামান্য/পরবর্তী প্রলেপ দেওয়া রাস্তার জন্য ছুড়িয়ে)

Surface dressing comprises a thin film of binder, generally bitumen or tar which is sprayed onto the road surface and then covered with a layer of stone chippings (ছোট ছোট পাথর). The thin film of binder acts as a waterproofing seal preventing the entry of surface water into the road structure. The stone chippings protect this film of binder from damage by vehicle tyres and form a durable, skid resistance and dust free wearing surface.

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Types of dressing :

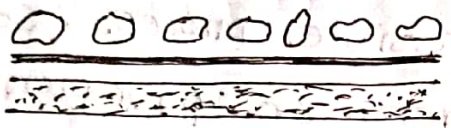
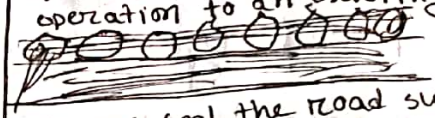


Fig: Single dressing

→ single surface dressing is not used on a new road base.
→ It is applied as a maintenance operation to an existing road



to re-seal the road surface, arresting deterioration & restoring skid resistance

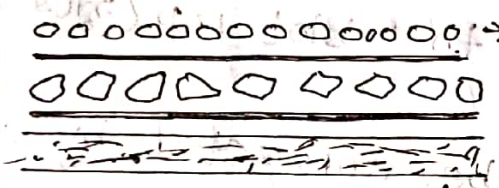


Fig : Double dressing

→ Double dressing should be used when -
(i) a new road surfacing is done
(ii) Extra protection required on an existing bituminous road surface because of its condition
(iii) maximum durability & minimum maintenance frequency

[BWDB'15, NHA'19, TCPGCBL'19]

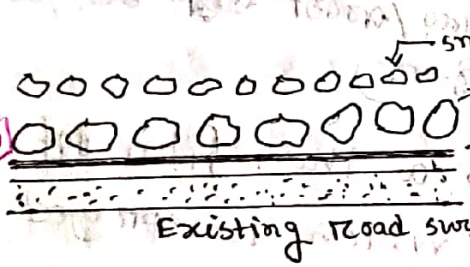


Fig: Racked-In surface dressing

This system is recommended for use where traffic is heavy or fast. A heavy single application of binder is made and a layer of large chippings is spread to give approximately 90% coverage. This is followed by the application of smaller chippings which should lock-in the larger aggregates and form a smaller mosaic. The main advantages of the racked-in surface dressing are -

(i) Less risk of dislodge large chippings
(ii) Early stability through good mechanical interlock
(iii) Good surface texture

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[BWDB'16]
[NHA'19]
[CPGCBL'19]
[MSC]

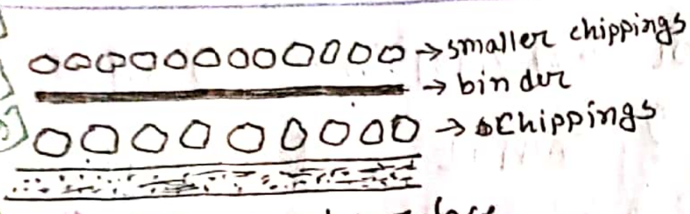

Fig: Sandwich Surface dressing

Where road surface's binder is very rich and on heavy traffic area on hot weather, a layer of chippings can be spread prior to a single surface dressing being applied.

* সাধারণ দিকে অতিরিক্ত (rich) binder থাকলে bleeding হয়ে single surface dressing এর sandwich করে দেওয়া। single surface dressing এর chipping layer এর আগেও এর নিচে আরেকটি chipping layer

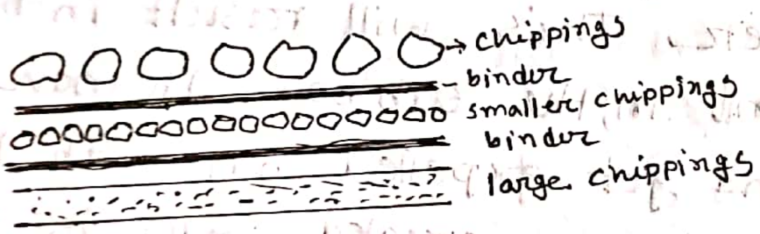

Fig: Pad Coat / Inverted double dressing

Pad coats are used where the hardness of the existing road surface allows very little embedment of the first layer of chippings. [surface hardness এর কারণে]

A first layer of nominal 6mm chippings will adhere well to the hard surface and will provide a key for larger 10mm or 14mm chippings in the second layer of the dressing.

