Geometric Design of Highways

2. ELEMENTS OF DESIGN

2.1. Sight Distance

2.2. Horizontal Alignment

2.2.1. Maximum Coefficient of lateral friction

2.2.2. Maximum Superelevation Rates for Streets and Highways

2.2.3. Minimum Radius R

Note: Heavy Weight Cars at High and Low Speed:

See video to see how dangerous to drive heavy trucks at high speed on curved roads. This is another video (for test purposes). Some vehicles have high centers of gravity and some passenger cars are loosely suspended on their axles. When these vehicles travel slowly on steep cross slopes, the down-slope tires carry a high percentage of the vehicle weight. A vehicle can roll over if this condition becomes extreme.

Video 1 Actual tractor-trailer overturn

Video 2 Remote Control Semi-Truck Crash

2.2.4. Criteria for Measuring Sight Distance

Height of Driver's Eye

For all sight distance calculations for passenger vehicles, the height of the driver's eye is considered to be 1.08 m above the road surface. For large trucks, the driver eye height is 2.33 m above the road surface.

Height of Object

For stopping sight distance and decision sight distance calculations, the height of object is considered to be 0.60 m above the road surface. For passing sight distance calculations, the height of object is considered to be 1.08 m above the road surface.

Sight Obstructions

On a tangent roadway, the obstruction that limits the driver's sight distance is the road surface at some point on a crest vertical curve. On horizontal curves, the obstruction that limits the driver's sight distance may be the road surface at some point on a crest vertical curve or it may be some physical feature outside of the travelled way, such as a longitudinal barrier, a bridge-approach fill slope, a tree, foliage, or the backslope of a cut section. Accordingly, all highway construction plans should be checked in both the vertical and horizontal plane for sight distance obstructions.

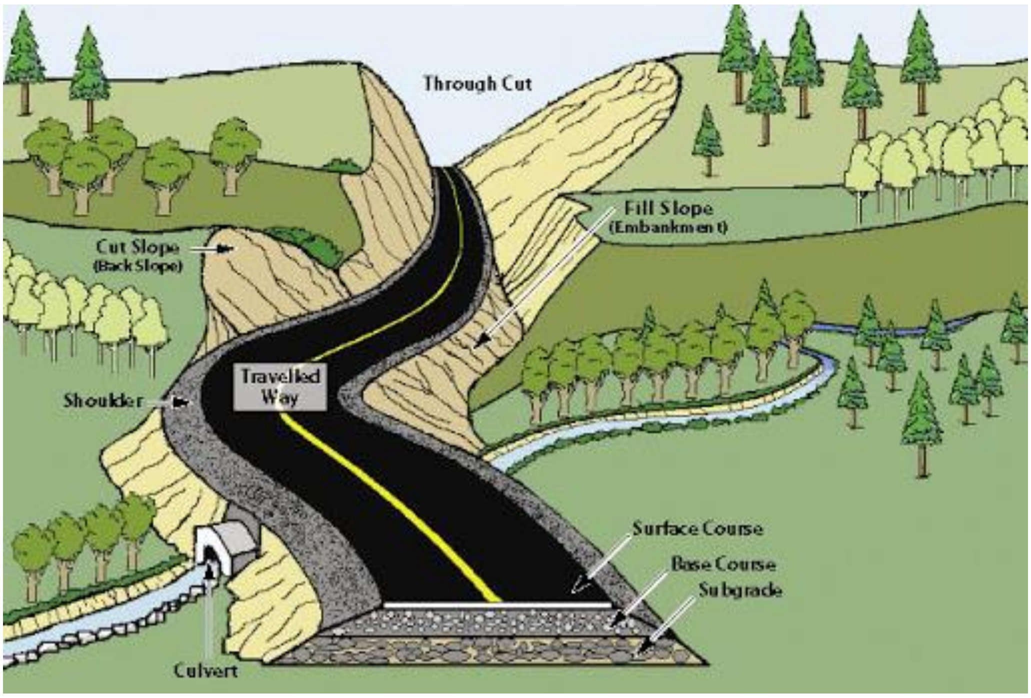

Figure 1 Backslope

Measuring and Recording Sight Distance

Sight distance should be considered in the preliminary stages of design when both the horizontal and vertical alignment are still subject to adjustment. By determining the available sight distances graphically on the plans and recording them at frequent intervals, the designer can review the overall layout and produce a more balanced design by minor adjustments in the plan or profile. Methods for scaling sight distances on plans are demonstrated in Figure 2, which also shows a typical sight distance record that would be shown on the final plans.

Because the view of the highway ahead may change rapidly in a short travel distance, it is desirable to measure and record sight distance for both directions of travel at each station. Both horizontal and vertical sight distances should be measured, and the shorter lengths recorded. In the case of a two-lane highway, passing sight distance should be measured and recorded in addition to stopping sight distance.

Examining sight distances along the proposed highway may be accomplished by direct scaling. Sight distance can be easily determined where plans and profiles are drawn using computer-aided design and drafting (CADD) systems.

Horizontal sight distance on the inside of a curve is limited by obstructions such as buildings, hedges, wooded areas, high ground, or other topographic features. These are generally plotted on the plans. Horizontal sight is measured with a straightedge, as indicated in the upper left portion of Figure 2. The cut slope obstruction is shown on the worksheets by a line representing the proposed excavation slope at a point 0.84 m above the road surface (i.e., the approximate average of 1.08 and 0.60 m for stopping sight distance and a point about 1.080 m above the road surface for passing sight distance. The position of this line with respect to the centerline may be scaled from the plotted highway cross sections. Preferably, the stopping sight distance should be measured between points on one traffic lane and passing sight distance from the middle of the other lane.

Vertical sight distance may be scaled from a plotted profile by the method illustrated at the right center of Figure 2. A transparent strip with parallel edges 1.08 m apart and with a scratched line 0.60 m from the upper edge, in accordance with the vertical scale, is a useful tool. The lower edge of the strip is placed on the station from which the vertical sight distance is desired, and the strip is pivoted about this point until the upper edge is tangent to the profile. The distance between the initial station and the station on the profile intersected by the 0.60-m line is the stopping sight distance. The distance between the initial station and the station on the profile intersected by the lower edge of the strip is the passing sight distance.

Sight distance records for two-lane highways may be used effectively to tentatively determine the marking of no-passing zones. Marking of such zones is an operational rather than a design responsibility. No-passing zones thus established serve as a guide for markings when the highway is completed. The zones so determined should be checked and adjusted by field measurements before actual markings are placed.

