APPENDIX F

SUPERELEVATION

Superelevation is used to modify the shape of the roadway templates. Superelevation is usually applied on the curves to compensate for centrifugal forces on the vehicle. Superelevation data can either be manually entered on a curve-by-curve basis or automatically generated.

Automatic superelevation and transition length computations can be requested by the user by selecting the automatic superelevation option when the alignment is being created or updated. For rural or high speed urban design conditions, the superelevation rate for a particular curve is calculated using the standard AASHTO process for development of the finalized superelevation rate distribution known as "Method 5". Calculations are based on the curve radius, and the design speed, running speed, maximum superelevation rate, and maximum friction factor for the PI being processed. The transition length is calculated using the standard AASHTO method and the number of lanes, lane width, calculated superelevation rate, design, and superelevation type. For low speed, urban design conditions, the superelevation rate and transition length for a particular curve are calculated using the appropriate formulas from the AASHTO Green Book and the low speed urban criteria. These automatic calculations are discussed in detail later in this Appendix.

All superelevation takes place about either the left or right pivot point on the template to provide smooth transitions. In a curve to the left, the superelevated segments rotate about the left pivot point and in a curve to the right, the superelevated segments rotate about the right pivot point. This can be seen in Figure F-1. Some or all of the template segments are superelevated, depending upon their slope options.

The template data supplements the data entered for superelevation. It includes data that pertains to the template section as follows:

° Location of the left and right pivot points and the profile grade point

° Designation of segments which are not to be superelevated or how the segments are to be superelevated

<u>Failure to correlate these data will result in errors.</u>

Since the template may change within a superelevation transition, it is extremely important to be sure both data are consistent when using superelevation. When there is template transition within superelevation transition (including the crown runoff length), the templates must have the same number of segments. The segment options and segment slopes of the same numbered segments of the templates in transition must be the same. The template to be superelevated must have some segments to be superelevated. Since superelevation transition type 0 inputs the crown runoff length and type 4 has to compute the crown runoff length, it is necessary at the beginning and ending of a job that the template stationing include this crown runoff length.

Superelevation can pivot about any ridge point on the template. Two common procedures are to pivot about the left and right edge of pavement or pivot about the centerline point, as illustrated in Figure F-1,below.

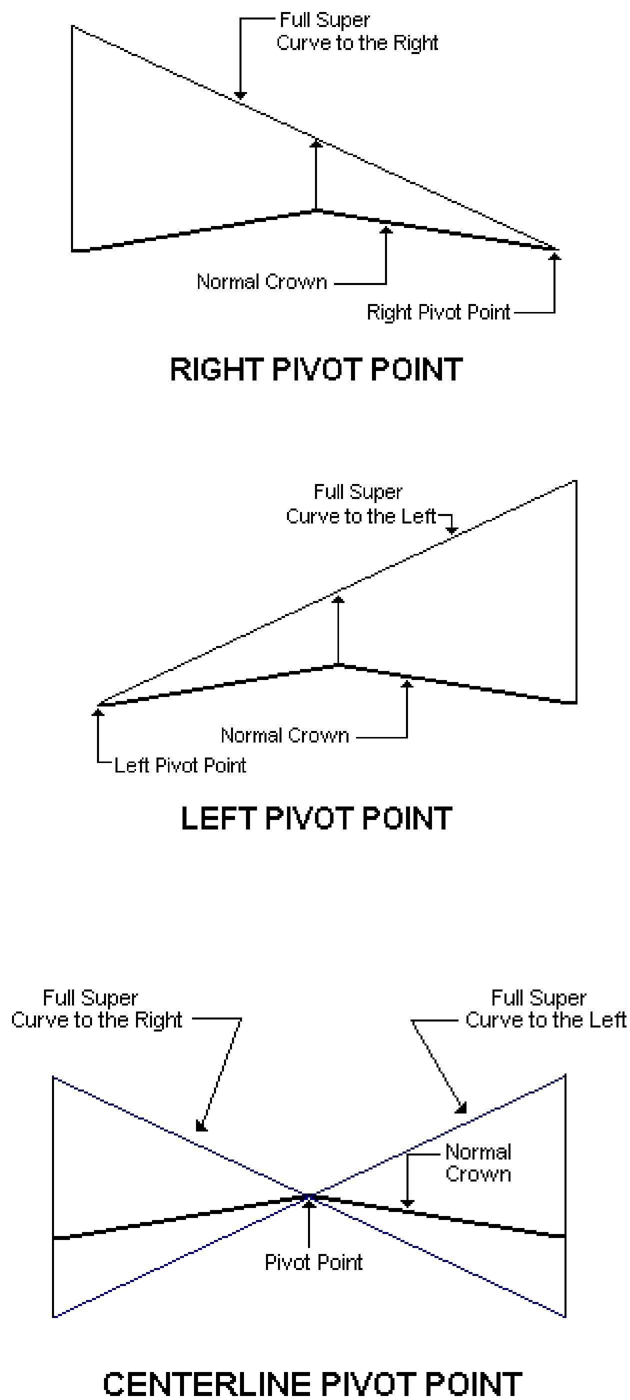


Figure F-1 - Pivot Point Locations

RELATION OF PROFILE GRADE POINT TO PIVOT POINTS

When the profile grade and pivot points are not the same, the elevation at the pivot point is calculated by taking the vertical alignment elevation at the profile grade point and calculating the elevation at the pivot point with the normal template cross slopes. Then, the profile grade point elevation in superelevation and transitioning sections is calculated from the pivot point elevation with the superelevation or transitioning cross slopes applied. Therefore, in the superelevation and transition sections, the elevation at the profile grade will be different from the vertical alignment elevation when the profile grade and pivot points are not the same. Agencies may change this procedure, as required, so that the profile grade point elevation does not change from the vertical alignment, but the pivot points change in elevation. The crown runoff length computed with the alternate process may be different than when the profile grade point and pivot point are the same point.

TRANSITION TYPE

There are five transition types (0, 1, 2, 3, and 4), which are pictured in Figure F-2.

In transition types 1, 2 and 3, all segments superelevate independent of each other with cross slopes varying from normal crown to full super, as shown. Types 1, 2, and 3 do not support automatic compound and reverse superelevation transitions. In transition types 0 and 4, all the segments superelevate depending on each other, as can be seen in Figure F-4. Additionally, types 0 and 4 provide for automatic compound and reverse superelevation discussed later in this section.

Transition types 0 and 4 both rotate starting with the template segment whose cross slope differs most from full super. This segment is rotated until it matches the slope of the segment next to it. Then these two segments are rotated as one, continuing until all segments rotate as one. This can be seen in Figure F-3 going through the various stages labeled A, B, C, D, E, and F.

TRANSITION METHOD

Traditionally within IGrds, superelevation transition is calculated by performing a linear interpolation of the relative offsets and elevations between the beginning and ending template shapes within the transition length, thereby generating relatively linear ridgelines. If the segment width does not vary, then the superelevation rate also varies linearly. However, if the segment width does vary, then the superelevation rate varies non-linearly. Some agencies prefer that the rate vary linearly, which, in this case, would mean that the ridgelines would vary non-linearly.

There is a flag in the design criteria table (ha.tbl) that controls the transition method used for superelevation (and templates). If the flag is set to normal (0), then superelevation transition is performed in the traditional fashion. If the flag is set to alternate (1), then superelevation transition is performed by performing a linear transition of the superelevation rate. This flag can be modified as required by the agency.

