Superelevation Calculation

TDOT Department of Transportation **Roadway Design Division**

Website www.tn.gov/tdot/roadway-design/training.html

Email TDOT.RoadwayDesignDivisionTraining@tn.gov

The purpose of this tutorial is to demonstrate the calculation of superelevation rates at critical points along a roadway alignment according to the standards specified in the Standard Drawings:

RD11-SE-1

RD11-SE-2

RD11-SE-2A

RD11-SE-3

RD11-SE-3A

RD11-LR-1

RD11-LR-2

Horizontal curves will no longer be identified by degree, they will be identified by radius only. Standard Drawings RD11-LR-1 (Urban) and RD11-LR2 (Rural) contain tables for different design speeds, and number of lanes, showing the superelevation rate (e_d) associated with curve radius. One important thing to note that is different from the earlier standards is that for a specific e_d, the radius shown is the minimum radius that can be used. Also for a given radius, the corresponding super rate is the minimum that can be used.

③

e_d	V = 20 (MPH)						
	R	Number of lanes					R
(%)	MIN. (FT.)	2	3	4	5	6	MIN (FT.
NC	1640	0	0	0	0	0	237(
2	1190	32	40	49	57	65	172(
2.2	1070	36	44	54	62	72	155(
2.4	959	39	48	58	68	78	140(
2.6	872	42	52	63	74	85	128(
2.8	796	45	57	68	79	91	117(
3	730	49	61	73	85	98	107(
3.2	672	52	65	78	91	104	985
3.4	620	55	69	83	96	111	911
3.6	572	58	73	88	102	117	845
3.8	530	62	77	92	108	124	784
4	490	65	81	97	114	130	729
4.2	453	68	85	102	119	137	678
4.4	418	71	89	107	125	143	630
4.6	384	75	93	112	131	150	585
4.8	349	78	97	117	136	156	542

For example, given a radius of 730 ft., the corresponding super rate is 3%. If the e_d is to remain at 3%, any radius higher than 730 can be used. If the radius is to remain at 730, any e_d lower than 3% can be used.

The numbers that appear under the number of lanes are runoff lengths (L_R). The total transition length (L) is the length at which the transition from Normal Crown (NC) to full super (e_d) takes place.

The formula for the total transition length is found on Standard Drawing RD11-SE-1.

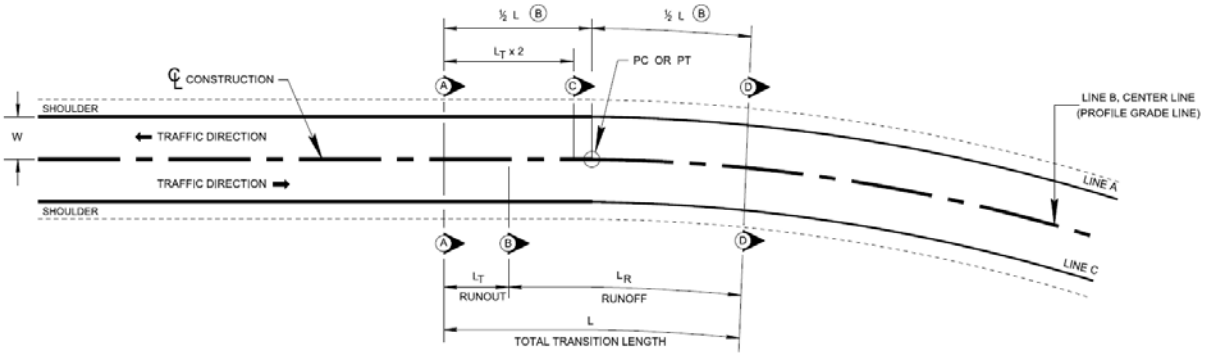
SUPERELEVATION TRANSITION EQUATIONS

$$L = L_R + L_T$$

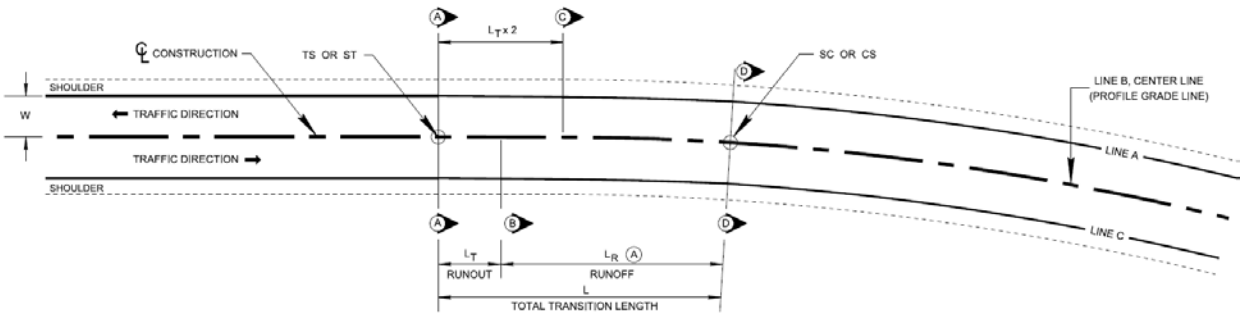
$$L_R = \frac{(W n 1)\, e_d}{\Delta\%} (b_w)$$

$$L_T = \frac{NC}{e_d} L_R$$

Standard Drawing RD11 SE-2 shows the relationship of L to the begin and end points of the horizontal curve.