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Q65 What do you mean by pumping of rigid pavement? What effect it create on rigid pavement? describe. [MSC]

Ans: The expulsion of water from the under layer of the pavement is called as ~~pavement~~ pumping. This distress is caused due to the active vehicle loads coming over the pavement in a repititive manner. This will result in the fine materials present in the sub-base to move along with water and get expelled out with the water. Larger voids are created under the pavement due to repeated expulsion.

Pumping can be avoided by the prevention of water accumulation at the pavement sub-base interface. This can be achieved by reducing the deflection to a minimum value and by the provision of a strong well constructed sub-base. The constructed sub-base must have a sufficient drainage facility so that the subgrade below is not saturated. Modern pavement construction makes use of underground drainage system that is the best solution for pumping distress.

Objective:

#Base course is used in rigid pavement for –

(A) Prevention of subgrade settlement
(B) Prevention of slab cracking
(C) Prevention of pumping
(D) Prevention of thermal expansion

* Viva Questions:

(1) বাংলাদেশে মোট কয় ধরণের রোড আছে?

Ans: 6 road catagories

(i) National Highways (ii) Regional Highways (iii) Zill Roads (iv) Upazilla Roads (v) Union Roads (vi) Village Roads

* weak soil/subgrade এর জন্য কোন ধরণের pavement উপযোগী?

Ans: weak subgrade এর জন্য rigid pavement উপযোগী, কারণ maximum load concrete slab ই নিয়ে থাকে, subgrade এ তেমন প্রভাব পরে না, কিন্তু flexible pavement এর জন্য subgrade কে improve করতে হয় বেশি costly।

* বাংলাদেশে মোট কোন ধরণের pavement বেশি উপযোগী?

Ans: Flexible pavement বেশি উপযোগী, কারণ বাংলাদেশে high traffic volume এর জন্য 21 দিন পর্যন্ত curing এর জন্য রাস্তা বন্ধ থাকা feasible না, তাছাড়া rigid pavement এ

underground drainage না থাকলে অনেক pumping হয়। আবার flexible pavement এর cost ও কম।
আবার light absorption at night, sound, ~~[illegible]~~ driving comfort এসব বিবেচনায় flexible pavement ভালো হয়। rigid pavement এ frictional resistance বেশি।

*** এখন কিছু জায়গায় যেমন, মার্কেট area, heavy loaded traffic area তে rigid pavement বেশি উপযোগী।

Q.66 Which type of road is suitable for hilly areas? [53BMA]

Ans: Flexible pavement.
Bituminous surfacing with a WBM base course is considered suitable for hilly roads.

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Flexible Pavement Design

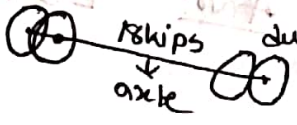
Flexible pavement design করতে হলে সবার আগে এই রাস্তায় এর design life এ কী পরিমান load encounter করতে হবে জানা জরুরী। কিন্তু রাস্তায় তো নানান ধরনের vehicle চলে যাদের load বিভিন্ন ভিন্ন। তাজন্য একটা standard load ঠিক করা জরুরী। সেটাই ESAL (Equivalent Single Axle Load)

আরেকটা concept হচ্ছে বিভিন্ন load এ গাড়ী চলার pavement এর উপর দিয়ে যায় প্রতিবার একটু unrecoverable damage হয়ে যায় pavement এর। তো বিভিন্ন thickness এর pavement এর জন্য কতটুকু cumulative damage পর্যন্ত রাস্তা servicable থাকে তাও হিসাব করতে করা জন্যও ESAL দরকার।

Q. 62 What is ESAL? [BGFCL'17]

Ans: The ESAL is the equivalent numbers of repeatitions of the 18kips (80KN) standard axle load that cause the same damage to the pavement caused by various numbers of repeatitions of various magnitude axle loads of vehicles.