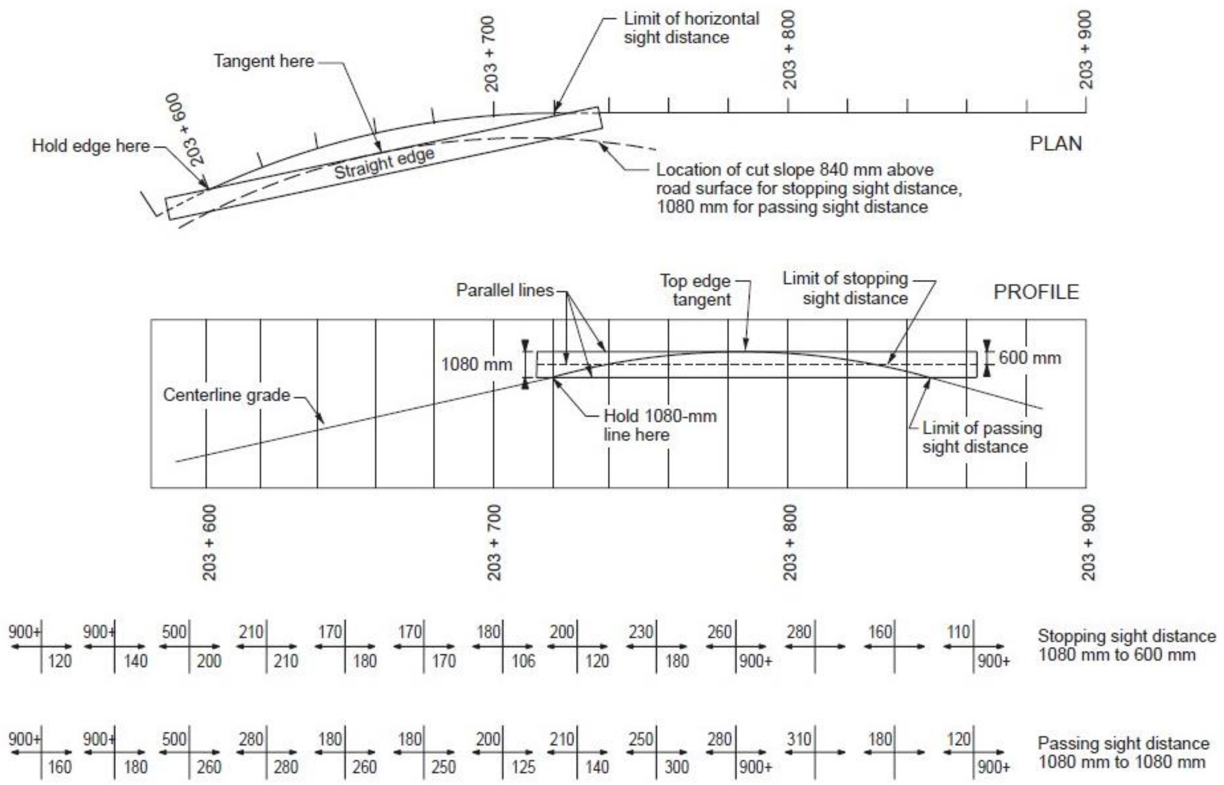

Figure 2 Scaling and Recording Sight Distances on Plans

2.2.5. Normal Cross Slope

The minimum rate of cross slope applicable to the traveled way is determined by drainage needs. Consistent with the type of highway and amount of rainfall, snow, and ice, the usually accepted minimum values for cross slope range from 1.5% percent to 2.0%.

2.2.6. Design for Rural Highways, Urban Freeways, and High-Speed Urban Streets

On rural highways, on urban freeways, and on urban streets where speed is relatively high and relatively uniform, horizontal curves are generally superelevated and successive curves are generally balanced to provide a smooth-riding transition from one curve to the next. A balanced design for a series of curves of varying radii is provided by the appropriate distribution of e and f values, as discussed before, to select an appropriate superelevation rate in the range from the normal cross slope to maximum superelevation.

Side Friction Factors

Figure 7 of Lecture 15 shows the recommended side friction factors for rural highways, urban freeways, and highspeed urban streets and highways as a solid line. They provide a reasonable margin of safety for the various speeds. The maximum side friction factors vary directly with design speed from 0.14 at 80 km/h to 0.08 at 130 km/h.

Superelevation

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. Use of Method 5 is discussed in the following text and figures.

Average Running Speed

Running speed was explained in Section 1.1.4 Lecture 14. The average running speed can be determined from the following table.

Table 1 Average running speed

Metric		U.S. Customary	
Design Speed (km/h)	Average Running Speed (km/h)	Design Speed (mph)	Average Running Speed (mph)
20	20	15	15
30	30	20	20
40	40	25	24
50	47	30	28
60	55	35	32
70	63	40	36
80	70	45	40
90	77	50	44
100	85	55	48
110	91	60	52
120	98	65	55
130	102	70	58
		75	61
		80	64

2.2.7. Procedure for Development of Method 5 Superelevation Distribution

The side friction factors shown as the solid line on Figure 7 of Lecture 15 represent the maximum f values selected for design for each speed. When these values are used in conjunction with the recommended Method 5, they determine the f distribution curves for the various speeds. Subtracting these computed f values from the computed value of $e/100 + f$ at the design speed, the finalized e distribution is thus obtained (see Figure 3). The finalized e distribution curves resulting from this approach, based on Method 5, and used below, are shown in Figures 4 to 8.

