Superelevation Calculations

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The purpose of this document is to demonstrate how the cross slope on each side of a road transitions in a superelevated area, and specifically how to calculate rates of transition and the cross slope for a particular station.

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 Roadway Standards Drawings provide information for Urban Superelevation Details (RD01-SE-2) and Rural Superelevation Details (RD01-SE-3). 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.

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 RD01-SE-3 with V = 30 M.P.H., Degree of Curve 13^{o}- 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 is shown in Figure 1. The SE, Design Speed, and Transition Length are all filled in by the user from the data in the standard drawing.

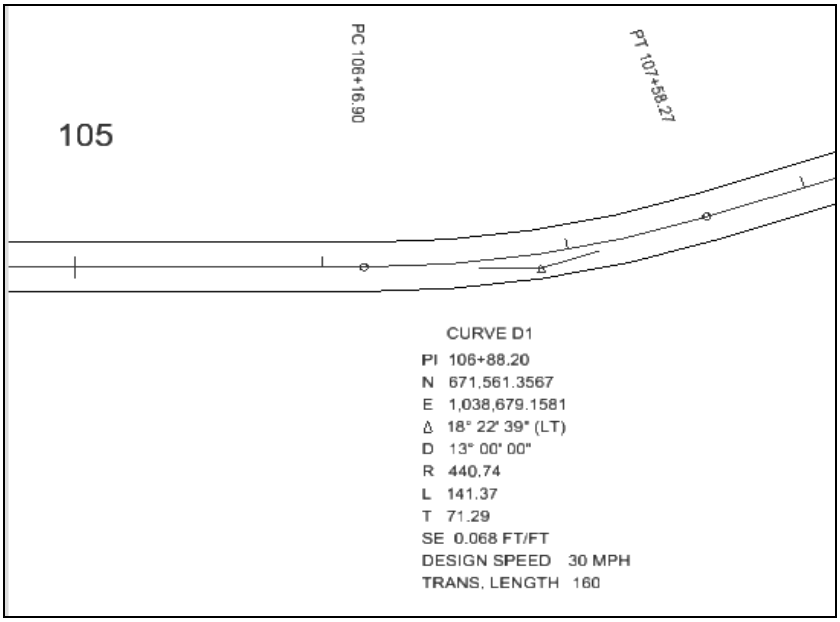

FIGURE 1 – HORIZONTAL ALIGNMENT CURVE D1

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.

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

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

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 Sta. 106+87.588683. The curve is only in full super for this station. This is because this station is at the mid point 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.

** On the previous page 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

The log file carries the numbers out 6 decimal places but calculations will not. For the figures and calculations, only 2 decimal places will be shown. 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.

- Full Superelevation minus 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.

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

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

The 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 before 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.

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

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

Zero percent cross slope is reached at 10527.5887 + 36.36' = **105+63.95**

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.

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

$$= \frac{(0.068 \text{ Minus } 0.00)}{0.00055} = \frac{0.068}{0.00055} = 123.64'$$

Zero percent cross slope is reached at 10687.5887 – 123.64' = **105+63.95**

REVERSE CROWN BEFORE FULL SUPERELEVATION (RIGHT LANE)

To find the station where reverse crown (+0.02) occurs for the right lane of the road before 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.

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

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

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.

- $\frac{\text{Curve Length}}{2} = \frac{141.37}{2} = 70.685'$

P.C. Station plus Length

10616.90 + 70.685 = 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.

- $\frac{\text{Curve Length}}{2} = \frac{141.37}{2} = 70.685'$

P.T. Station minus Length =

10758.27 - 70.685 = 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 plus 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 = $\frac{\text{Change in Cross Slope}}{\text{Transition Rate}}$

$$= \frac{\{-0.68 \text{ minus } (-0.02)\}}{-0.068 + 0.02} = \frac{0.048}{0.555} = \frac{0.048}{.000555} = 87.27$$

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 plus 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.

