Section 3-02
Horizontal Alignment and Superelevation

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HORIZONTAL ALIGNMENT

General: The operational characteristics of a roadway are directly affected by its alignment. The alignment, in turn, affects vehicle operating speeds, sight distances, and highway capacity. The horizontal alignment is influenced by many factors including:

- Terrain
- Functional classification
- Design speed
- Traffic volume
- Right-of-way availability
- Environmental concerns
- Anticipated level of service

The horizontal alignment must provide a safe, functional roadway facility that provides adequate sight distances within economical constraints. The alignment must adhere to specific design criteria such as minimum radii, superelevation rates, and sight distance. These criteria will maximize the overall safety of the facility and enhance the aesthetic appearance of the highway.

Construction of roadways along new alignments is relatively rare. Typically, roadways are reconstructed along existing alignments with horizontal and/or vertical changes to meet current design criteria. The horizontal alignment of a roadway is defined in terms of straight-line tangents and horizontal curves. The curves allow for a smooth transition between the tangent sections. Circular curves and spiral curves are two types of horizontal curves utilized to meet the various design criteria.

Circular Curves: The most common type of curve used in a horizontal alignment is a simple circular curve. A circular curve is an arc with a single constant radius connecting two tangents. A compound curve is composed of two or more adjoining circular arcs of different radii. The centers of the arcs of the compound curves are located on the same side of the alignment. The combination of a short length of tangent between two circular curves is referred to as a broken-back curve. A reverse curve consists of two adjoining circular arcs with the arc centers located on opposite sides of the alignment. Compound and reverse curves are generally used only in specific design situations such as mountainous terrain.

EXHIBIT 1 illustrates four examples of circular curves. The tangents intersect one another at the point of intersection (PI). The point at which the alignment changes from a tangent to circular section is the point of curvature (PC). The point at which the alignment changes from a circular to a tangent section is the point of tangency (PT). The point at which two adjoining circular curves turning in the same direction meet is the point of compound curvature (PCC). The point at which two adjoining circular curves turning in opposite directions meet is the point of reverse curvature (PRC).

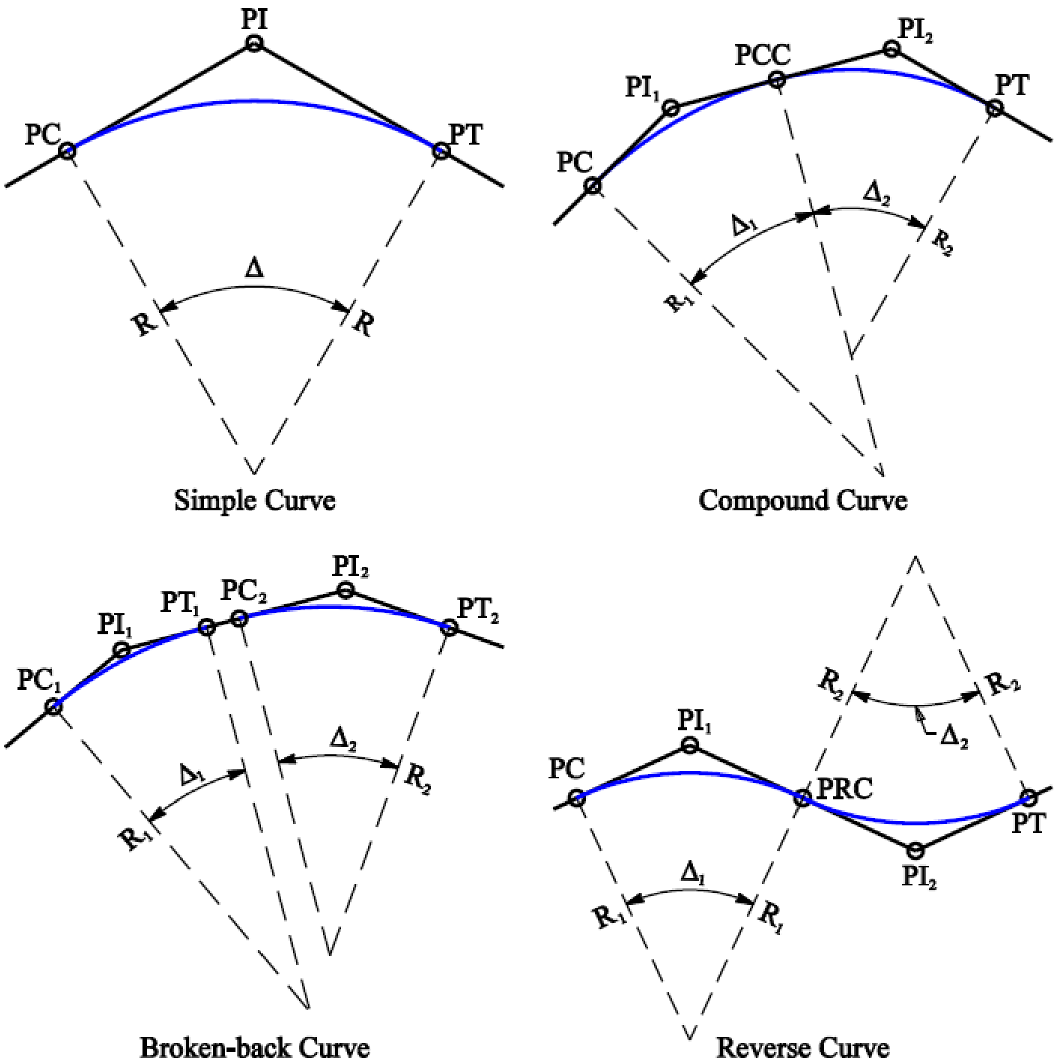

EXHIBIT 1
CIRCULAR CURVES

EXHIBIT 2 is an illustration of the standard components of a single circular curve connecting a back and forward tangent. The distance from the PC to the PI is defined by the tangent distance (T). The length of the circular curve (L) is dependent on the central angle (Δ) and the radius (R) of the curve. Since the curve is symmetrical about the PI, the distance from the PI to the PT is also defined by the tangent distance (T). A line connecting the PC and PT is the long chord (LC). The external distance (E) is the distance from the PI to the midpoint of the curve. The middle ordinate (M) is the distance from the midpoint of the curve to the midpoint of the long chord.

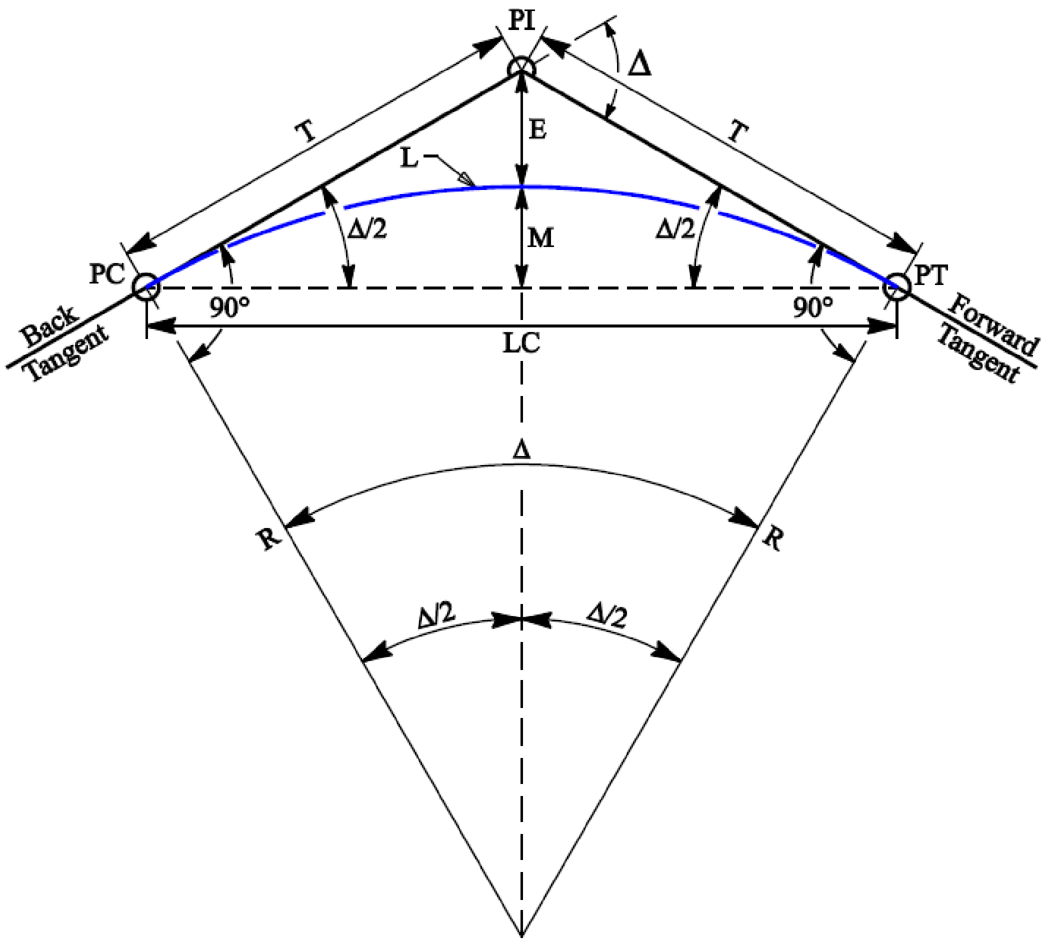

EXHIBIT 2
CIRCULAR CURVE COMPONENTS

Using the arc definition for a circular curve, the degree of curvature is the central angle (D) subtended by a 100 ft arc. A circle has an internal angle of 360° and a circumference of 2πR. Refer to EXHIBIT 3 for an illustration of the degree of curvature within a circle. The relationship between the central angle and the radius for a given circular curve is:

$$\frac{D}{360°} = \frac{100\,ft}{2\pi R};\;\; D = \frac{(100\,ft)(360°)}{2\pi R} = \frac{5729.58\,ft}{R}$$

$$\frac{\Delta}{360°} = \frac{L}{2\pi R};\;\; \Delta = \frac{L*360°}{2\pi R} = \frac{L*180°}{\pi R};\;\; L = \frac{\Delta\pi R}{180°}$$

$$\frac{D}{\Delta} = \frac{100}{L};\;\; L = \frac{100\Delta}{D}$$

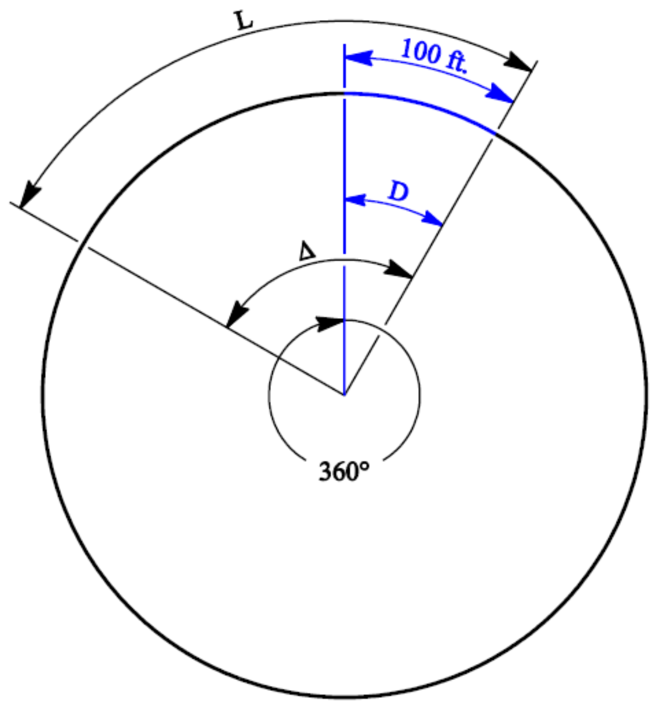

EXHIBIT 3
DEGREE OF CURVATURE

General Circular Curve Formulas:

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

$$L = \frac{100 \Delta R}{5729.58} = \frac{100\Delta}{D}$$

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

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

$$M = E \cos \frac{\Delta}{2}$$

Stationing:

$$Sta. PC = Sta. PI - T$$

$$Sta.PT = Sta.PC + L$$

Example Circular Curve Problem:

Given: Sta. PI = 100+00 Radius = 4200 ft Δ = 27°

Find: Sta. PT

Solution:

$$T = R\tan\frac{\Delta}{2} = 4200\tan\frac{27}{2} = 1008.33\,ft$$

$$Sta.PC = Sta.PI - T = 10000.00 - 1008.33$$
$$= 8991.67\ or\ 89 + 91.67$$

$$L = \frac{100\Delta R}{5729.58} = \frac{100 * 27 * 4200}{5729.58} = 1979.20\,ft$$

$$Sta.PT = Sta.PC + L = 8991.67 + 1979.20$$
$$= 10970.87\ or\ \mathbf{109 + 70.87}$$

Locating a point on a circular curve (see EXHIBIT 4):

The position of any point located at a distance l from the PC along a curve can be determined by utilizing the circular curve formulas.

$$t = R\tan\frac{\delta}{2}$$

$$D = \frac{5729.58}{R}$$

$$l = \frac{100\delta R}{5729.58} = \frac{100\delta}{D}$$

$$lc = 2R\sin\frac{\delta}{2}$$

Where *lc*, τ and δ mimic LC, T and Δ of the whole curve elements.

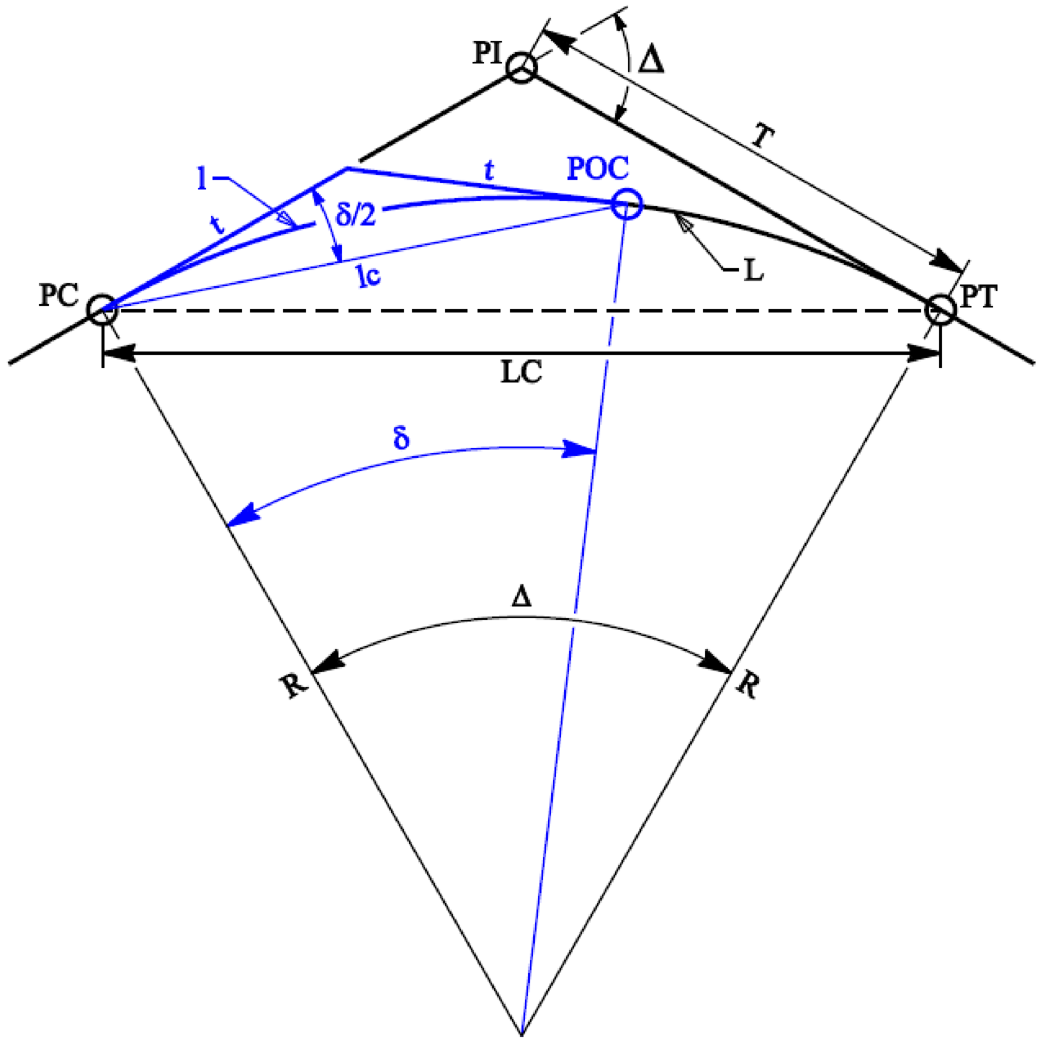

EXHIBIT 4
POINT ON A CIRCULAR CURVE

Spiral Curves: Spiral curves are used in horizontal alignments to provide a gradual transition between tangent sections and circular curves. While a circular curve has a radius that is constant, a spiral curve has a radius that varies along its length. The radius decreases from infinity at the tangent to the radius of the circular curve it is intended to meet.

A vehicle entering a curve must transition from a straight line to a fixed radius. To accomplish this, the vehicle travels along a path with a continually changing radius. Consequently, a spiral will more closely duplicate the natural path of the turning vehicle. If the curvature of the alignment is not excessively sharp, the vehicle can usually traverse this spiral within the width of the travel lane. When the curvature is relatively sharp for a given design speed, it may become necessary to place a spiral transition at the beginning and end of the circular curve. The spirals allow the vehicle to more easily transition into and out of a curve while staying within the travel lane.

EXHIBIT 5 illustrates the standard components of a spiral curve connecting tangents with a central circular curve. The back and forward tangent sections intersect one another at the point of intersection (PI). The alignment changes from the back tangent to the entrance spiral at the tangent to spiral (TS) point. The entrance spiral meets the circular curve at the spiral to curve (SC) point. The circular curve meets the exit spiral at the curve to spiral (CS) point. The alignment changes from the exit spiral to the forward tangent at the spiral to tangent (ST) point. The entrance and exit spiral at each end of the circular curve are geometrically identical.

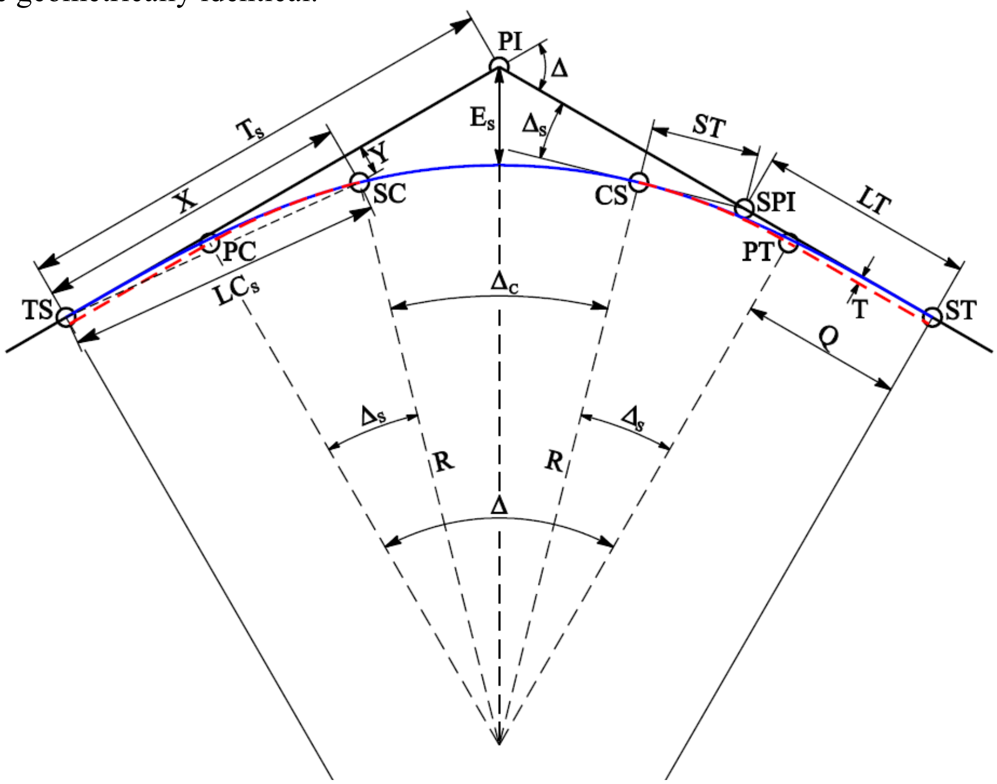

EXHIBIT 5

SPIRAL CURVE COMPONENTS

The length of the circular curve (L_C) is dependent on its central angle (Δ_C) and radius (R). The central angle (Δ) of the spiral-curve-spiral combination represents the deflection angle between the tangent sections. When spirals are placed at either end of the circular curve, the length of the curve is shortened. Instead of extending from the PC to the PT, the curve now extends from the SC to the CS. The offset distance or throw distance (T) represents the perpendicular distance from the back (or forward) tangent section to a tangent line extending from the PC (or PT) points. The length of the spiral (L_S) is typically determined by design speed and superelevation rates. The total length (L) of the spiral-curve-spiral combination is the sum of the length of curve (L_C) and the length of both spirals (L_S).

The distance from the TS to the PI is defined by the tangent distance (T_S). The external distance (E_S) is the distance from the PI to the midpoint of the circular curve. A line connecting the TS and SC (or the CS to the ST) is the long chord (LC_S) of the spiral. The Q dimension is the perpendicular distance from the TS to the PC (and the PT to the ST). The X dimension represents the distance along the tangent from the TS to the SC (and the CS to the ST). The Y dimension represents the tangent offset at the SC (and the CS). The LT and ST dimensions represent the long tangent and the short tangent of the spiral. The spiral tangents intersect at the spiral point of intersection (SPI).

