Sight Distance

And

Road Alignment

SIGHT DISTANCE

Stopping Sight Distance:

The sight line is a chord of the curve,
and the stopping sight distance is measured along the centerline of the inside lane around the curve.

Equation 3-40 applies only to circular curves longer than the sight distance for the pertinent design speed.

Where sufficient stopping sight distance is not available .the alternatives are:

- Increase the offset to the obstruction.
- Increase the radius.
- Reduce the design speed.

SIGHT DISTANCE (Contd.)

- A study reported by TRB, went on to develop a model to assist in determining the cost-effectiveness of lengthening a vertical curve to increase sight distance over a crest.
- It is cost-effective when the design speed is more than 20mph below operating speed in the area.
- Traffic flows exceed 1500 vpd
- High volume intersection
- Sharp curve
- Steep downgrade
- Lane drop

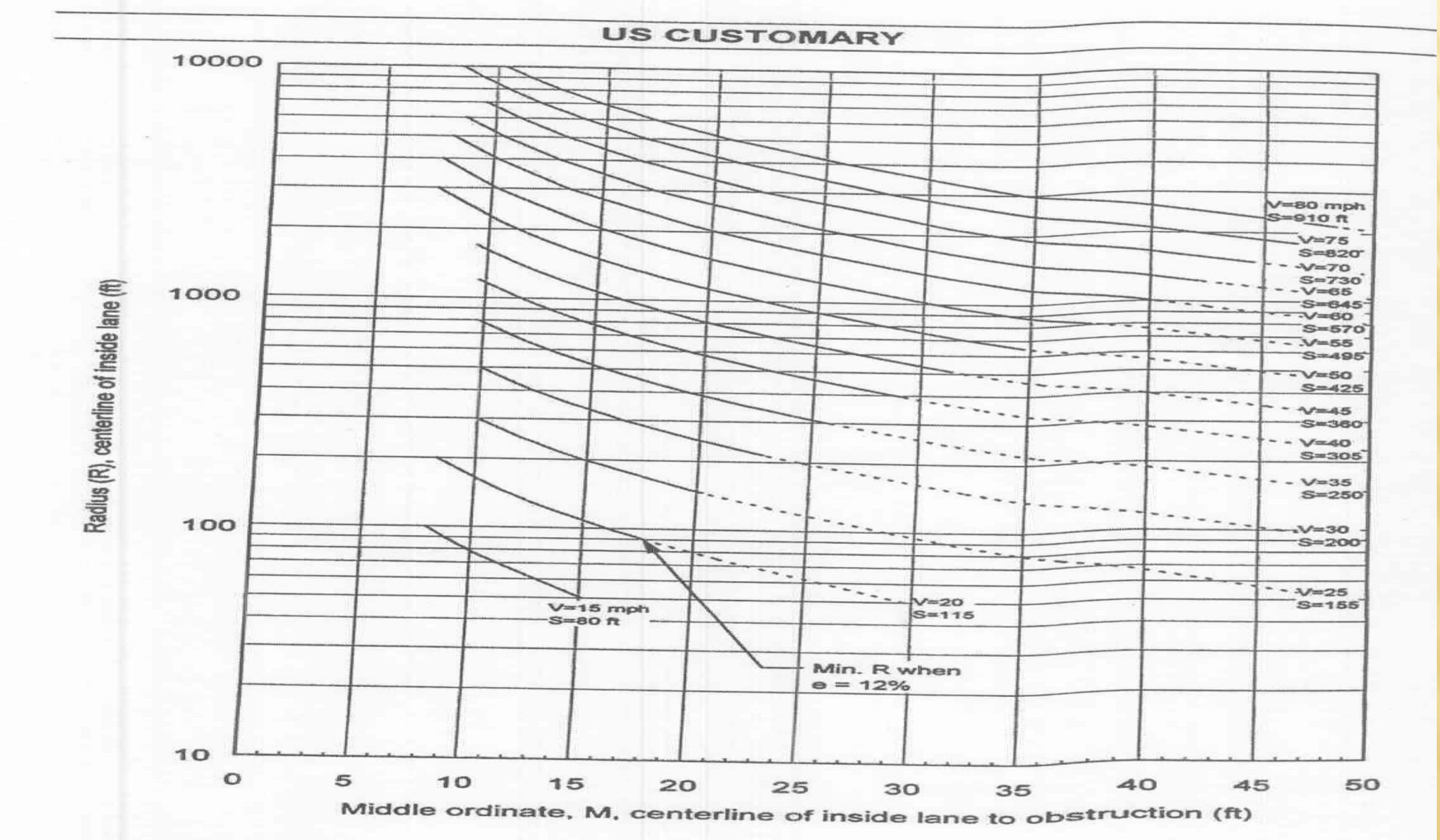


Exhibit 3-57. Design Controls for Stopping Sight Distance on Horizontal Curves (Continued)

Exhibit 3-57 is a design chart showing the middle ordinates needed for clear sight areas that satisfy stopping sight distance criteria presented in Exhibit 3-1