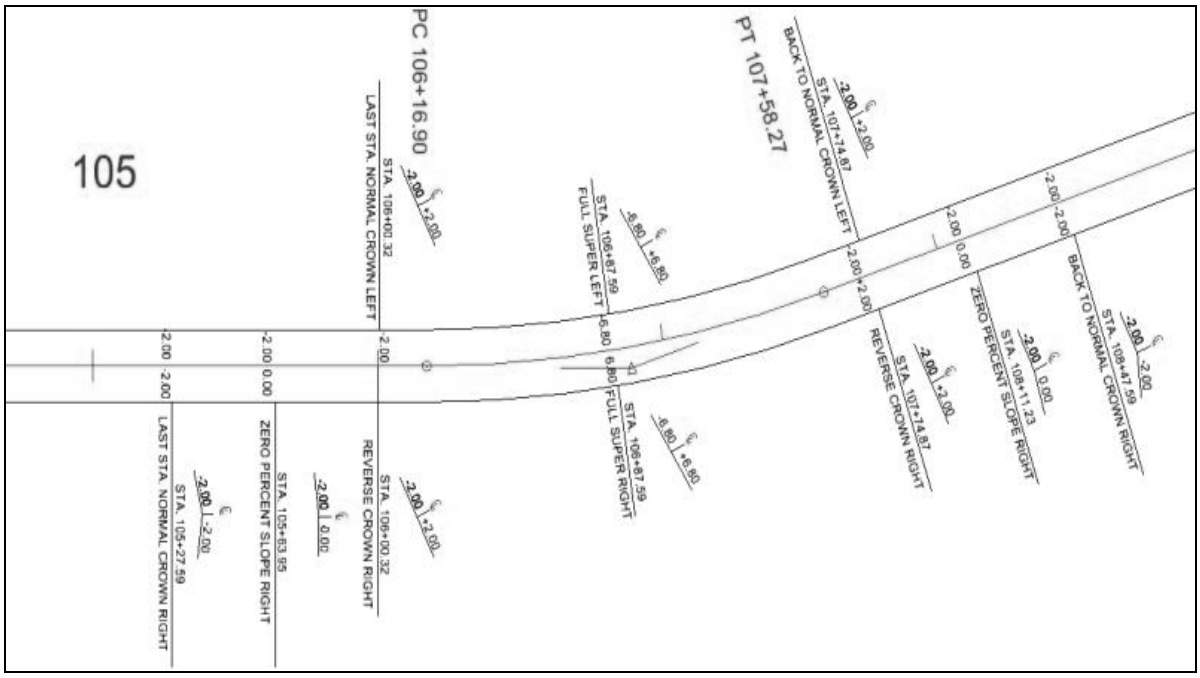

FIGURE 2 – STATIONS AND CROSS SLOPES

For clarity, the figure has been split into two sections representing the stations before and after full superelevation.

