Superelevation Design Guide

Engineering Division
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- GEOPAK Road Course Guide
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- Roadway Design Manual
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TDOT Roadway Design Reference Documents

- Plan-in-Hand Checklist
- PS&E Checklist

Roadway Design Plans

In a standard roadway plan set, superelevation is included on the following sheets:

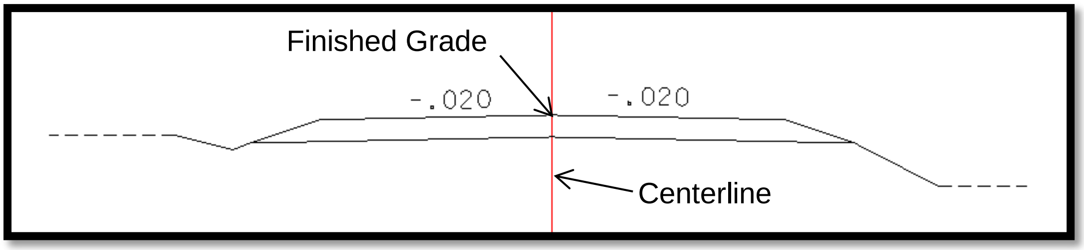
- Typical Sections Sheet: If a project has superelevation, a typical section and the station ranges of superelevation must be shown on this sheet.
- Proposed Profile: A superelevation diagram must be added to the Proposed Profile sheet.
- Cross Sections: The superelevation should be seen on the cross sections where superelevation is present.

Other Helpful Material

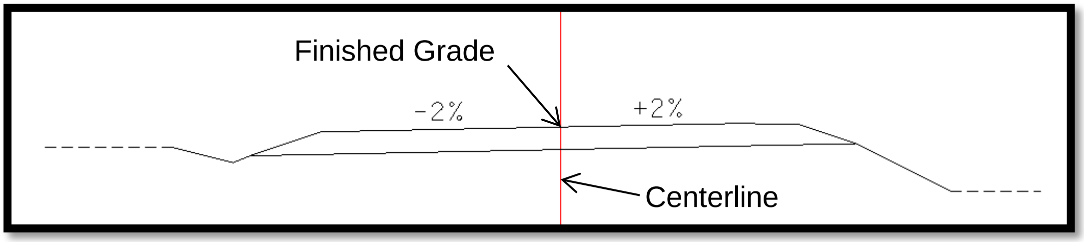
- Green Book (2011)

Part 2: Superelevation Calculation Guide

Superelevation is defined as the rate of cross slope on a curved section of roadway in which the outer edge is banked higher than the inner edge. The Standard Roadway Drawings provide information for Urban and Rural Superelevation Transition Details (RD11-SE-1 to RD11-SE-3A). Within the drawings, there are illustrations for a 2 lane and 4 or 6 lane road transition in superelevation. The following documentation will explain the log file created by running Superelevation in Geopak Road. It will also explain how to check information in the log file by performing calculations to find the stations where the lanes on each side of the centerline are at normal crown (-0.02) and where one of the lanes has transitioned from normal crown (-0.02) to straight surface or reverse crown (+0.02). Calculations will also be shown for the lane where maximum transition occurs from normal crown to a positive cross slope to identify the station where zero percent slope occurs.



Normal Crown



Reverse crown

The curve information that will be used for this example is for a rural 2 lane road based on the "E MAX = 0.08 Desirable" table on Standard Roadway Drawing RD11-SE-1 with v = 30 mph., degree of curve 13º- 00', maximum superelevation of 0.068, and transition length of 160.00'. When a horizontal alignment is added in Geopak Road, information for the curve can be found in Geopak Road by opening Coordinate Geometry>Navigator>Chain. Also, when the proposed horizontal alignment is displayed in the alignment file, the curve data will be part of the display. The curve data matches what is found in the Standard Roadway Drawing for Superelevation. The horizontal alignment and curve data are shown in *Figure 1- Horizontal Alignment Curve D1*. The SE, design speed, and transition length are all filled in by the user from the data in the standard drawing.

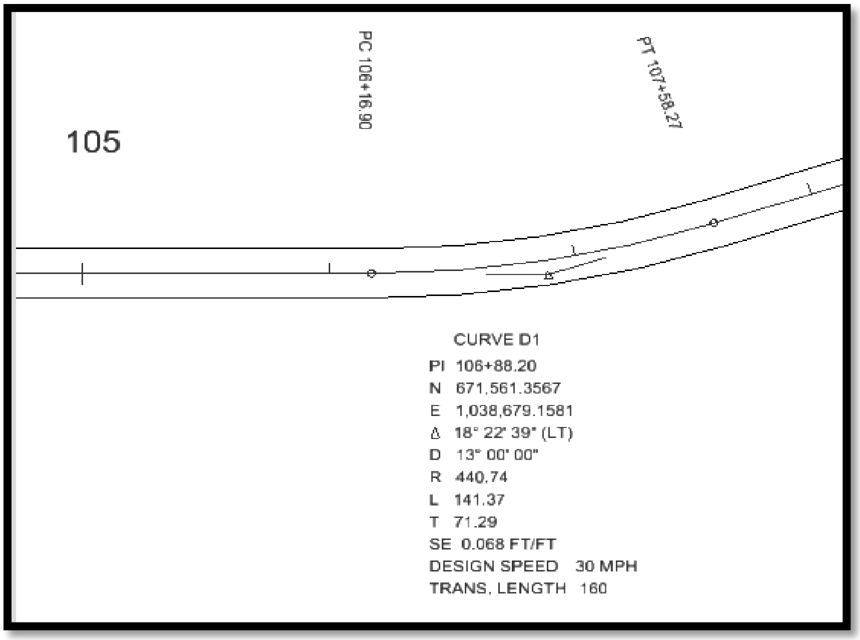


FIGURE 1 – HORIZONTAL ALIGNMENT CURVE D1

Notice the P.I. of the curve is to the right of the radius and the way the curve is laid out in *Figure 1- Horizontal Alignment Curve D1*. The transition from normal crown to full superelevation will begin on the right lane of the centerline first because that side goes from negative to positive cross slope while the other side remains negative.

The superelevation log file from Geopak Road contains information for the left and right lanes of the road as shown below. Because the transition begins on the right lane of the road, the right lane is listed first in the log file.

Left	**Right**
ROADNAME 8.0000	ROADNAME -8.0000
filler line station / slope	filler line station / slope
100+00.000000 -2.0000	100+00.000000 -2.0000
106+00.315956 -2.0000	105+27.588683 -2.0000
106+87.588683 -6.8000 /* Curve D1 */	106+87.588683 6.8000 /* Curve D1 */
107+74.861410 -2.0000	108+47.588683 -2.0000
112+03.385413 -2.0000	112+03.390000 -2.0000

The first entry line lists the road name and maximum superelevation rate from the “E MAX = 0.08 Desirable” table. The beginning and ending stations on the proposed horizontal alignment will always be listed for both the left and right lanes of the road. For this alignment, the beginning and ending stations are 100+00.00 and 112+03.39. The output shows that full super occurs at station. 106+87.588683. The curve is only in full super for this station. This is because this station is at the midpoint of the curve** and begins to transition back down to normal crown. If the curve remained in full superelevation for more than a station, there would be an additional entry. For example, if the curve was in full superelevation for 100', there would be an additional entry of 107+87.588683 6.8000 /* Curve D1 */, and the remaining stations would adjust accordingly.

Compare the output for the last station with normal crown listed on the right lane of the road (105+27.588683) prior to the full superelevation station with the last station with normal crown listed on the left lane of the of the road (106+00.315956). The station on the right precedes the station on the left because it has a longer transition. The same occurs after the full superelevation station where the station on the right (108+47.588683) follows the station of the left (107+74.861410) due to the longer transition length needed.

** In Figure 1, the length of the curve is shown to be 141.37.

141.37/2 = 70.69.

10616.90 (P.C.Sta.) +70.69 = 10687.59 = Station 106+87.59

This station (106+87.59) is the point on the curve with full superelevation.

The log file carries the numbers out 6 decimal places, but for the figures and calculations, only 2 decimal places will be used. When performing the calculations, there might be a slight difference in the 3rd decimal place due to rounding. Also, within the calculations, the plus sign in stations will be removed for clarity but will be shown in each result.

Verification and calculations for superelevation station:

For this example, the length of transition (160' from RD01-SE-3) is longer than the length of curve (141.37' from Geopak). Generally, one-half the transition length is before the PC and the other one-half is after the PC where maximum superelevation begins. Maximum superelevation continues to one-half the transition length before the PT and ends one-half the transition length after the PT. When the

Verification and calculations for stations will be shown for the right lane first:

Right

ROADNAME -8.0000

filler line station / slope

100+00.000000 -2.0000

105+27.588683 -2.0000

106+87.588683 6.8000 /* Curve D1 */

108+47.588683 -2.0000

112+03.390000 -2.0000

NORMAL CROWN BEFORE FULL SUPERELEVATION (RIGHT LANE)

To verify the last station where the right lane is at normal crown before it starts transitioning to full superelevation, subtract the transition length from the full superelevation station.

- Station of full Superelevation - Transition Length

  10687.5887 - 160 = **105+27.5887**

TRANSITION RATE

The transition rate for a curve is found for the lane of the road with the most change in cross slope, the right lane in this example. To find the transition rate, the maximum change in cross slope is divided by the known transition length for the curve.

- $$\text{Transition Rate} = \frac{\text{Maximum Change in Cross Slope}}{\text{Known Transition Length of Curve}}$$

  $$= \frac{(0.068 - (-0.02))}{160'} = \frac{0.088}{160'} = 0.00055$$

This Transition Rate will be used in other calculations.

ZERO PERCENT BEFORE FULL SUPERELEVATION (RIGHT LANE)

Since the right lane of the road goes from a negative slope (normal crown slope of -0.02) to a positive slope at full super (+0.068), there is a station where the cross slope for the right lane is at zero percent (0.00). This is an area of concern because of drainage issues and should be analyzed by the designer to ensure no ponding occurs.

To find the station where zero percent cross slope occurs for the right lane of the road <u>before</u> reaching full superelevation, reverse the formula used to calculate the transition rate. Using the known transition rate and the change in cross slope, find the length needed to transition from normal crown cross slope to zero percent cross slope. Add the length to the last station where normal crown occurred.

- $\text{Length} = \dfrac{\text{Change in Cross Slope}}{\text{Transition Rate}}$

$$= \frac{0.00 - (-0.02)}{0.00055} = \frac{0.020}{0.00055} = 36.36'$$

Zero percent cross slope is reached at 10527.5887 + 36.36' = **<u>105+63.95</u>**

> Another way to perform the calculation would have been to find the length of transition from zero percent cross slope to full superelevation cross slope and subtract from the superelevation station
>
> - $\text{Length} = \dfrac{\text{Change in Cross Slope}}{\text{Transition Rate}}$
>
> $$= \frac{(0.068 - 0.00)}{0.00055} = \frac{0.068}{0.00055} = 123.64'$$
>
> Zero percent cross slope is reached at 10687.5887 – 123.64' = **<u>105+63.95</u>**

REVERSE CROWN BEFORE FULL SUPERELEVATION (RIGHT LANE)

To find the station where reverse crown (+0.02) occurs for the right lane of the road <u>before</u> reaching full superelevation, use the same calculations as previously described. Find the length needed to transition from normal crown cross slope to reverse crown and add the length to the last station where normal crown occurred.

- $\text{Length} = \dfrac{\text{Change in Cross Slope}}{\text{Transition Rate}}$

$$= \frac{0.02 - (-0.02)}{0.00055} = \frac{0.040}{0.00055} = 72.72'$$

OR

Double the number found in calculation #4 since it was calculated for a 0.02 change in cross slope, and this is a 0.04 change. (36.36’ X 2) = 72.72’

Reverse crown cross slope is reached at 10527.5887 + 72.72’ = **106+00.32**

This station matches the station shown in the log file for the left lane of the road at the last station where normal crown occurs.

Once the right lane transitions from -0.20 to +0.20, both lanes will rotate at the same rate until full superelevation of 0.068 is reached (+0.068 for the right and -0.068 for the left).

FULL SUPERELEVATION

To verify the station where full superelevation is reached divide the curve length in half and add the result to the to the P.C. station.

P.C. Station + Curve Length /2 =

10616.90 + (141.37/2) = 106+87.59

Since the curve is only at full superelevation for one station, the station can be also be checked by using the P.T. station. To verify the station superelevation is reached, divide the curve length in half and subtract the result from to the P.T. station.

P.T. Station – Curve Length/2 =

10758.27 - (141.37/2) = 106+87.59

REVERSE CROWN AFTER FULL SUPERELEVATION (RIGHT LANE)

To find the station where reverse crown (+0.02) occurs for the right lane of the road after full superelevation, use the same concept as previously described except use the station listed after the full superelevation where the cross slope has transitioned back to normal crown and subtract the calculated length (72.72’) for a 0.04 change in cross slope.