General Spiral Equations: The central angle of a spiral (Δs) is a function of the average degree of curvature of the spiral. In other words, Δs of a spiral is one half of the central angle (Δ_C) for a circular curve of the same length and degree of curvature. These measurements are dependent on the spiral length (L_S) and central angle (Δ_S).

Since $\Delta_C = DL_C/100$ then $\Delta_S = DL_S/200$

$$\Delta = \Delta_C + 2\Delta_S$$

$$L = L_C + 2L_S$$

$$T_S = (R + T)\tan\frac{\Delta}{2} + Q$$

$$E_S = \frac{(R + T)}{\cos\frac{\Delta}{2}} - R$$

Locating a point on a spiral curve:

The position of any point located at a distance l from the TS along a spiral can be determined by modifying the spiral curve formulas.

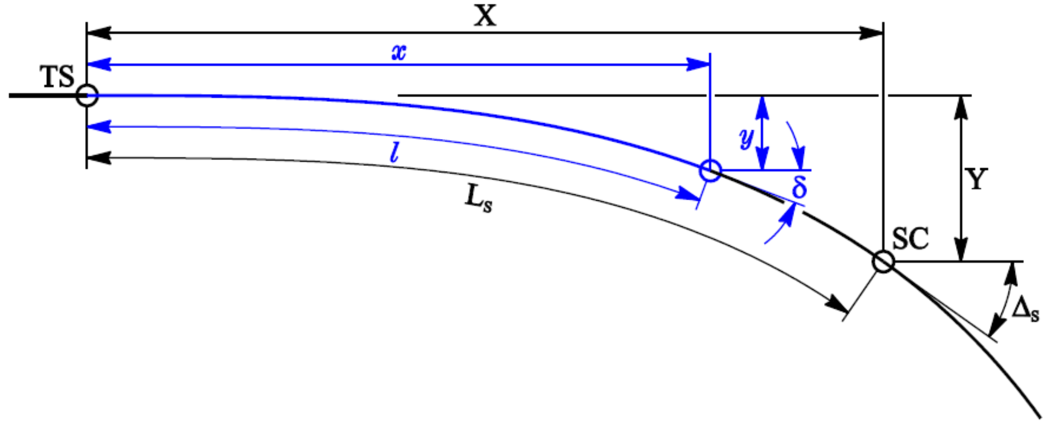

EXHIBIT 6
POINT ON A SPIRAL CURVE

The deflection angle (δ) at the intermediate point can be determined by the equation:

$$\delta = \Delta_S \frac{l^2}{{L_S}^2}$$

Using the equation for determining the spiral central angle equation, δ can also be solved by:

$$\Delta_S = \frac{DL_S}{200}; \quad \delta = \frac{Dl^2}{200L_S}$$

By using differential geometry and an infinite series for the sine and cosine functions, the distance along the tangent (x) and the tangent offset (y) can be determined. **In the following equations, δ must be converted to radians by multiplying the angle in degrees by π/180**.

$$x = l(1 - \frac{\delta^2}{(5)(2!)} + \frac{\delta^4}{(9)(4!)} - \frac{\delta^6}{(13)(6!)} + \cdots)$$

$$y = l(\frac{\delta}{3} - \frac{\delta^3}{(7)(3!)} + \frac{\delta^5}{(11)(5!)} - \frac{\delta^7}{(15)(7!)} + \cdots)$$

The X and Y values can be calculated by substituting L_S for l, and Δ_S for δ. After X and Y have been determined, the following values can be calculated using these equations:

$$Q = X - R\sin\Delta_S\,; \quad T = Y - R(1 - \cos\Delta_S)$$

$$ST = \frac{Y}{\sin\Delta_S}; \quad LT = X - ST\cos\Delta_S$$

$$LC_S = \sqrt{(X\cos\Delta_S + Y\sin\Delta_S)^2 + (X\sin\Delta_S - Y\cos\Delta_S)^2}$$

Spiral Curve Stationing Calculations:

$$Sta.TS = Sta.PI - T_S$$

$$Sta.SC = Sta.TS + L_S$$

$$Sta.CS = Sta.SC + L_C$$

$$Sta.ST = Sta.CS + L_S$$

Spiral Curve Stationing Example:

Given: Sta. PI = 100+00
L_S = 150 ft
$\Delta = 35°$
D = 10°

Find: Sta. TS, Sta. SC, Sta. CS, and Sta. ST

Solution:

$$R = \frac{5729.58}{D} = \frac{5729.58}{10} = 572.96\,ft$$

$$\Delta_S = \frac{DL_S}{200} = \frac{10 * 150}{200} = 7.5°$$

$$\Delta = \Delta_C + 2\Delta_S; \;\; \Delta_C = \Delta - 2\Delta_S = 35° - 2 * 7.5° = 20°$$

$$L_C = \frac{100\Delta c}{D} = \frac{100 * 20}{10} = \frac{2000}{10} = 200.00\,ft$$

Calculate the values for the spiral components T and Q, as described in the preceeding example. The calculated values will be: T = 1.64’, Q = 74.96’.

$$T_S = (R + T)\tan\frac{\Delta}{2} + Q = (572.96 + 1.64)\tan\frac{35}{2} + 74.96 = 256.13\ ft$$

$$Sta.TS = Sta.PI - T_S = 10000.00 - 256.13$$
$$= 9743.87\ or\ \mathbf{97 + 43.87}$$

$$Sta.SC = Sta.TS + L_S = 9843.87 + 150.00$$
$$= 9893.87\ or\ \mathbf{98 + 93.87}$$

$$Sta.CS = Sta.SC + L_C = 9893.87 + 200.00$$
$$= 10093.87\ or\ \mathbf{100 + 93.87}$$

$$Sta.ST = Sta.CS + L_S = 10093.87 + 150.0$$
$$= 10243.87\ or\ \mathbf{102 + 43.87}$$

Approximate Method of Calculating X and Y: The spiral deflection between the tangent section and the spiral long chord is approximately ⅓ of the spiral deflection angle (Δ_S). By using these substitutions, the calculations for the spiral components may be greatly simplified.

$$Y = L_S * \sin\frac{\Delta_S}{3};\quad X^2 + Y^2 = L_S{}^2\ or\ X = \sqrt{L_S{}^2 - Y^2}$$

$$Q = \frac{X}{2};\quad T = \frac{Y}{4}$$

$$ST = \sin\frac{\Delta_S}{3} * \frac{L_S}{\sin\Delta_S};\quad LT = \sin\frac{2\Delta_S}{3} * \frac{L_S}{\sin\Delta_S}$$

SUPERELEVATION

General: Centrifugal force is the outward pull on a vehicle traversing a horizontal curve. When traveling at low speeds or on curves with large radii, the effects of centrifugal force are minor. However, when traveling at higher speeds or around curves with smaller radii, the effects of centrifugal force increase. Excessive centrifugal force may cause considerable lateral movement of the turning vehicle and it may become impossible to stay inside the driving lane.

Superelevation and side friction are the two factors that help stabilize a turning vehicle. Superelevation is the banking of the roadway such that the outside edge of pavement is higher than the inside edge. The use of superelevation allows a vehicle to travel through a curve more safely and at a higher speed than would otherwise be possible. Side friction developed between the tires and the road surface also acts to counterbalance the outward pull on the vehicle. Side friction is reduced when water, ice, or snow is present or when tires become excessively worn.

If the pavement cross-slope is flat, side friction between the tires and the pavement is the only force that keeps the vehicle traveling on the curved path. Banking the vehicle by adding superelevation has two effects. It reduces the component of centrifugal force acting parallel to the pavement surface, and more importantly, it generates a component of the weight of a vehicle acting in a direction parallel to the pavement to resist and thereby reduce the effect of centrifugal force. Superelevation reduces the amount of side friction required to hold a vehicle on a curved path (side friction always acts in a direction parallel to the cross-slope of the pavement) and consequently reduces the sensation the driver feels of being pushed towards the outside of a curve.

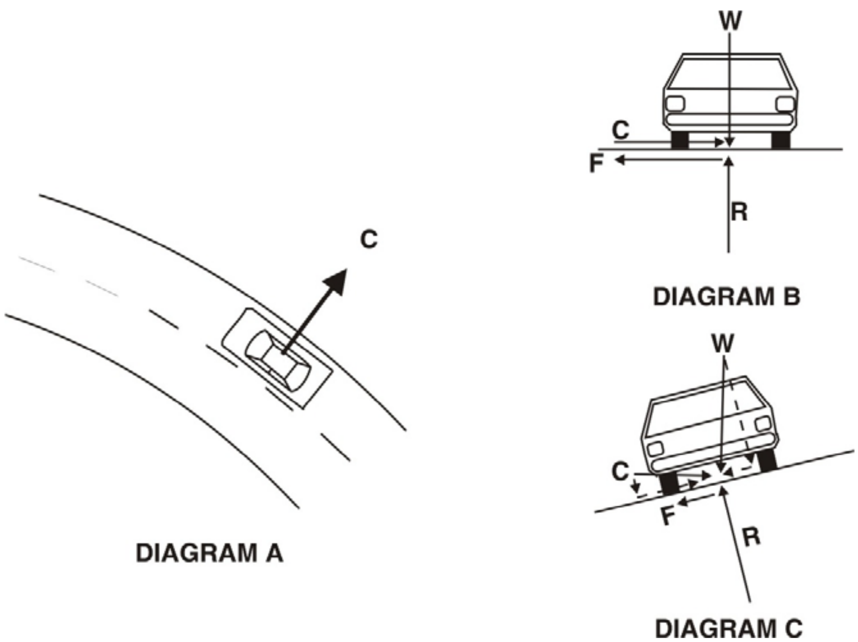

EXHIBIT 7
VEHICLE ON CURVE FORCE DIAGRAMS

The concept is best illustrated when looking at a diagram of the forces acting on a vehicle traveling a curved alignment as shown in EXHIBIT 7. For this analysis, we are only interested in the forces parallel to the pavement. In Diagram B, no superelevation exists, hence the entire value of centrifugal force (C) acts parallel to the pavement. Side friction force (F) must be equal in magnitude to C and must work in the opposite direction of C, or the vehicle will skid.

In Diagram C, superelevation is applied, resulting in a somewhat smaller force component of C acting parallel to the pavement. Additionally, the force of gravity pulling down on the mass of the vehicle (W) now has a component that acts parallel to the pavement cross-slope, thereby resisting the parallel component of centrifugal force. The magnitude of the side friction force becomes much smaller. If enough superelevation is added, no side friction component is required. If excessive superelevation is provided, the parallel weight component becomes greater than the parallel centrifugal force component, thereby requiring side friction in the opposite direction. This creates an unnatural driving maneuver since it requires the driver to steer back towards the outside of the curve; therefore, excessive superelevation should be avoided.