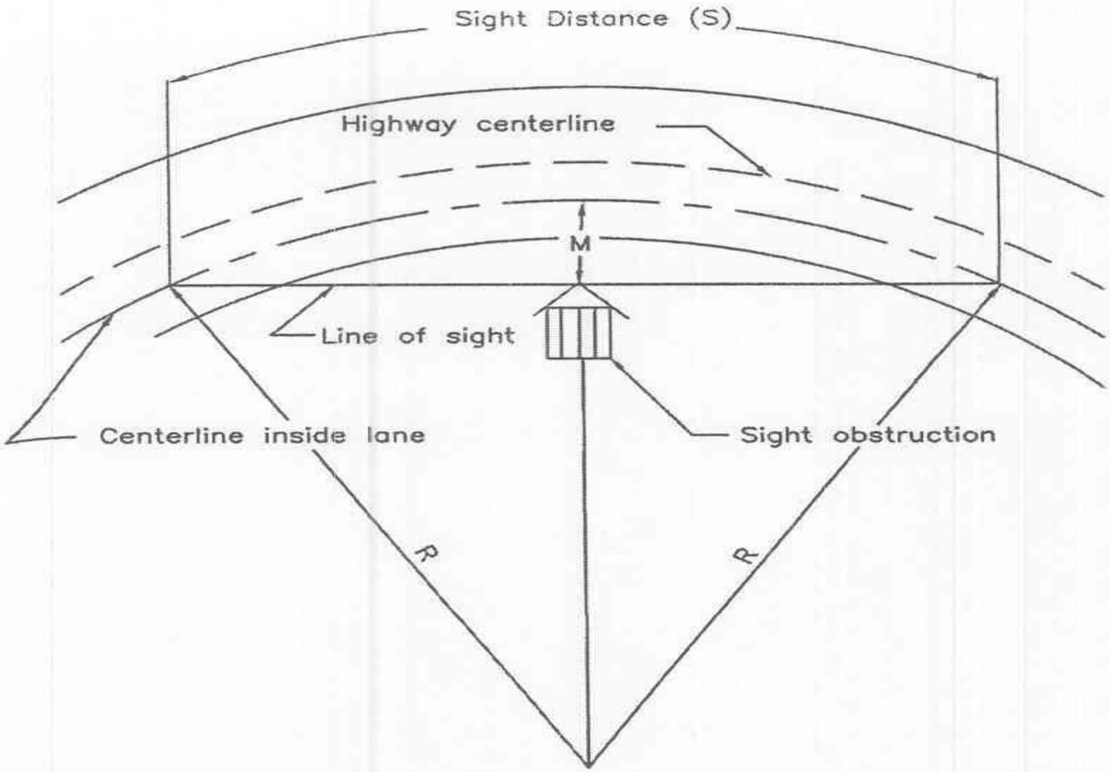


Exhibit 3-58. Diagram Illustrating Components for Determining Horizontal Sight Distance

Metric	US Customary	
$$M = R\left[\left(1 - \cos\frac{28.65S}{R}\right)\right]$$	$$M = R\left[\left(1 - \cos\frac{28.65S}{R}\right)\right]$$	(3-40)
where: S = Stopping sight distance, m; R = Radius of curve, m; M = Middle ordinate, m	where: S = Stopping sight distance, ft; R = Radius of curve, ft; M = Middle ordinate, ft	

SIGHT DISTANCE ON HORIZONTAL CURVES

Passing sight distance:

The minimum passing sight distance for a two-lane roads or street is about four times as great as the minimum stopping sight distance at the same design speed. Equation(3-40).

According to AASHTO's *A Policy on Geometric Design of Highways and Streets (2001)* passing sight distance can be broken into four components:

.

•The distance traveled by the passing vehicle during perception and reaction time and during the

•initial acceleration to the point of encroachment on the opposite lane.

•· The distance the passing vehicle travels while in the opposite lane.

•· The distance between the passing vehicle at the end of its maneuver and an opposing vehicle.

•· The distance traveled by an opposing vehicle for 2/3 of the time the passing vehicle occupies the

•opposite lane.

SIGHT DISTANCE AT UNDER-CROSSINGS

- Sight distance on the highway through a grade separation should be at least as long as the minimum stopping sight distance and preferably longer,

- the structure fascia may cut the line of sight and limit the sight distance to provide the minimum length of sag vertical curve discussed above at grade separation structures.

- The sight distance should not need to be reduced below the minimum recommended values for stopping sight distance.

- To check the available sight distance at an under-crossing use ex 3-54 to 3-57 using an eye height of 2.4 m and object height of 0.6 m

