Sub.: Problems

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Example : 4.2. Calculate the safe stopping sight distance for design speed of 50 kmph for (a) two-way traffic on a two lane road (b) two way traffic on a single lane road. Assume, coefficient of friction as ·37 and reaction time of driver as 2.5 seconds.

Solution : stopping distance = lag time + braking time.

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

$V = 50$ kmph or $V = \frac{50}{3.6} = 13.9$ m/sec.

$t = 2.5$ sec, $g = 9.8$ and $f = 0.37$.

$$\text{stopping distance} = 13.9 \times 2.5 + \frac{(13.9)^2}{2 \times 9.8 \times 0.37}$$

$$= 61.4 \text{ m}.$$

(b) stopping sight distance for two-way traffic with single lane

$= 2 \times$ (stopping distance).

$= 2 \times 61.4$

$= 122.8$

(Answer)

Example 4.3 : calculate the minimum sight distance required to avoid a head-on collision of two cars approaching from the opposite directions at 90 and 60 kmph. Assume a reaction time of 2.5 seconds, co-efficient friction of 0.7 and a brake efficiency of

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50 percent on either case.

Solution: Stopping distance of the cars..

$$SD \text{ metres} = vt + \frac{v^2}{2gf}$$

$$V_1 = 90 \text{ kmph}, \quad v = \frac{90}{3.6} = 25 \text{ m/sec}.$$

$$V_2 = 60 \text{ kmph}, \quad v = \frac{60}{3.6} = 16.67 \text{ m/sec}.$$

As the brake efficiency is 50%, the wheels will skid through 50% of the braking distance and rotate through the remaining distance. Therefore, the value of co-efficient of friction developed f may be taken as 50% of the co-efficient of friction.

$$f = 0.7 \times 0.5 = 0.35.$$

$$\therefore SD_1 = 25 \times 2.5 + \frac{25^2}{2 \times 9.8 \times 0.35} = ~~156~~ \; 153.6 \text{ m}.$$

For 2nd car;

$$SD_2 = 16.67 \times 2.5 + \frac{(16.67)^2}{2 \times 9.8 \times 0.35} = 82.2 \text{ m}.$$

Sight distance to avoid head-on collision of the two approaching cars $= SD_1 + SD_2$

$$= 153.6 + 82.2$$

$$= 235.8 \text{ m}.$$

Example 4.4: Calculating the stopping sight distance on a highway at a descending gradient of 0.2% for a design speed of 80 Kmph. Assume other data as per IRC recommendations.

Solution:

Total reaction time t may be taken as 2.5 seconds and design co-efficient of friction as f = 0.35.

$$V = 80 \text{ kmph} = \frac{80}{3.6} = 22.2 \text{ m/sec}.$$

$$n = -2\%, \quad g = 9.8 \text{ ms}^{-2}$$

$$\text{SSD on road with gradient} = vt + \frac{v^2}{2g(f \pm n\%)}$$

$$= 22.2 \times 2.5 + \frac{(22.2)^2}{2 \times 9.8 \times (0.35 - 0.02)}$$

$$= 131.7 \text{ m}.$$

$$\simeq 132 \text{ m}.$$

Example 4.5:

Calculate the values of (i) Head light sight distance (ii) Intermediate sight distance for a highway with a design speed of 65 kmph. Assume suitably all the required data.

Solution:

$$V = 65 \text{ kmph} = \frac{65}{3.6} = 18.06 \text{ m/sec}$$

$$f = 0.36, \quad t = 2.5 \text{ sec}.$$

$$SSD = vt + \frac{v^2}{2gf} = 18.06 \times 2.5 + \frac{(18.06)^2}{2 \times 9.8 \times 0.36}$$

$$= 91.4 \text{ m}$$

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(ii) Intermediate distance = 2 × SSD = 2 × 91.4

= 182.8 m

(Answer)

Example 4.6

The speed of overtaking and over taken vehicles are 70 and 40 kmph., respectively on a two way traffic rod. If the acceleration is overtaking vehicle is 0.99 m/sec².

(a) Calculate safe overtaking sight distance.

(b) mention the minimum length of overtaking zone and

(c) draw a neat-sketch of the overtaking zone and show the positions of the sign posts.

Solution:

(a) Overtaking sight distance ~~foo~~ for two way traffic.

$$= d_1 + d_2 + d_3$$

Assume the design speed as the speed of overtaking vehicle A.

$$V = 70 \text{ kmph}.$$

$$V_a = \frac{70}{3.6} = 19.4 \text{ m/sec}$$

$$V_b = \frac{40}{3.6} = 11.1 \text{ m/sec}.$$

Acceleration $a = 0.99 \text{ m/sec}^2$

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Assume, $t = 2$ sec.

