11.3 SUPERELEVATION DEVELOPMENT

The *SCDOT Standard Drawings* includes a graphical presentation of typical Department practices for superelevation development (e.g., point of revolution, distribution of superelevation between tangent and curve). Section 11.3 provides an elaboration on Department superelevation practices.

11.3.1 <u>Superelevation Rates</u>

11.3.1.1 Maximum Superelevation Rate

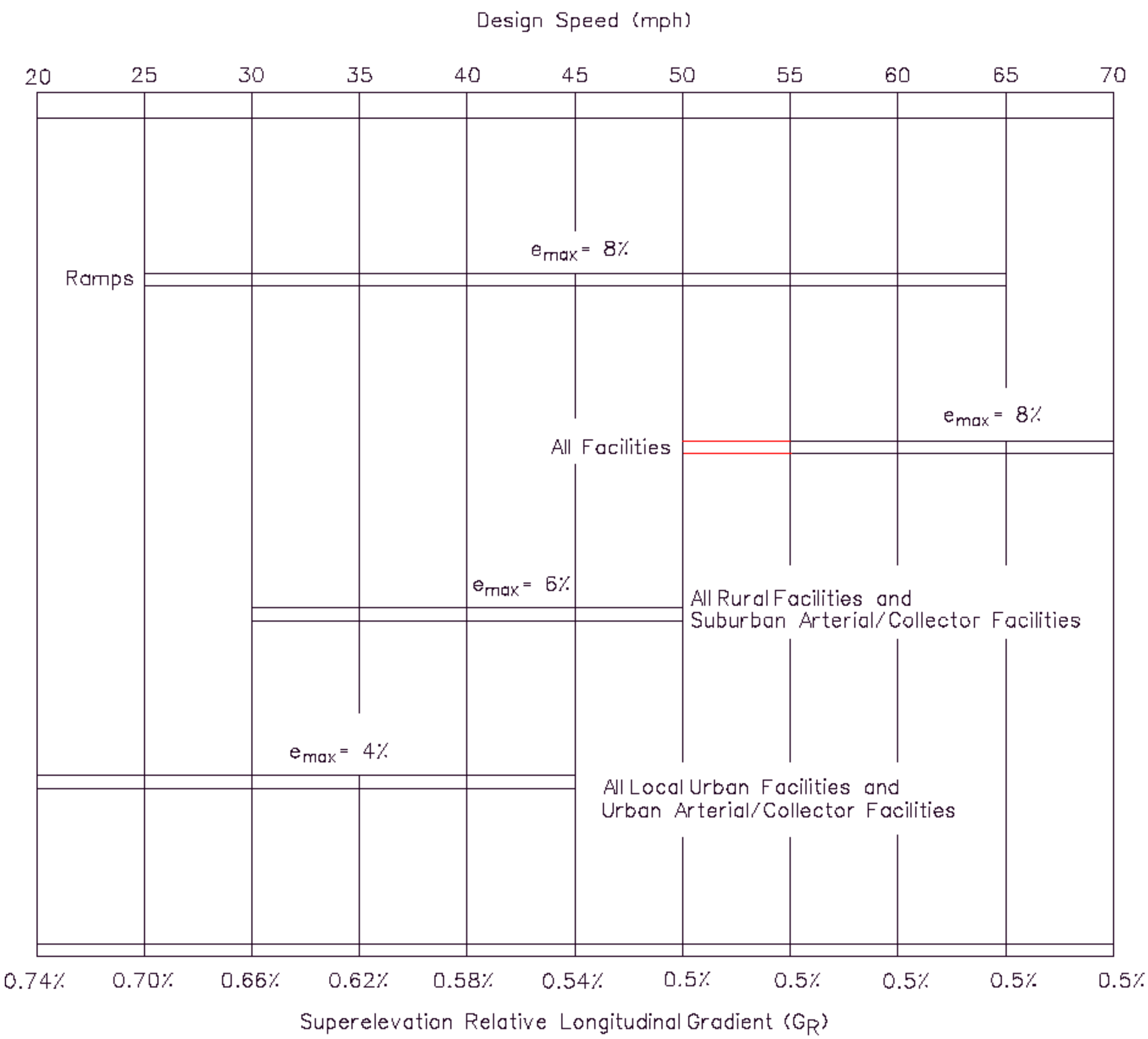
As discussed in Section 11.2, the selection of a maximum rate of superelevation (e_{max}) depends upon several factors. These include design speed, urban/rural location, type of existing or expected roadside development, type of traffic operations expected and prevalent climatic conditions within South Carolina. For new construction/reconstruction projects, Figure 11.3A summarizes the Department's selection of e_{max}.