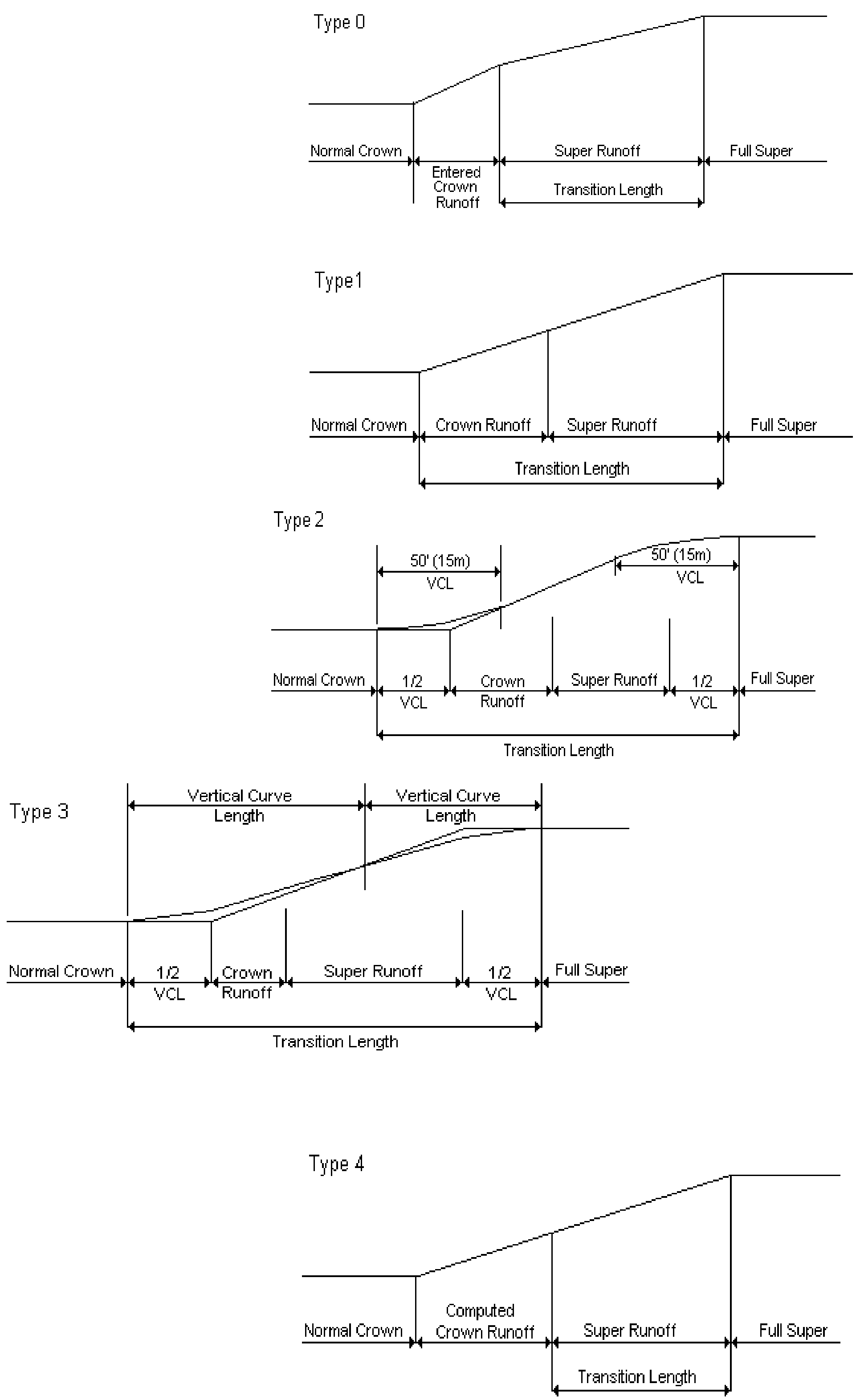


Figure F-2 - Transition Types

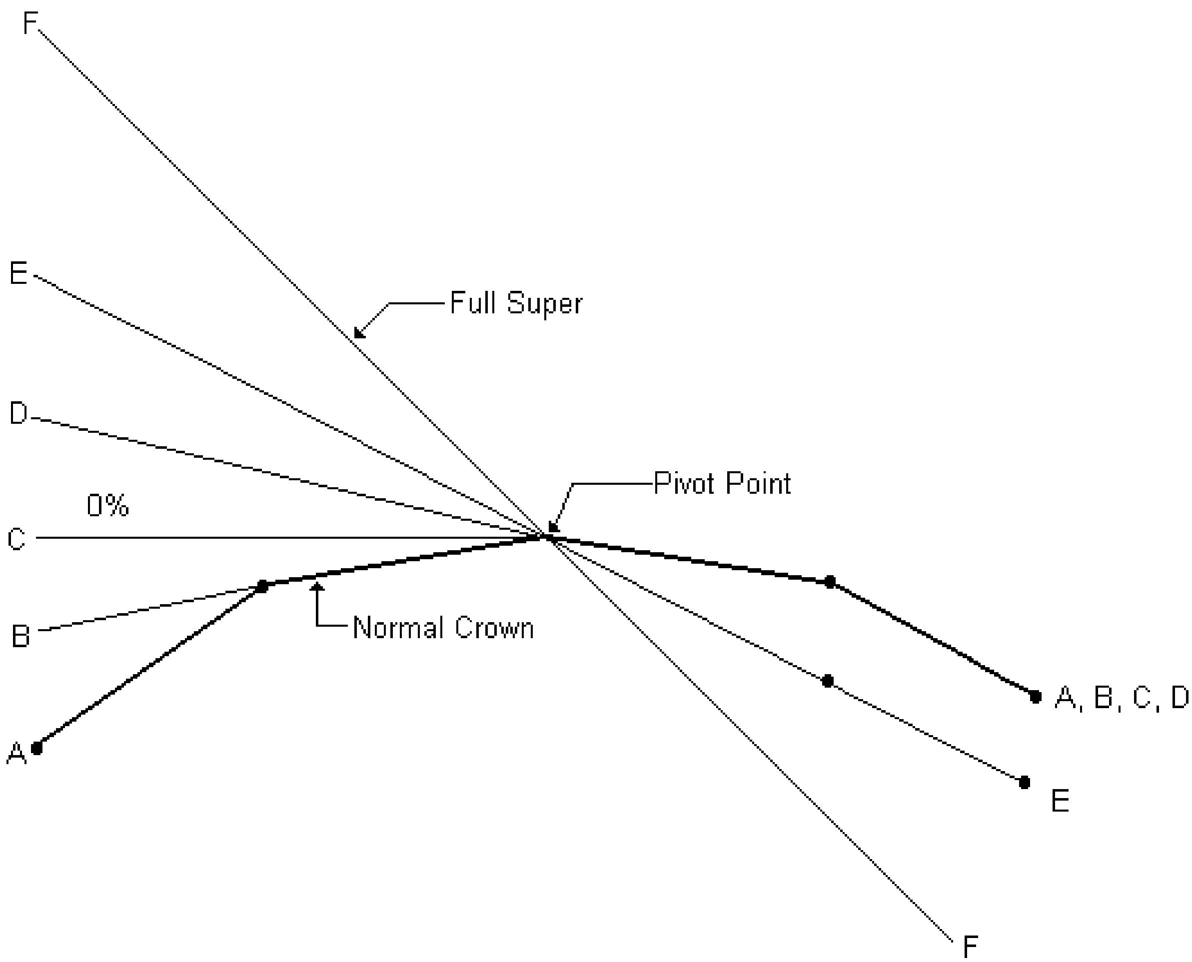


Figure F-3 - Segment Rotation, Types 0 and 4

The following superelevation terms, pictorially shown in Figure F-4, are defined as follows:

Normal crown - is the applicable segment cross slope for the template on a roadway.