Reverse crown cross slope is reached at 10847.5887 - 72.72’ = **107+74.86**

This station matches the number shown in the log file for the left lane of the road for the last station where the left lane is at normal crown.

ZERO PERCENT AFTER FULL SUPERELEVATION (RIGHT LANE)

To find the station where zero percent cross slope occurs for the right lane of the road after reaching full superelevation, use the same concept as previously described except use the station after the superelevation where the cross slope has transitioned back to normal crown. Subtract the calculated length (36.36) for a 0.02 change in cross slope

Zero percent cross slope is reached at 10847.5887 – 36.36’ = **108+11.23**

Check: Full superelevation station plus length found for change from 0.00 to 0.068.

10687.5887 + 123.64’ = **108+11.23**

NORMAL CROWN AFTER SUPERELEVATION (RIGHT LANE)

To verify where the right lane transitions back to normal crown after full superelevation is reached, add the transition length to the full superelevation station.

- Full Super + Transition Length

10687.5887 + 160 = **108+47.5887**

The next few steps will verify stations that are generated for the left lane of the road. The left lane of the road transitions from -0.02 to -0.068 so there is not a station for zero percent cross slope or reverse crown.

Left

ROADNAME 8.0000

filler line station / slope

100+00.000000 -2.0000

106+00.315956 -2.0000

106+87.588683 -6.8000 /* Curve D1 */

107+74.861410 -2.0000

112+03.385413 -2.0000

NORMAL CROWN BEFORE FULL SUPERELEVATION (LEFT LANE)

The full transition length of 160' is not needed on the left lane. The transition rate that was calculated for the right lane will be used to find the transition length needed to normal crown to superelevation. To verify the last station for normal crown prior to superelevation for the left lane, find the length needed for the change in cross slope from normal crown to full superelevation and divide by the known transition rate for the right lane. Subtract this length from the full superelevation station.

- Length = $\frac{\text{Change in Cross Slope}}{\text{Transition Rate}}$

$$= \frac{-0.068 - (-0.02)}{.00055} = \frac{0.048}{.00055} = 87.27$$

Full Super minus Length

10687.5887 - 87.27 = **106+00.32**

This station matches the station calculated for reverse crown for the right lane.

NORMAL CROWN AFTER FULL SUPERELEVATION (LEFT LANE)

To find the station where the left lane transitions back to normal crown, add the length calculated for the left lane to the full superelevation station.

- Full Super + Length

10687.5887 + 87.27 = **107+74.86**

This station matches the station calculated for reverse crown for the right lane.

Below is a figure for the entire curve with all the stations and cross slopes.

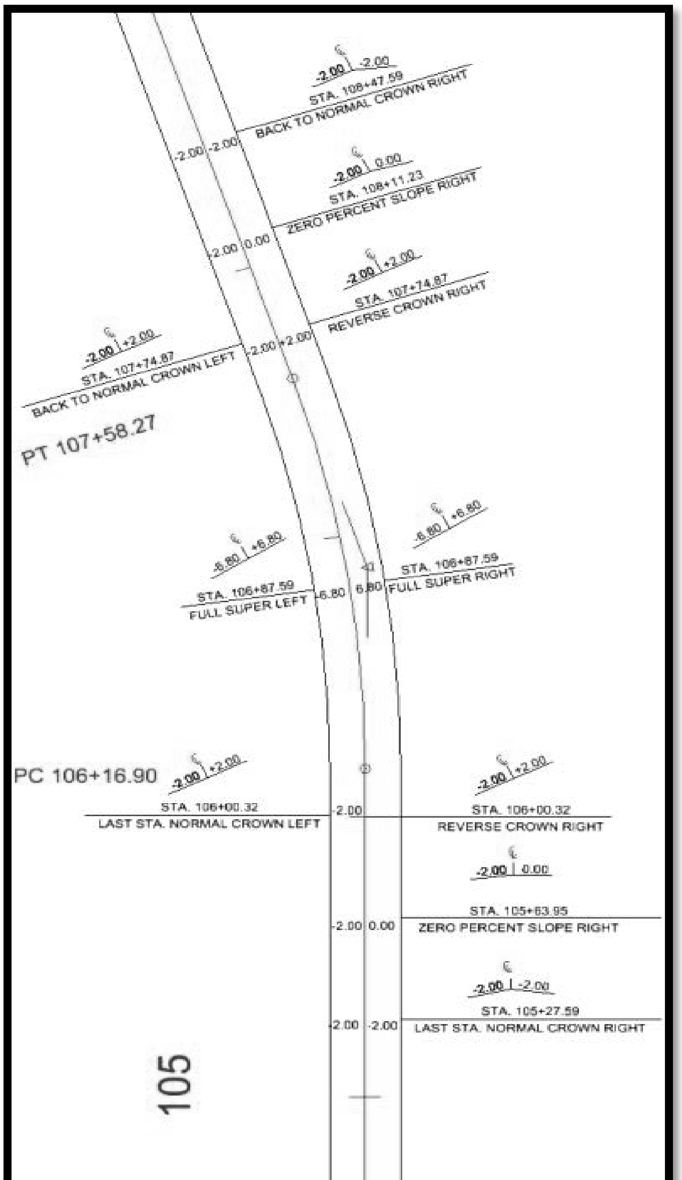


FIGURE 2 – STATIONS AND CROSS SLOPES

For clarity, the *Figure 2, Stations and Cross Slopes* has been split into two separate figures representing the stations before and after full superelevation.

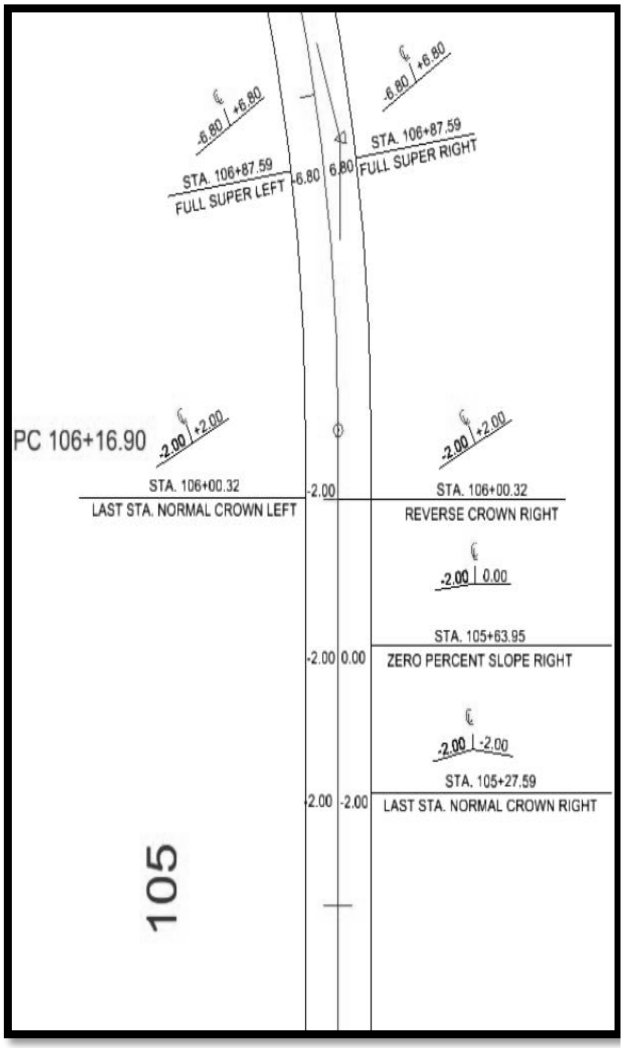


FIGURE 3 – STATIONS AND CROSS SLOPES BEFORE FULL SUPERELEVATION

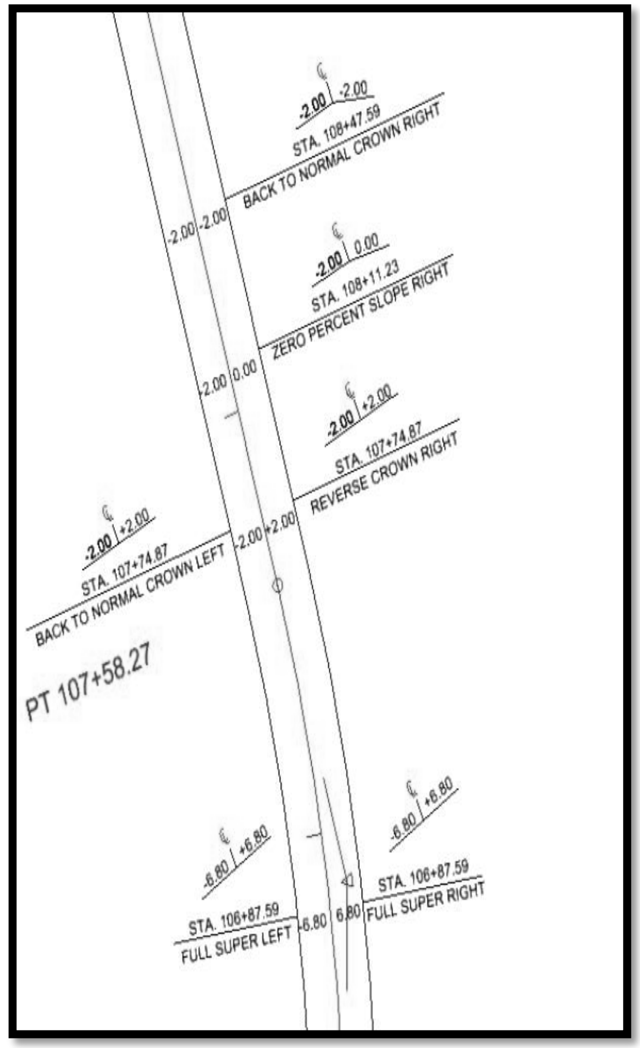


FIGURE 4 – STATIONS AND CROSS SLOPES AFTER FULL SUPERELEVATION

Part 3: Superelevation Calculation (RD11 Series)

Horizontal curves will no longer be identified by degree, they will be identified by radius only. Standard Drawings RD11-LR-1 (Urban) and RD11-LR-2 (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 <u>minimum</u> radius that can be used. Also, for a given radius, only use the corresponding e_d.

③ e_d (%)	V = 20 (MPH) R MIN. (FT.)	Number of lanes 2	3	4	5	6	R 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 greater than 730 can be used. If the radius is to remain at 730, no other e_d than 3% can be used.

The numbers that appear under the number of lanes are runoff lengths (L_R). Runoff Length (L_R) is the distance that is required to transition from zero (flat) superelevation to full superelevation. 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.

