

TS4447 Highway Geometric

Vertical Alignment

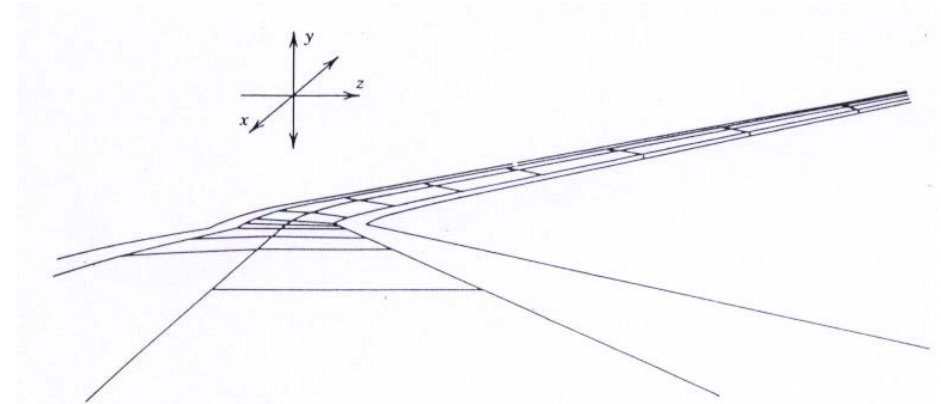
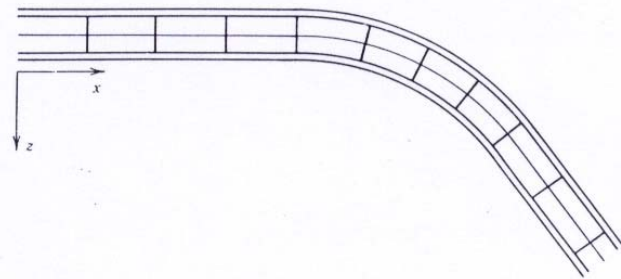


FIGURE 3.1

Highway alignment in 3-dimensions. (Reproduced by permission from F. L. Mannering, Computer Plotting of Highway Perspectives, unpublished Bachelor's Thesis, University of Saskatchewan, Saskatoon, Canada, 1976.)

Plan View (horizontal alignment)

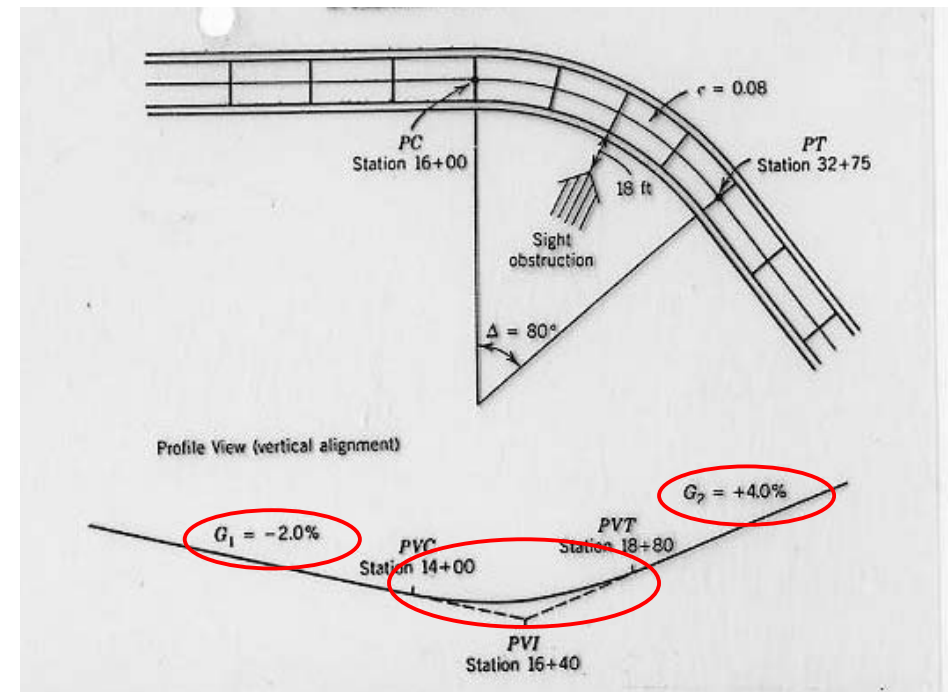


Profile View (vertical alignment)



FIGURE 3.2

Highway alignment in two-dimensional views.



Bad Combinations of Horizontal and Vertical Curvature

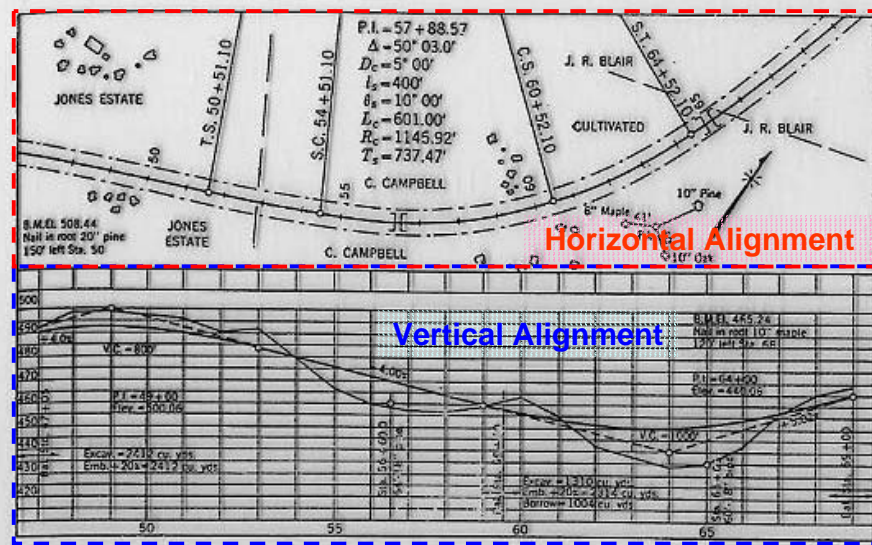
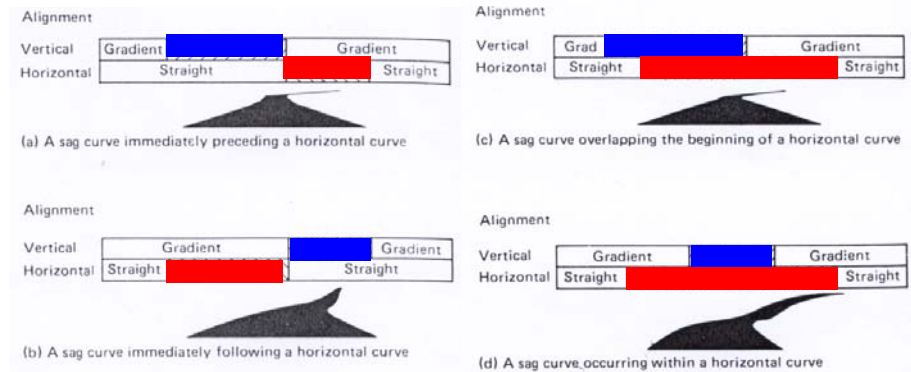
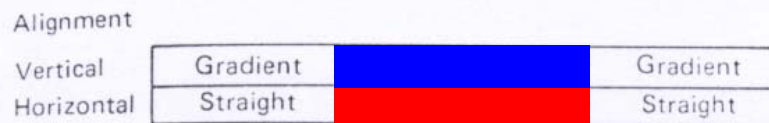