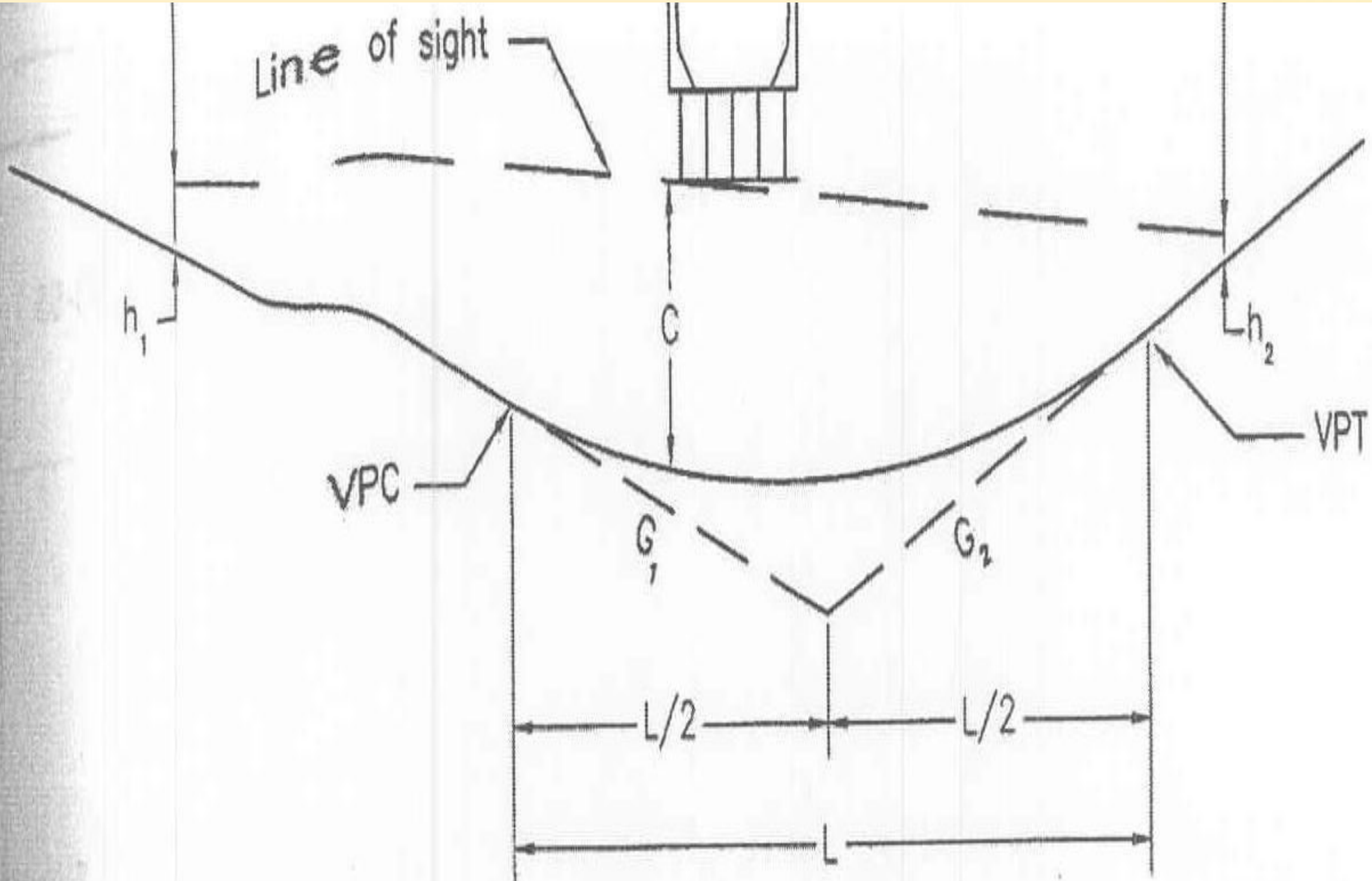
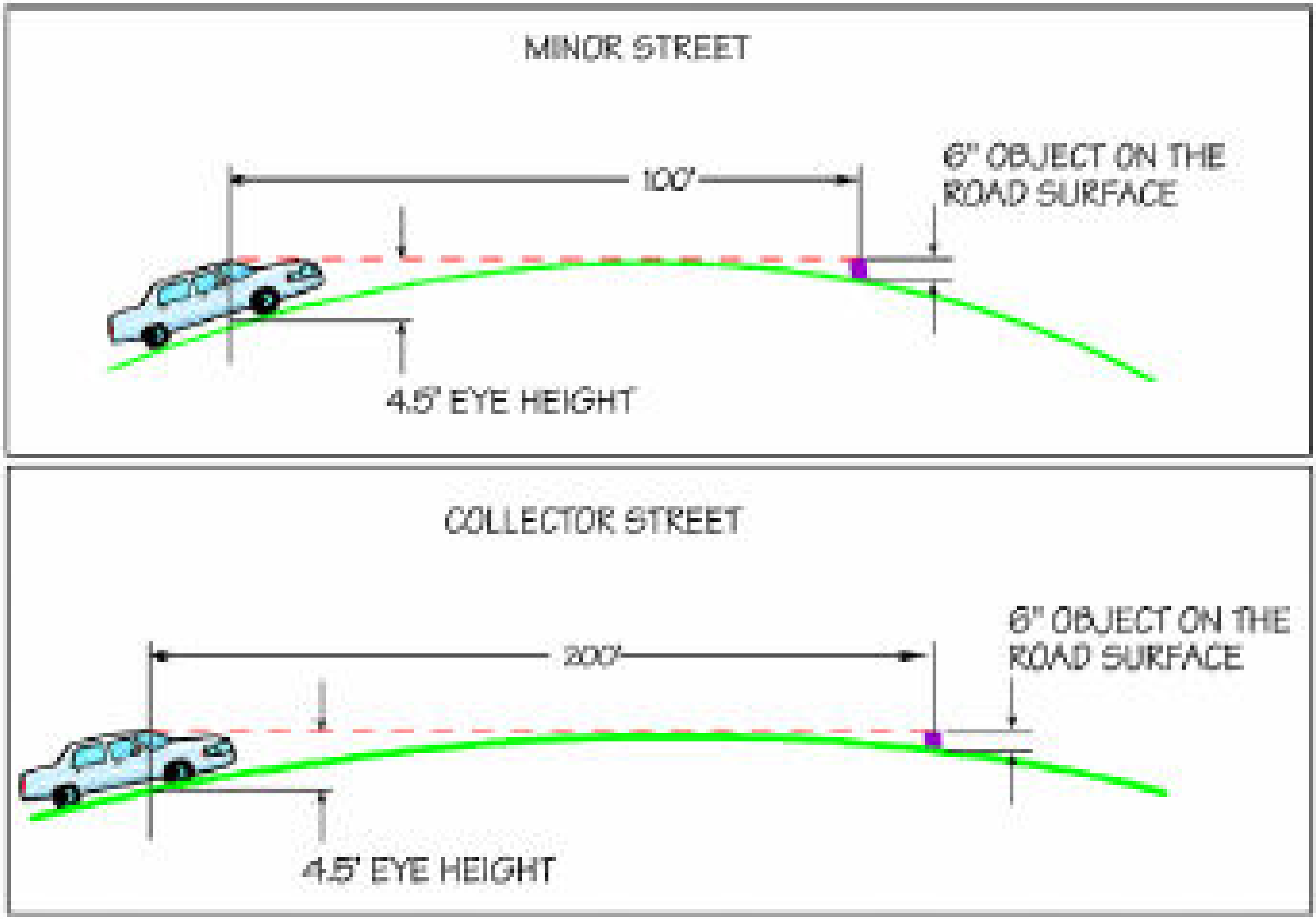
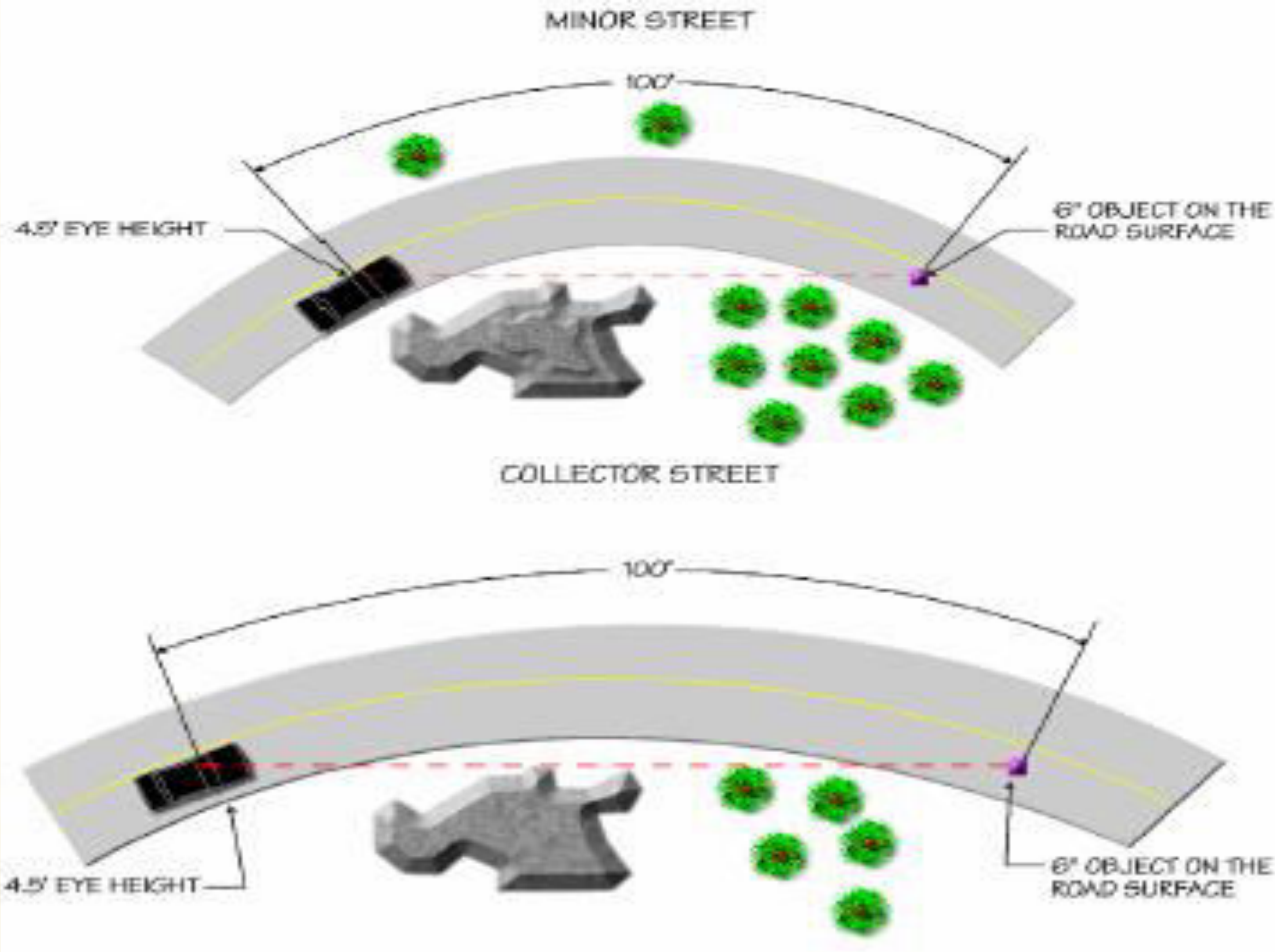