TRANSITION DETAILS - TANGENT TO CURVE

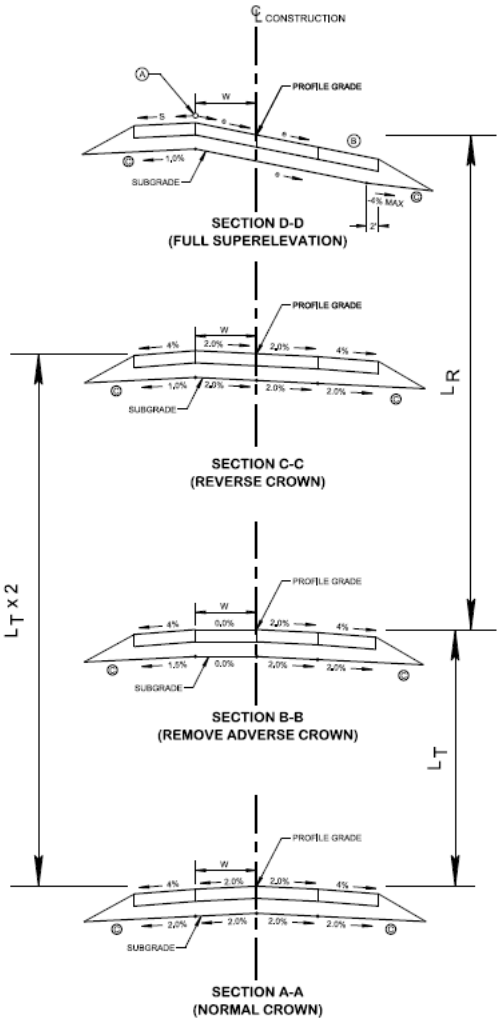


TRANSITION DETAILS - SPIRAL CURVE

For a simple curve half of the transition length is before and half after the P.C. or P.T.

For a spiral curve L is the same as the length of the spiral.

Standard Drawing RD11-SE-2A shows the lengths at which key points occur within the transition length.



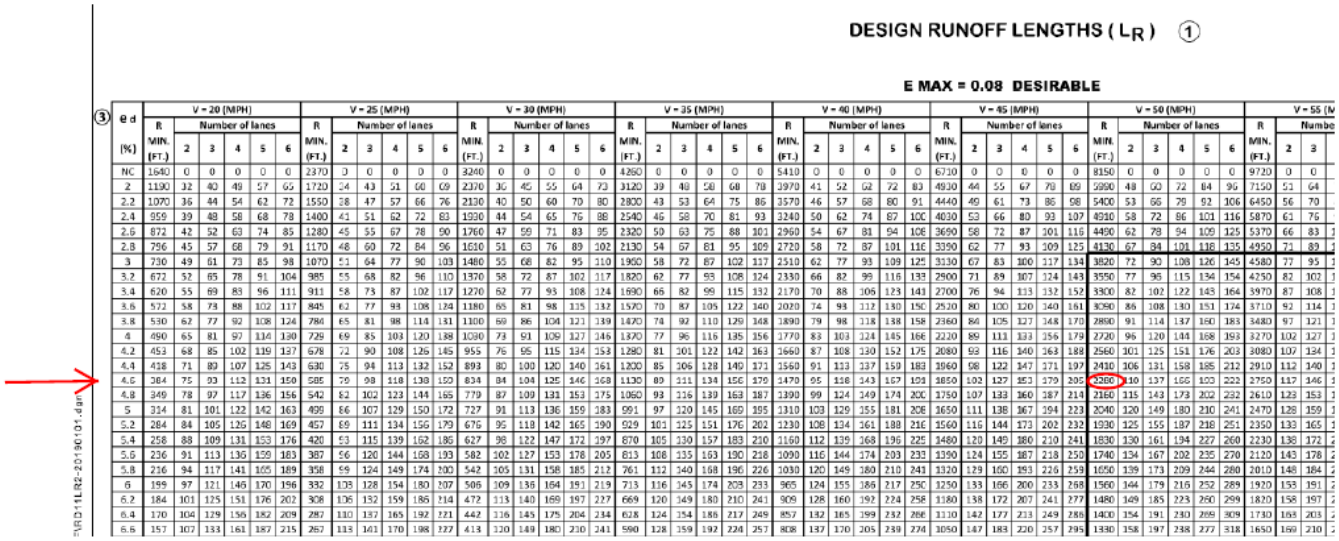
NOT TO SCALE

Standard Drawings RD11-SE-3 and 3A contain the same information as RD11-SE-2 and 2A, except for divided highways.

Example 1

1) 2 lane rural design
2) Design Speed 50 MPH
3) Curve Radius 2280 ft.

According to Std. Dwg. RD11-LR-2 (Minimum Runoff Lengths for Rural Highways), the superelevation rate (e_d) for this curve is 4.6% (.046 ft./ft.). 2280 ft. is the minimum radius that can be used with this rate. This also means that for a particular e_d rate a higher radius can be used.



