

2. HORIZONTAL DESIGN Practices and Procedures

2-1 RURAL HIGHWAYS AND HIGH-SPEED URBAN HIGHWAYS

2-1.01 Horizontal Curve Types and Definitions

Simple Curve A simple curve is that portion of the arc of a circle which achieves the desired deflection without using an entering or exiting transition.

Compound Curve A compound curve (with deflections in the same direction) is a combination of any number of individual simple curves (e.g., 2-centered or 3-centered) and may be symmetrical or asymmetrical.

Point of Intersection (PI) The PI is the point of intersection of two tangents.

Point of Curvature (PC) The PC is the point of change from tangent to circular curve.

Point of Tangent (PT) The PT is the point of change from circular curve to tangent.

Deflection Angle (Δ) The deflection angle is the intersection angle between the two tangents forming the circular curve (also referred to as the central angle of curve).

Degree of Curve (D) The degree of curve is the central angle which subtends an arc length of 100 feet (arc definition). The maximum degree of curve is a limiting value for a given design speed based on the maximum rate of superelevation and maximum allowable side friction factor.

Deflectional changes in horizontal alignment may be accomplished by using a simple curve or a compound curve. The following text discusses each of the horizontal curvature types:

Simple Curves

Figure 2-1 illustrates a typical simple curve layout. Considering their simplicity and ease of design, survey and construction, the simple curve is the type of curve used most often.

Compound Curves

Compound curves are used to establish alignment where a controlling obstruction cannot be relocated. They may occasionally be used to transition into and out of a simple curve.

Figure 2-2 illustrates the layout of a symmetrical 3-centered compound curve.

When a compound curve is used on a highway main line, the radius of the flatter circular arc (R_1) should not be more than 50 percent greater than the radius of the sharper circular arc (R_2). In other words, $R_1 \leq 1.5 R_2$. For degree of curve, the equation becomes $D_1 \geq 0.67 D_2$.

2-1.02 Minimum Radius

See EI C7 – Horizontal Curve Radius.

2-1.03 Off-Tracking

See Design Guidance – Off-Tracking.

2-1.04 Length of Curve

See Section 3.3.13 General Controls for Horizontal Alignment in the *AASHTO Green Book*

2-1.05 Superelevation Development

Superelevation Rate

See EI C6 – Superelevation Rate.

Superelevation Transition

See Design Guidance - Superelevation Transition.

Axis of Rotation

1. ***Undivided Highways:*** On 2-lane highways and undivided multilane highways, the axis of rotation will be the centerline of the roadway. On a 2-lane roadway with an auxiliary lane, such as a climbing lane, the axis of rotation will be the centerline of the two through lanes. See Figure 3-8A in the *AASHTO Green Book*.
2. ***Divided Highways:*** Divided highways with medians require special consideration. designer should select an axis based on the specific site conditions at the curve. For more discussion see Section 3.3.8.8 Axis of Rotation with a Median in the *AASHTO Green Book*.

Shoulder Superelevation

When super elevation exceeds the slope of the low side shoulder, the shoulder will have same slope as the travelway.

For discussion on the high side shoulder see Design Guidance – High Side Shoulder Rollover.

2-1.06 Horizontal Sight Distance

See EI C8 – Stopping Sight Distance and Section 3.3.12 Sight Distance on Horizontal Curves in the *AASHTO Green Book*.

2-2 LOW SPEED URBAN STREETS

2-2.01 Horizontal Curves

Minimum Radius

See EI C7 – Horizontal Curve Radius.

2-2.02 Length of Curves

See Section 3.3.13 General Control for Horizontal Alignment in the *AASHTO Green Book*.

2-2.03 Superelevation Development

Superelevation Rate

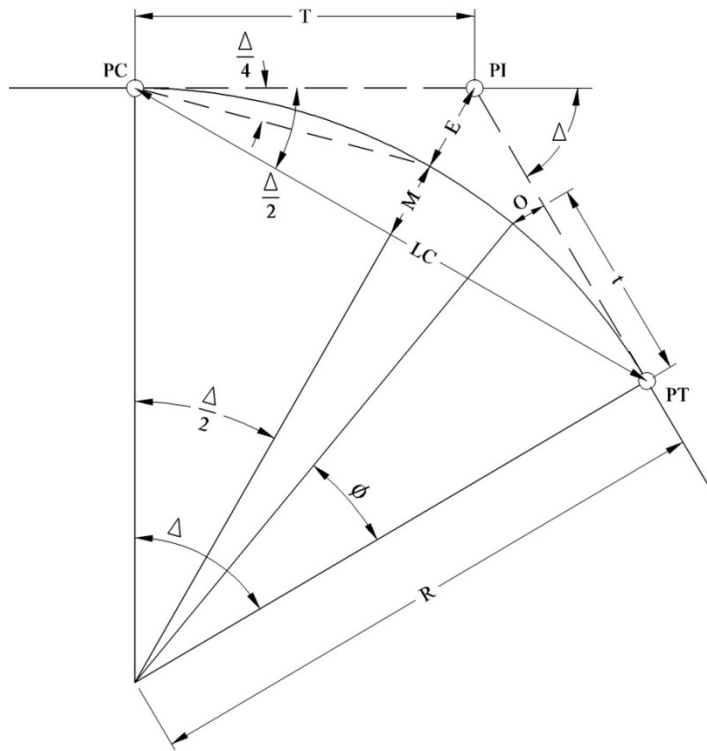
See EI C6 – Superelevation Rate.