11.3.1.2 Superelevation Tables

Based on the selection of e_{max}, Figures 11.3B, 11.3C and 11.3D allow the designer to select the appropriate superelevation rate (e) for any combination of curve radius (R) and design speed (V). Note that the superelevation rates in the tables are expressed as percents.

11.3.1.3 Minimum Radii Without Superelevation

A horizontal curve with a sufficiently large radius does not require superelevation, and the normal crown section (NC) used on tangent can be maintained throughout the curve. On sharper curves for the same design speed, a point is reached where a superelevation rate of 2.08 percent (the normal cross slope) across the total traveled way width is appropriate. This is considered remove adverse crown (RC). For sharper radii, superelevation rates steeper than 2.08 percent are necessary. Figure 11.3E provides the thresholds or radii ranges for a normal crown (NC) section and remove adverse crown (RC) section at various design speeds.



APPLICATION OF e_{max} AND RELATIVE LONGITUDINAL GRADIENTS

Figure 11.3A

Range of Design Speeds for All Facilities changed to 50mph - Revised: 10-2004

12.5 VERTICAL CURVES

12.5.1 Crest Vertical Curves

12.5.1.1 Equations

Crest vertical curves are in the shape of a parabola. The basic equations for determining the minimum length of a crest vertical curve are:

$$L = \frac{AS^2}{200\left(\sqrt{h_1} + \sqrt{h_2}\right)^2} \quad \text{(Equation 12.5.1)}$$

$$K = \frac{S^2}{200\left(\sqrt{h_1} + \sqrt{h_2}\right)^2} \quad \text{(Equation 12.5.2)}$$

$$L = KA \quad \text{(Equation 12.5.3)}$$

where:

- L = length of vertical curve, feet
- A = absolute value of the algebraic difference between the two tangent grades, percent
- S = sight distance, feet
- h_1 = height of eye above road surface, feet
- h_2 = height of object above road surface, feet
- K = horizontal distance needed to produce a 1 percent change in gradient

The length of a crest vertical curve will depend upon "A" for the specific curve and upon the selected sight distance, height of eye and height of object. Equation 12.5.1 and the resultant values of K are predicated on the sight distance being less than the length of vertical curve. However, these values can also be used, without significant error, where the sight distance is greater than the length of vertical curve. The following Sections discuss the selection of K-values. For design purposes, round the calculated length up to the next highest 50-foot increment.

12.5.1.2 Stopping Sight Distance

The principal control in the design of crest vertical curves is to insure that minimum stopping sight distance (SSD) is available throughout the vertical curve. The following discusses the application of K-values for various operational conditions:

1. Passenger Cars (Level Grade). Figure 12.5A presents K-values for passenger cars on a level grade. Level conditions are assumed where the grade on the far side of the vertical curve is less than 3 percent. The minimum values are calculated by assuming h_1 = 3.5 feet, h_2 = 2 feet and S = SSD in the basic equation for crest vertical curves (Equation 12.5.1).

2. Passenger Cars (Grade Adjusted). For grades on the crest vertical curve that are 3 percent or greater, it is desirable to design the length of curve using K-values that have been adjusted for the grade. No adjustment is necessary for grades less than 3 percent. Use Equation 12.5.1 and the grade adjusted SSD's from Figure 10.1C to determine the length of vertical curve. Note that the grade-adjusted K-values do not require a design exception when not met. The level K-values in Figure 12.5A apply when determining whether or not a design exception for stopping sight distance will be required.

3. Minimum Length. The minimum length of a crest vertical curve in feet should be 3V, where V is the design speed in miles per hour.

4. Minimum Values. Designs should be made to values as high as are commensurate with conditions. Minimum values should be used only where the use of higher value will result in unacceptable social, economic or environmental consequences. Provide higher K-values for the following highways:

   - Interstate and freeways, other than within complex interchange areas;
   - principal arterial highways (urban and rural);
   - minor arterial highways (rural); and
   - 3R projects on all of the above facilities.

