Chapter 1250 Cross Slope and Superelevation

1250.01 General

Use this chapter to design roadway cross slopes and superelevation. Cross slopes function to drain water away from the roadway and 2% is a commonly used slope rate. To maintain the design speed, highway and ramp curves are usually superelevated to overcome part of the centrifugal force that acts on a vehicle.

1250.02 Roadway Cross Slope

1250.02(1) Lanes

The cross slope on tangents and curves is a main element in roadway design. The cross slope or crown on tangent sections and large radius curves is complicated by the following two contradicting controls:

- Reasonably steep cross slopes aid in water runoff and minimize ponding as a result of pavement imperfections and unequal settlement.
- Steeper cross slopes are noticeable in steering, increase the tendency for vehicles to drift to the low side of the roadway, and increase the susceptibility of vehicles to slide to the side on icy or wet pavements.

A 2% cross slope is normally used for tangents and large-radius curves on high and intermediate pavement types, although cross slopes may vary from the target 2%.

The algebraic difference in cross slopes is an operational factor that can affect vehicles making a lane change across a grade-break during a passing maneuver on a two-lane two-way roadway. Its influence increases when increased traffic volumes decrease the number and size of available passing opportunities.

On ramps with metering, consider how cross slopes can impact driver comfort within the queue. Additionally, larger cross slopes may present concerns about maintaining vehicle lateral position within the queue lane, depending on weather and resulting pavement conditions.

A somewhat steeper cross slope may be needed to facilitate recommended drainage design, even though this might be less desirable from an operational point of view. In such areas, consider not exceeding design cross slopes of 2.5% with an algebraic difference of 5%.

For a two-lane two-way roadway, provide an algebraic difference to meet the appropriate conditions stated above except when drainage design recommends otherwise.

1250.02(2) Shoulders

Shoulder cross slopes are normally the same as the cross slopes for adjacent lanes. With justification, shoulder slopes may be increased to 6%. On the high side of a roadway with a plane section, such as a turning roadway in superelevation, the shoulder may slope in the opposite direction from the adjacent lane. The maximum difference in slopes between the lane and the shoulder is 8%. Locations where it may be desirable to have a shoulder slope different than the adjacent lane are:

- Where curbing is used.
- Where shoulder surface is bituminous, gravel, or crushed rock.
- Where overlays are planned and it is desirable to maintain the grade at the edge of the shoulder.
- On divided highways with depressed medians where it is desirable to drain the runoff into the median.
- On the high side of the superelevation on curves where it is desirable to drain stormwater or meltwater away from the roadway.
- At intersections where pedestrian signal accommodations are provided within the shoulder

Where extruded curb is used, see the *Standard Plans* for placement (see Chapter 1239 for information on curbs). Widening is also normally provided where traffic barrier is installed (see Chapter 1610 and the *Standard Plans*).

On ramps with metering, where the shoulder is or could be utilized for queuing, consider how the shoulder cross slope can impact driver comfort within the queue. Additionally, larger shoulder cross slopes may present concerns of maintaining vehicle lateral position within the queue lane, depending on weather and resulting pavement conditions.

The remainder of this chapter provides information to design superelevation.

1250.03 Superelevation Rate Selection

The maximum superelevation rate allowed is 10%.

Depending on design speed, construct large-radius curves with a normal crown section. The minimum radii for normal crown sections are shown in Exhibit 1250-1. Superelevate curves with smaller radii as follows:

- Exhibit 1250-4a (emax=10%) is desirable for all open highways, ramps, and long-term detours, especially when associated with a main line detour.
- Exhibit 1250-4b (emax =8%) may be used for freeways in urban design areas and areas where the emax =6% rate is allowed but emax =8% is preferred.
- Exhibit 1250-4c (emax =6%) may be used—with justification—for non-freeway highways in urban design areas, in mountainous areas, and for short-term detours, which are generally implemented and removed in one construction season.
- Exhibit 1250-5 may be used for turning roadways at intersections, urban managed access highways with a design speed of 40 mph or less, and—with justification—ramps in urban areas with a design speed of 40 mph or less.

When selecting superelevation for a curve, consider the existing curves on the corridor. To maintain route continuity and driver expectance on open highways, select the chart (see Exhibits 1250-4a, 4b, or 4c) that best matches the superelevation on the existing curves.

In locations that experience regular accumulations of snow and ice, limit superelevation from the selected chart to 6% or less. In these areas, provide justification for superelevation rates greater than 6%. Vehicles moving at slow speeds or stopped on curves with supers greater than 6% tend to slide inward on the radius (downslope).

Round the selected superelevation rate to the nearest full percent.

Exhibit 1250-1 Minimum Radius for Normal Crown Section

Design Speed (mph)	Minimum Radius for Normal Crown Section (ft)
15	945
20	1,680
25	2,430
30	3,325
35	4,360
40	5,545
45	6,860
50	8,315
55	9,920
60	11,675
65	13,130
70	14,675
75	16,325
80	18,065

1250.04 Existing Curves

Evaluate the superelevation on an existing curve to determine its adequacy. Use the equation in Exhibit 1250-2 to determine the minimum radius for a given superelevation and design speed.

Exhibit 1250-2 Minimum Radius for Existing Curves

$$R = \frac{6.68V^2}{e + f}$$

Where:

R = The minimum allowable radius of the curve (ft)
V = Design speed (mph)
e = Superelevation rate (%)

f = Side friction factor from Exhibit 1250-3

Address superelevation when the existing radius is less than the minimum radius calculated using the equation or when the maximum speed determined by a ball banking analysis is less than the design speed. When modifying the superelevation of an existing curve, provide superelevation as given in 1250.02.

Exhibit 1250-3 Side Friction Factor

Design Speed (mph)	Side Friction Factor (f)
15	32
20	27
25	23
30	20
35	18
40	16
45	15
50	14
55	13
60	12
65	11
70	10
75	9
80	8

1250.05 Turning Movements at Intersections

Curves associated with the turning movements at intersections are superelevated using Exhibit 1250-5. Use superelevation rates as high as practicable, consistent with curve length and climatic conditions. Exhibit 1250-5 shows the minimum radius for a selected superelevation and given design speed for intersections and low-speed curves. When using high superelevation rates on short curves, provide smooth transitions with merging ramps or roadways.

1250.06 Runoff for Highway Curves

Provide transitions for all superelevated highway curves as specified in Exhibits 1250-6a through 6e. Which transition to use depends on the location of the pivot point, the direction of the curve, and the roadway cross slope. The length of the runoff is based on a maximum allowable difference between the grade at the pivot point and the grade at the outer edge of traveled way for one 12-foot lane.