Crown runoff - is the length of roadway needed to accomplish the removal of the adverse slopes from a normal crown section to a section with the adverse slopes changed to a zero cross slope, or vice versa.

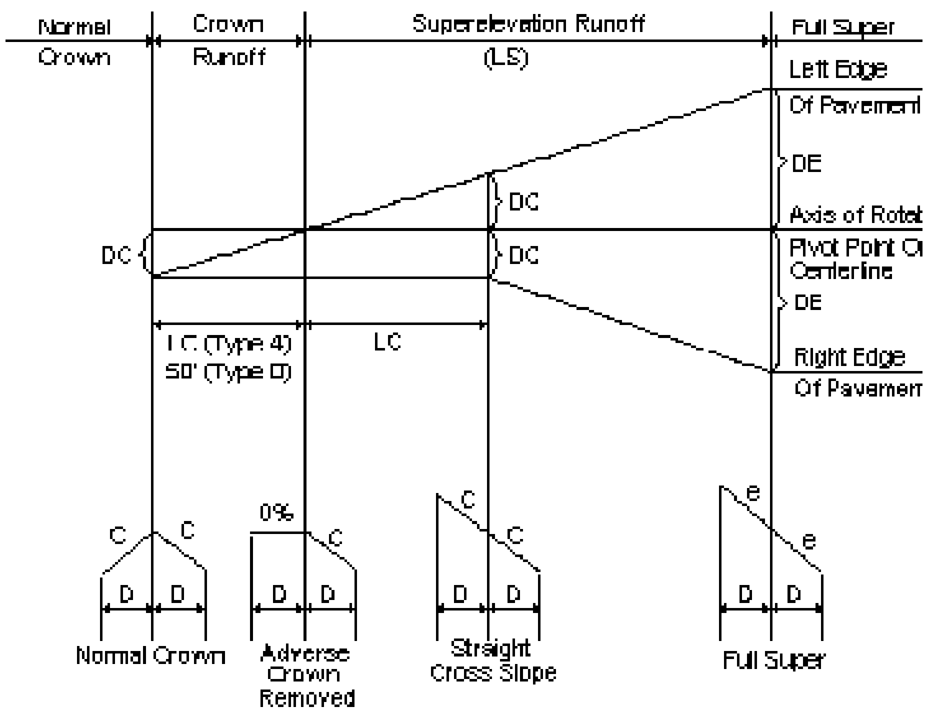
Super runoff - is the length of roadway needed to accomplish the change in cross slopes from a section with adverse crown removed (zero cross slope) to a full super section, or vice versa.

Full super - is a cross section where all segments to be fully superelevated are at the full superelevation rate entered.

SUPERELEVATION TRANSITION

TYPE 0 AND TYPE 4

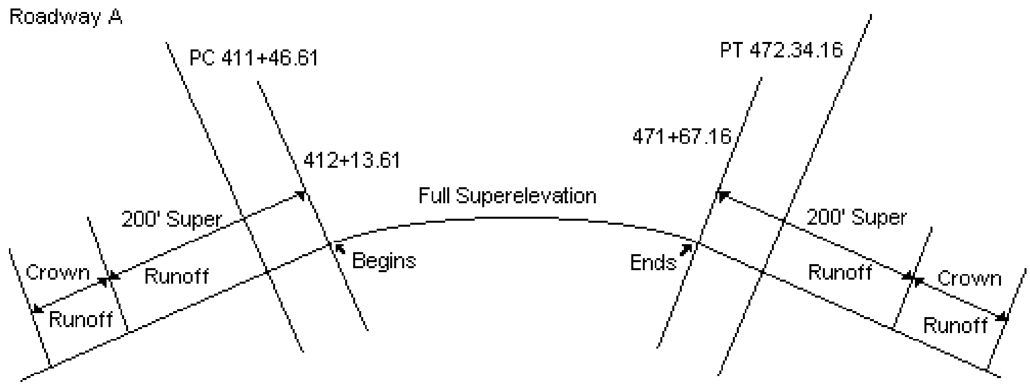
LS = LENGTH OF SUPERELEVATION RUNOFF IN FEET (METERS)
LC = LENGTH OF CROWN RUNOFF IN FEET (METERS)
C = NORMAL CROWN RATE IN FT./FT. (% / 100)
D = DISTANCE FROM AXIS OF ROTATION TO EDGE OF PAVEMENT IN FEET (METERS)
F = FULL SUPERELEVATION RATE IN FT./FT. (% / 100)

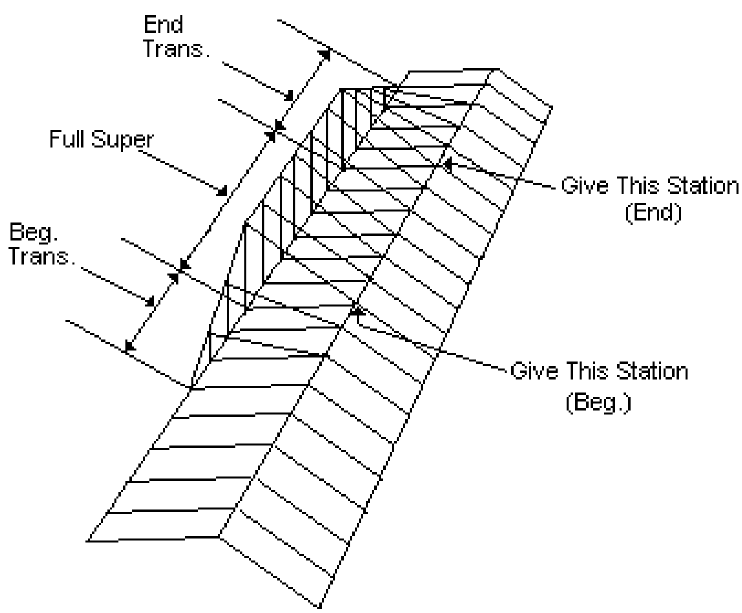


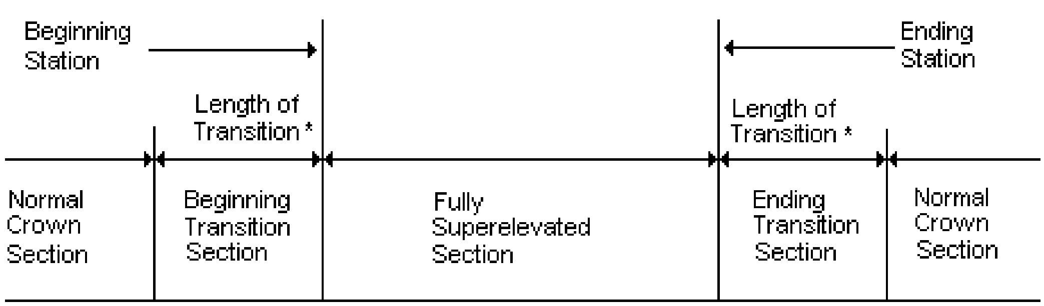
PROFILE OF TRANSITION

Figure F-4 - Superelevation Transitions, Types 0 and 4

The following diagram illustrates how superelevation data is normally applied at the beginning and end of curves. When two curves are close together or when they are compounded, a special transition will be needed. This is discussed in the next section.