Exhibit 3-80. Sight Distance at Undercrossings

SITE DISTANCE




MINOR STREET
100'
4.5' EYE HEIGHT
6" OBJECT ON THE ROAD SURFACE
COLLECTOR STREET
100'
4.5' EYE HEIGHT
6" OBJECT ON THE ROAD SURFACE

Equations

HORIZONTAL ALIGNMENT

ROAD ALIGNMENT

HORIZONTAL ALIGNMENT

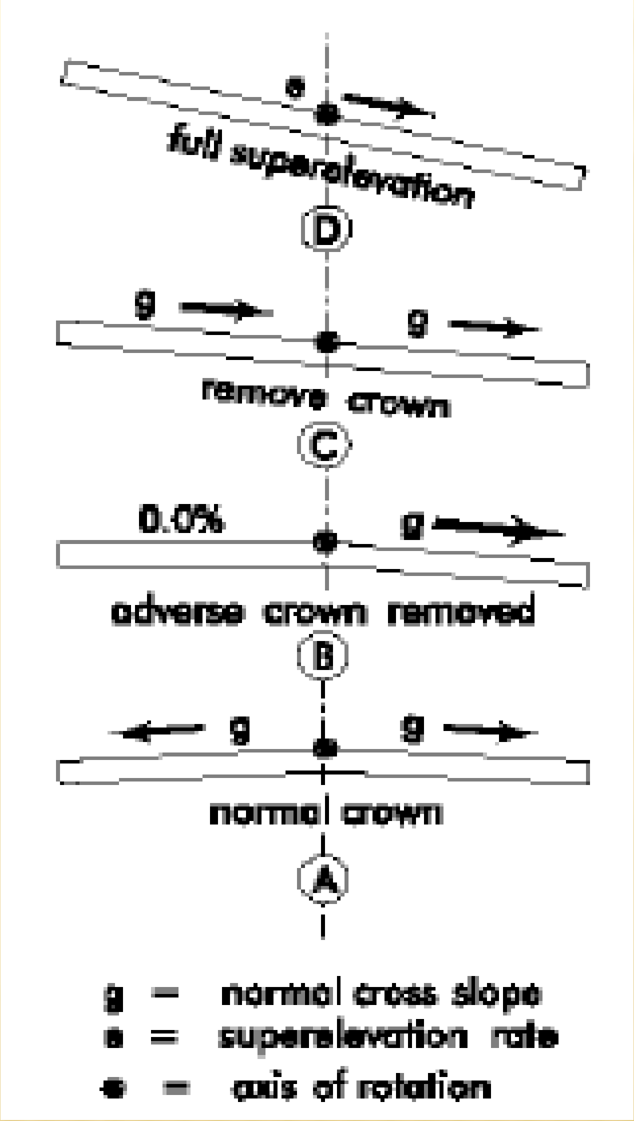
- Design based on appropriate relationship between design speed and curvature and their interaction with side friction and super elevation
- Along circular path, inertia causes the vehicle to attempt to continue in a straight line
- Super elevation and friction between tire and roadway provides a force to offset the vehicle's inertia; this force is directed toward the center of curvature (often called centrifugal or centripetal force)

HORIZONTAL ALIGNMENT

1. Tangents
2. Curves
3. Transitions

Curves require super elevation (next lecture)

Reason for super: Banking of curve, retard sliding, allow more uniform speed, also allow use of smaller radii curves (less land)



RADIUS CALCULATION

$$R_{min} = \frac{V^2}{15(e + f)}$$

Where:

V = velocity (mph)

e = superelevation

f = friction   (15 = gravity and unit conversion)

