Chapter

3

ELEMENTS OF DESIGN

3.1 INTRODUCTION

This chapter provides general design element information that applies to almost every project. Standards are presented for horizontal and vertical alignment, superelevation & sight distance. The practical application of these standards will depend on the purpose, need and unique constraints of the project. Later chapters on design standards are broken down into specific design areas such as rural design, urban design, freeway design, and intersection design.

3.2 SIGHT DISTANCE

3.2.1 GENERAL

Sight distance is unobstructed distance of roadway ahead visible to the driver. There are multiple types of sight distance that include stopping sight distance, passing sight distance, decision sight distance and intersection sight distance. It is critical that sight distance issues be properly developed and applied to projects. Required stopping sight distance is shown in Table 3-1. Figure 3-1 indicates how sight distances are measured.

Check Horizontal sight distance when designing slopes and retaining walls or where median barriers raised medians, center piers, structure screening or screen plantings are used. Combinations of slight horizontal curvature with crest vertical curves may seriously diminish sight distance where high curb or planting is used. Set slopes, walls and other side obstructions back from the pavement edge to provide at least minimum stopping sight distance for a driver in the traffic lane nearest the obstruction. Take into consideration the possibility of future conversion of shoulders or parking areas to driving lanes.

For intersections at grade, a vehicle entering the highway from a side street or access must be able to clearly see a vehicle throughout the sight triangle based on minimum stopping sight distance and preferably intersection sight distance for the design speed. It is desirable to provide sufficient sight distance so that the entering vehicle may cross or make a turn without significant slowing of the through traffic. On high speed, high volume roadway intersections, providing intersection sight distance, rather than the minimum stopping sight distance, will minimize operational and safety problems. Horizontal sight distance, as measured 2 feet above the centerline of the inside lane at the point of obstruction, must at least equal the stopping sight distance. This assumes there is little or no vertical curvature. When the normal cut bank reduces the horizontal sight distance below the stopping sight distance for the design speed, the cut bank is flattened or benched.

Vertical curves designed to the minimum stopping sight distance may need to be flattened to obtain intersection sight distance, passing sight distance, etc. All forms of sight distance must be checked and provided for as appropriate.

3.2.2 STOPPING SIGHT DISTANCE

Stopping sight distance is the minimum distance required for a vehicle traveling at a particular design speed to come to a complete stop after an obstacle on the road becomes visible. Stopping sight distance is normally sufficient to allow an alert and prudent driver to come to a hurried stop under normal circumstances. Stopping sight distance is measured from the driver's eye

(assumed to be 3.5 feet above the roadway surface) to an object 2 ft above the roadway surface. Stopping sight distance is the summation of two distances: the distance traveled by a vehicle from the time the driver sees an object that requires a stop to the instant the brakes are applied, and the distance required to stop the vehicle from the time the brakes are applied. These two distances are called brake reaction distance and braking distance. Table 3-1 contains the stopping sight distance standards.

Stopping sight distance must, at a minimum, be obtained on all vertical and horizontal alignments. Figure 3-8 and Figure 3-9 show the minimum stopping sight distance requirements for crest and sag vertical curves (See Table 9-4 for sight distance on ramps). Figure 3-2 indicates the minimum stopping sight distance for horizontal curves. Care must be taken to ensure that these minimum distances are obtained in project design. Roadside elements such as cut slopes, guardrail, tunnels, retaining walls, bridgerail, and barriers can obstruct the view of the driver and must be properly located to ensure that proper stopping sight distance is achieved. As noted previously, other types of sight distance may control in a design. For example, it would be desireable to flatten a crest vertical curve in order to provide full intersection sight distance from a side street.

Highway grades can have a significant affect on stopping sight distances. Refer to Figure 3-1 or Figure 3-2 on page 3-17 of the AASHTO's *"A Policy on Geometric Design of Highways and Streets - 2011"*, for more information about the effects of grades on stopping sight distances.

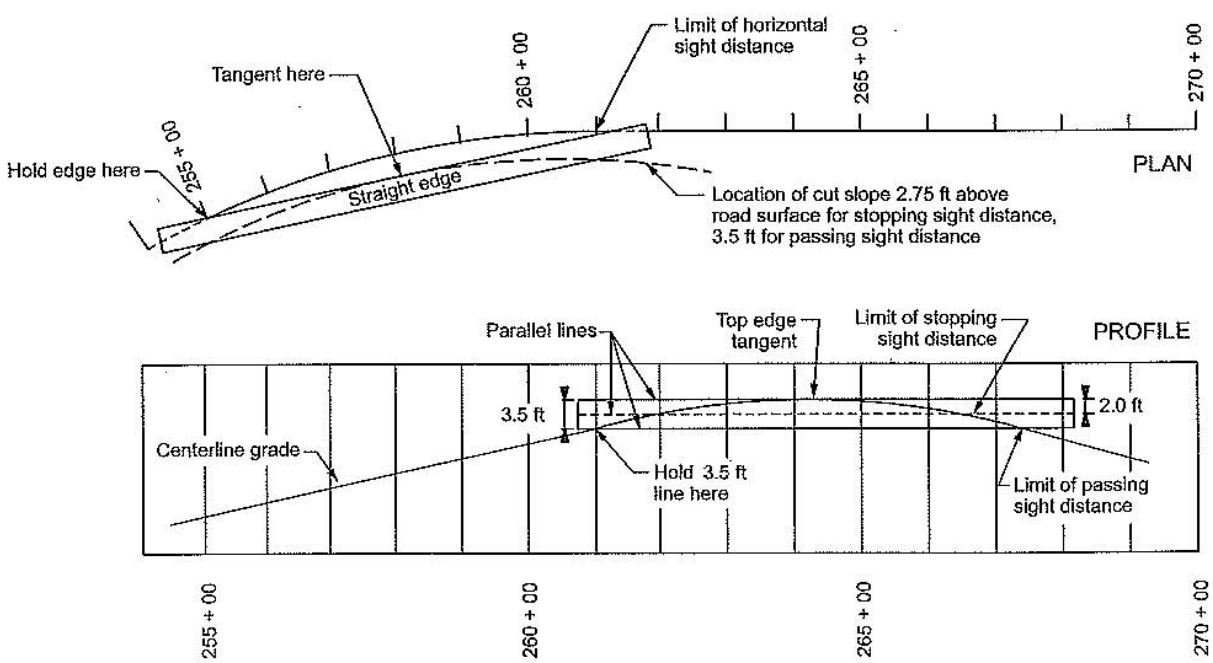


Figure 3-1: Determining Stopping Sight Distance

Table 3-1: Stopping Sight Distance

Design Speed	Stopping Sight Distance
25 mph	155 ft.
30 mph	200 ft.
35 mph	250 ft.
40 mph	305 ft.
45 mph	360 ft.
50 mph	425 ft.
55 mph	495 ft.
60 mph	570 ft.
65 mph	645 ft.
70 mph	730 ft.

Source: 2011 AASHTO

3.2.3 DECISION SIGHT DISTANCE

Many times the elements of the roadway become complex and require additional distances for drivers to make the proper maneuver. Stopping sight distance may not be adequate when drivers must process complex roadway information in an instance or when the roadway information is difficult to decipher or unexpected. Endeavor to provide decision sight distance at locations where multiple information processing, decision making, and corrective actions are needed. Sample locations where decision sight distance is needed include unusual intersection or interchange configuration and lane drops. If site characteristics allow, locate these highway features where decision sight distance can be provided. If this is not practicable, use suitable traffic control devices and positive guidance to give advanced warning of the conditions. Work with the Region Traffic Engineer on the need for decision sight distance at certain locations - also if there is need for additional signing, illumination, etc. Decision sight distance is calculated using the 3.5 foot eye height and the 2 ft object height that is also used for stopping sight distance. Pages 3-6 thru 3-8 of the AASHTO's *"A Policy on Geometric Design of Highways and Streets - 2011"* provide more information on decision sight distance.

3.2.4 INTERSECTION SIGHT DISTANCE

Obtaining intersection sight distance is important in the design of intersections. Intersection sight distance is considered adequate when drivers at or approaching an intersection have an unobstructed view of the entire intersection and of sufficient lengths of the intersecting

highways to permit the drivers to anticipate and avoid potential collisions. Sight distance must be unobstructed along both approaches at an intersection and across the corners to allow the vehicles simultaneously approaching, to see each other and react in time to prevent a collision. Intersection sight distance is determined by using a 3.5 foot eye height and a 3.5 foot height of object.

It is desirable to provide intersection sight distance at every road approach, whether it is a signalized intersection or private driveway. In no case is the sight distance to be lower than stopping sight distance. On high speed, high volume roadway intersections, providing intersection sight distance, rather than the minimum stopping sight distance, will minimize operational and safety problems.

When reviewing intersection sight distance, items such as building clearances, street appurtenances, potential sound walls, landscaping, on-street parking and other roadway elements must be taken into consideration in determining and obtaining the appropriate sight distance at intersections. Railroad and rail crossings are treated in the same manner as roadway intersections in determining intersection sight distance for the vehicle crossing the tracks. For placement of trees within the intersection sight distance triangle, see Sections 4.2 and 4.3.

Pages 9-28 thru 9-49 of the AASHTO's *"A Policy on Geometric Design of Highways and Streets - 2011"* indicate intersection sight distance for traffic turning left, crossing, or turning right onto a major highway. While it is desirable to obtain intersection sight distance at all intersections, in no case is the sight distance to be less than stopping sight distance.

3.2.5 PASSING SIGHT DISTANCE

Passing sight distance is the minimum distance required for a vehicle to safely and comfortably pass another vehicle. An assumption made for passing sight distance includes the passing vehicle accelerating to a speed of 10 mph above the vehicle being passed and the oncoming vehicle not reducing speed. A 3.5 foot height of eye of the passing vehicle and 3.5 foot height of object are used for measuring passing sight distance. If adequate passing sight distance opportunities cannot be accommodated in the project design, passing lanes or climbing lanes are desirable. Work with the Region Traffic Engineer on locations for passing opportunities, or passing or climbing lanes. Pages 3-8 thru 3-13 of the AASHTO's *"A Policy on Geometric Design of Highways and Streets - 2011"* provide more information on passing sight distance.

3.3 HORIZONTAL & VERTICAL ALIGNMENT

3.3.1 HORIZONTAL ALIGNMENT

3.3.1.1 GENERAL

The horizontal alignment of a highway affects vehicle operating speeds, sight distances, passing opportunities and highway capacities. Decisions on alignment also have a major impact on the cost of a project. To provide a consistent alignment, avoid sudden changes from tangents and gentle curves to sharp curves.

