Chapter 16

Horizontal alignment III

16.1 Overview

In this section we will deal with the design of transition curves and setback distances. Transition curve ensures a smooth change from straight road to circular curves. Setback distance looks in for safety at circular curves taking into consideration the sight distance aspects. A short note on curve resistance is also included.

16.2 Horizontal Transition Curves

Transition curve is provided to change the horizontal alignment from straight to circular curve gradually and has a radius which decreases from infinity at the straight end (*tangent point*) to the desired radius of the circular curve at the other end (*curve point*) There are five objectives for providing transition curve and are given below:

1. to introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, avoiding sudden jerk on the vehicle.This increases the comfort of passengers.
2. to enable the driver turn the steering gradually for his own comfort and security,
3. to provide gradual introduction of super elevation, and
4. to provide gradual introduction of extra widening.
5. to enhance the aesthetic appearance of the road.

16.2.1 Type of transition curve

Different types of transition curves are spiral or clothoid, cubic parabola, and Lemniscate. IRC recommends spiral as the transition curve because:

1. it fulfills the requirement of an ideal transition curve, that is;
   (a) rate of change or centrifugal acceleration is consistent (smooth) and
   (b) radius of the transition curve is ∞ at the straight edge and changes to R at the curve point ($L_s \propto \frac{1}{R}$) and calculation and field implementation is very easy.

16.2.2 Length of transition curve

The length of the transition curve should be determined as the maximum of the following three criteria: rate of change of centrifugal acceleration, rate of change of superelevation, and an empirical formula given by IRC.

1. Rate of change of centrifugal acceleration

At the tangent point, radius is infinity and hence centrifugal acceleration is zero. At the end of the transition, the radius R has minimum value R. The rate of change of centrifugal acceleration should be adopted such that the design should not cause discomfort to the drivers. If c is the rate of change of centrifugal acceleration, it can be written as:

$$\begin{aligned} c &= \frac{\frac{v^2}{R} - 0}{t}, \\ &= \frac{\frac{v^2}{R}}{\frac{L_s}{v}}, \\ &= \frac{v^3}{L_s R}. \end{aligned}$$

Therefore, the length of the transition curve L_{s_1} in m is

$$L_{s_1} = \frac{v^3}{cR}, \tag{16.1}$$

where c is the rate of change of centrifugal acceleration given by an empirical formula suggested by by IRC as below:

$$\begin{aligned} c &= \frac{80}{75 + 3.6v}, \qquad (16.2) \\ \text{subject to :} & \\ c_{\min} &= 0.5, \\ c_{\max} &= 0.8. \end{aligned}$$

2. Rate of introduction of super-elevation

Raise (E) of the outer edge with respect to inner edge is given by $E = eB = e(W + W_e)$. The rate of change of this raise from 0 to E is achieved gradually with a gradient of 1 in N over the length of the transition curve (typical range of N is 60-150). Therefore, the length of the transition curve L_{s_2} is:

$$L_{s_2} = Ne(W + W_e) \tag{16.3}$$

3. By empirical formula

IRC suggest the length of the transition curve is minimum for a plain and rolling terrain:

$$L_{s_3} = \frac{35v^2}{R} \tag{16.4}$$

and for steep and hilly terrain is:

$$L_{s_3} = \frac{12.96v^2}{R} \tag{16.5}$$

and the shift s as:

$$s = \frac{L_s^2}{24R} \tag{16.6}$$

The length of the transition curve L_s is the maximum of equations 16.1, 16.3 and 16.4/16.5, i.e.

$$L_s = \text{Max}: \; (L_{s_1}, L_{s_2}, L_{s_3}) \tag{16.7}$$

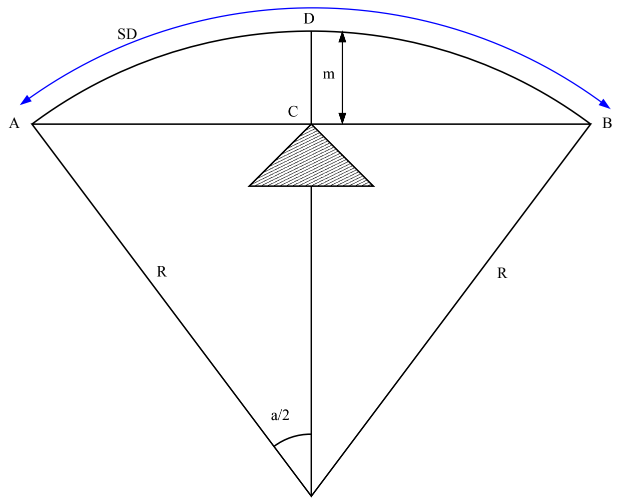

Figure 16:1: Set-back for single lane roads ($L_s < L_c$)

16.3 Setback Distance

Setback distance m or the clearance distance is the distance required from the centerline of a horizontal curve to an obstruction on the inner side of the curve to provide adequate sight distance at a horizontal curve. The setback distance depends on:

1. sight distance (OSD, ISD and OSD),
2. radius of the curve, and
3. length of the curve.

Case (a) $L_s < L_c$

For single lane roads:

$$\begin{aligned} \alpha &= \frac{s}{R} \text{ radians} \\ &= \frac{180s}{\pi R} \text{ degrees} \\ \alpha/2 &= \frac{180s}{2\pi R} \text{ degrees} \end{aligned} \tag{16.8}$$

Therefore,

$$m = R - R\cos\left(\frac{\alpha}{2}\right) \tag{16.9}$$

For multi lane roads, if d is the distance between centerline of the road and the centerline of the inner lane, then

$$m = R - (R-d)\cos\left(\frac{180s}{2\pi(R-d)}\right) \tag{16.10}$$

$$m = R - R\cos\left(\frac{\alpha}{2}\right) \tag{16.11}$$

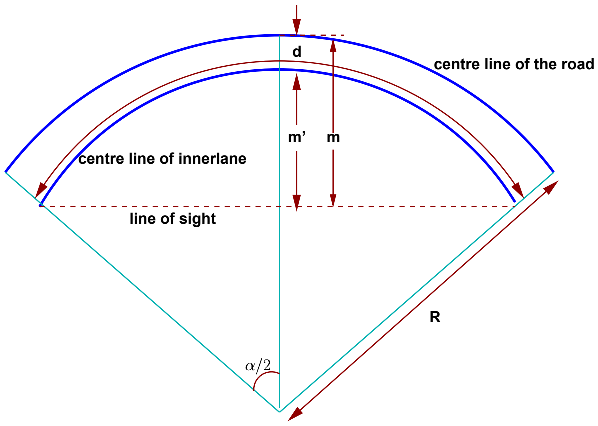

Figure 16:2: Set-back for multi-lane roads ($L_s < L_c$)

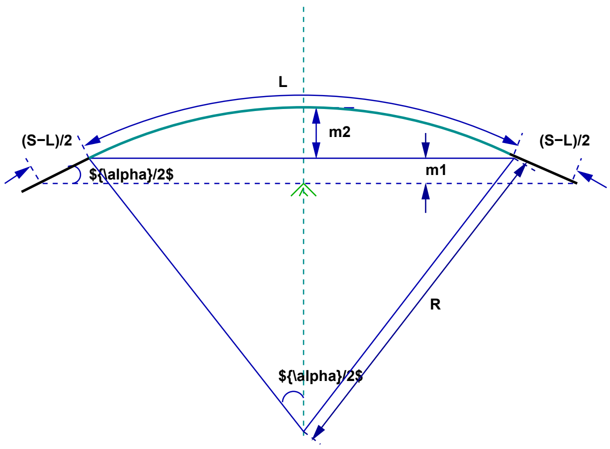

Figure 16:3: Set back for single lane roads ($L_s < L_c$)

Case (b) $L_s > L_c$

For single lane:

$$\begin{aligned} m_1 &= R - R\cos(\alpha/2) \\ m_2 &= \frac{(S-L_c)}{2}\sin(\alpha/2) \end{aligned}$$

The set back is the sum of m_1 and m_2 given by:

$$m = R - R\cos(\alpha/2) + \frac{(S-L_c)}{2}\sin(\alpha/2) \tag{16.12}$$

where $\frac{\alpha}{2} = \frac{180 L_c}{2\pi R}$. For multi-lane road $\frac{\alpha}{2} = \frac{180 L_c}{2\pi(R-d)}$, and m is given by

$$m = R - (R-d)\cos(\alpha/2) + \frac{(S-L_c)}{2}\sin(\alpha/2) \tag{16.13}$$

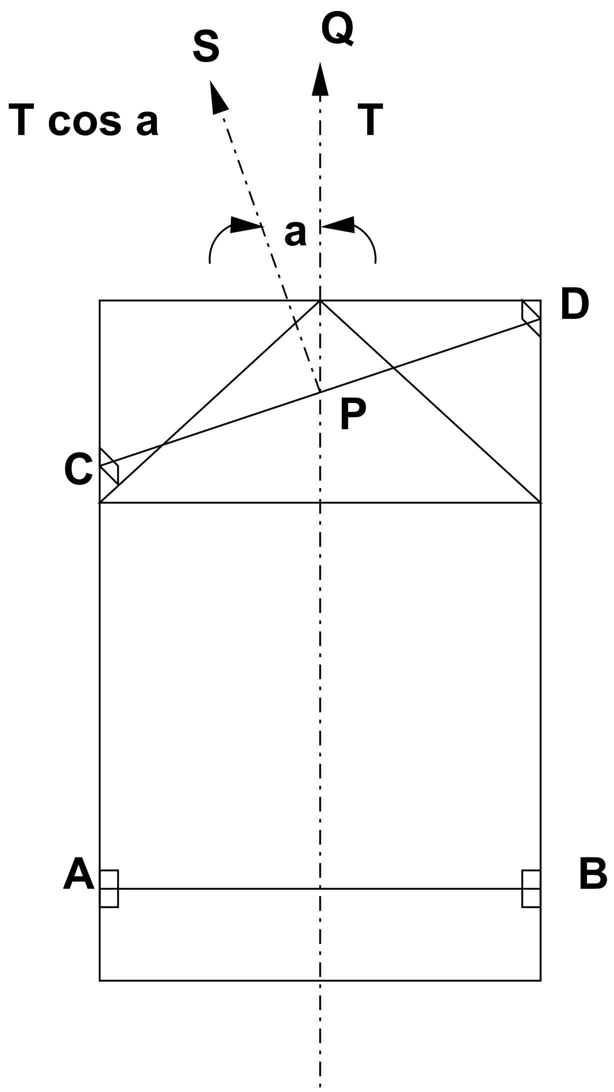

Figure 16:4: Curve resistance

16.4 Curve Resistance

When the vehicle negotiates a horizontal curve, the direction of rotation of the front and the r ear wheels are different. The front wheels are turned to move the vehicle along the curve, whereas the rear wheels seldom turn. This is illustrated in figure 16:4.

The rear wheels exert a tractive force T in the PQ direction . The tractive force available on the front wheels is $Tcos\alpha$ in the PS direction as shown in the figure 16:4. This is less than the actual tractive force, T applied. Hence, the loss of tractive force for a vehicle to negotiate a horizontal curve is:

$$CR = T - T\cos\alpha \tag{16.14}$$

16.5 Summary

Transition curves are introduced between straight road and circular curve. Setback distance controls alignment around obstacles at intersections and curves. Vehicles negotiating a curve are subjected to tractive resistances due to the curvature.

16.6 Problems

1. Calculate the length of transition curve and shift for V=65kmph, R=220m, rate of introduction of super elevation is 1 in 150, W+We=7.5 m. (Hint: c=0.57) [Ans: L_{s1}=47.1m, L_{s2}=39m (e=0.07, pav. rotated w.r.t centerline), L_{s3}=51.9m, s=0.51m, L_s=52m]

2. NH passing through rolling terrain of heavy rainfall area, R=500m. Design length of Transition curve. (Hint: Heavy rainfall=¿pav. surface rotated w.r.t to inner edge. V=80kmph, W=7.0m, N=1 in 150) [Ans: c=0.52, L_{s1}=42.3, L_{s2}=63.7m (e=0.057, W+We=7.45), L_{s3}=34.6m, L_s=64m]

3. Horizontal curve of R=400m, L=200 m. Compute setback distance required to provide (a) SSD of 90m, (b) OSD of 300 m. Distance between center line of road and inner land (d) is 1.9m. [Ans: (a) $\alpha/2 \approx 6.5^o$, m=4.4 m (b)ODS>L, for multi lane, with d=1.9, m=26.8 m]