12.5.1.3 Passing Sight Distance

At some locations, it is desirable to provide passing sight distance in the design of crest vertical curves. Section 10.2 discusses the application and design values for passing sight distance on two-lane, two-way highways. Passing sight distance values are used as the "S" value in the basic equation for crest vertical curves (Equation 12.5.1). In addition, the following will apply:

1. Height of Eye (h_1). For passenger cars, h_1 = 3.5 feet.

2. Height of Object (h_2). Passing sight distance is predicated upon the passing driver being able to see a sufficient portion of the top of the oncoming car. Therefore, h_2 = 3.5 feet.

3. K-Values. Figure 12.5B presents the K-values for passenger cars using the passing sight distances presented in Figure 10.2B.

In Bullet 2, Figure 10.1B changed to Figure 10.1C – Revised: 10-2004

12.5.1.4 Drainage

Proper drainage must be considered in the design of crest vertical curves. Typically, drainage problems will not be experienced if the vertical curvature is sharp enough so that a minimum longitudinal gradient of at least 0.3 percent is reached at a point about 50 feet from either side of the apex. To insure that this objective is achieved, determine the length of the crest vertical curve assuming a K-value of 167 or less. Where the maximum drainage K-value is exceeded, carefully evaluate the drainage design near the apex. With the use of proper cross slopes, drainage generally should not be a problem on crest vertical curves.

12.5.2 <u>Sag Vertical Curves</u>

12.5.2.1 Equations

Sag vertical curves are in the shape of a parabola. Typically, they are designed to allow the vehicular headlights to illuminate the roadway surface (i.e., the height of object = 0.0 feet for a given distance "S." The light beam from the headlights is assumed to have a 1° upward divergence from the longitudinal axis of the vehicle. These assumptions yield the following basic equations for determining the minimum length of sag vertical curves:

$$L = \frac{AS^2}{200[h_3 + S(\tan 1^\circ)]} = \frac{AS^2}{200h_3 + 3.5S} \quad \text{(Equation 12.5.4)}$$

$$K = \frac{S^2}{200h_3 + 3.5S} \quad \text{(Equation 12.5.5)}$$

$$L = KA \quad \text{(Equation 12.5.6)}$$

where:

- L = length of vertical curve, feet
- A = absolute value of the algebraic difference between the two tangent grades, percent
- S = sight distance, feet
- h_3 = height of headlights above pavement surface, feet
- K = horizontal distance needed to produce a 1 percent change in gradient

The length of a sag vertical curve will depend upon "A" for the specific curve and upon the selected sight distance and headlight height. Equation 12.5.4 and the resultant values of K are predicated on the sight distance being less than the length of vertical curve. However, these values can also be used, without significant error, where the sight distance is greater than the length of vertical curve. The following Sections discuss the selection of K-values.

12.5.2.2 Stopping Sight Distance

The principal control in the design of sag vertical curves is to insure minimum stopping sight distance (SSD) is available for headlight illumination throughout the sag vertical curve. The following discusses the application of K-values for various operational conditions:

1. Passenger Cars (Level Grade). Figure 12.5C presents K-values for passenger cars. These are calculated by assuming h_3 = 2 feet and S = SSD in the basic equation for sag vertical curves (Equation 12.5.4). The minimum values represent the lowest acceptable sight distance on a facility. Use longer than the minimum lengths of curves to provide a more aesthetically pleasing design.

2. Passenger Cars (Grade Adjusted). For sag vertical curves, consider grade adjustments where the sag curve is between grades that are 3 percent or greater. No adjustment is necessary for grades less than 3 percent. Use Equation 12.5.4 and the grade adjusted SSD from Figure 10.1C to determine the length of vertical curve. Note that the grade adjusted K-values require a design exception when not met. The level K-values in Figure 12.5C apply when determining whether a design exception for stopping sight distance will be required.

3. Minimum Length. The minimum length of a crest vertical curve in feet should be 3V, where V is the design speed in miles per hour.

13.5 BRIDGE AND UNDERPASS CROSS SECTIONS

The roadway cross section should be carried over and under bridges, which often requires special considerations because of the confining nature of bridges and their high unit costs.