Check the combination of horizontal alignment and sight obstructions. Analyze horizontal curves through cut areas, through tunnels, and at intersections with minimum building set-backs to determine that stopping and intersection sight distances are met. Figure 3-2 provides design speed, stopping sight distance, and line of sight requirements for horizontal curves.

3.3.1.2 HORIZONTAL CURVES

Curve calculations are based on the arc definition for a circular curve. Minimum degree of curvature can be found in Tables 5-2, 6-1, 6-2, 6-3, 6-4, 6-5, and 7-2. Sufficient curve length must be used in open country to prevent the appearance of a "kink" in the line. For small deflection angles, a minimum arc length of 15 times the design speed is required. For larger deflection angles where spiral transitions are required, the minimum arc length of the simple curve is 50 ft. An angle point is considered a curve with an arc length of zero, and therefore, does not meet the minimum standard.

Compound curves are adjoining curves in the same direction with differing degrees of curvature. They may be used where necessary with an intermediate spiral segment. Design the spiral segment to provide an "a" value equal to or less than the standard spiral for the sharper curve see Appendix J. The “a” value is a measure of the rate of change of the curvature. (Change in Degree of curve x 100 / length of spiral).

Broken back curves are curves in the same direction connected with a short segment of tangent. It is desirable to avoid the use of broken back curves. When the use of a broken back alignment cannot be avoided, design the tangent section so that all travel lanes slope in the same direction as the superelevation of the curves. This avoids the introduction of two flat spots on the travel lane toward the outside of the curves and prevents the development of a dip on the edge of the pavement that can affect driver comfort and drainage (See Figure 3-4). Generally this treatment is required when the length of the tangent is 500 feet or less.

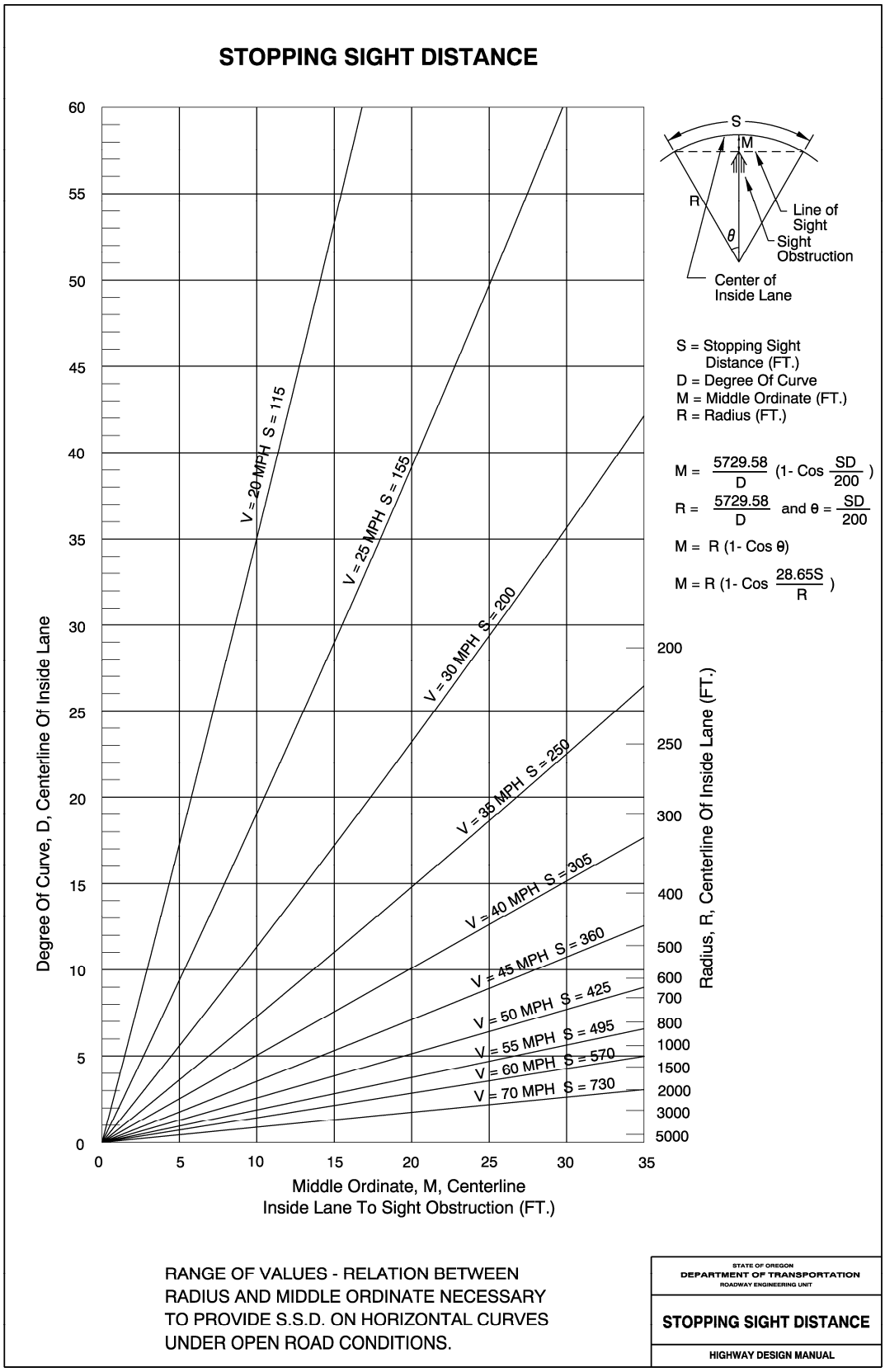


Figure 3-2: SSD on Horizontal Curves

A. SPIRALS

Spirals provide a transition between tangents and curves and between circular curves of substantially different degrees of curve (spiral segment). The natural path of a vehicle entering a curve is to drive a spiral. Spirals also provide a location for developing superelevation. Apply spirals to all curves of 1° or sharper. This applies to secondary as well as to primary highways. Curves with a degree of curve flatter than 1° are not required to be spiraled. It is recommended that spirals be used for curves with a degree of curve flatter than 1° to assist in developing the superelevation runoff. When designing an unspiraled curve, refer to Figure 3-4. Longer spirals than the standard may be used wherever advantage in their use is apparent. Many existing alignments on the highway system include longer than standard spirals and operate very well. Consider using longer spirals appropriate for a section with additional lanes when future widening is anticipated. The standard spiral lengths for typical design speeds in open road, urban, and suburban settings are presented in Table 3-2, Table 3-3 and Table 3-4. The minimum spiral length for any curve not covered by these tables can be calculated using the three formulas also presented on Table 3-2, Table 3-3 and Table 3-4. Note that the spiral lengths presented in the tables are based on the formulas and then adjusted to provide a consistent progression in the "a" value. The "a" value is a measure of the rate of change of the curvature. (Change in Degree of curve x 100 / length of spiral). This results in a consistent feel for the driver. Spiral lengths are normally rounded up to the nearest 5 ft.

The minimum length of the simple curve between spirals is 50 feet. At times it may be appropriate to install a spiral segment to transition from one central curve to another central curve. These are called compound curves. The spiral segment assists in providing a smooth transition between two curves in close proximity to each other. Back to back spirals between reversing curves are permissible.

The type and locations of the facility (urban or rural in nature) will dictate the proper combination of curve, spiral, and superelevation rate. See Appendix J for additional details on the design of spiral transitions.

On some low speed non-superelevated roadways, the use of spirals may not be warranted. Designing such roadways without spirals requires a design exception.

B. SUPERELEVATIONS

The standard method of developing superelevation runoff is shown in Figure 3-4 and Figure 3-7. The standard method of superelevation development for ODOT is rotation around the profile grade. The profile grade is normally carried along the centerline or the low side edge of travel. Other options as shown in Figure 3-6 are also available. Where the grade is 4% or greater, the superelevation is developed according to Section 3.3.4. When the super is rotated about centerline, ensure the design doesn't create a low spot on the inside of the curve where ponding can occur. For flat curves with a degree of curve less than 0° 30′ superelevation is typically not required. In the design of runoff, the use of multiple line profiles is suggested. Multiple line

profiles are especially useful in situations where grade controls at road approaches, building elevations or interchange designs are encountered.

When a horizontal curve has less than 200 feet of main circular curve, the superelevation along the main curve is determined by joining the runoffs in the center of the curve and using a continuous vertical curve of a length equal to twice the length of the main curve, with a minimum vertical curve length of 200 feet.

On multi-lane divided highways, each direction may have an independent alignment. In these situations, the superelevation for one direction may be developed independent of the other to minimize run-out lengths. Each direction follows the superelevation rules contained in this section for the number of lanes on each alignment.

When the tangent distance between reversing curves is less than 400 feet, adjust the runoff of the superelevation so that the edges of pavement and the centerline fall on a uniform grade between the Point of Curve to Spiral (PCS) of the first curve and the Point of Spiral to Curve (PSC) of the second curve. (See Figure 3-4).

Standard superelevation applies on climbing lanes, when climatic conditions warrant it, a design exception for reduced superelevation may be granted for a climbing lane on the high side of a curve.

Use Table 3-2 to determine proper superelevation and spiral lengths for freeways and rural highways. For design speed other than shown, determine the superelevation by interpolation and calculate the spiral length. This table is also used for constrained rural mountainous locations.

Table 3-2 also applies to rural areas where snow and ice conditions prevail. Elevations over 3000 feet can be considered where snow and ice prevail. Other locations, such as the Columbia River Gorge may be considered for discussion as a snow and ice area. In these areas, avoid using a degree of curve that would normally be designed with a superelevation greater than 8%.. For example, if the design speed is 70 mph, the maximum degree of curve where snow and ice prevail would be 3°. If a sharper curvature must be used, the superelevation may be held at 8% with the understanding that the curve would have a "comfort speed" lower than the design speed and may need to be posted with a speed rider. In this situation, the comfort speed table (Table 3-5) can be used to determine the comfort speed of any curve at 8% superelevation. Limiting the superelevation to 8% on roadways where snow and ice prevail requires a design exception. It is generally not appropriate to limit the superelevation to anything less than 8% on a rural highway as that may compromise safety and operations during warmer times of the year.

Use Table 3-3 for urban locations where design speeds range from 25-40 mph and the maximum superelevation rate is 4%. Use Table 3-4 for transition areas between urban/suburban and rural areas and design speeds range from 45-55 mph, with a maximum superelevation rate of 6%.