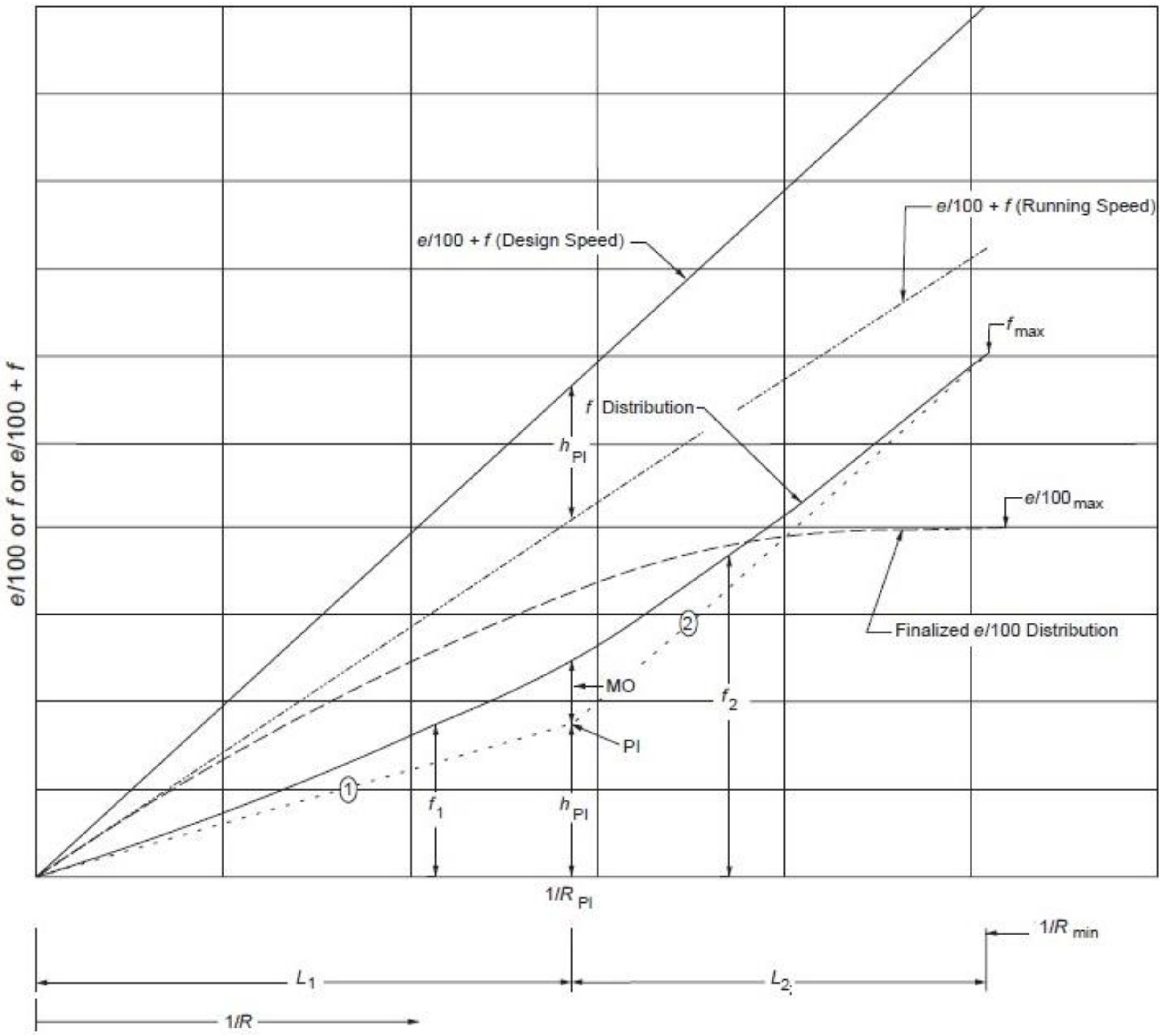

Figure 3 Method 5 Procedure for Development of the Superelevation Distribution

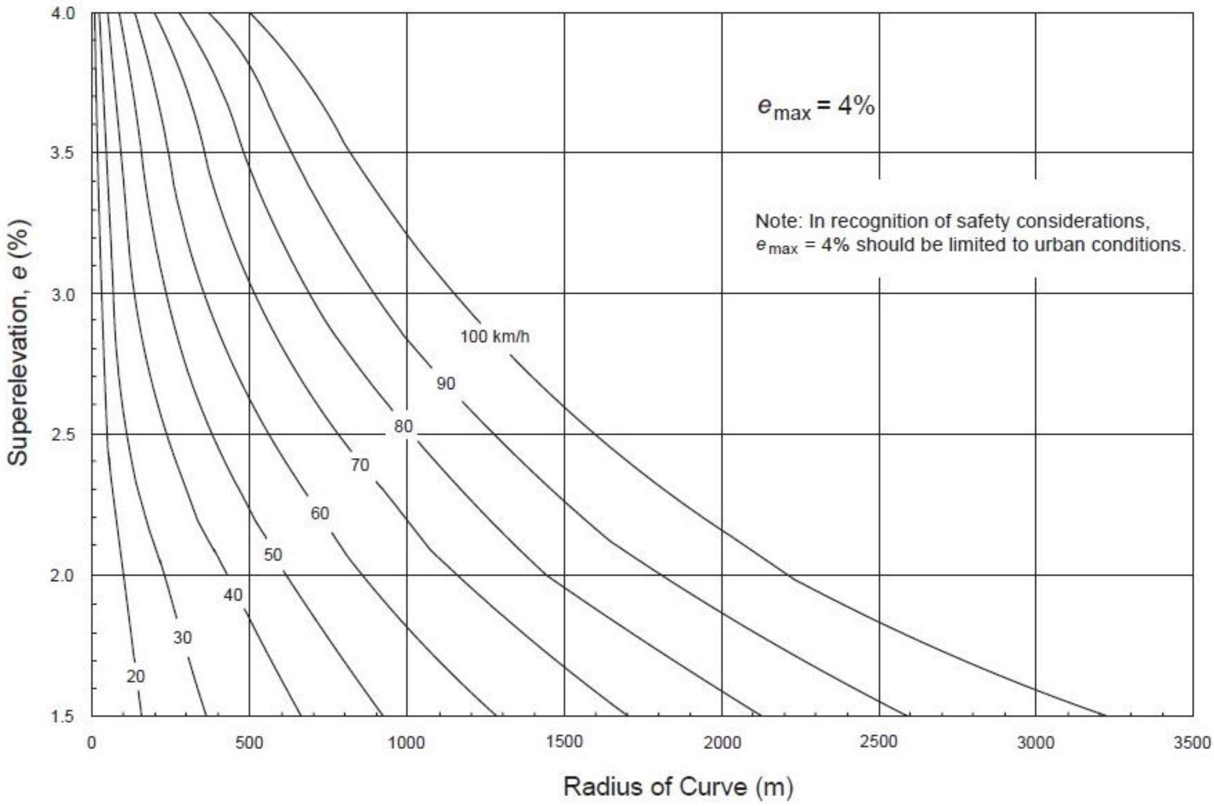

Figure 4 Design Superelevation Rates for Maximum Superelevation Rate of 4 Percent