RADIUS CALCULATION

- R_{min} related to max. f and max. e allowed
- R_{min} use max e and max f (defined by AASHTO, DOT, and graphed in Green Book) and design speed
- *f* is a function of speed, roadway surface, weather condition, tire condition, and based on comfort – drivers brake, make sudden lane changes and changes within a lane when acceleration around a curve becomes “uncomfortable”
- AASHTO: 0.5 @ 20 mph with new tires and wet pavement to 0.35 @ 60 mph
- f decreases as speed increases (less tire/pavement contact)

RADIUS CALCULATION (EXAMPLE)

Design radius example:

assume a maximum e of 8% and design speed of 60 mph, what is the minimum radius?

f_{max} = 0.12 (from Green Book)

$$R_{min} = \frac{60^2}{15(0.08 + 0.12)}$$

R_{min} = 1200 feet

For, e_{max} = 4%?

$$R_{min} = \frac{60^2}{15(0.04 + 0.12)}$$

R_{min} = 1,500 feet

Radius Calculation (Example)

For e_{max} = 4%?

$$R_{min} = \frac{60^2}{15(0.04 + 0.12)}$$

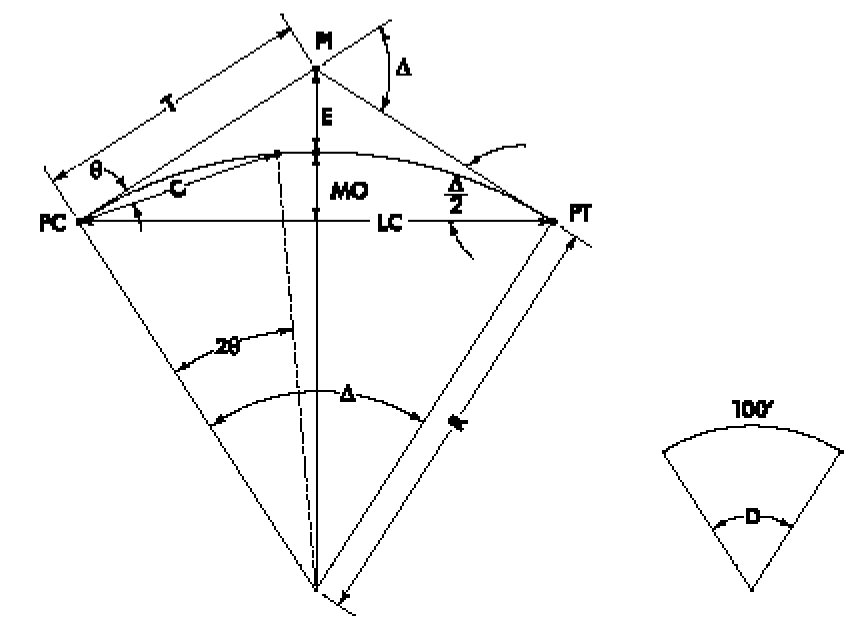
R_{min} = 1,500 feet

CURVE TYPES

1. Simple curves with spirals
2. Broken Back – two curves same direction (avoid)
3. Compound curves: multiple curves connected directly together (use with caution) go from large radii to smaller radii and have R(large) < 1.5 R(small)
4. Reverse curves – two curves, opposite direction (require separation typically for superelevation attainment)

IMPORTANT COMPONENTS OF SIMPLE CIRCULAR CURVE

- PC, PI, PT, E, M, and Δ
- $L = 2(\pi)R(\Delta)/360$
- $T = R \tan(\Delta/2)$



Source: Iowa DOT Design Manual

SIGHT DISTANCE FOR HORIZONTAL CURVES

- Location of object along chord length that blocks line of sight around the curve
- $m = R\left(1 - \cos\left[\frac{28.65\,S}{R}\right]\right)$

Where:

m = line of sight

S = stopping sight distance

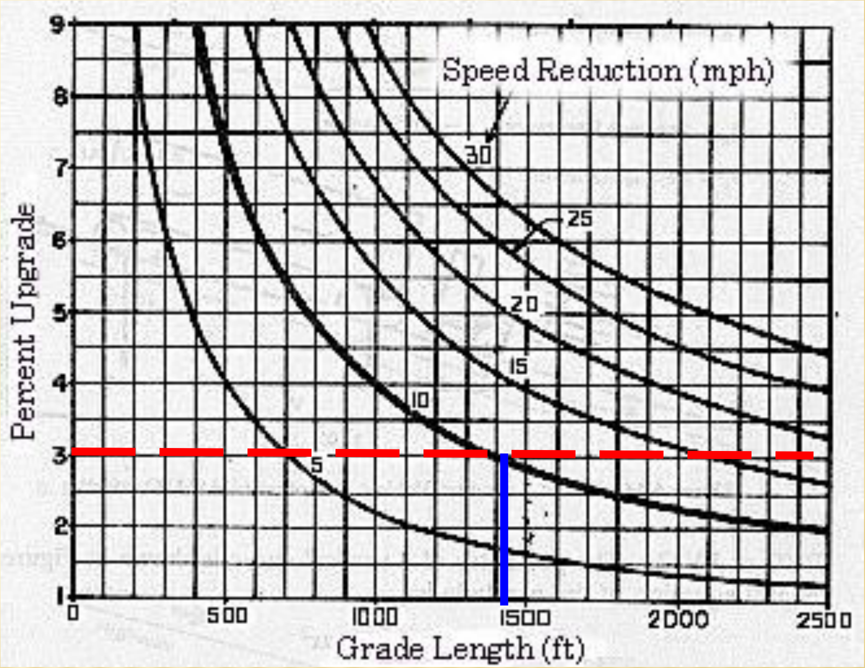
R = radius

Equations

VERTICAL ALIGNMENT

CURVE/GRADE TRADEOFF

- a 3% grade causes a reduction in speed of 10 mph after 1400 feet



VERTICAL ALIGNMENT - GENERAL

1. Parabolic shape
2. VPI, VPC, VPT, +/- grade, L
3. Types of crest and sag curves – see Exhibit 3-73 p. 269

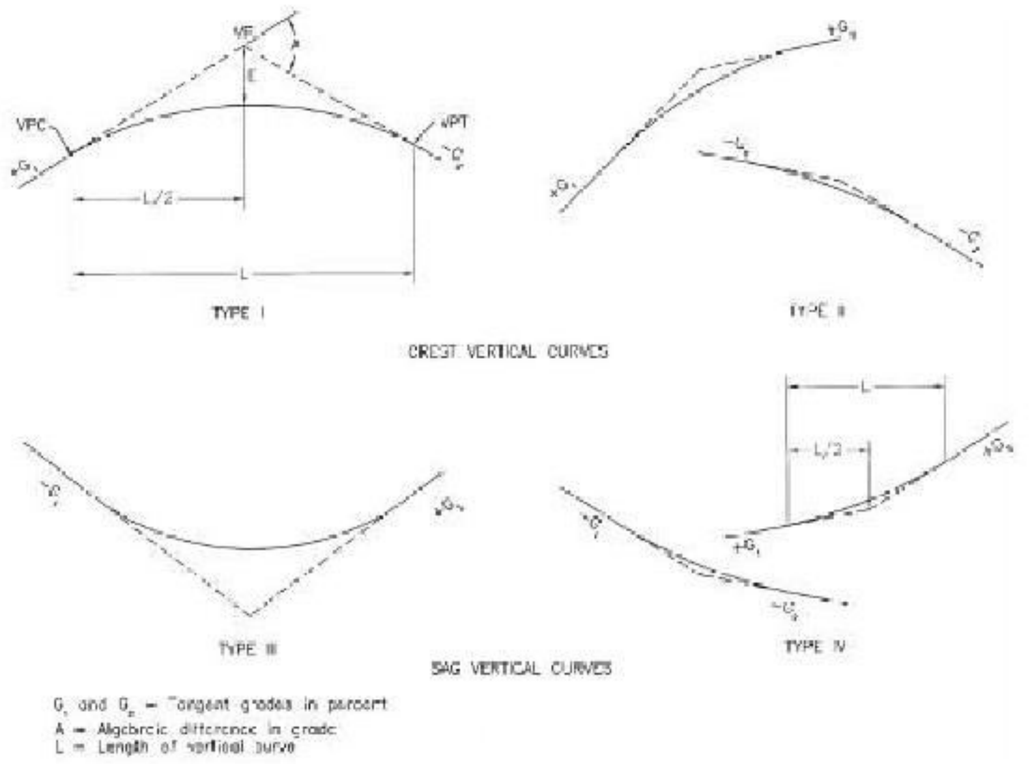


Exhibit 3-73. Types of Vertical Curves

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

VERTICAL ALIGNMENT – GENERAL (CONT.)

4. Crest – stopping, or passing sight distance controls
5. Sag – headlight/SSD distance, comfort, drainage and appearance control
6. Green Book vertical curves defined by K = L/A = length of vertical curve/difference in grades (in percent) = length to change one percent in grade

VERTICAL ALIGNMENT - GENERAL

Parabolic shape as applied to vertical curves

$$y = ax^2 + bx + c$$

Where:

y = roadway elevation at distance x

x = distance from beginnning of vertical curve

a, b = coefficients that define shape

c = elevation of PVC

VERTICAL ALIGNMENT - GENERAL

Parabolic shape as applied to vertical curves

$$a = \frac{G_2 - G_1}{L}$$

$$b = G_1$$

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

VERTICAL CURVE AASHTO CONTROLS (CREST)

1. Based on stopping sight distance
2. Minimum length must provide sight distance S
3. Two situations (Crest, assumes 3.5 and 2.0 ft. heights)

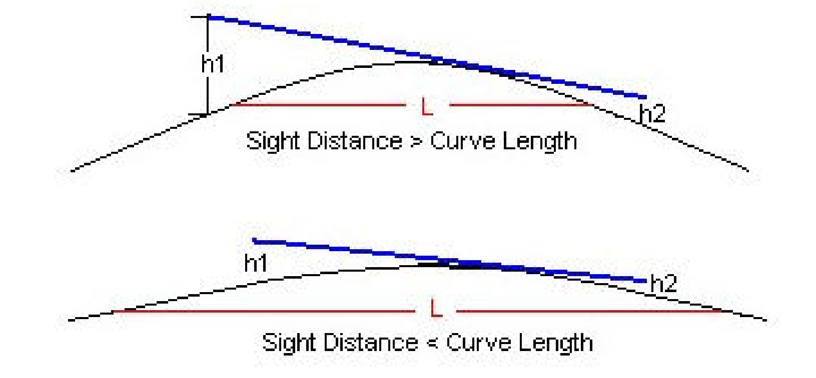


Figure 1.0: Sight Distance Possibilities

Source: Transportation Engineering On-line Lab Manual, http://www.its.uidaho.edu/niatt_labmanual/


Assistant with Target Rod (2ft object height)
Observer with Sighting
Rod (3.5 ft)

VERTICAL CURVE AASHTO CONTROLS (CREST)

US Customary	
When S is less than L, $$L = \frac{AS^2}{2158}$$	(3-45)
When S is greater than L, $$L = 2S - \frac{2158}{A}$$	(3-46)

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

Note: for passing site distance, use 2800 instead of 2158

- Can also use

$$K = L / A$$

Where

K = length of curve per percent algebraic difference in intersecting grade

Charts from Green Book

Metric				US Customary			
Design speed (km/h)	Stopping sight distance (m)	Rate of vertical curvature, K[a]		Design speed (mph)	Stopping sight distance (ft)	Rate of vertical curvature, K[a]	
		Calculated	Design			Calculated	Design
20	20	0.6	1	15	80	3.0	3
30	35	1.9	2	20	115	6.1	7
40	50	3.8	4	25	155	11.1	12
50	65	6.4	7	30	200	18.5	19
60	85	11.0	11	35	250	29.0	29
70	105	16.8	17	40	305	43.1	44
80	130	25.7	26	45	360	60.1	61
90	160	38.9	39	50	425	83.7	84
100	185	52.0	52	55	495	113.5	114
110	220	73.6	74	60	570	150.6	151
120	250	95.0	95	65	645	192.8	193
130	285	123.4	124	70	730	246.9	247
				75	820	311.6	312
				80	910	383.7	384

[a] Rate of vertical curvature, K, is the length of curve per percent algebraic difference in intersecting grades (A). K = L/A

Exhibit 3-76. Design Controls for Stopping Sight Distance and for Crest and Sag Vertical Curves