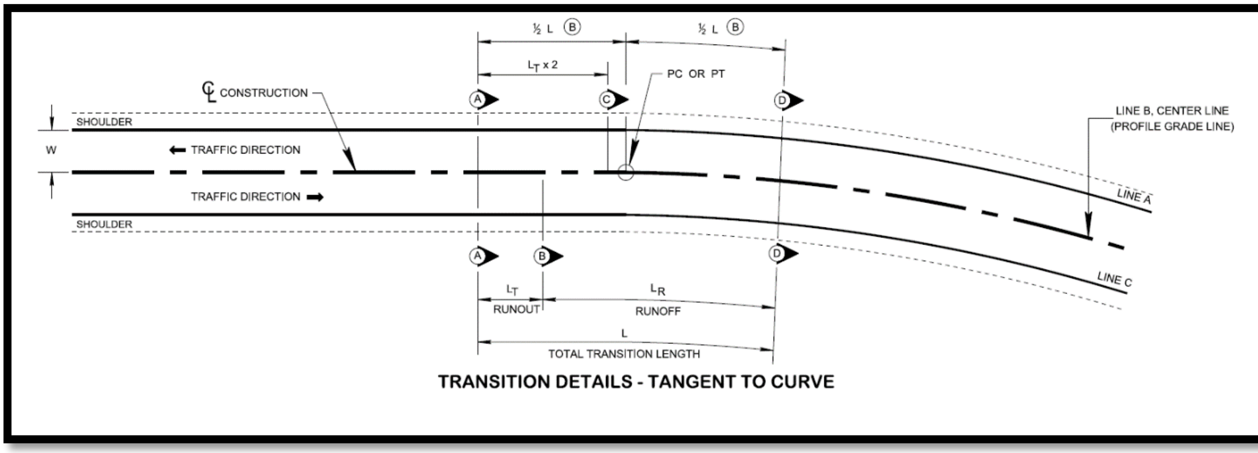
SUPERELEVATION TRANSITION EQUATIONS

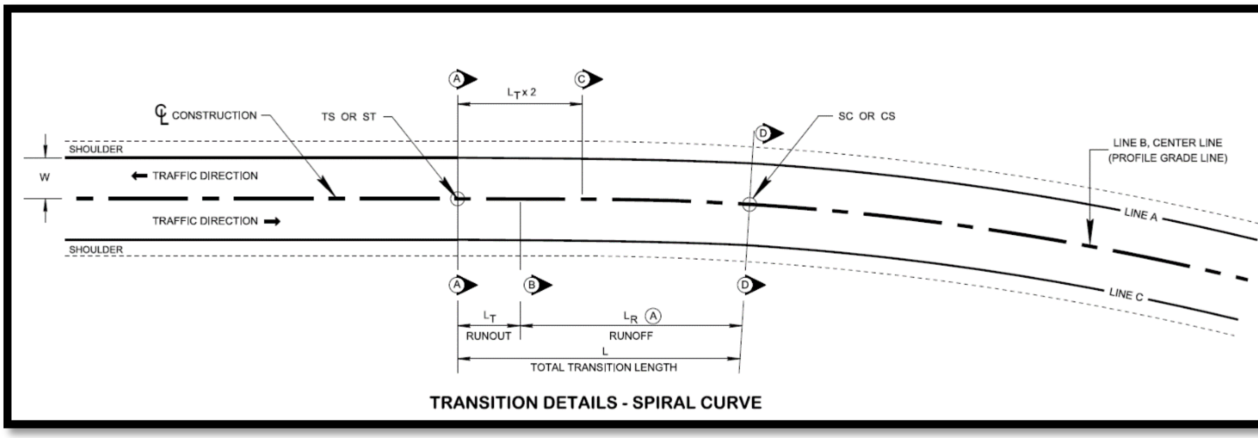
$$L = L_R + L_T$$

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

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

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

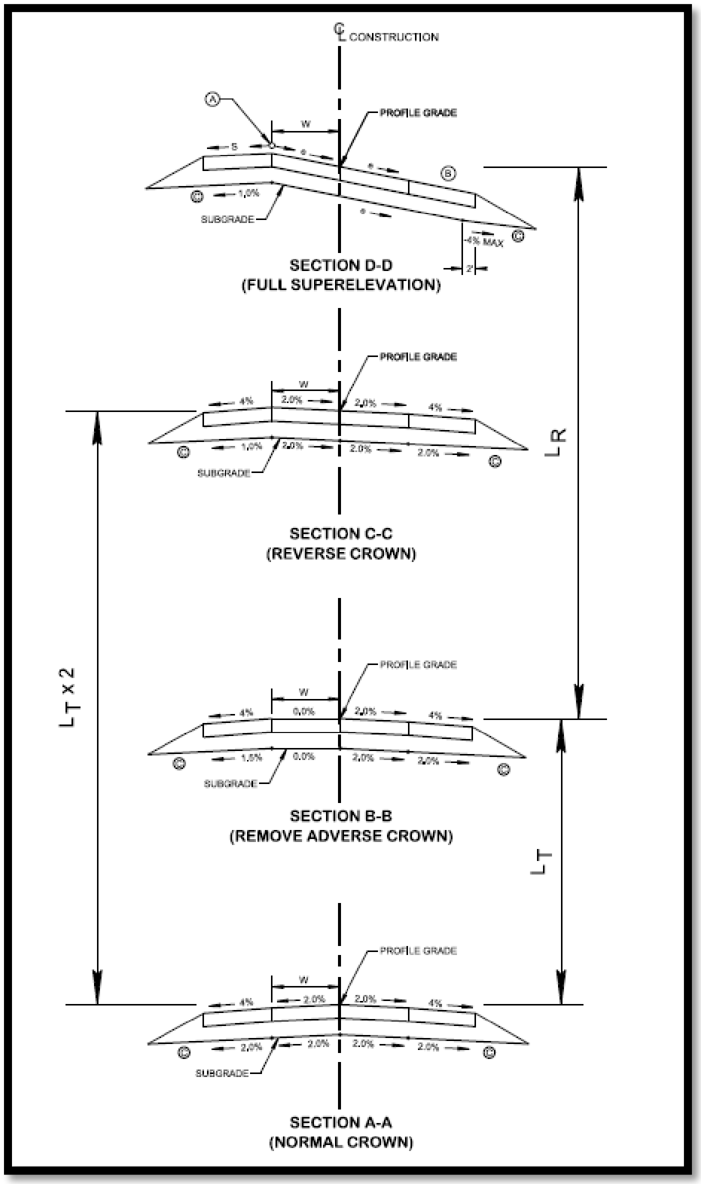




For a simple curve half of the transition length is before and half after the P.C. or P.T.

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.



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

Example 1

- 2 lane rural design
- Design Speed 50 MPH
- Curve Radius 2280 ft.

According to Standard Drawing 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)					
	R	Number of lanes					R	Number of lanes					R	Number of lanes				
(%)	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
2	1190	32	40	49	57	65	1720	34	43	51	60	69	2370	36	45	55	64	73
2.2	1070	36	44	54	62	72	1550	38	47	57	66	76	2130	40	50	60	70	80
2.4	959	39	48	58	68	78	1400	41	51	62	72	83	1930	44	54	65	76	88
2.6	872	42	52	63	74	85	1280	45	55	67	78	90	1760	47	59	71	83	95
2.8	796	45	57	68	79	91	1170	48	60	72	84	96	1610	51	63	76	89	102
3	730	49	61	73	85	98	1070	51	64	77	90	103	1480	55	68	82	95	110
3.2	672	52	65	78	91	104	985	55	68	82	96	110	1370	58	72	87	102	117
3.4	620	55	69	83	96	111	911	58	73	87	102	117	1270	62	77	93	108	124
3.6	572	58	73	88	102	117	845	62	77	93	108	124	1180	65	81	98	115	132
3.8	530	62	77	92	108	124	784	65	81	98	114	131	1100	69	86	104	121	139
4	490	65	81	97	114	130	729	69	85	103	120	138	1030	73	91	109	127	146
4.2	453	68	85	102	119	137	678	72	90	108	126	145	955	76	95	115	134	153
4.4	418	71	89	107	125	143	630	75	94	113	132	152	893	80	100	120	140	161
4.6	384	75	93	112	131	150	585	79	98	118	138	159	834	84	104	125	146	168
4.8	349	78	97	117	136	156	542	82	102	123	144	165	779	87	109	131	153	175
5	314	81	101	122	142	163	499	86	107	129	150	172	727	91	113	136	159	183
5.2	284	84	105	126	148	169	457	89	111	134	156	179	676	95	118	142	165	190
5.4	258	88	109	131	153	176	420	93	115	139	162	186	627	98	122	147	172	197
5.6	236	91	113	136	159	183	387	96	120	144	168	193	582	102	127	153	178	205
5.8	216	94	117	141	165	189	358	99	124	149	174	200	542	105	131	158	185	212
6	199	97	121	146	170	196	332	103	128	154	180	207	506	109	136	164	191	219
6.2	184	101	125	151	176	202	308	106	132	159	186	214	472	113	140	169	197	227
6.4	170	104	129	156	182	209	287	110	137	165	192	221	442	116	145	175	204	234
6.6	157	107	133	161	187	215	267	113	141	170	198	227	413	120	149	180	210	241

③ e d	V = 35 (MPH)						V = 40 (MPH)						V = 45 (MPH)					
	R	Number of lanes					R	Number of lanes					R	Number of lanes				
(%)	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3	4	5	6
NC	4260	0	0	0	0	0	5410	0	0	0	0	0	6710	0	0	0	0	0
2	3120	39	48	58	68	78	3970	41	52	62	72	83	4930	44	55	67	78	89
2.2	2800	43	53	64	75	86	3570	46	57	68	80	91	4440	49	61	73	86	98
2.4	2540	46	58	70	81	93	3240	50	62	74	87	100	4030	53	66	80	93	107
2.6	2320	50	63	75	88	101	2960	54	67	81	94	108	3690	58	72	87	101	116
2.8	2130	54	67	81	95	109	2720	58	72	87	101	116	3390	62	77	93	109	125
3	1960	58	72	87	102	117	2510	62	77	93	109	125	3130	67	83	100	117	134
3.2	1820	62	77	93	108	124	2330	66	82	99	116	133	2900	71	89	107	124	143
3.4	1690	66	82	99	115	132	2170	70	88	106	123	141	2700	76	94	113	132	152
3.6	1570	70	87	105	122	140	2020	74	93	112	130	150	2520	80	100	120	140	161
3.8	1470	74	92	110	129	148	1890	79	98	118	138	158	2360	84	105	127	148	170
4	1370	77	96	116	135	156	1770	83	103	124	145	166	2220	89	111	133	156	179
4.2	1280	81	101	122	142	163	1660	87	108	130	152	175	2080	93	116	140	163	188
4.4	1200	85	106	128	149	171	1560	91	113	137	159	183	1960	98	122	147	171	197
4.6	1130	89	111	134	156	179	1470	95	118	143	167	191	1850	102	127	153	179	205
4.8	1060	93	116	139	163	187	1390	99	124	149	174	200	1750	107	133	160	187	214
5	991	97	120	145	169	195	1310	103	129	155	181	208	1650	111	138	167	194	223
5.2	929	101	125	151	176	202	1230	108	134	161	188	216	1560	116	144	173	202	232
5.4	870	105	130	157	183	210	1160	112	139	168	196	225	1480	120	149	180	210	241
5.6	813	108	135	163	190	218	1090	116	144	174	203	233	1390	124	155	187	218	250
5.8	761	112	140	168	196	226	1030	120	149	180	210	241	1320	129	160	193	226	259
6	713	116	145	174	203	233	965	124	155	186	217	250	1250	133	166	200	233	268
6.2	669	120	149	180	210	241	909	128	160	192	224	258	1180	138	172	207	241	277
6.4	628	124	154	186	217	249	857	132	165	199	232	266	1110	142	177	213	249	286
6.6	590	128	159	192	224	257	808	137	170	205	239	274	1050	147	183	220	257	295

③ e d	V = 50 (MPH)						V = 55 (M		
	R	Number of lanes					R	Numbe	
(%)	MIN. (FT.)	2	3	4	5	6	MIN. (FT.)	2	3
NC	8150	0	0	0	0	0	9720	0	0
2	5990	48	60	72	84	96	7150	51	64
2.2	5400	53	66	79	92	106	6450	56	70
2.4	4910	58	72	86	101	116	5870	61	76
2.6	4490	62	78	94	109	125	5370	66	83
2.8	4130	67	84	101	118	135	4950	71	89
3	3820	72	90	108	126	145	4580	77	95
3.2	3550	77	96	115	134	154	4250	82	102
3.4	3300	82	102	122	143	164	3970	87	108
3.6	3090	86	108	130	151	174	3710	92	114
3.8	2890	91	114	137	160	183	3480	97	121
4	2720	96	120	144	168	193	3270	102	127
4.2	2560	101	125	151	176	203	3080	107	134
4.4	2410	106	131	158	185	212	2910	112	140
4.6	2280	110	137	166	193	222	2750	117	146
4.8	2160	115	143	173	202	232	2610	123	153
5	2040	120	149	180	210	241	2470	128	159
5.2	1930	125	155	187	218	251	2350	133	165
5.4	1830	130	161	194	227	260	2230	138	172
5.6	1740	134	167	202	235	270	2120	143	178
5.8	1650	139	173	209	244	280	2010	148	184
6	1560	144	179	216	252	289	1920	153	191
6.2	1480	149	185	223	260	299	1820	158	197
6.4	1400	154	191	230	269	309	1730	163	203
6.6	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%.