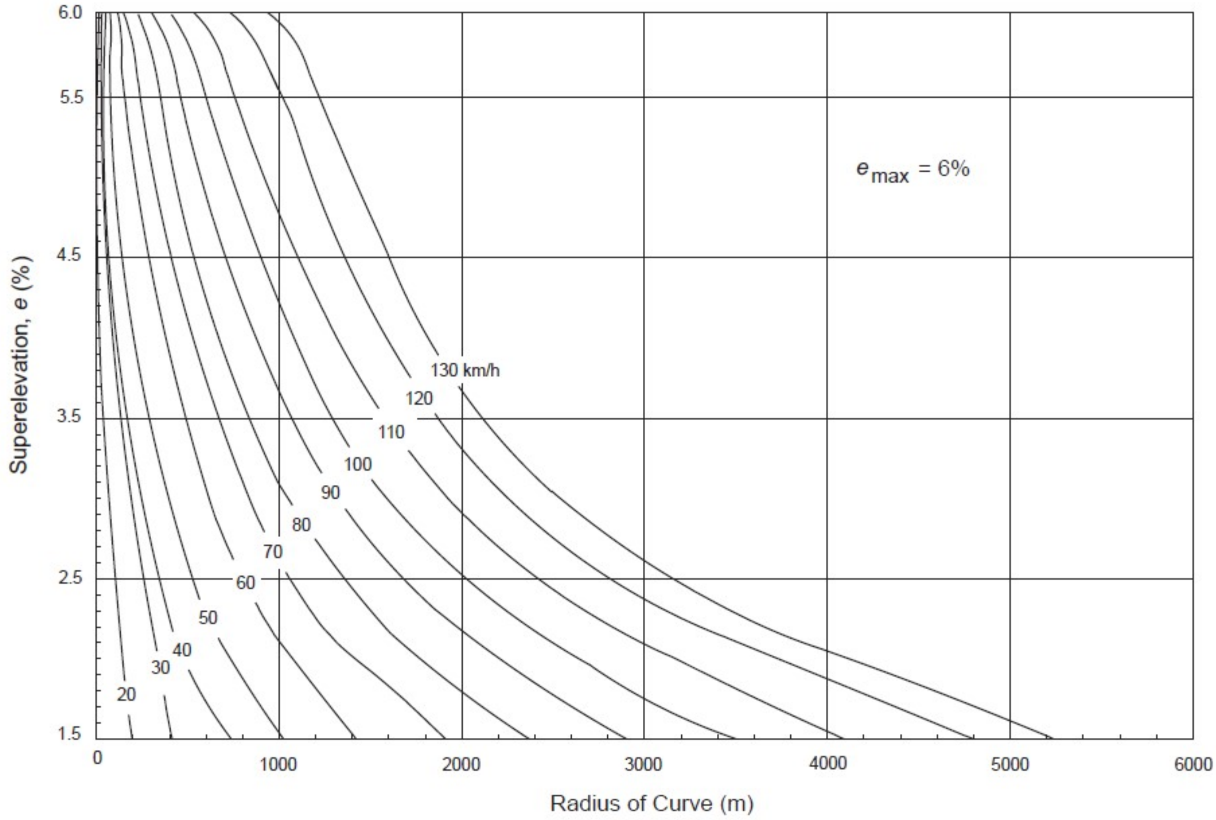

Figure 5 Design Superelevation Rates for Maximum Superelevation Rate of 6 Percent

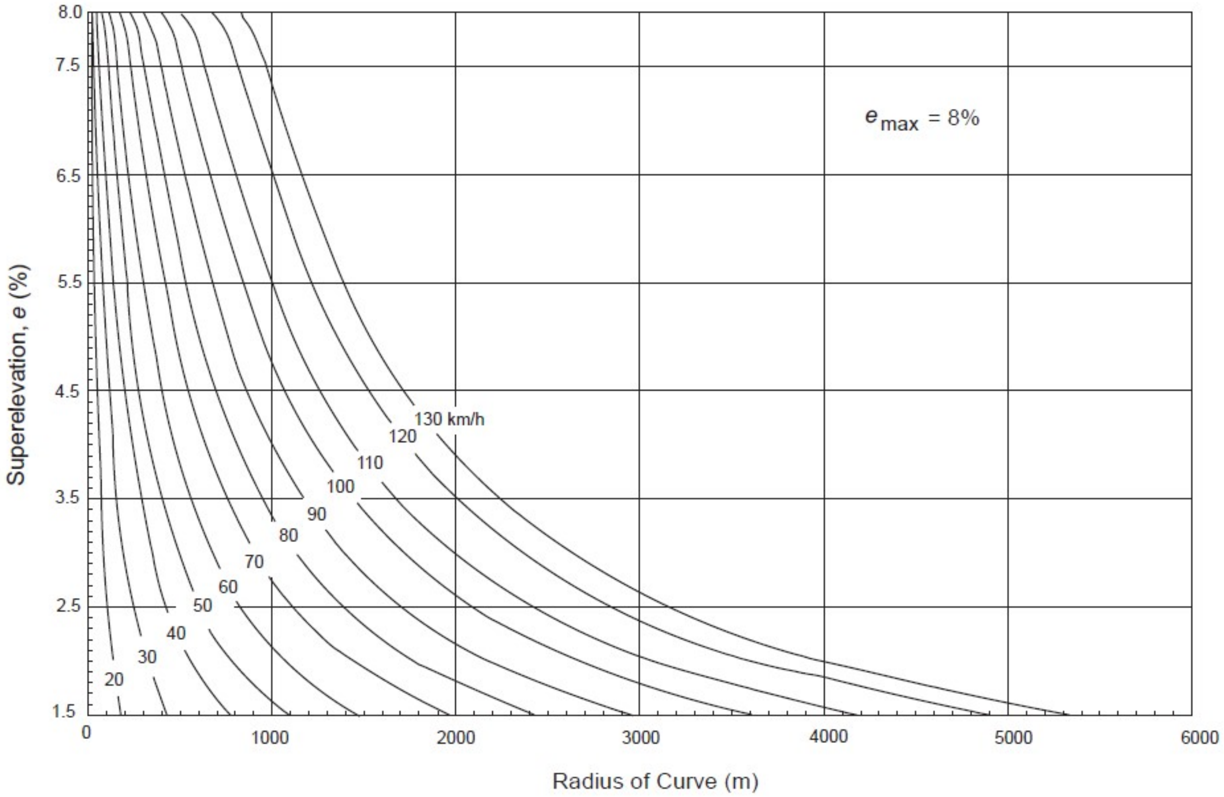

Figure 6 Design Superelevation Rates for Maximum Superelevation Rate of 8 Percent