* A standard axle load was selected as 18000lb/18kips /80KN applied on a single axle with dual wheel at each end.



kip = kilo pound

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MCQ

BWDB'16

**ESAL: Standard Axle Load = 18 kips / 18000 lb

= 80 KN = 8.16 ton

~~= 8.16 tonnes~~ = 8160 kg

~~= 8200 kg~~

Equivalent Axle load factor, EALF = $\left(\frac{L_x}{L_s}\right)^4$

L_x = Load on a given axle

L_s = Load on a standard axle

4.08 এর ওজনের গাড়ীর damage factor = $\left(\frac{4.08}{8.16}\right)^4 = 0.0625 = \frac{1}{16}$

অর্থাৎ একটি 8.16 ton এর standard axle pavement এর উপর দিয়ে একবার চলাচল করলে যে ক্ষতি করে, ঠিক সেই ক্ষতি করে 4.08 টনের axle এর 16 বার চলাচল (pass) হলে।

[Q.68] Determine ESAL for 1 million repeatation when axle load is 20,000 lb. [BG.FCL'17]

Ans: ESAL = $\left(\frac{20,000}{18000}\right)^4 \times 1 \times 10^6 = 1.524 \times 10^6$

[Q.69] A 36 kips axle load is repeated 100 times a day what will be ESAL in a year? [PGCB'19]

Ans: ESAL = $\left(\frac{36}{18}\right)^4 \times 100 \times 365 = 584000$ **A**

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Q70 Axle load of 27kips & 36kips are repeated 30 & 60 times respectively on pavement of 24 hrs. What will be the equivalent single axle load in a year? [DWIASA '17] [MSc '17]

Ans: $\left[\left(\frac{27}{18}\right)^4 \times 30 + \left(\frac{36}{18}\right)^4 \times 60\right] \times 365$

$= 405.834$ Ans

Q71 Calculate the axle-load of the 3500kg for 1.5 million repeatition

Ans: $ESAL = \left(\frac{3500}{8160}\right)^4 \times 1.5 \times 10^6 = 50770$ Ans

Q72 What will be the ESAL for 1 million repeatition?

Ans: $ESAL = \left(\frac{18}{18}\right)^4 \times 10^6 = 10^6$ Ans

Q73 4 lane two way street having ADT 4000. If the commercial vehicle is 45% and load is 27 kips. Calculate ESAL for commercial vehicles in one direction [ERL '17]

Ans: $ESAL = \left(\frac{27}{18}\right)^4 \times 4000 \times 0.45 \times 0.5 \times 0.9$

$= 4101$

* Directional distribution factor = 0.5 (two way)

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Lane distribution factor (AASHTO 1993)

No of Lanes in one direction	Factor
1	1
2	0.9
3	0.7
4 & more	0.6

উদাহরণ 4 lane two way এবং প্রতি দিকে 2টি করে lane

* A new 4 lane two way highway has to be constructed on a subgrade of CBR 5%. The ADT of commercial truck was 8000. The directional split of traffic is 55:45. Vehicle damage factor is 4. Design period is 15 years & construction period is 3 years. Growth rate is 7%. Calculate Design ESAL?

Ans: এখানে ESAL বের করার জন্য construction period 3 বছর। এখানে ADT কে initial ADT হিসেবে ধরা হয়। কারণ construction এর সময় কোন traffic চলবে না। এখন আমরা traffic future forecasting এর সূত্র ব্যবহার করে n= Desing period + construction period (15+3) হিসেবে, future ESAL বের করতে হবে।

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∴ ADT after construction period = $8000 \times (1+0.07)^3$
$= 9800$

Directional distribution factor = 0.55 (max of the two)

lane distribution factor = 0.9 (2 lane in each direction)

vehicle damage factor = EALF = 4

∴ Design ESAL = $\frac{(1+0.07)^{15}-1}{0.07} \times 9800 \times 365 \times 0.55 \times 0.9 \times 4$