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
61	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 Standard Drawing 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

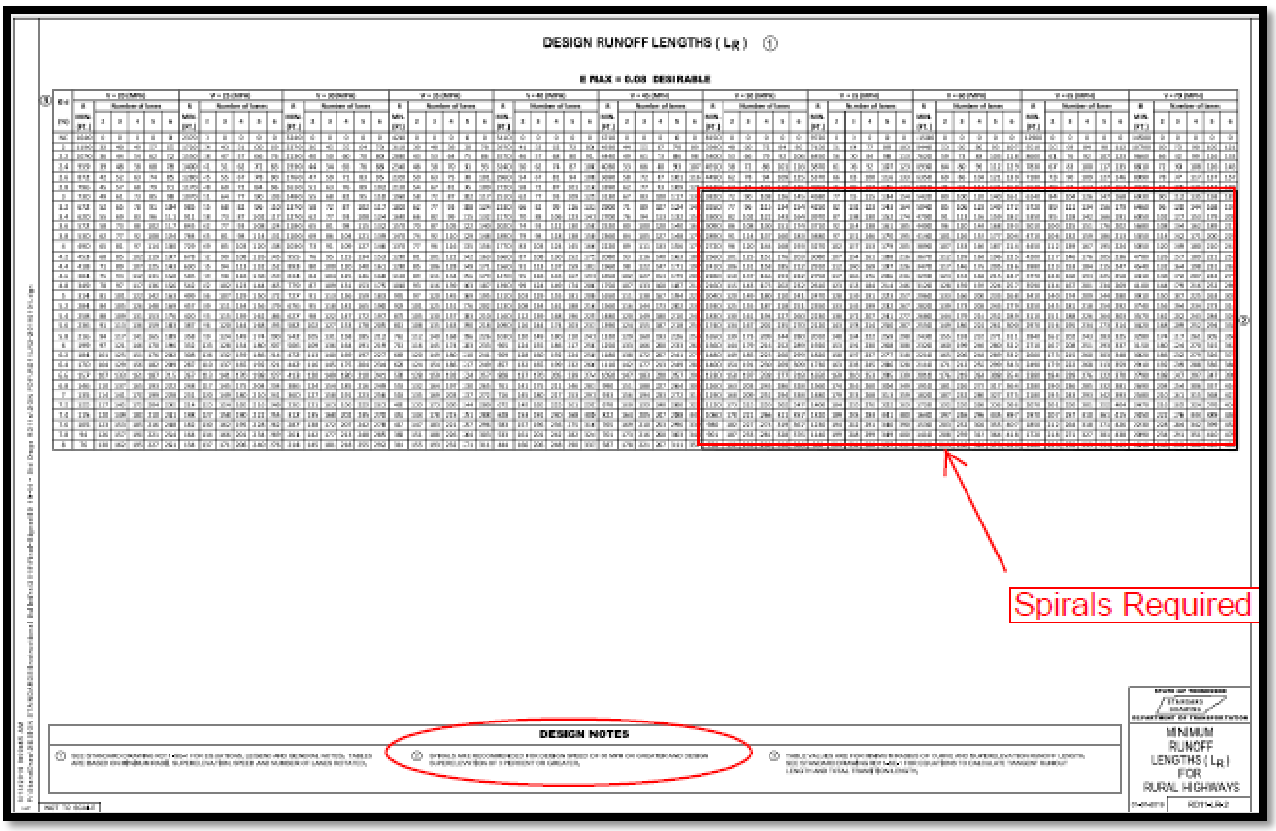
$$L = L_R + L_T$$

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

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

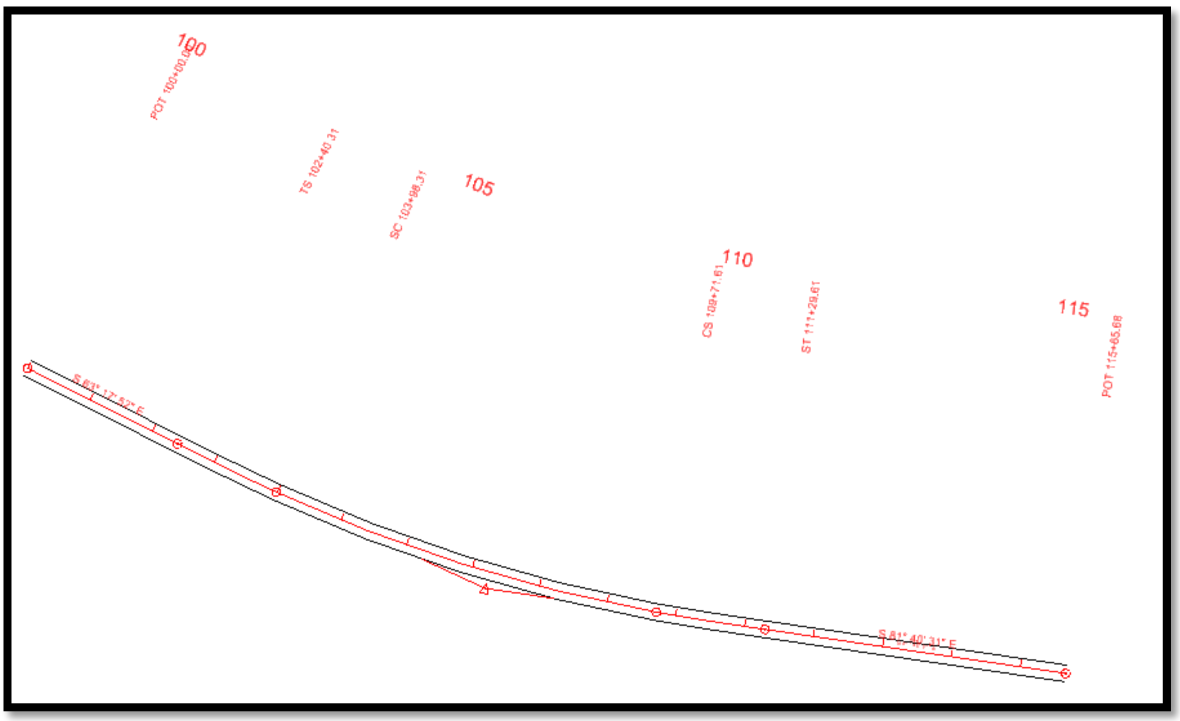
According to the equation on RD11-SE-1, L_T equals to <u>47.83</u> (2/4.6 x 110), and the total transition length (L) would be 110 + 47.83 = <u>157.83</u>, rounded to 158 ft.

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.



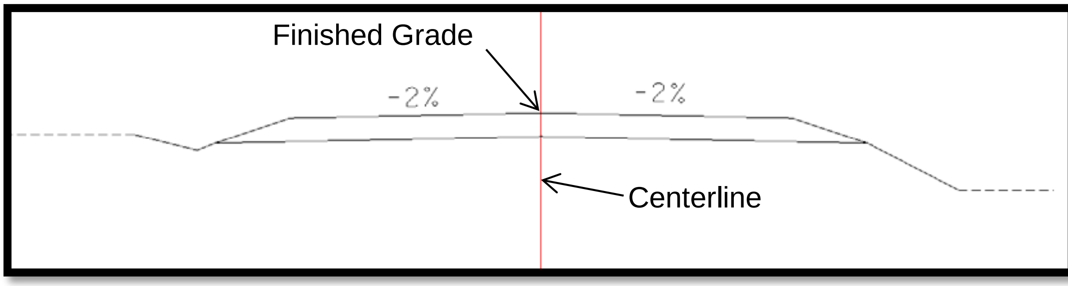
Plan view of proposed alignment

Station 100+00	Alignment Begins
Station 102+40.31	T.S. of the curve
Station 103+98.31	S.C. of the curve
Station 109+71.61	C.S. of the curve
Station 111+29.61	S.T. of the curve
Station 115+65.68	Alignment Ends



Normal Crown

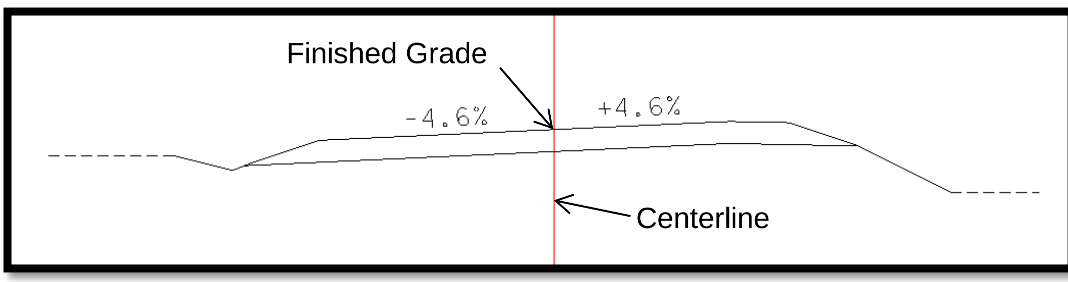
The alignment starts out at normal crown at station 100+00.



Full Superelevation

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

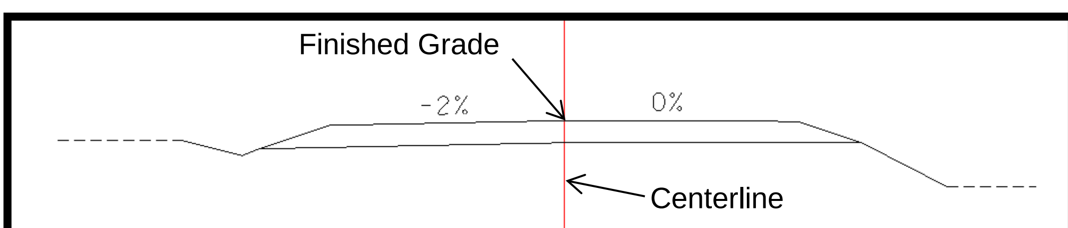
The transition ends at the S.C. point, station 103+98.31. This in the station at which full superelevation begins.



Remove Adverse Crown

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

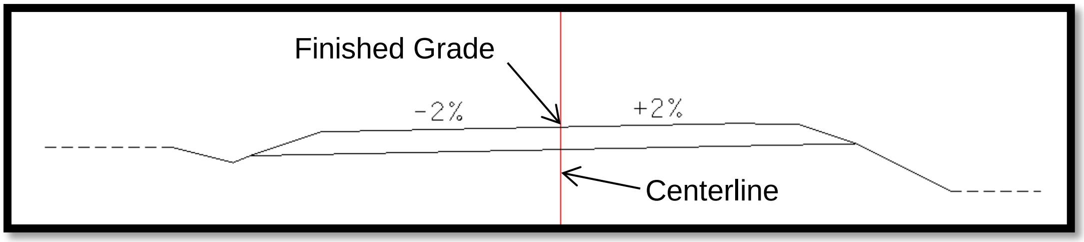
Going from Normal Crown to Full Super the point Remove Adverse Crown point will occur first.



Reverse 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 T.S. station, or

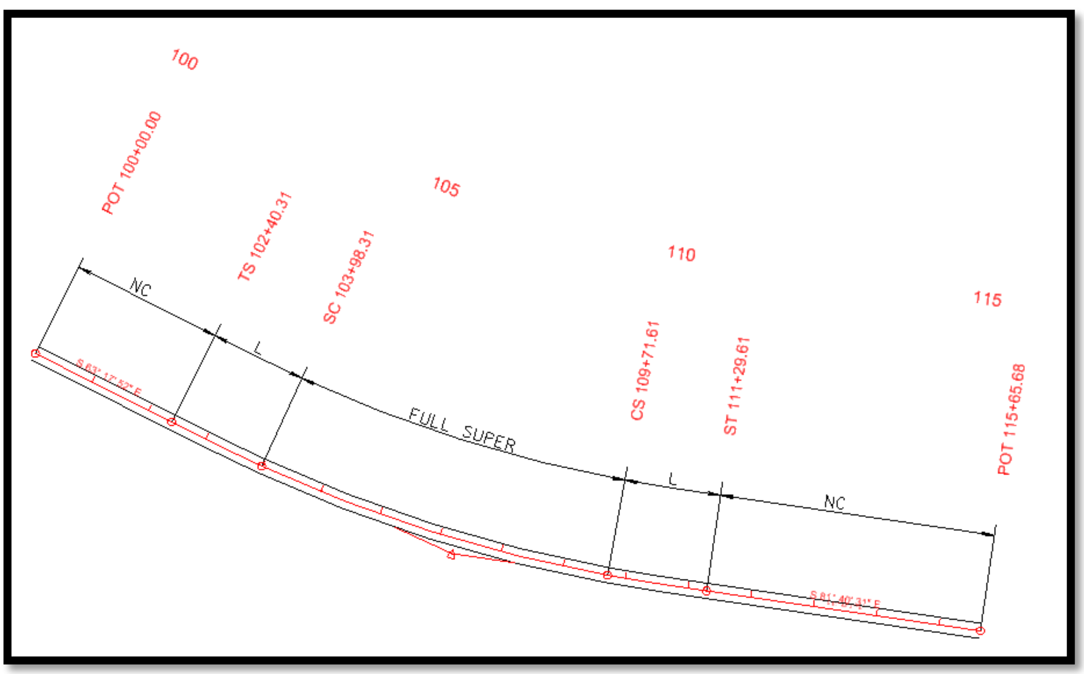
10240.31 + 47.83 = 10288.14, or station <u>102+88.14</u>



Also, from RD11-SE-2A, Reverse Crown occurs at T.S. + (L_T x 2), or

10240.31 + (47.83 x 2) =10335.97, or station <u>103+35.97</u>

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 the 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, $\frac{[.046 - (-.020)]}{158} = \frac{.066}{158} = \underline{.0004177}$

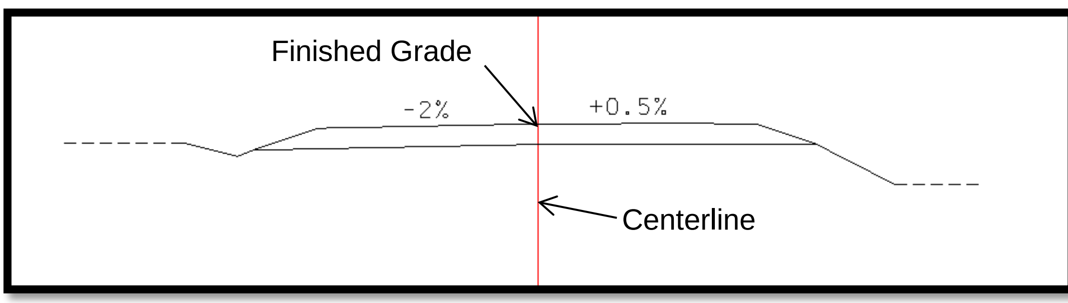
L= 10300 – 10240.31 = 59.69

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.