Table 3-2: Open Road Superelevation & Spiral Lengths

		70 mph									60 MPH									50 MPH									
D	R	e	L1	L2	L3	L4	L5	L6	L7	L8	e	L1	L2	L3	L4	L5	L6	L7	L8	e	L1	L2	L3	L4	L5	L6	L7	L8	D
0°30'	11459.16	2.0	-	-	-	-	-	-	-	-	NC	-	-	-	-	-	-	-	-	NC	-	-	-	-	-	-	-	-	0°30'
0°35'	9822.13	2.0	-	-	-	-	-	-	-	-	2.0	-	-	-	-	-	-	-	-	NC	-	-	-	-	-	-	-	-	0°35'
0°40'	8594.37	2.5	-	-	-	-	-	-	-	-	2.0	-	-	-	-	-	-	-	-	NC	-	-	-	-	-	-	-	-	0°40'
0°45'	7639.44	3.0	-	-	-	-	-	-	-	-	2.0	-	-	-	-	-	-	-	-	NC	-	-	-	-	-	-	-	-	0°45'
0°50'	6875.49	3.0	-	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-	-	-	2.0	-	-	-	-	-	-	-	-	0°50'
0°55'	6250.45	3.5	-	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-	-	-	2.0	-	-	-	-	-	-	-	-	0°55'
1°00'	5729.58	3.5	205	310	410	515	615	720	820	925	3.0	175	265	350	440	525	615	700	790	2.0	145	220	290	365	435	510	580	655	1°00'
1°05'	5288.84	4.0	205	310	410	515	615	720	820	925	3.0	175	265	350	440	525	615	700	790	2.5	145	220	290	365	435	510	580	655	1°05'
1°10'	4911.07	4.0	205	310	410	515	615	720	820	925	3.5	175	265	350	440	525	615	700	790	2.5	145	220	290	365	435	510	580	655	1°10'
1°15'	4583.66	4.5	205	310	410	515	615	720	820	925	3.5	175	265	350	440	525	615	700	790	2.5	145	220	290	365	435	510	580	655	1°15'
1°20'	4297.18	4.5	205	310	410	515	615	720	820	925	4.0	175	265	350	440	525	615	700	790	3.0	145	220	290	365	435	510	580	655	1°20'
1°25'	4044.41	5.0	205	310	410	515	615	720	820	925	4.0	175	265	350	440	525	615	700	790	3.0	145	220	290	365	435	510	580	655	1°25'
1°30'	3819.72	5.0	205	310	410	515	615	720	820	925	4.0	175	265	350	440	525	615	700	790	3.0	145	220	290	365	435	510	580	655	1°30'
1°35'	3618.68	5.5	205	310	410	515	615	720	820	925	4.5	175	265	350	440	525	615	700	790	3.5	145	220	290	365	435	510	580	655	1°35'
1°40'	3437.75	5.5	205	310	410	515	615	720	820	925	4.5	175	265	350	440	525	615	700	790	3.5	145	220	290	365	435	510	580	655	1°40'
1°45'	3274.04	6.0	205	310	410	515	615	720	820	925	5.0	175	265	350	440	525	615	700	790	3.5	145	220	290	365	435	510	580	655	1°45'
1°50'	3125.22	6.0	205	310	410	515	615	720	820	925	5.0	175	265	350	440	525	615	700	790	4.0	145	220	290	365	435	510	580	655	1°50'
1°55'	2989.35	6.5	205	310	410	515	615	720	820	925	5.0	175	265	350	440	525	615	700	790	4.0	145	220	290	365	435	510	580	655	1°55'
2°00'	2864.79	6.5	205	310	410	515	615	720	820	925	5.5	175	265	350	440	525	615	700	790	4.0	145	220	290	365	435	510	580	655	2°00'
2°10'	2644.42	7.0	215	325	430	540	645	755	860	970	6.0	175	265	350	440	525	615	700	790	4.5	145	220	290	365	435	510	580	655	2°10'
2°15'	2546.48	7.0	220	330	440	550	660	770	880	990	6.0	175	265	350	440	525	615	700	790	4.5	145	220	290	365	435	510	580	655	2°15'
2°20'	2455.53	7.5	225	340	450	565	675	790	900	1015	6.0	175	265	350	440	525	615	700	790	4.5	145	220	290	365	435	510	580	655	2°20'
2°30'	2291.83	7.5	225	340	450	565	675	790	900	1015	6.5	175	265	350	440	525	615	700	790	5.0	150	225	300	375	450	525	600	675	2°30'
2°45'	2083.48	8.0	240	360	480	600	720	840	960	1080	7.0	190	285	380	475	570	665	760	855	5.5	165	250	330	415	495	580	660	745	2°45'
3°00'	1909.86	8.0	250	375	500	625	750	875	1000	1125	7.5	205	310	410	515	615	720	820	925	6.0	180	270	360	450	540	630	720	810	3°00'
3°15'	1762.95	8.5	255	385	510	640	765	895	1020	1150	8.0	220	330	440	550	660	770	880	990	6.0	195	295	390	490	585	685	780	880	3°15'
3°30'	1637.02	9.0	270	405	540	675	810	945	1080	1215	8.0	220	330	440	550	660	770	880	990	6.5	210	315	420	525	630	735	840	945	3°30'
3°45'	1527.89	9.0	285	430	570	715	855	1000	1140	1285	8.0	225	340	450	565	675	790	900	1015	7.0	210	315	420	525	630	735	840	945	3°45'
4°00'	1432.39	9.0	300	450	600	750	900	1050	1200	1350	8.5	230	345	460	575	690	805	920	1035	7.5	210	315	420	525	630	735	840	945	4°00'
4°15'	1348.14	9.5	300	450	600	750	900	1050	1200	1350	8.5	230	345	460	575	690	805	920	1035	7.5	215	325	430	540	645	755	860	970	4°15'
4°30'	1273.24	9.5	300	450	600	750	900	1050	1200	1350	9.0	240	360	480	600	720	840	960	1080	8.0	220	330	440	550	660	770	880	990	4°30'
4°45'	1206.23	9.5	300	450	600	750	900	1050	1200	1350	9.0	245	370	490	615	735	860	980	1105	8.0	220	330	440	550	660	770	880	990	4°45'
5°00'	1145.92	9.5	300	450	600	750	900	1050	1200	1350	9.5	255	385	510	640	765	895	1020	1150	8.5	230	345	460	575	690	805	920	1035	5°00'
5°15'	1091.35	10.0	300	450	600	750	900	1050	1200	1350	10.0	300	450	600	750	900	1050	1200	1350	8.5	230	345	460	575	690	805	920	1035	5°15'
5°30'	1041.74	10.0	300	450	600	750	900	1050	1200	1350	10.0	300	450	600	750	900	1050	1200	1350	8.5	230	345	460	575	690	805	920	1035	5°30'
5°45'	996.45	10.0	300	450	600	750	900	1050	1200	1350	10.0	300	450	600	750	900	1050	1200	1350	9.0	230	345	460	575	690	805	920	1035	5°45'
6°00'	954.93	10.0	300	450	600	750	900	1050	1200	1350	10.0	300	450	600	750	900	1050	1200	1350	9.0	240	360	480	600	720	840	960	1080	6°00'
6°15'	916.73	10.0	300	450	600	750	900	1050	1200	1350	10.0	300	450	600	750	900	1050	1200	1350	9.0	245	370	490	615	735	860	980	1105	6°15'
6°30'	881.47	10.0	300	450	600	750	900	1050	1200	1350	10.0	300	450	600	750	900	1050	1200	1350	9.5	250	375	500	625	750	875	1000	1125	6°30'
6°45'	848.83	10.5	285	430	570	715	855	1000	1140	1285	10.5	285	430	570	715	855	1000	1140	1285	9.5	255	385	510	640	765	895	1020	1150	6°45'
7°00'	818.51	10.5	285	430	570	715	855	1000	1140	1285	10.5	285	430	570	715	855	1000	1140	1285	9.5	260	390	520	650	780	910	1040	1170	7°00'
7°15'	790.29	10.5	285	430	570	715	855	1000	1140	1285	10.5	285	430	570	715	855	1000	1140	1285	10.0	265	400	530	665	795	930	1060	1195	7°15'
7°30'	763.94	10.5	285	430	570	715	855	1000	1140	1285	10.5	285	430	570	715	855	1000	1140	1285	10.0	270	405	540	675	810	945	1080	1215	7°30'
8°00'	716.20	10.5	285	430	570	715	855	1000	1140	1285	10.5	285	430	570	715	855	1000	1140	1285	10.5	280	420	560	700	840	980	1120	1260	8°00'
8°30'	674.07	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	8°30'
9°00'	636.62	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	9°00'
9°30'	603.11	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	9°30'
10°00'	572.96	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	10°00'
10°30'	545.67	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	11.0	265	400	530	665	795	930	1060	1195	10°30'
11°00'	520.87	11.5	250	375	500	625	750	875	1000	1125	11.5	250	375	500	625	750	875	1000	1125	11.5	250	375	500	625	750	875	1000	1125	11°00'
12°00'	477.46	11.5	250	375	500	625	750	875	1000	1125	11.5	250	375	500	625	750	875	1000	1125	11.5	250	375	500	625	750	875	1000	1125	12°00'
14°00'	409.26	11.5	250	375	500	625	750	875	1000	1125	11.5	250	375	500	625	750	875	1000	1125	11.5	250	375	500	625	750	875	1000	1125	14°00'
16°00'	358.10	12.0	235	355	470	590	705	825	940	1060	12.0	235	355	470	590	705	825	940	1060	12.0	235	355	470	590	705	825	940	1060	16°00'
18°00'	318.31	12.0	235	355	470	590	705	825	940	1060	12.0	235	355	470	590	705	825	940	1060	12.0	235	355	470	590	705	825	940	1060	18°00'
20°00'	286.48	12.0	220	330	440	550	660	770	880	990	12.0	220	330	440	550	660	770	880	990	12.0	220	330	440	550	660	770	880	990	20°00'
24°00'	238.73	12.0	220	330	440	550	660	770	880	990	12.0	220	330	440	550	660	770	880	990	12.0	220	330	440	550	660	770	880	990	24°00'
36°00'	159.15	12.0	205	310	410	515	615	720	820	925	12.0	205	310	410	515	615	720	820	925	12.0	205	310	410	515	615	720	820	925	36°00'

NOTES:

1 Select only one design speed that is appropriate to the corridor or section of highway.
DO NOT use more than one column in the design of a corridor or section of highway.

2 The shaded area represents degree of curvature that should only be used in constrained areas. These curves would need to be posted at a lower speed since the comfort speed is lower than the selected design speed. See Table 3-5 in this chapter.

3 For a degree of curve that falls between values listed use the super rate and spiral length for the next highest degree of curve listed.

4 For design speeds other than shown, the superelevation & spiral length can be interpolated from the table.

5 The formulas below can be used to determine the minimum spiral length for superelevation runoff, comfort and aesthetics: Use the longest spiral solution of the three and round up to the nearest 5 ft.

