300 ALIGNMENT CHAPTER

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330
HORIZONTAL AND VERTICAL ALIGNMENT

330.01 CIRCULAR CURVES

BC adopts and concurs with the engineering principles and discussion throughout Section 3.2 of TAC. However, we wish to supplement the Tables provided with MoTI specific procedures and recommended guidelines.

Maximum Superelevation

Rural Areas: Design Domain

As stated in TAC, 0.06 m/m is the preferred maximum superelevation. The following guidelines indicate the MoTI recommendations in the selection of Design e_{max} values.

- Rural Ambient Designs Match existing e_{max}
- All other Rural Roads 0.06 m/m

Where a Rural Ambient Project is reconstructing a significant length of highway, the designer should consider using 0.06 m/m as maximum superelevation.

Minimum Radius

Urban Areas: Design Domain

As per discussion in TAC Section 3.2.2.4

Minimum Radius

Rural Areas: Design Domain

The following table is provided for Minimum Radii for Rural Design. This is a supplement to TAC Table 3.2.4

Table 330.A Minimum Radii for Rural Designs

Design Speed (km/h)	Minimum Radius (m)				
	Crown Section			Superelevated Section	
	Normal[2] (-0.02 m/m)	Reverse[3] (0.02 m/m)		Maximum Rate[1]	
		emax +0.06	emax + 0.08	+0.06 m/m	+0.08 m/m
40	700	475	525	55	50
50	1100	745	820	90	80
60	1600	1080	1190	130	120
70	2150	1470	1615	190	170
80	2800	1950	2120	250	230
90	3550	2470	2700	340	300
100	4380	3070	3350	440	390
110	5300	3780	4100	600	530
120	6300	4535	4920	750	670

Notes	**1.**	On downgrades in excess of 3%, the minimum horizontal radius should be increased. The method to calculate the increase is described on the following page.
	2.	To determine the minimum radius for normal crown, the (e+f) value is set at 0.018* in TAC Eqn 3.2.1: $e+f = V^2/127R$. (*Referenced from 1994 BC MoTH *Highway Engineering Design Manual* which stated "Both TAC and Ontario have selected this value …")
	3.	The minimum radius reverse crown is solved by re-arranging the basic equation for superelevation (TAC Eqn. 3.2.1) and solving for R when e = +0.02. Superelevation distribution is non-linear, resulting in different minimum radius values at Reverse Crown for e_{max} 0.06 and e_{max} 0.08. The method of distributing "e" and "f" is described in more detail on the following page.
	4.	All values are based on Max. Lateral Friction values from TAC Table 3.2.1

Minimum Radius on Downgrades

The minimum horizontal radius should be increased on steep downgrades to enhance road safety.

The minimum curve radius should be increased by 10% for each 1% increase in grade over 3%.

$R_{g\,(min)} = R_{(min)}\ (1 + (G-3)/10)$

Where:

$R_{(min)}$ = minimum radii from Table 330.A
G = grade (%)
$R_{g\,(min)}$ = minimum radius on grade (m)

Example: Design Speed = 100 km/h; e=0.06; G=6%
$R_{(min)}$ = 440 m from Table 330.A.

$R_{g\,(min)}$ = 440(1+(6-3)/10) = 572 m or
570 m (rounded)

[Note: Rounding should be to the nearest 10 m increment.]

The applied superelevation rate shall be selected from the appropriate table of superelevations (**Table 330.D or 330.E)** for the adjusted value of $R_{g\,(min)}$.

Rural and High Speed Urban Design – Superelevation Distribution:

The general formula for the relationship of speed, radius, superelevation and friction is given by TAC Equation 3.2.1 as: $e+f = V^2/127R$

For rural and high speed urban roadways the method used for distributing e and f is referred to as "Method 5" in the AASHTO publication. The formula for calculating *e* is as follows:

For any radius R :

$$e = \frac{V^2}{127R + V^2\left[\frac{1}{e_{max}} - \frac{1}{(e+f)_{max}}\right]} \qquad \textbf{330.01.01}$$

Where e_{max} is 0.06 or 0.08 and $(e+f)_{max}$ is e_{max} plus f_{max} which is taken from TAC Table 3.2.1

For clarity, let's call the bracketed part of the denominator 'z'

$$e = \frac{V^2}{127R + V^2 z} \qquad \textbf{330.01.02}$$

The 'z' value is a function of design speed and maximum superelevation. It is a constant for each design speed and maximum superelevation as shown in the following table.

The designer can now calculate the superelevation for any radius that may be desired.

Table 330.B Superelevation Calculation Factors

Speed (km/h)	"z" for Max. Super of: 0.06 m/m	0.08 m/m
40	12.319	8.500
50	12.121	8.333
60	11.905	8.152
70	11.905	8.152
80	11.667	7.955
90	11.404	7.738
100	11.111	7.500
110	10.417	6.944
120	10.000	6.618
130	9.524	6.250

The resultant friction *f* is solved as $V^2/127R$ minus the solved *e* from **Equation 330.01.02**. The friction can be used as the entry point into the Barrier Warrant Index Nomograph, **Figure 610.A.**

TAC Tables 3.2.6 and 3.2.7 have an insufficient number of design radii that are often necessary to deal with the challenges of horizontal alignment in British Columbia.

In order to facilitate design, MoTI has developed superelevation tables that cover a greater number of design radii. On the following pages are two tables: **Table 330.D** for e_{max} = 0.06 m/m and **Table 330.E** for e_{max} = 0.08 m/m.

These tables also indicate design values for Spiral Lengths (see Section 330.02) and Tangent Runout.

Maximum Superelevation for Auxiliary Truck Climbing Lanes

For auxiliary truck climbing lanes, the designer should use the value obtained from the appropriate superelevation table (**Table 330.D** or **330.E** as applicable) or the value from **Table 330.C**, whichever is lower.

Table 330.C e_{max} on Auxiliary Truck Climbing Lanes

Gradient	e_{max}
4%(*)	0.070
5%(*)	0.065
6%	0.055
7%	0.045
8%	0.040
9%	0.040
10%	0.040
11%	0.040
12%	0.040

(*) These values are used only when **Table 330.E** is applied.

Notes:

1) e_{max} in this table should also be applied to the auxiliary slow moving vehicle pullout and the outside auxiliary passing lane, in the uphill direction only.
2) For adjacent through lanes, the designer should use the values obtained from the applicable superelevation table (**Table 330.D** or **330.E**).