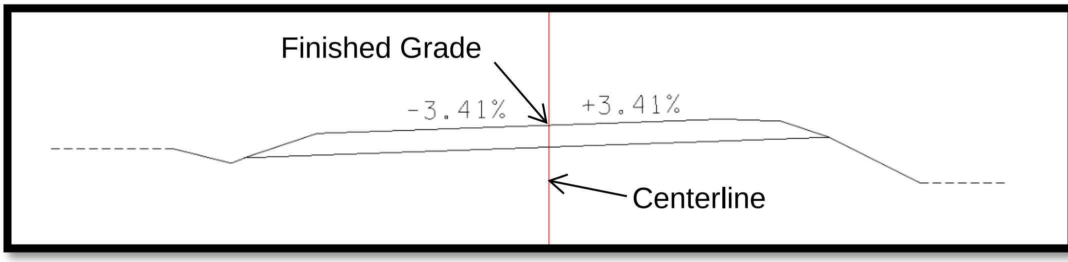
<u>110+00</u>

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

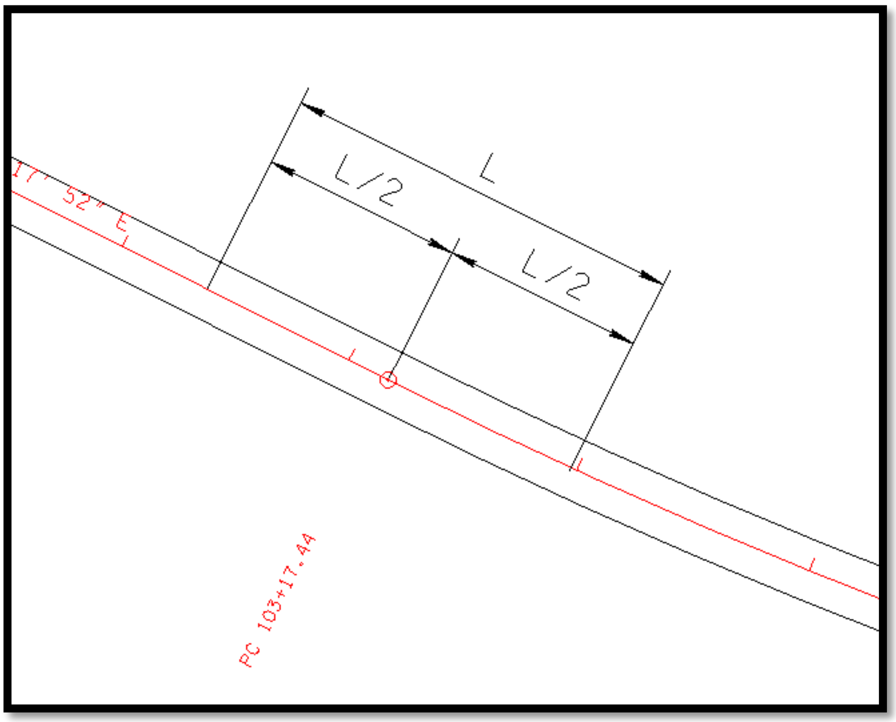
11000 – 10971.61 = 28.39. The rate of change is the same as for the transition at the beginning end of the curve (.0004177).

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

- 4 lane rural design
- Design Speed 30 MPH
- Curve Radius 261 ft.

Find L

Use Standard Drawing 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 the previous page.

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

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

Remove Adverse Crown is 10248.94 + L_T = 10248.94 + 54.67 = 10303.61, station <u>103+03.61</u>

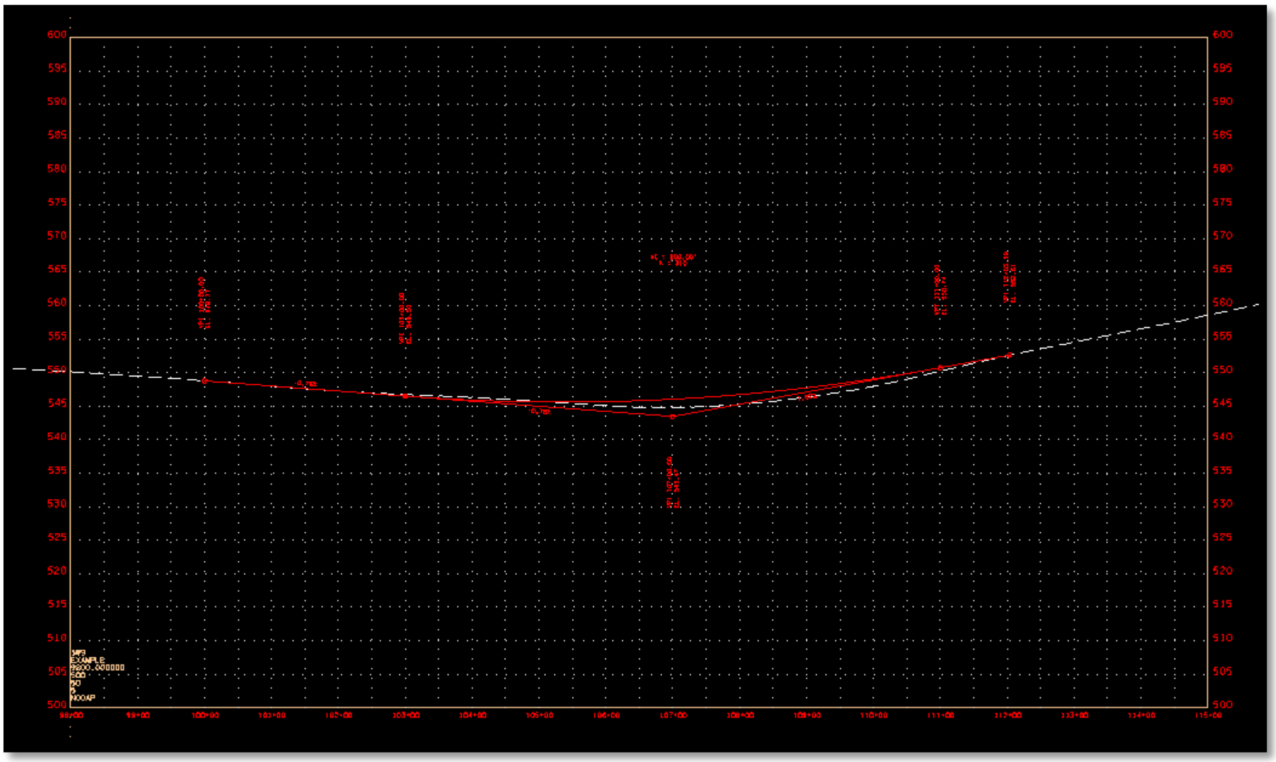
Reverse Crown is 10248.94+ 2 x L_T = 10248.94 + 109.34 = 10358.28, station <u>103+58.28</u>

Part 4: Superelevation Profile Diagram

The purpose of this section is to provide the designer information to draw the superelevation diagram. This diagram is important to show so that it is easily seen where superelevation changes take place.

<u>Superelevation Diagram Placement</u>

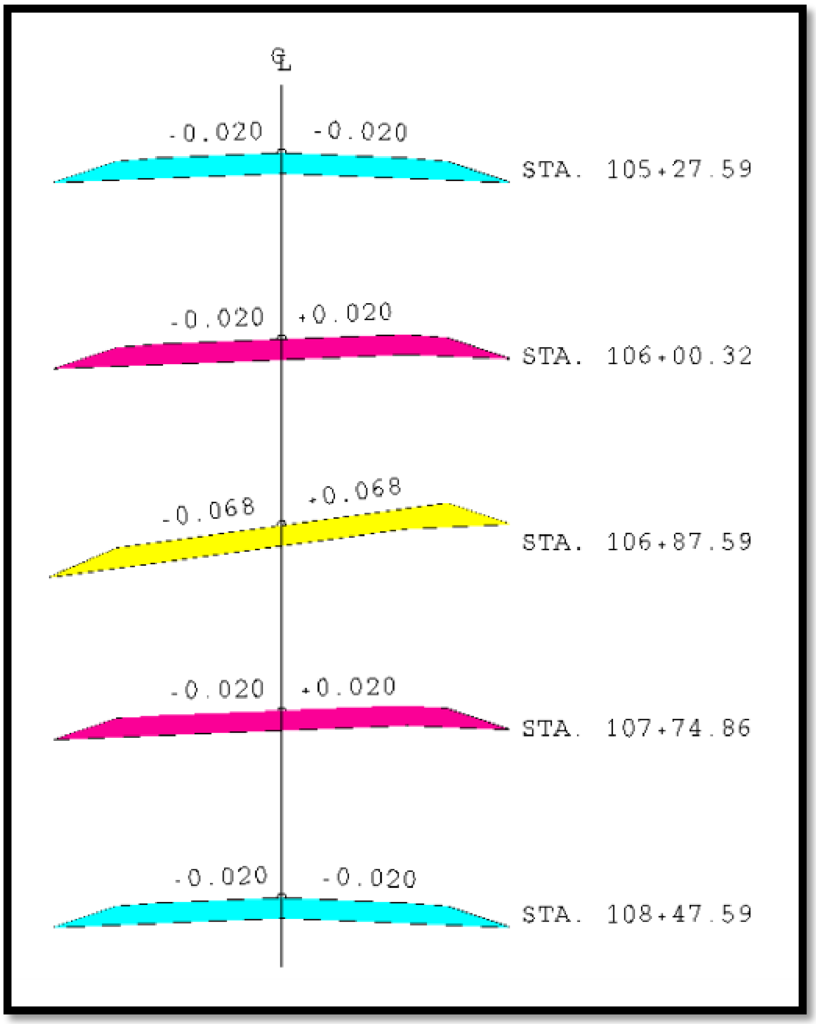
The best place to draw the superelevation diagram is in the alignment file. If you have displayed the proposed vertical alignment and a profile grid (See GEOPAK v8i Road Course Guide), the diagram should go in the lower portion of this area.



Determining Critical Superelevation Stations

From the Superelevation Calculations tutorial (.inp file created when “Generate Superelevation Transitions” operation is performed in GEOPAK), the stations where superelevations change are as follows:

Left	Right
ROADNAME 8.0000	ROADNAME -8.0000
filler line station / slope	filler line station / slope
100+00.000000 -2.0000	100+00.000000 -2.0000
106+00.315956 -2.0000	105+27.588683 -2.0000
106+87.588683 -6.8000 /* Curve D1 */	106+87.588683 6.8000 /* Curve D1 */
107+74.861410 -2.0000	108+47.588683 -2.0000
112+03.385413 -2.0000	112+03.390000 -2.0000



Drawing the Profile Diagram

Using the 510-elevation line on the grid, draw a line representing the finished grade which has a slope of 0% or 0 ft/ft.

Use the following symbology settings:

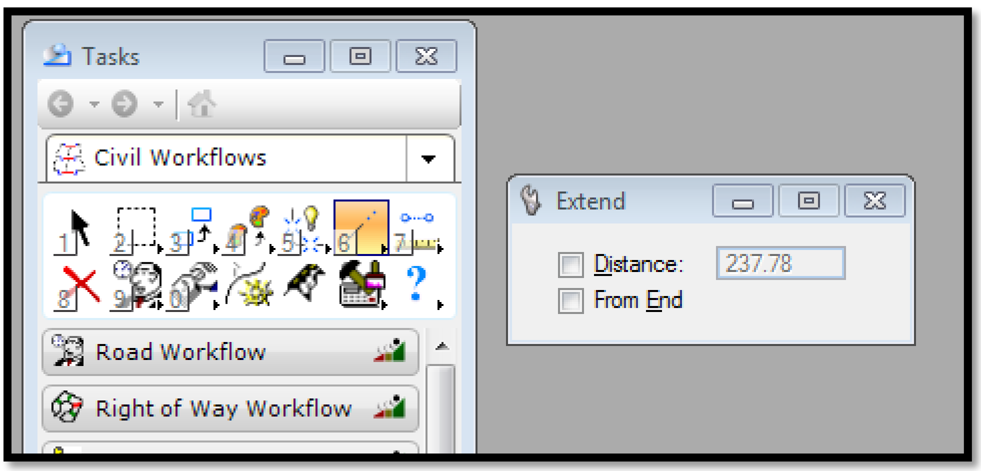
LV: DESIGN-CENTERLINE-Proposed Text

CO: 6

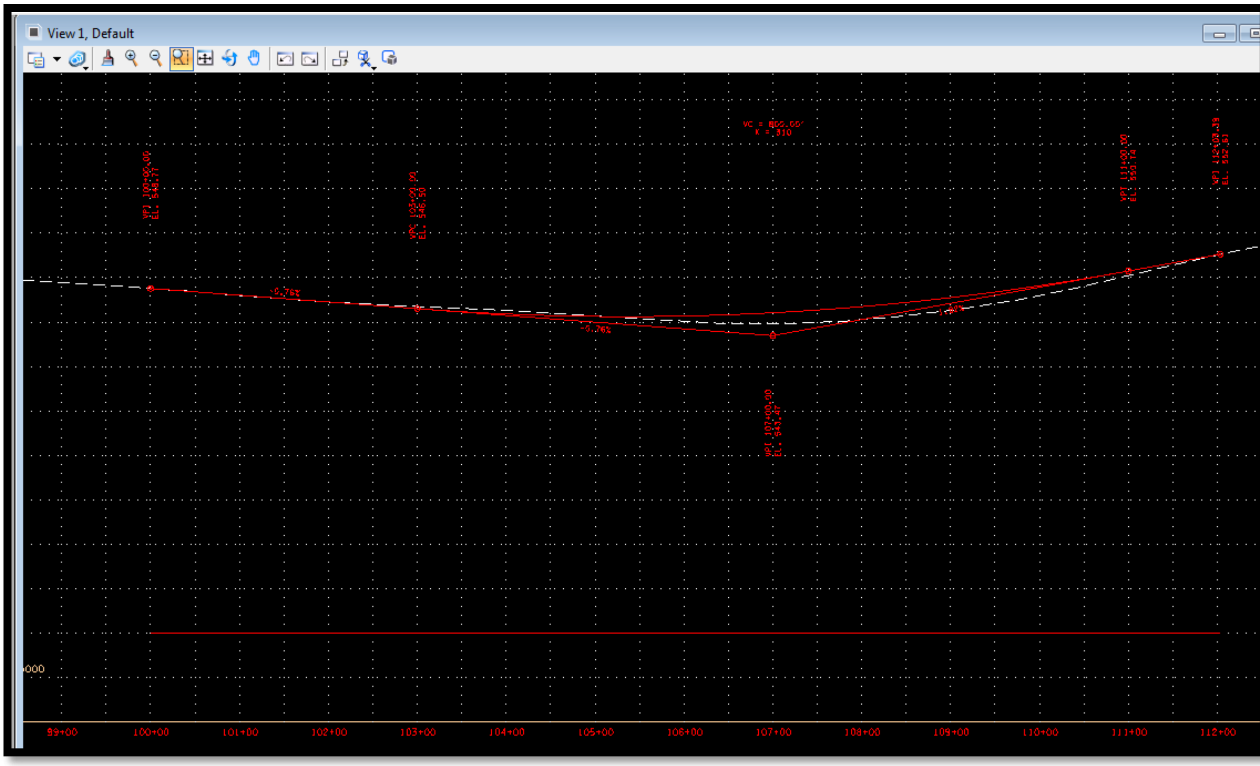
LC: 0

WT:10

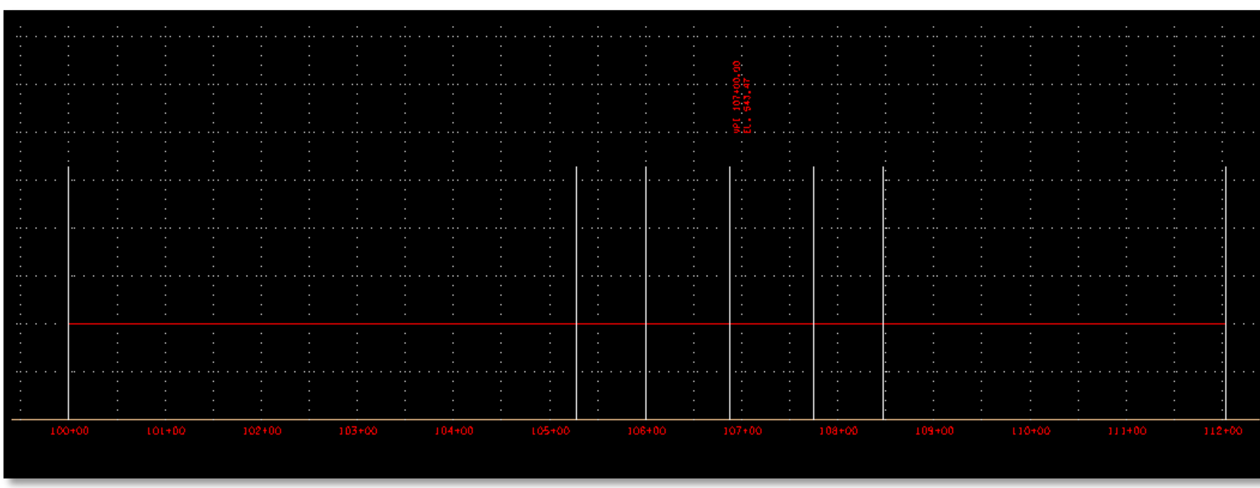
Make sure the line limits are the same as the proposed vertical grade. For this example, sta. 100+00 and sta. 112+03.39.



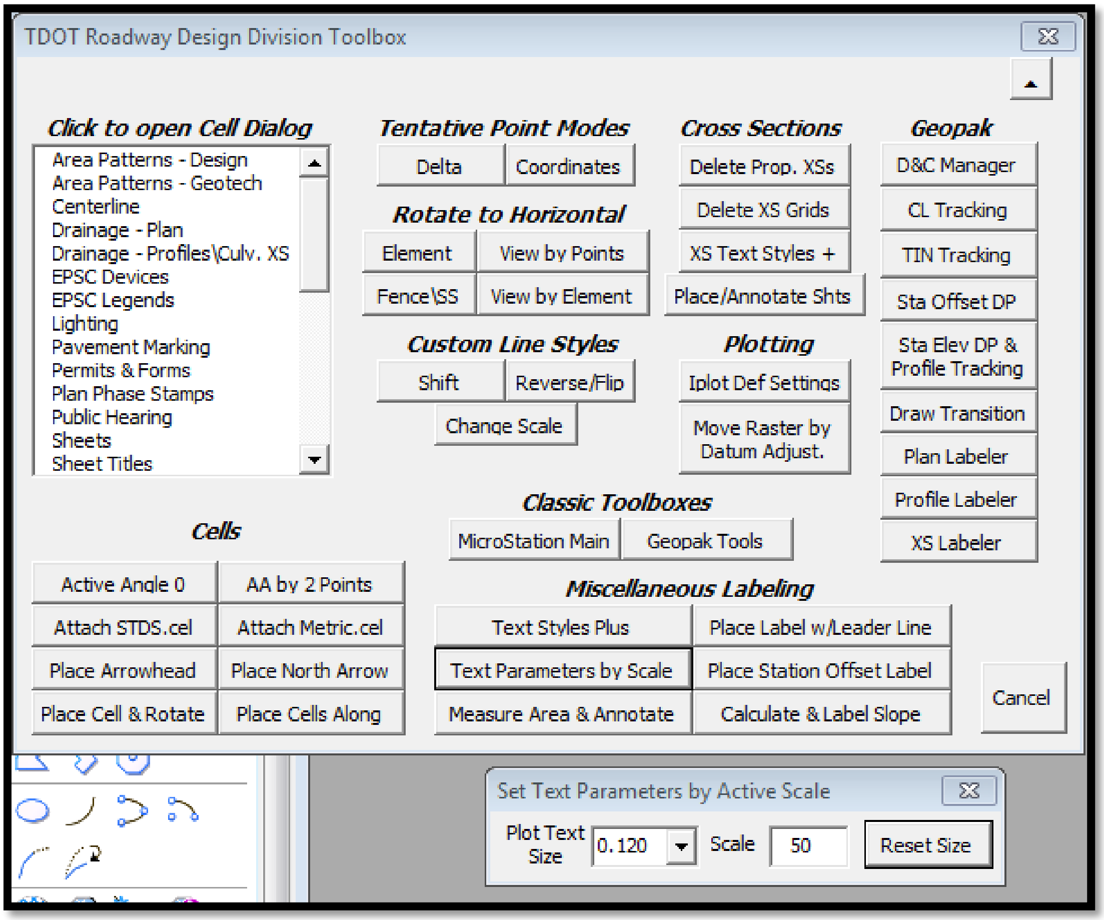
Use “Extend Line” and snap to each end of the profile.

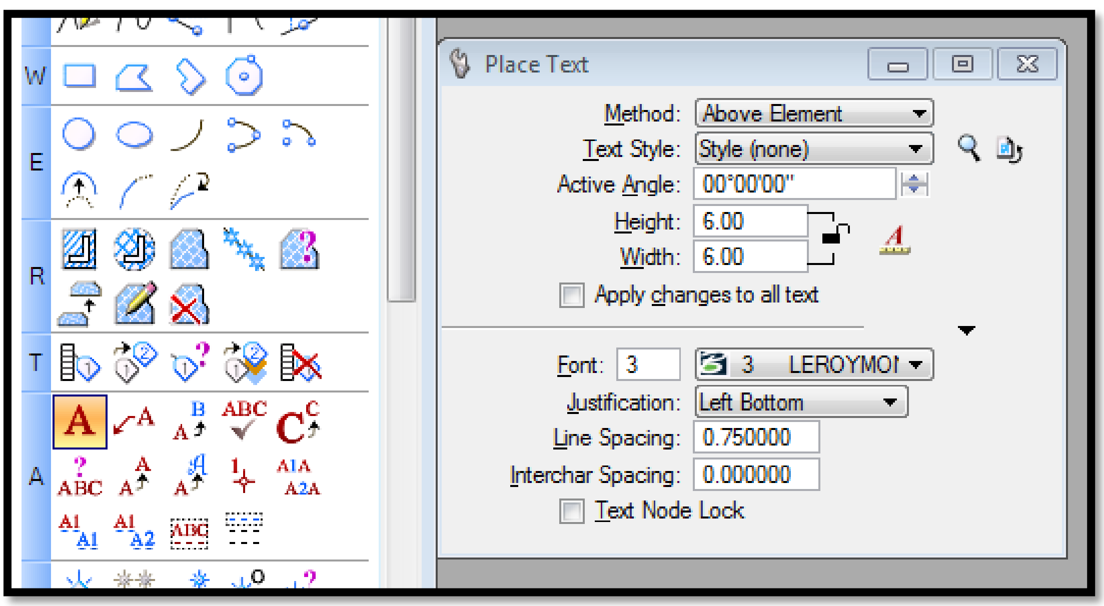


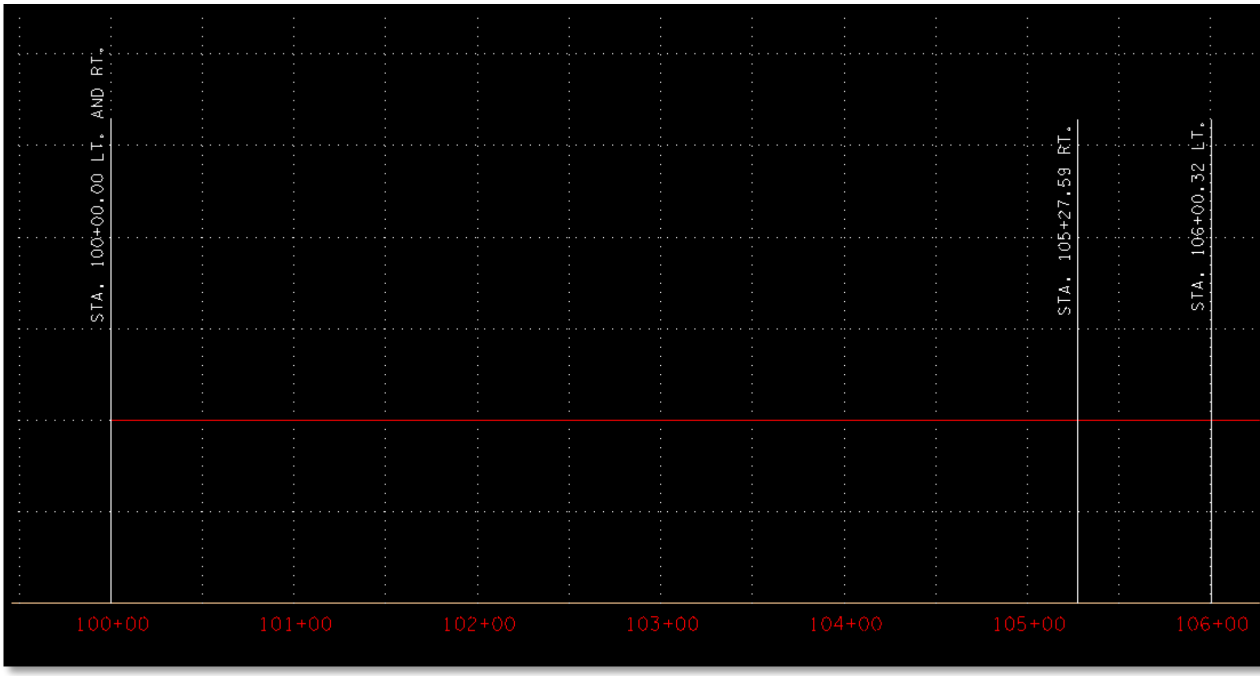
Change line symbology settings WT to 4 and CO to 0, draw vertical lines to represent the superelevation change stations listed on page 2 for both the right and left.