DESIGN RUNOFF LENGTHS (L_R) ①

E MAX = 0.08 DESIRABLE

③ e_d	V = 20 (MPH)						V = 25 (MPH)						V = 30 (MPH)						V = 35 (MPH)						V = 40 (MPH)						V = 45 (MPH)						V = 50 (MPH)						V = 55 (M					
	R	Number of lanes					R	Number of lanes					R	Number of lanes					R	Number of lanes					R	Number of lanes					R	Number of lanes					R	Number of lanes					R	Numbe				
(%)	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3	4	5	6
NC	1640	0	0	0	0	0	2370	0	0	0	0	0	3240	0	0	0	0	0	4260	0	0	0	0	0	5410	0	0	0	0	0	6710	0	0	0	0	0	8150	0	0	0	0	0	9720	0	0			
2	1190	32	40	49	57	65	1720	34	43	51	60	69	2370	36	45	55	64	73	3120	39	48	58	68	78	3970	41	52	62	72	83	4930	44	55	67	78	89	5990	48	60	72	84	96	7150	51	64			
2.2	1070	36	44	54	62	72	1550	38	47	57	66	76	2130	40	50	60	70	80	2800	43	53	64	75	86	3570	46	57	68	80	91	4440	49	61	73	86	98	5400	53	66	79	92	106	6450	56	70			
2.4	959	39	48	58	68	78	1400	41	51	62	72	83	1930	44	54	65	76	88	2540	46	58	70	81	93	3240	50	62	74	87	100	4030	53	66	80	93	107	4910	58	72	86	101	116	5870	61	76			
2.6	872	42	52	63	74	85	1280	45	55	67	78	90	1760	47	59	71	83	95	2320	50	63	75	88	101	2960	54	67	81	94	108	3690	58	72	87	101	116	4490	62	78	94	109	125	5370	66	83			
2.8	796	45	57	68	79	91	1170	48	60	72	84	96	1610	51	63	76	89	102	2130	54	67	81	95	109	2720	58	72	87	101	116	3390	62	77	93	109	125	4130	67	84	101	118	135	4950	71	89			
3	730	49	61	73	85	98	1070	51	64	77	90	103	1480	55	68	82	95	110	1950	58	72	87	102	117	2510	62	77	93	109	125	3130	67	83	100	117	134	3820	72	90	108	126	145	4580	77	95			
3.2	672	52	65	78	91	104	985	55	68	82	96	110	1370	58	72	87	102	117	1820	62	77	93	108	124	2330	66	82	98	116	133	2900	71	89	107	124	143	3550	77	96	115	134	154	4250	82	102			
3.4	620	55	69	83	96	111	911	58	73	87	102	117	1270	62	77	93	108	124	1690	66	82	99	115	132	2170	70	88	106	123	141	2700	76	94	113	132	152	3300	82	102	122	143	164	3970	87	108			
3.6	572	58	73	88	102	117	845	62	77	93	108	124	1180	65	81	98	115	132	1570	70	87	105	122	140	2020	74	93	112	130	150	2520	80	100	120	140	161	3090	86	108	130	151	174	3710	92	114			
3.8	530	62	77	92	108	124	786	65	81	98	114	131	1100	69	86	104	121	139	1470	74	92	110	129	148	1890	79	98	118	138	158	2360	86	105	127	148	170	2890	91	114	137	160	183	3480	97	121			
4	490	65	81	97	114	130	729	69	85	103	120	138	1030	73	91	109	127	146	1370	77	96	116	135	156	1770	83	103	124	145	166	2220	89	111	133	156	179	2720	96	120	144	168	193	3270	102	127			
4.2	453	68	85	102	119	137	678	72	90	108	126	145	955	76	95	115	134	153	1280	81	101	122	142	163	1660	87	108	130	152	175	2080	93	116	140	163	188	2560	101	125	151	176	203	3080	107	134			
4.4	418	71	89	107	125	143	630	75	94	113	132	152	893	80	100	120	140	161	1200	85	106	128	149	171	1560	91	113	137	159	183	1960	98	122	147	171	197	2410	106	131	158	185	212	2910	112	140			
4.6	384	75	93	112	131	150	585	79	98	118	138	159	834	84	104	125	146	168	1130	89	111	134	156	179	1470	95	118	143	167	193	1850	102	127	153	179	205	2260	110	137	166	193	222	2750	117	146			
4.8	349	78	97	117	136	156	542	82	102	123	144	165	779	87	109	131	153	175	1060	93	116	139	163	187	1390	99	124	149	174	200	1750	107	133	160	187	214	2160	115	143	173	202	232	2610	123	153			
5	314	81	101	122	142	163	499	86	107	129	150	172	727	91	113	136	159	183	991	97	120	145	169	195	1310	103	129	155	181	208	1650	111	138	167	194	223	2040	120	149	180	210	241	2470	128	159			
5.2	284	84	105	126	148	169	457	89	111	134	156	179	676	95	118	142	165	190	929	101	125	151	176	202	1230	108	134	161	188	216	1560	116	144	173	202	232	1930	125	155	187	218	251	2350	133	165			
5.4	258	88	109	131	153	176	420	93	115	139	162	186	627	98	122	147	172	197	870	105	130	157	183	210	1160	112	139	168	196	225	1480	120	149	180	210	241	1830	130	161	194	227	260	2230	138	172			
5.6	236	91	113	136	159	183	387	96	120	144	168	193	582	102	127	153	178	205	813	108	135	163	190	218	1090	116	144	174	203	233	1390	124	155	187	218	250	1740	134	167	202	235	270	2120	143	178			
5.8	216	94	117	141	165	189	358	99	124	149	174	200	542	105	131	158	185	212	761	112	140	168	196	226	1030	120	149	180	210	241	1320	129	160	193	226	259	1650	139	173	209	244	280	2010	148	184			
6	199	97	121	146	170	196	332	103	128	154	180	207	506	109	136	164	191	219	713	116	145	174	203	233	965	124	155	186	217	250	1250	133	166	200	233	268	1560	144	179	215	252	289	1920	153	191			
6.2	184	101	125	151	176	202	308	106	132	159	186	214	472	113	140	169	197	227	669	120	149	180	210	241	909	128	160	192	224	258	1180	138	172	207	241	277	1480	149	185	223	260	299	1820	158	197			
6.4	170	104	129	156	182	209	287	110	137	165	192	221	442	116	145	175	204	234	628	124	154	186	217	249	857	132	165	199	232	266	1110	142	177	213	249	286	1400	154	191	230	269	309	1730	163	203			
6.6	157	107	133	161	187	215	267	113	141	170	198	227	413	120	149	180	210	241	590	128	159	192	224	257	808	137	170	205	239	274	1050	147	183	220	257	295	1330	158	197	238	277	318	1650	169	210			