Table 330.D Superelevation and Spiral Lengths, e_{max} = 0.06 m/m

	40 km/h				50 km/h				60 km/h				70 km/h				80 km/h				90 km/h				100 km/h				110 km/h				120 km/h				
Rad.	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	Rad.
8000	NC				NC				NC				NC				NC				NC				NC				NC				NC				8000
5000	NC				NC				NC				NC				NC				NC				NC				RC	60	60	60	RC	70	70	70	5000
3000	NC				NC				NC				NC				NC				RC	50	50	50	0.020	60	60	60	0.024	60	60	60	0.027	70	70	70	3000
2000	NC				NC				NC				RC	40	40	40	RC	50	50	50	0.023	50	50	50	0.027	60	60	60	0.032	60	60	60	0.036	70	70	70	2000
1500	NC				NC				RC	40	40	40	RC	40	40	40	0.024	50	50	50	0.029	50	50	50	0.033	60	60	60	0.038	60	60	70	0.043	70	70	80	1500
1300	NC				NC				RC	40	40	40	0.022	40	40	40	0.027	50	50	50	0.031	50	50	50	0.036	60	60	60	0.042	60	60	70	0.047	70	70	90	1300
1250	NC				NC				RC	40	40	40	0.023	40	40	40	0.027	50	50	50	0.032	50	50	50	0.037	60	60	60	0.042	60	60	80	0.048	70	70	90	1250
1200	NC				NC				RC	40	40	40	0.023	40	40	40	0.028	50	50	50	0.033	50	50	50	0.038	60	60	60	0.043	60	60	80	0.049	70	70	90	1200
1150	NC				NC				RC	40	40	40	0.024	40	40	40	0.029	50	50	50	0.034	50	50	50	0.039	60	60	70	0.044	60	60	80	0.050	70	70	90	1150
1100	NC				NC				RC	40	40	40	0.025	40	40	40	0.030	50	50	50	0.035	50	50	60	0.040	60	60	70	0.046	60	60	80	0.051	70	70	90	1100
1050	NC				NC	30	30	30	0.020	40	40	40	0.026	40	40	40	0.031	50	50	50	0.036	50	50	60	0.041	60	60	70	0.047	60	60	80	0.052	70	70	100	1050
1000	NC				RC	30	30	30	0.021	40	40	40	0.027	40	40	40	0.032	50	50	50	0.037	50	50	60	0.042	60	60	70	0.048	60	60	80	0.053	70	70	100	1000
950	NC				RC	30	30	30	0.022	40	40	40	0.027	40	40	40	0.033	50	50	50	0.038	50	50	60	0.043	60	60	70	0.049	60	70	90	0.054	70	80	100	950
900	NC				RC	30	30	30	0.023	40	40	40	0.028	40	40	40	0.034	50	50	50	0.039	50	50	60	0.044	60	60	70	0.050	60	70	90	0.056	70	80	100	900
850	NC				RC	30	30	30	0.024	40	40	40	0.030	40	40	40	0.035	50	50	50	0.040	50	50	60	0.046	60	60	80	0.052	60	70	90	0.057	80	80	110	850
800	NC				RC	30	30	30	0.025	40	40	40	0.031	40	40	40	0.036	50	50	50	0.042	50	50	70	0.047	60	60	80	0.053	60	70	90	0.059	80	80	110	800
750	NC				RC	30	30	30	0.026	40	40	40	0.032	40	40	40	0.038	50	50	60	0.043	50	50	70	0.048	60	60	80	0.055	70	70	100	0.060	80	80	110	
700	NC				0.021	30	30	30	0.027	40	40	40	0.033	40	40	50	0.039	50	50	60	0.045	50	50	70	0.050	60	60	80	0.056	70	80	100	min R = 750				
650	RC	30	30	30	0.022	30	30	30	0.029	40	40	40	0.035	40	40	50	0.041	50	50	60	0.046	50	60	70	0.052	60	60	90	0.058	80	80	100					
600	RC	30	30	30	0.023	30	30	30	0.030	40	40	40	0.037	40	40	50	0.042	50	50	60	0.048	50	60	80	0.053	60	70	90	0.060	80	80	110					
550	RC	30	30	30	0.025	30	30	30	0.032	40	40	40	0.038	40	40	50	0.044	50	50	60	0.050	50	60	80	0.055	70	70	90	min R = 600								
500	RC	30	30	30	0.027	30	30	30	0.034	40	40	40	0.040	40	40	60	0.046	50	50	70	0.052	60	60	80	0.057	70	70	90									
475	0.020	30	30	30	0.028	30	30	30	0.035	40	40	40	0.041	40	40	60	0.047	50	50	70	0.053	60	60	80	0.058	80	80	100									
450	0.021	30	30	30	0.029	30	30	30	0.036	40	40	50	0.043	40	40	60	0.049	50	60	70	0.054	60	60	80	0.059	80	80	100									
425	0.022	30	30	30	0.030	30	30	40	0.037	40	40	50	0.044	40	50	60	0.050	50	60	70	0.055	60	70	90	0.060	80	80	100									
400	0.023	30	30	30	0.031	30	30	40	0.038	40	40	50	0.045	40	50	60	0.051	50	60	80	0.057	70	70	90	min R = 440												
380	0.024	30	30	30	0.032	30	30	40	0.039	40	40	50	0.046	40	50	60	0.052	50	60	80	0.058	70	70	90													
360	0.025	30	30	30	0.033	30	30	40	0.041	40	40	50	0.047	40	50	60	0.053	50	60	80	0.059	80	80	90													
340	0.026	30	30	30	0.034	30	30	40	0.042	40	40	50	0.048	40	50	70	0.054	60	60	80	0.060	80	80	90													
320	0.027	30	30	30	0.035	30	30	40	0.043	40	40	50	0.050	40	50	70	0.056	60	60	80	min R = 340																
300	0.028	30	30	30	0.037	30	30	40	0.044	40	40	60	0.051	40	50	70	0.057	60	60	80																	
290	0.028	30	30	30	0.037	30	30	40	0.045	40	40	60	0.052	50	50	70	0.057	70	70	90																	
280	0.029	30	30	30	0.038	30	30	50	0.046	40	40	60	0.052	50	50	70	0.058	70	70	90																	
270	0.030	30	30	30	0.039	30	40	50	0.047	40	40	60	0.053	50	60	70	0.059	70	70	90																	
260	0.030	30	30	30	0.040	30	40	50	0.047	40	50	60	0.054	50	60	70	0.059	70	70	90																	
250	0.031	30	30	40	0.040	30	40	50	0.048	40	50	60	0.055	50	60	70	0.060	80	80	90																	
240	0.032	30	30	40	0.041	30	40	50	0.049	40	50	60	0.055	50	60	80	min R = 250																				
230	0.033	30	30	40	0.042	30	40	50	0.050	40	50	60	0.056	60	60	80																					
220	0.034	30	30	40	0.043	30	40	50	0.051	40	50	60	0.057	60	60	80																					
210	0.035	30	30	40	0.044	30	40	50	0.052	40	50	60	0.058	60	60	80																					
200	0.036	30	30	40	0.045	30	40	50	0.053	40	50	70	0.059	60	60	80																					
190	0.037	30	30	40	0.046	30	40	50	0.054	40	50	70	0.060	70	70	80																					
180	0.038	30	30	40	0.047	30	40	60	0.055	50	50	70	min R = 190																								
170	0.039	30	30	40	0.048	30	40	60	0.056	50	50	70																									
160	0.040	30	30	40	0.049	30	40	60	0.057	50	50	70																									
150	0.041	30	30	50	0.051	30	50	60	0.058	50	60	70																									
145	0.042	30	40	50	0.051	30	50	60	0.059	60	60	70																									
140	0.043	30	40	50	0.052	30	50	60	0.059	60	60	70																									
135	0.044	30	40	50	0.053	40	50	60	0.060	60	60	70																									
130	0.044	30	40	50	0.054	40	50	60	0.060	60	60	70																									
125	0.045	30	40	50	0.054	40	50	60	min R = 130																												
120	0.046	30	40	50	0.055	40	50	60																													
115	0.047	30	40	50	0.056	40	50	60																													
110	0.048	30	40	50	0.057	40	50	70																													
105	0.049	30	40	50	0.057	50	50	70																													
100	0.050	30	40	50	0.058	50	50	70																													
95	0.051	30	40	60	0.059	50	50	70																													
90	0.052	30	40	60	0.060	50	50	70																													
85	0.053	30	40	60	min R = 90																																
80	0.054	30	40	60																																	
75	0.055	30	50	60																																	
70	0.056	40	50	60																																	
65	0.058	40	50	60																																	
60	0.059	40	50	60																																	
55	0.060	40	50	70																																	
	min R = 55																																				

e Max 0.06 m/m

e — Superelevation

NC — Normal Crown Section

RC — Remove adverse crown and superelevate at 0.02 m/m

L2 — MINIMUM spiral for two lanes and ramps

L4 — MINIMUM spiral for three lanes and for four lanes with up to 3.0 m median

L6 — MINIMUM spiral for six lanes with up to 3.0 m median

Tangent Runout:

Normally established as 15 times the number of lanes. I.E. 30 m for two lanes; 60 m for four lanes and 90 metres for six lanes.

Use the following method - superelevation runout - where grade and pavement width may result in an otherwise poor drainage design:

1. Tangent runout for 2-lane, 4-lane and 6-lane is 0.02/e times L2, L4 or L6 respectively; where e is the design superelevation for the radius in question.
2. Using the above method, the tangent runout must still fall within the following ranges:

   L2: Runout between 20 and 30 metres
   L4: Runout between 30 and 60 metres
   L6: Runout between 40 and 90 metres

NOTE:
There are more precise transition points for RC and NC values in the Civil 3D Roadway Design Standards table. These more precise values have been rounded to the nearest 50 or 100 m and usually fall between the radii listed above.