13.5.1 Bridges

13.5.1.1 Bridge Roadway Widths

In general, bridge widths should match the approach roadway widths (traveled way plus shoulders). Figure 13.5A provides guidelines for bridge widths. However, in determining the width for major water crossings, consider the cost of the structure, traffic volume and potential for future width requirements.

13.5.1.2 Vertical Clearance

Vertical clearances should be established above all sections of pavement including the shoulder. Section 12.6 and the design criteria tables in Chapters 19 through 22 provide the minimum vertical clearances for new construction and reconstruction projects.

13.5.1.3 Highway Grade Separations

Horizontal clearances for highway grade separation structures, where guardrail or barrier protection is not provided, should conform to the requirements in Figure 13.5B; however, they may be reduced where protection is provided. These are minimum requirements and should be increased as required.

13.5.1.4 Highway Overpassing Railroad

The horizontal clearance, measured from the centerline of the track to the face of the adjacent bridge substructure, should be a minimum of 25 feet. The horizontal clearance from the centerline of track to the face of the embankment fill slope, measured to the elevation to the highest rail, should be 20 feet. This 20-foot clearance may be increased at individual structure locations, as required, to provide adequate drainage or to allow adequate room to accommodate other special situations (e.g., future tracks).

When an existing overpass over a railroad is to be widened or rehabilitated, the existing horizontal clearances should be maintained, if less than 25 feet.

Approach Roadway	Conditions	Bridge Width (Gutter to Gutter)
Urban Streets (Curb and Gutter)	With or without concrete sidewalk.	Provide a sidewalk on bridge matching roadway gutter hinge points with bridge gutter hinge points.
Freeways and Arterials	12-foot shoulder (10 foot paved + 2 foot unpaved).	Use 12-foot shoulder hinge point for bridge gutter line.
	10-foot shoulder (paved and unpaved).	Use 10-foot shoulder hinge point for bridge gutter line.
	10-foot shoulder (6 foot paved + 4 foot unpaved).	Use 10-foot shoulder hinge point for bridge gutter line on inside of divided highways.
	10-foot shoulder (4 foot paved + 6 foot unpaved).	
Rural Collectors and Local Roads	6- to 8- foot shoulders (2 foot paved + 4 to 6 foot unpaved) with paved roadway.	Use shoulder hinge point for bridge gutter line. Bridge width is equal to width of roadway section (outside shoulder to outside shoulder).
Ramps	In direction of traffic (left) 10-foot shoulder (4 foot paved + 6 foot unpaved).	Use 10-foot shoulder line for bridge gutter line.
	In direction of traffic (right) 10-foot shoulder (6 foot paved + 4 foot unpaved).	Use 10-foot shoulder hinge point for bridge gutter line.

GUIDELINES FOR BRIDGE ROADWAY WIDTHS

Figure 13.5A

Highway Below Structure	Horizontal Clearance to Overpassing Structure*
Design Speed $\leq$ 40 mph	10 feet from edge of traveled way
Design Speed = 45 to 50 mph	20 feet from edge of traveled way
Design Speed $\geq$ 55 mph	30 feet from edge of traveled way

* or as determined by clear zone requirements, if greater.

HORIZONTAL CLEARANCES

Figure 13.5B

Bridge Width for Freeways – Revised: 10-2004

14.3.2.5 Alignment (Horizontal Curve Adjustment)

The clear zone values in Figure 14.3A assume a tangent alignment. Horizontal curves may increase the angle of departure from the roadway and thus increase the distance the vehicle will need to recover. Desirably and if practical, the designer should adjust the tangent values to provide wider clear zones on the outside of horizontal curves. Figure 14.3C provides recommended adjustments for clear zones on horizontal curves. Where adjustments are determined to be cost effective, Figure 14.3D illustrates the application of the clear zone adjustment on a curve.

* * * * * * * * * *

Example 14.3(1)

Given: Design Speed = 55 miles per hour
Design ADT = 3000
Horizontal curve with a radius of 2000 feet
Flat side slope

Problem: Find the clear zone adjusted for the horizontal curve.

Solution: From Figure 14.3A, the minimum clear zone on the tangent (CZ_t) = 20 feet.

From Figure 14.3C, the curve correction factor (K_{cz}) = 1.2
The clear zone for the curve (CZ_c) = (20)(1.2) = 24 feet

The transition length (equal to the runout length (L_R)) from Figure 14.6D = 345 feet. See Figure 14.3D for application.