$\simeq 177.98 \times 10^6$ Ans

$= 177.98$ msa [msa = million standard axle]

Q.24 Two closely spaced wheels of load 20.5KN each and tyre pressure 0.7MPa are acting on a pavement section. If the two wheels are replaced by a single wheel with the same tyre pressure, calculate the radius of the tyre imprint (idealized as circle) of the single wheel. [BPDB '16] [CPGCBL '18]

Ans: Total load acting on pavement = 2×20.5KN
$= 41$KN

tyre pressure = 0.7MPa $= 0.7 \times 10^6$ Pa $= 0.7 \times 10^6$ N/m²

take radius of tyre imprint = r

∴ $\pi r^2 \times 0.7 \times 10^6 = 41 \times 10^3$

∴ $r = 0.136$m $= 136$mm Ans

Pressure = Force / Area
∴ Area × Pressure = Force

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* Calculate ESAL for 20years following the data below considering 4th degree estimation of axle load.

Axle load :	16k	18k	22k	24k	28k	30k
repeatitions/day :	50	48	36	55	60	38

[BPDB'23]

Soln:

$$\left[50\times\left(\frac{16}{18}\right)^4+48\times\left(\frac{18}{18}\right)^4+\left(\frac{22}{18}\right)^4\times 36+\left(\frac{24}{18}\right)^4\times 55+\left(\frac{28}{18}\right)^4\times 60+\left(\frac{30}{18}\right)^4\times 38\right]\times 365\times 20$$

$$= 7138661 \text{ Nos}$$

Standard Axle load = 18kips = 80kN

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Q.75 The radius of a tyre imprint is approximated to a circle of 150mm. What is the maximum loading duration on that particular point of pavement by a truck moving at a speed of 60 kmph? [RPGCL'17] [GTCL'16]

Ans: ... tyre ... truck ... loading duration.

$$\therefore \text{loading duration} = \frac{\text{distance}}{\text{speed}} = \frac{\text{diameter of tyre}}{\frac{60\times1000}{3600}\ m/s}$$

$$= \frac{2\times150\times10^{-3}\ m}{\frac{60\times1000}{3600}\ m/s} = 0.018\ sec$$ Ans:

Q.76 Tire radius = 4.5 inch, pressure = 70 psi. Determine Equivalent axle load [GTCL'16] [GTCL'19]

~~Ans: Single wheel load~~ → max pressure

Ans: Total load = $4\times\pi\times(4.5)^2\times70 = 17892\ lb$

$\therefore$ ESAL = $\left(\frac{17892.1}{18000}\right)^4 \doteq 0.98$ [say 1 repeatation]

An

rail মানে ওইটার উপর দিয়ে যেই train চলে।

~~BG Track এর Standard rail length 12.8m~~,

Q:77 Standard rail length of BG track is ~~12.80~~ 12.80m. If the unit weight of rail is 45kg/m, what is the total weight of each individual rail ~~girder~~? What max^m axle load can be imposed safely on that track? [SGFL'17]