Note: Refer to section 330.01 - **Minimum Radius on Downgrades.**

Table 330.E Superelevation and Spiral Lengths, e_{max} = 0.08 m/m

	40 km/h				50 km/h				60 km/h				70 km/h				80 km/h			
Rad.	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6
8000	NC				NC				NC				NC				NC			
5000	NC				NC				NC				NC				NC			
3000	NC				NC				NC				NC				NC			
2000	NC				NC				NC				RC	40	40	40	0.021	50	50	50
1500	NC				NC				RC	40	40	40	0.021	40	40	40	0.027	50	50	50
1300	NC				NC				RC	40	40	40	0.024	40	40	40	0.030	50	50	50
1250	NC				NC				RC	40	40	40	0.025	40	40	40	0.031	50	50	50
1200	NC				NC				RC	40	40	40	0.026	40	40	40	0.031	50	50	50
1150	NC				NC				0.021	40	40	40	0.026	40	40	40	0.032	50	50	50
1100	NC				NC				0.021	40	40	40	0.027	40	40	40	0.034	50	50	50
1050	NC				RC	30	30	30	0.022	40	40	40	0.028	40	40	40	0.035	50	50	50
1000	NC				RC	30	30	30	0.023	40	40	40	0.029	40	40	40	0.036	50	50	50
950	NC				RC	30	30	30	0.024	40	40	40	0.031	40	40	40	0.037	50	50	60
900	NC				RC	30	30	30	0.025	40	40	40	0.032	40	40	40	0.039	50	50	60
850	NC				RC	30	30	30	0.026	40	40	40	0.033	40	40	50	0.040	50	50	60
800	NC				0.020	30	30	30	0.027	40	40	40	0.035	40	40	50	0.042	50	50	60
750	NC				0.022	30	30	30	0.029	40	40	40	0.036	40	40	50	0.044	50	50	70
700	NC				0.023	30	30	30	0.030	40	40	40	0.038	40	40	50	0.046	50	50	70
650	RC	30	30	30	0.024	30	30	30	0.032	40	40	40	0.040	40	40	60	0.048	50	50	70
600	RC	30	30	30	0.026	30	30	30	0.034	40	40	40	0.042	40	40	60	0.050	50	60	80
550	RC	30	30	30	0.028	30	30	30	0.036	40	40	50	0.045	40	50	60	0.053	50	60	80
500	0.021	30	30	30	0.030	30	30	40	0.039	40	40	50	0.048	40	50	70	0.056	50	60	80
475	0.022	30	30	30	0.031	30	30	40	0.040	40	40	50	0.049	40	50	70	0.058	50	70	90
450	0.023	30	30	30	0.032	30	30	40	0.042	40	40	50	0.051	40	50	70	0.059	50	70	90
425	0.023	30	30	30	0.033	30	30	40	0.042	40	40	50	0.051	40	50	70	0.060	50	70	90
400	0.025	30	30	30	0.035	30	30	40	0.045	40	40	60	0.054	40	60	70	0.063	50	70	90
380	0.026	30	30	30	0.036	30	30	40	0.046	40	40	60	0.056	40	60	80	0.065	50	70	100
360	0.027	30	30	30	0.038	30	30	40	0.048	40	50	60	0.057	40	60	80	0.066	50	70	100
340	0.028	30	30	30	0.039	30	40	50	0.050	40	50	60	0.059	40	60	80	0.068	60	80	100
320	0.030	30	30	30	0.041	30	40	50	0.051	40	50	60	0.061	40	60	80	0.070	60	80	100
300	0.031	30	30	30	0.042	30	40	50	0.053	40	50	70	0.063	40	60	90	0.072	60	80	110
290	0.032	30	30	40	0.043	30	40	50	0.054	40	50	70	0.064	50	70	90	0.073	70	80	110
280	0.033	30	30	40	0.044	30	40	50	0.055	40	50	70	0.065	50	70	90	0.074	70	80	110
270	0.034	30	30	40	0.045	30	40	50	0.056	40	50	70	0.066	50	70	90	0.075	70	80	110
260	0.034	30	30	40	0.046	30	40	50	0.058	40	50	70	0.068	50	70	90	0.076	70	90	110
250	0.035	30	30	40	0.048	30	40	60	0.059	40	60	70	0.069	50	70	90	0.077	80	90	110
240	0.036	30	30	40	0.049	30	40	60	0.060	40	60	80	0.070	50	70	90	0.079	80	90	120
230	0.037	30	30	40	0.050	30	40	60	0.061	40	60	80	0.071	60	70	100	0.080	80	90	120
220	0.039	30	30	40	0.051	30	50	60	0.063	40	60	80	0.073	60	70	100	min R = 230			
210	0.040	30	30	40	0.053	30	50	60	0.064	40	60	80	0.074	60	80	100				
200	0.041	30	30	50	0.054	30	50	60	0.066	40	60	80	0.075	60	80	100				
190	0.043	30	40	50	0.056	30	50	60	0.067	40	60	80	0.077	70	80	100				
180	0.044	30	40	50	0.057	30	50	70	0.069	50	60	90	0.078	70	80	110				
170	0.046	30	40	50	0.059	40	50	70	0.070	50	70	90	0.080	80	80	110				
160	0.047	30	40	50	0.061	40	50	70	0.072	50	70	90	min R = 170							
150	0.049	30	40	50	0.063	40	60	70	0.074	50	70	90								
145	0.050	30	40	50	0.064	40	60	70	0.075	60	70	90								
140	0.051	30	40	60	0.065	40	60	70	0.076	60	70	90								
135	0.052	30	40	60	0.066	40	60	80	0.077	60	70	100								
130	0.053	30	40	60	0.067	40	60	80	0.078	60	70	100								
125	0.055	30	50	60	0.068	40	60	80	0.079	60	70	100								
120	0.056	30	50	60	0.069	40	60	80	0.080	70	80	100								
115	0.057	30	50	60	0.071	40	60	80	min R = 120											
110	0.058	30	50	60	0.072	40	60	80												
105	0.060	30	50	60	0.073	50	60	80												
100	0.061	30	50	70	0.075	50	70	90												
95	0.063	40	50	70	0.076	50	70	90												
90	0.064	40	50	70	0.078	50	70	90												
85	0.066	40	50	70	0.079	60	70	90												
80	0.068	40	60	70	0.080	60	70	90												
75	0.070	40	60	70	min R = 80															
70	0.072	40	60	80																
65	0.074	40	60	80																
60	0.076	40	60	80																
55	0.078	40	60	80																
50	0.080	50	70	90																
	min R = 50																			

	90 km/h				100 km/h				110 km/h				120 km/h				
Rad.	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	e	L2	L4	L6	Rad.
8000	NC				NC				NC				NC				8000
5000	NC				NC				RC	60	60	60	RC	70	70	70	5000
3000	RC	50	50	50	0.022	60	60	60	0.026	60	60	60	0.030	70	70	70	3000
2000	0.026	50	50	50	0.030	60	60	60	0.036	60	60	60	0.041	70	70	80	2000
1500	0.032	50	50	50	0.038	60	60	60	0.044	60	60	80	0.050	70	70	90	1500
1300	0.036	50	50	60	0.042	60	60	70	0.049	60	70	90	0.055	70	80	100	1300
1250	0.037	50	50	60	0.043	60	60	70	0.050	60	70	90	0.057	70	80	110	1250
1200	0.038	50	50	60	0.044	60	60	70	0.051	60	70	90	0.058	70	80	110	1200
1150	0.039	50	50	60	0.045	60	60	80	0.053	60	70	90	0.060	70	80	110	1150
1100	0.040	50	50	60	0.047	60	60	80	0.054	60	70	100	0.061	70	90	110	1100
1050	0.041	50	50	60	0.048	60	60	80	0.056	60	70	100	0.063	70	90	120	1050
1000	0.043	50	50	70	0.050	60	60	80	0.057	60	80	100	0.065	70	90	120	1000
950	0.044	50	50	70	0.051	60	60	80	0.059	60	80	100	0.067	70	90	120	950
900	0.046	50	50	70	0.053	60	70	90	0.061	60	80	110	0.069	70	100	130	900
850	0.047	50	60	70	0.055	60	70	90	0.063	60	80	110	0.071	80	100	130	850
800	0.049	50	60	80	0.057	60	70	90	0.065	60	90	110	0.073	80	100	130	800
750	0.051	50	60	80	0.059	60	70	100	0.067	70	90	120	0.076	90	110	140	750
700	0.053	50	60	80	0.061	60	80	100	0.070	70	90	120	0.078	90	110	140	700
650	0.056	50	70	90	0.063	60	80	100	0.073	80	100	130	0.080	100	110	150	650
600	0.058	50	70	90	0.066	60	80	110	0.076	80	100	130	min R = 670				
550	0.061	50	70	90	0.069	70	90	110	0.079	90	100	140					
500	0.064	60	80	100	0.072	70	90	120	0.080	100	110	140					
475	0.066	60	80	100	0.074	80	90	120	min R = 530								
450	0.068	60	80	100	0.076	80	90	120									
425	0.068	60	80	110	0.076	80	90	130									
400	0.071	70	80	110	0.079	90	100	130									
380	0.073	70	90	110	0.080	100	100	130									
360	0.075	80	90	120	min R = 390												
340	0.077	80	90	120													
320	0.078	80	90	120													
300	0.080	90	90	120													
290	min R = 300																

e Max 0.08 m/m

e Superelevation

NC Normal Crown Section

RC Remove adverse crown and superelevate at 0.02 m/m

L2 MINIMUM spiral for two lanes and ramps

L4 MINIMUM spiral for three lanes and for four lanes with up to 3.0 m median

L6 MINIMUM spiral for six lanes with up to 3.0 m median

Tangent Runout:

Normally established as 15 times the number of lanes. I.E. 30 m for two lanes; 60 m for four lanes and 90 metres for six lanes.