$d_1 = v_b \cdot t = 11.1 \times 2 = 22.2$ m.

$d_2 = V_b \cdot T + 2S$

$S = (0.7 v_b + 6) = (0.7 \times 11.1 + 6) = 13.8$ m

~~$d_2 = V_t$~~ $T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 13.8}{0.99}} = 7.47$ secs.

$d_2 = 11.1 \times 7.47 + 2 \times 13.8 = 110.5$ m.

$d_3 = V_c \cdot T = 19.4 \times 7.47 = 144.9$ m.

$\therefore$ OSD $= d_1 + d_2 + d_3$

$= 22.2 + 110.5 + 144.9$

$= 277.6$ m say 278 m.

(b) Minimum Length of overtaking zone = 3 (OSD)

$= (3 \times 278)$ for two way traffi

$= 834$ metres.

Desirable length of overtaking zone = $5 \times$ (OSD)

$= 5 \times 278$

$= 1390$ m

(Ans)

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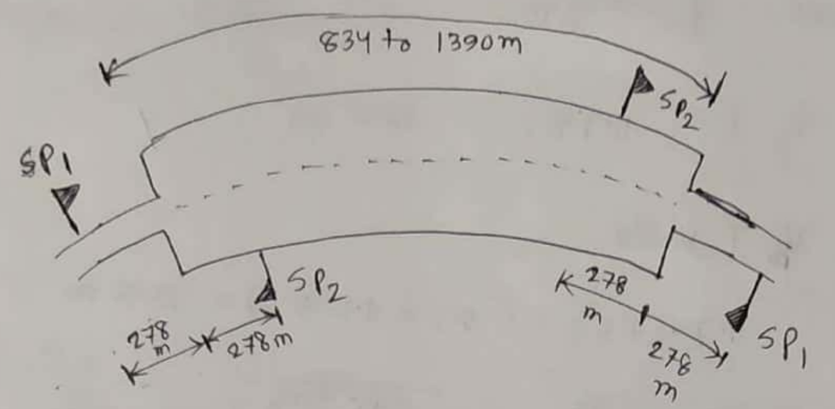
(c)



SP_1 = Sign post over taking zone ahead.

SP_2 = sign post End of over taking zone.

Example 4.7: Calculate the safe overtaking sight distance for a design speed of 96 kmph. Assume all other data suitably.

Solution: $OSD = (d_1 + d_2)$ for one way traffic.

$= (d_1 + d_2 + d_3)$ for two way traffic.

$V = 96$ kmph.

Assume, $V_b = 96 - 16 = 80$ kmph. and

Assume, $t = 2$ sec. , $A = 2.5$ km h/sec

$d_1 = 0.28 V_b t = 0.28 \times 80 \times 2 = 44.8$ m

$d_2 = 0.28 V_b T + 2S$.

$S = (0.2 V_b + 6) = 0.2 \times 80 + 6 = 22$ m.

$$T = \sqrt{\frac{14.45}{A}} = \sqrt{\frac{14.4 \times 22}{2.5}} = 11.3 \text{ sec.}$$

$$d_2 = 0.28 \times 80 \times 11.3 + 2 \times 22 = 297 \text{ m}$$

$$d_3 = 0.28VT = 0.28 \times 96 \times 11.3 = 303.7 \text{ m.}$$

OSD on one-way traffic road $= d_1 + d_2 = 341.8$ say 342 m.

OSD on two-way traffic road $= d_1 + d_2 + d_3 = 645.5$ m say 646 m

Example: 4.14 : Calculate the extra widening required for a pavement of within 7m on a horizontal curve of radius 250 m if the longest wheel expected on the road is 7.0 m. Design speed is 70 kmph. Compare the value obtained with IRC recommendations.

Solution:

Extra widening required, $W_e = W_m + W_{ps}$

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

Hence, $n = 2$ (two lanes for pavement width of 7.0m).

$l = 7.0$

$R = 250$ m

$V = 70$ Kmph.

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$$W_e = \frac{2 \times 7^2}{2 \times 250} + \frac{70}{9.5\sqrt{250}}$$

$$= 0.662 \text{ m}$$

The IRC recommends extra widening of 0.6 m when the radius of the curve is 101 to 300 m.

See, Table - 4.11 Khanna's Book (Page-122)

Problem- 4.15 Find the total width of a pavement on a horizontal curve for a new national highway to be aligned along a rolling terrain with a ruling minimum radius. Assume necessary data.

Solution: Assume the following data:

(i) National highway on rolling terrain, ruling design speed, $V = 80$ Kmph.

(ii) Normal pavement width, $W = 7.0$

(iii) Number of lanes, $n = 2$

(iv) Wheel base of the truck, $l = 6$ m.