Pay close attention to the profile of the edge of traveled way created by the superelevation runoff; do not let it appear distorted. The combination of superelevation transition and grade may result in a hump and/or dip in the profile of the edge of traveled way. When this happens, the transition may be lengthened to eliminate the hump and/or dip. If the hump and/or dip cannot be eliminated this way, pay special attention to drainage in the low areas to prevent ponding. Locate the pivot point at the centerline of the roadway to help minimize humps and dips at the edge of the traveled lane and reduce the superelevation runoff length.

When reverse curves are necessary, provide sufficient tangent length for complete superelevation runoff for both curves—that is, from full superelevation of the first curve, to level to full superelevation of the second curve. If tangent length is longer than this, but not sufficient to provide full super transitions—that is, from full superelevation of the first curve, to normal crown to full superelevation of the second curve—increase the superelevation runoff lengths until they abut. This provides one continuous transition, without a normal crown section, similar to Designs C2 and D2 in Exhibits 1250-6c and 6d, except that full super will be attained rather than the normal pavement slope as shown.

Superelevation runoff on structures is permissible but not desirable. Whenever practicable, strive for full super or normal crown slopes on structures.

1250.07 Runoff for Ramp Curves

Superelevation runoff for ramps use the same maximum relative slopes as the specific design speeds used for highway curves. Multilane ramps have a width similar to the width for highway lanes; therefore, Exhibits 1250-6a through 6e are used to determine the superelevation runoff for ramps. Superelevation transition lengths (L_T) for single-lane ramps are given in Exhibits 1250-7a and 7b. Additional runoff length for turning roadway widening is not required.

1250.08 Documentation

Refer to Chapter 300 for design documentation requirements.

1250.09 References

1250.09(1) Design Guidance

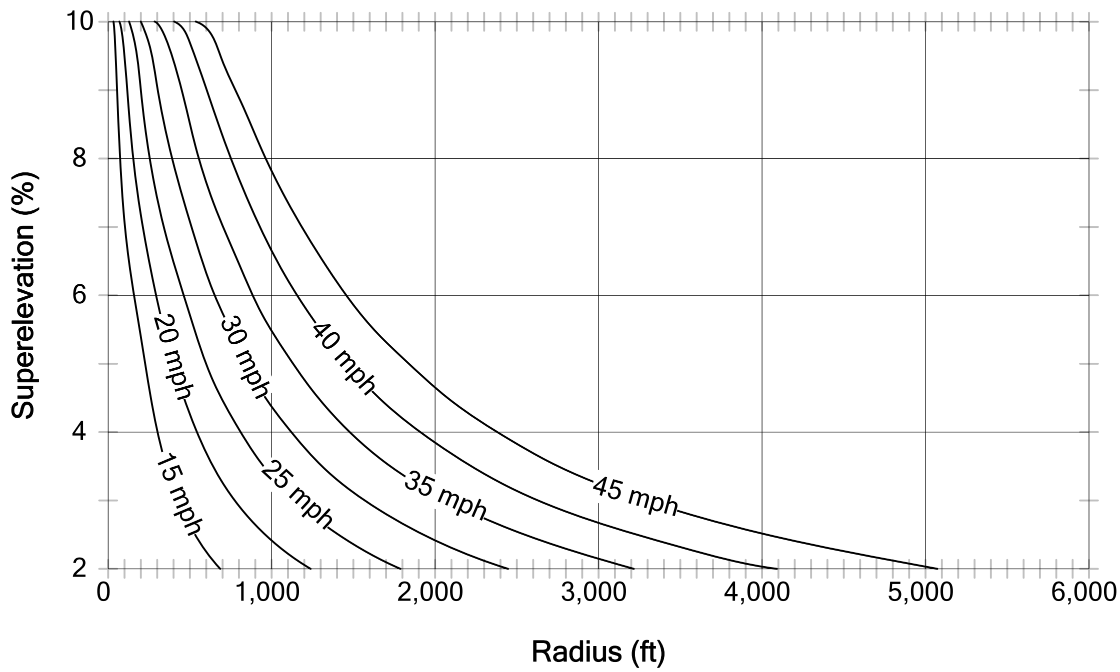
Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, WSDOT

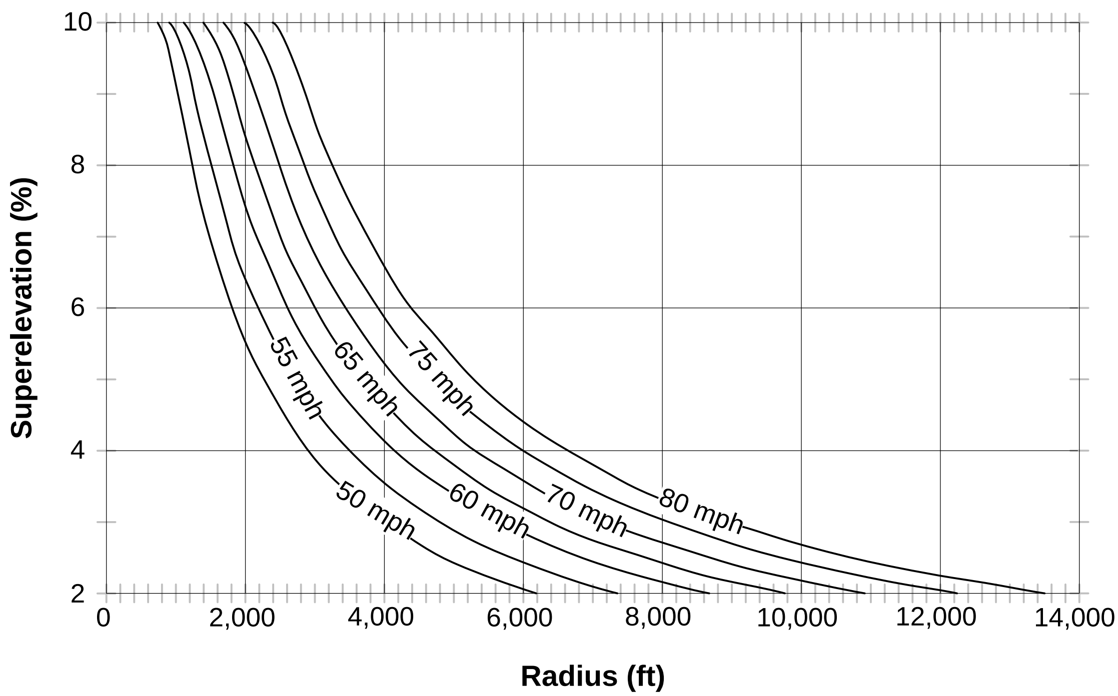
Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications), M 41-10, WSDOT