Use the following method - superelevation runout - where grade and pavement width may result in an otherwise poor drainage design:

1. Tangent runout for 2-lane, 4-lane and 6-lane is 0.02/e times L2, L4 or L6 respectively; where e is the design superelevation for the radius in question.
2. Using the above method, the tangent runout must fall within the following ranges:

   L2: Runout between 20 and 30 metres
   L4: Runout between 30 and 60 metres
   L6: Runout between 40 and 90 metres

NOTE:
There are more precise transition points for RC and NC values in the Civil 3D Roadway Design Standards table. These more precise values have been rounded to the nearest 50 or 100 m and usually fall between the radii listed above.

Notes:

1. Table 330.E is only used in special cases such as:
   a. On ramps with tight radii where truck overturning is a concern;
   b. For rehabilitation or reconstruction projects on existing highways for which the MoTI's approved ambient design element on the Design Criteria Sheet is 8% maximum superelevation.
2. Refer to section 330.01 - **Minimum Radius on Downgrades**.

330.02 SPIRAL CURVES

BC uses ***Spiral Length*** as opposed to Spiral Parameter; as shown on **Table 330.D** and **Table 330.E**. The lengths are based upon the same rationale as used in TAC; the formulae are converted below to express the Spiral as a Spiral Length "Ls" rather than a Spiral Parameter "A".

For **Comfort**: $Ls = \frac{V^3}{28R}$ **330.02.01**

For **Superelevation** $Ls = \frac{100we}{2s}$ **330.02.02**

For **Aesthetics**: $Ls = \frac{V}{1.8}$ **330.02.03**

Segmental Spirals

It is preferable to use a connecting or segmental spiral between two curves of different radii and it is mandatory when the radius of the flatter curve is more than 50% greater than the radius of the sharper curve.

There are two distinct cases where a segmental spiral would be used. First, where the spiral is needed to adjust the superelevation between the two curves. The second case is where the segmental spiral is used for a speed-change facility, as between a highway curve and an interchange loop.

Case 1

80 km/h; e_{max} =0.08; R_1=600 m; R_2=230 m. What is the La Length? From Table 330.E, Min Ls for R 230 = 80 m

Min Segmental $La = Ls * \frac{R_1 - R_2}{R_1}$ = 49.333 m

Use La = 50 m

Whenever a solved La is rounded, the Ls generated by the La needs to be determined for detailed calculations of the segmental spiral data.

Resultant $Ls = La * \frac{R_1}{R_1 - R_2}$ = 81.081 m

Case 2:

135 m of Segmental spiral is needed to decelerate from a highway curve of R_1 250 m at 70 km/h to an interchange loop of R_2 50 m at 40 km/h. What is the length of the total spiral?

$$Ls = La * \frac{R_1}{R_1 - R_2} = 135 * \frac{250}{250 - 50}$$ = 168.750 m

330.03 CREST VERTICAL CURVE

(Ref. BC MoTH Technical Bulletin DS96004)

The design speed shall be used to determine the minimum design rate of vertical curvature (K).

Taillight height shall be used for all roads other than Low-Volume Roads. The additional 1.0 second perception reaction time is NOT required for taillight height designs. This represents the minimum and should be exceeded where possible.

The use of rock as object height is only required for low volume roads; the additional perception reaction time is also required. This represents the minimum and should be exceeded where possible.

Table 330.F Minimum K Factors to Provide Stopping Sight Distance on Crest Curves

Design Speed (km/h)	Minimum SSD (m)		Minimum K for Crest Curve	
	Rock (150 mm)	Taillight (600 mm)**	Rock	Taillight
40	50	50	7	4
50	65	65	11	7
60	85	85	18	11
70	105	105	28	17
80	130	130	42	26
90	185*	160	85*	39
100	215*	185	114*	52
110	250*	220	154*	74
120	285*	250	200*	95

* Represents 1 second of additional perception/reaction time (based on interpretation of 1976 RTAC *Geometric Design Guide for Canadian Roads and Streets*, Section B.2.5).

** SSD based on 2017 TAC Table 3.3.2

There is no maximum K value for open shoulder designs with unimpeded flows into the ditch. For curbed designs, K values greater than 50 may have poor drainage near the flat points (grade less than 0.3%).

330.04 VERTICAL AND HORIZONTAL ALIGNMENTS NEAR AND ON BRIDGES

Alignment Constraints

While it may be aesthetically pleasing to place a bridge on a reversing curve with spirals, this often will introduce logistical complexities in the design and construction of the structure. The introduction of a superelevation transition such as tangent runout can add substantially to the design calculations and construction efforts resulting in a higher the final cost for bridges.

Bridges over fish-bearing streams often have special drainage requirements. In cases where the grade is insufficient to carry water across a bridge or at the bottom of a sag curve, water will pond unless special and very costly drainage works are constructed on both sides of the bridge deck to meet environmental regulations. Many jurisdictions have established grade requirements for bridges to minimize the risk of water accumulation on the deck.

In selecting the roadway's horizontal and vertical alignments near and at bridge crossings, the highway designer should take into account the above constraints on the design of the structure.

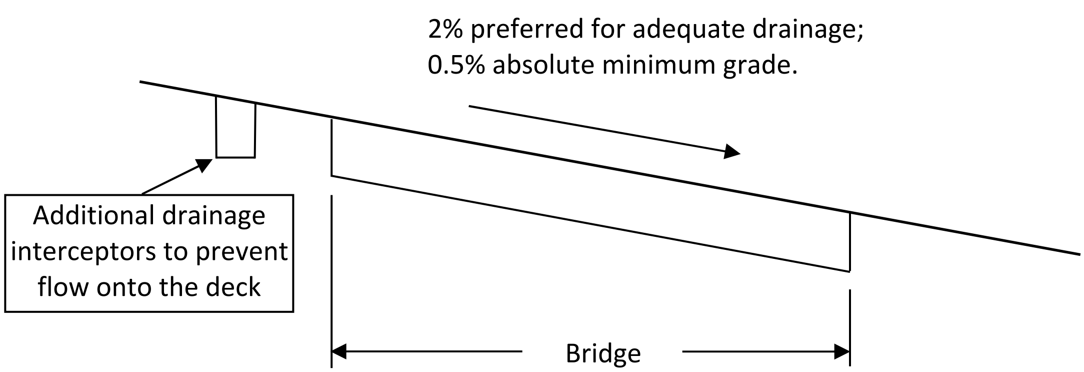
Recommendations

The Bridge Engineering Section and the Geometric Standards and Design Section have developed the following guidelines for use by Highway Design Staff and Consultants.

- Bridge Section and/or the Bridge Design Consultant should be part of the preliminary design process to address the following concerns and to balance needs of both the grading and structural design;
- Desirable Grade on Bridges is 2%. Absolute Minimum Grade is 0.5% based on extreme topographical hardship;
- Avoid bridges in the bottom of Sag Vertical Curves;
- Because of our winter conditions and the ease with which bridge decks can freeze, additional drainage pickups should be standard for the downgrade (upstream) approach to bridges;
- Bridges should be located on tangent and outside of tangent runout of the nearest curve or located completely within the circular curve portion.

Reference

Rural Road Design, A Guide to the Geometric Design of Rural Roads, AUSTROADS, Sydney 2003.