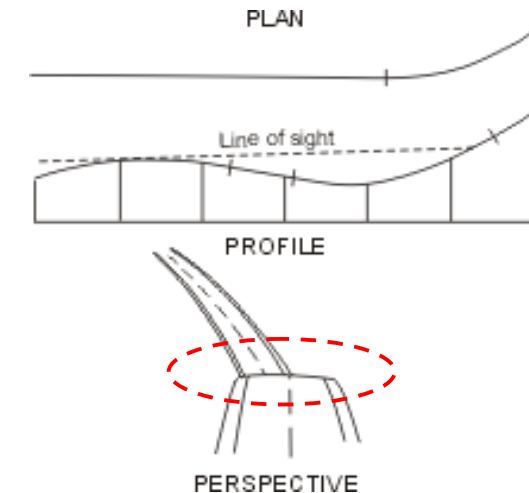
Figure 2.4.17 Typical plan and profile of a highway. (From T. F. Hickerson, *Route Surveys and Design*, 4th ed., McGraw-Hill, New York, 1959. Reproduced with permission of the publisher.)

Good Combinations of Horizontal and Vertical Curvature



(e) The ends of the vertical curve are coincident with the corresponding ends of the horizontal curve

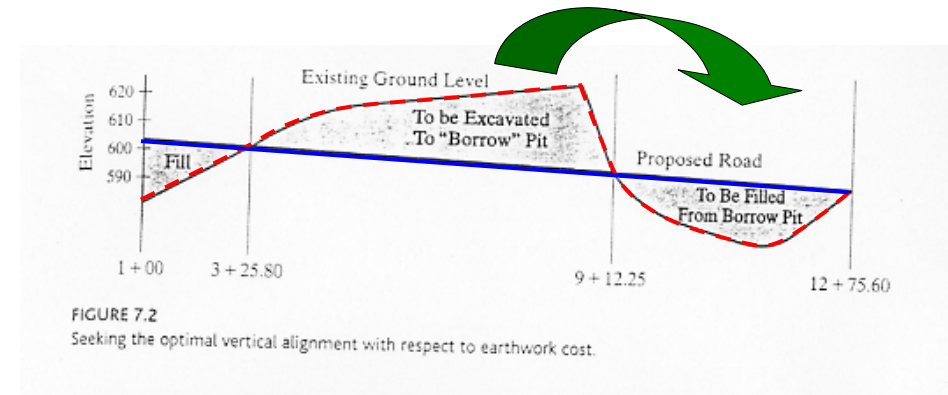
Bad Combinations of Horizontal and Vertical Curvature



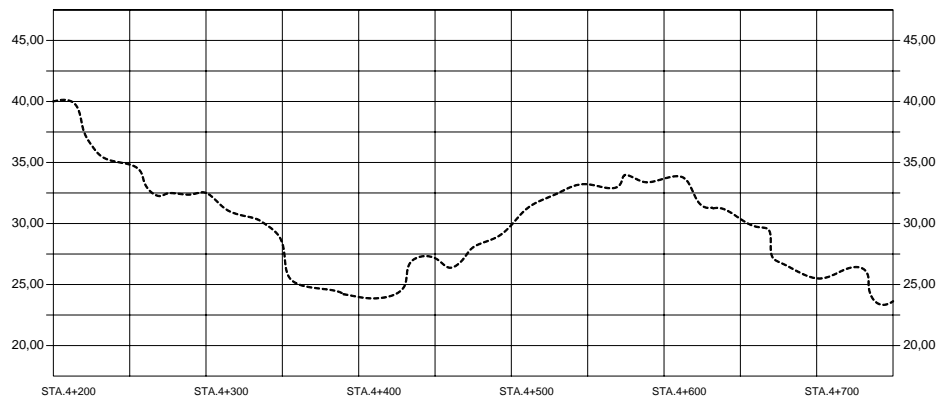
Vertical Alignment

- Maximum Grade
- Critical Length of Climbing Lane
- Property of Simple Parabolic Curve
- Vertical Curve
 - Crest
 - Sag
- Minimum Length of Vertical Curve