For instance, according to the table, a radius of 4400 ft. can be used with a superelevation rate of 4.6%. Conversely, for a radius of 2280 ft. a superelevation rate of lower than 4.6% can be used.

In the table, the runoff lengths are given. For a rate of 4.6% and R = 2280, the runoff length (L_R) is 110 feet for 2 lanes.

	V = 50 (MPH)						
	R	Number of lanes					R
5	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)
0	8150	0	0	0	0	0	9720
9	5990	48	60	72	84	96	7150
8	5400	53	66	79	92	106	6450
07	4910	58	72	86	101	116	5870
16	4490	62	78	94	109	125	5370
25	4130	67	84	101	118	135	4950
34	3820	72	90	108	126	145	4580
43	3550	77	96	115	134	154	4250
52	3300	82	102	122	143	164	3970
51	3090	86	108	130	151	174	3710
70	2890	91	114	137	160	183	3480
79	2720	96	120	144	168	193	3270
88	2560	101	125	151	176	203	3080
97	2410	106	131	158	185	212	2910
05	2280	110	137	166	193	222	2750
14	2160	115	143	173	202	232	2610
23	2040	120	149	180	210	241	2470
32	1930	125	155	187	218	251	2350

In Std. Dwg. RD11-SE-1, the total transition length (L) is equal to $L_R + L_T$, where L_T is the Tangent Runout Length.