(v) Maximum value of superelevation, $e = 0.07$ and skid resistance, $f = 0.15$

$$R_{(ruling)} = \frac{V^2}{(e+f)\,127} = \frac{80^2}{(0.07+0.15)\times 127}$$

$$= 229 \text{ m}, \text{ say } 230 \text{ m}.$$

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

$$= \frac{2\times 6^2}{2\times 230} + \frac{80}{9.5\times\sqrt{250}}$$

$$= 0.712 \text{ m}$$

Total pavement width on curve $= W + W_e = 7.0 + 0.712$

$$= 7.712 \text{ m}.$$

Example: 4.8:

The radius of a horizontal circular curve is 100 m. the design speed is 50 kmph and the design co-efficient of lateral friction is 0.15.

(a) Calculate the superelevation required if full lateral friction is assumed to develop.

(b) Calculate the co-efficient of friction needed if no superelevation is provided.

(c) calculate the equilibrium superelevation if the pressure on inner and outer wheels should be equaled.

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Solution:

(a) ~~Super~~ Given, $R = 100\ m$

$V = 50\ kmph.$

$f = 0.15$.

(a) if full lateral friction is assumed to develop.

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

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

$$\Rightarrow e = (0.197 - 0.15)$$

$$\Rightarrow e = 0.047$$

∴ Super elevation rate is 1 in 21.3.

(b) if no super elevation is provided, $e = 0$.

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

$$\Rightarrow f = 0.197$$

(c) For the pressure on inner and outer wheels to be equal. $f = 0$.

$$\therefore e + 0 = \frac{V^2}{127R} = \frac{50^2}{127 \times 100} = 0.197$$

$$\therefore e = 0.197$$

(Answer)

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Example - 4.9 :

A two lane road with design speed 80 kmph has horizontal curve of radius 480 m. Design the rate of superelevation for mixed traffic. By how much should the outer edges of the pavement be raised with respect to the centre line, if the pavement is rotated with respect to the centre line and the width of the pavement at the horizontal curve is 7.5 m.

Solution:

For mixed traffic conditions the superelevation should fully counteract the centrifugal force for 75% of design speed.

$$e = \frac{v^2}{225R} = \frac{80^2}{225 \times 480} = 0.059 < 0.07$$

(OK)

Hence, superelevation of 0.059 may be adopted.

The total width of pavement B = 7.5 m.

Raising the outer edge with respect to center

$$, E = \frac{B.e}{2} = \frac{7.5 \times 0.059}{2}$$

$$= 0.22 m.$$

Example - 4.10

Design the rate of superelevation for a horizontal highway curve of radius 500 m and speed 100 kmph.

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Solution:

For mixed traffic conditions, superelevation is given by

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

$V = 100$ kmph

$R = 500$ m

$$e = \frac{100^2}{225 \times 500}$$

$$= 0.089.$$

As the value is greater than the maximum superelevation of 0.07, the actual superelevation to be provided is restricted to 0.07.

check for the co-efficient of lateral friction developed for full speed.

$$f = \frac{V^2}{127R} - 0.07$$

$$= \frac{100^2}{127 \times 500} - 0.07$$

$$= 0.087.$$

As the value is less than 0.15, the design is safe with a superelevation of 0.07.

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Example- 4.11 : The design speed of a highway is 80 kmph. There is a horizontal curve of radius 200 m on a certain locality. Calculate the super elevation of ~~0.07~~ needed to maintain this speed. If the maximum superelevation of 0.07 is not to be exceeded calculate the maximum allowable speed on this horizontal curve as it is not possible to increase the radius. safe limit of transverse co-efficient of friction is 0.15.

Solution: Given, $R = 200\ m$

$V = 80\ kmph.$

Step-1:

$$e = \frac{V^2}{225R} = \frac{80^2}{225 \times 200} = 0.142 > 0.07$$

The actual super elevation to be provided is restricted to 0.07.

Step-2: (check for friction)

$$f = \frac{V^2}{127R} - 0.07$$

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

$$\therefore f = 0.18 > 0.15$$

Step-3 : Hence, the speed has to be restricted.

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$$V_a = \sqrt{27.94 R}$$

$$= \sqrt{27.94 \times 200} = 74.75 \text{ kmph}.$$

∴ The speed may be restricted to less than 74.75 kmph on that curve.

(Ans)

SUMMIT CURVE

When, $L > SSD$, $L = \frac{NS^2}{4.4}$ Here, $N = n_1 - n_2$

$S = SSD$.

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

When $L > O.S.D$, $L = \frac{NS^2}{9.6}$ Here, $N = n_1 - n_2$

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

Problem 4.22: A vertical summit curve is formed at the intersection of two gradients, +3 and −5.0 percent. Design the length of summit curve to provide a stopping sight distance for a design speed of 80 kmph - Assume other data.