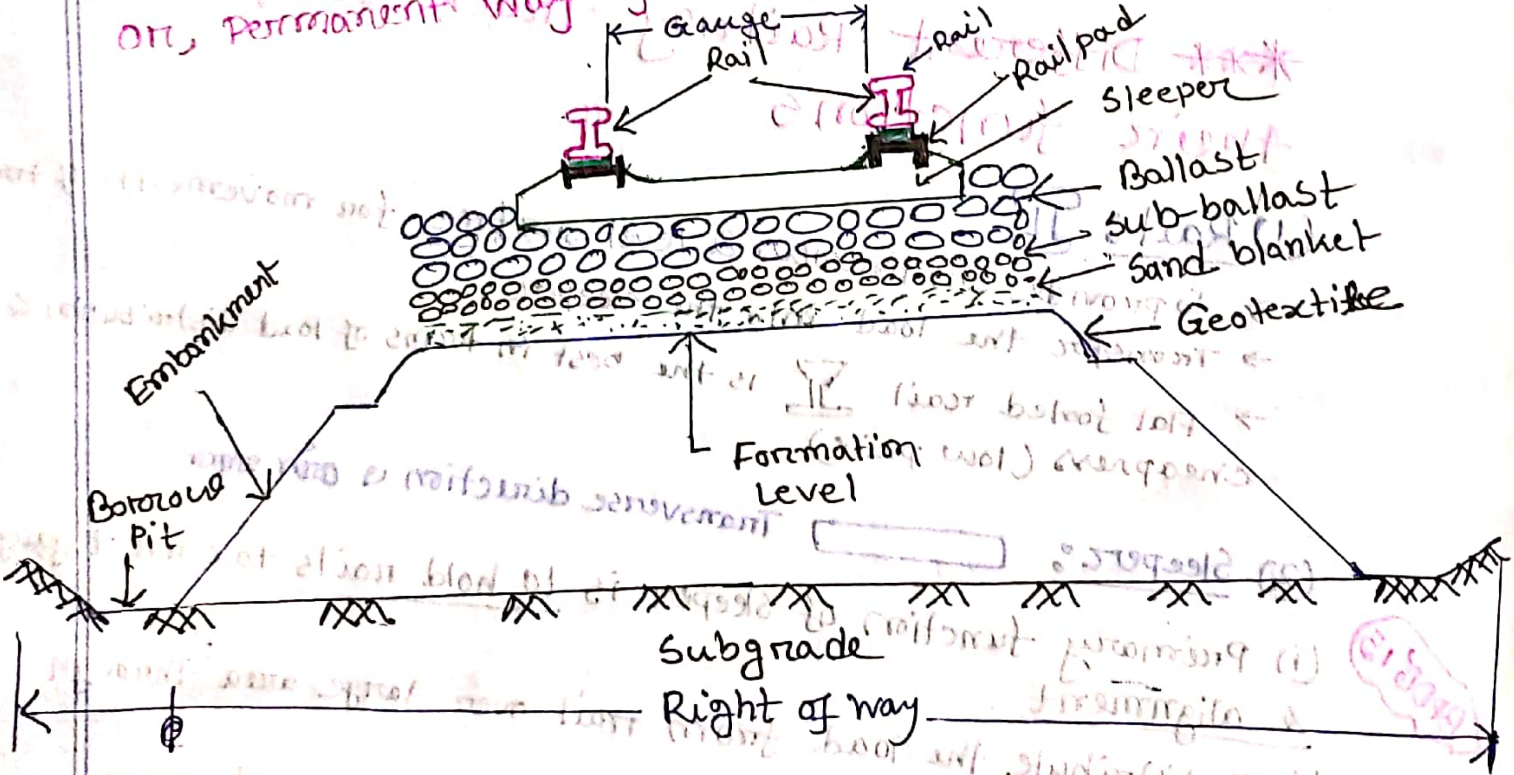
Ans: Total Weight of rail = $12.8 \times 45 = 576$kg

Max^m axle load on that track $= \frac{45 \times 560}{}$

$= 25200$kg

*45kg এর মানে train, ~~মানে~~ unit weight এর 560 গুণ axle load carry করতে পারে। [560 constant]

Q:78 Draw the typical cross-section of Railway track or, Permanent way of railway track [MSC'14][PGCB'19][MSC'17]



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Q79 Which types of gauges used in BD? [WZPDCL'19]

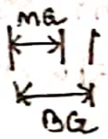
Ans: Types of ~~gau~~ gauges in Bangladesh—

(1) Broad gauge (1676mm)

(2) Meter ~~gauge~~ gauge (1000mm)

(3) Dual gauge (unique feature ~~invented~~ adapted by BD railway to facilitate transportation of both types of rails in same tracks. ভিতর rail track থাকে.