1250.09(2) Supporting Information

A Policy on Geometric Design of Highways and Streets (Green Book), AASHTO, current edition

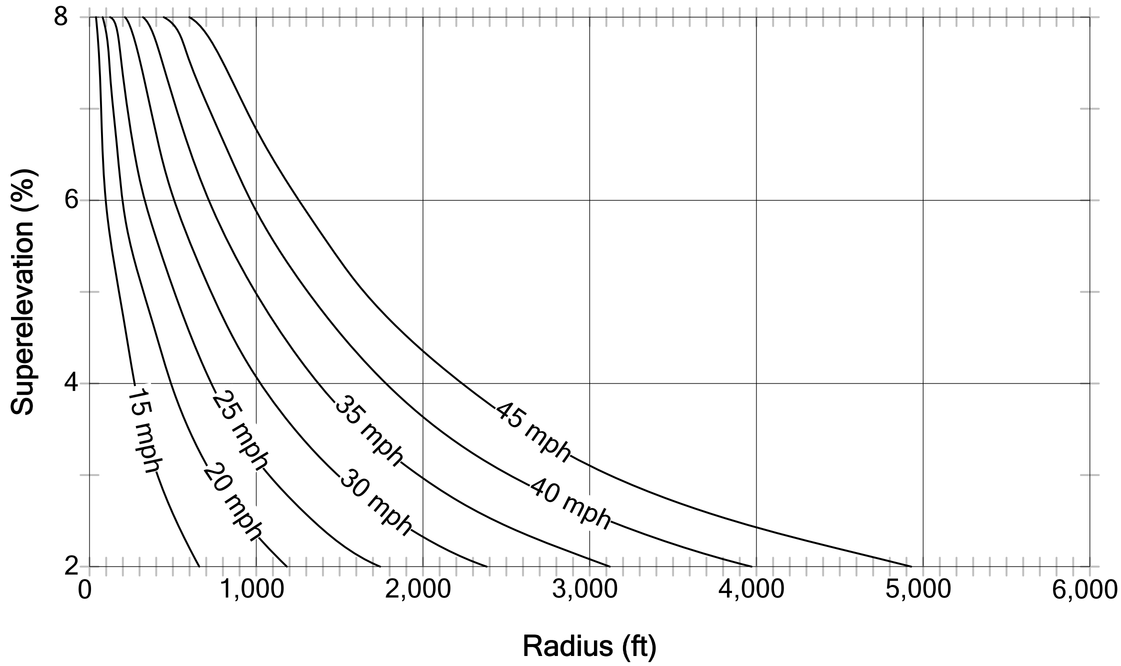
Exhibit 1250-4a Superelevation Rates (10% Max)

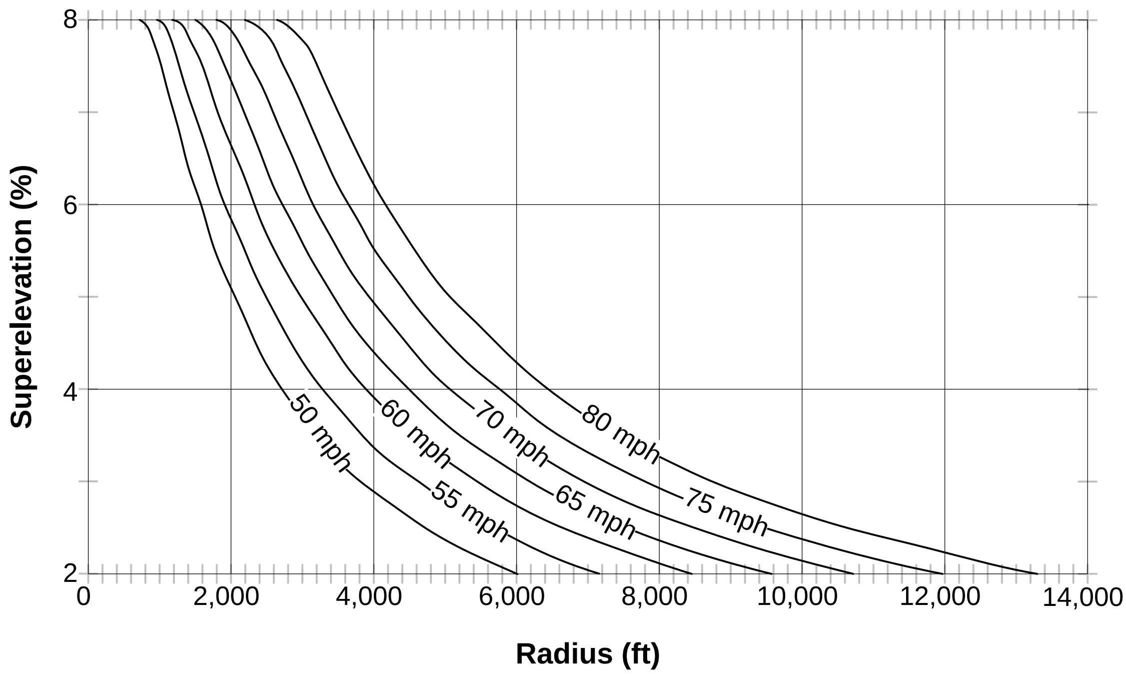




Design Speed (mph)	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Minimum Radius (ft)	40	75	130	205	295	415	545	700	880	1,095	1,345	1,640	1,980	2,380

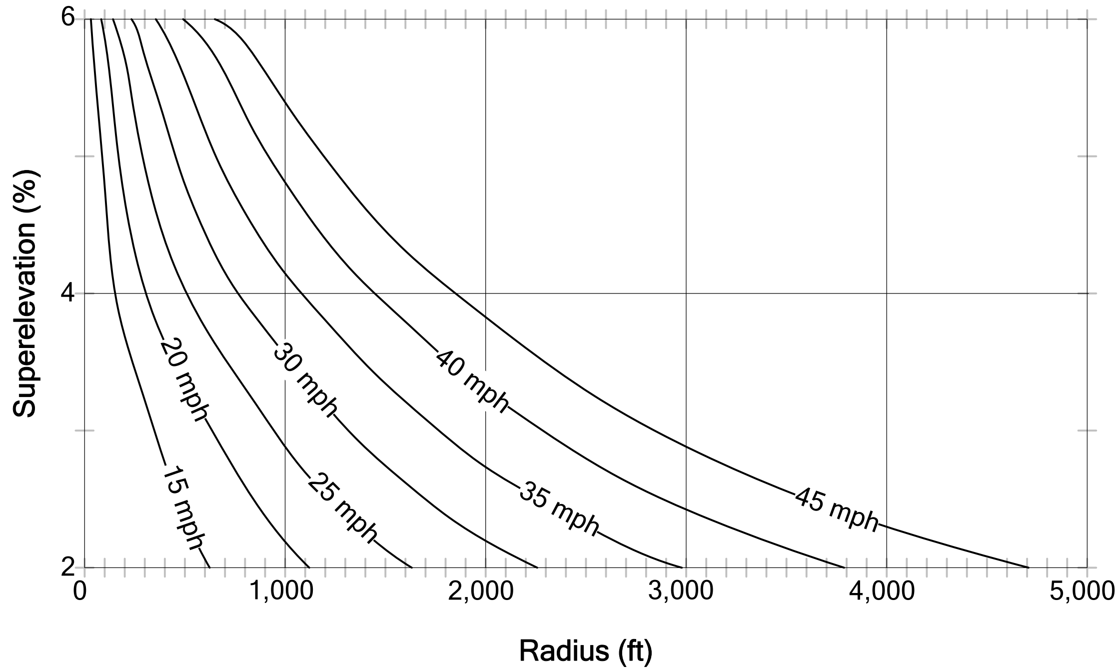
Exhibit 1250-4b Superelevation Rates (8% Max)