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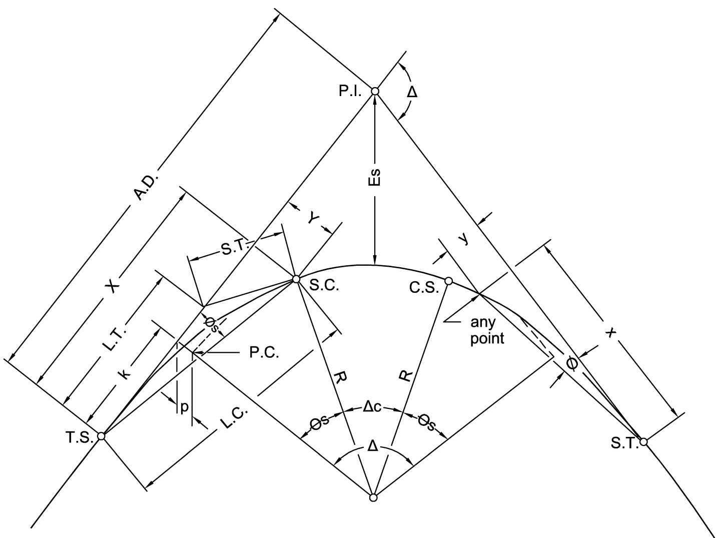
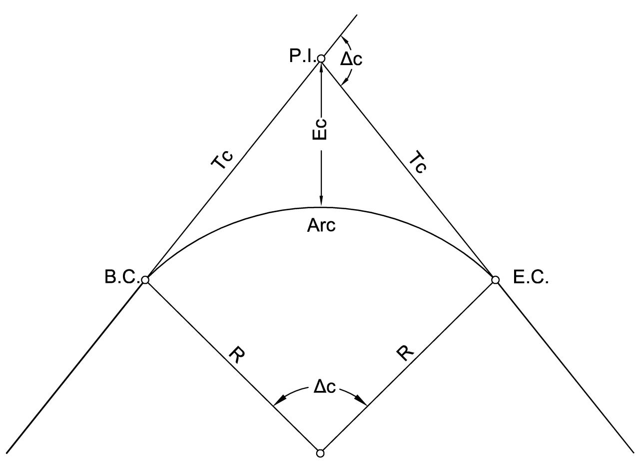
GEOMETRIC DESIGN AIDS

Figure 340.A Spiral and Circular Curve Nomenclature



CURVE WITH TRANSITION BOTH ENDS
Figure (a)



CIRCULAR CURVE
Figure (b)

P.I.	Point of intersection of the main tangents
T.S.	Tangent to Spiral: common point of tangent and spiral - beginning of spiral
S.C.	Spiral to Curve: common point of spiral and circular curve - beginning of circular curve
C.S.	Curve to Spiral: common point of circular curve and spiral - end of circular curve
S.T.	Spiral to Tangent: common point of spiral and tangent - end of spiral
S.C.S.	Mid-point of a curve which is transitional throughout
R	Radius of the circular curve
r	Radius of a curve at any length on the spiral
Ls	Length of spiral between T.S. and S.C.
ℓ	Length between any two points on the spiral
A.D.	Tangent distance P.I. to T.S. or S.T.; apex distance
Es	External distance from P.I. to centre of circular curve portion or to S.C.S. of a curve transitional throughout
Arc	Length of circular curve from S.C. to C.S.
Δ	Intersection angle between the tangents of the entire curve
Δc	Intersection angle between tangents at the S.C. and at the C.S. or the central angle of a circular curve
Ɵs	Spiral Angle: The intersection angle between the tangent of the complete curve and the tangent at the S.C.
Ɵ	Intersection angle between tangent of complete curve and tangent at any other point on the spiral
Øs	Deflection angle from tangent at T.S. to S.C.
Ø	Deflection angle from tangent at any point on spiral to any other point on spiral
L.T.	Long tangent distance of spiral only
S.T.	Short tangent distance of spiral only
L.C.	Long chord of the spiral curve; distance from T.S. to S.C.
P	Offset distance from the tangent of P.C. of circular curve produced
k	Distance from T.S. to point on tangent opposite the P.C. of the circular curve produced
X,Y	Coordinates of S.C. from T.S.
x,y	Coordinates of any other point on spiral from the T.S.
Tc	Tangent distance P.I. to B.C. or E.C.
B.C.	Beginning of curve
E.C.	End of curve
Arc	Length of curve from B.C. to E.C.
Δc	Intersection angle between the tangents
Ec	External distance from P.I. to centre of curve

(Tc through Ec: Circular Curve only)

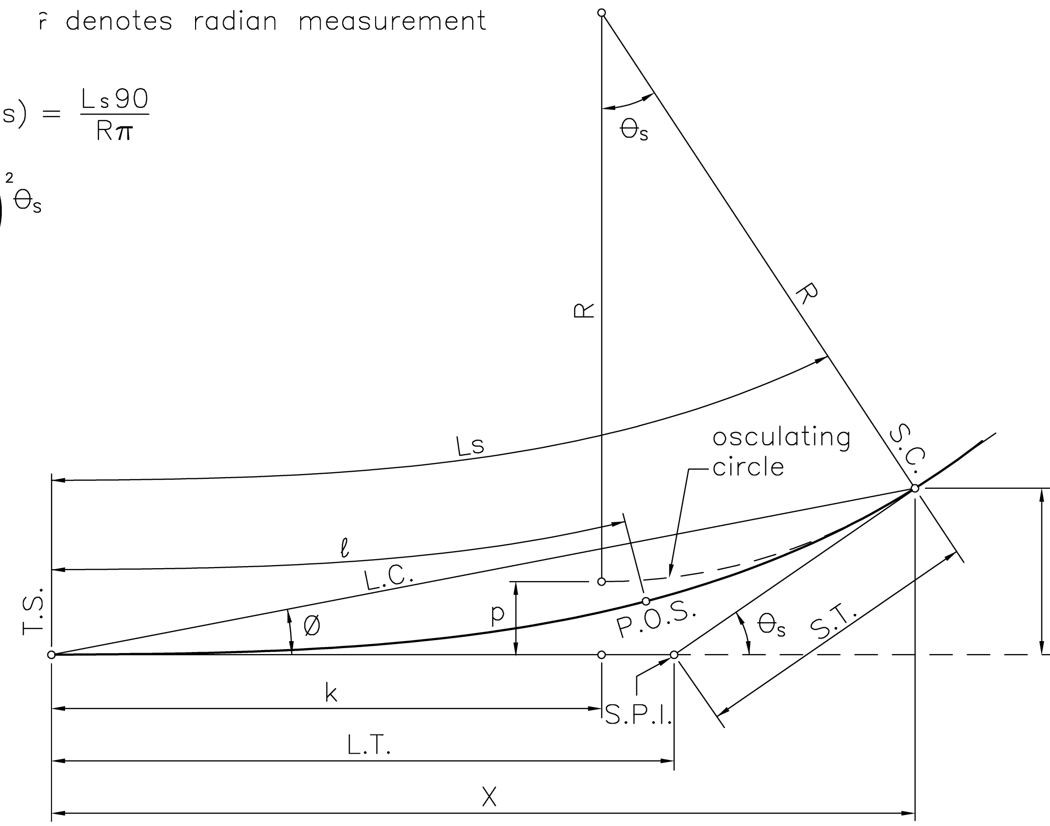
Figure 340.B Spiral Formulae

$$\theta_{s\hat{r}} = \frac{L_s}{2R}$$ $\hat{r}$ denotes radian measurement

$$\theta_s\,(\text{degrees}) = \frac{L_s\,90}{R\pi}$$

$$\theta_\ell = \left(\frac{\ell}{L_s}\right)^2 \theta_s$$

$$r = \frac{L_s R}{\ell}$$



$$X = L_s\left(1 - \frac{\theta_{s\hat{r}}^2}{5x2!} + \frac{\theta_{s\hat{r}}^4}{9x4!} - \frac{\theta_{s\hat{r}}^6}{13x6!} + ---\right)$$

For any point on the spiral substitute:

1. ℓ for L_s
2. $\theta_{\ell\hat{r}}$ for $\theta_{s\hat{r}}$

$$Y = L_s\left(\frac{\theta_{s\hat{r}}}{3x1!} - \frac{\theta_{s\hat{r}}^3}{7x3!} + \frac{\theta_{s\hat{r}}^5}{11x5!} - \frac{\theta_{s\hat{r}}^7}{15x7!} + ---\right)$$

$$k = \frac{L_s}{2}\left(1 - \frac{\theta_{s\hat{r}}^2}{5x3!} + \frac{\theta_{s\hat{r}}^4}{9x5!} - \frac{\theta_{s\hat{r}}^6}{13x7!} + ---\right) = X - R\,\sin\theta_s$$