SUPERELEVATION TRANSITION EQUATIONS

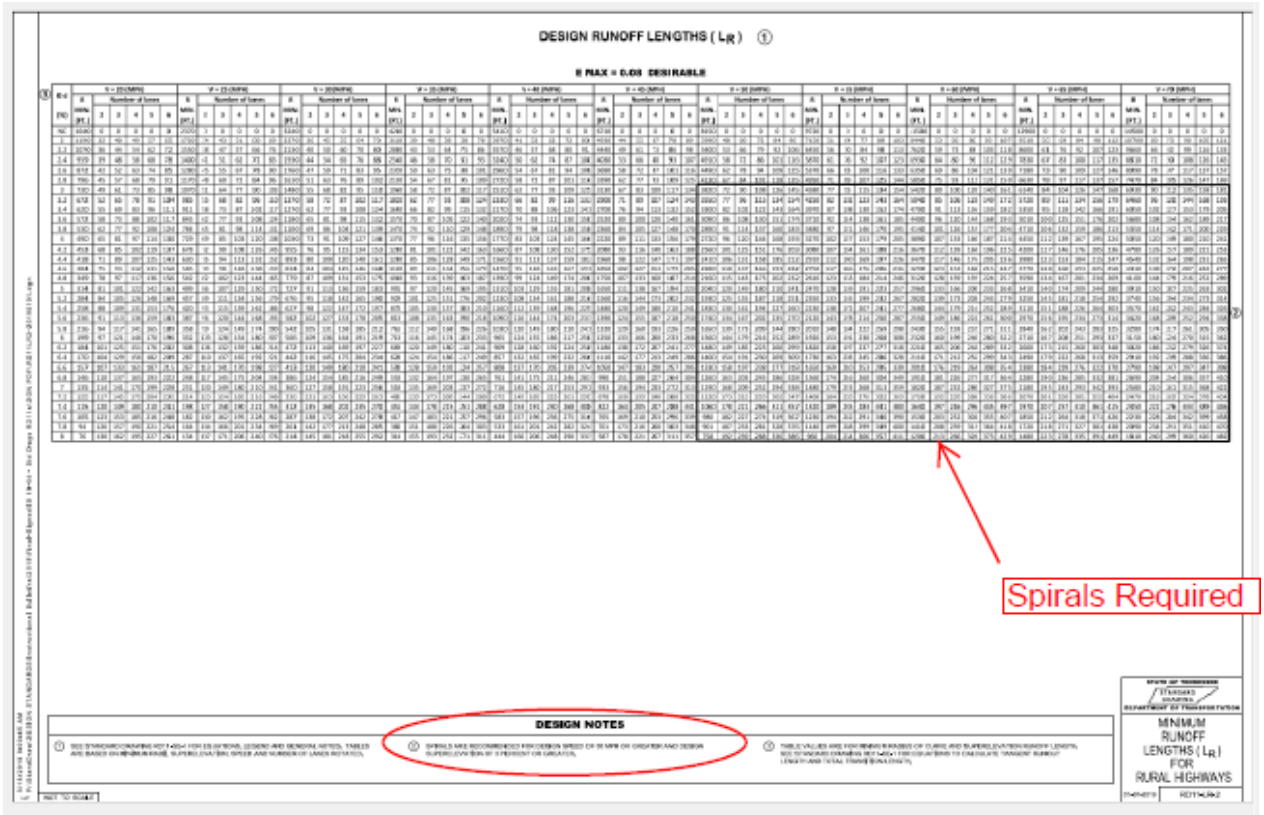
$$L = L_R + L_T$$

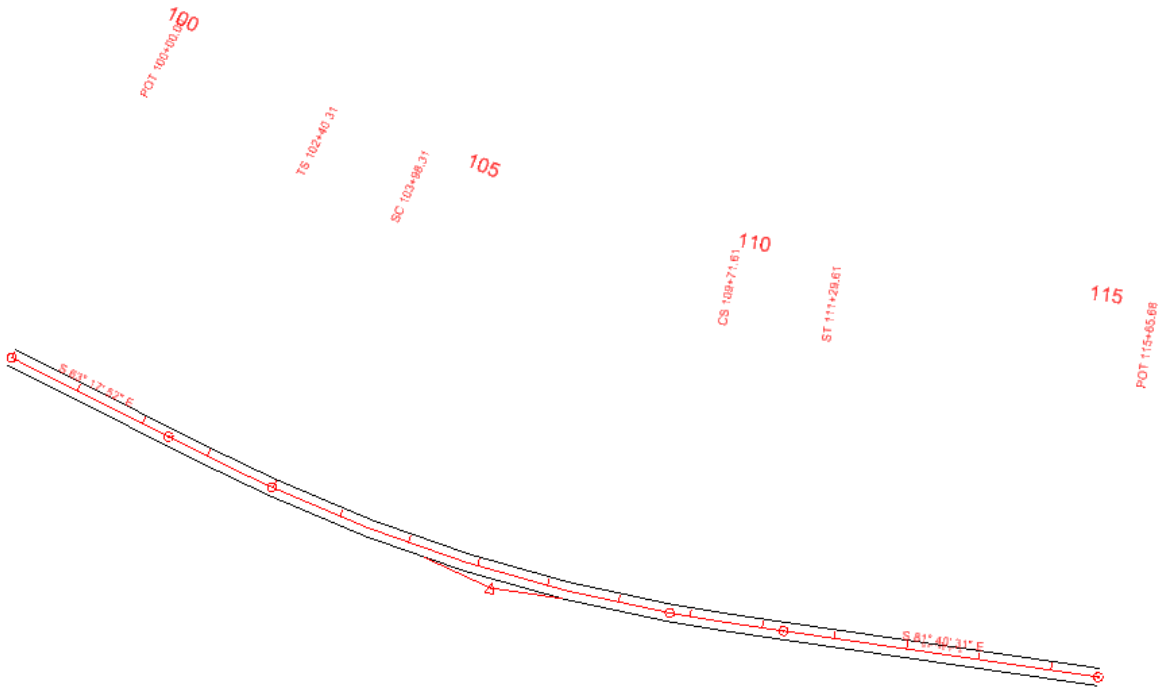
$$L_R = \frac{(W n 1)\, e_d}{\Delta\%} (b_w)$$

$$L_T = \frac{NC}{e_d} L_R$$

According to the equation on RD11-SE-1, L_T equals to 47.83 (2/4.6 x 110), and the total transition length (L) would be 110 + 47.83 = 157.83, rounded to 158 ft.

Going back to RD11-LR-2, note #2 at the bottom of the sheet says that spirals are recommended for design speeds of 50 MPH or greater and superelevation of 3% or greater. So, in our example L is also equal to spiral length.





Plan view of proposed alignment

The alignment's beginning station is 100+00.

The T.S. of the curve is at station 102+40.31.

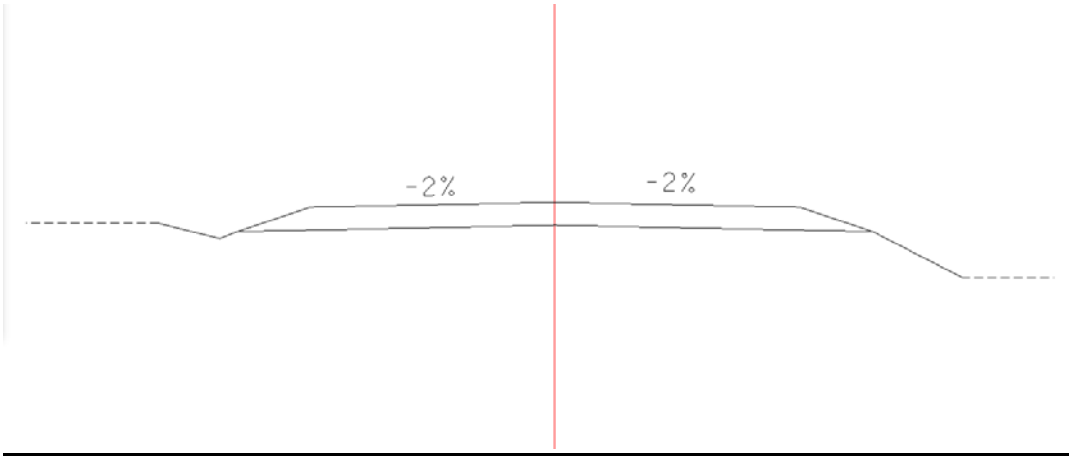
The S.C. of the curve is at station 103+98.31.