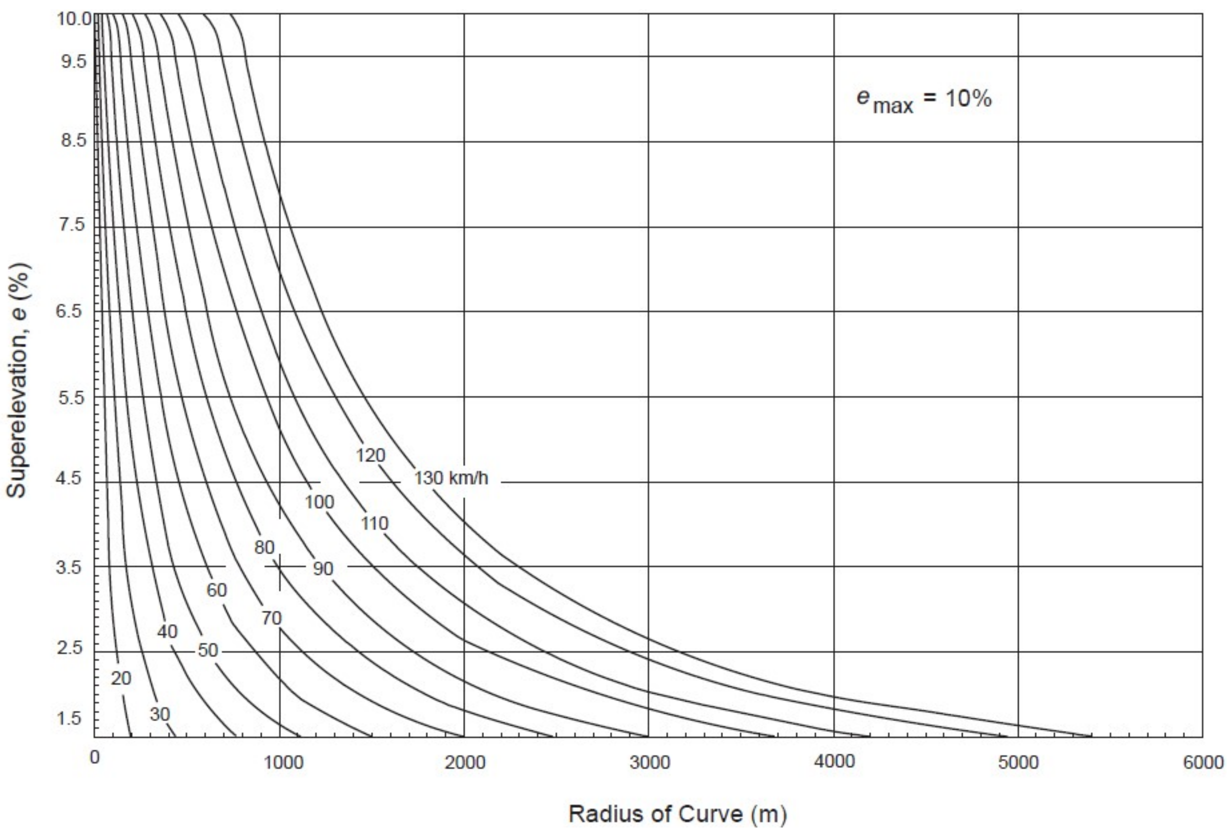

Figure 7 Design Superelevation Rates for Maximum Superelevation Rate of 10 Percent

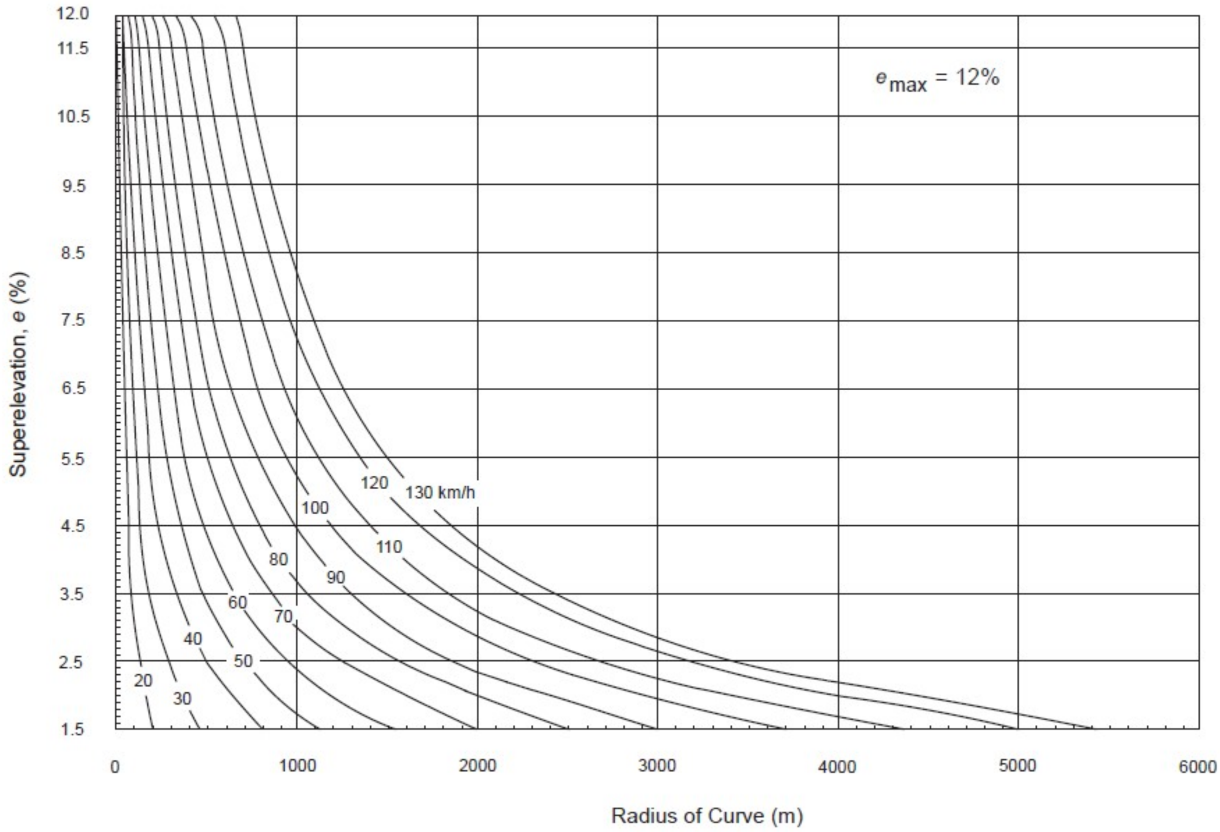

Figure 8 Design Superelevation Rates for Maximum Superelevation Rate of 12 Percent

The e and f distributions for Method 5 may be derived using the basic curve equation, neglecting the $(1 - 0.01ef)$ term as discussed earlier in this chapter, using the following sequence of equations:

$$0.01e + f = \frac{V^2}{127R}$$

where:

$V = V_D$ = design speed, km/h

$e = e_{max}$ = maximum superelevation, percent

$f = f_{max}$ = maximum allowable side friction factor

$R = R_{min}$ = minimum radius, m

then:

$$R_{min} = \frac{V_D^2}{127(0.01e_{max} + f_{max})}$$

and where:

$V = V_R$ = running speed, km/h

$R = R_{PI}$ = radius at the Point of Intersection, PI, of legs (1) and (2) of the f distribution parabolic curve (= R at the point of intersection of $0.01e_{max}$ and $(0.01e + f)_R$)

then:

$$R_{PI} = \frac{V_R^2}{1.27e_{max}}$$

Because $(0.01e + f)_D - (0.01e + f)_R = h$, at point R_{PI} the equations reduce to the following:

$$h_{PI} = \frac{(0.01e_{max})\ V_D^2}{V_R^2} - 0.01e_{max}$$

where h_{PI} = PI offset from the $1/R$ axis.