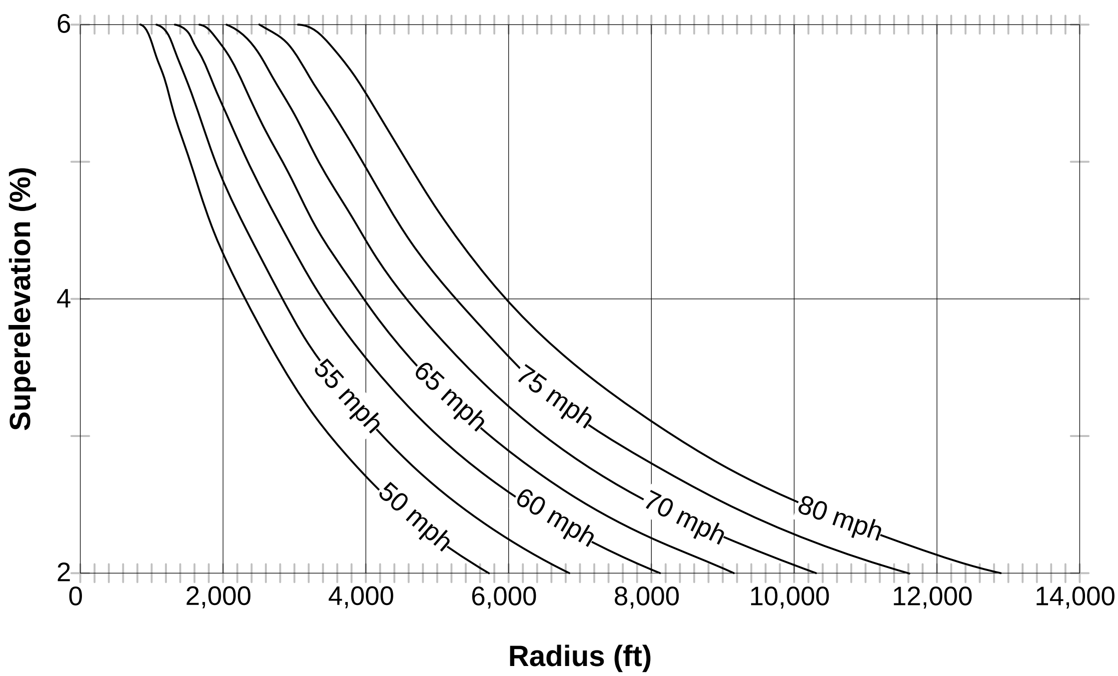




Design Speed (mph)	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Minimum Radius (ft)	40	80	135	215	315	450	590	760	965	1,205	1,490	1,820	2,215	2,675

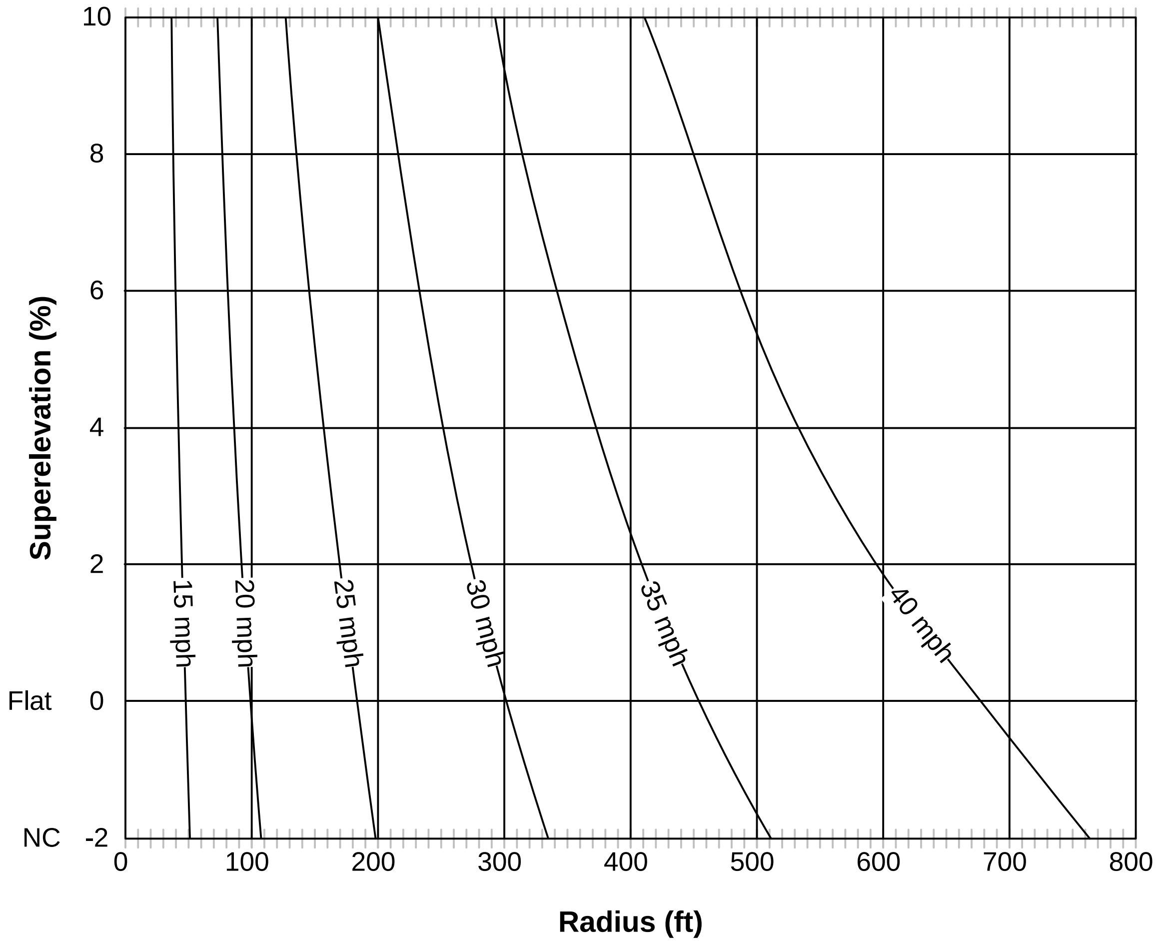
Exhibit 1250-4c Superelevation Rates (6% Max)