The C.S. of the curve is at station 109+71.61.

The S.T. of the curve is at station 111+29.61.

The alignment's end station is 115+65.68.

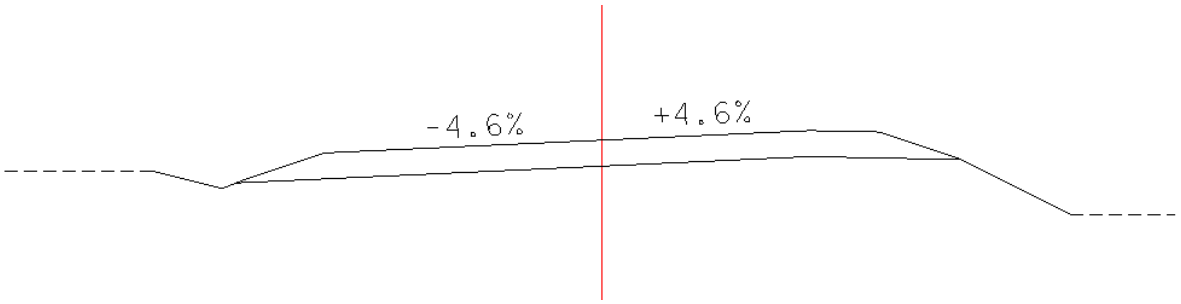
The alignment starts out at normal crown at station 100+00.



Normal Crown

The transition to superelevation will begin at the T.S. point, station 102+40.31.

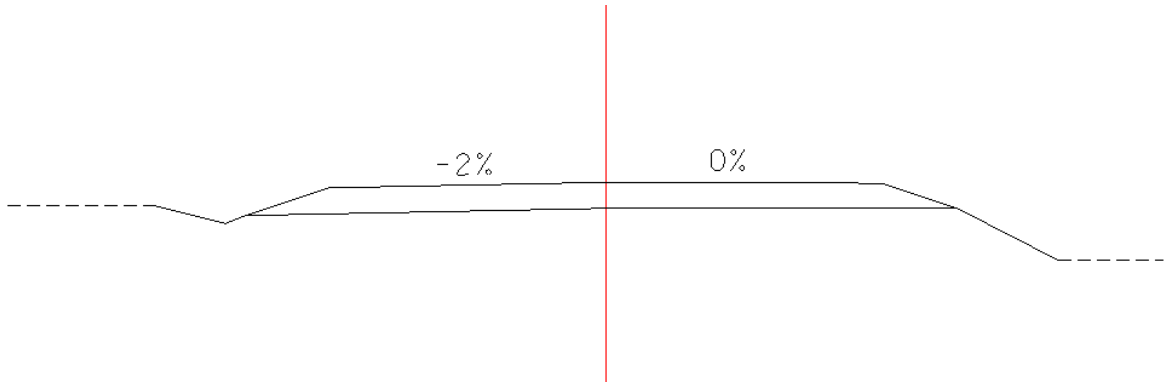
The transition ends at the S.C. point, station 103+98.31. This in the station at which full superelevation begins.



Full Superelevation

In the transition area a couple of key points to know are the Reverse Crown station and the Remove Adverse Crown station.

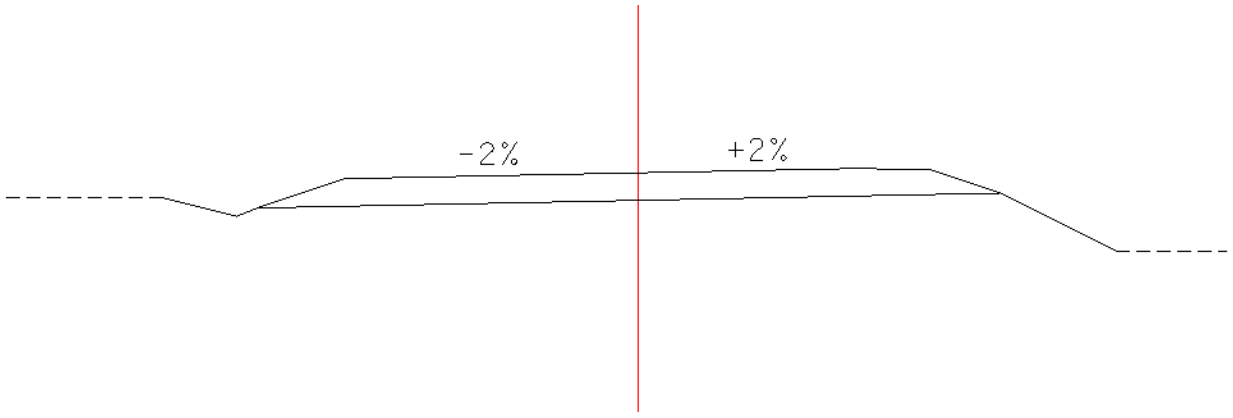
Going from Normal Crown to Full Super the point Remove Adverse Crown point will occur first.