Also,

$$S_1 = h_{PI}(R_{PI})$$

where S_1 = slope of leg 1 and

$$S_2 = \frac{f_{\max} - h_{PI}}{\dfrac{1}{R_{\min}} - \dfrac{1}{R_{PI}}}$$

where S_2 = slope of leg 2.

The equation for the middle ordinate (MO) of an unsymmetrical vertical curve is the following:

$$MO = \frac{L_1 L_2 \left(S_2 - S_1\right)}{2\left(L_1 + L_2\right)}$$

where: $L_1 = 1/R_{PI}$ and $L_2 = 1/R_{\min} - 1/R_{PI}$.

It follows that:

$$MO = \frac{1}{R_{PI}}\left(\frac{1}{R_{\min}} - \frac{1}{R_{PI}}\right)\left(\frac{S_2 - S_1}{2}\right)R_{\min}$$

where MO = middle ordinate of the f distribution curve, and

$$\left(0.01e + f\right)_D = \frac{\left(0.01e_{\max} + f_{\max}\right)R_{\min}}{R}$$

in which R = radius at any point.

Use the general vertical curve equation:

$$\frac{Y}{MO} = \left(\frac{x}{L}\right)^2$$

with $1/R$ measured from the vertical axis.

With $1/R \leq 1/R_{PI}$,

$$f_1 = MO\left(\frac{R_{PI}}{R}\right)^2 + \frac{S_1}{R}$$

where: $f_1 = f$ distribution at any point $1/R \leq 1/R_{PI}$; and

$$0.01e_1 = (0.01e + f)_D - f_1$$

where: $0.01e_1 = 0.01e$ distribution at any point $1/R \leq 1/R_{PI}$.

For $1/R > 1/R_{PI}$,

$$f_2 = MO\left(\frac{\frac{1}{R_{min}} - \frac{1}{R}}{\frac{1}{R_{min}} - \frac{1}{R_{PI}}}\right)^2 + h_{PI} + S_2\left(\frac{1}{R} - \frac{1}{R_{PI}}\right)$$

where: $f_2 = f$ distribution at any point $1/R > 1/R_{PI}$; and

$$0.01e_2 = (0.01e + f)_D - f_2$$

where: $0.01e_2 = 0.01e$ distribution at any point $1/R > 1/R_{PI}$.

Figure 3 is a typical layout illustrating the Method 5 procedure for development of the finalized e distribution. The figure depicts how the f value is determined for $1/R$ and then subtracted from the value of ($e/100 + f$) to determine $e/100$.

Sample Example 1:

Calculate e for a design speed of 80 km/h and an e_{max} of 8 percent.

Solution:

From Table 1 of Lecture 15: V_R = 70 km/h

From Table 3-7 of Lecture 15: f = 0.14 (maximum allowable side friction factor)

Using the appropriate equations yields:

$$R_{\min} = \frac{{V_{\mathrm{D}}}^2}{127(0.01e_{\max} + f_{\max})} = \frac{80^2}{127(0.01 \times 8 + 0.14)} = 229.1 \text{ m}$$

$$R_{\mathrm{PI}} = \frac{V^2{}_{\mathrm{R}}}{1.27e_{\max}} = \frac{70^2}{1.27 \times 8} = 482.3 \text{ m}$$

$$h_{\mathrm{PI}} = \frac{(0.01e_{\max}){V_{\mathrm{D}}}^2}{{V_{\mathrm{R}}}^2} - 0.01e_{\max} = \frac{0.08 \times 80^2}{70^2} - 0.08 = 0.02449$$

$$S_1 = h_{\mathrm{PI}}(R_{\mathrm{PI}}) = 0.02449 \times 482.3 = 11.8$$

$$S_2 = \frac{f_{\max} - h_{\mathrm{PI}}}{\left(\frac{1}{R_{\min}} - \frac{1}{R_{\mathrm{PI}}}\right)} = \frac{0.14 - 0.02449}{\left(\frac{1}{229.1} - \frac{1}{482.3}\right)} = 50.4$$

$$L_1 = \frac{1}{R_{\mathrm{PI}}} = \frac{1}{482.3} = 0.002073$$

$$L_2 = \frac{1}{R_{\min}} - \frac{1}{R_{\mathrm{PI}}} = \frac{1}{229.1} - \frac{1}{482.3} = 0.002292$$

$$MO = \frac{L_1 L_2 (S_2 - S_1)}{2(L_1 + L_2)} = \frac{0.002073 \times 0.002292 \times (50.4 - 11.8)}{2(0.002073 + 0.002292)} = 0.02101$$

$$f_1 = MO\left(\frac{R_{\mathrm{PI}}}{R}\right)^2 + \frac{S_1}{R}$$

Assume $R = R_{\mathrm{PI}}$

$$f_1 = 0.02101 + \frac{11.8}{482.3} = 0.0455$$

$$0.01e + f = \frac{V^2{}_{\mathrm{D}}}{127R} = \frac{80^2}{127 \times 482.3} = 0.1045$$

$$e_1 = 0.01e + f - f_1 = 0.1045 - 0.0455 = 0.059 = 0.06 = 6\%$$

$$e = e_1 = 6\%$$

Method 5 Using Tables or Figures

Tables 2 to 6 show minimum values of R for various combinations of superelevation and design speeds based on the Method 5 superelevation distribution for each of five values of maximum superelevation rate.

Example 2:

Repeat Example 1 using Method 5 Tables.

Solution:

$$R = R_{\mathrm{PI}} = \frac{V^2{}_{\mathrm{R}}}{1.27e_{\max}} = \frac{70^2}{1.27 \times 8} = 482.3 \text{ m}$$

For 80 km/h and an $e_{\max}$ of 8%, use Table 4 or Figure 6 to find $e = 6\%$

*Table 2 Minimum Radii for Design Superelevation Rates, Design Speeds, and e_{max} = **4%***

Metric									
e (%)	V_d = 20 km/h	V_d = 30 km/h	V_d = 40 km/h	V_d = 50 km/h	V_d = 60 km/h	V_d = 70 km/h	V_d = 80 km/h	V_d = 90 km/h	V_d = 100 km/h
	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)
NC	163	371	679	951	1310	1740	2170	2640	3250
RC	102	237	441	632	877	1180	1490	1830	2260
2.2	75	187	363	534	749	1020	1290	1590	1980
2.4	51	132	273	435	626	865	1110	1390	1730
2.6	38	99	209	345	508	720	944	1200	1510
2.8	30	79	167	283	422	605	802	1030	1320
3.0	24	64	137	236	356	516	690	893	1150
3.2	20	54	114	199	303	443	597	779	1010
3.4	17	45	96	170	260	382	518	680	879
3.6	14	38	81	144	222	329	448	591	767
3.8	12	31	67	121	187	278	381	505	658
4.0	8	22	47	86	135	203	280	375	492

Note: Use of e_{max} = 4% should be limited to urban areas. For low-speed (70 km/h or less) facilities in urban areas, Method 2 may be used for superelevation distribution; see Table 3-13 for details.