Design Speed (mph)	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Minimum Radius (ft)	40	85	145	235	345	490	645	840	1,065	1,340	1,665	2,050	2,510	3,055

Exhibit 1250-5 Superelevation Rates for Intersections and Urban Roadways 40 mph and slower



NC = Normal crown

Exhibit 1250-6a Superelevation Transitions for Highway Curves

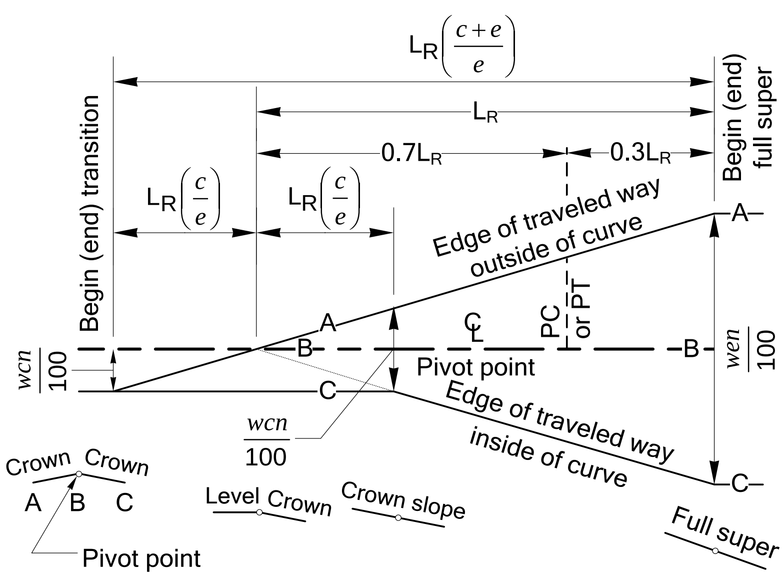
e (%)	L_B=Basic Runoff in Feet for Design Speed*													
	15 mph	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph	60 mph	65 mph	70 mph	75 mph	80 mph
2	30	30	35	35	40	40	45	50	50	55	55	60	65	70
3	45	50	50	55	60	60	65	70	75	80	85	90	95	105
4	60	65	70	75	75	85	90	95	100	105	110	120	125	135
5	75	80	85	90	95	105	110	120	130	135	140	150	160	170
6	90	95	105	110	115	125	135	145	155	160	170	180	190	205
7	110	115	120	130	135	145	155	170	180	185	195	210	220	240
8	125	130	135	145	155	165	180	190	205	215	225	240	250	275
9	140	145	155	165	175	185	200	215	230	240	250	270	285	310
10	155	160	170	180	195	205	220	240	255	265	280	300	315	345

*Based on one 12-ft lane between the pivot point and the edge of traveled way. When the distance exceeds 12 ft, use the following equation to obtain L_R:

$$L_R = L_B(1+0.04167X)$$

Where:

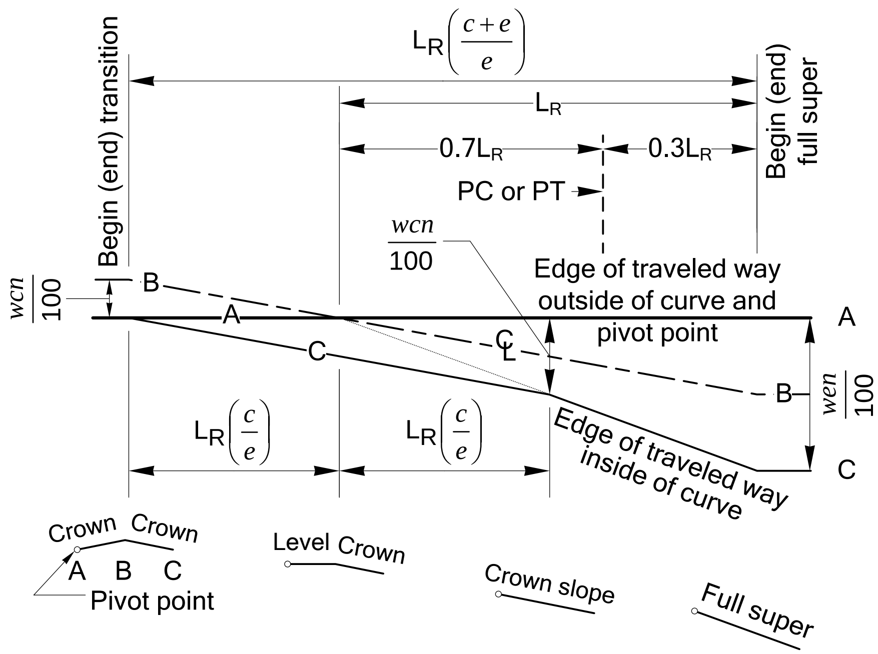
X = The distance in excess of 12 ft between the pivot point and the farthest edge of traveled way, in ft.



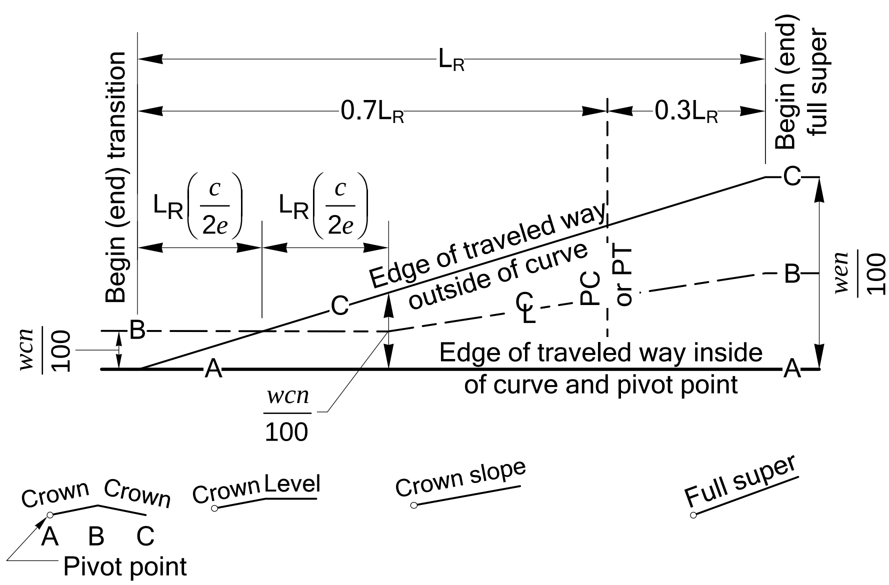
Design A – Pivot Point on Centerline Crown Section

c = Normal crown (%)
e = Superelevation rate (%)
n = Number of lanes between points
w = Width of lane