Remove Adverse Crown

Since the roadway curves to the left, the pavement transitions from a negative cross slope to a positive cross slope only on the right side, therefore zero cross slope would only be on the right side. According to RD11-SE-2A, this point occurs at the distance L T from the S.C. station, or

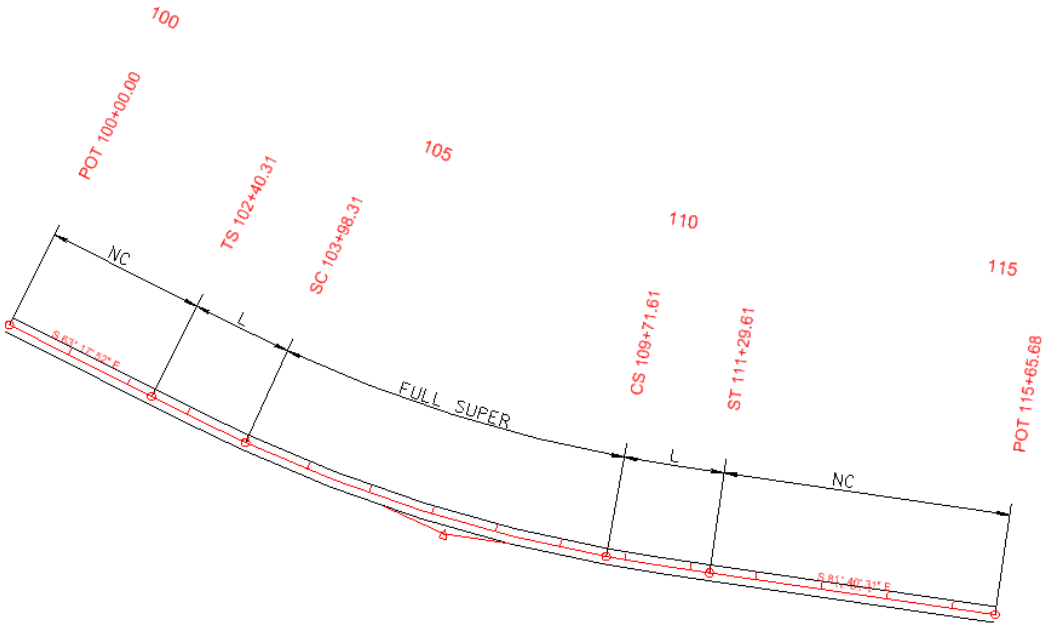
10240.31 + 47.83 = 10288.14, or station 102+88.14



Reverse Crown

Also, from RD11-SE-2A, Reverse Crown occurs at S.C. + (L T x 2), or
10240.31 + (47.83 x 2)=10335.97, or station 103+35.97

At the other end of the curve the alignment transitions from full super back to normal crown. The transition begins at the C.S. point (station 109+71.61) and ends at the S.T. point (station 111+29.61). The Reverse Crown and Zero Cross Slope stations would be calculated in the same manner as for the first transition and would occur in reverse order.



Now let's pick some random stations and calculate the superelevation:

<u>103+00</u>

This station occurs in the spiral portion of rthe alignment which is in the transition.

The rate of change in superelevation is found by dividing the difference between normal crown and full super by the transition length.

For this example, [.046 – (-.020)]/158 = .066/158 = <u>.0004177</u>

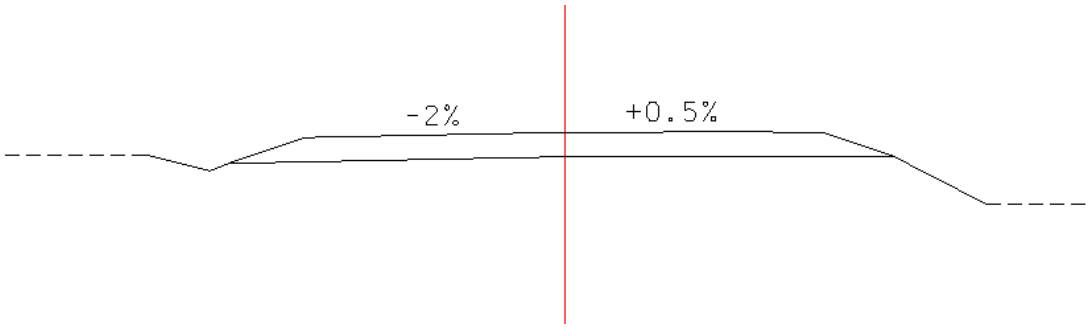
L= 10300 – 10240.31 = 59.69

59.69 x .0004177 =.025, or 2.5%

This number is added to the cross slope at the beginning transition station, 102+40.31, which is normal crown (-2%)

2.5% + (-2%) = + 0.5%

Since this number is less than + 2%, and has not yet reached reverse crown, the other side will be - 2%



<u>107+00</u>

Station 107+00 is in the full super area, between the S.C and C. S. , + 4.6% in this example.

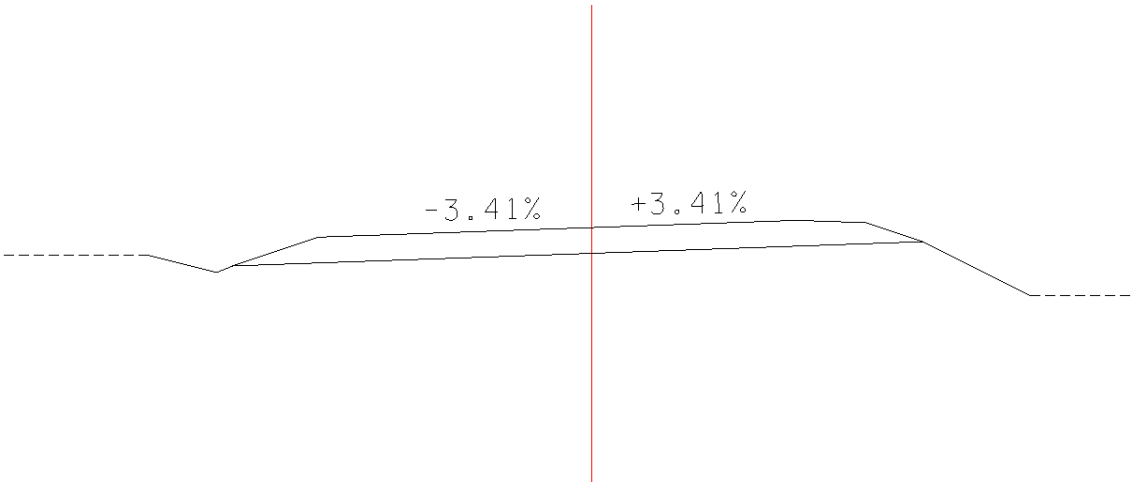
<u>110+00</u>

This station is in the transition from full super to normal crown (109+71.61 - 111+29.61), so subtract the beginning station of the transition

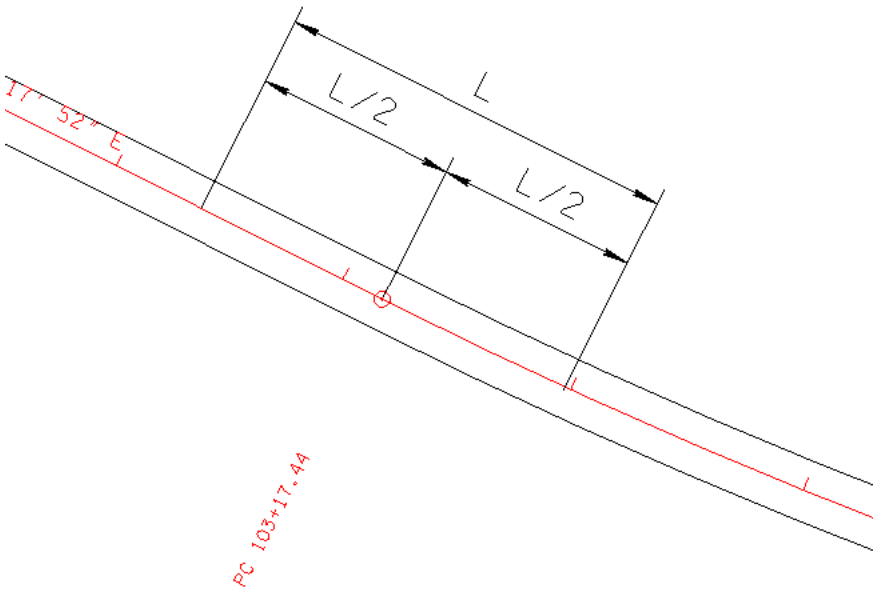
11000 – 10971.61 = 28.39. The rate of change is the same as for the transition at the beginning end of the curve (.0004177).

28.39 x .0004177 = .0119, or 1.19%

This number is subtracted from the full super rate at 109+77.61, 4.6 -1.19 = 3.41%



For curves where a spiral is not required, the calculation methods are the same. The calculated transition lengths are spaced so that the P.C. and P.T. points are at the halfway point of L.



Example 2

1) 4 lane rural design
2) Design Speed 30 MPH
3) Curve Radius 261 ft.

Find L

Use Std. Dwg. RD11-LR-1, Minimum Runoff Lengths for Urban Highways, E max = 0.04.

From the Table, e_d =3%. This is the minimum superelevation rate for this radius.

According to the table on RD11-LR-1, L_R is 82 feet.

According to the Superelevation Transition equation on RD11-SE-1, L_T is 54.67

$L = L_R + L_T$ = 82 + 54.67 = 136.67, rounded to 137 feet

A spiral curve is not required for this design speed so half of L is on either side of the P.C. or P. T. as shown on page 10.

If the P.C. is at station 103+17.44:

Transition begins at 10317.44 – (137/2)= 10248.94, station 102+48.94

Remove Adverse Crown is 10248.94+ L_T = 10248.94 + 54.67 = 10303.61, station 103+03.61

Reverse Crown is 10248.94+ 2x L_T = 10248.94 + 109.34 = 10358.28, station 103+58.28