Typical Mass-Haul Diagram

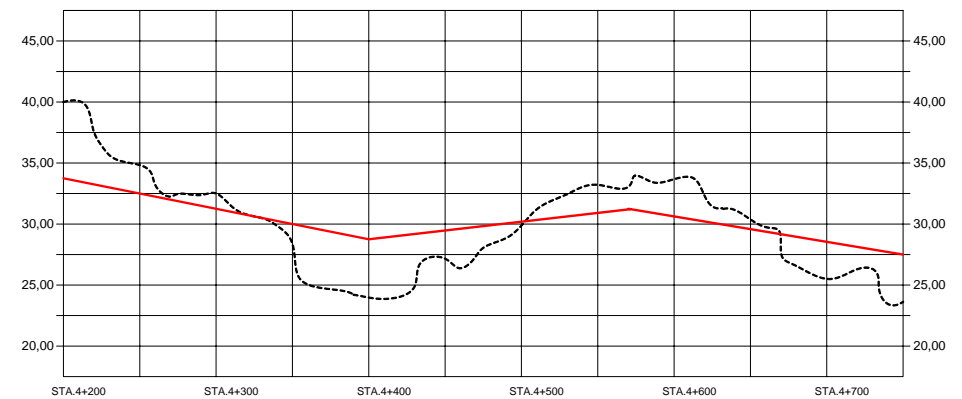


Existing Ground Profile



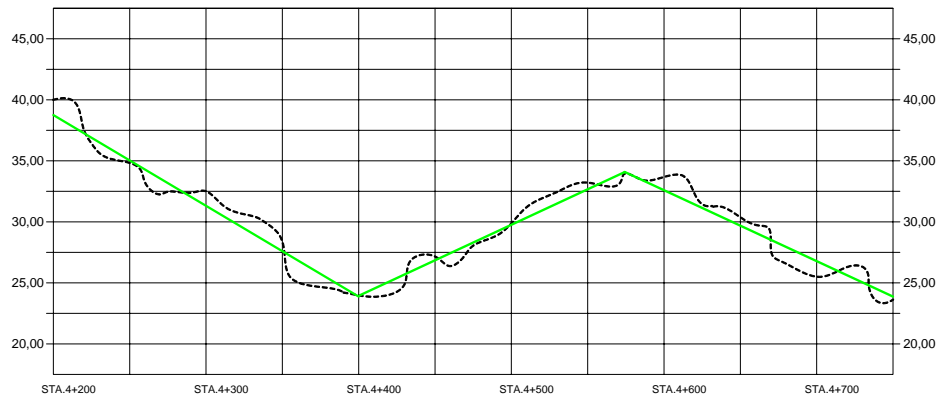
Gambar 2 Profil Elevasi Tanah

Existing Ground Profile



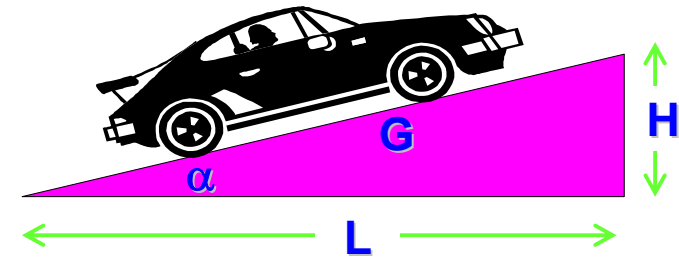
Gambar 2 Profil Elevasi Tanah

Existing Ground Profile



Gambar 2 Profil Elevasi Tanah

MAXIMUM GRADE (G)



$$\text{Grade (\%)} = (H / L) \times 100$$

$$\text{Slope Ratio} = H : L$$

$$\tan \alpha (^{\circ}) = H / L$$

RSNI 2004 Table 19 p. 41

Design Speed (km/h)	Maximum Grade (%)
100	5
90	5
80	6
70	6
60	7
50	8

MAXIMUM CRITICAL LENGTH OF GRADE WITHOUT CLIMBING LANE

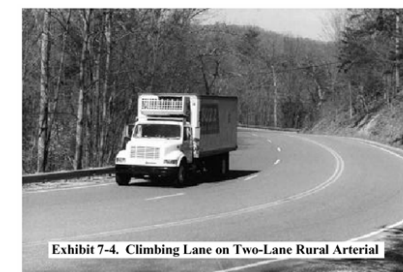
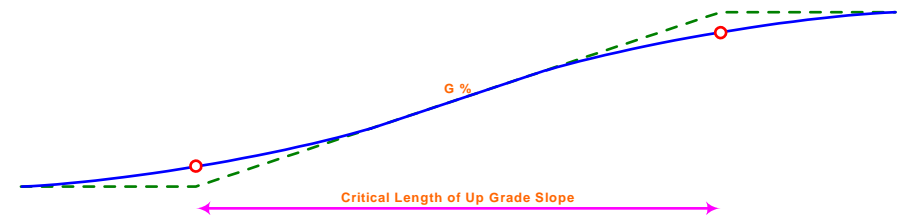


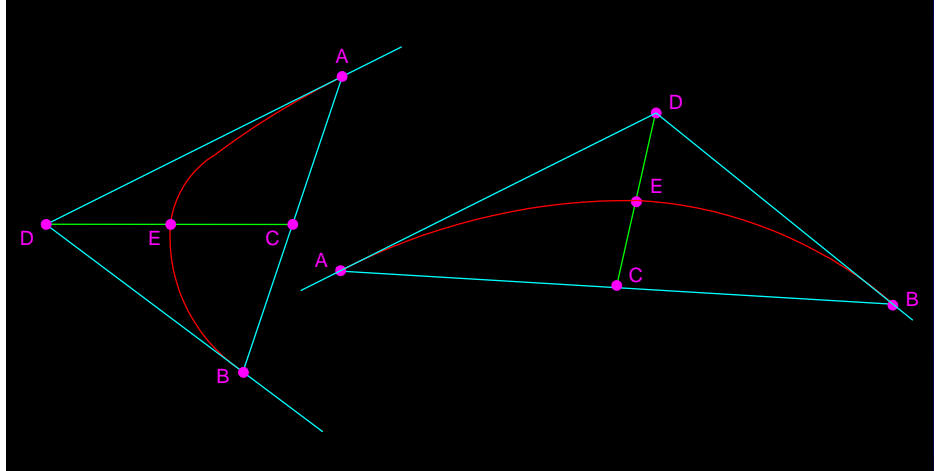
Exhibit 7-4. Climbing Lane on Two-Lane Rural Arterial

PROPERTIES OF PARABOLA

1. The line joining the midpoint C of a chord AB of a parabola with the intersection D of the tangents at the ends of the chords is bisected by the parabola it self at E. Thus $DE = EC$.
2. Offsets from the tangent to the parabola vary as the square of the distance from the point of tangency.
3. The rate of change of curvature of the parabola varies directly as the distance.