Superelevation Transition

See Design Guidance - Superelevation Transition.

Axis of Rotation

See the discussion in 2-1.05 Superelevation Development – Axis of Rotation.



$$R = \frac{5729.5780}{D}$$

$$L = 100 \frac{\Delta}{D} = \frac{\Delta R}{57.2958}$$

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

$$E = T \tan \frac{\Delta}{4}$$

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

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

$$O = R - \sqrt{R^2 - t^2}$$

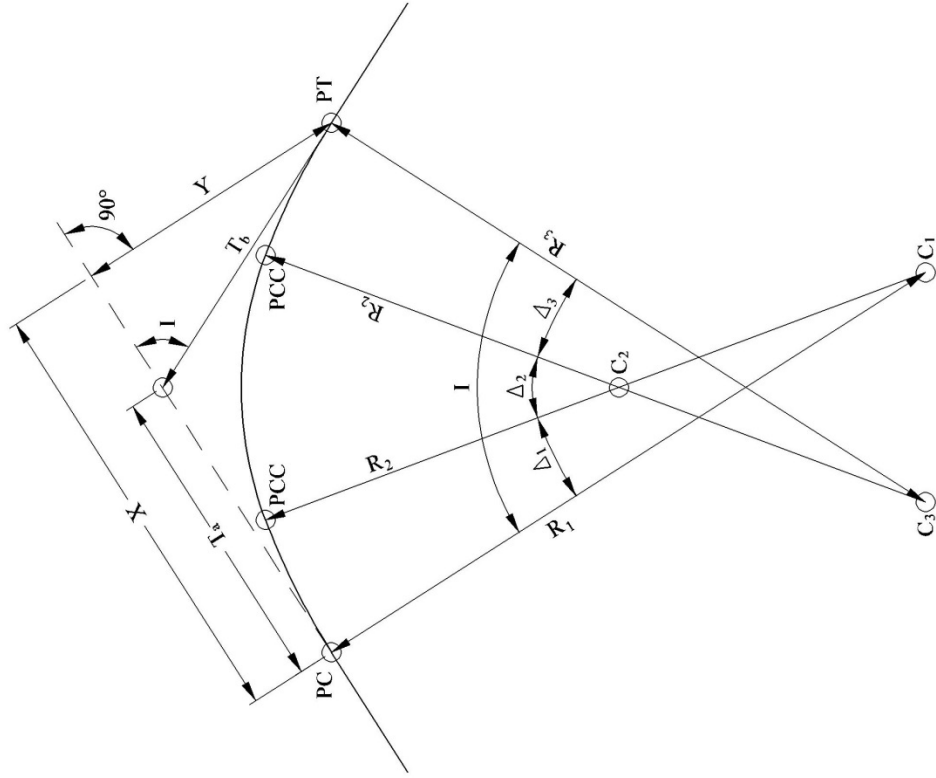
$$O = R (1 - \cos \phi)$$

- PI = Point of Intersection of tangents
 PC = Point of Curvature
 PT = Point of Tangency
 Δ = Central angle of curve (deflection angle)
 D = Degree of curvature
 L = Length of curve (ft); arc length from PC to PT
 R = Radius of curve (ft)
 T = Tangent length (ft) from PC to PI or from PT to PI
 E = External distance (ft) from PI to midpoint of circular arc
 M = Middle ordinate (ft) connecting midpoints of circular arc and long chord
 LC = Long chord (ft) from PC to PT
 φ = Deflection angle from PT to any point on curve
 t = Tangent distance (ft) from PT to any point on curve along tangent
 O = Tangent distance (ft) from tangent to any point on curve

TYPICAL SIMPLE CURVE LAYOUT

Figure 2-1

Equations for Any Two-Centered Compound Curves:	
I	= Total Deflection Angle = $\Delta_1 + \Delta_2$
X	= $R_2 \sin I + (R_1 - R_2) \sin \Delta_1$
Y	= $R_1 - R_2 \cos I - (R_1 - R_2) \cos \Delta_1$
T_b	= $Y / \sin I$
T_a	= $X - T_b \cos I$
Equations for Any Three-Centered Compound Curves:	
I	= Total Deflection Angle = $\Delta_1 + \Delta_2 + \Delta_3$
X	= $(R_1 - R_2) \sin \Delta_1 + (R_2 - R_3) \sin (\Delta_1 + \Delta_2) + R_3 \sin I$
Y	= $R_1 - R_3 \cos I - (R_1 - R_2) \cos \Delta_1 - (R_2 - R_3) \cos (\Delta_1 + \Delta_2)$
T_b	= $Y / \sin I$
T_a	= $X - T_b \cos I$
Equations for Symmetrical Three-Centered Compound Curve ($R_1 = R_3$; $\Delta_1 = \Delta_3$, as shown in Figure):	
I	= Total Deflection Angle = $2 \Delta_1 + \Delta_2$
X	= $(R_1 - R_2) \sin \Delta_1 + (R_2 - R_1) \sin (\Delta_1 + \Delta_2) + R_1 \sin I$
Y	= $R_1 - R_2 \cos I - (R_1 - R_2) \cos \Delta_1 - (R_2 - R_1) \cos (\Delta_1 + \Delta_2)$
T_b	= $Y / \sin I$
T_a	= $X - T_b \cos I$
Note: $R_1 \leq 1.5 R_2$	



Note: This is only one example of how a compound curve can be designed.

SYMMETRICAL THREE-CENTERED COMPOUND CURVE

Figure 2-2