The transitional rate of applying superelevation into and out of curves is influenced by several factors. These factors include design speed, curve radius, and number of travel lanes. Minimum curve radii for a horizontal alignment are determined by the design speed and superelevation rate. Higher design speeds require more superelevation than lower design speeds for a given radius. Additionally, sharper curves require more superelevation than flatter curves for a given design speed.

The maximum superelevation for a section of roadway is dependent on climatic conditions, type of terrain, and type of development. Roadways in rural areas are typically designed with a maximum superelevation rate of 8 percent. In mountainous areas, a maximum superelevation rate of 6 percent is used due to the increased likelihood of ice and snow. Urban roadways are normally designed with a maximum superelevation rate of 4 percent. Superelevation is of limited use in urban areas because of the lower operating speeds. In most cases, superelevation in urban areas is completely eliminated. The superelevation of the roadway may interfere with drainage systems, utilities, and pavement tie-ins at intersecting streets and driveways.

Maximum Allowable Side Friction Factor: The maximum allowable side friction factor (f) is established for each design speed based on studies that have been conducted for a variety of tires, pavement types and conditions. The side friction factor is the side coefficient of friction which when multiplied by the weight of the vehicle, gives the resultant side friction force. Since highway curves are designed to avoid skidding with a sufficient margin of safety, the maximum allowable side friction factor is significantly below the side coefficient of friction for impending skid. In fact, a major consideration in selecting the maximum allowable side friction factors is the point at which the **sensation** of centrifugal force will cause the driver to experience enough discomfort to react instinctively to avoid greater lateral forces. The *ASHTO A Policy on Geometric Design of Highways and Streets* has established the maximum allowable side friction factors for various design speeds as shown in EXHIBIT 8.

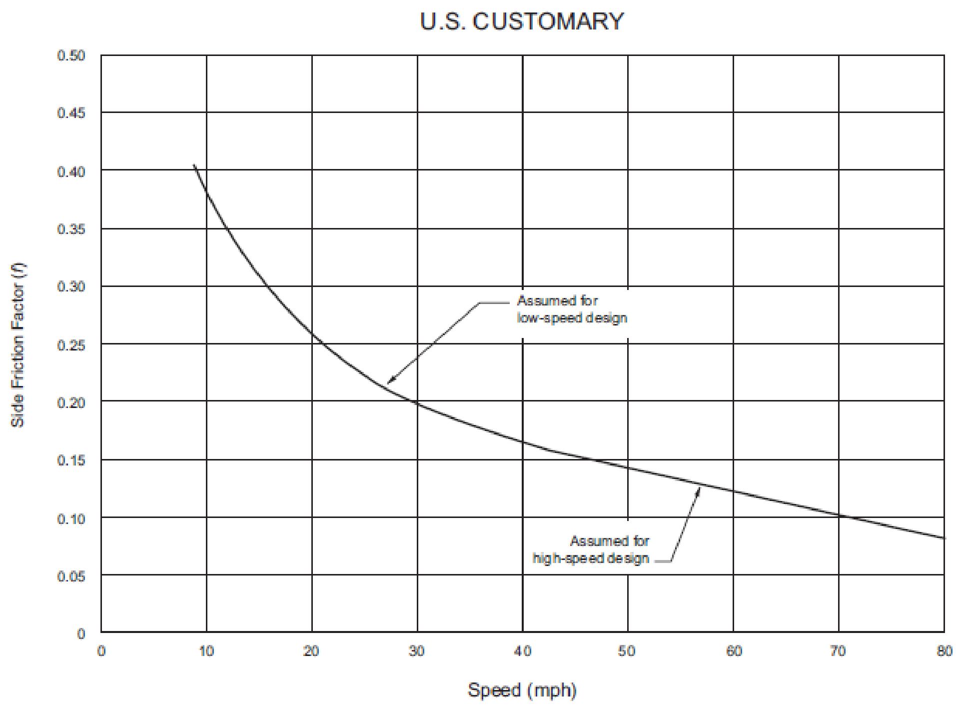

Figure 3-6. Side Friction Factors Assumed for Design

EXHIBIT 8
AASHTO SIDE FRICTION FACTORS

Minimum Radius: The simplified curve formula relates the balance of forces between the centrifugal force, the side friction force and the effect of superelevation. In its fundamental form the simplified curve formula is:

$$f = \frac{V^2}{15R} - 0.01e$$

where: *f* = side friction factor
V = vehicle speed, mph
R = radius of curve, ft
e = superelevation rate, %

The minimum radius for a given design speed can be calculated by substituting e(max) for e, f(max) for f and the design speed for V into the simplified curve formula.

Distribution of Superelevation for High Speed Roadways (>45 mph): The simplified curve formula shown above establishes a linear relationship between the sum of superelevation (e) and friction factor (f) and the inverse of the radius, for a given design speed. Although the relationship is linear for the sum of e and f, the simplified curve formula does not indicate how e and f are individually distributed. For high speed roadways, it is recognized that many drivers tend to overdrive the flat to intermediate range of curves (i.e. those curves which are flatter than the minimum radius curves for a given design speed). Rather than applying a straight line distribution of superelevation from 0 to e(max) as the inverse of the radius varies from 0 to l/R(min), it becomes desirable to distribute e (and thereby f) parabolically so that less side friction is required in the flat to intermediate range of curves by providing additional superelevation. This procedure is described in the AASHTO Policy as Method 5.

Method 5 has an asymmetrical parabolic form and represents a practical distribution for superelevation over the range of curvature. Method 5 is recommended for the distribution of *e* and *f* for all curves with radii greater than the minimum radius of curvature on rural highways, urban freeways, and high-speed urban streets.

The WYDOT 0.08, 0.06, 0.04 maximum superelevation tables were calculated using the aforementioned methodology. The designer should choose the appropriate table based on the criteria below:

CONDITION	**SUPERELEVATION TABLE**
Rural Design - (except for mountainous)	0.08 max
Rural Design - mountainous terrain	0.06 max
Urban Design – high speed (>45 mph)	0.04 or 0.06 max
Urban Design – low speed (<45 mph)	0.04 max

Note: Use of 0.04 max superelevation tables should be limited to urban design.

The WYDOT Superelevation Tables are included at the end of this Chapter.

Distribution of Superelevation for Low Speed Urban Roadways (<45 mph): It is desirable to use the e(max) = 0.04 ft/ft superelevation tables for low speed urban roadways. In many cases the designer may wish to also limit the minimum radius to curves that require no more than 0.02 ft/ft of superelevation (i.e. reverse crown). Drainage and connections to intersecting roads can be more easily dealt with in an urban environment when superelevation is kept to a minimum. In most cases, superelevation in urban areas is completely eliminated. The superelevation of the roadway may interfere with drainage systems, utilities, and pavement tie-ins at intersecting streets and driveways.

If used, the designer may consider other methods of superelevation distribution for low speed (45 mph and less) urban design. As previously discussed, when the friction factor reaches its maximum allowable value, the driver feels the greatest level of discomfort due to centrifugal force. Method 2 from AASHTO Policy is acceptable for low speed urban streets where drivers have been conditioned to expect a greater level of discomfort. In this method, no superelevation is applied until the maximum allowable friction factor is required. Superelevation is then added as needed to counteract the centrifugal force while holding f at f(max). This discourages drivers from "overdriving" conditions (i.e. exceeding the design speed) because less superelevation is used to offset centrifugal force which now pulls harder on the driver and vehicle. The designer must weigh other conditions such as the roadway function, drainage, and good geometry at connecting roads and approaches in selecting appropriate superelevation rates. In all cases, the maximum allowable side friction factor should not be exceeded.

Superelevation Runoff: Superelevation runoff length (S) is defined as the distance to go from zero (e = 0.00) to the specified superelevation (e) for the given radius and design speed. Superelevation runoff length is calculated for a two lane roadway rotated about the centerline by applying the established maximum relative gradients and then adjusting the runoff length for wider roadways or roadways with a different point of rotation.

The maximum relative gradient is defined as the difference between the longitudinal slope between the centerline profile and the edgeline profile (edge of traveled way) for a two lane roadway rotated about the centerline. The maximum recommended relative gradients from AASHTO Policy are shown in Exhibit 9.

Design Speed (mph)	Maximum Relative Gradient (%)
15	0.78
20	0.74
25	0.70
30	0.66
35	0.62
40	0.58
45	0.54
50	0.50
55	0.47
60	0.45
65	0.43
70	0.40
75	0.38
80	0.35

EXHIBIT 9

MAXIMUM RELATIVE GRADIENTS

Superelevation runoff length can be calculated with the following formula:

$$L_r = \frac{(wn_1)\, e_d}{\Delta}(b_w)$$

where:

L_r = minimum length of superelevation runoff, ft

w = width of one traffic lane, ft (typically 12 ft)

n_1 = number of lanes rotated

e_d = design superelevation rate, percent

b_w = adjustment factor for number of lanes rotated

Δ = maximum relative gradient, percent

Superelevation is gradually introduced by rotating the pavement cross-section about a point of rotation. For undivided highways, the point of rotation is located at the centerline. For divided highways, the point of rotation is typically located at the inside edge of traveled way. The location of the point of rotation is generally indicated on the roadway typical sections. Superelevation is applied by first rotating the lane(s) on the outside of the curve. The inside lane(s) do not rotate until the outside lane(s) achieve a reverse crown. At this point, all lanes rotate simultaneously until full superelevation is reached.

Crown Runoff: Crown runoff (C) is the distance required for the outside lane(s) to transition from a normal crown to a flat crown. The length of crown runoff is also the distance for the outside lane(s) to transition from a flat crown to a reverse crown. For each given superelevation and corresponding runoff length, the roadway cross-slope will rotate at a given rate. Crown runoff should occur at the same rate as superelevation runoff to create a smooth transition. The crown runoff length is, therefore, equal to the superelevation runoff length (S) multiplied by the ratio of the normal crown rate to the actual superelevation rate. Normal crown (NC) for most WYDOT projects is 0.020 ft/ft.

$$C = S * (NC/e)$$

The values of C and S are determined from superelevation tables for various combinations of design speed and degree of curvature.