From Green book

Metric			US Customary		
Design speed (km/h)	Passing sight distance (m)	Rate of vertical curvature, K* design	Design speed (mph)	Passing sight distance (ft)	Rate of vertical curvature, K* design
30	200	46	20	710	180
40	270	84	25	900	289
50	345	138	30	1090	424
60	410	195	35	1280	585
70	485	272	40	1470	772
80	540	338	45	1625	943
90	615	438	50	1835	1203
100	670	520	55	1985	1407
110	730	617	60	2135	1628
120	775	695	65	2285	1865
130	815	769	70	2480	2197
			75	2580	2377
			80	2680	2565

Note: *Rate of vertical curvature, K, is the length of curve per percent algebraic difference in intersecting grades (A). K=L/A

Exhibit 3-77. Design Controls for Crest Vertical Curves Based on Passing Sight Distance

From Green book

VERTICAL CURVE AASHTO CONTROLS (CREST)

Since you do not at first know L, try one of these equations and compare to requirement, or use L = KA (see tables and graphs in Green Book for a given A and design speed)

Note min. L(ft) = 3V(mph) – Why?

SAG VERTICAL CURVES

- Sight distance is governed by nighttime conditions
  - Distance of curve illuminated by headlights need to be considered
- Driver comfort
- Drainage
- General appearance

VERTICAL CURVE AASHTO CONTROLS (SAG)

Headlight Illumination sight distance with S < L

Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

S < L

$$L = \frac{AS^2}{400 + (3.5 * S)}$$

S > L

$$L = 2S - \frac{(400 + 3.5S)}{A}$$

Headlight Illumination sight distance with S > L

VERTICAL CURVE AASHTO CONTROLS (SAG)

- For driver comfort use:

$$L = \frac{AV^2}{46.5}$$

(limits g force to 1 fps/s)

- To consider general appearance use:

$$L = 100\,A$$

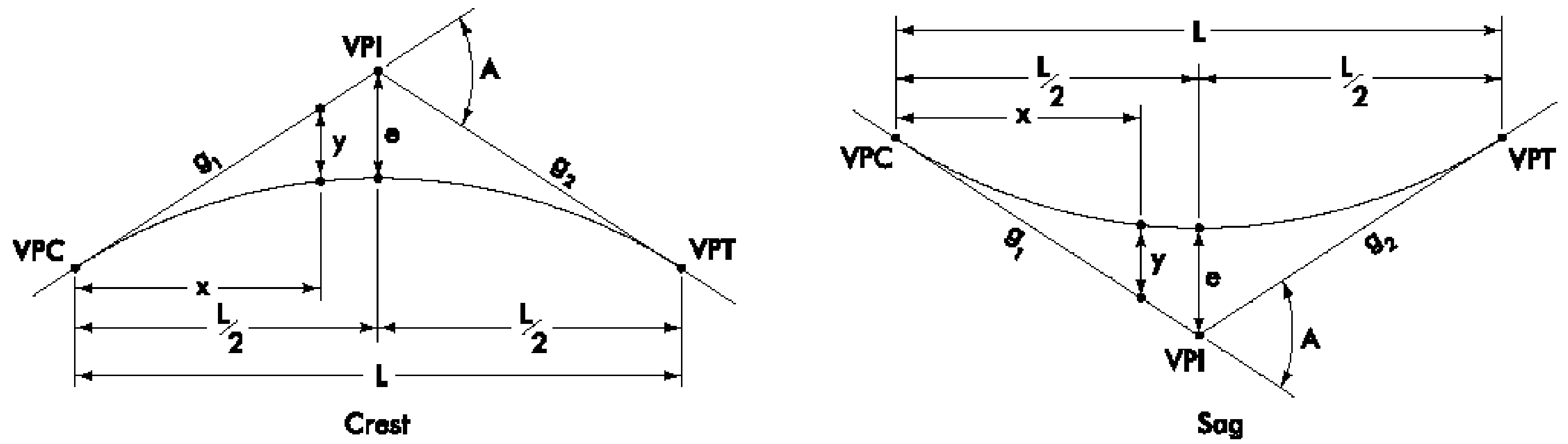
Source: *A Policy on Geometric Design of Highways and Streets* (The Green Book). Washington, DC. American Association of State Highway and Transportation Officials, 2001 4th Ed.

VERTICAL CURVE AASHTO CONTROLS (SAG)

- For curb drainage, want minimum of 0.3 percent grade within 50’ of low point = need K_{max} = 167 (US units)
- For appearance on high-type roads, use minimum design speed of 50 mph (K = 100)
- As in crest, use minimum L = 3V

OTHER IMPORTANT ISSUES:

- Use lighting if need to use shorter L than headlight requirements
- Sight distance at under crossings



A = Algebraic difference in gradients, $g_2 - g_1$.

L = Total length of vertical curve.

K = Rate of vertical curvature.

l_1 = Length of curve 1 (unsymmetrical vertical curve only).

l_2 = Length of curve 2 (unsymmetrical vertical curve only).

VPC = The Vertical Point of Curvature.

VPT = The Vertical Point of Tangency.

VPI = The Vertical Point of Intersection.

x = Horizontal distance to any point on the curve from the VPC.

x_t = Turning point, which is the minimum or maximum point of the curve.

e = Middle ordinate, which is the vertical distance from the VPI to the arc.

y = Vertical distance at any point on the curve to the tangent grade.

r = Rate of change of grade.

E_{VPC} = Elevation of VPC.

E_{VPT} = Elevation of VPT.

E_x = Elevation of a point on the curve at a distance x from the VPC.

E_t = Elevation of the turning point.