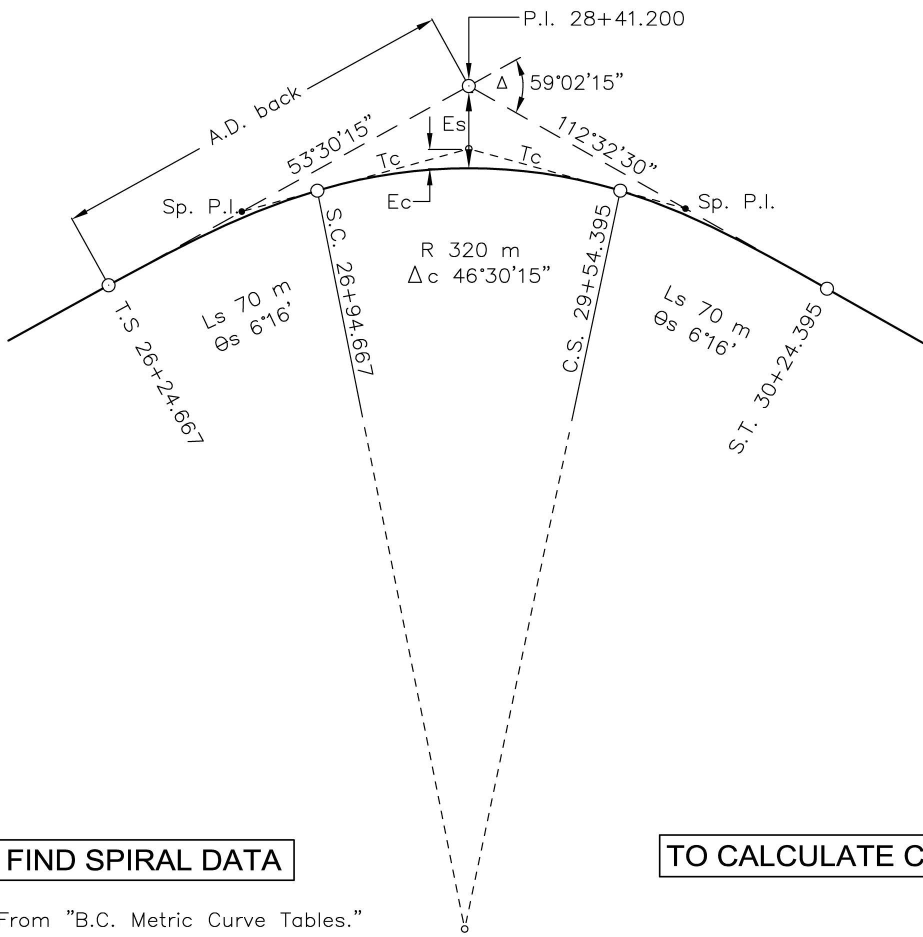
$$L.T. = X - \frac{Y}{\tan\theta_s}$$

$$p = \frac{L_s}{2}\left(\frac{\theta_{s\hat{r}}}{3x2!} - \frac{\theta_{s\hat{r}}^3}{7x4!} + \frac{\theta_{s\hat{r}}^5}{11x6!} - \frac{\theta_{s\hat{r}}^7}{15x8!} + ---\right) = Y - R + R\,\cos\theta_s$$

$$S.T. = \frac{Y}{\sin\theta_s}$$

$$L.C. = \sqrt{X_s^2 + Y_s^2} \qquad \text{Ø}_s = \text{arc tan}\left(\frac{Y_s}{X_s}\right) = \frac{\theta_s}{3} - C_s$$ where C_s (in seconds) $= 0.0031\theta_s^3$

Figure 340.C Circular Curve with Equal Spirals



N.T.S.

GIVEN

Design Speed 80 km/h
Radius 320 m
Ls 70 m
Δ 59°02'15"

FIND

Curve Data

TO FIND SPIRAL DATA

1. From "B.C. Metric Curve Tables."
   TABLE B

Ls 70 m	X = 69.916
R 320 m	Y = 2.550
	k = 34.986
	p = 0.638
	L.T. = 46.696
Theta (θs) = 6°16'	S.T. = 23.360
Phi (Øs) = 2°05'19"	L.C. = 69.963

$$\text{Theta } (\theta s) = \frac{Ls}{2R}\left(\frac{180}{\pi}\right)$$

OR

$$(\theta s) = \frac{Ls}{R}\left(\frac{90}{\pi}\right)$$

$$= \frac{70}{320}(28.6479) = 6.26673^\circ$$

$$\theta s = 6^\circ 16'$$

TO CALCULATE CURVE DATA

$$\Delta c = \Delta - 2\theta s$$
$$= 59^\circ 02'15'' - (2 \times 6^\circ 16')$$
$$\Delta c = 46^\circ 30'15''$$

$$Arc = R \times \text{radian } 46^\circ 30'15'' \ *$$
$$= 320 \times 0.8116508$$
$$Arc = 259.728$$

$$Tc = R \tan\frac{\Delta c}{2}$$
$$= 320 \times 0.429677$$
$$Tc = 137.497$$

$$Ec = \frac{R}{\cos\frac{\Delta c}{2}} - R$$
$$= \frac{320}{0.918777} - 320$$
$$Ec = 28.289$$

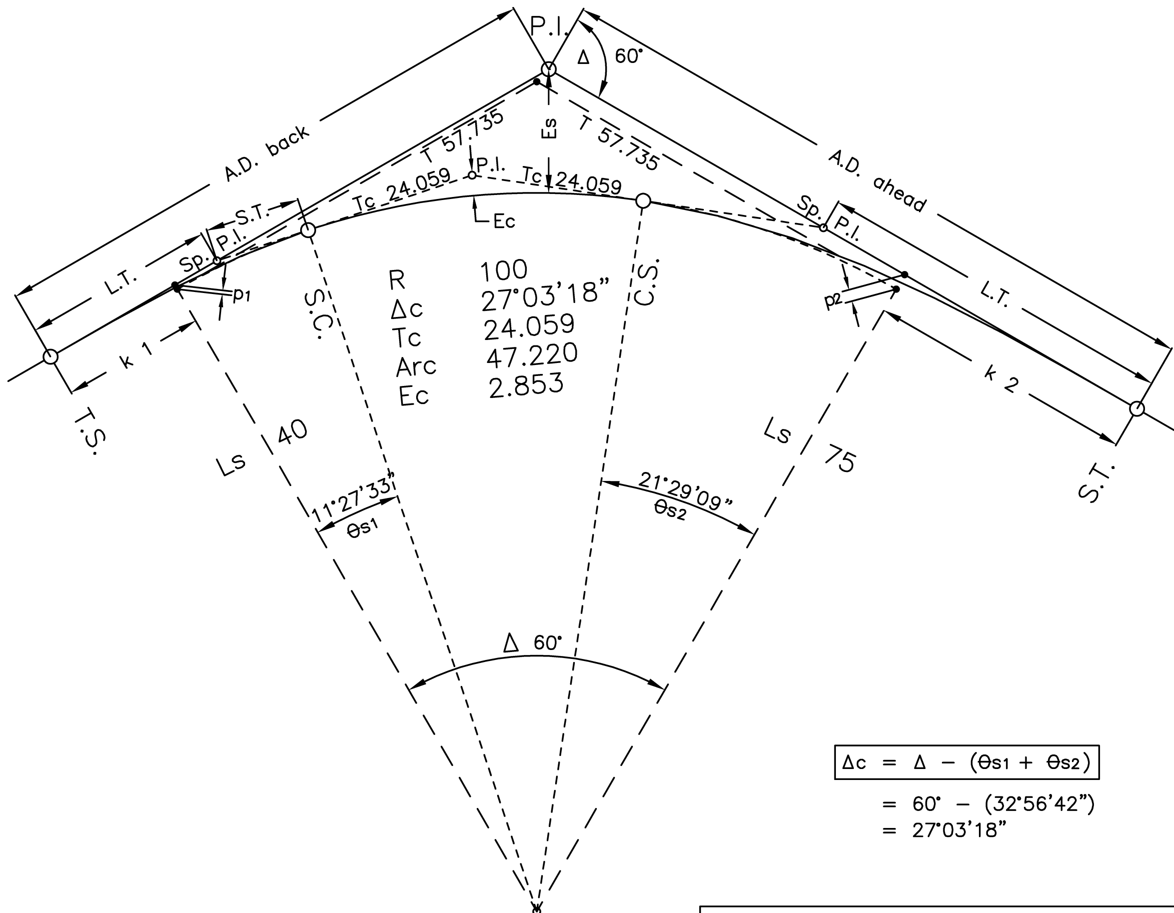
$$A.D. = (R + p)\tan\frac{\Delta}{2} + k$$
$$A.D. = 216.533$$

$$Es = \frac{R + p}{\cos\frac{\Delta}{2}} - R$$
$$= \frac{320.638}{0.870195} - 320$$
$$Es = 48.467$$