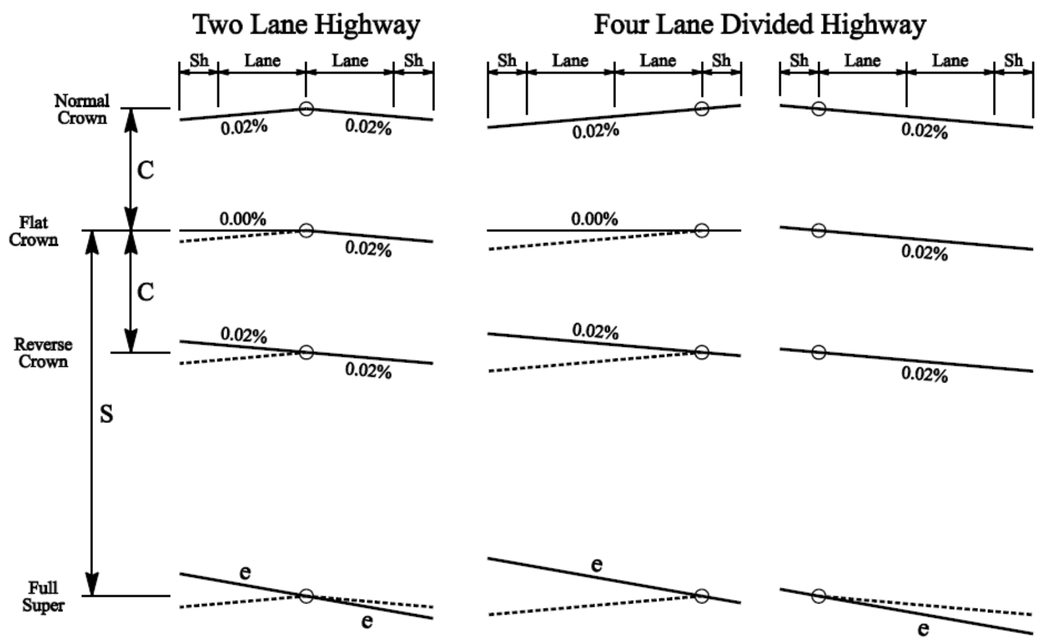

EXHIBIT 10

SUPERELEVATION ROTATION

Superelevation on Circular Curves: Superelevation is uniformly applied to provide a smooth transition from a normal crown section to a full superelevation section. Two-thirds of superelevation runoff occurs prior to the PC and then again after the PT. One-third of the superelevation runoff occurs on the curve between the PC and the PT at each end of the curve. The rest of the curve is in a full superelevation section. The crown runoff that transitions from a normal crown to a flat crown (and vice versa) is placed outside each superelevation runoff section. The crown runoff that transitions from a flat crown to a reverse crown (and vice versa) is placed just inside each superelevation runoff section. See EXHIBIT 11 for an illustration of the crown and superelevation runoff distances as they are applied to circular curves.

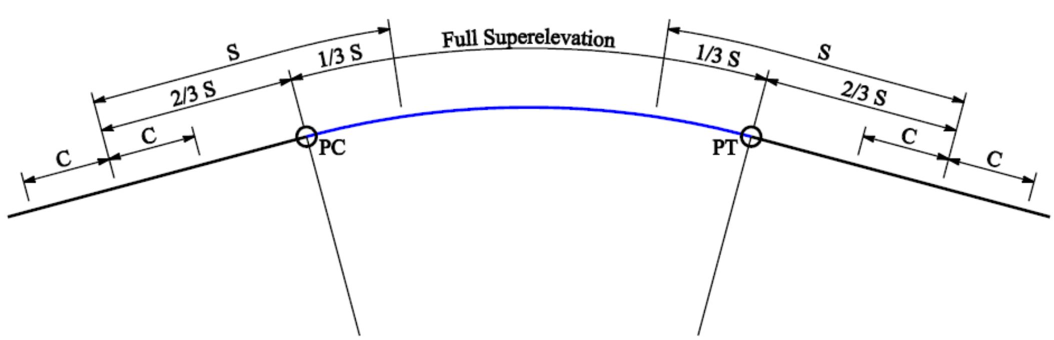

EXHIBIT 11

SUPERELEVATION ON A CIRCULAR CURVE

Superelevation on Spiral Curves: Where spiral transition curves are used, the full length of the spiral is equal to the superelevation runoff. The full superelevation is reached at the SC point and the entire circular curve is in a full superelevation section. The crown runoffs that transition from a normal crown to a flat crown (and vice versa) occurs prior to the TS point and after the ST point. The crown runoff that transitions from a flat crown to a reverse crown is placed just after the TS point and before the ST point. See EXHIBIT 12 for an illustration of the crown and superelevation runoff distances as they are applied to spiral curves.

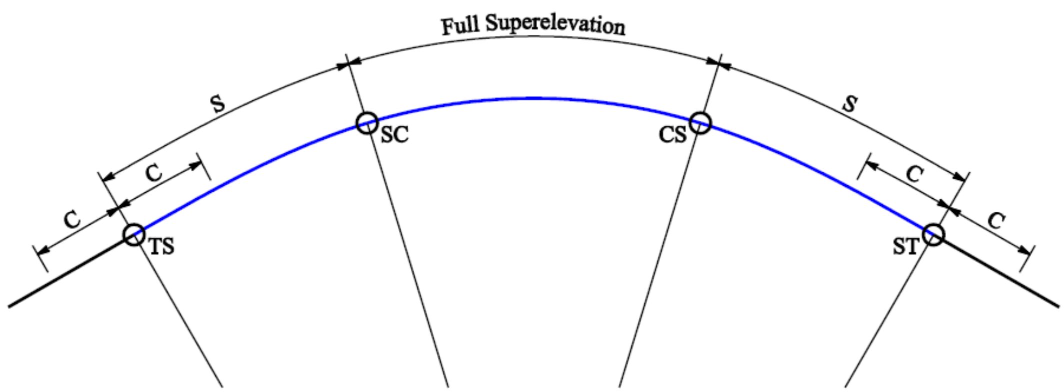

EXHIBIT 12

SUPERELEVATION ON A SPIRAL/CIRCULAR CURVE COMBINATION

Compound and Reverse Curves: Compound and reverse curves can sometimes be used advantageously in certain design situations. Because of their unique configuration, compound and reverse curves demand careful consideration when applying superelevation. The use of these alignments should be restricted to cases where non-consecutive curves with or without spirals are not effective and do not fit the terrain and proposed alignment. See EXHIBIT 13 for typical compound curves, and EXHIBIT 14 for reverse curves.

As a general rule, the ratio of the larger radius curve to the smaller radius curve should not be greater than 1.5 to 1 for open highways. The ratio for slower speed highways should not exceed 2 to 1. Superelevation runoff needs to be carefully considered for compound and reverse curves.

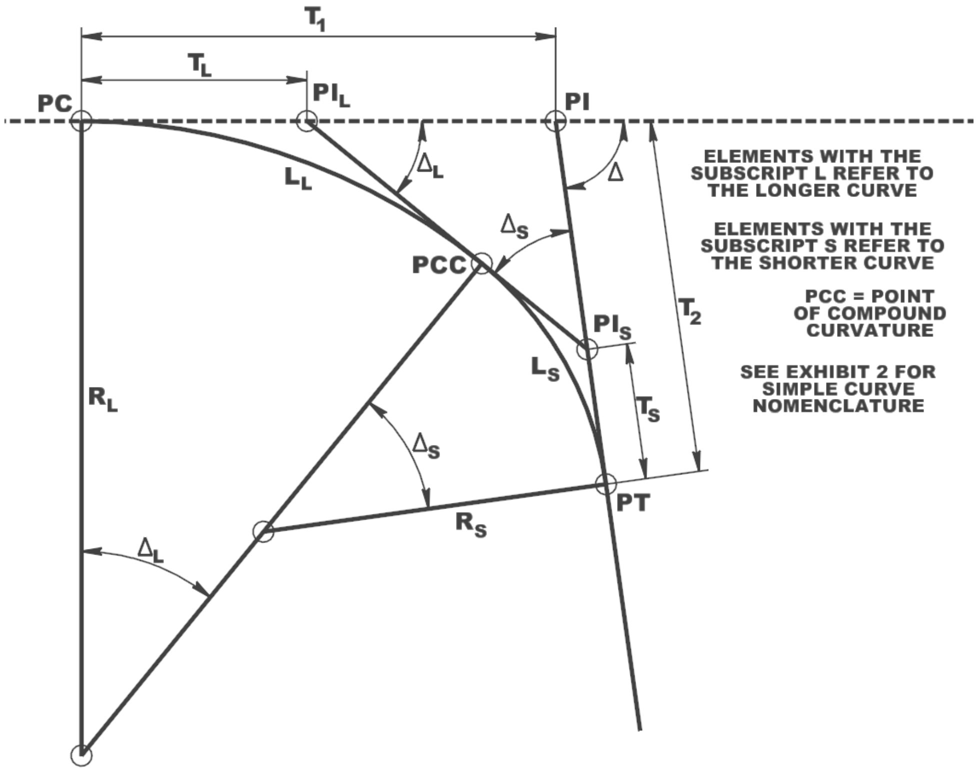

EXHIBIT 13
COMPOUND CURVES

Compound Curvature Design Considerations: Superelevation and crown runoff areas demand careful consideration for consecutive curves in the same or opposite directions. WYDOT considers the desirable length of normal crown tangent to be a minimum of 200 feet between consecutive curve sections as shown in EXHIBIT 15.

If there is not room for 200 feet of normal crown tangent or if the total tangent length between curves is less than two-thirds S1 + two-thirds S2 (see diagram), the designer will want to consider alternate means of providing superelevation runoff distance.

Although there are several ways to design these areas, there is no one best approach. The designer will need to decide which method or combination of methods is appropriate for the given situation.

Two-thirds of superelevation runoff is typically off the curve while one-third is typically on the curve. Consideration could be given to running off up to one-half of the superelevation on the curve to avoid overlapping adjacent runoff lengths.

The designer could also utilize a tangent section with 0.01 ft/ft crown between curves to reduce the crown runoff length in tight situations.

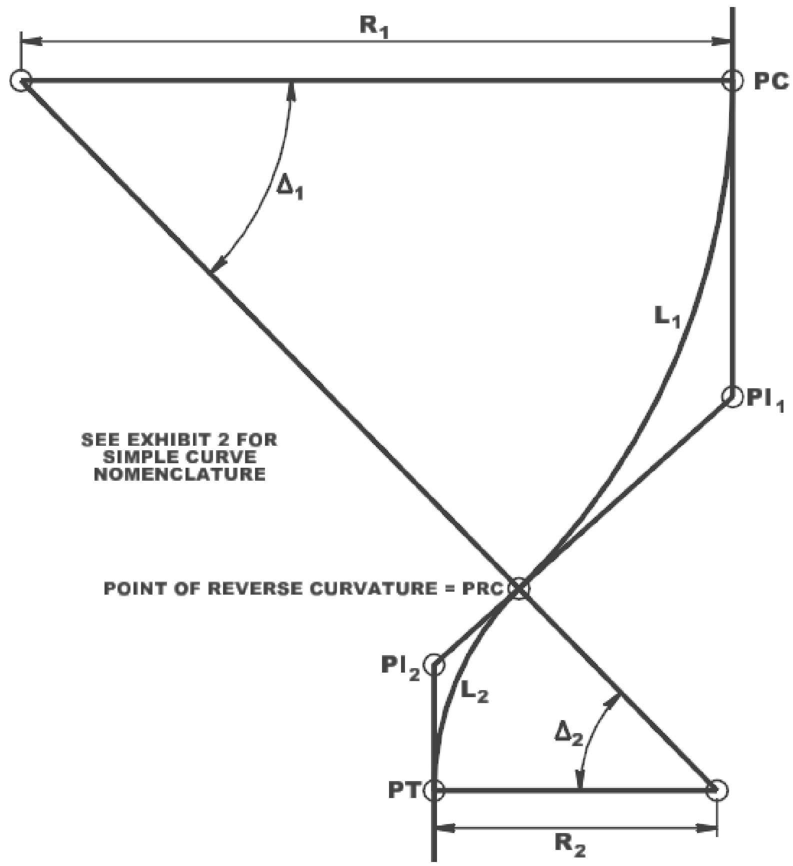

EXHIBIT 14
REVERSE CURVES

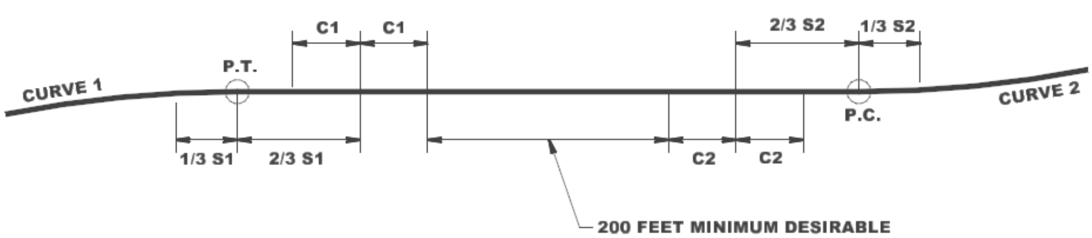

EXHIBIT 15
MINIMUM NORMAL CROWN DISTANCE

If consecutive curves are curving the same direction, (their centers are on the same side) then consider holding 0.02 ft/ft reverse crown between the superelevation runoff areas instead of attempting to rotate to normal crown.