* * * * * * * * * *

14.3.2.6 Facilities with Curbs

Because substantial development typically occurs in areas with curbs, it is often impractical to remove or shield all obstacles within the clear zone. Because curbs do not have a significant redirectional capability, obstructions behind a curb should be located at or beyond the minimum clear zone distances shown in Figure 14.3A. In many instances, it will not be feasible to obtain the recommended clear zone distances on existing facilities. On new construction where minimum recommended clear zones cannot be provided, fixed objects should be located as far from traffic as practical on a project-by-project basis, desirably 5.5 feet, but in no case closer than 1.5 feet from the face of the curb.

In above paragraph, objectives corrected to objects – Revised: 10-2004

Radius (ft)	Design Speed (mph)						
	≤40	45	50	55	60	65	70
2860	1.1	1.1	1.1	1.2	1.2	1.2	1.3
2290	1.1	1.1	1.2	1.2	1.2	1.3	1.3
1910	1.1	1.2	1.2	1.2	1.3	1.3	1.4
1640	1.1	1.2	1.2	1.3	1.3	1.4	1.5
1430	1.2	1.2	1.3	1.3	1.4	1.4	
1270	1.2	1.2	1.3	1.3	1.4	1.5	
1150	1.2	1.2	1.3	1.4	1.5		
950	1.2	1.3	1.4	1.5	1.5		
820	1.3	1.3	1.4	1.5			
720	1.3	1.4	1.5				
640	1.3	1.4	1.5				
570	1.4	1.5					
380	1.5						

Notes:

1. *Adjustments apply to the <u>outside</u> of a horizontal curve only.*

2. *No adjustments are warranted for curve radii greater than 2860 feet.*

3. *The applicable clear zone distance on a horizontal curve is calculated by:*

   $CZ_c = (K_{cz})(CZ_t)$

   where: CZ_c = *clear zone on a curve, feet*
   K_{cz} = *curve adjustment factor*
   CZ_t = *clear zone on a tangent section from Figure 14.3A, feet*

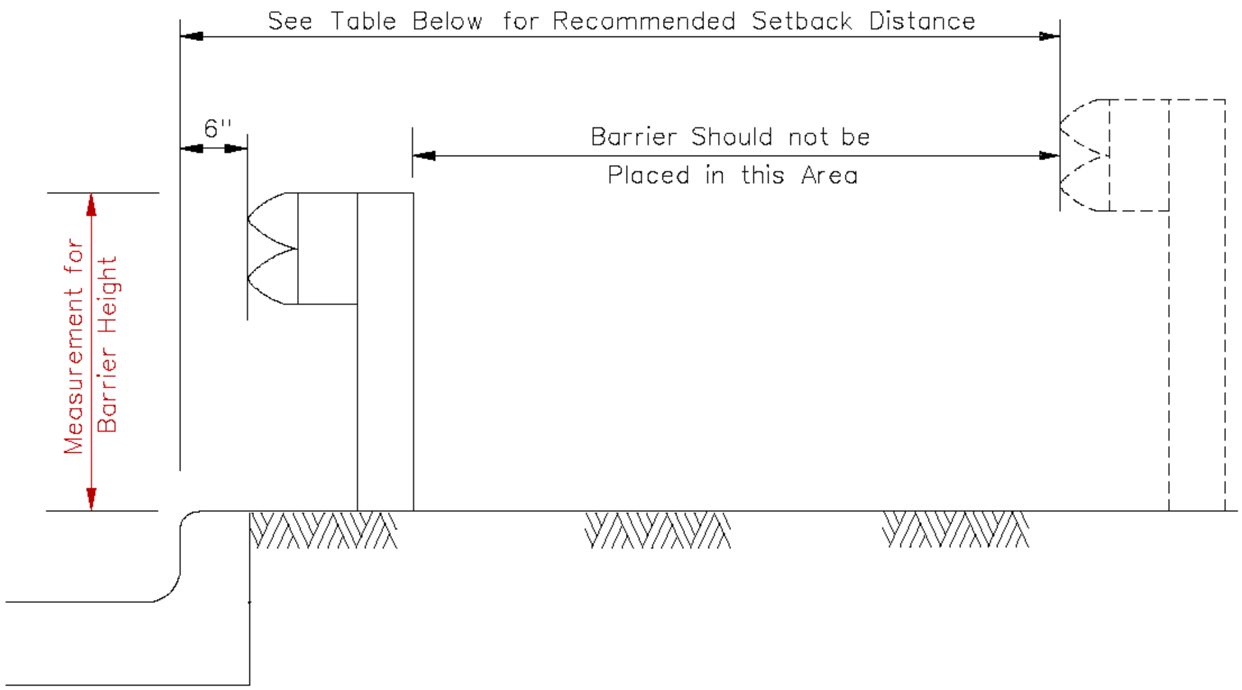
   Round calculated CZ_c up to the next highest 1-foot increment.