Exhibit 1250-6b Superelevation Transitions for Highway Curves



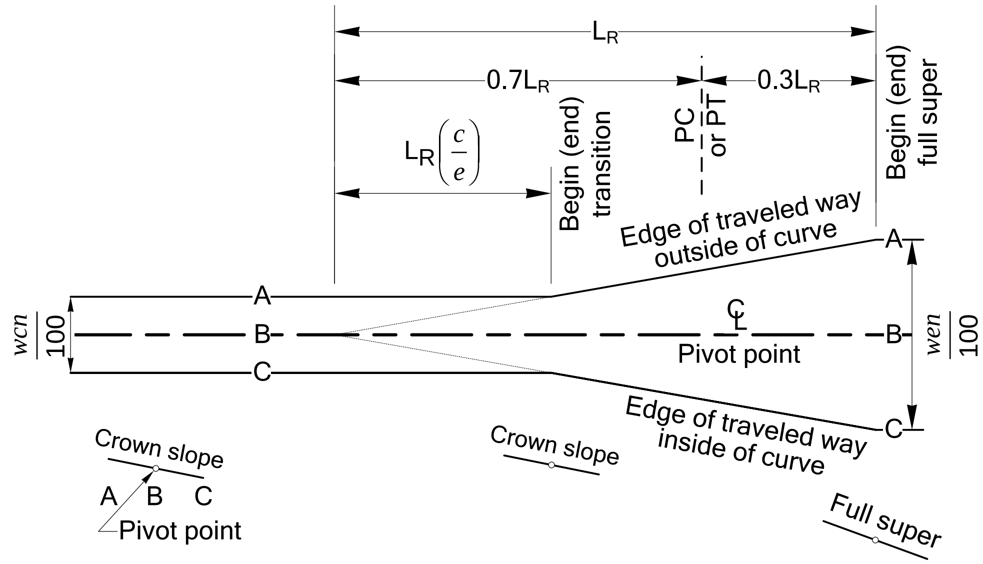
Design B[1] – Pivot Point on Edge of Traveled Way: Outside of Curve Crowned Section



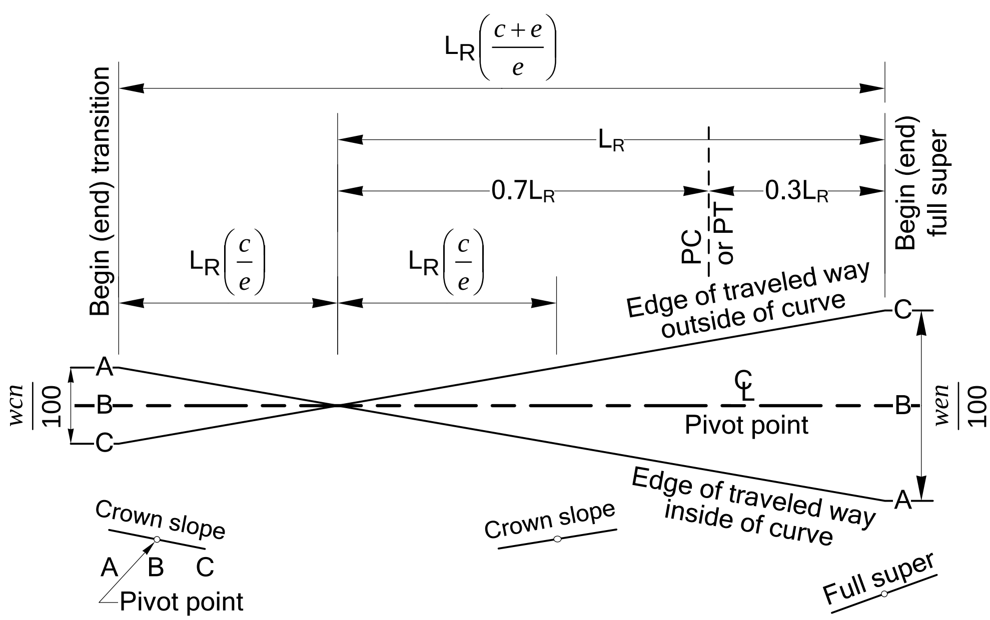
Design B[2] – Pivot Point on Edge of Traveled Way: Inside of Curve Crowned Section

c = Normal crown (%)
e = Superelevation rate (%)
n = Number of lanes between points
w = Width of lane

Exhibit 1250-6c Superelevation Transitions for Highway Curves



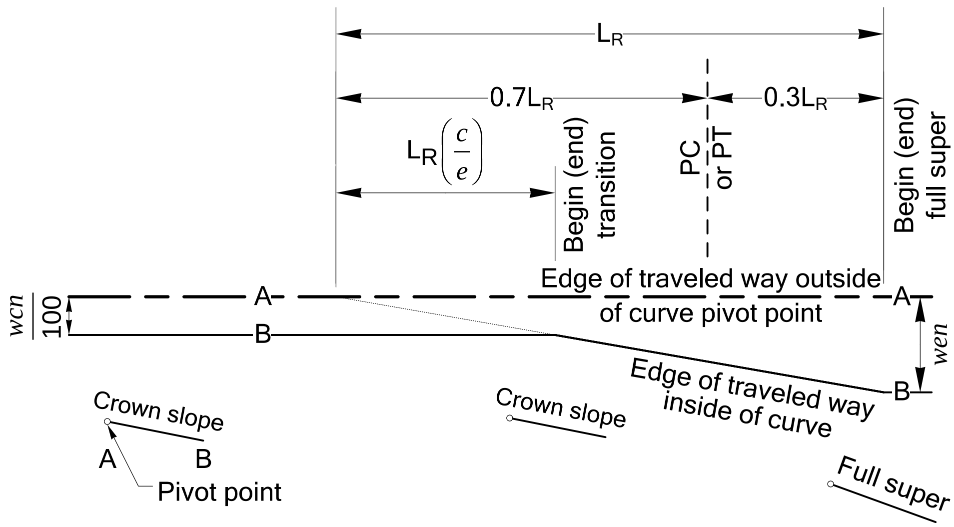
Design C[1] – Pivot Point on Centerline Curve in Direction of Normal Pavement Slope: Plane Section