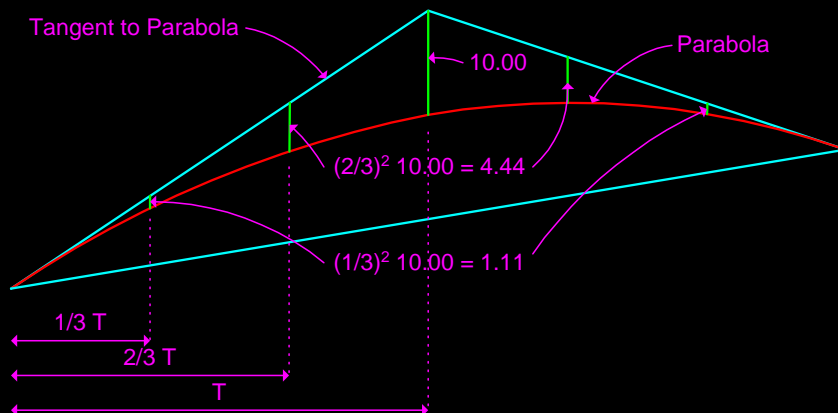
Source: Barry, B. Austin (1988)

1ST PROPERTY OF PARABOLA



Source: Barry, B. Austin (1988)

2ND PROPERTY OF PARABOLA



3RD PROPERTY OF PARABOLA

The initial gradient changes uniformly with the distance: the rate of change of gradient in percent per station (r) is constant between the initial gradient (g_1) and the final gradient (g_2):

$$r = \frac{g_2 - g_1}{L}$$

3RD PROPERTY OF PARABOLA (CONT'D)

For,

$$g_1 = -2.00\%$$

$$g_2 = +4.00\%$$

$$L = 6 \text{ Sta.}$$

$$r = (-2.00\% - (+4.00\%))/6 \text{ Sta.}$$

$$= -1.00\%/\text{Sta.}$$

3RD PROPERTY OF PARABOLA (CONT'D)

The initial gradient = + 4.00% will run out to 0% at this constant rate in four stations, thus giving the high point at Sta. 61:

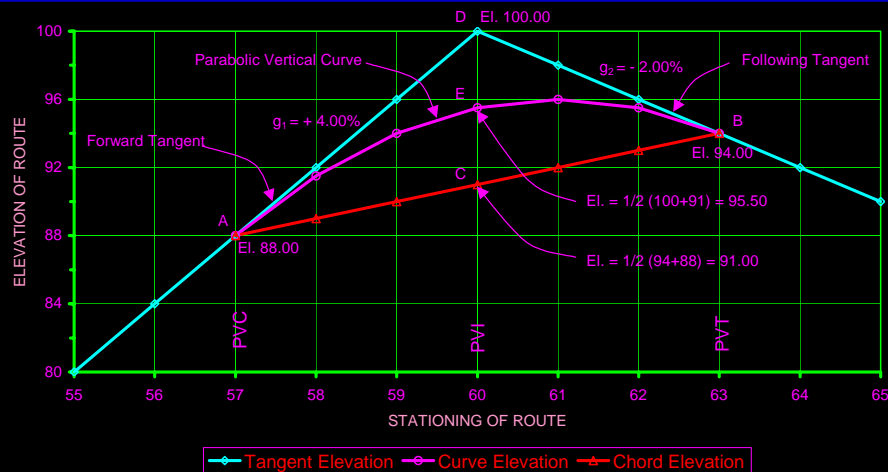
$$g_1 + r(n') = 0\%;$$

$$n' = -g_1/r$$

$$= -4.00\%/-1.00\%$$

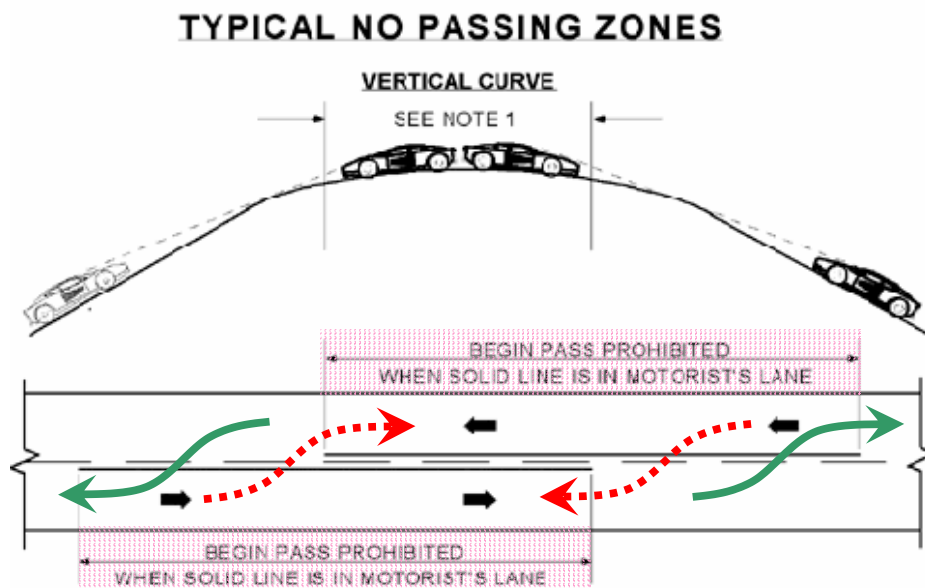
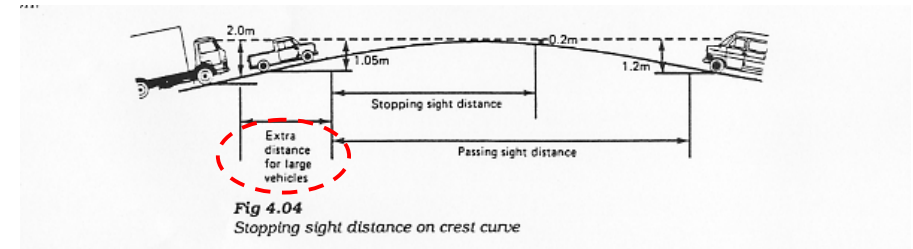
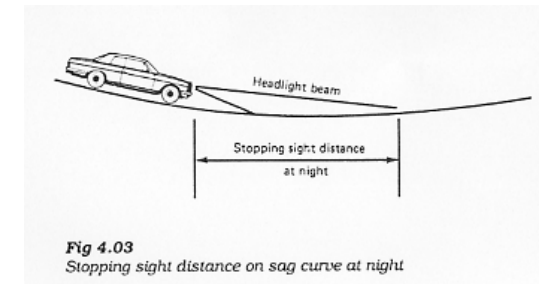
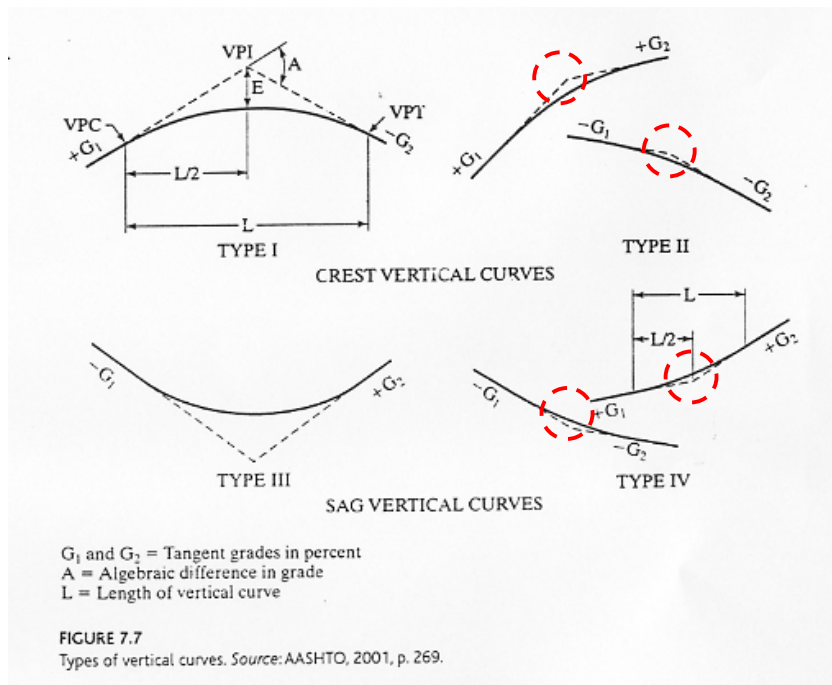
$$= 4.00 \text{ Sta. From PVC}$$