* NOTE

$$1 \text{ degree} = \frac{\pi}{180} \text{ radian}$$
$$\therefore 46^\circ 30'15'' = 46.5041667\left(\frac{\pi}{180}\right)$$
$$= 0.8116508 \text{ radian}$$

Figure 340.D Circular Curve with Unequal Spirals



$$\Delta c = \Delta - (\theta s_1 + \theta s_2)$$

$$= 60^\circ - (32^\circ 56' 42")$$

$$= 27^\circ 03' 18"$$

$$\text{A.D. back} = k_1 + \frac{(R + p_2) - (R + p_1)\cos\Delta}{\sin\Delta}$$

$$= 19.973 + \frac{102.332 - 100.666 \cos 60^\circ}{\sin 60^\circ}$$

A.D. back = 80.016

GIVEN:	From B.C. Metric Curve Tables
R 100 Δ 60° Ls_1 40 Ls_2 75	T.5. → L.S. 40, R 100 k_1 19.973 p_1 0.666 L.T. 26.723 S.T. 13.384 θs_1 11°27'33"
FIND: A.D. ahd. A.D. back Curve data	

$$\text{A.D. ahead} = k_2 + \frac{(R + p_1) - (R + p_2)\cos\Delta}{\sin\Delta}$$

$$= 37.325 + \frac{100.666 - 102.332 \cos 60^\circ}{\sin 60^\circ}$$

A.D. ahead = 94.483

Ls 75 not given in Tables

$$\theta s = \frac{Ls}{R}\left(\frac{90}{\pi}\right) \quad \therefore \theta s_2 = \frac{75}{100}\ 28.6479$$

$$= 21.485917^\circ$$

From Table C (Unit Spiral) = 21°29'09"

T.71 → Theta 21.486° (interpolate)
p_2 0.031094 x 75 = 2.332
k_2 0.497666 x 75 = 37.325
L.T. 0.671645 x 75 = 50.373
S.T. 0.337863 x 75 = 25.340

$$Es = \sqrt{(\text{A.D. back} - k_1)^2 + (R + p_1)^2} - R$$

$$= \sqrt{(80.016 - 19.973)^2 + (100 + 0.666)^2} - 100$$

Es = 17.213

(Formula valid only if Es is on a Circular Curve)

Figure 340.E Three Transition Compound Curve – General Layout

EXAMPLE 1

Proceeding from flatter to sharper curve.

GIVEN
ΔI = 42° 03'
R_1 = 600
R_2 = 230
Ls_1 = 50
Ls_2 = 80
La = 50

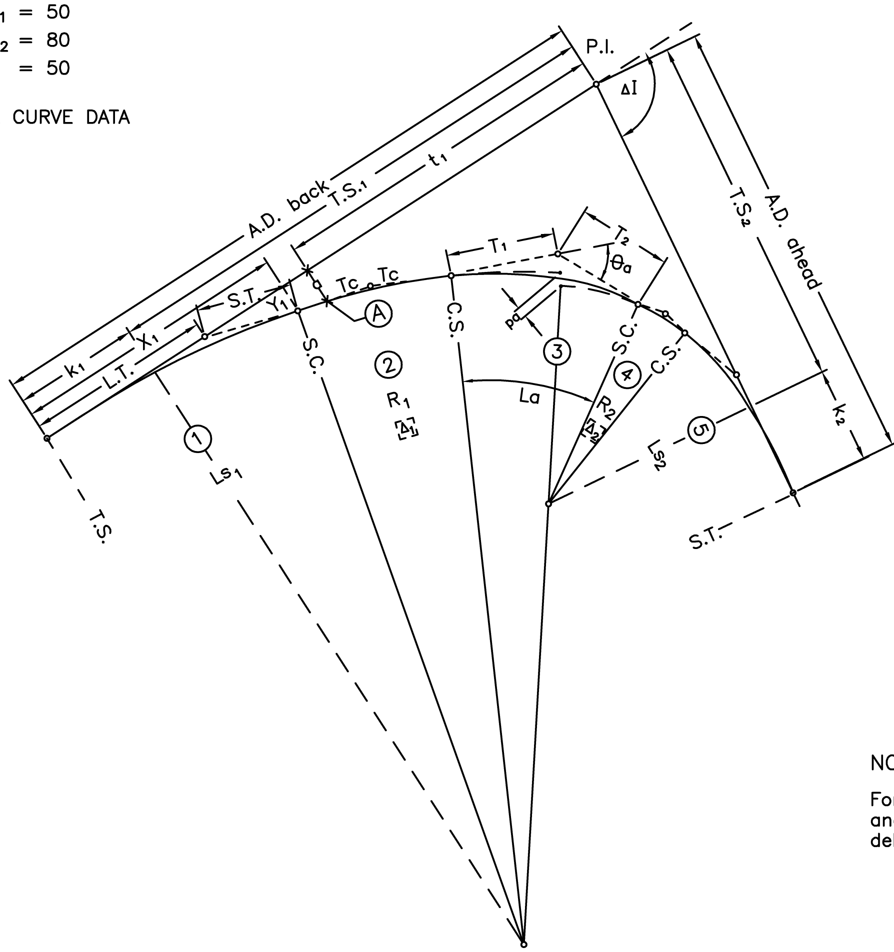
FIND ALL CURVE DATA

CASE 1

Δ_1 and Δ_2 are not given.

From a preliminary plan showing P.I., ΔI and bearings, it was determined that curve ② (R 600) has to pass through point Ⓐ;

∴ T.S.₁ is fixed.



NOTE:

For graphical reasons, scale and proportions are distorted deliberately.

CALCULATED CURVE DATA

1	Ls₁ 50
X	49.991
Y	0.694
k	24.999
p	0.174
L.T.	33.336
S.T.	16.669
L.C.	49.996
θs	2° 23' 14"
Ø	0° 47' 45"

2	R₁ 600
Δ	9° 03' 34"
Tc	47.534
Arc	94.870
Ec	1.880
Ch	94.771

3	La 50
θa	8° 36' 54"
θa1	2° 23' 12"
θa2	6° 13' 42"
pa	0.279
Xa	49.850
Ya	3.195
T1	28.761
T2	21.329
Øa	3° 40' 02"

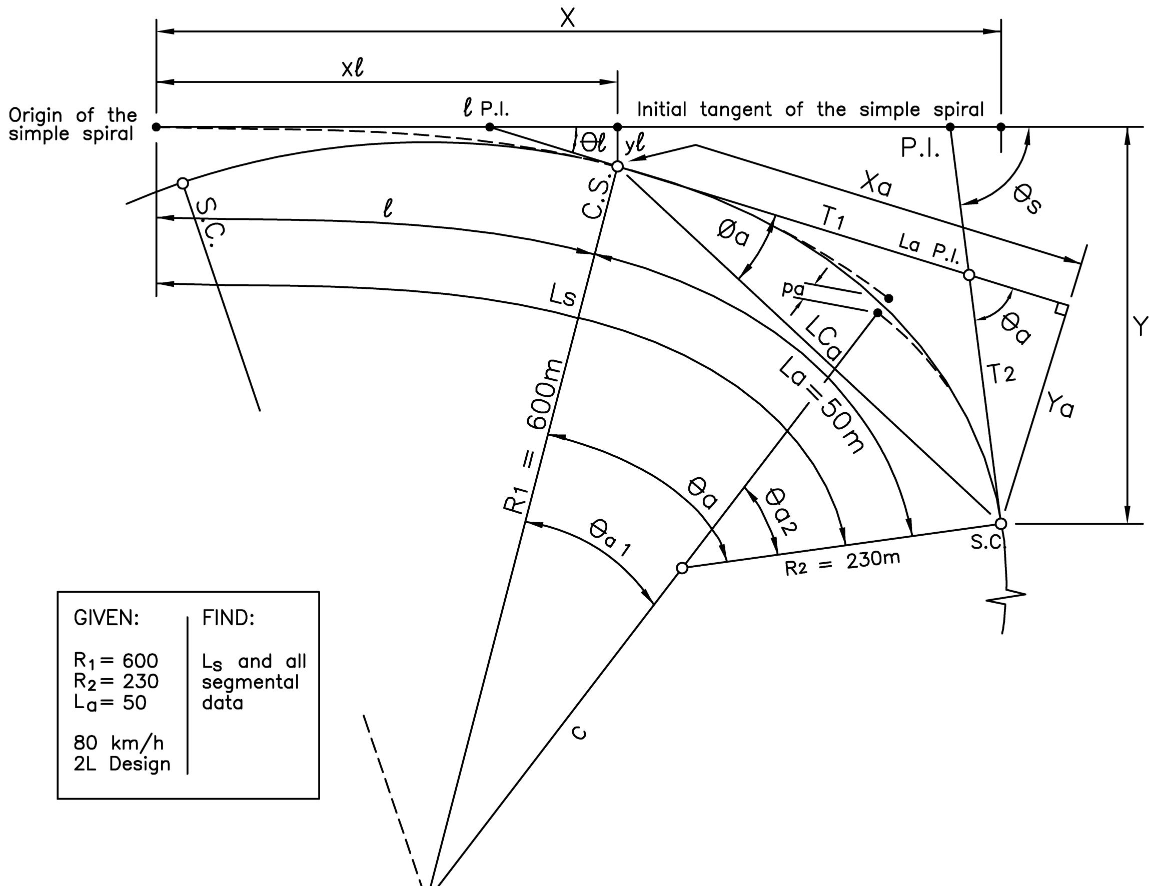
P.I.	N.	1000.000
	E.	500.000
A	N.	924.199
	E.	507.000

