Vertical Curves

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Sag Vertical Curves

The selection of the minimum length of a sag vertical curve is controlled by:

- sight distance provided by the headlight (at night)
- rider comfort
- control of drainage
- general appearance
Headlight Criterion

The headlight is angled upward at an inclined angle ($\beta$), the headlight intersects the road at D, restricting the available sight distance to S. The values for H and $\beta$ are 0.6m and 1 degree.

If $S > L$

$$L = 2S - \frac{200(H + S \tan \beta)}{A}$$

where $A =$ absolute difference in grade

If $S < L$

$$L = \frac{AS^2}{200(H + S \tan \beta)}$$
Stopping Sight Distance and Length of Sag Vertical Curve

Stopping Sight Distance vs. Length of Sag Vertical Curve

- Blue line: \( L (A=2) \)
- Red line: \( L (A=6) \)
Comfort Criterion

\[ L > \frac{AV^2}{395} \]

where \( V \) is design speed in km/h and \( L \) in meters
Drainage Criterion

A grade of 0.35% percent be provided within 15m of the level point of the curve
California Appearance Criterion

$L_{\text{min}}=2V$

(if Design speed $(V) > 60 \text{ km/h}$)
Example 5: Minimum Length of a Sag Vertical Curve

A sag vertical curve is being designed to join a -2 percent grade to a plus 3 percent grade.

If the design speed is 60 km/h, determine the minimum length of the curve that will satisfy headlight criteria.

Assume $f=0.32$ and $\text{PRT} = 2.5 \text{ sec.}$
Solution (1/3)

Find the stopping sight distance

(0.03 is critical grade)

\[ S = d_s = 0.278t, v + \frac{v^2}{254(f + G)} = 0.278(2.5)60 + \frac{60^2}{254(0.32 - 0.03)} = 41.7 + 48.9 = 90.57 m \]
Solution 2/3

Determine whether $S < L$ or $S > L$ for the headlight criterion.

If $S > L$

$$L = 2S - \frac{200(H + S\tan\beta)}{A} = 2 \times 90.57 - \frac{200((0.6) + 90.57(\tan(1^\circ)))}{5} = 181.14 - 87.2 = 93.94\ m$$

$L > S = 90.57$, oops
Solution 3/3

Determine whether $S < L$ or $S > L$ for the headlight criterion

If $S < L$

$$L = \frac{AS^2}{200(H + S\tan \beta)} = \frac{5(90.57)^2}{200((0.6) + 90.57 \tan(1^\circ))} = \frac{41014}{436.18} = 94\ m$$

Check,

So $S < L$
Problem: Design of a Sag Vertical Curve

A sag vertical curve joins a -2 percent grade with a +3 percent grade.

If the PVI of the grades is at metric station 57+550 and has an elevation of 75 meters, determine the station elevation of the PVC and PVT for a design speed of 100 km/hr, coefficient of friction = 0.28.
Solution (A)

For a design speed of 100 km/hr, coefficient of friction = 0.28

\[
S = d_s = 0.278t_v + \frac{v^2}{254(f \pm G)} = 0.278(2.5)100 + \frac{100^2}{254(0.28 - 0.03)} = 69.5 + 157 = 226m
\]

Length of Curve

\[
L = \frac{AS^2}{200(H + S \tan \beta)} = \frac{5(226)^2}{200\left((0.6) + 226 \tan \left(1^\circ \right)\right)} = \frac{255380}{908.97} = 281m
\]
Solution (B)

- Station of PVC = (57+550) - (140.5) = 57+409.5
- Station of PVT = (57+550) + (140.5) = 57+690.5
- Elevation of PVC = 75 + 0.02 * 140.5 = 77.81 m
- Elevation of PVT = 75 + 0.03 * 140.5 = 79.21 m
Questions

Questions?
Abbreviations

- PVI - Point of Vertical Intersection (sometimes VPI)
- PVC - Point of Vertical Curvature (sometimes VPC)
- PVT - Point of Vertical Tangency (sometimes VPT)
- SSD - Stopping sight distance ($d_s$) or (S)
Key Terms

- Sag vertical curve
- Crest vertical curve
Variables

- $y =$ Elevation of the curve at a distance $x$ meters from the PVC (m)
- $c =$ elevation of PVC (m)
- $b = G_1$
- $a = (G_2 - G_1)/2L$
- $L =$ Length of the crest vertical curve (m)
- $S =$ Sight distance (m)
- $A =$ The change in grades ($|G_2 - G_1|$ as a percent)
- $h_1 =$ Height of the driver's eyes above the ground (m)
- $h_2 =$ Height of the object above the roadway (m)