Highway Pavement

Civil Engineering Department

4th stage, 2nd Semester, 2019-2020

3rd Lecture: Horizontal Alignment

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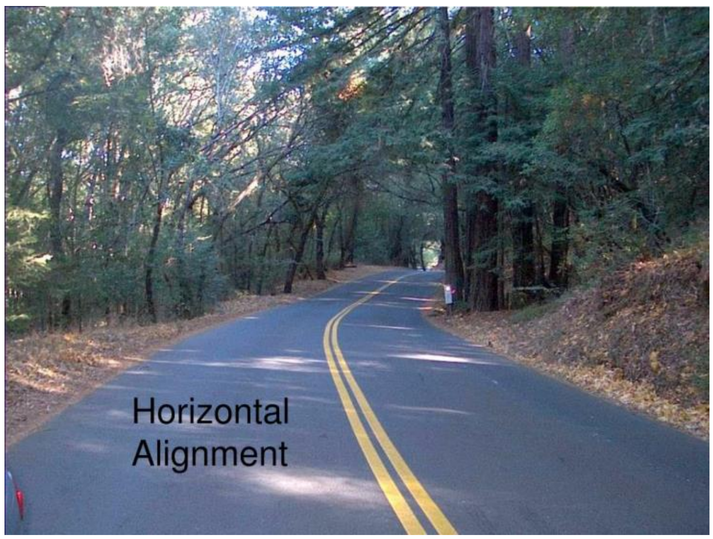
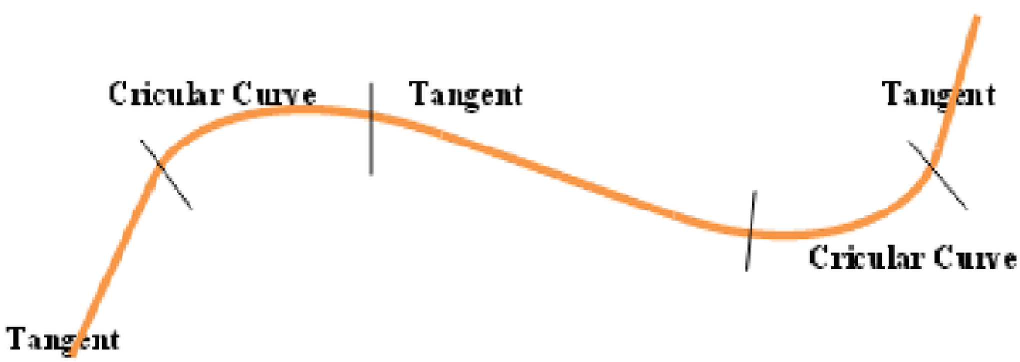
Horizontal Alignment

Horizontal alignments represent the projection of the facility on a horizontal plane. The horizontal alignment consists of straight roadway sections (tangents) connected by horizontal curves, which are normally circular curves with or without transitions (spiral) curves.





Horizontal Alignment

1. Tangents

2. Curves

3. Transitions or Spiral Curves

The design of the horizontal alignment (which consists of level tangents connected by circular curves is influenced by the design speed and the super-elevation of the curve itself. The curves are usually segments of circles, which have radii that will provide for a smooth flow of traffic.

Types of horizontal curves

For connecting straight tangent sections of roadway with a curve, several options are available.

1. Simple Circular Curves, the most obvious is the simple curve, which is just a standard curve with a single, constant radius.

2. Compound Circular Curves; which consist of 2 or more circular curves having two or more radiuses & deflection angles.

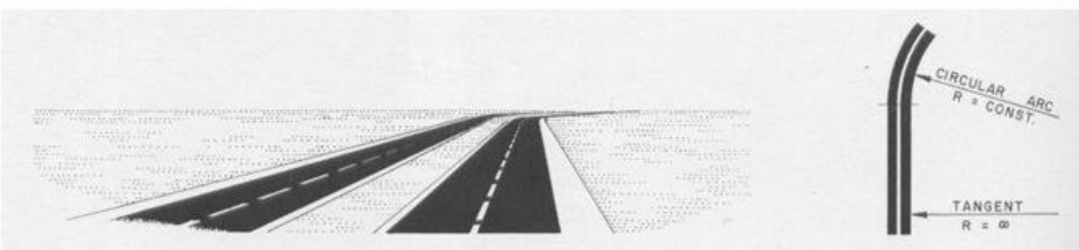
3. Reverse Circular Curves consist of two simple curves with two radii turning in opposite direction with a common tangent

4. Transition or Spiral curves; which are placed between tangents and circular curves or between two adjacent circular curves with substantially different radii. Spiral curves are continuously changing radius curves.