A SIMPLE COMPUTATION OF PARABOLIC VERTICAL CURVE



FINDING OFFSETS AT ANY POINT FOR A VERTICAL PARABOLIC CURVE

- Offset at Sta. 58 = offset at Sta. 62
 $= (1/3)^2 4.50 = 0.50$
- Offset at Sta. 59 = offset at Sta. 61
 $= (2/3)^2 4.50 = 2.00$



Standard Minimum Crest Vertical Curve Length for Stopping Sight Distance

RSNI 2004 p.41 & Table 20 p.42

$$L = (A \times S^2) / 658 \quad \rightarrow \quad S < L$$

$$L = 2S - (658 / A) \quad \rightarrow \quad S > L$$

L → crest curve length (m)

A → algebraic difference in grade (%)

S → stopping sight distance (m)

$S < L$ or $S > L$?

$$Z = AS / 800$$

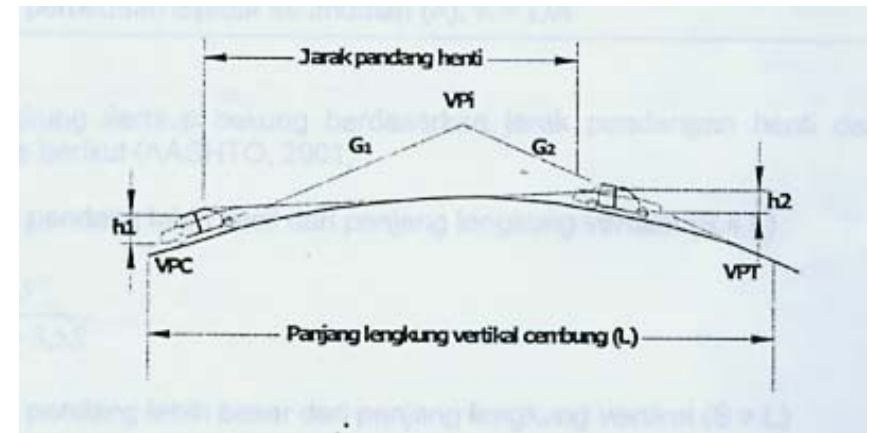
$A \rightarrow$ algebraic difference in grade (%)

$S \rightarrow$ stopping sight distance (m)

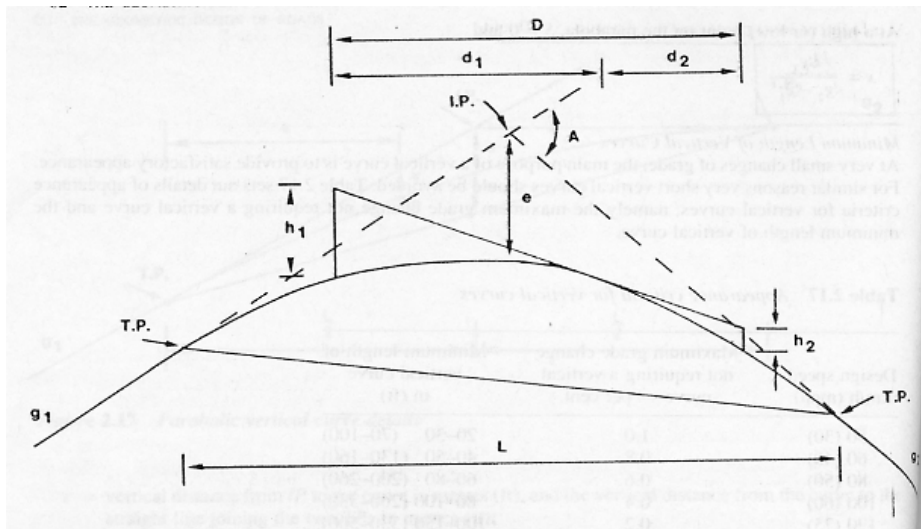
$$Z > h_1 \rightarrow S < L$$

$$Z < h_1 \rightarrow S > L$$

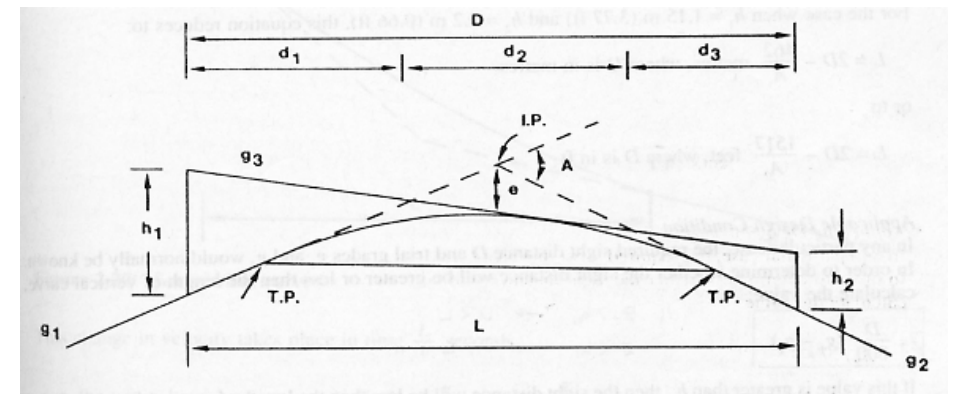
Standard Minimum Crest Vertical Curve Length for Stopping Sight Distance