Source: Iowa DOT Design Manual

Formulas

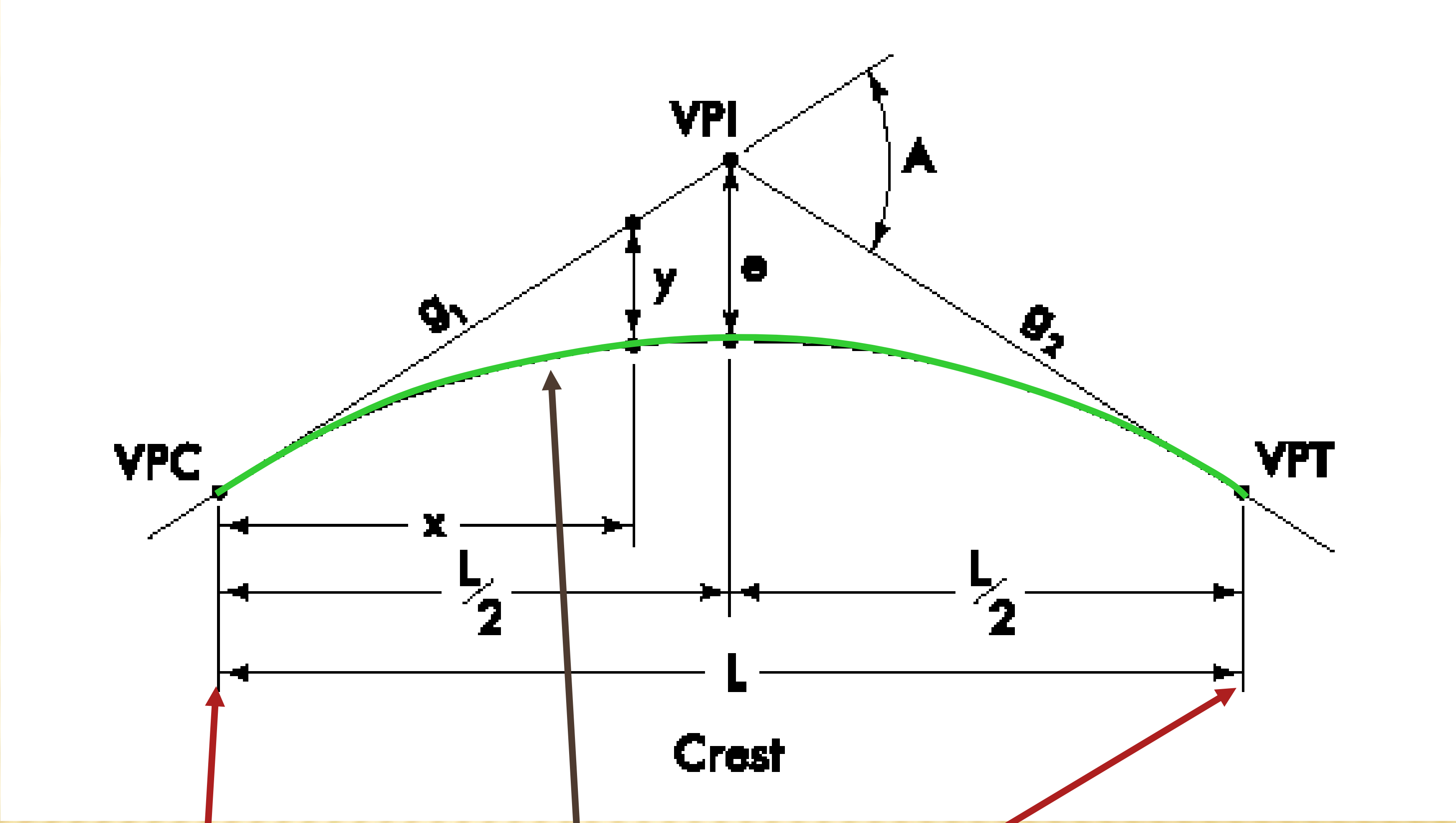
Symmetrical Vertical Curves

$A = g_2 - g_1$	g_1 and g_2 are in percent
$K = \frac{L}{A}$	L is given in feet and g_1 and g_2 are in percent
$r = \frac{A}{100L}$	L is given in feet and g_1 and g_2 are in percent
$e = \frac{AL}{800}$	L is given in feet
$y = \frac{4ex^2}{L^2} = \frac{1}{2}rx^2 = \frac{Ax^2}{200L}$	measured from the tangent that passes through VPC and VPI: L and x are given in feet
$E_x = E_{VPC} + g_1 x + \frac{1}{2}rx^2$	L and x are given in feet: convert g_1 to a decimal
$x_t = -\frac{g_1}{r}$	x_t is in feet: convert g_1 to a decimal
$E_t = E_{VPC} - \frac{g_1^2}{2r}$	convert g_1 to a decimal

Plan Curve Data

The following Plan Curve Data shall be provided on the plan sheets for each vertical curve: K, elevation and station of PI, and length of curve.

Source: Iowa DOT Design Manual



Note: L is measured from here to here

Not here

Source: Iowa DOT Design Manual

GENERAL CONTROLS FOR VERTICAL ALIGNMENT

- A smooth grade-line with gradual changes.
- “roller=coaster” or “hidden-dip” type of profile should be avoided.
- A “broken-back” grade-line (two vertical curves in the same direction separated by a short section of tangent grade) generally should be avoided.
- Where at-grade intersections occur on roadway sections with moderate to steep grade, it is desirable to reduce the grade through the intersection.
- Sag vertical curves should be avoided in cuts unless adequate drainage can be provided.

COMBINATIONS OF HORIZONTAL AND VERTICAL ALIGNMENT

General Design Controls:

- Curvature and grades should be in proper balance. Tangent alignment or flat curvature or long grades and excessive curvature with flat grades. A logical design is between those two.
- Vertical curvature superimposed on horizontal curvature, or vice versa, generally results in amore pleasing facility.
- Sharp horizontal curvature should not be introduced at or near the top of a crest vertical curve, this condition is undesirable because the driver may not perceive the horizontal change in alignment. Suitable designs can also be developed by using design values will above the appropriate minimum values for the design speed.
- Sharp horizontal curvature should not be introduced near the bottom of a steep grade approaching or near the low point of sag vertical curve. Because the view of the road ahead is foreshortened..

COMBINATIONS OF HORIZONTAL AND VERTICAL ALIGNMENT

- On two-lane roads and streets. It is appropriate to work toward long tangent sections to assure sufficient passing sight distance in design.
- Both horizontal curvature and profile should be made as flat as practical at intersections where sight distance along both roads or streets is important .
- On divided highways and streets, variation on width of median and the use of independent profiles and horizontal alignments for the separate one-way roadways are some times desirable.
- In residential areas, the alignment should be designed to minimize nuisance to the neighborhood, a depressed facility makes a highway less visible . Minor horizontal adjustments increase the buffer zone .
- The alignment should be designed to enhance attractive scenic views of the natural and manmade environment, such as rivers, rock formations