Superelevation Runoff
Ln= [(w * n * e) / s] * b; b=[1 + 0.5 * (n-1)] / n

Where: w=width of lane; typically 12 ft
Where: e=superelevation rate in percent
Where: n=number of lanes rotated
Where: b=adjustment factor
Where: s=relative slope in percent
s=0.70 @ 25 mph
s=0.66 @ 30 mph
s=0.62 @ 35 mph
s=0.58 @ 40 mph
s=0.54 @ 45 mph
s=0.50 @ 50 mph
s=0.47 @ 55 mph
s=0.45 @ 60 mph
s=0.43 @ 65 mph
s=0.40 @ 70 mph

Centrifugal Control: Ls= (D)(V^3/3638)
Where: V=velocity in mph and D= Degree of curve

Aesthetic Control: Ls=2.9V
Where: V=velocity in mph

LEGEND:

NC - Normal crown
D - Degree of curve
e - Superelevation in percent
Ln - Standard spiral length for n lanes rotated;

Table 3-3: Urban Superelevation & Spiral Lengths

	40						35						30						25						
D	e	L1	L2	L3	L4	L5	e	L1	L2	L3	L4	L5	e	L1	L2	L3	L4	L5	e	L1	L2	L3	L4	L5	D
1°00'	NC	-	-	-	-	-	NC	-	-	-	-	-	NC	-	-	-	-	-	NC	-	-	-	-	-	1°00'
1°15'	NC	-	-	-	-	-	NC	-	-	-	-	-	NC	-	-	-	-	-	NC	-	-	-	-	-	1°15'
1°30'	2	120	180	240	300	360	NC	-	-	-	-	-	NC	-	-	-	-	-	NC	-	-	-	-	-	1°30'
1°45'	2	120	180	240	300	360	NC	-	-	-	-	-	NC	-	-	-	-	-	NC	-	-	-	-	-	1°45'
2°00'	2	120	180	240	300	360	2	105	160	210	265	315	NC	-	-	-	-	-	NC	-	-	-	-	-	2°00'
2°15'	2.5	120	180	240	300	360	2	105	160	210	265	315	NC	-	-	-	-	-	NC	-	-	-	-	-	2°15'
2°30'	2.5	130	195	260	325	390	2	105	160	210	265	315	NC	-	-	-	-	-	NC	-	-	-	-	-	2°30'
2°45'	2.5	140	210	280	350	420	2	105	160	210	265	315	NC	-	-	-	-	-	NC	-	-	-	-	-	2°45'
3°00'	2.5	120	180	240	300	360	2.5	105	160	210	265	315	2	90	135	180	225	270	NC	-	-	-	-	-	3°00'
3°15'	2.5	120	180	240	300	360	2.5	105	160	210	265	315	2	90	135	180	225	270	NC	-	-	-	-	-	3°15'
3°30'	2.5	120	180	240	300	360	2.5	105	160	210	265	315	2	90	135	180	225	270	2	75	115	150	190	225	3°30'
3°45'	2.5	120	180	240	300	360	2.5	105	160	210	265	315	2.5	90	135	180	225	270	2	75	115	150	190	225	3°45'
4°00'	2.5	120	180	240	300	360	2.5	105	160	210	265	315	2.5	90	135	180	225	270	2	75	115	150	190	225	4°00'
4°15'	3	120	180	240	300	360	2.5	105	160	210	265	315	2.5	90	135	180	225	270	2	75	115	150	190	225	4°15'
4°30'	3	120	180	240	300	360	2.5	105	160	210	265	315	2.5	90	135	180	225	270	2	75	115	150	190	225	4°30'
4°45'	3	120	180	240	300	360	2.5	105	160	210	265	315	2.5	90	135	180	225	270	2	75	115	150	190	225	4°45'
5°00'	3	120	180	240	300	360	2.5	105	160	210	265	315	2.5	90	135	180	225	270	2	75	115	150	190	225	5°00'
5°15'	3	120	180	240	300	360	2.5	105	160	210	265	315	2.5	90	135	180	225	270	2	75	115	150	190	225	5°15'
5°30'	3	120	180	240	300	360	2.5	105	160	210	265	315	2.5	90	135	180	225	270	2.5	75	115	150	190	225	5°30'
5°45'	3	125	190	250	315	375	2.5	105	160	210	265	315	2.5	90	135	180	225	270	2.5	75	115	150	190	225	5°45'
6°00'	3	130	195	260	325	390	3	105	160	210	265	315	2.5	90	135	180	225	270	2.5	75	115	150	190	225	6°00'
6°15'	3	135	205	270	340	405	3	105	160	210	265	315	2.5	90	135	180	225	270	2.5	75	115	150	190	225	6°15'
6°30'	3	140	210	280	350	420	3	105	160	210	265	315	2.5	90	135	180	225	270	2.5	75	115	150	190	225	6°30'
7°00'	3.5	140	210	280	350	420	3	105	160	210	265	315	2.5	90	135	180	225	270	2.5	75	115	150	190	225	7°00'
7°30'	3.5	150	225	300	375	450	3	105	160	210	265	315	2.5	90	135	180	225	270	2.5	75	115	150	190	225	7°30'
8°00'	3.5	160	240	320	400	480	3	105	160	210	265	315	2.5	90	135	180	225	270	2.5	80	120	160	200	240	8°00'
8°30'	3.5	165	250	330	415	495	3	110	165	220	275	330	3	90	135	180	225	270	2.5	85	130	170	215	255	8°30'
9°00'	4	170	255	340	425	510	3	115	175	230	290	345	3	90	135	180	225	270	2.5	90	135	180	225	270	9°00'
9°30'	4	175	265	350	440	525	3	120	180	240	300	360	3	95	145	190	240	285	2.5	95	145	190	240	285	9°30'
10°00'	4	180	270	360	450	540	3.5	125	190	250	315	375	3	100	150	200	250	300	2.5	100	150	200	250	300	10°00'
10°30'							3.5	130	195	260	325	390	3	105	160	210	265	315	2.5	105	160	210	265	315	10°30'
11°00'							3.5	135	205	270	340	405	3	105	160	210	265	315	2.5	105	160	210	265	315	11°00'
11°30'							3.5	140	210	280	350	420	3	110	165	220	275	330	2.5	105	160	210	265	315	11°30'
12°00'							3.5	145	220	290	365	435	3	110	165	220	275	330	2.5	105	160	210	265	315	12°00'
12°30'							3.5	150	225	300	375	450	3	115	175	230	290	345	2.5	105	160	210	265	315	12°30'
13°00'							3.5	155	235	310	390	465	3	115	175	230	290	345	2.5	105	160	210	265	315	13°00'
13°30'							3.5	160	240	320	400	480	3	120	180	240	300	360	2.5	105	160	210	265	315	13°30'
14°00'							4	165	250	330	415	495	3	120	180	240	300	360	3	105	160	210	265	315	14°00'
15°00'							4	175	265	350	440	525	3.5	125	190	250	315	375	3	105	160	210	265	315	15°00'
16°00'													3.5	130	195	260	325	390	3	105	160	210	265	315	16°00'
17°00'													3.5	135	205	270	340	405	3	105	160	210	265	315	17°00'
18°00'													3.5	140	210	280	350	420	3	105	160	210	265	315	18°00'
19°00'													3.5	145	220	290	365	435	3	105	160	210	265	315	19°00'
20°00'													3.5	150	225	300	375	450	3	105	160	210	265	315	20°00'
21°00'													4	160	240	320	400	480	3	105	160	210	265	315	21°00'
22°00'													4	165	250	330	415	495	3	110	165	220	275	330	22°00'
23°00'																			3	115	175	230	290	345	23°00'
24°00'																			3.5	120	180	240	300	360	24°00'
25°00'																			3.5	120	180	240	300	360	25°00'
26°00'																			3.5	120	180	240	300	360	26°00'
27°00'																			3.5	120	180	240	300	360	27°00'
28°00'																			3.5	120	180	240	300	360	28°00'
29°00'																			3.5	125	190	250	315	375	29°00'
30°00'																			3.5	130	195	260	325	390	30°00'
32°00'																			3.5	150	225	300	375	450	32°00'
34°00'																			4	155	235	310	390	465	34°00'
36°00'																			4	155	235	310	390	465	36°00'

When standard length spirals cannot be attained, use the formulas below for minimum spiral lengths by runoff, comfort, & aesthetics:
Use the longest spiral solution of the three and round to the nearest higher even 5 feet.

Superelevation Runoff:
Ln= [(w * n * e) / s] * b; b=[1 + 0.5 * (n-1)] / n

Where: w=width of lane; typically 12 ft
Where: e=superelevation rate in percent
Where: n=number of lanes rotated
Where: b=adjustment factor
Where: s=relative slope in percent
s=0.70 @ 25 mph
s=0.66 @ 30 mph
s=0.62 @ 35 mph
s=0.58 @ 40 mph
s=0.54 @ 45 mph
s=0.50 @ 50 mph
s=0.47 @ 55 mph
s=0.45 @ 60 mph
s=0.43 @ 65 mph
s=0.40 @ 70 mph

Centrifugal Control: Ls= (D)(V^3/3638)
Where: V=velocity in mph and D= Degree of curve

Aesthetic Control: Ls=2.9V
Where: V=velocity in mph

LEGEND:

NC - Normal crown
D - Degree of curve
e - Superelevation in percent
Ln - Standard spiral length for n lanes rotated;