Standard Minimum Crest Vertical Curve Length for Stopping Sight Distance



Standard Minimum Crest Vertical Curve Length for Stopping Sight Distance



Standard Minimum Sag Vertical Curve Length for Stopping Sight Distance

RSNI 2004 p.42 & Table 21 p.43

$$L = (A \times S^2) / (120 + 3,5S) \rightarrow S < L$$

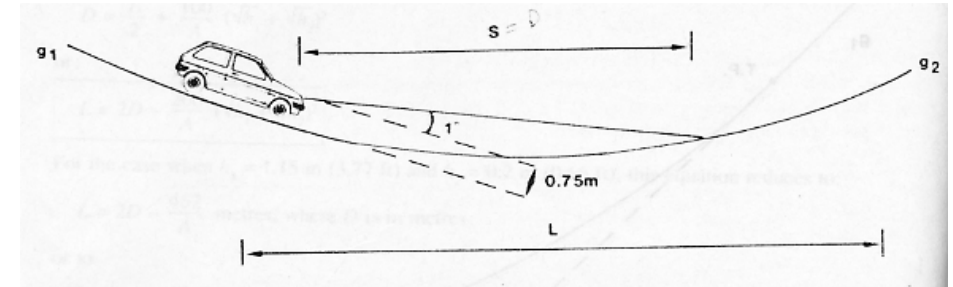
$$L = 2S - [(120 + 3,5S) / A] \rightarrow S > L$$

$L \rightarrow$ sag curve length (m)

$A \rightarrow$ algebraic difference in grade (%)

$S \rightarrow$ stopping sight distance (m)

Standard Minimum Sag Vertical Curve Length for Stopping Sight Distance



STOPPING SIGHT DISTANCE

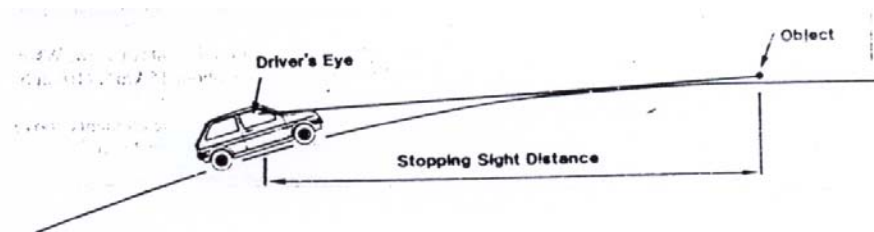
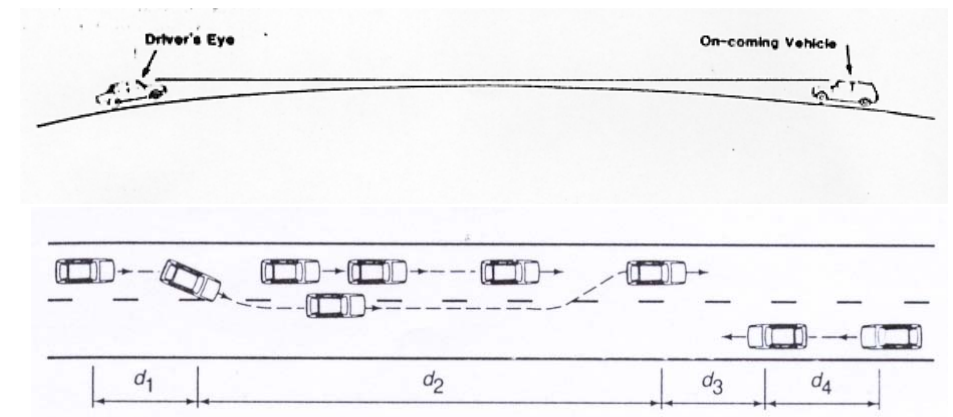


Figure 2.6 Stopping sight distance

$$D_{SSD} = 0,7V + \frac{V^2}{254(f \pm g)}$$

PASSING SIGHT DISTANCE



$$D_{PSD} = d_1 + d_2 + d_3 + d_4 \quad D_{PSD_{min}} = \frac{2}{3} d_2 + d_3 + d_4$$

[SSGDUR 1992 p.33 or p.123-125]

Calculated Stopping Sight Distance

$$SSD = 0.694V + 0.00394 \frac{V^2}{(f + g)}$$

V = running speed (kph)
f = friction coefficient
g = grade (%)

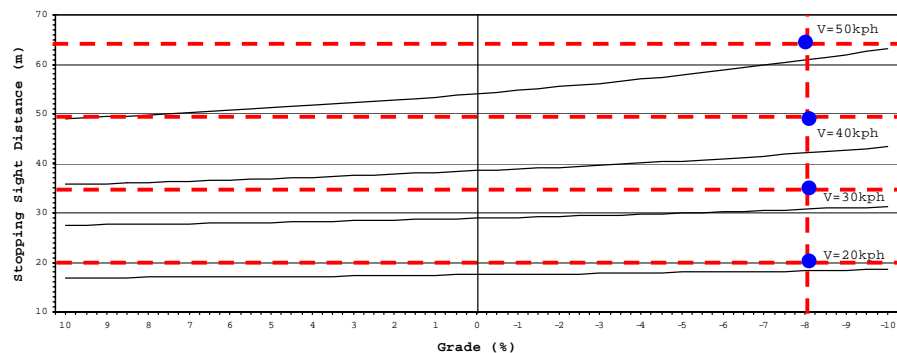
Source: Standar Specification for Geometric Design of Urban Roads, 1992

Calculated Stopping Sight Distance (cont'd)

Design Speed (kph)	Running Speed (kph)	Friction Coefficient
120	102	0.29
100	85	0.30
80	68	0.31
60	54	0.33
50	45	0.35
40	36	0.38
30	30	0.44
20	20	0.44