The designer can have the superelevation of the first curve transition directly into the superelevation rate of the second consecutive curve, taking care to avoid drainage problems on long flat curves and also on the high/low point on vertical curves.

Overall Horizontal Design Considerations: Roadways should be designed to blend with the contours of the natural surroundings. The roadway should not appear awkward or unnatural by having a horizontal alignment that is inconsistent with the existing terrain. The roadway construction, when completed, should have minimal impact on the surroundings. The terrain in the vicinity of the new construction should blend into the natural condition as much as possible.

The design speed used for a particular section of roadway should be as high as practical, considering the nature of the surrounding terrain and the function of the roadway. Smooth transitions should be provided in areas where the design speed changes to allow the driver to gradually become accustomed to the changed condition.

Directional changes in alignment are best accomplished by using simple, circular curves, unless the use of spirals is recommended. Use of gradual curves with flatter superelevation is preferable where the terrain allows for it. Spirals increase safety and comfort on sharper curves, especially at higher design speeds. The use of sharp curvature, compound, or reverse curvature should only be used in critical areas such as mountainous terrain.

Rural curves that are gradual enough to not require superelevation will function better if reverse 0.02 ft/ft crown is applied. Otherwise, the driver on the side of the adverse crown experiences the discomfort caused by centrifugal force.

Superelevation is of limited use in urban areas because of the lower operating speeds. In most cases, superelevation in urban areas is completely eliminated. The superelevation of the roadway may interfere with drainage systems, utilities, and pavement tie-ins at intersecting streets and driveways.

WYDOT Superelevation Tables

RURAL DESIGN e(max) = 0.08 ft/ft

Lane Adjustment Factor L(adj) = 1.0

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e(max)= 0.08 L(adj) = 1.0 12 ft Lanes							
		e(max) 0.08	f(max) 0.32	GRAD 0.78	e(max) 0.08	f(max) 0.27	GRAD 0.74
		V(R) 15	V(D) 15		V(R) 20	V(D) 20	
CURVE		15 mph (24km/h)			20 mph (32km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0
12000	0.48	NC	0	0	NC	0	0
10000	0.57	NC	0	0	NC	0	0
8000	0.72	NC	0	0	NC	0	0
6000	0.95	NC	0	0	NC	0	0
5000	1.15	NC	0	0	NC	0	0
4000	1.43	NC	0	0	NC	0	0
3500	1.64	NC	0	0	NC	0	0
3000	1.91	NC	0	0	NC	0	0
2500	2.29	NC	0	0	NC	0	0
2000	2.86	NC	0	0	NC	0	0
1800	3.18	NC	0	0	NC	0	0
1600	3.58	NC	0	0	NC	0	0
1400	4.09	NC	0	0	RC	32	32
1200	4.77	NC	0	0	RC	32	32
1000	5.73	NC	0	0	0.023	37	32
900	6.37	NC	0	0	0.025	41	33
800	7.16	RC	31	31	0.028	45	32
700	8.19	RC	31	31	0.031	50	32
600	9.55	0.022	34	31	0.035	57	33
500	11.46	0.026	40	31	0.040	65	33
450	12.73	0.028	43	31	0.042	68	32
400	14.32	0.031	48	31	0.045	73	32
350	16.37	0.034	52	31	0.048	78	33
300	19.10	0.038	58	31	0.051	83	33
250	22.92	0.043	66	31	0.055	89	32
200	28.65	0.048	74	31	0.060	97	32
150	38.20	0.053	82	31	0.067	109	33
100	57.30	0.061	94	31	0.077	125	32
75	76.39	0.068	105	31	0.080	130	33
50	114.59	0.077	118	31			
		R(min) = 38 ft			R(min) = 76 ft		

L(adj) = 1.0

For 2 - lane roadways rotated about the centerline.

Definitions for Superelevation Tables:

R = Radius of Curve

D = Degree of Curve (100 ft arc length definition)

e = Superelevation Rate

S = Length of Superelevation Runoff & Spiral Length

Flat crown to full superelevation length.

WYDOT uses 2/3 S off curve, 1/3 S on curve.

C = Length of Crown Runoff

NC (normal crown) to flat crown length.

NC = Normal Crown (typically 0.02 ft/ft)

RC = Reverse Crown (typically 0.02 ft/ft)

L(adj) = Lane Adjustment Factor

Used to adjust the length of S and C for multilane highways.

L(adj) = 1.25 For 3 - lane roadways rotated about the centerline.

L(adj) = 1.5 For 4 - lane roadways rotated about the centerline, and divided 4 - lane roadways rotated about the median edge of traveled way.

L(adj) = 1.75 For 5 - lane roadways rotated about the centerline.

Spiral transitions should be considered when e, S, and C are shaded.

Superelevation values based on AASHTO 2011 Greenbook.

WYDOT Superelevation Tables

RURAL DESIGN e(max) = 0.08 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)= 0.08 L(adj) = 1.0 12 ft Lanes													
		e(max)	0.08		e(max)	0.08		e(max)	0.08		e(max)	0.08	
		f(max)	0.23		f(max)	0.20		f(max)	0.18		f(max)	0.16	
		GRAD	0.7		GRAD	0.66		GRAD	0.62		GRAD	0.58	
		V(R)	24		V(R)	28		V(R)	32		V(R)	36	
		V(D)	25		V(D)	30		V(D)	35		V(D)	40	
CURVE		25 mph (40km/h)			30 mph (48km/h)			35 mph (56km/h)			40 mph (64km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	0.48	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	0.57	NC	0	0	NC	0	0	NC	0	0	NC	0	0
8000	0.72	NC	0	0	NC	0	0	NC	0	0	NC	0	0
6000	0.95	NC	0	0	NC	0	0	NC	0	0	NC	0	0
5000	1.15	NC	0	0	NC	0	0	NC	0	0	RC	41	41
4000	1.43	NC	0	0	NC	0	0	RC	39	39	RC	41	41
3500	1.64	NC	0	0	NC	0	0	RC	39	39	0.022	46	42
3000	1.91	NC	0	0	RC	36	36	0.021	41	39	0.026	54	42
2500	2.29	NC	0	0	RC	36	36	0.024	46	38	0.030	62	41
2000	2.86	RC	34	34	0.023	42	37	0.030	58	39	0.036	74	41
1800	3.18	RC	34	34	0.025	45	36	0.032	62	39	0.039	81	42
1600	3.58	0.021	36	34	0.028	51	36	0.035	68	39	0.043	89	41
1400	4.09	0.024	41	34	0.031	56	36	0.039	75	38	0.048	99	41
1200	4.77	0.027	46	34	0.036	65	36	0.044	85	39	0.053	110	42
1000	5.73	0.032	55	34	0.041	75	37	0.050	97	39	0.059	122	41
900	6.37	0.034	58	34	0.044	80	36	0.053	103	39	0.063	130	41
800	7.16	0.038	65	34	0.047	85	36	0.057	110	39	0.067	139	41
700	8.19	0.041	70	34	0.051	93	36	0.061	118	39	0.071	147	41
600	9.55	0.045	77	34	0.055	100	36	0.066	128	39	0.075	155	41
500	11.46	0.050	86	34	0.060	109	36	0.071	137	39	0.079	163	41
450	12.73	0.053	91	34	0.064	116	36	0.074	143	39			
400	14.32	0.055	94	34	0.067	122	36	0.077	149	39			
350	16.37	0.059	101	34	0.071	129	36	0.079	153	39			
300	19.10	0.063	108	34	0.075	136	36						
250	22.92	0.068	117	34	0.079	144	36						
200	28.65	0.074	127	34									
150	38.20	0.079	135	34									
100	57.30												
75	76.39												
50	114.59												
		R(min) = 134 ft			R(min) = 214 ft			R(min) = 314 ft			R(min) = 444 ft		

WYDOT Superelevation Tables

RURAL DESIGN e(max) = 0.08 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)= 0.08 L(adj) = 1.0 12 ft Lanes		e(max) 0.08 f(max) 0.15 GRAD 0.54 V(R) 40 V(D) 45			e(max) 0.08 f(max) 0.14 GRAD 0.5 V(R) 44 V(D) 50			e(max) 0.08 f(max) 0.13 GRAD 0.47 V(R) 48 V(D) 55			e(max) 0.08 f(max) 0.12 GRAD 0.45 V(R) 52 V(D) 60		
CURVE		45 mph (72km/h)			50 mph (80km/h)			55 mph (89km/h)			60 mph (97km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	0.48	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	0.57	NC	0	0	NC	0	0	NC	0	0	RC	53	53
8000	0.72	NC	0	0	NC	0	0	RC	51	51	0.021	56	53
6000	0.95	RC	44	44	RC	48	48	0.024	61	51	0.027	72	53
5000	1.15	RC	44	44	0.024	58	48	0.028	71	51	0.032	85	53
4000	1.43	0.024	53	44	0.029	70	48	0.034	87	51	0.039	104	53
3500	1.64	0.027	60	44	0.032	77	48	0.038	97	51	0.044	117	53
3000	1.91	0.031	69	45	0.037	89	48	0.043	110	51	0.050	133	53
2500	2.29	0.036	80	44	0.043	103	48	0.050	128	51	0.057	152	53
2000	2.86	0.043	96	45	0.051	122	48	0.058	148	51	0.066	176	53
1800	3.18	0.047	104	44	0.055	132	48	0.063	161	51	0.070	187	53
1600	3.58	0.051	113	44	0.059	142	48	0.067	171	51	0.075	200	53
1400	4.09	0.056	124	44	0.064	154	48	0.072	184	51	0.078	208	53
1200	4.77	0.061	136	45	0.070	168	48	0.077	197	51	0.080	213	53
1000	5.73	0.068	151	44	0.076	182	48	0.080	204	51			
900	6.37	0.071	158	45	0.078	187	48						
800	7.16	0.075	167	45	0.080	192	48						
700	8.19	0.078	173	44									
600	9.55	0.080	178	45									
500	11.46												
450	12.73												
400	14.32												
350	16.37												
300	19.10												
250	22.92												
200	28.65												
150	38.20												
100	57.30												
75	76.39												
50	114.59												
		R(min) = 587 ft			R(min) = 758 ft			R(min) = 960 ft			R(min) = 1200 ft		