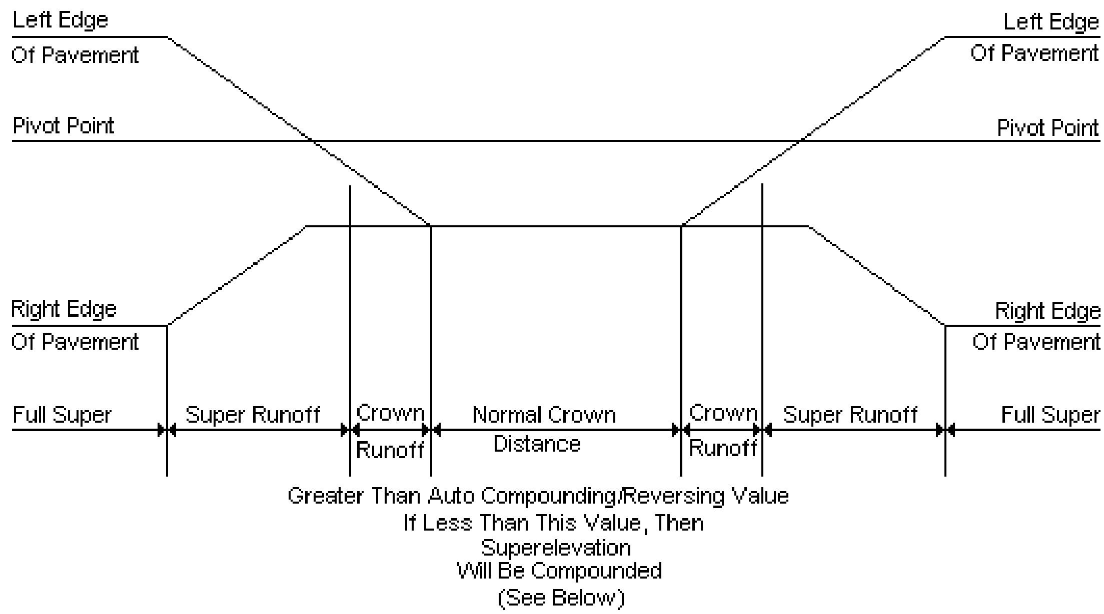


*Transition length may include the crown runoff length depending on type of transition.

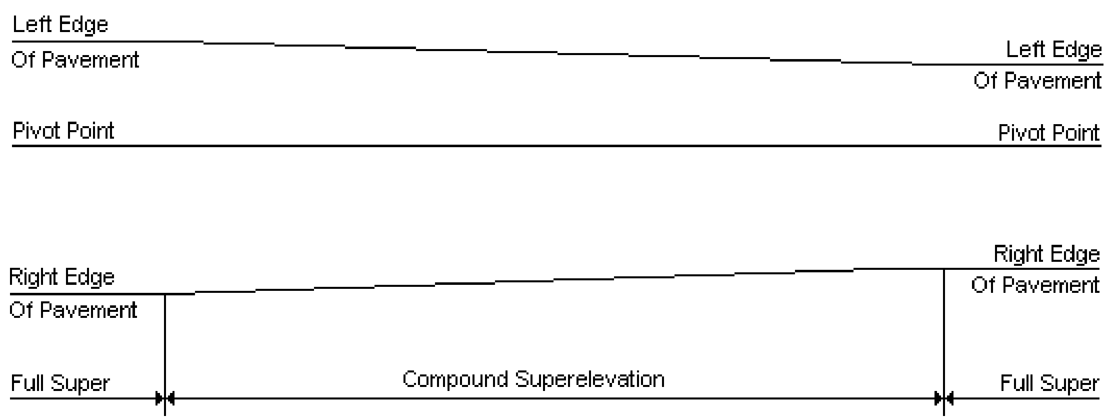
COMPOUNDING AND REVERSING (SUPERELEVATION TYPES 0 AND 4 ONLY)

If the normal crown section is less than or equal to the automatic compound/reversing value between the ending of one superelevation transition and the beginning of the next superelevation transition for superelevation types 0 and 4 only, the superelevation will be compounded or reversed between the two curves. The default value is stored in the design criteria table (ha.tbl) and may be changed, as required, on an agency-by-agency basis. As an horizontal alignment is being created, this default automatic compounding/reversing value is displayed to the user in the roadway design parameters dialog box and can then be modified for that particular alignment. Figure F-5 shows a compounded superelevation profile. Figure F-6 shows a reversed superelevation profile with the same left and right pivot points. Figure F-7 shows reversed superelevation profiles with different left and right pivot points. When the left and right pivot points are different points, the pivot point changes points at the flat spot (0% cross slope). The transition is a straight line grade from the points of one full super section to the points of the other full super section. Again, this procedure may be changed on an agency-by-agency basis so that the reversing transition is independent of the profile grade and pivot points.

When automatic compounding of curves is done, a line of output is printed in the listing of messages specifying that automatic compounding or reversing is being done. When transition type 4 is used, the computed crown runoff length is printed in the listing of messages.