Source: Standar Specification for Geometric Design of Urban Roads, 1992

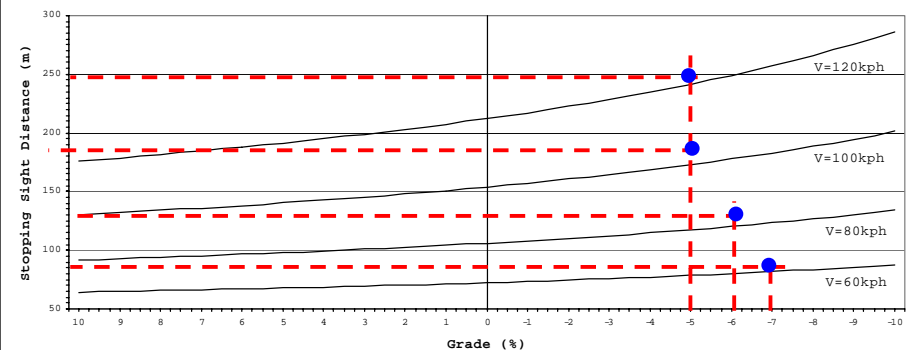
STOPPING SIGHT DISTANCE CHART FOR DESIGN SPEED 20 - 50 kph



$$SSD = 0.694V + 0.00394 \frac{V^2}{(f + g)}$$

V = running speed (kph)
f = friction coefficient
g = grade

STOPPING SIGHT DISTANCE CHART FOR DESIGN SPEED 60 - 100 kph



$$SSD = 0.694V + 0.00394 \frac{V^2}{(f + g)}$$

V = running speed (kph)
f = friction coefficient
g = grade

Standard Minimum Sag Vertical Curve Length for Underpass Sight Distance

RSNI 2004 p.43 & Table 21 p.43

$$L = (A \times S^2) / [800 (C-1,5)] \rightarrow S < L$$

$$L = 2S - [800 (C-1,5) / A] \rightarrow S > L$$

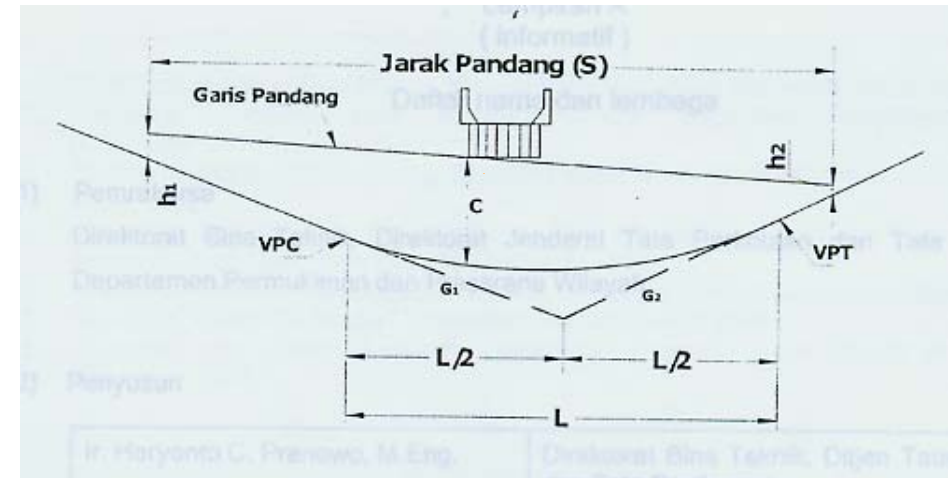
$L \rightarrow$ sag curve length (m)

$A \rightarrow$ algebraic difference in grade (%)

$S \rightarrow$ stopping sight distance (m)

$C \rightarrow$ vertical clearance (m)

Standard Minimum Sag Vertical Curve Length for Underpass Sight Distance



Standard Minimum Vertical Curve Length for K-Value

RSNI 2004 Table 20 p.42 & Table 21 p.43

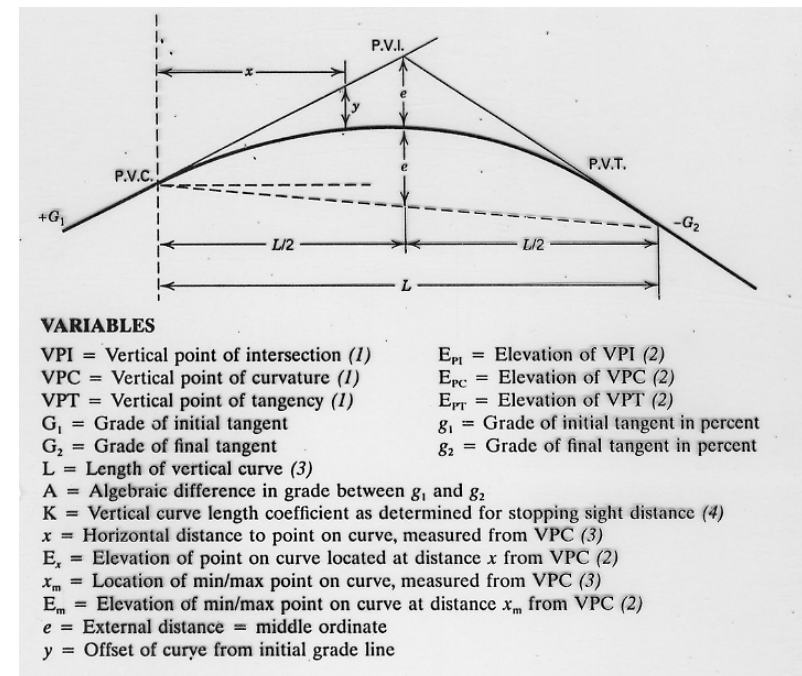
$$L = K \times A$$

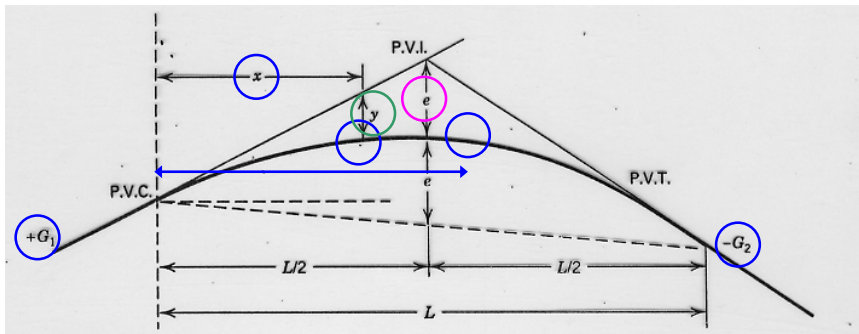
$K \rightarrow$ Crest Curve \rightarrow Table 20 page 42

Sag Curve \rightarrow Table 21 page 43

$L \rightarrow$ crest curve length (m)

$A \rightarrow$ algebraic difference in grade (%)