4	R₂ 230
Δ	12° 01' 26"
Tc	24.222
Arc	48.267
Ec	1.272
Ch	48.178

5	Ls₂ 80
X	79.758
Y	4.628
k	39.960
p	1.158
L.T.	53.418
S.T.	26.744
L.C.	79.893
θs2	9° 57' 52"
Ø2	3° 19' 14"

1. USE B.C. METRIC CURVE TABLES TO FIND SPIRAL DATA FOR Ls_1 AND Ls_2.
2. SOLVE SEGMENTAL SPIRAL – La 50, USING PROCEDURE SHOWN ON FIGURE 340.F
3. CALCULATE CURVE DATA, USING PROCEDURE SHOWN ON FIGURE 340.G

Figure 340.F Three Transition Compound Curve – Segmental Spiral



(1) $L_a = 50$ (see 330.02)

(2) $L_s = L_a \left(\frac{R_1}{R_1 - R_2} \right) = 81.081$

(3) $\theta_s = \frac{L_s}{R_2} \times \frac{90}{\pi} = 10.099^\circ = 10^\circ 05' 57''$

(4) $\theta_a = L_a \left(\frac{1}{R_2} + \frac{1}{R_1} \right) \frac{90}{\pi} = 8.615^\circ = 8^\circ 36' 54''$

(5) $\ell = L_s - L_a = 31.081$

(6) $\theta_\ell = \frac{\ell}{R_1} \times \frac{90}{\pi} = 1.484^\circ = 1^\circ 29' 02''$

(7) From Unit Spiral Tables $\theta_s = 10.099^\circ$ interpolate (or use spiral formulae 340.B)
$X = 80.829$ $Y = 4.753$

(8) From Unit Spiral Tables $\theta_\ell = 1.484^\circ$ interpolate (or use spiral formulae 340.B)
$x_\ell = 31.079$ $y_\ell = 0.268$

(9) $X_a = (X - x_\ell)\cos\theta_\ell + (Y - y_\ell)\sin\theta_\ell = 49.849\ 5^*$

(10) $Y_a = (Y - y_\ell)\cos\theta_\ell - (X - x_\ell)\sin\theta_\ell = 3.195\ 1^*$

(11) $\theta_{a1} = \arctan\left(\frac{X_a - (R_2 \sin\theta_a)}{R_1 - [Y_a + (R_2 \cos\theta_a)]} \right) = 2^\circ 23' 12''$

(12) $\theta_{a2} = \theta_a - \theta_{a1} = 6^\circ 13' 42''$

(13) $C = R_1 - R_2 - pa$

$= \sqrt{[X_a - (R_2 \sin\theta_a)]^2 + \{R_1 - [Y_a + (R_2 \cos\theta_a)]\}^2}$

$= 369.721$

(14) $T_1 = X_a - \frac{Y_a}{\tan\theta_a} = 28.760$

(15) $T_2 = \frac{Y_a}{\sin\theta_a} = 21.330$

(16) $Ø_a = \arctan\left(\frac{Y_a}{X_a} \right) = 3^\circ 40' 02''$

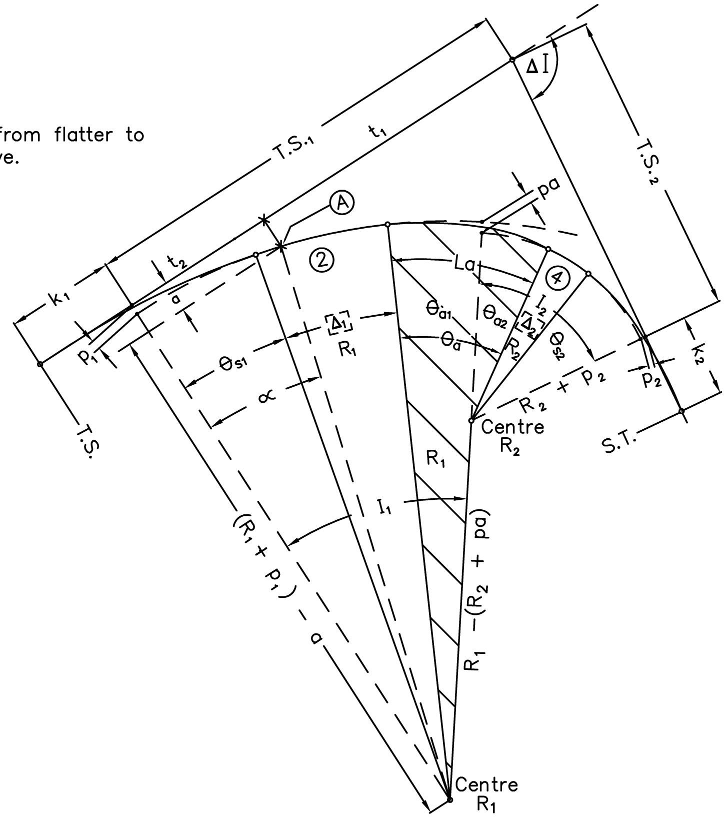
(17) $LC_a = \sqrt{X_a^2 + Y_a^2} = 49.952$

* For sufficient accuracy of T_1 and T_2, use at least 4 decimal places

Figure 340.G Three Transition Compound Curve Calculation

EXAMPLE 1

Proceeding from flatter to sharper curve.



GIVEN
ΔI = 42° 03'
R_1 = 600
R_2 = 230
Ls_1 = 50
Ls_2 = 80
La = 50

FIND ALL CURVE DATA

FIGURE 2

CALCULATION PROCEDURE

Solve curve data for La (see Figure 340.F)

From coordinates of (A) : a = 7.014 t_1 = 75.801
Centre of R_1 and T.S.$_1$ become fixed.

$$\text{Cos} \propto = \frac{(R_1 + p_1) - a}{R_1} = \frac{600.174 - 7.014}{600} \quad \therefore \propto = 8° \; 39' \; 35''$$

$$t_2 = R_1 \sin \propto = 600 \sin 8° \; 39' \; 35'' = 90.340$$

T.S.$_1$ = t_1 .... 75.801
+ t_2 ... 90.340
166.141

$$\text{Cos } I_2 = \frac{T.S._1 \sin \Delta I - (R_2 + p_2) + (R_1 + p_1) \cos \Delta I}{R_1 - R_2 - pa}$$

$$= \frac{166.141 \sin 42° \; 03' - 231.158 + 600.174 \cos 42° \; 03'}{369.721}$$

I_2 = 28° 13' 00"

$[\Delta_2]$ = $I_2 - (\theta_{a2} + \theta_{s2})$
= 28° 13' 00" − (6° 13' 42" + 9° 57' 52")
= 12° 01' 26"

I_1 = $\Delta I - I_2$
= 42° 03' 00" − 28° 13' 00"
= 13° 50' 00"

$[\Delta_1]$ = $I_1 - (\theta_{a1} + \theta_{s1})$
= 13° 50' 00" − (2° 23' 12" + 2° 23' 14")
= 9° 03' 34"

$$T.S._2 = \frac{(R_1 + p_1) - (R_2 + p_2)\cos \Delta I - (R_1 - R_2 - pa)\cos I_1}{\sin \Delta I}$$

$$= \frac{600.174 - 231.158 \cos 42° \; 03' - 369.721 \cos 13°50'}{\sin 42° \; 03'}$$

= 103.807

AD back = T.S.$_1$ + k_1 = 166.141 + 24.999 = 191.140

AD ahead = T.S.$_2$ + k_2 = 103.807 + 39.960 = 143.767

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