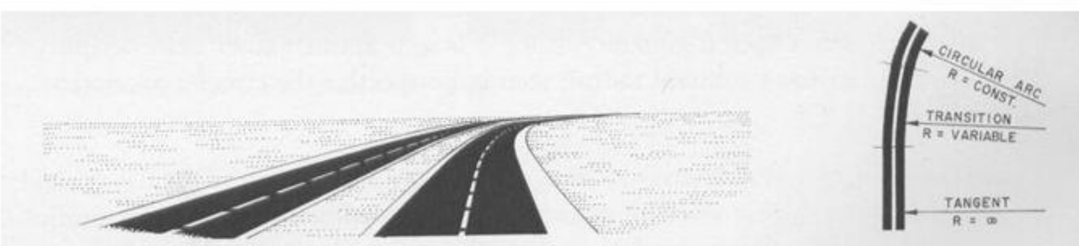
Tangents & Curves

Tangent

Curve

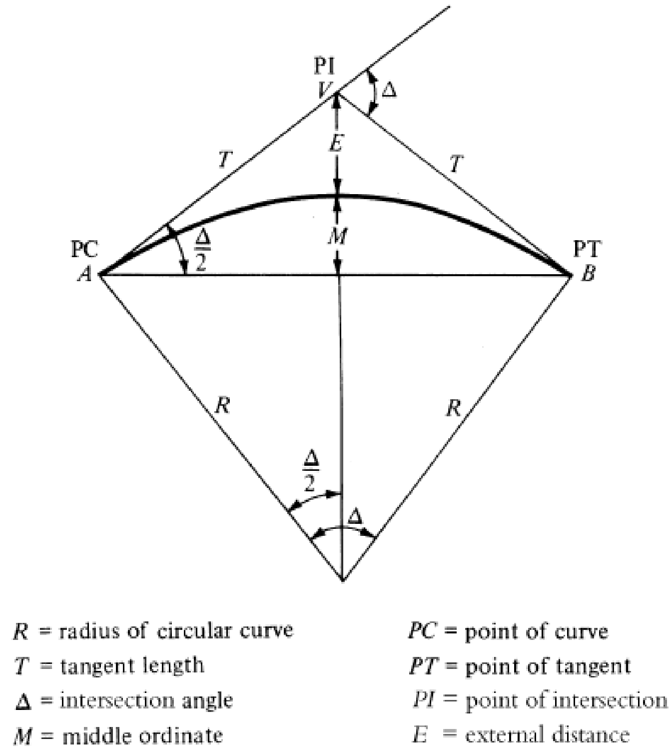


Tangent to Circular Curve



Tangent to Spiral Curve to Circular Curve

1. Simple Circular Curves,



Simple circular curves: These curves have one radius & one deflection angle.

- Elements of simple circular curve:-

Point of curvature **(PC):** the point where the curve begins or (BC): beginning of curve

Point of tangency **(PT):** the point where the curve ends or (EC): end of curve

Point of intersection **(PI)**: The point that resembles intersection of the two tangents

*Radius of the curve **(R)*** External distance **(E)**

Deflection angle **(Δ)** Middle ordinate **(M)**

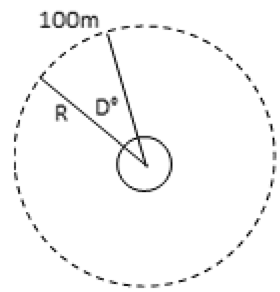
Degree of curvature **(D_a)**

Length of tangent **(T)**

Length of chord **(C) (L_C)**

Length of curve **(L)**

Degree of curvature $(D°)$:



$$\frac{D^{\circ}}{100} = \frac{360}{2\pi R}$$

$$D^{\circ} = \frac{5730}{R}$$

- Length of Tangent (T)

$$\tan\frac{\Delta}{2} = \frac{T}{R}$$

$$T = R.\tan\frac{\Delta}{2}$$

- Length of Chord (C) or (L_C)

$$\sin\frac{\Delta}{2} = \frac{\frac{C}{2}}{R}$$

$$C = 2\,R\sin\frac{\Delta}{2}$$

- Length of Curve (L)

$$\frac{L}{\Delta^{\circ}} = \frac{2\,\pi\,R}{360}$$

$$L = \frac{\pi\,R\,\Delta^{\circ}}{180^{\circ}}$$

- External Distance

$$\cos\frac{\Delta}{2} = \frac{R}{R+E}$$

$$E = R\,(\frac{1}{\cos\frac{\Delta}{2}} - 1)$$

$$E = R\,(\sec\frac{\Delta}{2} - 1)$$

- Middle Ordinate (M)

$$\cos\frac{\Delta}{2} = \frac{R-M}{R}$$

$$M = R\,(1 - \cos\frac{\Delta}{2})$$

- Major point stations: St. PC = St. PI - T

St. PT = St. PC + L

Example 1: Calculate the elements and the main stations for the simple circular curve, the radius

R= 300m, Δ = 0.917 rad and the station of intersection point = 14 + 80?

Solution:-

$$\Delta = 0.917 * \frac{180}{\pi} = 52.56^{\circ}$$

$$T = R * \tan\frac{\Delta}{2} = 300 * \tan\frac{52.56}{2} = 148.138\,m$$

$$C = 2\,R \sin\frac{\Delta}{2} = 2 * 300 * \sin\frac{52.56}{2} = 265.65\,m$$

$$L = \frac{R * \Delta\,(deg)}{57.3} = \frac{300 * 52.56}{57.3} = 275.183\,m$$

$$E = R\left(\sec\frac{\Delta}{2} - 1\right) = 300 * \left(\frac{1}{\cos\frac{52.56}{2}} - 1\right) = 34.58\,m$$

$$M = R\left(1 - \cos\frac{\Delta}{2}\right) = 300 * \left(1 - \cos\frac{52.56}{2}\right) = 31\,m$$

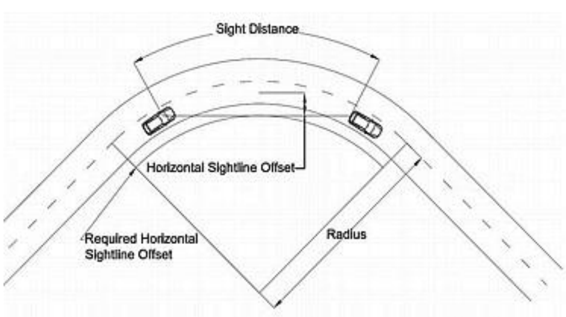
$$St.PC = St.PI - T = (14 + 80) - (1 + 48.138) = 13 + 31.862$$

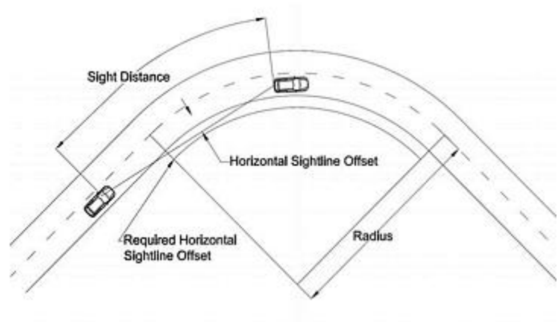
$$St.PT = St.PC + L = (13 + 31.862) + (2 + 75.183) = 16 + 07.04$$

Example 2: Calculate the elements and the stations for the simple circular curve if you know that: R=250m, Δ=52°36', St. PI=14+80

- Min radius of circular curve (sight distance)

- Sight distance → Stopping
  → Passing
  → Decision

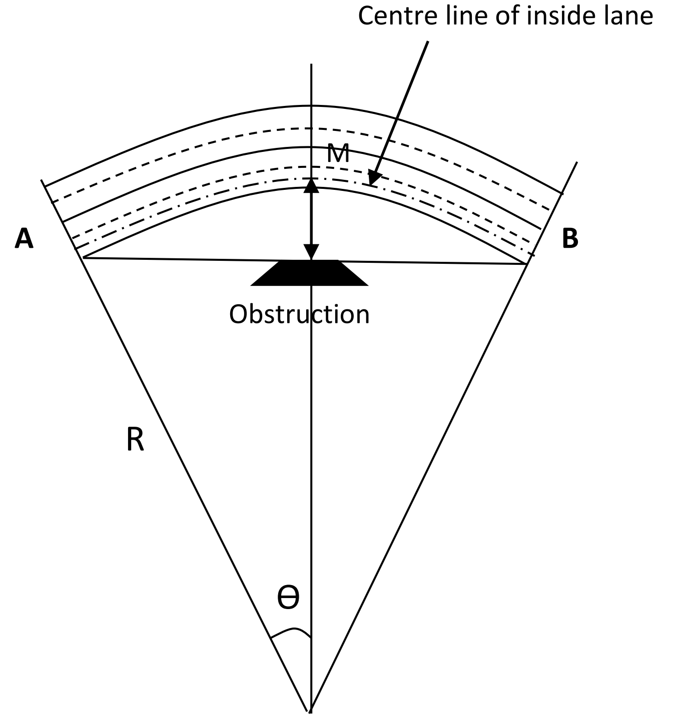




Sight distance on horizontal curve:-

- Clear sight for safety

  Sight distance = AB = S



A- $S \le L$

$M = R\,(1 - \cos\theta) \quad from\ \theta$

$\frac{2\theta}{S} = \frac{D}{100} \rightarrow \theta = \frac{SD}{200}$

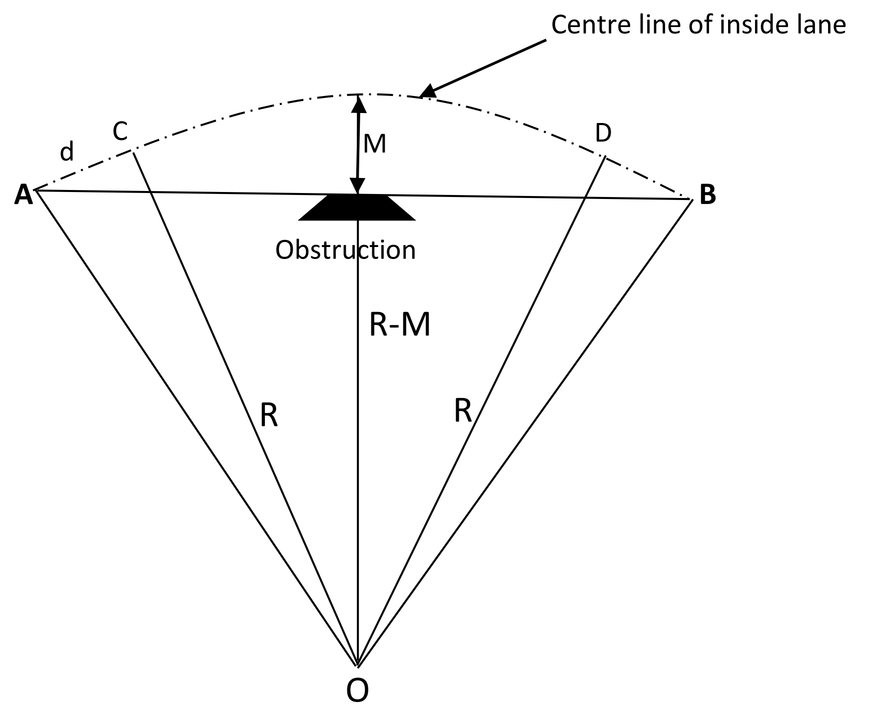
Or

$\left(\frac{S}{2}\right)^2 - M^2 = R^2 - (R - M)^2$

$R = \frac{S^2}{8M}$

M: distance from the center line of the inner lane to the obstruction edge.

B- $S > L$



L = arc CD
S = ACDB

$\left(\frac{S}{2}\right)^2 - M^2 = (AO)^2 - (R - M)^2$

$(AO)^2 = R^2 + d^2$

$d = \frac{(S - L)}{2}$

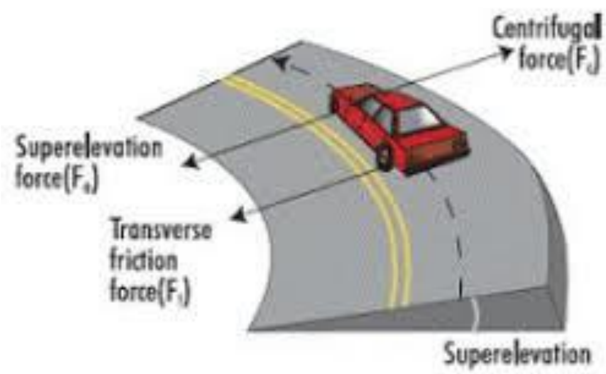
$M = \frac{L(2S - L)}{8R}$

Superelevation (e)

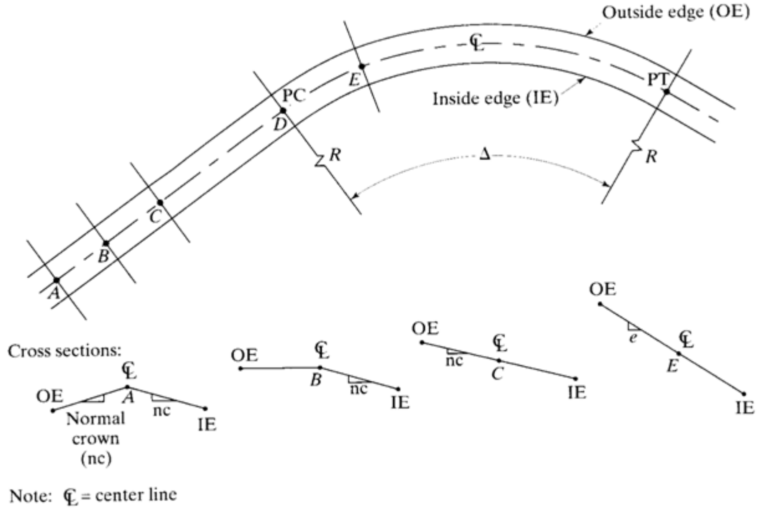
When a vehicle travels along a horizontal curve, it is forced radially outward by a centrifugal force. The centrifugal force is counterbalanced by the vehicle weight component related to the roadway superelevation and the friction force between the tire and pavement. From the law of mechanics.

$$R = \frac{V^2}{127\,(e + f_s)}$$

Superelevation: May be defined as the raising of the outer edge of the road to control act the effect of centrifugal force in combination with the friction between the road surface and tires developed in lateral direction.

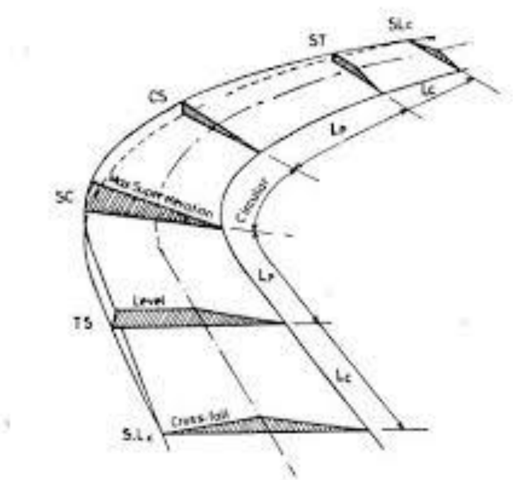


Curves require superelevation because: retard sliding, allow more uniform speed and allow use of smaller radius curves (less land).



Distance AB defined as the tangent runout

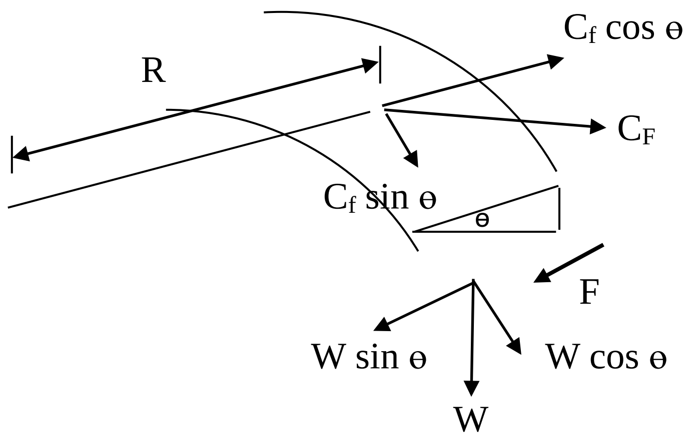
Distance BE defined as the super-elevation runoff



$C_F : Centrifugal\ force$

$$C_F = \frac{w}{9.81} * \frac{v^2}{R}$$

$F: friction\ force$



$$F = f_S\ (w\ Cos\ \theta + C_F \sin\theta)$$

$C_F \sin\theta = 0$

$$F = f_S\ w\ Cos\ \theta$$

$$C_F\ cos\ \theta = w \sin\theta + f_s\ w\cos\theta$$

$$[\frac{w}{9.81} * \frac{v^2}{R} \cos\theta = w\sin\theta + f_S\ w\cos\theta] \div w\cos\theta$$

$$\frac{v^2}{9.81 * R} = \tan\theta + f_S$$

$$\frac{v^2}{9.81\ R} = e + f_S$$

$$R = \frac{V^2 * (0.278)^2}{9.81\ (e + f_s)}$$

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

$Where:$

R : *main radius of circular curve* (m)