WYDOT Superelevation Tables

RURAL DESIGN e(max) = 0.08 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)= 0.08 L(adj) = 1.0 12 ft Lanes		e(max)		0.08	e(max)		0.08	e(max)		0.08	e(max)		0.08
		f(max)		0.11	f(max)		0.10	f(max)		0.09	f(max)		0.08
		GRAD		0.43	GRAD		0.4	GRAD		0.38	GRAD		0.35
		V(R)		55	V(R)		58	V(R)		61	V(R)		64
		V(D)		65	V(D)		70	V(D)		75	V(D)		80
CURVE		65 mph (105km/h)			70 mph (113km/h)			75 mph (121km/h)			80 mph (129km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0	NC	0	0	RC	69	69
14000	0.41	NC	0	0	NC	0	0	RC	63	63	RC	69	69
12000	0.48	RC	56	56	RC	60	60	RC	63	63	0.022	75	68
10000	0.57	RC	56	56	0.021	63	60	0.024	76	63	0.026	89	68
8000	0.72	0.024	67	56	0.026	78	60	0.029	92	63	0.033	113	68
6000	0.95	0.031	87	56	0.034	102	60	0.038	120	63	0.043	147	68
5000	1.15	0.036	100	56	0.040	120	60	0.045	142	63	0.051	175	69
4000	1.43	0.044	123	56	0.049	147	60	0.055	174	63	0.062	213	69
3500	1.64	0.049	137	56	0.055	165	60	0.062	196	63	0.070	240	69
3000	1.91	0.055	153	56	0.062	186	60	0.070	221	63	0.078	267	68
2500	2.29	0.064	179	56	0.071	213	60	0.078	246	63			
2000	2.86	0.073	204	56	0.079	237	60						
1800	3.18	0.077	215	56									
1600	3.58	0.079	220	56									
1400	4.09												
1200	4.77												
1000	5.73												
900	6.37												
800	7.16												
700	8.19												
600	9.55												
500	11.46												
450	12.73												
400	14.32												
350	16.37												
300	19.10												
250	22.92												
200	28.65												
150	38.20												
100	57.30												
75	76.39												
50	114.59												
		R(min) = 1480 ft			R(min) = 1810 ft			R(min) = 2210 ft			R(min) = 2670 ft		

WYDOT Superelevation Tables

MTN. DESIGN e(max) = 0.06 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)= 0.06 L(adj) = 1.0 12 ft Lanes		e(max) 0.06 f(max) 0.32 GRAD 0.78 V(R) 15 V(D) 15			e(max) 0.06 f(max) 0.27 GRAD 0.74 V(R) 20 V(D) 20		
CURVE		15 mph (24km/h)			20 mph (32km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0
12000	0.48	NC	0	0	NC	0	0
10000	0.57	NC	0	0	NC	0	0
8000	0.72	NC	0	0	NC	0	0
6000	0.95	NC	0	0	NC	0	0
5000	1.15	NC	0	0	NC	0	0
4000	1.43	NC	0	0	NC	0	0
3500	1.64	NC	0	0	NC	0	0
3000	1.91	NC	0	0	NC	0	0
2500	2.29	NC	0	0	NC	0	0
2000	2.86	NC	0	0	NC	0	0
1800	3.18	NC	0	0	NC	0	0
1600	3.58	NC	0	0	NC	0	0
1400	4.09	NC	0	0	RC	32	32
1200	4.77	NC	0	0	RC	32	32
1000	5.73	NC	0	0	0.022	36	33
900	6.37	NC	0	0	0.024	39	33
800	7.16	RC	31	31	0.026	42	32
700	8.19	RC	31	31	0.028	45	32
600	9.55	RC	31	31	0.031	50	32
500	11.46	0.023	35	30	0.034	55	32
450	12.73	0.025	38	30	0.035	57	33
400	14.32	0.027	42	31	0.037	60	32
350	16.37	0.030	46	31	0.038	62	33
300	19.10	0.032	49	31	0.041	66	32
250	22.92	0.034	52	31	0.043	70	33
200	28.65	0.037	57	31	0.047	76	32
150	38.20	0.040	62	31	0.052	84	32
100	57.30	0.046	71	31	0.059	96	33
75	76.39	0.052	80	31			
50	114.59	0.058	89	31			
		R(min) = 39 ft			R(min) = 81 ft		

Rev. 12-20-13

L(adj) = 1.0
For 2 - lane roadways rotated about the centerline.

Definitions for Superelevation Tables:

R = Radius of Curve
D = Degree of Curve (100 ft arc length definition)
e = Superelevation Rate
S = Length of Superelevation Runoff & Spiral Length
Flat crown to full superelevation length.
WYDOT uses 2/3 S off curve, 1/3 S on curve.
C = Length of Crown Runoff
NC (normal crown) to flat crown length.
NC = Normal Crown (typically 0.02 ft/ft)
RC = Reverse Crown (typically 0.02 ft/ft)

L(adj) = Lane Adjustment Factor
Used to adjust the length of S and C for multilane highways.

L(adj) = 1.25 For 3 - lane roadways rotated about the centerline.

L(adj) = 1.5 For 4 - lane roadways rotated about the centerline, and divided 4 - lane roadways rotated about the median edge of traveled way.

L(adj) = 1.75 For 5 - lane roadways rotated about the centerline.

Spiral transitions should be considered when e, S, and C are shaded.

Superelevation values based on AASHTO 2011 Greenbook.

WYDOT Superelevation Tables

MTN. DESIGN e(max) = 0.06 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)= 0.06 L(adj) = 1.0 12 ft Lanes		e(max) 0.06, f(max) 0.23, GRAD 0.7, V(R) 24, V(D) 25			e(max) 0.06, f(max) 0.20, GRAD 0.66, V(R) 28, V(D) 30			e(max) 0.06, f(max) 0.18, GRAD 0.62, V(R) 32, V(D) 35			e(max) 0.06, f(max) 0.16, GRAD 0.58, V(R) 36, V(D) 40		
CURVE		25 mph (40km/h)			30 mph (48km/h)			35 mph (56km/h)			40 mph (64km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	0.48	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	0.57	NC	0	0	NC	0	0	NC	0	0	NC	0	0
8000	0.72	NC	0	0	NC	0	0	NC	0	0	NC	0	0
6000	0.95	NC	0	0	NC	0	0	NC	0	0	NC	0	0
5000	1.15	NC	0	0	NC	0	0	NC	0	0	RC	41	41
4000	1.43	NC	0	0	NC	0	0	NC	0	0	RC	41	41
3500	1.64	NC	0	0	NC	0	0	RC	39	39	0.021	43	41
3000	1.91	NC	0	0	RC	36	36	RC	39	39	0.024	50	42
2500	2.29	NC	0	0	RC	36	36	0.023	45	39	0.028	58	41
2000	2.86	RC	34	34	0.022	40	36	0.027	52	39	0.033	68	41
1800	3.18	RC	34	34	0.024	44	37	0.029	56	39	0.035	72	41
1600	3.58	RC	34	34	0.026	47	36	0.032	62	39	0.038	79	42
1400	4.09	0.023	39	34	0.029	53	37	0.035	68	39	0.041	85	41
1200	4.77	0.025	43	34	0.032	58	36	0.038	74	39	0.044	91	41
1000	5.73	0.029	50	34	0.036	65	36	0.041	79	39	0.048	99	41
900	6.37	0.031	53	34	0.037	67	36	0.043	83	39	0.050	103	41
800	7.16	0.033	57	35	0.039	71	36	0.046	89	39	0.053	110	42
700	8.19	0.035	60	34	0.042	76	36	0.049	95	39	0.056	116	41
600	9.55	0.038	65	34	0.045	82	36	0.052	101	39	0.058	120	41
500	11.46	0.040	69	35	0.048	87	36	0.056	108	39	0.060	124	41
450	12.73	0.042	72	34	0.050	91	36	0.057	110	39			
400	14.32	0.044	75	34	0.053	96	36	0.059	114	39			
350	16.37	0.047	81	34	0.055	100	36	0.060	116	39			
300	19.10	0.050	86	34	0.058	105	36						
250	22.92	0.053	91	34	0.060	109	36						
200	28.65	0.057	98	34									
150	38.20	0.060	103	34									
100	57.30												
75	76.39												
50	114.59												
		R(min) = 144 ft			R(min) = 231 ft			R(min) = 340 ft			R(min) = 485 ft		

WYDOT Superelevation Tables

MTN. DESIGN e(max) = 0.06 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)= 0.06 L(adj) = 1.0 12 ft Lanes		e(max) 0.06 f(max) 0.15 GRAD 0.54 V(R) 40 V(D) 45			e(max) 0.06 f(max) 0.14 GRAD 0.5 V(R) 44 V(D) 50			e(max) 0.06 f(max) 0.13 GRAD 0.47 V(R) 48 V(D) 55			e(max) 0.06 f(max) 0.12 GRAD 0.45 V(R) 52 V(D) 60		
CURVE		45 mph (72km/h)			50 mph (80km/h)			55 mph (89km/h)			60 mph (97km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	0.48	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	0.57	NC	0	0	NC	0	0	NC	0	0	RC	53	53
8000	0.72	NC	0	0	NC	0	0	RC	51	51	RC	53	53
6000	0.95	RC	44	44	RC	48	48	0.022	56	51	0.026	69	53
5000	1.15	RC	44	44	0.022	53	48	0.026	66	51	0.030	80	53
4000	1.43	0.023	51	44	0.027	65	48	0.031	79	51	0.036	96	53
3500	1.64	0.026	58	45	0.030	72	48	0.034	87	51	0.039	104	53
3000	1.91	0.029	64	44	0.034	82	48	0.038	97	51	0.043	115	53
2500	2.29	0.033	73	44	0.038	91	48	0.043	110	51	0.048	128	53
2000	2.86	0.038	84	44	0.043	103	48	0.049	125	51	0.054	144	53
1800	3.18	0.041	91	44	0.046	110	48	0.051	130	51	0.056	149	53
1600	3.58	0.043	96	45	0.049	118	48	0.054	138	51	0.058	155	53
1400	4.09	0.046	102	44	0.052	125	48	0.057	146	51	0.060	160	53
1200	4.77	0.050	111	44	0.055	132	48	0.059	151	51			
1000	5.73	0.054	120	44	0.059	142	48						
900	6.37	0.056	124	44	0.060	144	48						
800	7.16	0.058	129	44									
700	8.19	0.060	133	44									
600	9.55												
500	11.46												
450	12.73												
400	14.32												
350	16.37												
300	19.10												
250	22.92												
200	28.65												
150	38.20												
100	57.30												
75	76.39												
50	114.59												
		R(min) = 643 ft			R(min) = 833 ft			R(min) = 1060 ft			R(min) = 1330 ft		