Table 3-4: Suburban Superelevation & Spiral Lengths

	55						50						45						
D	e	L1	L2	L3	L4	L5	e	L1	L2	L3	L4	L5	e	L1	L2	L3	L4	L5	D
0°45'	2	160	240	320	400	480	NC	-	-	-	-	-	NC	-	-	-	-	-	0°45'
0°50'	2	160	240	320	400	480	NC	-	-	-	-	-	NC	-	-	-	-	-	0°50'
0°55'	2	160	240	320	400	480	2	145	220	290	365	435	NC	-	-	-	-	-	0°55'
1°00'	2.5	160	240	320	400	480	2	145	220	290	365	435	NC	-	-	-	-	-	1°00'
1°05'	2.5	160	240	320	400	480	2	145	220	290	365	435	2	135	205	270	340	405	1°05'
1°10'	2.5	160	240	320	400	480	2.5	145	220	290	365	435	2	135	205	270	340	405	1°10'
1°15'	3	160	240	320	400	480	2.5	145	220	290	365	435	2	135	205	270	340	405	1°15'
1°20'	3	160	240	320	400	480	2.5	145	220	290	365	435	2	135	205	270	340	405	1°20'
1°25'	3	160	240	320	400	480	2.5	145	220	290	365	435	2.5	135	205	270	340	405	1°25'
1°30'	3	160	240	320	400	480	3	145	220	290	365	435	2.5	135	205	270	340	405	1°30'
1°35'	3.5	160	240	320	400	480	3	145	220	290	365	435	2.5	135	205	270	340	405	1°35'
1°40'	3.5	160	240	320	400	480	3	145	220	290	365	435	2.5	135	205	270	340	405	1°40'
1°45'	3.5	160	240	320	400	480	3	145	220	290	365	435	2.5	135	205	270	340	405	1°45'
1°50'	3.5	160	240	320	400	480	3.5	145	220	290	365	435	3	135	205	270	340	405	1°50'
1°55'	4	160	240	320	400	480	3.5	145	220	290	365	435	3	135	205	270	340	405	1°55'
2°00'	4	160	240	320	400	480	3.5	145	220	290	365	435	3	135	205	270	340	405	2°00'
2°05'	4	160	240	320	400	480	3.5	145	220	290	365	435	3	135	205	270	340	405	2°05'
2°10'	4	160	240	320	400	480	3.5	145	220	290	365	435	3	135	205	270	340	405	2°10'
2°15'	4.5	160	240	320	400	480	4	145	220	290	365	435	3.5	135	205	270	340	405	2°15'
2°20'	4.5	160	240	320	400	480	4	145	220	290	365	435	3.5	135	205	270	340	405	2°20'
2°25'	4.5	160	240	320	400	480	4	145	220	290	365	435	3.5	135	205	270	340	405	2°25'
2°30'	4.5	160	240	320	400	480	4	145	220	290	365	435	3.5	135	205	270	340	405	2°30'
2°35'	4.5	160	240	320	400	480	4	145	220	290	365	435	3.5	135	205	270	340	405	2°35'
2°40'	4.5	160	240	320	400	480	4	145	220	290	365	435	3.5	135	205	270	340	405	2°40'
2°45'	4.5	160	240	320	400	480	4	145	220	290	365	435	3.5	135	205	270	340	405	2°45'
2°50'	4.5	160	240	320	400	480	4	145	220	290	365	435	4	135	205	270	340	405	2°50'
2°55'	4.5	160	240	320	400	480	4.5	145	220	290	365	435	4	135	205	270	340	405	2°55'
3°00'	4.5	160	240	320	400	480	4.5	145	220	290	365	435	4	135	205	270	340	405	3°00'
3°15'	5	165	250	330	415	495	4.5	145	220	290	365	435	4	135	205	270	340	405	3°15'
3°30'	5	170	255	340	425	510	4.5	145	220	290	365	435	4	135	205	270	340	405	3°30'
3°45'	5	180	270	360	450	540	4.5	150	225	300	375	450	4.5	135	205	270	340	405	3°45'
4°00'	5	190	285	380	475	570	4.5	160	240	320	400	480	4.5	135	205	270	340	405	4°00'
4°15'	5.5	200	300	400	500	600	5	170	255	340	425	510	4.5	135	205	270	340	405	4°15'
4°30'	5.5	210	315	420	525	630	5	180	270	360	450	540	4.5	135	205	270	340	405	4°30'
4°45'	5.5	220	330	440	550	660	5	190	285	380	475	570	4.5	135	205	270	340	405	4°45'
5°00'	6	230	345	460	575	690	5	195	295	390	490	585	4.5	140	210	280	350	420	5°00'
5°15'	6	240	360	480	600	720	5.5	200	300	400	500	600	5	145	220	290	365	435	5°15'
5°30'							5.5	205	310	410	515	615	5	150	225	300	375	450	5°30'
5°45'							5.5	210	315	420	525	630	5	155	235	310	390	465	5°45'
6°00'							5.5	215	325	430	540	645	5	160	240	320	400	480	6°00'
6°15'							5.5	220	330	440	550	660	5	165	250	330	415	495	6°15'
6°30'							6	225	340	450	565	675	5	170	255	340	425	510	6°30'
6°45'							6	230	345	460	575	690	5.5	175	265	350	440	525	6°45'
7°00'													5.5	180	270	360	450	540	7°00'
7°15'													5.5	185	280	370	465	555	7°15'
7°30'													5.5	190	285	380	475	570	7°30'
7°45'													5.5	195	295	390	490	585	7°45'
8°00'													6	200	300	400	500	600	8°00'

When standard length spirals cannot be attained, use the formulas below for minimum spiral lengths by runoff, comfort, & aesthetics:
Use the longest spiral solution of the three and round to the nearest higher even 5 feet.

Superelevation Runoff:
Ln= [(w * n * e) / s] * b; b=[1 + 0.5 * (n-1)] / n

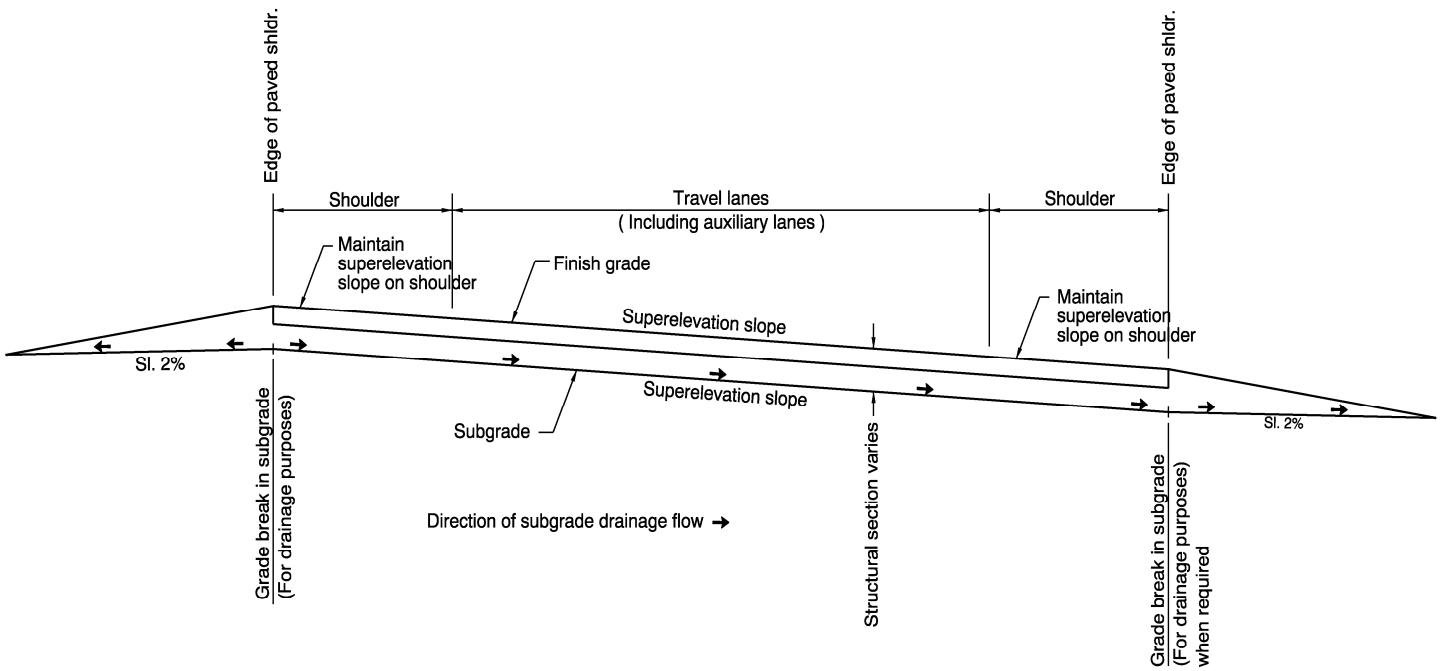
Where: w=width of lane; typically 12 ft
Where: e=superelevation rate in percent
Where: n=number of lanes rotated
Where: b=adjustment factor
Where: s=relative slope in percent
s=0.70 @ 25 mph
s=0.66 @ 30 mph
s=0.62 @ 35 mph
s=0.58 @ 40 mph
s=0.54 @ 45 mph
s=0.50 @ 50 mph
s=0.47 @ 55 mph
s=0.45 @ 60 mph
s=0.43 @ 65 mph
s=0.40 @ 70 mph

Centrifugal Control: $Ls= (D)(V^3/3638)$
Where: V=velocity in mph and D= Degree of curve

Aesthetic Control: Ls=2.9V
Where: V=velocity in mph

LEGEND:

NC - Normal crown
D - Degree of curve
e - Superelevation in percent
Ln - Standard spiral length for n lanes rotated;



GENERAL NOTES FOR ALL DETAILS:

1. For superelevation of roadway, and other details, see project plans.

STATE OF OREGON
DEPARTMENT OF TRANSPORTATION
ROADWAY ENGINEERING UNIT

ROADWAY CROSS SLOPES SUPERELEVATED SECTIONS

HIGHWAY DESIGN MANUAL

rd140.dgn 30-JUN-2009

RD140

Figure 3-3: Standard Superelevation

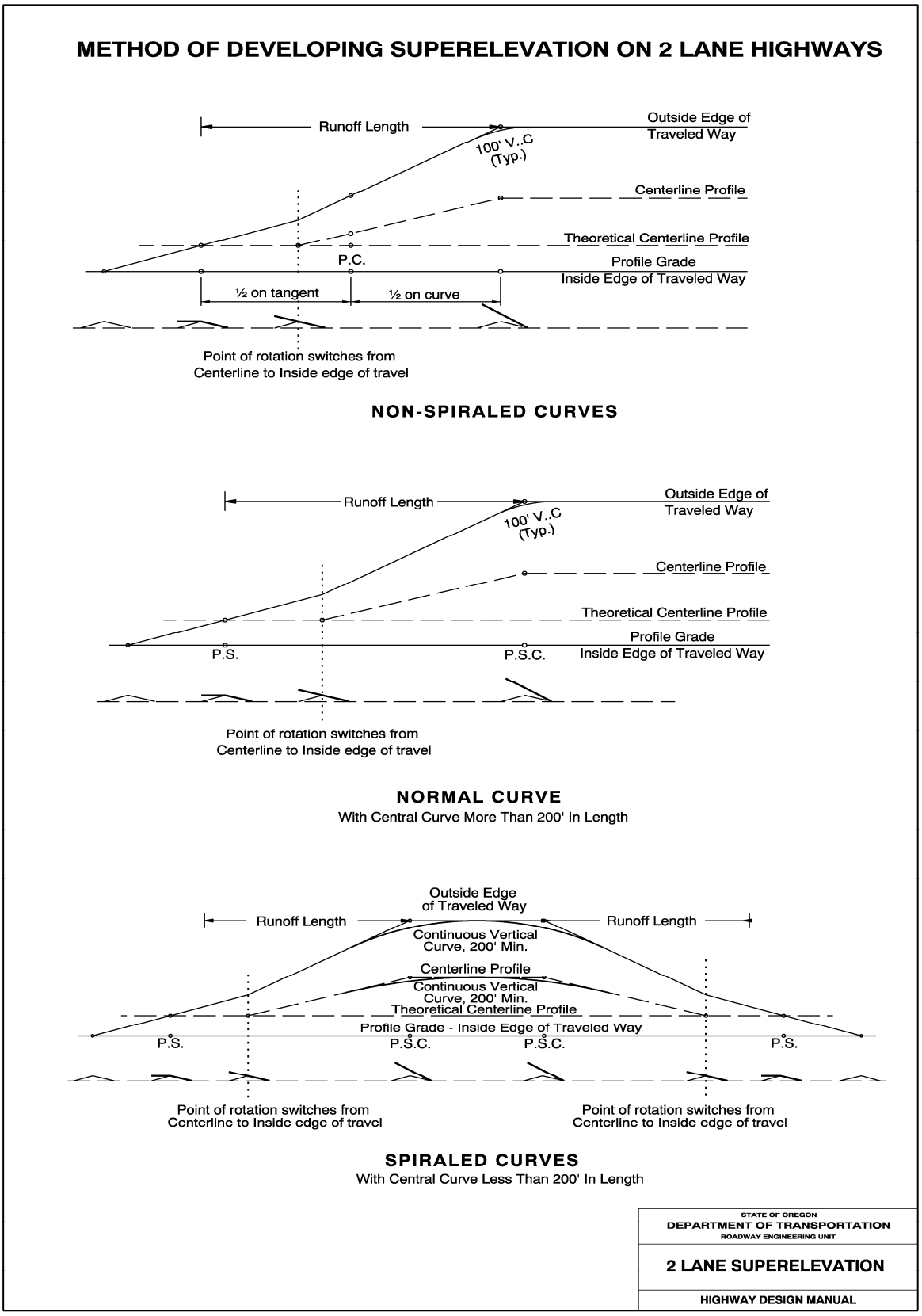


Figure 3-4: Developing Superelevation on 2-Lane Highways

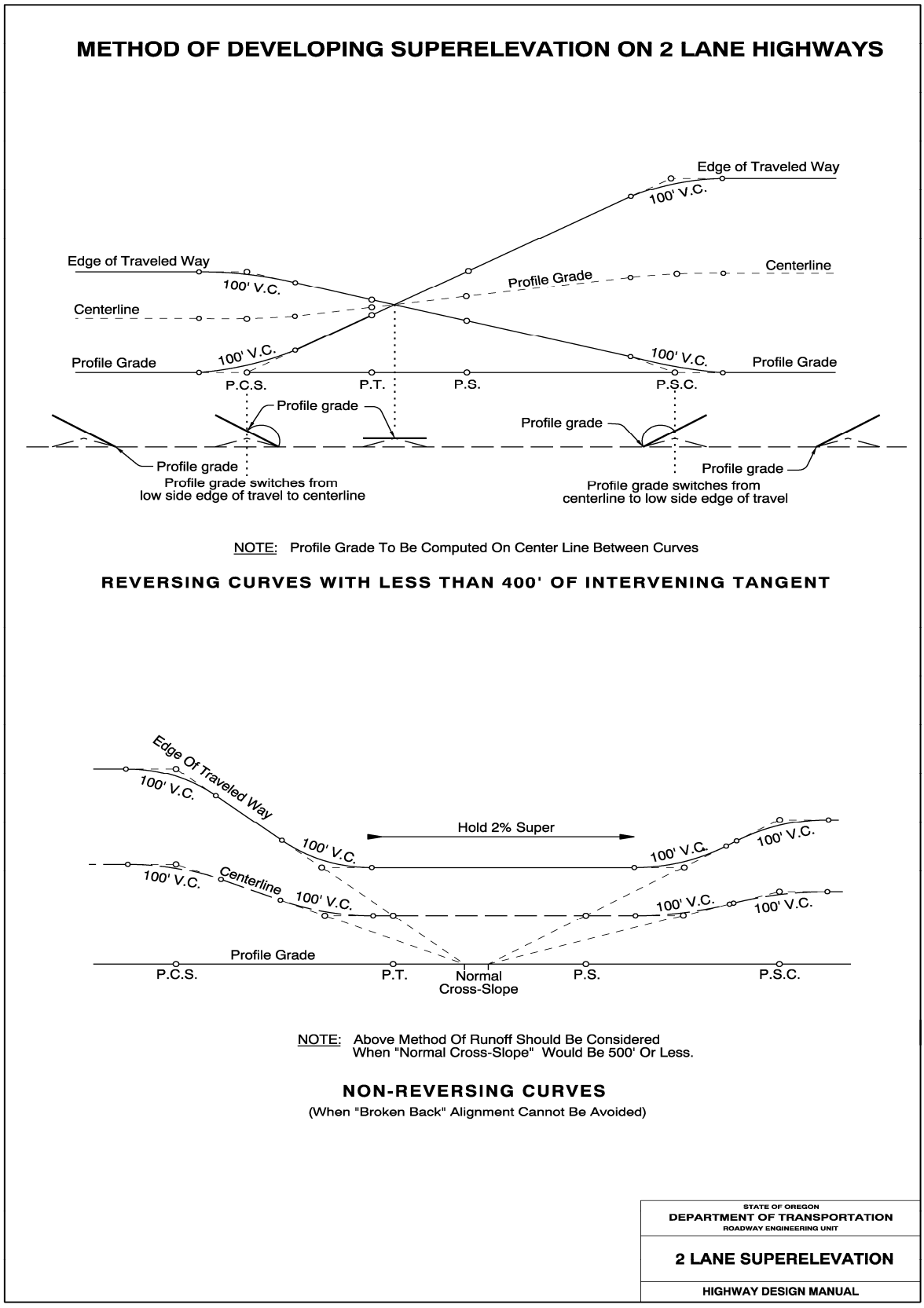
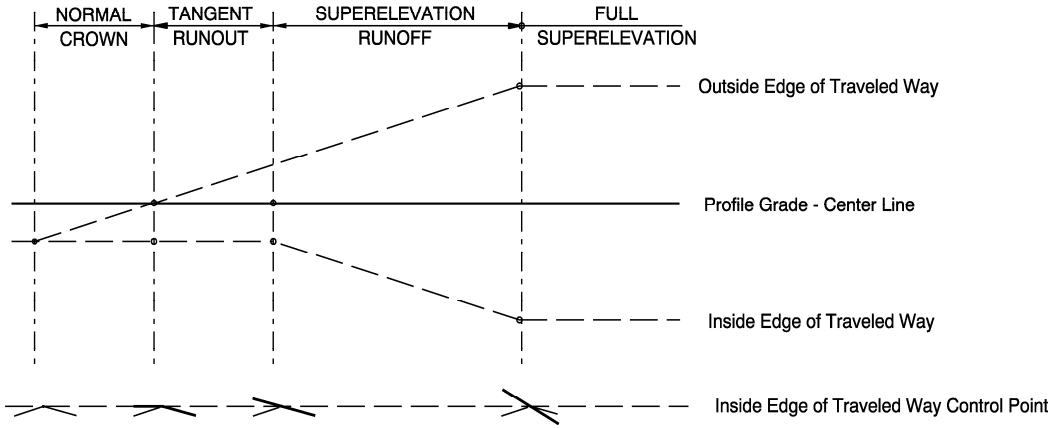
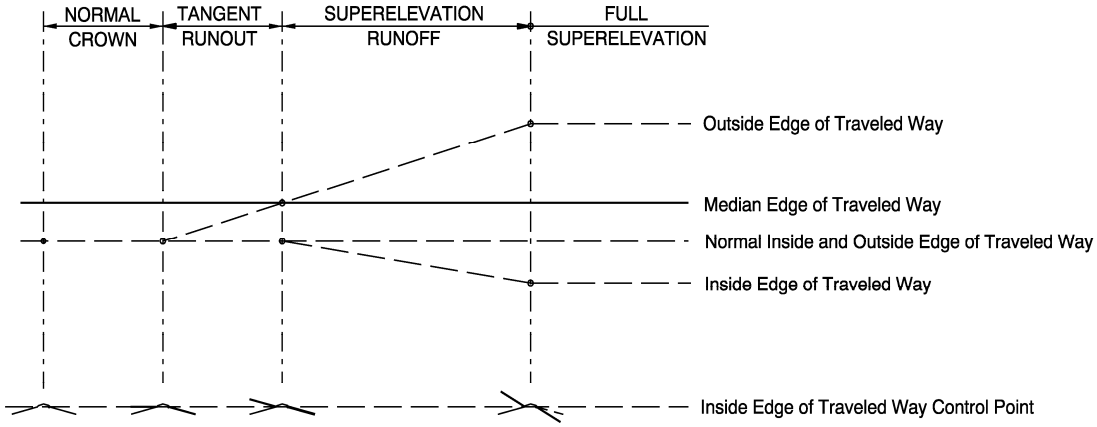


Figure 3-5: Developing Superelevation on 2-Lane Highways (Cont'd)