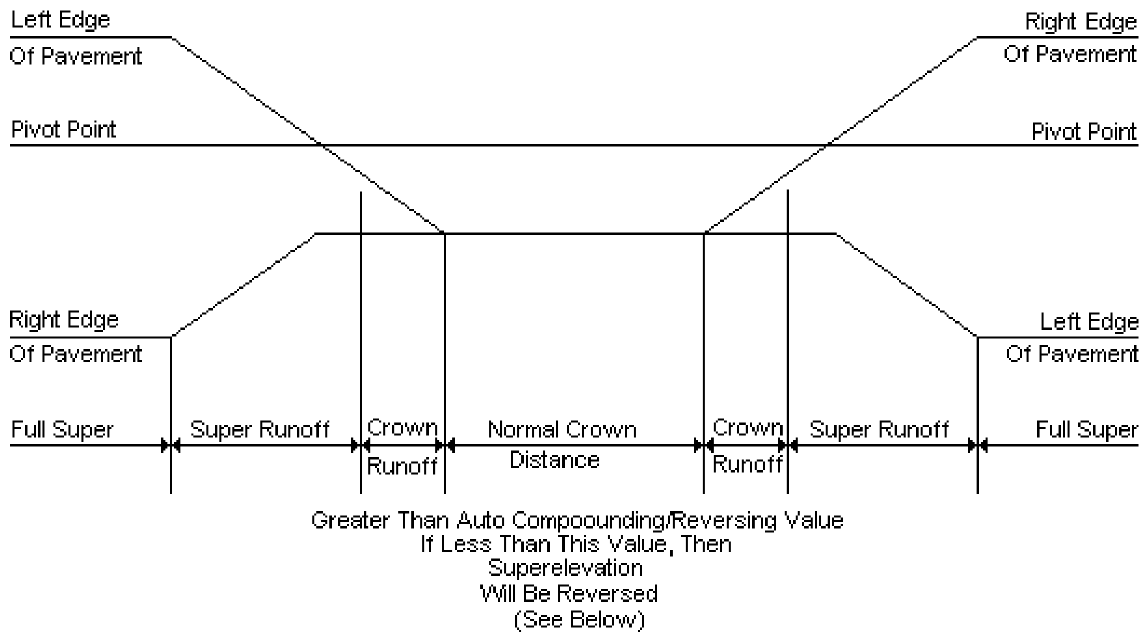


TWO CURVES NOT COMPOUNDED

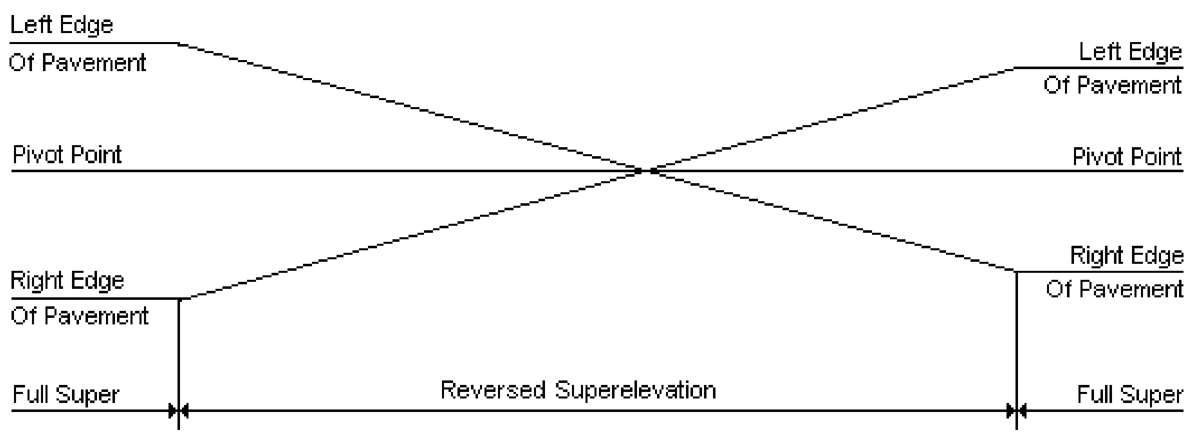


TWO CURVES COMPOUNDED

Figure F-5 - Compounded Curves

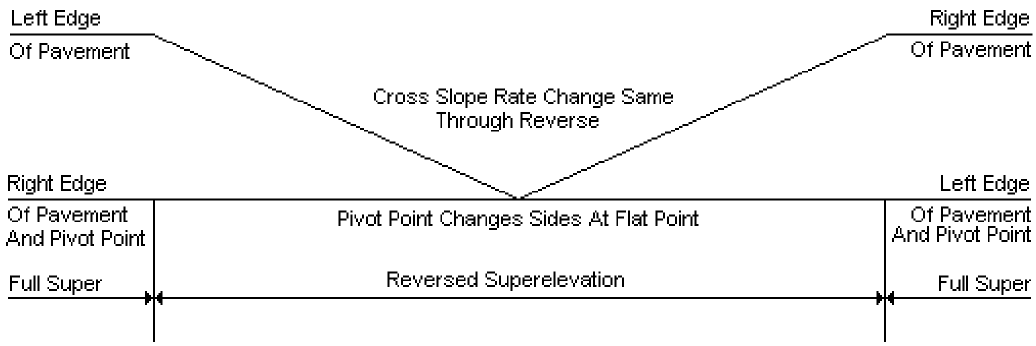


TWO CURVES NOT REVERSED

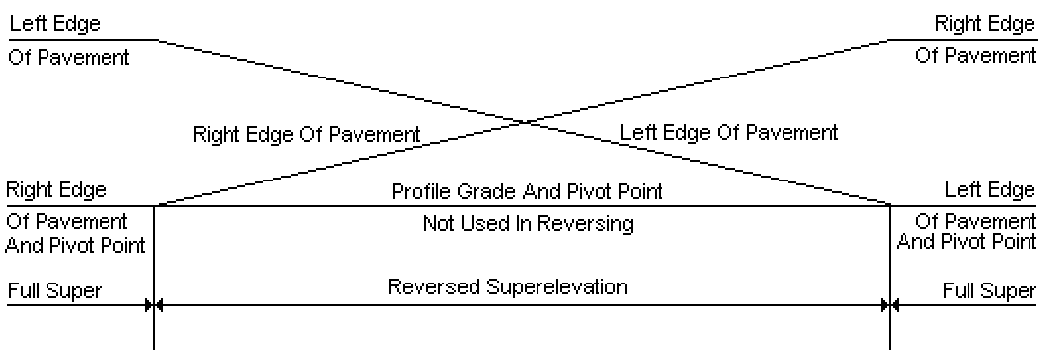


TWO CURVES REVERSED

Figure F-6
Reversed Curves with Same Left and Right Pivot Points



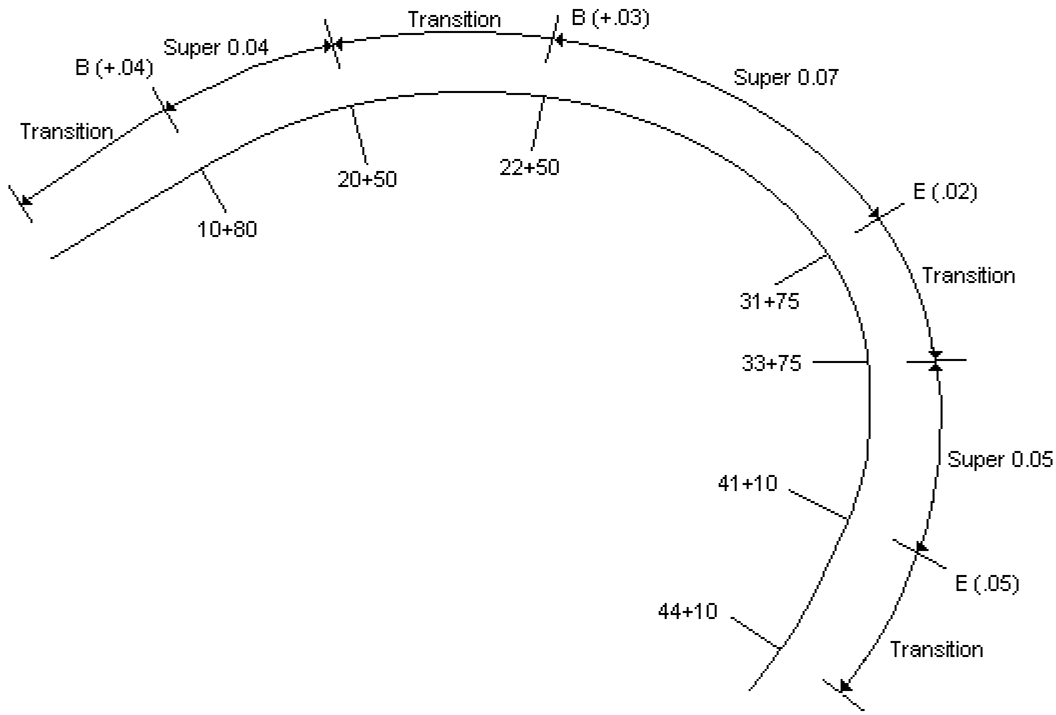
TWO CURVES REVERSED
TYPE 0 AND 4 ONLY



TWO CURVES REVERSED WITH INSTALLATION PARAMETER
TYPE 0 AND 4 ONLY

Figure F-7
Reversed Curves with Different Left and Right Pivot Points

If desired, compounded superelevations can be coded explicitly by the user (types 0 and 4). An example of superelevation accumulation of compound curves is shown below.