VERTICAL CURVE EQUATIONS

$$A = g_2 - g_1$$

$$K = \frac{L}{A}$$

$$e = \frac{(G_1 - G_2)L}{8} = \frac{AL}{800} = \frac{A^2 K}{800}$$

For high (low) point on curve,

$$x_m = \frac{g_1 L}{g_2 - g_1} = \frac{g_1 L}{A}$$

For any point p on curve,

$$y = \frac{(G_2 - G_1)x^2}{2L} = \frac{A x^2}{200L} = \frac{x^2}{200K}$$

$$E_x = E_{PC} + G_1 x + \frac{(G_2 - G_1)x^2}{2L}$$

similarly,

$$E_x = E_{PC} + \frac{g_1 x}{100} + \frac{x^2}{200K}$$

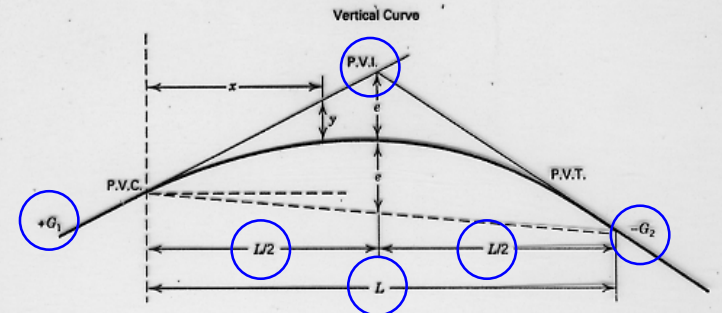
Calculation of Elevations Along a Crest Vertical Curve A plus 3.0 percent grade intersects a minus 2.0 percent grade at station 4+350 and at an elevation of 190.500 m. Given that a 250-m length of curve is utilized, determine the station and elevation of the PC and PT. Calculate elevations at every 20-m station and locate the station and elevation of the high point of the curve. A sketch of the given conditions is shown below.

$$g_1 = +3.0\%$$

$$g_2 = -2.0\%$$

$$PI \text{ Sta} = 4+350 \text{ m}$$

$$PI \text{ EL} = 190.500 \text{ m}$$

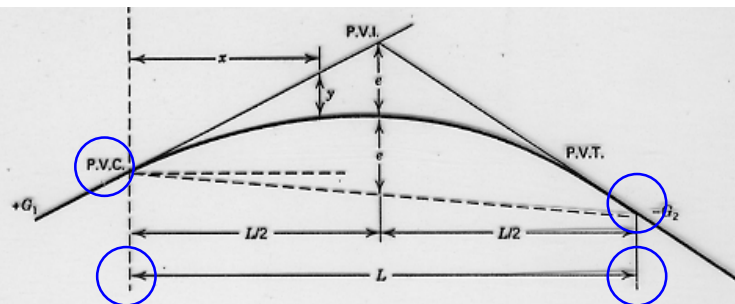


$$G_1 = +0.03 \text{ m per m}$$

$$G_2 = -0.02 \text{ m per m}$$

$$L = 250 \text{ m}$$

$$L/2 = 125 \text{ m}$$



$$G_1 = +0.03 \text{ m per m}$$

$$G_2 = -0.02 \text{ m per m}$$

$$L = 250 \text{ m}$$

$$L/2 = 125 \text{ m}$$

Station locations for the PC and PT are

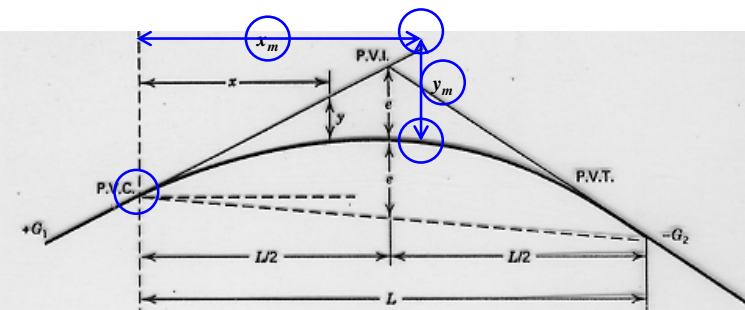
$$PC \text{ Sta} = PI \text{ Sta} - L/2 = 4+350 - 125 = 4+225$$

$$PT \text{ Sta} = PC \text{ Sta} + L = 4+225 + 250 = 4+475$$

Elevations for the PC and PT are

$$E_{PC} = E_{PI} - G_1 (L/2) = 190.500 - 0.03(125) = 186.750 \text{ m}$$

$$E_{PT} = E_{PI} - G_2 (L/2) = 190.500 - 0.02(125) = 188.000 \text{ m}$$



Location of high point can be calculated as follows:

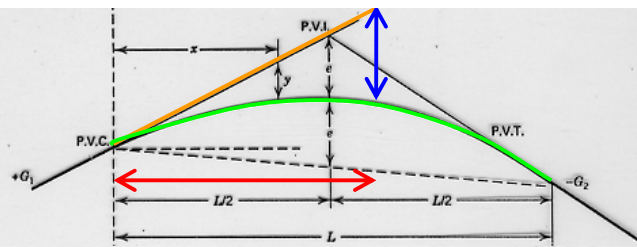
$$x_m = \frac{g_1 L}{g_2 - g_1} = \frac{3.0(250)}{5.0} = 150 \text{ m}$$

$$\text{High point Sta} = PC \text{ Sta} + 150 \text{ m} = 4+225 + 150 = 4+375$$

Elevation of high point can be calculated as follows:

$$E_x = E_{PC} + G_1 x_m + \frac{(G_2 - G_1)x_m^2}{2L}$$

$$E_x = 186.750 + 0.03(150) + \frac{(-0.05)150^2}{2(250)} = 189.000 \text{ m}$$



Calculations for point elevations at even 20-m stations along the vertical curve can be conveniently tabulated as follows;

Station	x (meters)	Elevation on initial tangent ($E_{PC} + G_1 x$)	y	Final elevation on curve (Elev on tan - y)
4+240	15	187.200	-0.023	187.178
4+260	35	187.800	-0.123	187.678
4+280	55	188.400	-0.303	188.098
4+300	75	189.000	-0.563	188.438
4+320	95	189.600	-0.903	188.698
4+340	115	190.200	-1.323	188.878
4+360	135	190.800	-1.823	188.978
4+380	155	191.400	-2.403	188.998
4+400	175	192.000	-3.063	188.938
4+420	195	192.600	-3.803	188.798
4+440	215	193.200	-4.623	188.578
4+460	235	193.800	-5.523	188.278
4+475	250	194.250	-6.250	188.000

Tugas Minggu Depan

1. Elevasi rencana
2. Maximum Grade
3. Lengkung Vertikal

Dikumpulkan 29 April
2009 sebelum jam 12:00
wib (via email & CDRW)