EXAMPLE S OF ADDITIONAL METHODS FOR DEVELOPING SUPERELEVATION



METHOD OF DEVELOPING SUPERELEVATION REVOLVES AROUND CENTER LINE



METHOD OF DEVELOPING SUPERELEVATION REVOLVES AROUND INNER EDGE OF TRAVELED WAY

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EXAMPLE S OF ADDITIONAL METHODS FOR DEVELOPING SUPERELEVATION

HIGHWAY DESIGN MANUAL

Figure 3-6: Examples of Additional Methods for Developing Superelevation

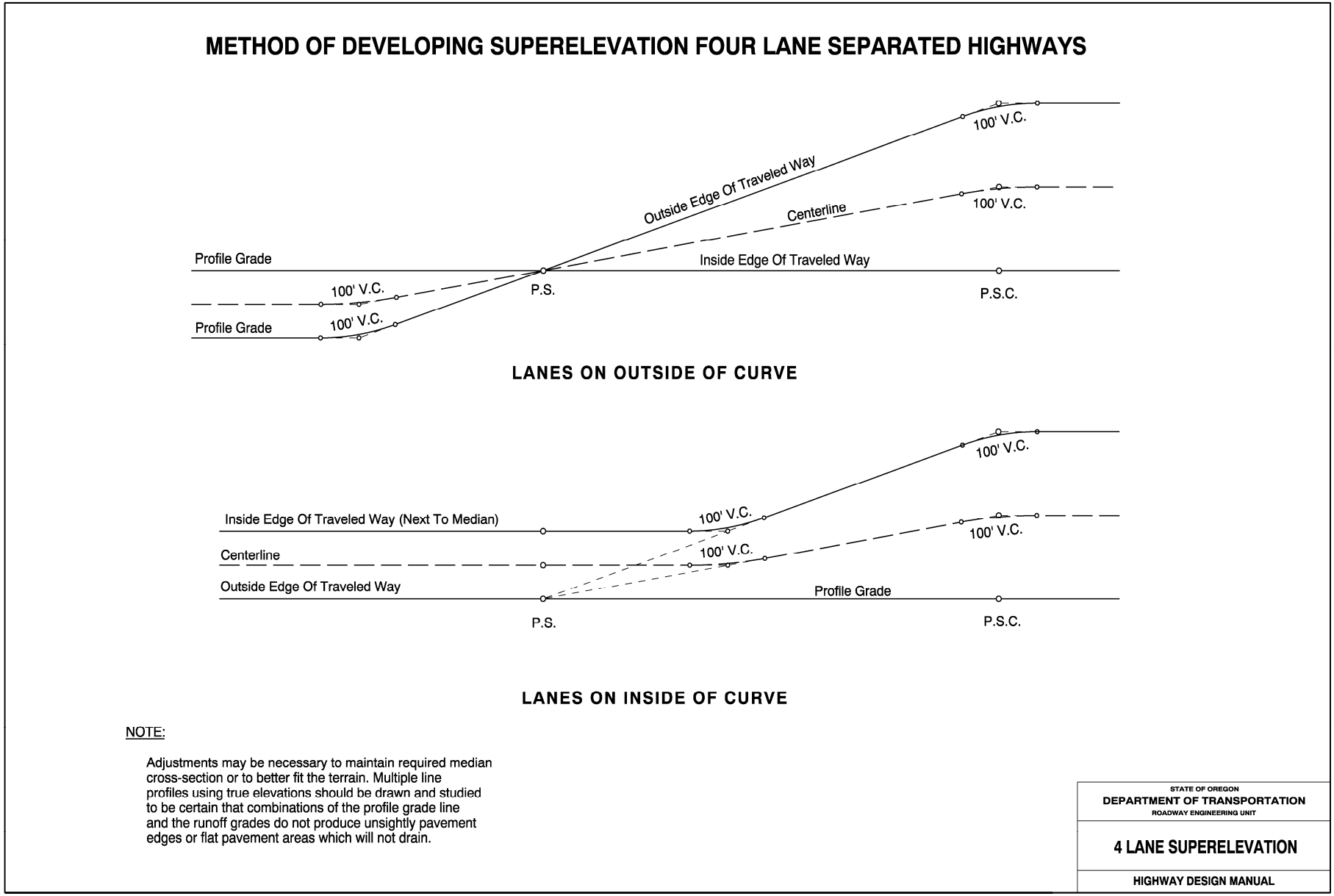


Figure 3-7: Developing Superelevation on 4-Lane Highways

C. COMFORT SPEED CHART

The Comfort Speed Chart shown in Table 3-5 represents the vehicle speed, degree of curvature and superelevation at the point where the driver begins to experience an unacceptable level of discomfort. *The data in this chart does not represent a design standard.* Design standards for superelevation are provided in Table 3-2, Table 3-3 and Table 3-4**.** This chart is provided as a tool to evaluate existing or proposed sections for safety and operation. It can also be used for supporting data as part of a design exception.

Table 3-5: Comfort Speed

Curve		Superelevation in Feet per Foot of Width																						
Degree	Radius (ft)	-0.020	0.000	0.020	0.025	0.030	0.035	0.040	0.045	0.050	0.055	0.060	0.065	0.070	0.075	0.080	0.085	0.090	0.095	0.100	0.105	0.110	0.115	0.120
0°30'	11459.16	87	94	100																				
0°45'	7639.44	81	86	92	93	95																		
1°00'	5729.58	76	81	86	87	88	90	91																
1°15'	4583.66	72	76	81	82	83	84	86	87	88														
1°30'	3819.72	68	73	77	78	79	80	81	82	83														
1°45'	3274.04	65	70	74	75	76	77	78	78	79	80	81	82											
2°00'	2864.79	63	67	71	72	72	73	74	75	76	77	78	79	80										
2°15'	2546.48	61	64	68	69	70	71	72	72	73	74	75	76	77	77	78								
2°30'	2291.83	59	62	66	67	67	68	69	70	71	72	72	73	74	75	75	76							
2°45'	2083.48	57	60	64	64	65	66	67	68	68	69	70	71	72	72	73	74							
3°00'	1909.86	55	59	62	63	63	64	65	66	66	67	68	69	69	70	71	72							
3°15'	1762.95	54	57	60	61	62	62	63	64	65	65	66	67	67	68	69	69	70						
3°30'	1637.02	52	56	59	59	60	61	61	62	63	64	64	65	66	66	67	68	68						
3°45'	1527.89	51	54	57	58	59	59	60	61	61	62	63	63	64	65	65	66	67						
4°00'	1432.39	50	53	56	56	57	58	58	59	60	60	61	62	62	63	64	64	65						
4°30'	1273.24	48	51	53	54	55	55	56	57	57	58	58	59	60	60	61	61	62	63					
5°00'	1145.92	46	49	51	52	53	53	54	54	55	56	56	57	57	58	58	59	60	60					
5°30'	1041.74	45	47	50	50	51	51	52	52	53	54	54	55	55	56	56	57	57	58	58				
6°00'	954.93	43	46	48	48	49	50	50	51	51	52	52	53	53	54	54	55	55	56	56				
6°30'	881.47	42	44	46	47	47	48	49	49	50	50	51	51	52	52	53	53	54	54	55				
7°00'	818.51	41	43	45	46	46	47	47	48	48	49	49	50	50	51	51	52	52	53	53	53			
7°30'	763.94	40	42	44	44	45	45	46	46	47	47	48	48	49	49	50	50	51	51	52	52			
8°00'	716.20	39	41	43	43	44	44	45	45	46	46	47	47	47	48	48	49	49	50	50	51			
8°30'	674.07	38	40	42	42	43	43	44	44	44	45	45	46	46	47	47	48	48	48	49	49	50		
9°00'	636.62	37	39	41	41	42	42	43	43	43	44	44	45	45	46	46	46	47	47	48	48	49		
9°30'	603.11	36	38	40	40	41	41	42	42	42	43	43	44	44	45	45	45	46	46	47	47	47		
10°00'	572.96	36	37	39	39	40	40	41	41	42	42	42	43	43	44	44	44	45	45	46	46	46		
10°30'	545.67	35	37	38	39	39	39	40	40	41	41	42	42	42	43	43	44	44	44	45	45	45		
11°00'	520.87	35	36	38	38	38	39	39	40	40	40	41	41	42	42	42	43	43	43	44	44	45		
11°30'	498.22	34	36	37	37	38	38	39	39	39	40	40	40	41	41	41	42	42	43	43	43	44		
12°00'	477.46	34	35	36	37	37	38	38	38	39	39	39	40	40	40	41	41	41	42	42	43	43		
14°00'	409.26	32	33	34	35	35	35	36	36	36	37	37	37	38	38	38	39	39	39	39	40	40	40	
16°00'	358.10	30	31	33	33	33	34	34	34	34	35	35	35	36	36	36	37	37	37	37	38	38	38	39
18°00'	318.31	29	30	31	32	32	32	32	33	33	33	33	34	34	34	35	35	35	35	36	36	36	36	37
20°00'	286.48	28	29	30	30	31	31	31	31	32	32	32	32	33	33	33	33	34	34	34	34	35	35	35
22°00'	260.44	27	28	29	29	29	30	30	30	30	31	31	31	31	32	32	32	32	33	33	33	33	34	34
24°00'	238.73	26	27	28	28	28	29	29	29	29	30	30	30	30	31	31	31	31	31	32	32	32	32	33
26°00'	220.37	25	26	27	27	28	28	28	28	28	29	29	29	29	30	30	30	30	30	31	31	31	31	31
28°00'	204.63	25	25	26	27	27	27	27	27	28	28	28	28	28	29	29	29	29	30	30	30	30	30	31
30°00'	190.99	24	25	26	26	26	26	26	27	27	27	27	27	28	28	28	28	28	29	29	29	29	29	30
32°00'	179.05	23	24	25	25	25	26	26	26	26	26	27	27	27	27	27	28	28	28	28	28	29	29	29
34°00'	168.52	23	24	24	25	25	25	25	25	26	26	26	26	26	26	27	27	27	27	27	28	28	28	28
36°00'	159.15	22	23	24	24	24	24	25	25	25	25	25	26	26	26	26	26	26	27	27	27	27	27	27