e: *super elevation rate* $= \tan\theta = (0.04 - 0.12)$

V: *speed in* Km/hr

f_s: *coef. of sliding friction* $(0.11 - 0.17)$

0.11 *when velocity equals* $130\,\frac{Km}{hr}$

0.17 *when velocity equals* $50\,\frac{Km}{hr}$

V (Km/hr)	Min R (m)
130	650
110	500
80	250
50	100

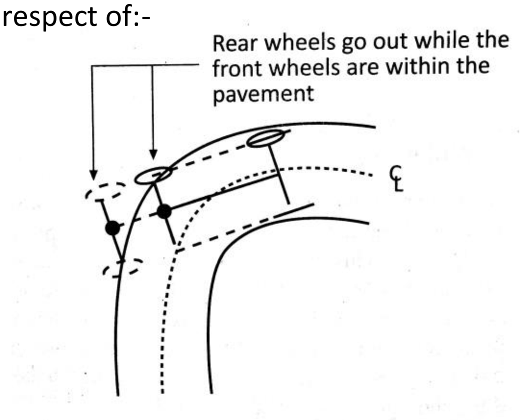
Pavement Widening on Circular Curves

Pavement widening may be required on highway curves because of the manner in which the vehicle traverses the curves.

As shown in below figure, the rear wheels of a vehicle will track around a curve on a shorter radius than do the front wheels. Thus the vehicle occupies more pavement width than it does on a tangent section.

Widening: it is the value of extra width on curves varies with respect of:-

1. Width of pavement
2. Degree of curve (D)
3. Design speed

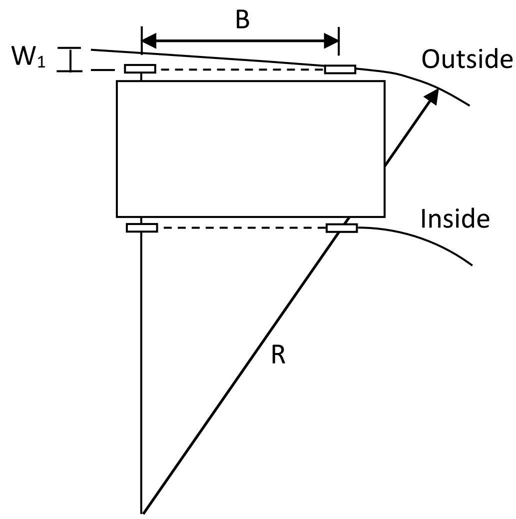


(a) Off-tracking

$$W_1 = R - \sqrt{R^2 - B^2}$$

$$W_2 = \frac{V}{19\sqrt{R}}$$

$$Total\ widening\ for\ 2\ lane.dir = 2\,W_1 + W_2$$



Where: W_1, W_2, R, B in **meter**

V in **Km/hr**

W_1: vehicle characteristics (m/lane)

W_2: operation (difficulty in steering while rounding curve) (m/dir)

B = 3.3 (P-car)

6.1 (Truck)

Design values for pavement widening on highway curves are shown in the below table:

Radius of curve (m)	***Degree of curve***	***Value for widening (in meter) for standard width of pavement***		
		6 meters 50-70 Km/hr	***7 meters 60-80 Km/hr***	***7.5 meters 70-120 Km/hr***
60 or less	*9 or more*	*1.8*	*1*	–
80	*7*	*1.4*	*0.7*	–
100	*6*	*1.2*	*0.5*	–
150	*4*	*1.1*	*0.4*	–
200	*3*	*1*	*0.3*	*0.3*
300	*2*	*0.8*	*0.3*	*0.3*
500	*1*	*0.7*	*0.3*	–

Example 3: Find the minimum distance of un-removable object from the inner edge of a pavement for two lane roadway at it's curved section if you know that: it's width equal to 7.2m, R = 500m, S_s = 160m and the curve length is 200m.

Solution:

S = 160 < 200

$\therefore$ S < L

$$M = \frac{S^2}{8\,R}$$

$$= \frac{(160)^2}{8 * 500} = 6.4$$ المسافة من منتصف الممر الداخلي

$\therefore$ Min distance from pavement edge = $6.4 - \frac{3.6}{2} = 4.6\,m$

Example 4: A roadway is being designed for a speed of 120 Km/hr at one horizontal curve, it is known that the superelevation is (8.0%) and the coefficient of sliding friction is 0.09. Determine the minimum radius of curve (measured to the travelled path) that will provide safe vehicle operation.

Solution:

$$Min\,R = \frac{V^2}{127\,(e+f)} = \frac{120^2}{127\,(0.08+0.09)} = 667m$$