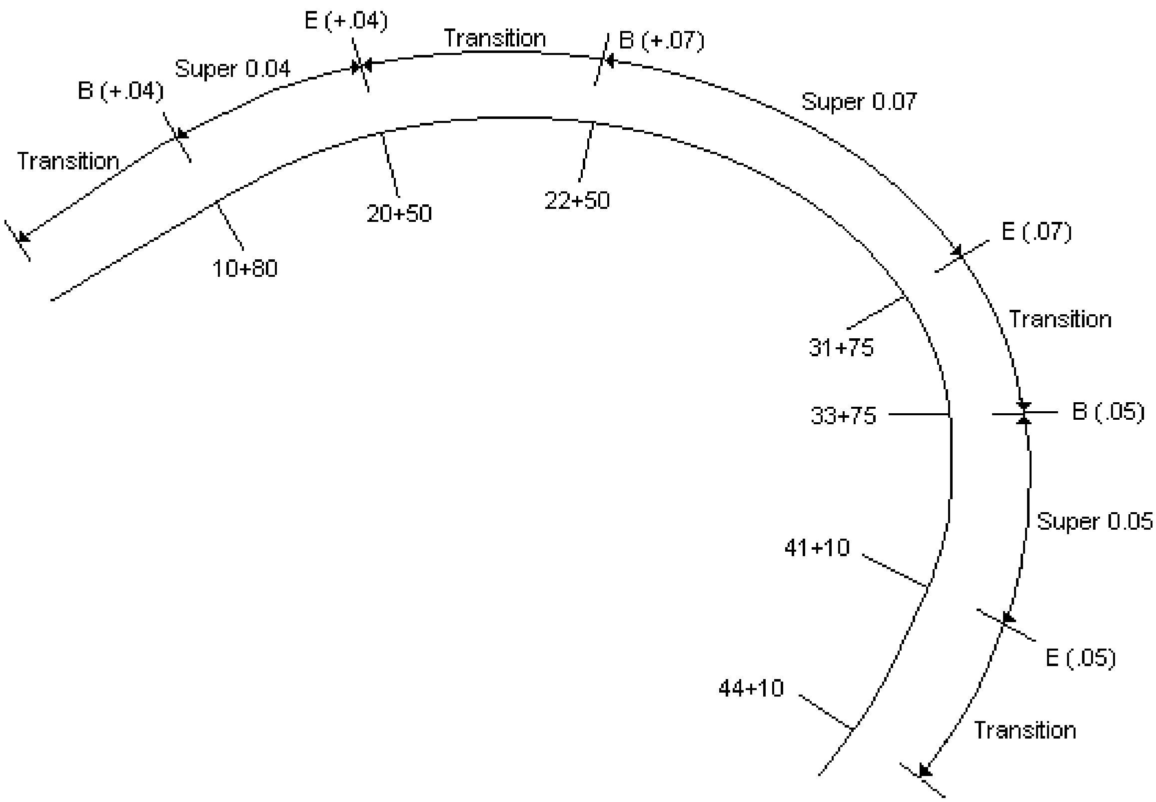


Explanation

First B - Begin 0.04 Superelevation, Transition Back
Second B - Add 0.03 to Get 0.07, Transition Back
First E - Subtract 0.02 to Get 0.05, Transition Forward
Second E - End 0.05 Superelevation, Transition Forward

Currently, the user may enter only two beginnings and two endings. Types 1, 2 and 3 require only one beginning and one ending for each curve, and always transition back to the normal template.

Reverse or compounded superelevations can also be coded for types 0 and 4, using the method shown below.



Explanation

10+80	First B -	Begin 0.04 Superelevation, Transition Back
20+50	First E -	End 0.04 Superelevation, Transition 200 Forward
22+50	Second B -	Begin 0.07 Superelevation, Transition 200 Back
31+75	Second E -	End 0.07 Superelevation, Transition 200 Forward
33+75	Third B -	Begin 0.05 Superelevation, Transition 200 Back
41+10	Third E -	End 0.05 Superelevation, Transition Forward

Transition lengths in the compound or reverse area must overlap. This will cause the superelevation to compound or reverse between the E (End) and B (Begin) stations.

AUTOMATIC CURVATURE AND SUPERELEVATION RATE CALCULATIONS

For curvature and superelevation, two design conditions must be addressed: rural/high speed urban and low speed urban. Within the AASHTO Green Book (The 1990 Imperial and 1994 Metric and 2001 combined Metric and Imperial editions), these design conditions are discussed in great detail. See pages 140-172 for Rural/High Speed Urban and pages 186-194 for Low Speed Urban design conditions in the 1990 edition. Also, see pages 141-173 and pages 187-195 in the 1994 edition. For the 2001 combined units edition, see pages 131-168 for Rural/High Speed Urban designs and pages 192-198 for Low Speed Urban design. The criteria tables and appropriate formulae for all editions are discussed below.

Rural and High Speed Urban

Criteria tables for both Imperial and Metric conditions are derived from the appropriate AASHTO Green Books (all of which are supported). These criteria are embodied in the design criteria table (ha.tbl) in two partitions, one for 2001 and the other for 1990/1994. This ASCII table is normally customized by each user agency. For curvature and superelevation calculations in rural and high speed urban conditions, the “Curvature/Superelevation Criteria for Rural and High Speed Urban Design (Imperial Units or Metric Units)” is used to provide the appropriate information for the curvature and superelevation formulae.

The relationship among design speed, radius, superelevation rate and friction factor for Imperial unit projects is given by this formula.

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

where:

R = radius of curve in feet
V = design speed in mph
e = super rate in ft/ft
f = friction factor

For Metric unit projects, the following formula is employed:

$$R = V^2/127\ (e+f)$$

where:

R = radius of curve in meters
V = design speed in km/h
e = super rate in m/m
f = friction factor

Note that the coefficients of 15 and 127 are approximate; a more precise value is used within the actual calculation processes.

As mentioned above, the final superelevation rate for a particular design speed, maximum superelevation rate, and radius is accomplished using Method 5 from the AASHTO Green Book. The IGrds product uses the formulae shown in the appropriate Green Book to solve the e+f distribution and then extract the correct e for the given radius.

Low Speed Urban

The Curvature/Superelevation Criteria for Low Speed Urban Design (Imperial and Metric Units) show superelevation and curvature criteria for urban low speed design derived from tables in the AASHTO Green Book. The same basic relationship formulae discussed above are also used for urban low speed design. However, Method 2 is used to determine the e+f distribution.

In either case, the calculated superelevation rate is then rounded upwards according to the rounding factor also found in the ha.tbl. The default Imperial units rounding factor is .0001; for Metric unit projects, the default rounding factor is .001 (one tenth of one percent).

AUTOMATIC SUPERELEVATION AND WIDENING TRANSITION LENGTH CALCULATIONS

For superelevation and automatic pavement widening transition length calculations, the same two design conditions are addressed: rural/high speed urban and low speed urban. Within the AASHTO Green Book, these two conditions are discussed in great detail. See pages 173-186 for Rural/High Speed Urban and pages 189-194 for Low Speed Urban in the 1990 edition. Also, see pages 174-187 and 191-193 in the 1994 edition. For the 2001 combined units edition, see pages 168-191 for Rural and High Speed Urban design and pages 192-198 for Low Speed Urban designs. Only rural/high speed urban length calculations are addressed below. The transition length calculations discussed below relate to IGrds superelevation Types 0 and 4. Transition lengths for Types 1, 2, and 3 are derived by adding the "transition length" from these calculations to the "crown runoff" discussed later. See Figure F-2, earlier in this Appendix.