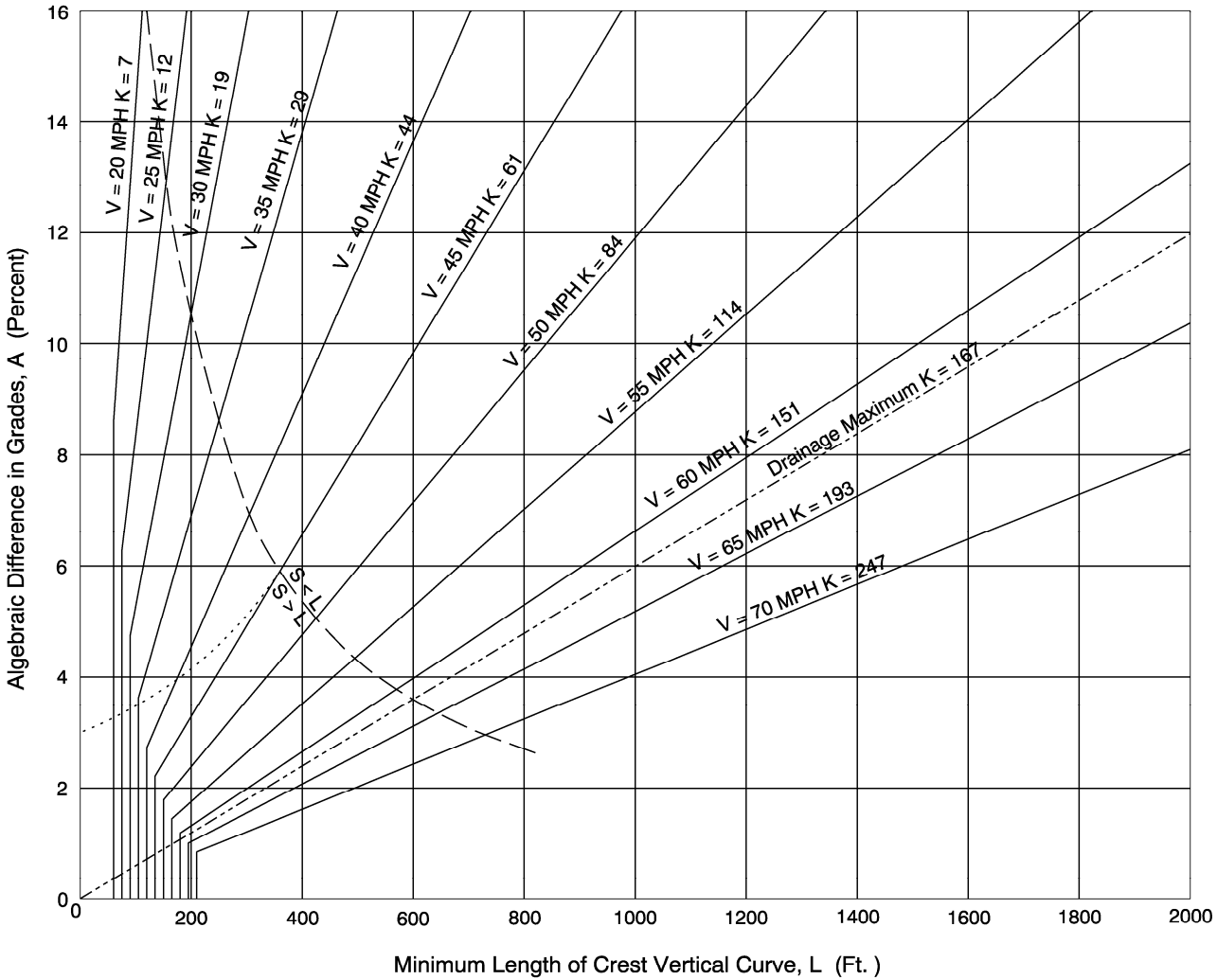
$R=V^2/[15(e+f)]$

e=rate of superelevation
f= sidefriction factor
V= Vehicle speed, mph
R=Radius, ft

Speed	Friction Factor
25	0.23
30	0.20
35	0.18
40	0.16
45	0.15
50	0.14
55	0.13
60	0.12
65	0.11
70	0.10

3.3.2 VERTICAL ALIGNMENT

Design vertical curves to provide sight distance at least equal to the stopping sight distance for the indicated design speed. The vertical sight distance is the distance from the operator's eye, assumed to be 3.5 feet above the pavement to the point 2 ft above the pavement. While objects less than 2 ft in height may be encountered on Oregon highways, it is rare that a complete emergency stop would be required to avoid such an object. Therefore, it is typically not practical to design for an object height of less than 2 ft. The minimum lengths of vertical curves which may be used for the various design speeds are shown in Figure 3-8 and Figure 3-9. It is desirable to increase the length of vertical curves over that shown whenever it is economically possible. When the algebraic difference in the grades is small, the minimum curve length is three times the design speed. This is represented by the vertical lines in the lower left hand corner of Figure 3-8 and Figure 3-9. An angle point is considered a curve with a length of zero, and therefore, does not meet the minimum standard.



L = Length of Vertical Curve in Feet
A = Algebraic Difference in Grades
S = Stopping Sight Distance
V = Design Speed in M.P.H.

K = L / A
L = KA
L = 3V (for small values of A)

— — S = L
- - - - - - - - Computed value when S>L and V = 45 MPH
—-—-- Drainage Maximum K = 167

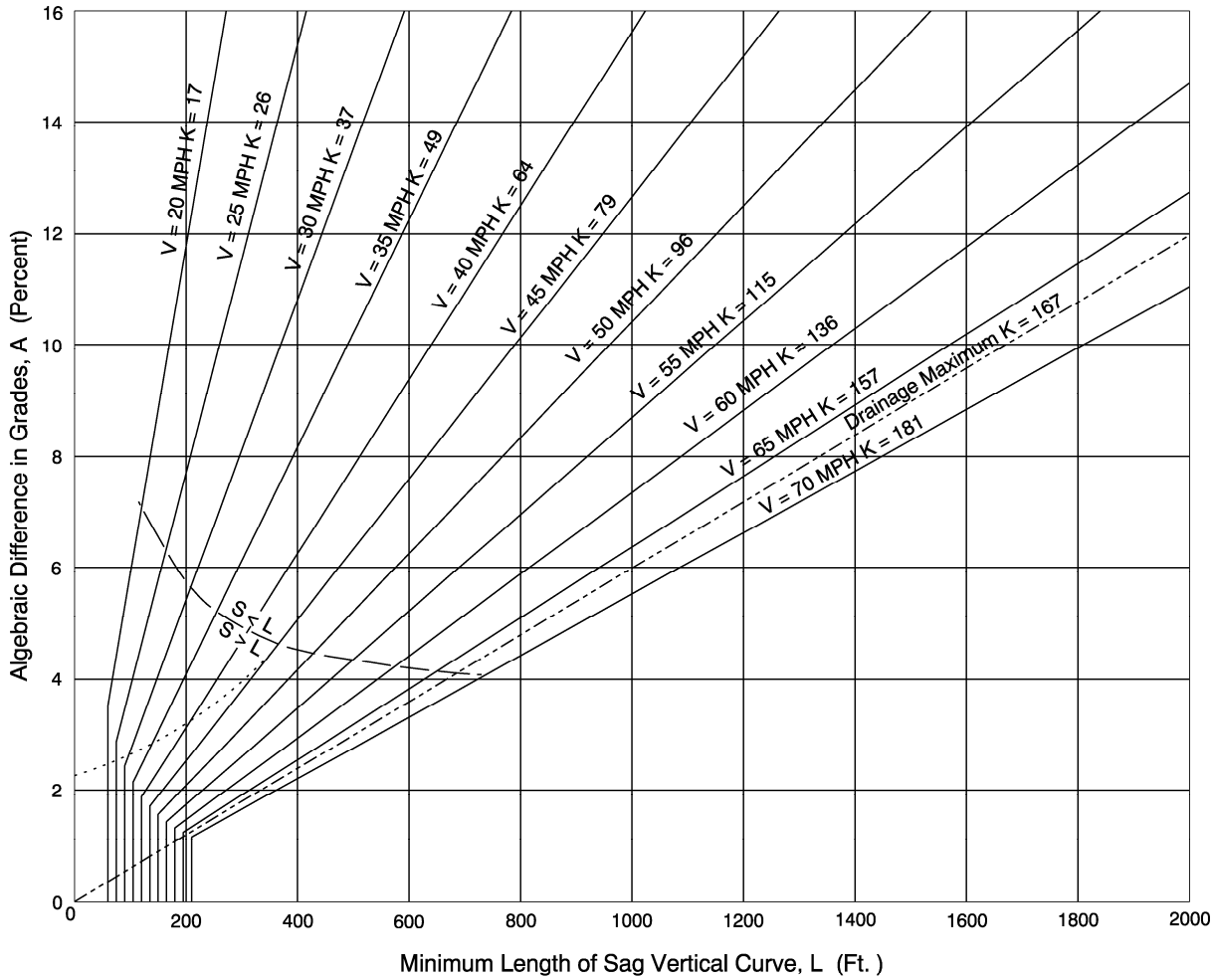
DESIGN CONTROLS FOR CREST VERTICAL CURVES, FOR STOPPING SIGHT DISTANCE AND OPEN ROAD CONDITIONS.

STATE OF OREGON
DEPARTMENT OF TRANSPORTATION
ROADWAY ENGINEERING UNIT

S.S.D. CREST VERTICAL

HIGHWAY DESIGN MANUAL

Figure 3-8 : SSD Crest Vertical Curve



L = Length of Vertical Curve in Feet
A = Algebraic Difference in Grades
S = Stopping Sight Distance
V = Design Speed in M.P.H.

K = L / A
L = KA
L = 3V (for small values of A)

— — S = L
· · · · · · Computed value when S>L and V = 45 MPH
— · — · Drainage Maximum K = 167

DESIGN CONTROLS FOR SAG VERTICAL CURVES, OPEN ROAD CONDITIONS.

STATE OF OREGON
DEPARTMENT OF TRANSPORTATION
ROADWAY ENGINEERING UNIT

S.S.D. SAG VERTICAL

HIGHWAY DESIGN MANUAL

Figure 3-9 : SSD Sag Vertical Curve

3.3.3 COMBINED HORIZONTAL AND VERTICAL ALIGNMENT

The combined effect of the horizontal and vertical alignment must be considered during design of a highway (see AASHTO's "*A Policy on Geometric Design of Highways and Streets - 2011*").

When designing for the coordination of horizontal and vertical alignment, the following issues need to be considered.

1. Balance curvature and grades. Tangent alignment mixed with steep grades or flat grades with excessive curvature is poor design. A balance of both elements leads to uniform operation, aesthetically pleasing, and safe designs.
2. Vertical and horizontal alignments should complement each other.
3. Avoid locating sharp horizontal curves at or near the top of a crest vertical curve or at the low point of a sharp vertical curve.
4. Design horizontal and vertical curvature to be as flat as possible in the area of intersections to allow for proper sight distance.

On summits with both horizontal and vertical curves, make the horizontal curve longer than the vertical curve. There is a limit of one vertical curve within a horizontal curve. It is desirable to provide a tangent grade on tangent alignment. Once the sight distance is broken by a curve in either the vertical or the horizontal alignment, there is little value in maintaining a tangent. The ideal alignment extends from control point to control point without unnecessary curvature in between. However, extremely long tangents may cause problems, due to driver boredom. (See AASHTO's, "*A Policy on Geometric Design of Highways and Streets - 2011*")

In the design of two-lane arterials, provide for passing at frequent intervals. Work with the Region Traffic Engineer on locations for passing opportunities, or passing or climbing lanes.

3.3.4 GRADES

On grades of 4% or over, carry the profile grade at the edge of the traveled way to the right of the centerline ascending the grade. The superelevation is obtained by raising the center and left side of the roadway on curves turning to the right going up hill, and by lowering the center and left side of the roadway on curves turning to the left. Where this rule applies and the horizontal curve passes over a summit, the profile grade is carried on the outside of the curve developing superelevation by lowering the center and inside edge of the roadway. For grades less than 4%, use the standard method of superelevation in conformance with Section 3.3.1.

Maximum grade for principal arterials and expressways is shown in Tables 6-1, 6-2, 6-3, 6-4, 6-5, 7-1, and 7-2. Maximum grade for freeways is shown in the ODOT 4R/New Freeway Standards Table 5-2.

It is important to take into account the impact from grades in the different design elements such as acceleration and deceleration lanes, stopping sight distance, passing sight distance, and intersection sight distance. Figure 3-2 in AASHTO's *"A Policy on Geometric Design of Highways and Streets - 2011"*, page 3-17 shows the effects of grade on stopping sight distance.