2.7.1 Effect of Grade on Passing Sight Distance

Appreciable grades increase the sight distance required for safe passing. Passing is easier for the vehicle traveling downgrade because the overtaking vehicle can accelerate more rapidly that on the level and thus can reduce the time of passing. But overtaken vehicle can also accelerate easily so that a dangerous situation may result.

The sight distances required to permit vehicles traveling up-grade to pass safely are greater than those required on level roads because reduced acceleration of passing vehicle (which increases the time of passing) and the likelihood of opposing traffic speeding up (which increases the distance traveled by it). Compensating for this somewhat are the factors that the passed vehicle frequently is a truck that usually loses some speed on up-grades and that many drivers are aware of the greater distances needed for passing up-grade compared with level conditions.

If passing is to be performed safely on up-grades, the passing sight distance should be greater than the derived minimum. Specific adjustments for design use are not available, but the designer should recognize the desirability of increasing the minimum shown on Table-A.5.

3. Crest Vertical Curves

The main design consideration at crest vertical curves is that of sight distance. At all crest vertical curves, the stopping sight distance corresponding to the design speed must be provided as a minimum, although wherever practicable provision of greater sight distance is desirable. in particular on single-lane and two lane two-way roads, provision of intermediate sight distance or greater is desirable where it can be economically justified. On these roads, overtaking sight distance is usually can be provided only in flat country where grade changes are small.

The main factors to be considered when determining the length of a crest vertical curve are the change of grade to be accommodated and the length of sight distance to be provided. In any given case, the change of grade is largely dictated by topography and general longitudinal grading considerations, including practical and economical factors. However, in many cases there may be scope to alter one or both grades to obtain an optimum solution, hence fixing the final grade line is often an interactive process to obtain the most satisfactory combination of grades and vertical curves.

When calculating the length of a crest vertical curve, there are two cases to consider, namely:

1. When the required sight distance is less than the length of the vertical curve.
2. When the required sight distance is greater than the length of the vertical curve.

Derivation of the formulas for computing the sight distances for both cases are as follows:

3.1 Sight Distance Less Than Length of Vertical Curve

This case is illustrated in Figure-A.2

L	= length of vertical curve (ft)
D	= required sight distance (ft)
g_1 and g_2	= per cent grade, an up-grade being +, and a down grade being –
h_1	= height of the driver's eye (ft)
h_2	= height of the object on the road (ft)
d_1 and d_2	= horizontal distance (ft)
e	= vertical distance from intersection point (ft)
A	= per cent change in grade
k	= rate of vertical curvature

Since the vertical curve in Figure 3x is parabolic

$h_1 = k\ d_1$

$h_2 = k\ d_2$

$e = k\ (L/2)$, $e = L\ A / 800$

$k = A / (200\ L)$

$h_1 = A\ d_1^2 / (200\ L)$ and $h_2 = A\ d_2^2 / (200\ L)$

or

$d_1 = \sqrt{[(200\ L\ h_1) / A]}$ and $d_2 = \sqrt{[(200\ L\ h_2) / A]}$

$D = d_1 + d_2$

$D = \sqrt{[200\ L / A]} * (\sqrt{h_1} + \sqrt{h_2})$

or

$$L = \frac{A\ D^2}{200(\sqrt{h_1} + \sqrt{h_2})^2} \qquad \text{(A-3)}$$

3.2 Sight Distance Greater Than Length of Vertical Curve

This case is illustrated in Figure-A.3, where notation is same as above, but in addition:
d_3 = horizontal distance (ft)

g_3 = per cent grade of the line of sight

By trigonometry:

$d_1 = (100\ h_1) / (g_1 + g_3)$ and $d_3 = (100\ h_2) / (g_1 + g_2)$

because vertical curve is a parabola

$d_2 = L / 2$

Let g1 + g3 = g

Since $A = g_1 + g_2$, it follows that $g_2 - g_3 = A - g$

$d_1 = 100\ h_1 / g$ and $d_3 = 100\ h_2 / (A - g)$

$$D = \frac{100\ h_1}{g} + \frac{L}{2} + \frac{100\ h_2}{(A - g)}$$

for D to be minimum dD/dg = 0

$$[\ 100\ h_1 / g_2\ ] - [\ 100\ h_2 / (A\text{-}g)^2] = 0$$

which reduces to:

$$g = \frac{A \sqrt{h_1}}{\sqrt{h_1} + \sqrt{h_2}}$$

Substituting for g in the above equation for D gives

$$D = \frac{\mathbf{L}}{\mathbf{2}} + \frac{\mathbf{100}}{\mathbf{A}} (\sqrt{h_1} + \sqrt{h_2})^2$$

or

$$L = 2D - \frac{200}{A} (\sqrt{h_1} + \sqrt{h_2})^2 \qquad \text{(A-4)}$$