> Meter gauges are used in under developed areas. T/F (BWDB'15)



* Rail length is 12.80 m for BG & 11.89 m for MG. (এই দুই রেল এর joint দিয়ে ২২- rail track)

*** Different Railway track components & their functions

(1) **Rail:** I

→ To provide continuous & level surface for movement of train

→ Transfer the load into the sleeper

→ Flat footed rail I is the best in terms of load distribution & cheapness (low price)

(2) **Sleeper:** ▭ Transverse direction এ থাকে

(i) Primary function of sleeper is to hold rails to correct gauge & alignment. (BPDB'15)

(ii) To distribute the load from rail over large area through ballast

(iii) Slipers are made of timber, steel, concrete or cast iron

(3) Ballast: ✓ T/F (BWDB'16)

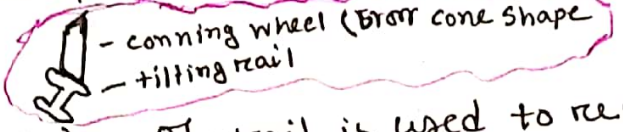
(i) Ballast is a layer of broken stone, gravel or any other granular materials

(ii) To provide a level foundation for the sleepers to rest on

(iii) To hold the ~~set~~ sleepers in position during the passage of train

(iv) To transfer & distribute load from sleeper to a large area.

Rail distresses



* Conning of wheel & Tilting of rail is used to reduce wear of rail. (2017)

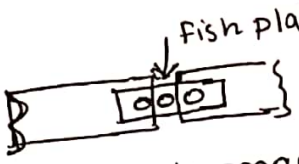
* Rails which are bent vertically at the end are known as hogged rail. This happens due to wear of rails on ends.

* Formation of buckles takes place due to insufficient gap for expansion of rails. Buckling means the train has gone out of its original position.

T/F (BWDB'16, GTCL'16)

*** Longitudinal deformation of rails in a track is termed as creep

Fishplate [BWDB'10]



→ Fish plate are used in rail joints to maintain the continuity of the rails & to allow for expansion & contraction of rail due to temperature difference.

→ Holes are drilled through web and rails, and fish bolts, nuts are provided in these holes.

→ (BWDB'16) The track from which train diverts is known as main line (T/F)

*** The track from which train diverts is known as main line (T/F)

** A cross over requires 2 sets of ~~switch~~ switches/points & 2 sets of crossings

*** A complete set of points & crossings along with lead rails it called turnout

* If vehicle moves from thin end to thick end of switch it is the direction of turnout is facing direction

* If vehicle moves from thick end to thin end, the ~~trailing~~ direction of turnout is trailing direction. (যে দিক দিয়ে crossing to negotiate করতে হয়।)

* Right rail, right rail to or left rail, left rail to cross করলে obtuse angle

* Right and left rail to or left rail, right rail to cross করে acute angle

* Right angle crossing বলে square crossing.

*** Which is used for diverting rolling stock? ⇒ turnout

Date :
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Factors affecting that the design of ~~superelevation~~ superelevation [BEPAZ '21]

→ Design speed of vehicle
→ Friction
→ maximum allowable superelevation
→ permissible centrifugal ratio

*** Factors affecting geometric design of highways [MIST pattern এ খুব important]

(1) Topography or Terrain:

⇒ The topography or terrain condition influence the design speed, then in turn governs the designing of highway elements.

⇒ For example, in plain terrain, on the state highways, permissible design speed is 100 km/hr, whereas on mountain terrain, speed is limited to 50 km/hr.

(2) Design Speed: Design speed helps in deciding the cross section elements, width, clearance, side distance, radius of curvature, super elevation etc.

(3) Function & types of Roads: ~~National hi~~ Design characteristics varies according to road types & functions i.e. National highways, City roads, District roads, upazila roads etc.

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(3) Traffic factors:

Traffic factors include vehicle & human characteristics.

In order to design highway element standard size of vehicle is considerd (car).

Human characteristics include physical, mental & psychological characteristics of driver & pedestrain.

(4) Design Hourly Volume:

The traffic volume fluctuate over the time, hence desiging is being done for design hourly volume.

(5) Environmental Factor: aesthetics, air & noise pollution, landscaping also governs the desiging of highway element.

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Factors affecting Pavement Design

[DESCO '22]

⇒ Traffic Loading
- → contact pressure
- → Wheel load
- → Axle configuration
- → Moving loads
- → Repetition of Loads

⇒ Design speed

⇒ Subgrade type

⇒ Environmental factors
- → Temperature
- → Precipitation

⇒ Topography & locations
- → Urban roads
- → Rural roads
- → Plain terrain
- → Hilly areas

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