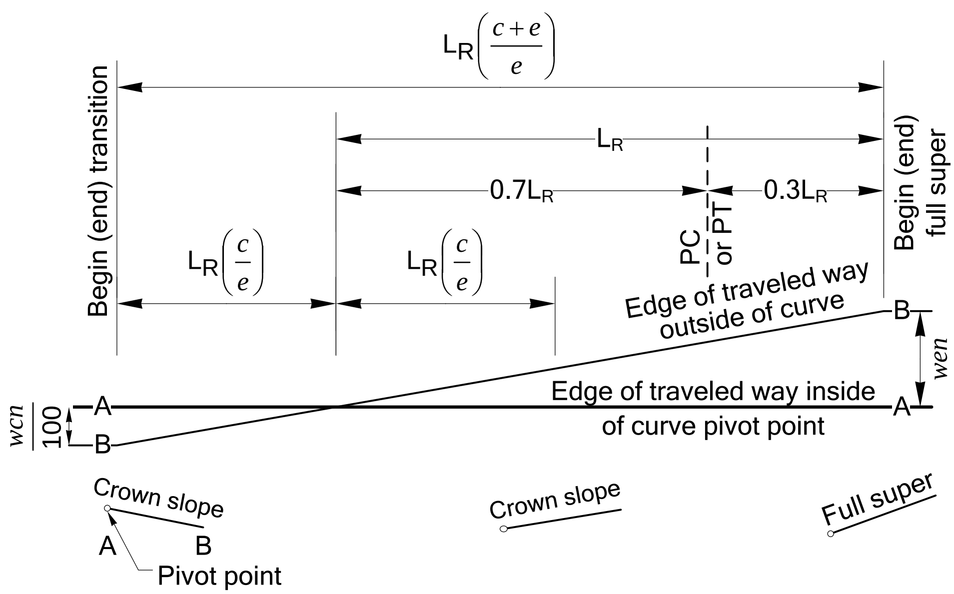
Design C[2] – Pivot Point on Centerline Curve Opposite to Normal Pavement Slope: Plane Section

c = Normal crown (%)
e = Superelevation rate (%)
n = Number of lanes between points
w = Width of lane

Exhibit 1250-6d Superelevation Transitions for Highway Curves



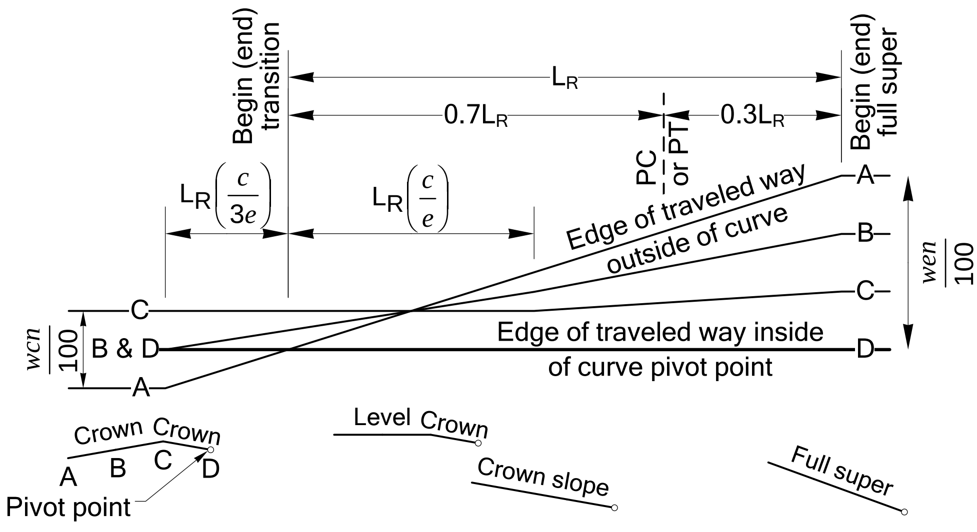
Design D[1] – Pivot Point on Edge of Traveled Way Curve in Direction of Normal Pavement Slope: Plane Section



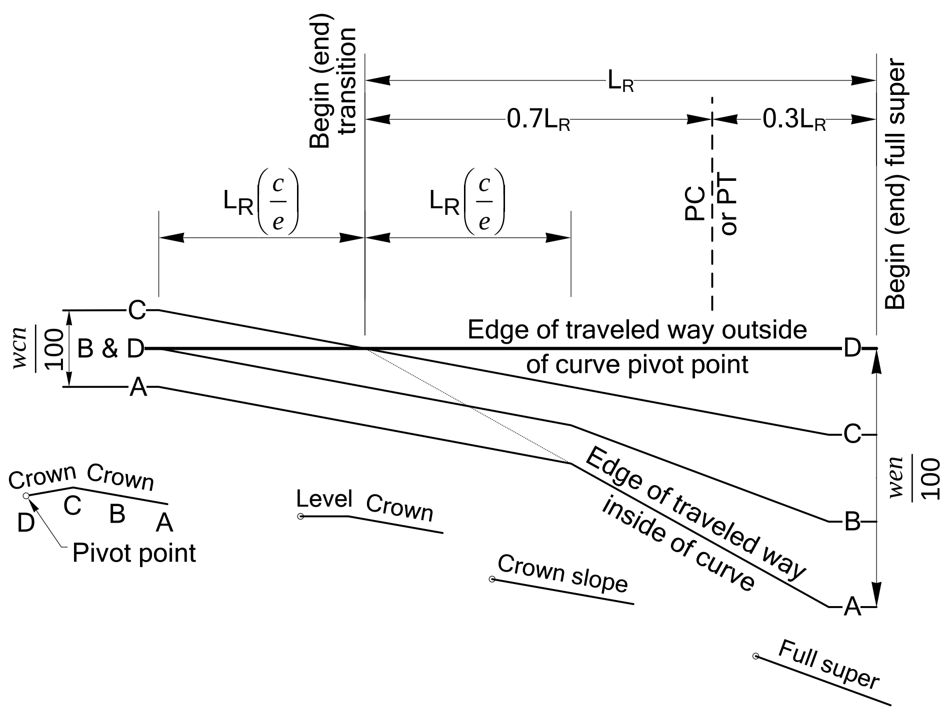
Design D[2] – Pivot Point on Edge of Traveled Way Curve Opposite to Normal Pavement Slope: Plane Section

c = Normal crown (%)
e = Superelevation rate (%)
n = Number of lanes between points
w = Width of lane

Exhibit 1250-6e Superelevation Transitions for Highway Curves



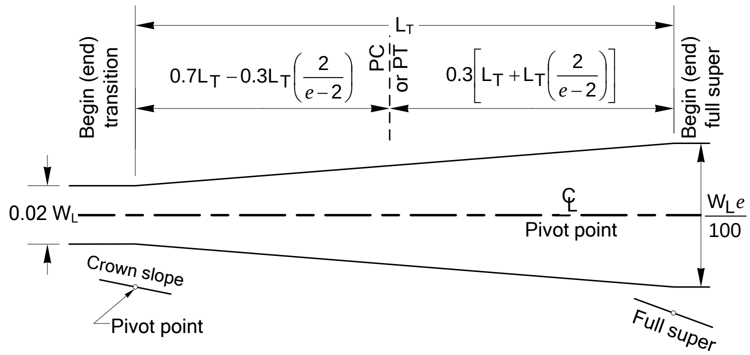
Design E[1] – Six-Lane With Median, Pivot Point on Edge of Traveled Way: Inside of Curve Crown Section



Design E[2] – Six-Lane With Median, Pivot Point on Edge of Traveled Way: Outside of Curve Crown Section

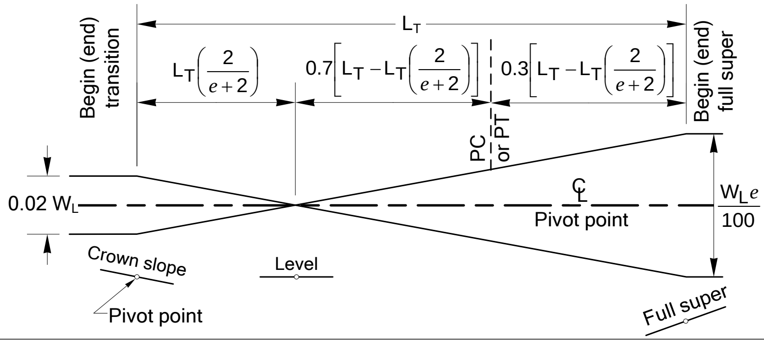
c = Normal crown (%)
e = Superelevation rate (%)
n = Number of lanes between points
w = Width of lane

Exhibit 1250-7a Superelevation Transitions for Ramp Curves



e (%)	Length of Transition in Feet for Design Speed							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
3	10	15	15	15	15	15	15	15
4	20	25	25	25	25	30	30	35
5	30	35	35	35	40	45	45	50
6	40	45	45	50	55	55	60	65
7	50	55	55	60	65	70	75	80
8	60	65	70	75	80	85	90	95
9	70	75	80	85	95	100	105	110
10	80	85	90	100	105	115	120	130

Table 1 Pivot Point on Centerline: Curve in Direction of Normal Pavement Slope

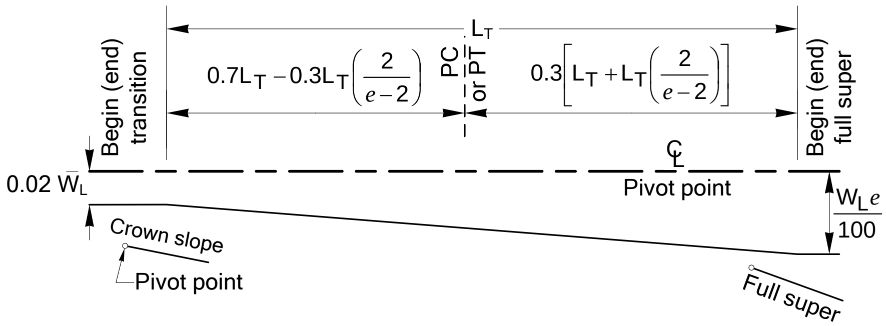


e (%)	Length of Transition in Feet for Design Speed							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
2	40	40	45	50	55	55	60	65
3	50	55	55	60	65	70	75	80
4	60	65	70	75	80	85	90	95
5	70	75	80	85	90	100	105	110
6	80	85	90	95	105	115	120	130
7	90	95	100	110	120	125	135	145
8	100	105	115	120	130	140	150	160
9	110	120	125	135	145	155	165	175
10	120	130	135	145	160	170	180	190

Table 2 Pivot Point on Centerline: Curve in Direction Opposite to Normal Pavement Slope

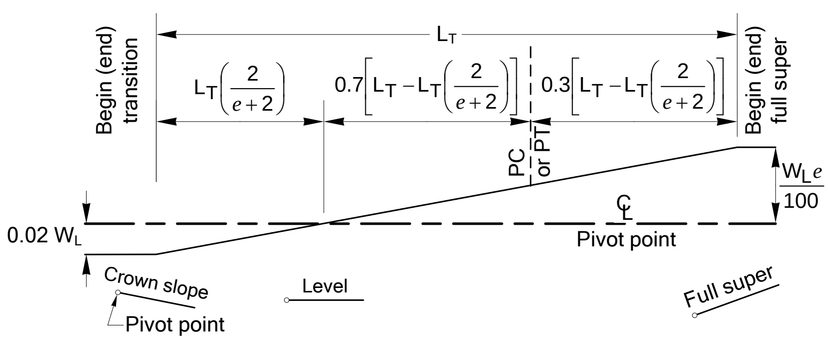
W_L = Width of ramp lane

Exhibit 1250-7b Superelevation Transitions for Ramp Curves



e (%)	Length of Transition in Feet for Design Speed							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
3	20	25	25	25	25	30	30	35
4	40	45	45	50	55	55	60	65
5	60	65	70	75	80	85	90	95
6	80	85	90	100	105	115	120	130
7	100	105	115	120	130	140	150	160
8	120	130	135	145	160	170	180	190
9	140	150	160	170	185	195	210	225
10	160	170	180	195	210	225	240	255

Table 3 Pivot Point on Edge of Traveled Way: Curve in Direction of Normal Pavement Slope



e (%)	Length of Transition in Feet for Design Speed							
	20 mph	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph
	L_T	L_T	L_T	L_T	L_T	L_T	L_T	L_T
2	80	85	90	100	105	115	120	130
3	100	105	115	120	130	140	150	160
4	120	130	135	145	160	170	180	190
5	140	150	160	170	185	195	210	225
6	160	170	180	195	210	225	240	255
7	180	190	205	220	235	255	270	290
8	200	210	225	245	265	280	300	320
9	220	235	250	265	290	310	330	350
10	240	255	270	290	315	340	360	385

Table 4 Pivot Point on Edge of Traveled Way: Curve in Direction Opposite to Normal Pavement Slope

W_L = Width of ramp lane