*Table 3 Minimum Radii for Design Superelevation Rates, Design Speeds, and $e_{\max}$ = **6%***

Metric												
e (%)	V_d = 20 km/h	V_d = 30 km/h	V_d = 40 km/h	V_d = 50 km/h	V_d = 60 km/h	V_d = 70 km/h	V_d = 80 km/h	V_d = 90 km/h	V_d = 100 km/h	V_d = 110 km/h	V_d = 120 km/h	V_d = 130 km/h
	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)
NC	194	421	738	1050	1440	1910	2360	2880	3510	4060	4770	5240
RC	138	299	525	750	1030	1380	1710	2090	2560	2970	3510	3880
2.2	122	265	465	668	919	1230	1530	1880	2300	2670	3160	3500
2.4	109	236	415	599	825	1110	1380	1700	2080	2420	2870	3190
2.6	97	212	372	540	746	1000	1260	1540	1890	2210	2630	2930
2.8	87	190	334	488	676	910	1150	1410	1730	2020	2420	2700
3.0	78	170	300	443	615	831	1050	1290	1590	1870	2240	2510
3.2	70	152	269	402	561	761	959	1190	1470	1730	2080	2330
3.4	61	133	239	364	511	697	882	1100	1360	1600	1940	2180
3.6	51	113	206	329	465	640	813	1020	1260	1490	1810	2050
3.8	42	96	177	294	422	586	749	939	1170	1390	1700	1930
4.0	36	82	155	261	380	535	690	870	1090	1300	1590	1820
4.2	31	72	136	234	343	488	635	806	1010	1220	1500	1720
4.4	27	63	121	210	311	446	584	746	938	1140	1410	1630
4.6	24	56	108	190	283	408	538	692	873	1070	1330	1540
4.8	21	50	97	172	258	374	496	641	812	997	1260	1470
5.0	19	45	88	156	235	343	457	594	755	933	1190	1400
5.2	17	40	79	142	214	315	421	549	701	871	1120	1330
5.4	15	36	71	128	195	287	386	506	648	810	1060	1260
5.6	13	32	63	115	176	260	351	463	594	747	980	1190
5.8	11	28	56	102	156	232	315	416	537	679	900	1110
6.0	8	21	43	79	123	184	252	336	437	560	756	951

Table 4 Minimum Radii for Design Superelevation Rates, Design Speeds, and e_{max} *=* ***8%***

Metric												
e (%)	V_d – 20 km/h	V_d – 30 km/h	V_d – 40 km/h	V_d – 50 km/h	V_d – 60 km/h	V_d – 70 km/h	V_d – 80 km/h	V_d – 90 km/h	V_d – 100 km/h	V_d – 110 km/h	V_d – 120 km/h	V_d – 130 km/h
	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)
NC	184	443	784	1090	1490	1970	2440	2970	3630	4180	4900	5360
RC	133	322	571	791	1090	1450	1790	2190	2680	3090	3640	4000
2.2	119	288	512	711	976	1300	1620	1980	2420	2790	3290	3620
2.4	107	261	463	644	885	1190	1470	1800	2200	2550	3010	3310
2.6	97	237	421	587	808	1080	1350	1650	2020	2340	2760	3050
2.8	88	216	385	539	742	992	1240	1520	1860	2160	2550	2830
3.0	81	199	354	496	684	916	1150	1410	1730	2000	2370	2630
3.2	74	183	326	458	633	849	1060	1310	1610	1870	2220	2460
3.4	68	169	302	425	588	790	988	1220	1500	1740	2080	2310
3.6	62	156	279	395	548	738	924	1140	1410	1640	1950	2180
3.8	57	144	259	368	512	690	866	1070	1320	1540	1840	2060
4.0	52	134	241	344	479	648	813	1010	1240	1450	1740	1950
4.2	48	124	224	321	449	608	766	948	1180	1380	1650	1850
4.4	43	115	208	301	421	573	722	895	1110	1300	1570	1760
4.6	38	106	192	281	395	540	682	847	1050	1240	1490	1680
4.8	33	96	178	263	371	509	645	803	996	1180	1420	1610
5.0	30	87	163	246	349	480	611	762	947	1120	1360	1540
5.2	27	78	148	229	328	454	579	724	901	1070	1300	1480
5.4	24	71	136	213	307	429	549	689	859	1020	1250	1420
5.6	22	65	125	198	288	405	521	656	819	975	1200	1360
5.8	20	59	115	185	270	382	494	625	781	933	1150	1310
6.0	19	55	106	172	253	360	469	595	746	894	1100	1260
6.2	17	50	98	161	238	340	445	567	713	857	1060	1220
6.4	16	46	91	151	224	322	422	540	681	823	1020	1180
6.6	15	43	85	141	210	304	400	514	651	789	982	1140
6.8	14	40	79	132	198	287	379	489	620	757	948	1100
7.0	13	37	73	123	185	270	358	464	591	724	914	1070
7.2	12	34	68	115	174	254	338	440	561	691	879	1040
7.4	11	31	62	107	162	237	318	415	531	657	842	998
7.6	10	29	57	99	150	221	296	389	499	621	803	962
7.8	9	26	52	90	137	202	273	359	462	579	757	919
8.0	7	20	41	73	113	168	229	304	394	501	667	832

Table 5 Minimum Radii for Design Superelevation Rates, Design Speeds, and e_{max} = 10%