For rural and high speed urban conditions, the transition length for superelevation is based on the superelevation rate e and the width of roadway to be elevated. The same transition length is used for both curves with and without spirals. This length is the length of transition from the point where adverse crown is removed to the point of full superelevation.

Transition length and/or spiral length is computed using this formula:

$$LS = \frac{100we}{rg}$$

where LS = Spiral or Super Transition length

w = Effective width from axis of rotation to edge of travelway on the outside of curve (includes any pavement widening, if relevant)

e = Calculated superelevation rate (decimal, not %)

rg = The relative gradient from the appropriate relative gradient table within the ha.tbl (depending on design speed, number of lanes, Imperial or Metric Units and Standards, 1990/1994 or 2001).

1990/1994 Standards Computational Methodology

According to the AASHTO Green Book (both editions) for pavements wider than two lanes (one in each direction), the calculated transition lengths should be increased by a factor, not doubled or tripled for four or six lane undivided pavements. AASHTO states that for three lane pavements, this factor should be 1.2; for four lanes, 1.5; for six lanes, 2.0. No clear guideline is given for pavements wider than this. Within IGrds for extra wide pavements (more than six undivided lanes), the effective relative gradient for six lane pavements is used in the calculations. The adjustment factor is equal to the number of lanes in one direction for numbers of lanes greater than three in one direction.

Effective widths and relative gradients are found within the 1990/1994 partition in the ha.tbl for both Imperial and Metric units. For clarity, these tables are reproduced below for Metric units.

Number of Lanes	Effective Widths (Without Pavement Widening)						Effective Width Factor
	2.4m Lanes	2.7m Lanes	3.0m Lanes	3.3m Lanes	3.6m Lanes	4.8m Lanes	
1	2.4	2.7	3.0	3.3	3.6	4.8	1.0
1.5	2.9	3.2	3.6	4.0	4.3	5.8	1.2
2	3.6	4.1	4.5	5.0	5.4	7.2	1.5
3	4.8	5.4	6.0	6.6	7.2	9.6	2.0
4	9.6	10.8	12.0	13.2	14.4	19.2	4.0
5	12.0	13.5	15.0	16.5	18.0	24.0	5.0
6	14.4	16.2	18.0	19.8	21.6	28.8	6.0
7	16.8	18.9	21.0	23.1	25.2	33.6	7.0
8	19.2	21.6	24.0	26.4	28.8	38.4	8.0

Maximum Relative Gradients (and Equivalent Maximum Relative Slopes) for Profiles Between the Edge Pavement and the Axis of Rotation (Percent)				
Design Speed $V_D\left(\frac{km}{h}\right)$	Up to 3 Lanes	Four or More Lanes	Minimum Transition Length in Meters (2 Second Rule)	
			Rural	Urban
30	0.75 (1:33)	1.11 (1:90)	17	17
40	.70 (1:143)	1.05 (1:95)	23	23
50	.65 (1:54)	1.00 (1:100)	28	28
60	.60 (1:167)	0.90 (1:111)	33	33
70	.55 (1:182)	0.80 (1:125)	39	39
80	.50 (1:200)	0.75 (1:133)	44	44
90	.48 (1:208)	0.71 (1:140)	50	50
100	.45 (1:222)	0.67 (1:150)	56	56
110	.42 (1:238)	.63 (1:159)	61	61
120	.40 (1:250)	.60 (1:167)	67	67
130	.38 (1:263)	.56 (1:179)	72	72

When the superelevation transition length is calculated, it is checked against the minimum transition length as shown in the relative gradient table depending on whether the design is for rural or urban.

The computed transition length is then rounded up according to values in the ha.tbl. As a default, Imperial lengths are rounded upward to the nearest even five feet, and Metric lengths are rounded upward to the nearest even meter. Exact lengths are not rounded.

When spirals are used, the superelevation and curve widening transitions coincide with the spiral location.

When spirals are not used, 33% of the superelevation and curve widening transitions are placed on the curve. Crown runoff is always achieved outside of the transition.

Examples:

Within IGrds, the user specifies the number of lanes and lane widths within the design criteria dialog box. Remember, the number of lanes is the number of lanes from the axis of rotation to the edge of the farthest lane traveled to be superelevated, and the lane width is the individual width of these lanes.

Example 1 - If for a particular PI, the number of lanes is 2 and the lane width is 3.6m for a rural Metric project with a design velocity of 100 km/h and a superelevation rate of 5.5%, then the superelevation transition length is calculated as follows:

The effective width factor is 1.5 for two lanes and the effective width for two 3.6m lanes is 5.4m (see effective width table). The relative gradient for 100 km/h up to 3 lanes is 0.45.

$$LS = \frac{100x(1.5x3.6)x.055}{.45}$$ = 66.0 which is greater than the minimum of 56m for 100 km/h design speed

Since the calculated value is exact, the LS is set to 66; not rounded up.

Example 2 - If the number of lanes is 1 and the lane width is 3.3m for an urban high speed Metric project with a design velocity of 40 km/h and a superelevation rate of 3.7%, then the superelevation transition length is calculated as follows:

The effective width factor is 1 for one lane and the effective width for one 3.3m lane is 3.3. The relative gradient for 40 km/h up to three lanes is 0.70.

$$LS = \frac{100x(1.0x3.3)x.037}{0.70}$$ = 17.44m which is less than the urban minimum transition length of 23m for 40 km/h design speed so LS is set to 23m.

No rounding is necessary.

Example 3 - If the number of lanes is 4 and the lane width is 3.6m for a rural Metric project with a design velocity of 110 km/h and a superelevation rate of 6.1%, then the transition length is calculated as follows:

The effective width factor is 4 for four lanes and the effective width for four 3.6m lanes is 14.4m. The relative gradient for 110 km/h four or more lanes is 0.63.

$$LS = \frac{100x(4x3.6)x.061}{.63}$$ = 139.43m which is greater than the rural minimum length of 61m for 110 km/h design speed

LS is then rounded up to 140m.

Example 4 - For rural conditions where pavement widening is required, the appropriate widening is added to the lane width when calculating the transition length. For instance, for a one 3.0m lane rural Metric PI with a design velocity of 80 km/h and a curve radius of 300m, the calculations are as follows:

Superelevation rate is calculated to be 7.6%; widening is calculated to be 0.518m per lane. This value is rounded up to 0.6m (1.2m total).

Factor = 1.0
Relative Gradient = 0.50

$$LS = \frac{100x((1.0x(3.0+0.6))x.076}{0.50} = 54.72$$

which is greater than the minimum rural transition length of 44m for 80 km/h design speed

LS is then rounded to 55m.

2001 Standards Computational Methodology

According to the AASHTO Green Book (2001 edition) for pavements wider than two lanes (one in each direction), the calculated transition lengths should be increased by a factor, not doubled or tripled for four or six lane undivided pavements. AASHTO states that for 1.5 lanes rotated the factor should be 1.25; for 2 lanes 1.5; for 2.5 lanes, 1.75; for 3 lanes, 2; etc. Within IGrds, these factors have been extrapolated to 8 lanes rotated. Note that these factors are slightly different than those used in the 1990/1994 standards.

Effective widths and relative gradients are found within the 2001 partition in the ha.tbl for both Metric and Imperial units. For clarity, these tables are reproduced below for Imperial Units.