WYDOT Superelevation Tables

MTN. DESIGN e(max) = 0.06 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)= 0.06 L(adj) = 1.0 12 ft Lanes		e(max) 0.06	f(max) 0.11	GRAD 0.43 V(R) 55 V(D) 65	e(max) 0.06	f(max) 0.10	GRAD 0.4 V(R) 58 V(D) 70	e(max) 0.06	f(max) 0.09	GRAD 0.38 V(R) 61 V(D) 75	e(max) 0.06	f(max) 0.08	GRAD 0.35 V(R) 64 V(D) 80
CURVE		65 mph (105km/h)			70 mph (113km/h)			75 mph (121km/h)			80 mph (129km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0	RC	63	63	RC	69	69
12000	0.48	RC	56	56	RC	60	60	RC	63	63	0.021	72	69
10000	0.57	RC	56	56	0.021	63	60	0.023	73	63	0.025	86	69
8000	0.72	0.023	64	56	0.025	75	60	0.028	88	63	0.031	106	68
6000	0.95	0.029	81	56	0.032	96	60	0.036	114	63	0.040	137	69
5000	1.15	0.034	95	56	0.037	111	60	0.042	133	63	0.046	158	69
4000	1.43	0.040	112	56	0.044	132	60	0.049	155	63	0.055	189	69
3500	1.64	0.044	123	56	0.048	144	60	0.054	171	63	0.059	202	68
3000	1.91	0.048	134	56	0.053	159	60	0.058	183	63			
2500	2.29	0.053	148	56	0.058	174	60	0.060	189	63			
2000	2.86	0.058	162	56									
1800	3.18	0.060	167	56									
1600	3.58												
1400	4.09												
1200	4.77												
1000	5.73												
900	6.37												
800	7.16												
700	8.19												
600	9.55												
500	11.46												
450	12.73												
400	14.32												
350	16.37												
300	19.10												
250	22.92												
200	28.65												
150	38.20												
100	57.30												
75	76.39												
50	114.59												
		R(min) = 1660 ft			R(min) = 2040 ft			R(min) = 2500 ft			R(min) = 3050 ft		

WYDOT Superelevation Tables

URBAN DESIGN e(max) = 0.04 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)= 0.04 L(adj) = 1.0 12 ft Lanes		e(max) 0.04 f(max) 0.32 GRAD 0.78 V(R) 15 V(D) 15			e(max) 0.04 f(max) 0.27 GRAD 0.74 V(R) 20 V(D) 20		
CURVE		15 mph (24km/h)			20 mph (32km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0
12000	0.48	NC	0	0	NC	0	0
10000	0.57	NC	0	0	NC	0	0
8000	0.72	NC	0	0	NC	0	0
6000	0.95	NC	0	0	NC	0	0
5000	1.15	NC	0	0	NC	0	0
4000	1.43	NC	0	0	NC	0	0
3500	1.64	NC	0	0	NC	0	0
3000	1.91	NC	0	0	NC	0	0
2500	2.29	NC	0	0	NC	0	0
2000	2.86	NC	0	0	NC	0	0
1800	3.18	NC	0	0	NC	0	0
1600	3.58	NC	0	0	NC	0	0
1400	4.09	NC	0	0	NC	0	0
1200	4.77	NC	0	0	RC	32	32
1000	5.73	NC	0	0	RC	32	32
900	6.37	NC	0	0	RC	32	32
800	7.16	NC	0	0	0.021	34	32
700	8.19	RC	31	31	0.022	36	33
600	9.55	RC	31	31	0.023	37	32
500	11.46	RC	31	31	0.024	39	33
450	12.73	0.021	32	30	0.025	41	33
400	14.32	0.022	34	31	0.026	42	32
350	16.37	0.023	35	30	0.027	44	33
300	19.10	0.024	37	31	0.028	45	32
250	22.92	0.025	38	30	0.030	49	33
200	28.65	0.026	40	31	0.033	54	33
150	38.20	0.028	43	31	0.036	58	32
100	57.30	0.033	51	31	0.040	65	33
75	76.39	0.036	55	31			
50	114.59	0.039	60	31			
		R(min) = 42 ft			R(min) = 86 ft		

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L(adj) = 1.0

For 2 - lane roadways rotated about the centerline.

Definitions for Superelevation Tables:

R = Radius of Curve

D = Degree of Curve (100 ft arc length definition)

e = Superelevation Rate

S = Length of Superelevation Runoff & Spiral Length

Flat crown to full superelevation length.

WYDOT uses 2/3 S off curve, 1/3 S on curve.

C = Length of Crown Runoff

NC (normal crown) to flat crown length.

NC = Normal Crown (typically 0.02 ft/ft)

RC = Reverse Crown (typically 0.02 ft/ft)

L(adj) = Lane Adjustment Factor

Used to adjust the length of S and C for multilane highways.

L(adj) = 1.25 For 3 - lane roadways rotated about the centerline.

L(adj) = 1.5 For 4 - lane roadways rotated about the centerline, and divided 4 - lane roadways rotated about the median edge of traveled way.

L(adj) = 1.75 For 5 - lane roadways rotated about the centerline.

Spiral transitions should be considered when e, S, and C are shaded.

Superelevation values based on AASHTO 2011 Greenbook.

WYDOT Superelevation Tables

URBAN DESIGN e(max) = 0.04 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)= 0.04 L(adj) = 1.0 12 ft Lanes													
		e(max)	0.04		e(max)	0.04		e(max)	0.04		e(max)	0.04	
		f(max)	0.23		f(max)	0.20		f(max)	0.18		f(max)	0.16	
		GRAD	0.7		GRAD	0.66		GRAD	0.62		GRAD	0.58	
		V(R)	24		V(R)	28		V(R)	32		V(R)	36	
		V(D)	25		V(D)	30		V(D)	35		V(D)	40	
CURVE		25 mph (40km/h)			30 mph (48km/h)			35 mph (56km/h)			40 mph (64km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	0.48	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	0.57	NC	0	0	NC	0	0	NC	0	0	NC	0	0
8000	0.72	NC	0	0	NC	0	0	NC	0	0	NC	0	0
6000	0.95	NC	0	0	NC	0	0	NC	0	0	NC	0	0
5000	1.15	NC	0	0	NC	0	0	NC	0	0	NC	0	0
4000	1.43	NC	0	0	NC	0	0	NC	0	0	RC	41	41
3500	1.64	NC	0	0	NC	0	0	RC	39	39	RC	41	41
3000	1.91	NC	0	0	NC	0	0	RC	39	39	0.021	43	41
2500	2.29	NC	0	0	RC	36	36	RC	39	39	0.023	48	42
2000	2.86	NC	0	0	RC	36	36	0.023	45	39	0.026	54	42
1800	3.18	RC	34	34	0.021	38	36	0.024	46	38	0.027	56	41
1600	3.58	RC	34	34	0.022	40	36	0.025	48	38	0.028	58	41
1400	4.09	RC	34	34	0.023	42	37	0.026	50	38	0.030	62	41
1200	4.77	0.021	36	34	0.024	44	37	0.028	54	39	0.032	66	41
1000	5.73	0.023	39	34	0.026	47	36	0.030	58	39	0.034	70	41
900	6.37	0.024	41	34	0.027	49	36	0.031	60	39	0.036	74	41
800	7.16	0.024	41	34	0.028	51	36	0.033	64	39	0.037	77	42
700	8.19	0.025	43	34	0.030	55	37	0.034	66	39	0.038	79	42
600	9.55	0.027	46	34	0.032	58	36	0.036	70	39	0.040	83	42
500	11.46	0.029	50	34	0.034	62	36	0.038	74	39			
450	12.73	0.030	51	34	0.035	64	37	0.039	75	38			
400	14.32	0.031	53	34	0.037	67	36	0.040	77	39			
350	16.37	0.032	55	34	0.038	69	36						
300	19.10	0.034	58	34	0.039	71	36						
250	22.92	0.036	62	34	0.040	73	37						
200	28.65	0.039	67	34									
150	38.20												
100	57.30												
75	76.39												
50	114.59												
		R(min) = 154 ft			R(min) = 250 ft			R(min) = 371 ft			R(min) = 533 ft		

WYDOT Superelevation Tables

URBAN DESIGN e(max) = 0.04 ft/ft

Lane Adjustment Factor L(adj) = 1.0

e(max)=			e(max)	0.04		e(max)	0.04		e(max)	0.04		e(max)	0.04
0.04			f(max)	0.15		f(max)	0.14		f(max)	0.13		f(max)	0.12
L(adj) =			GRAD	0.54		GRAD	0.5		GRAD	0.47		GRAD	0.45
1.0			V(R)	40		V(R)	44		V(R)	48		V(R)	52
12 ft Lanes			V(D)	45		V(D)	50		V(D)	55		V(D)	60
CURVE		45 mph (72km/h)			50 mph (80km/h)			55 mph (89km/h)			60 mph (97km/h)		
R (ft)	D (deg)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)	e (ft/ft)	S (ft)	C (ft)
23000	0.25	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	0.29	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	0.34	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	0.41	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	0.48	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	0.57	NC	0	0	NC	0	0	NC	0	0	NC	0	0
8000	0.72	NC	0	0	NC	0	0	RC	51	51	RC	53	53
6000	0.95	NC	0	0	RC	48	48	RC	51	51	0.023	61	53
5000	1.15	RC	44	44	RC	48	48	0.023	59	51	0.025	67	54
4000	1.43	RC	44	44	0.023	55	48	0.026	66	51	0.028	75	54
3500	1.64	0.022	49	45	0.025	60	48	0.027	69	51	0.030	80	53
3000	1.91	0.024	53	44	0.027	65	48	0.030	77	51	0.033	88	53
2500	2.29	0.026	58	45	0.029	70	48	0.032	82	51	0.035	93	53
2000	2.86	0.029	64	44	0.032	77	48	0.035	89	51	0.038	101	53
1800	3.18	0.030	67	45	0.033	79	48	0.037	94	51	0.039	104	53
1600	3.58	0.032	71	44	0.035	84	48	0.038	97	51	0.040	107	54
1400	4.09	0.033	73	44	0.037	89	48	0.039	100	51			
1200	4.77	0.035	78	45	0.039	94	48	0.040	102	51			
1000	5.73	0.038	84	44	0.040	96	48						
900	6.37	0.039	87	45									
800	7.16	0.040	89	45									
700	8.19												
600	9.55												
500	11.46												
450	12.73												
400	14.32												
350	16.37												
300	19.10												
250	22.92												
200	28.65												
150	38.20												
100	57.30												
75	76.39												
50	114.59												
		R(min) = 711 ft			R(min) = 926 ft			R(min) = 1190 ft			R(min) = 1500 ft		