Metric												
e (%)	V_d = 20 km/h	V_d = 30 km/h	V_d = 40 km/h	V_d = 50 km/h	V_d = 60 km/h	V_d = 70 km/h	V_d = 80 km/h	V_d = 90 km/h	V_d = 100 km/h	V_d = 110 km/h	V_d = 120 km/h	V_d = 130 km/h
	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)
NC	197	454	790	1110	1520	2000	2480	3010	3690	4250	4960	5410
RC	145	333	580	815	1120	1480	1840	2230	2740	3160	3700	4050
2.2	130	300	522	735	1020	1340	1660	2020	2480	2860	3360	3680
2.4	118	272	474	669	920	1220	1520	1840	2260	2620	3070	3370
2.6	108	249	434	612	844	1120	1390	1700	2080	2410	2830	3110
2.8	99	229	399	564	778	1030	1290	1570	1920	2230	2620	2880
3.0	91	211	368	522	720	952	1190	1460	1790	2070	2440	2690
3.2	85	196	342	485	670	887	1110	1360	1670	1940	2280	2520
3.4	79	182	318	453	626	829	1040	1270	1560	1820	2140	2370
3.6	73	170	297	424	586	777	974	1200	1470	1710	2020	2230
3.8	68	159	278	398	551	731	917	1130	1390	1610	1910	2120
4.0	64	149	261	374	519	690	866	1060	1310	1530	1810	2010
4.2	60	140	245	353	490	652	820	1010	1240	1450	1720	1910
4.4	56	132	231	333	464	617	777	953	1180	1380	1640	1820
4.6	53	124	218	315	439	586	738	907	1120	1310	1560	1740
4.8	50	117	206	299	417	557	703	864	1070	1250	1490	1670
5.0	47	111	194	283	396	530	670	824	1020	1200	1430	1600
5.2	44	104	184	269	377	505	640	788	975	1150	1370	1540
5.4	41	98	174	256	359	482	611	754	934	1100	1320	1480
5.6	39	93	164	243	343	461	585	723	896	1060	1270	1420
5.8	36	88	155	232	327	441	561	693	860	1020	1220	1370
6.0	33	82	146	221	312	422	538	666	827	976	1180	1330
6.2	31	77	138	210	298	404	516	640	795	941	1140	1280
6.4	28	72	130	200	285	387	496	616	766	907	1100	1240
6.6	26	67	121	191	273	372	476	593	738	876	1060	1200
6.8	24	62	114	181	261	357	458	571	712	846	1030	1170
7.0	22	58	107	172	249	342	441	551	688	819	993	1130
7.2	21	55	101	164	238	329	425	532	664	792	963	1100
7.4	20	51	95	156	228	315	409	513	642	767	934	1070
7.6	18	48	90	148	218	303	394	496	621	743	907	1040
7.8	17	45	85	141	208	291	380	479	601	721	882	1010
8.0	16	43	80	135	199	279	366	463	582	699	857	981
8.2	15	40	76	128	190	268	353	448	564	679	834	956
8.4	14	38	72	122	182	257	339	432	546	660	812	932
8.6	14	36	68	116	174	246	326	417	528	641	790	910
8.8	13	34	64	110	166	236	313	402	509	621	770	888
9.0	12	32	61	105	158	225	300	386	491	602	751	867
9.2	11	30	57	99	150	215	287	371	472	582	731	847
9.4	11	28	54	94	142	204	274	354	453	560	709	828
9.6	10	26	50	88	133	192	259	337	432	537	685	809
9.8	9	24	46	81	124	179	242	316	407	509	656	786
10.0	7	19	38	68	105	154	210	277	358	454	597	739

Table 6 Minimum Radii for Design Superelevation Rates, Design Speeds, and e_{max} = 12%

Metric												
e (%)	V_d = 20 km/h	V_d = 30 km/h	V_d = 40 km/h	V_d = 50 km/h	V_d = 60 km/h	V_d = 70 km/h	V_d = 80 km/h	V_d = 90 km/h	V_d = 100 km/h	V_d = 110 km/h	V_d = 120 km/h	V_d = 130 km/h
	R (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)	*R* (m)
NC	210	459	804	1130	1540	2030	2510	3040	3720	4280	4990	5440
RC	155	338	594	835	1150	1510	1870	2270	2770	3190	3740	4080
2.2	139	306	536	755	1040	1360	1690	2050	2510	2900	3390	3710
2.4	127	278	488	688	942	1250	1550	1880	2300	2650	3110	3400
2.6	116	255	448	631	865	1140	1420	1730	2110	2440	2860	3140
2.8	107	235	413	583	799	1060	1320	1600	1960	2260	2660	2910
3.0	99	218	382	541	742	980	1220	1490	1820	2110	2480	2720
3.2	92	202	356	504	692	914	1140	1390	1700	1970	2320	2550
3.4	86	189	332	472	648	856	1070	1300	1600	1850	2180	2400
3.6	81	177	312	443	609	805	1010	1230	1510	1750	2060	2270
3.8	76	166	293	417	573	759	947	1160	1420	1650	1950	2150
4.0	71	157	276	393	542	718	896	1100	1350	1560	1850	2040
4.2	67	148	261	372	513	680	850	1040	1280	1490	1760	1940
4.4	64	140	247	353	487	646	808	988	1220	1420	1680	1850
4.6	60	132	234	335	436	615	770	941	1160	1350	1600	1770
4.8	57	126	222	319	441	586	734	899	1110	1290	1530	1700
5.0	54	119	211	304	421	560	702	860	1060	1240	1470	1630

5.2	52	114	201	290	402	535	672	824	1020	1190	1410	1570
5.4	49	108	192	277	384	513	644	790	973	1140	1360	1510
5.6	47	103	183	265	368	492	618	759	936	1100	1310	1460
5.8	45	98	175	254	353	472	594	730	900	1060	1260	1410
6.0	43	94	167	244	339	454	572	703	867	1020	1220	1360
6.2	41	90	159	234	326	436	551	678	837	981	1180	1310
6.4	39	86	153	225	313	420	531	654	808	948	1140	1270
6.6	37	82	146	216	302	405	512	632	781	917	1100	1230
6.8	35	78	140	208	290	391	494	611	755	888	1070	1200
7.0	34	75	134	200	280	377	478	591	731	860	1040	1160
7.2	32	71	128	192	270	364	462	572	708	834	1010	1130
7.4	30	68	122	185	260	352	447	554	686	810	974	1100
7.6	29	65	117	178	251	340	433	537	666	786	947	1070
7.8	27	61	112	172	243	329	420	521	646	764	921	1040
8.0	26	58	107	165	235	319	407	506	628	743	897	1020
8.2	24	55	102	159	227	309	395	491	610	723	874	989
8.4	23	52	97	154	219	299	383	477	593	704	852	965
8.6	22	50	93	148	212	290	372	464	577	686	831	942
8.8	20	47	88	142	205	281	361	451	562	668	811	921
9.0	19	45	85	137	198	273	351	439	547	652	792	900
9.2	18	43	81	132	191	264	341	428	533	636	774	880
9.4	18	41	77	127	185	256	332	416	520	621	756	861
9.6	17	39	74	123	179	249	323	406	507	606	739	843
9.8	16	37	71	118	173	241	314	395	494	592	723	826
10.0	15	36	68	114	167	234	305	385	482	579	708	809
10.2	14	34	65	110	161	226	296	375	471	566	693	793
10.4	14	33	62	105	155	219	288	365	459	553	679	778
10.6	13	31	59	101	150	212	279	355	448	541	665	763
10.8	12	30	57	97	144	204	270	345	436	529	652	749
11.0	12	28	54	93	139	197	261	335	423	516	639	735
11.2	11	27	51	89	133	189	252	324	411	503	626	722
11.4	11	25	49	85	127	182	242	312	397	488	613	709
11.6	10	24	46	80	120	173	232	300	382	472	598	697
11.8	9	22	43	75	113	163	219	285	364	453	579	685
12.0	7	18	36	64	98	143	194	255	328	414	540	665