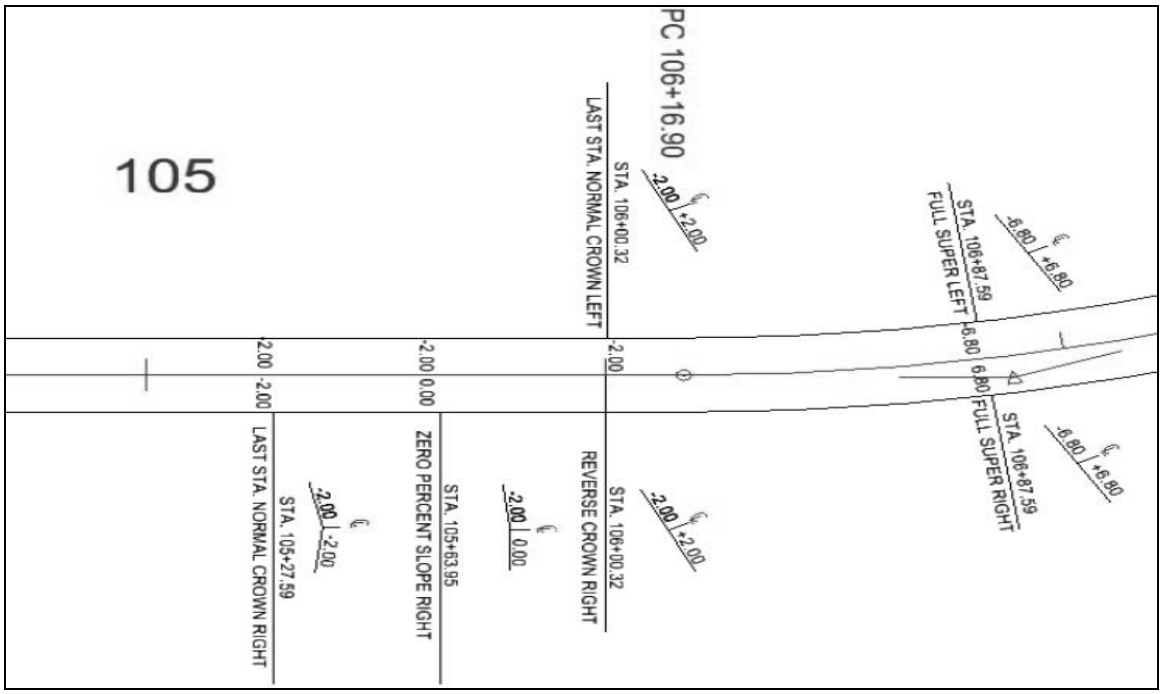

FIGURE 3 – STATIONS AND CROSS SLOPES BEFORE FULL SUPERELEVATION

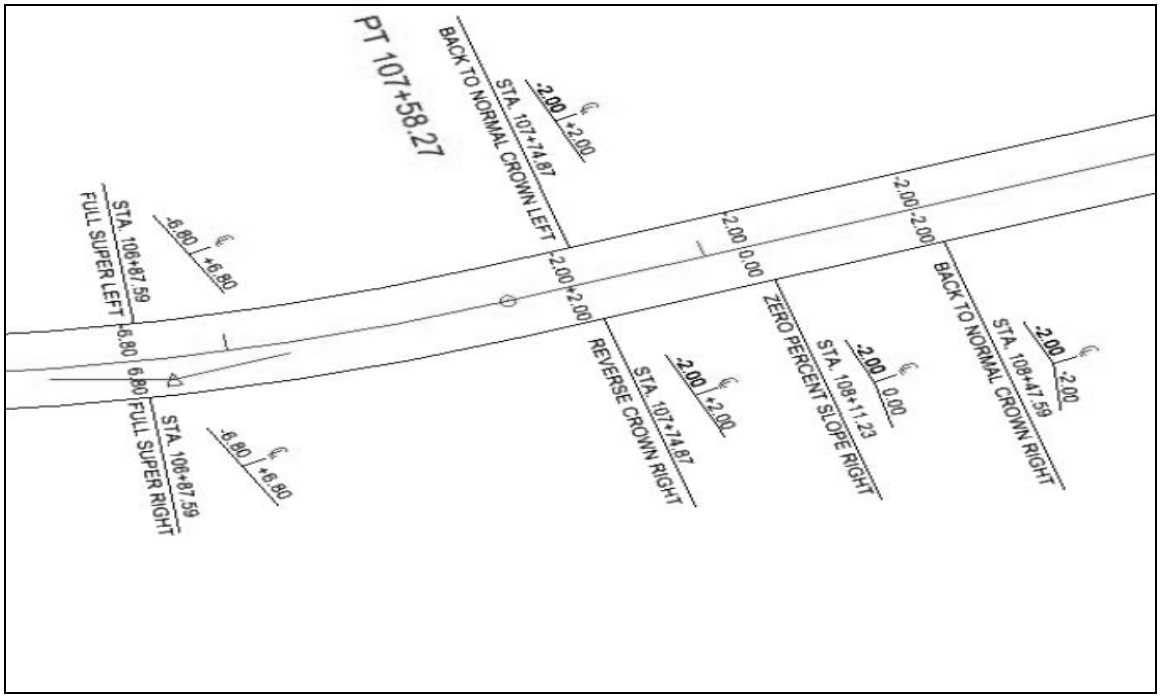

FIGURE 4 – STATIONS AND CROSS SLOPES AFTER FULL SUPERELEVATION