Effective Widths

Number of Lanes	10' Lanes	11' Lanes	12' Lanes	16' Lanes	Effective Width Factor
1	10	11	12	16	1.0
1.5	12.5	13.75	15	20	1.25
2	15	16.5	18	24	1.5
2.5	17.5	19.25	21	28	1.75
3	20	22	24	32	2.0
3.5	22.5	24.75	27	36	2.25
4	25	27.5	30	40	2.5
5	30	33	36	48	3.0
6	35	38.5	42	56	3.5
7	40	44	48	64	4.0
8	45	49.5	54	72	4.5

Relative Gradients

	Relative Gradients		Minimum Transition Length	
Design Speed	Up to 3 Lanes	Four or More Lanes	Rural	Urban
15	.78	.78	0	0
20	.74	.74	0	0
25	.70	.70	0	0
30	.66	.66	0	0
35	.62	.62	0	0
40	.58	.58	0	0
45	.54	.54	0	0
50	.50	.50	0	0
55	.47	.47	0	0
60	.45	.45	0	0
65	.43	.43	0	0
70	.40	.40	0	0
75	.38	.38	0	0
80	.35	.35	0	0

When the superelevation transition length is calculated, it is checked against the minimum transition length as shown in the relative gradient table depending on whether the design is for rural or urban. Note that the standard value is zero (0) for 2001 standards.

The computed transition length is then rounded up according to values in the ha.tbl. As a default, Imperial lengths are rounded upward to the nearest foot, and Metric lengths are rounded upward to the nearest meter. Exact lengths are not rounded.

When spirals are used, the superelevation and curve widening transitions coincide with the spiral location. The spiral length is then checked against the minimum and maximum spiral lengths.

When spirals are not used, a portion of the superelevation and curve widening transitions are placed on the curve. This proportion depends on the design speed and number of lanes rotated as shown in the table below extracted from the ha.tbl for Imperial units.

Transition Runoff Location Parameters for Curves Without Spirals

Design Speed	1 Lane	1.5	2.0	2.5	3 or more
15	0.8	0.85	0.9	0.9	0.9
20	0.8	0.85	0.9	0.9	0.9
25	0.8	0.85	0.9	0.9	0.9
30	0.8	0.85	0.9	0.9	0.9
35	0.8	0.85	0.9	0.9	0.9
40	0.8	0.85	0.9	0.9	0.9
45	0.8	0.85	0.9	0.9	0.9
50	0.7	0.75	0.8	0.8	0.85
55	0.7	0.75	0.8	0.8	0.85
60	0.7	0.75	0.8	0.8	0.85
65	0.7	0.75	0.8	0.8	0.85
70	0.7	0.75	0.8	0.8	0.85
75	0.7	0.75	0.8	0.8	0.85
80	0.7	0.75	0.8	0.8	0.85

<u>Examples:</u>

Within IGrds, the user specifies the number of lanes and lane widths within the design criteria dialog box. Remember, the number of lanes is the number of lanes from the axis of rotation to the edge of the farthest lane traveled to be superelevated, and the lane width is the individual width of these lanes.

Example 1 – If for a particular PI, the number of lanes is 2 (to be rotated) and the lane width is 12' for a rural imperial units project with a design velocity at 60 mph and a superelevation value of 5.6%, then the superelevation transition length is calculated as follows:

Note that with the recommended design vehicle, WB-50, curve widening should be considered for all types of projects and lane configurations. In this case, none is required. So, from the tables, the effective width factor for two lanes is 1.5 and the effective width for two (unwidened) 12 ft. lanes is 18 ft.

$$LS = \frac{100x(1.5x12)x0.0560}{0.45} = 224.0\,ft.$$

Since the calculated value is exact, the LS is set to 224 ft; not rounded up.

Example 2 – If for a particular PI, the number of rotated lanes is one and the lane width is 11 ft. for an urban high speed project with a design velocity of 25 mph and a calculated superelevation value of 3.7%, then the superelevation transition length is calculated as follows:

As discussed above, curve widening should be considered and, in this case, the required widening per lane is calculated to be 3.05 ft. Again from the tables, the effective width factor is 1 and the unwidened lane width is 11 ft. The relative gradient for 25 mph design velocity is 0.70.

$$LS = \frac{100x(1x(11+3.05))x0.037}{0.70} = 74.26\,ft.$$

This value is rounded upwards to the next ft.; so the LS is 75 ft.

Example 3 – If the number of lanes is 4 and the lane width is 12' for a rural imperial project with a design velocity of 70 mph and a superelevation rate of 6.1%, then the transition lengths is calculated as follows:

Again, curve widening should be considered and in this case, the required widening per lane is calculated to be 0.4 ft. From the tables, the effective width factor for four lanes is 2.5 and the relative gradient for 70 mph is 0.40.

$$LS = \frac{100x(2.5x(12+0.4))x0.061}{0.40} = 472.75\,ft.$$

This value is rounded upwards to the next ft.; so the LS is 473 ft.

AUTOMATIC CROWN RUNOFF LENGTH CALCULATIONS

Within IGrds for superelevation types 0 and 4, the crown runoff length is a calculated value. The crown runoff length is defined as the distance from where the design template is at normal crown cross slope to where adverse crown has been removed. The crown runoff length calculation method depends on the Superelevation Transition Method (see discussion earlier in this appendix). The two methods are discussed in the following paragraphs.

Normal Method (Flag = 0)

If the Superelevation Transition Method is set to zero, then the template pavement widths are taken into account, thereby achieving relatively linear ridge lines. The crown runoff length is calculated using the following formula.

$$\text{CR} = \frac{\text{abs. value(WNCxNC)xLS}}{\text{abs. value(WFSxe)}}$$

where:

CR = Crown runoff length

WNC = Actual pavement width at the last station with normal crown slope (from IGrds processing) measured from the axis of rotation (pivot point) to the edge of the last segment that would be superelevated.

NC = Normal crown cross slope rate. (Note, if there are multiple lanes and the cross slopes are different for the lanes, then this is taken into account so that a “relative elevation” is calculated.

LS = Superelevation transition length

WFS = Actual pavement width at the first station of full superelevation (from IGrds processing) measured from the axis of rotation (pivot point) to the edge of the last segment that would be superelevated.

e = Full superelevation cross slope rate.

The actual relative gradient of the edge of pavement is also calculated within IGrds for each transition and reported as a part of the earthwork calculations report.

$$\text{Actual Relative Gradient} = \frac{\text{abs. value(WNCxNC)} + \text{abs. value(WFSxe)}}{\text{LS} + \text{CR}}$$

This gradient is reported in percent grade.

Alternate Method (Flag = 1)

If the Superelevation Transition Method flag is set to one, then the crown runoff length is calculated based on a linear transition of the superelevation rate independent of pavement width. In this case, the crown runoff length is calculated using the following formula.

$$CR = \frac{\text{abs. value}(NCxLS)}{\text{abs. value} \quad e}$$

where:

CR = Crown runoff length,

NC = Normal crown cross slope rate (Note, if there are multiple lanes and the cross slopes are different for the lanes, then this is taken into account in the calculations.)

LS = Superelevation transition length.

e = Full superelevation cross slope rate.

The rate of change of cross slope is then calculated using the following formula:

$$\text{rate of change} = \frac{\text{abs. value} \quad NC + \text{abs. value} \quad e}{\text{abs. value}\, LS + \text{abs. value} \quad CR}$$

This value is reported in percent change per 100 units (feet or meters).

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