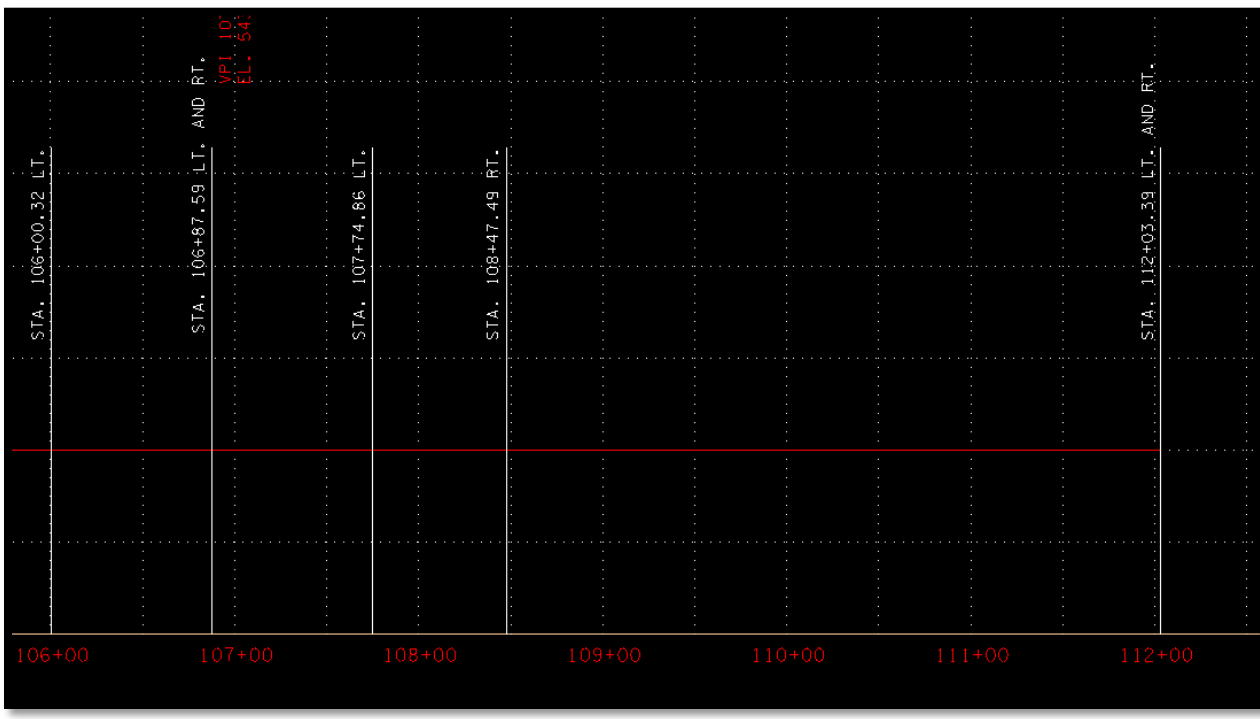


Make text settings as follows and label each vertical line as shown below:






STA. 100+00.00 LT. AND RT.
STA. 105+27.59 RT.
STA. 106+00.32 LT.
100+00
101+00
102+00
103+00
104+00
105+00
106+00


STA. 106+00.32 LT.
STA. 106+87.59 LT. AND RT.
STA. 107+74.86 LT.
STA. 108+47.49 RT.
STA. 112+03.39 LT. AND RT.
106+00
107+00
108+00
109+00
110+00
111+00
112+00

Draw the Left Profile Diagram

To distinguish between the left and right diagrams, they should be drawn in different colors. For the left diagram, use the following settings:

LV: DESIGN-CENTERLINE-Proposed Text

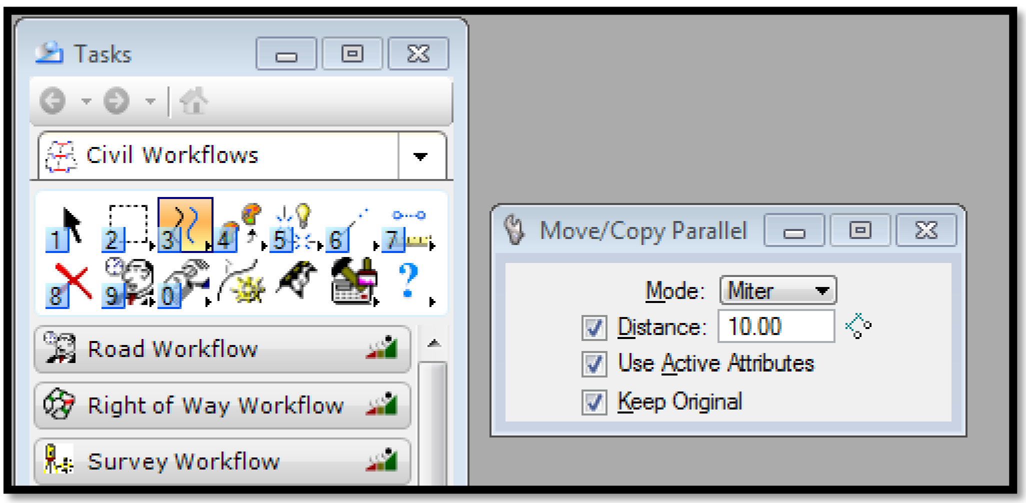
CO: 7

WT: 10

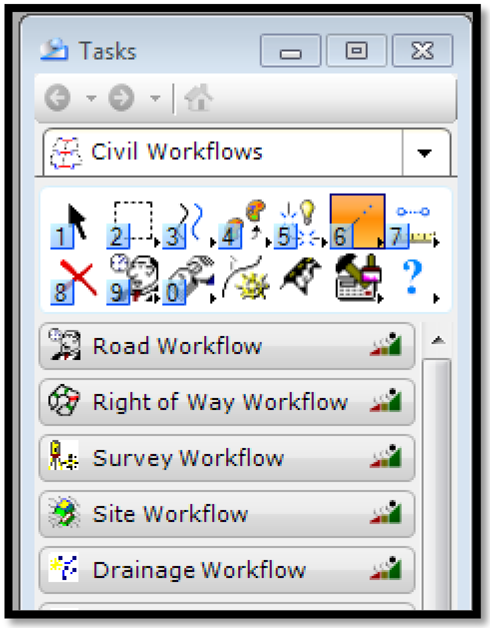
From sta. 100+00 to 106+00.32, the cross slope is a constant -2.00%, or -.020 ft/ft. To draw the diagram proportionally, set one vertical grid, 50 ft, equal to a maximum superelevation of 0.10 ft/ft. Therefore,

$$0.020 \text{ ft/ft} \times \frac{(50 \text{ ft})}{0.100 \text{ ft/ft}} = 10 \text{ ft}$$

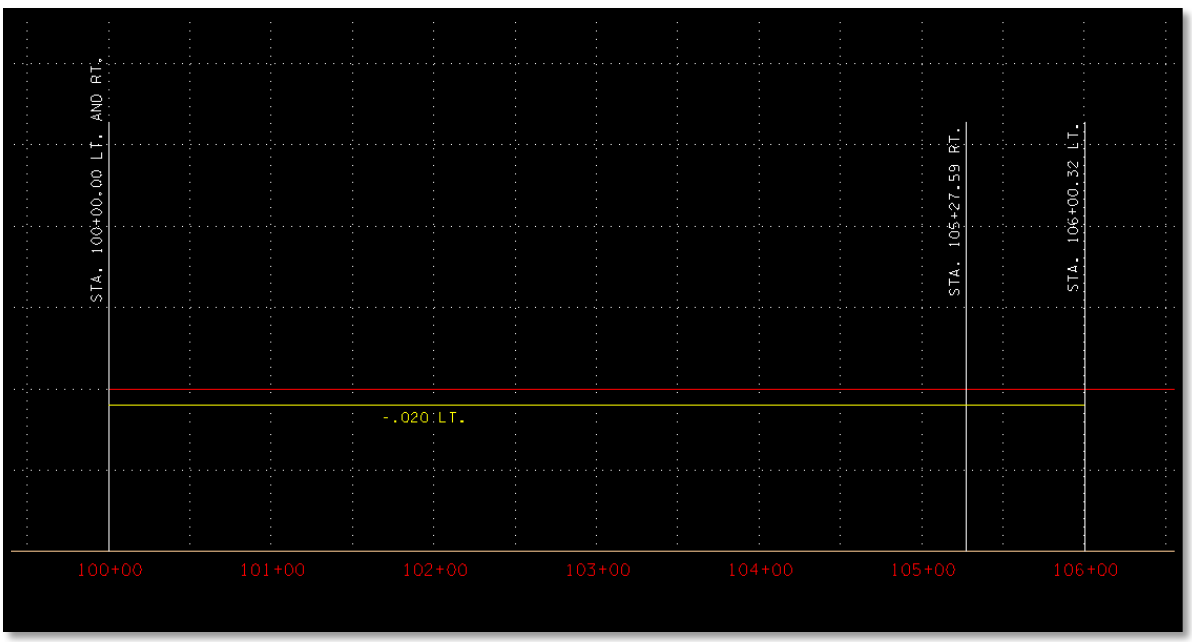
The line representing -.020 ft/ft superelevation for the left side can be drawn by copying parallel the red line drawn earlier using the settings:



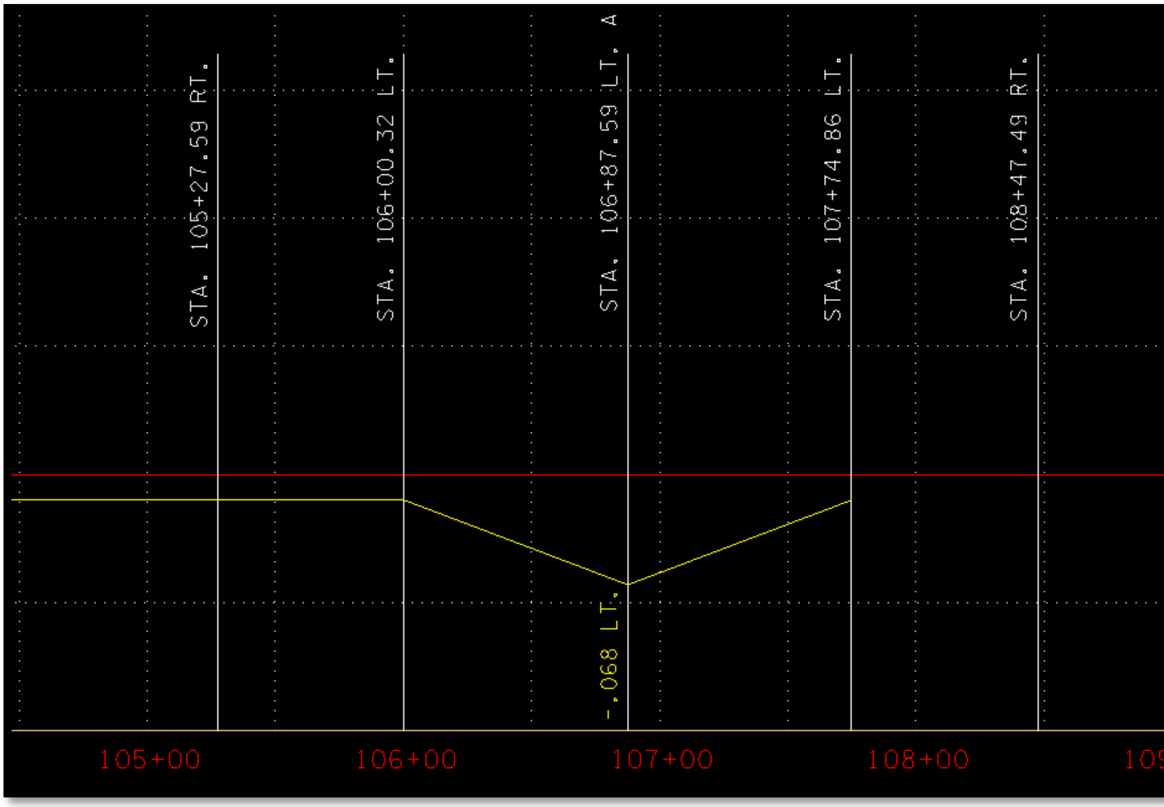
Make sure line ends at the sta. 106+00.32 line by using the “Lengthen or Shorten element to element” command:



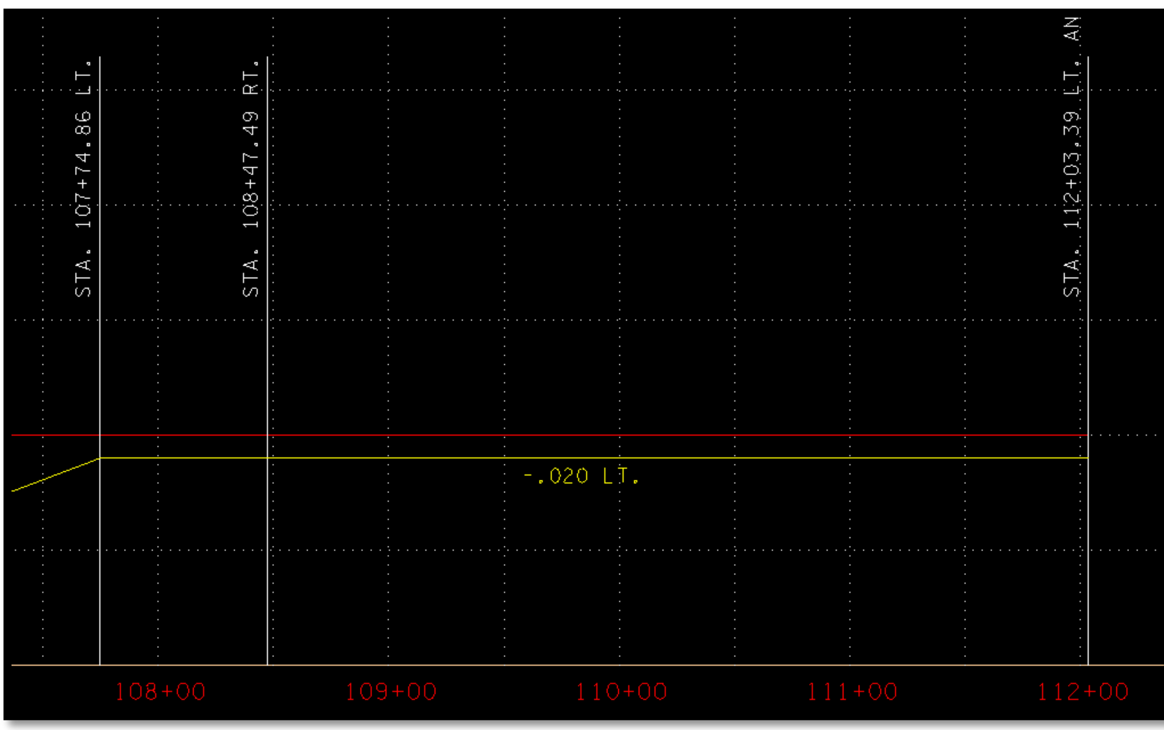
Label line as shown below using "Place text Under Element" option:



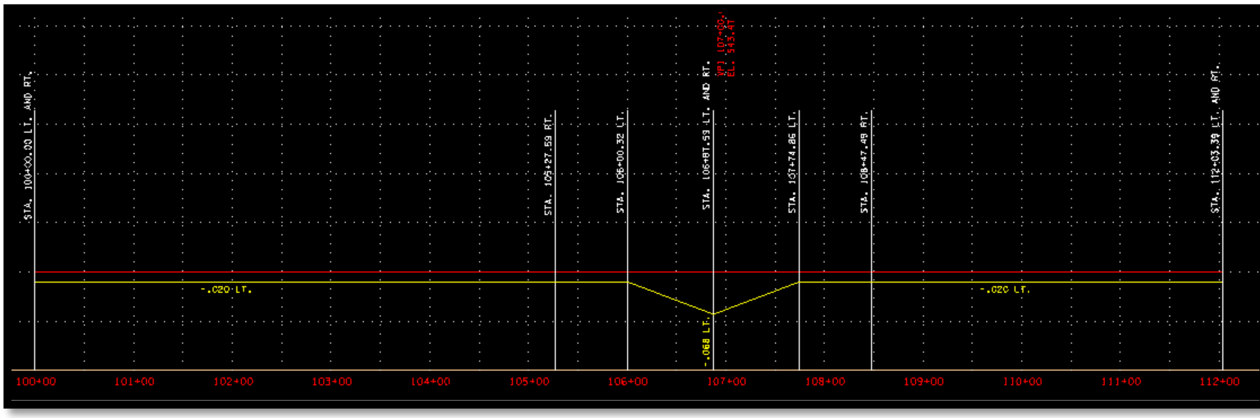
The next segment transitions from -.020 ft/ft at sta. 106+00.32 to -.068 ft/ft at sta.106+87.59, then back to -.020 ft/ft at sta. 107+74.86. Using the same conversion on page 6, -0.068 ft/ft converts to 34 ft. below the red line. Label superelevation at sta. 106+87.59 as shown below using text settings as shown on page 5.



The last segment, from sta. 107+74.86 to sta. 112+03.39, has a constant slope of -0.020 ft/ft. Draw this segment and label similar to the first segment.



The diagram for the left side should look as shown:



Draw the Right Profile Diagram

Use the following symbology settings:

LV: DESIGN-CENTERLINE-Proposed Curve Text

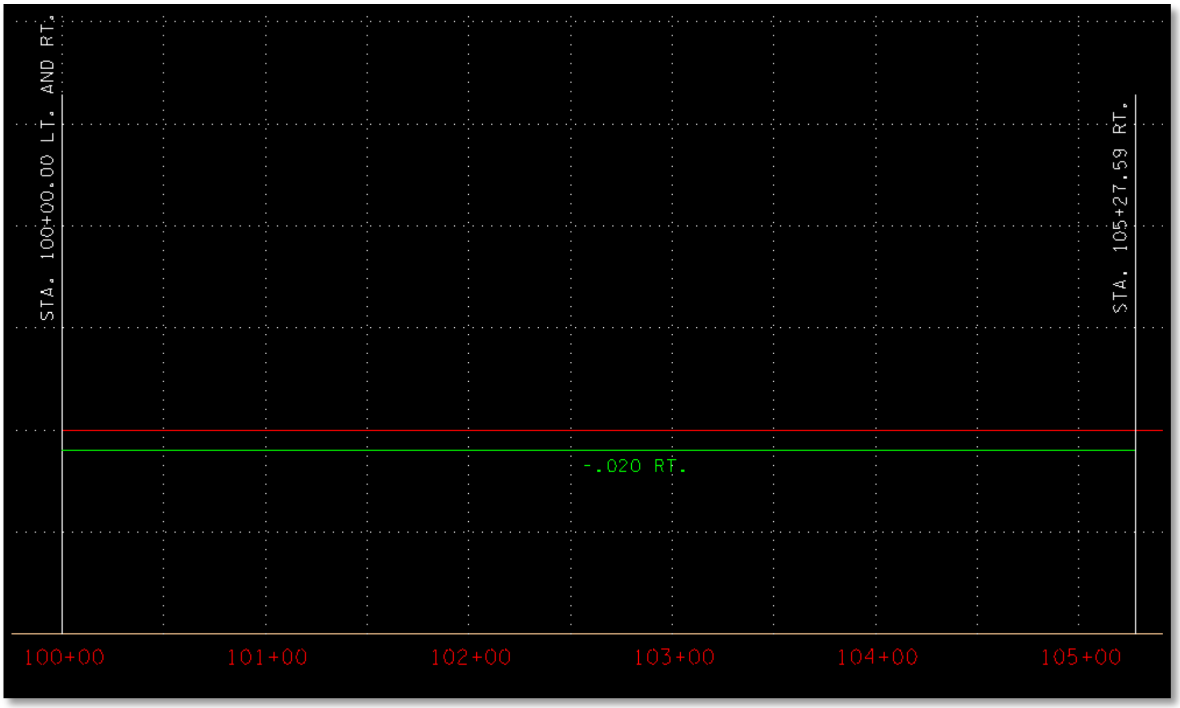
CO: 8

WT: 10

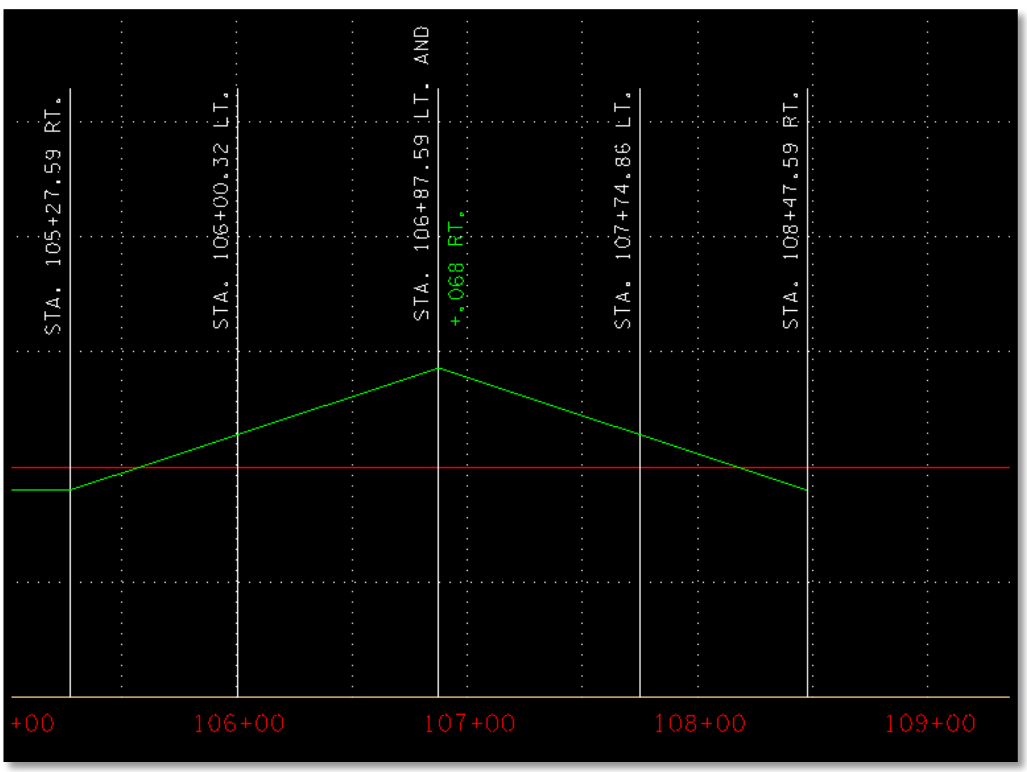
Before drawing the right-side diagram, turn off the level “DESIGN – PROFILE – Proposed Text”, which was used for the left side diagram.

From sta. 100+00 to 105+27.59, the cross slope is a constant -0.020 ft/ft.

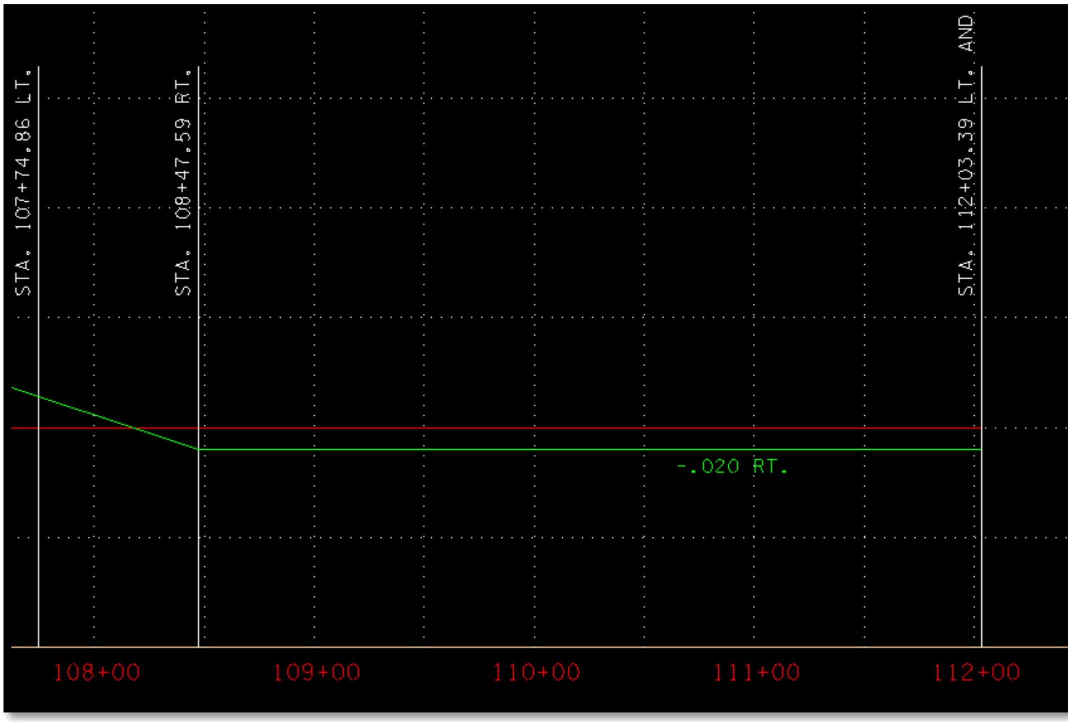
Similar to the left side diagram, copy parallel the line representing finished grade 10 ft below itself. Modify the new line to end at sta. 105+27.59.



The next segment transitions from -.020 ft/ft at sta. 105+27.59 to +.068 ft/ft at sta.106+87.59, then back to -.020 ft/f at sta. 108+47.59. Using the same conversion on page 6, +0.068 ft/ft converts to 34 ft. above the red line. Label superelevation at sta. 106+87.59 as shown below using text settings as shown on page 5.



The last segment, from sta. 108+47.59 to sta. 112+03.39, has a constant slope of -0.020 ft/ft. Draw this segment and label similar to the first segment



Turn the level “DESIGN-PROFILE-Proposed Text” back on and the finished product should look like this: