

# Spiral Curve Design

Spiral curves are generally used to provide a gradual change in curvature from a straight section of road to a curved section. Figure 1 shows the placement of spiral curves in relation to circular curves. Figure 2 shows the components of a spiral curve. Spiral curves are necessary on high-speed roads from the standpoint of comfortable operation and gradually bringing about the full superelevation of the curves<sup>1</sup>. A spiral should be utilized with a circular curve with a superelevation of 3% or greater.

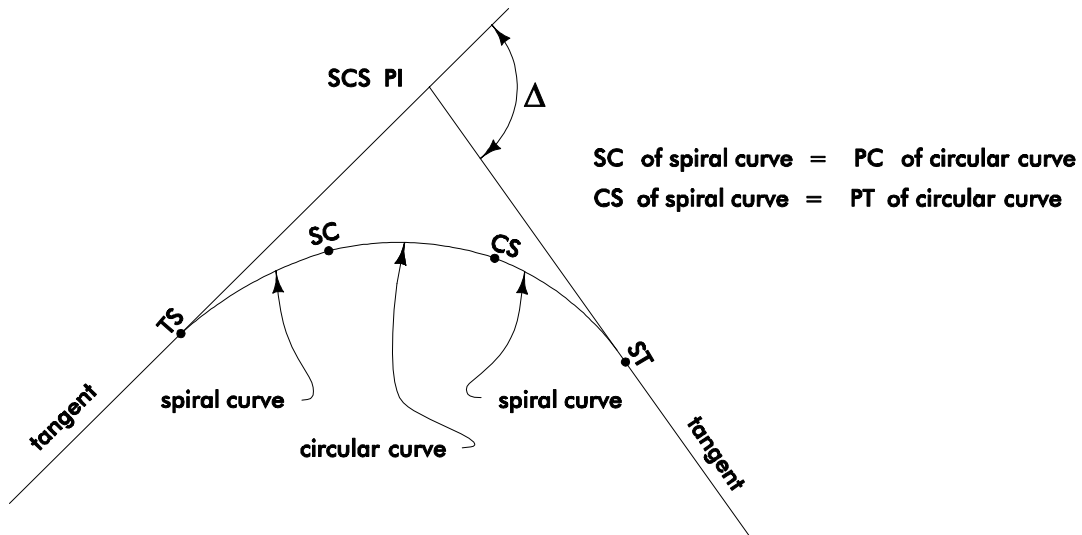


Figure 1: Placement of spiral curve.

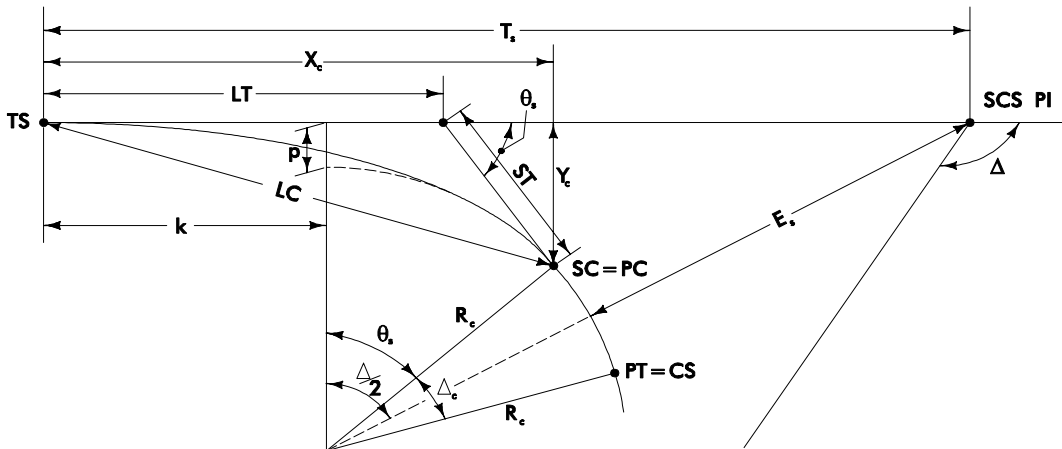


Figure 2: Components of a spiral curve (based on Hickerson, p. 175).

<sup>1</sup> Hickerson, T.F., *Route Location and Design*. 2<sup>nd</sup> ed. (New York: McGraw-Hill, Inc., 1964), 168.

## Definitions

SCS PI = Point of intersection of main tangents.

TS = Point of change from tangent to spiral curve.

SC = Point of change from spiral curve to circular curve.

CS = Point of change from circular curve to spiral curve.

ST = Point of change from spiral curve to tangent.

LC = Long chord.

LT = Long tangent.

ST = Short tangent.

PC = Point of curvature for the adjoining circular curve.

PT = Point of tangency for the adjoining circular curve.

$T_s$  = Tangent distance from TS to SCS PI or ST to SCS PI.

$E_s$  = External distance from the SCS PI to the center of the circular curve.

$R_c$  = Radius of the adjoining circular curve.

$D_c$  = Degree of curve of the adjoining circular curve, based on a 100 foot arc (English units only).

$D$  = Degree of curve of the spiral at any point, based on a 100 foot arc (English units only).

$l$  = Spiral arc from the TS to any point on the spiral ( $l = l_s$  at the SC).

$l_s$  = Total length of spiral curve from TS to SC.

$L$  = Length of the adjoining circular curve.

$\theta_s$  = Central (or spiral) angle of arc  $l_s$ .

$\Delta$  = Total central angle of the circular curve from TS to ST.

$\Delta_c$  = Central angle of circular curve of length  $L$  extending from SC to CS.

$p$  = Offset from the initial tangent.

$k$  = Abscissa of the distance between the shifted PC and TS.

$Y_c$  = Tangent offset at the SC.

$X_c$  = Tangent distance at the SC.

$x$  and  $y$  = coordinates of any point on the spiral from the TS.

## Formulas

$$D_c = \frac{18000}{\pi R_c} \quad R_c \text{ given in feet, } D_c \text{ in decimal degrees (English units only)}$$

$$D_c = 200 \times \frac{\theta_s}{l_s} \quad \theta_s \text{ and } D_c \text{ in decimal degrees, } l_s \text{ in feet (English units only)}$$

$$l_s = 200 \times \frac{\theta_s}{D_c} \quad \theta_s \text{ and } D_c \text{ in decimal degrees, } l_s \text{ in feet (English units only)}$$

$$\theta_s = \frac{l_s \times D_c}{200} \quad \theta_s \text{ and } D_c \text{ in decimal degrees, } l_s \text{ in feet (English units only)}$$

$$\Delta = \frac{180 \times L}{\pi \times R_c} \quad L \text{ and } R_c \text{ in feet (meters)}$$

$$\theta_s = \frac{l_s}{2 \times R_c} \quad \theta_s \text{ in radians, } l_s \text{ and } R_c \text{ in feet (meters)}$$

$$\theta_s \text{ (decimal degrees)} = \frac{180}{\pi} \times \theta_s \text{ (radians)}$$

$$X_c = \left( \frac{l_s}{100} \right) \times (100 - 0.0030462\theta_s^2) \quad \theta_s \text{ in decimal degrees, } l_s \text{ in feet (meters)}$$

$$Y_c = \left( \frac{l_s}{100} \right) \times (0.58178\theta_s - 0.000012659\theta_s^3) \quad \theta_s \text{ in decimal degrees, } l_s \text{ in feet (meters)}$$

$$p = Y_c - R_c \times (1.0 - \cos \theta_s) \quad Y_c, R_c \text{ and } p \text{ in feet (meters) and } \theta_s \text{ in decimal degrees}$$

$$A = \frac{20000 \times \theta_s}{l_s^2} \quad A \text{ and } l_s \text{ in feet (meters), } \theta_s \text{ in decimal degrees}$$

$$k = \frac{1}{2} l_s - 0.000127 A^2 \times \left( \frac{l_s}{100} \right)^5 \quad A \text{ and } l_s \text{ in feet (meters)}$$

$$T_s = (R_c + p) \times \tan \frac{\Delta}{2} + k \quad T_s, R_c, p, \text{ and } k \text{ in feet (meters), } \Delta \text{ in decimal degrees}$$

$$E_s = (R_c + p) \times \text{exsec} \frac{\Delta}{2} + p \quad E_s, R_c, p, \text{ and } k \text{ in feet (meters), } \Delta \text{ in decimal degrees, and}$$

exsec $\alpha$  is defined as  $(\tan \alpha) \left( \tan \frac{1}{2} \alpha \right)$

$$LT = X_c - (Y_c \times \cot \theta_s) \quad LT, X_c, \text{ and } Y_c \text{ in feet (meters), } \theta_s \text{ in decimal degrees}$$

$$ST = \frac{Y_c}{\sin \theta_s} \quad ST \text{ and } Y_c \text{ in feet (meters), } \theta_s \text{ in decimal degrees}$$

$$LC = l_s - 0.00034 A^2 \times \left( \frac{l_s}{100} \right)^5 \quad LC, A \text{ and } l_s \text{ in feet (meters)}$$

$$\Delta_c = \Delta - 2 \times \theta_s \quad \Delta_c, \Delta, \text{ and } \theta_s \text{ measured in decimal degrees}$$

## Plan Curve Data

The following Plan Curve Data shall be provided on the plan sheets for each spiral curve:  $\Delta$ ,  $E_s$ ,  $T_s$ ,  $l_s$ ,  $\theta_s$ ,  $p$ ,  $k$ ,  $X_c$ ,  $Y_c$ ,  $LT$ ,  $ST$ ,  $LC$ , and SCS PI stationing. Plans in English units should also include  $D_c$ .