4. *For curve radii intermediate in the figure, use a straight-line interpolation.*

5. *See Figure 14.3D for the application of CZ_c to the roadside around a curve.*

CLEAR ZONE ADJUSTMENT FACTORS FOR HORIZONTAL CURVES (K_{CZ})

Figure 14.3C



Design Speed (mph)	Curb-to-Barrier Distance* (ft)	
	Vertical	Sloping
V ≤ 30	0.5	0.5
30 < V ≤ 45	5.6	8.0
V > 45	18.2	16.3

**Values in table represent distance beyond which it is acceptable to place a barrier.*

Notes:

1. *The curb-to-barrier distances in the table are based on information presented in the AASHTO 1977* Guide for Selecting, Locating, and Designing Traffic Barriers, *Appendix F, pp. 284 – 287. Specifically, the criteria for the vertical curb are based on the Type A Curb. For the 30 < V ≤ 45 mile-per-hour range, the 5-foot distance assumes an encroachment speed of 40 miles per hour and a 10-degree impact angle. For the V > 45 mile-per-hour range, the 18-foot distance assumes 60 miles per hour and 25 degrees.*

   The criteria for the sloping curb are based on the Type E Curb. For the 30 < V ≤ 45 mile-per-hour range, the 8-foot distance assumes an encroachment speed of 45 miles per hour and a 12.5 degree impact angle. For the V > 45 mile-per-hour range, the 16-foot distance assumes 60 miles per hour and 20 degrees.

2. *Barrier should be placed 6 inches behind curb; rail stiffening should be considered. See Section 14.6.3.*

PLACEMENT OF BARRIER RELATIVE TO CURBS

Figure 14.6K

Curb to Barrier Distances – Revised: 10-2003

Dimension moved to top of curb – Revised: 10-2004

14.6.4 Placement on Slopes

Slopes in front of a barrier should be 10H:1V or flatter. This also applies to the areas in front of the flared section of guardrail and to the area approaching the terminal ends.

14.6.5 Barrier Flare

Using a flared barrier in advance of a roadside hazard may be advantageous. A barrier may be flared to:

- locate the barrier terminal farther from the traveled way,
- minimize a driver's reaction to an obstacle near the roadway by gradually introducing a parallel barrier installation,
- transition a roadside barrier closer to the roadway because of an obstacle, or
- to reduce the total length of barrier need.

Also consider the following:

1. Flared guardrail results in increased impact angles with the potential for greater severity of impact.
2. Flared guardrail increases the likelihood that the vehicle will be redirected into the opposing lane of traffic or across the roadway.
3. The grading required to provide 10H:1V or flatter slopes in front of the flared section of guardrail may interfere with roadside drainage and/or may require additional right of way.

Figure 14.6L presents suggested flare rates for roadside barriers which are intended to balance the advantages and disadvantages of flares.

14.6.6 Terminal Treatments

Barrier terminal sections present a potential roadside hazard for run-off-the-road vehicles; however, they are also critical to the proper structural performance of the barrier system. Therefore, the designer must carefully consider the selection and placement of the terminal end.

GEOMETRIC REQUIREMENTS										
RAMP DESIGN SPEED (mph)		65	60	55	50	45	40	35	30	25
STOPPING SIGHT DISTANCE (ft)		645	570	495	425	360	305	250	200	155
HORIZONTAL ALIGNMENT										
Minimum Radius (ft)	e_{max} = 8%	1485	1205	965	760	600	465	350	250	170
Minimum Length of Arc (ft)		See Figure 16.5G								
VERTICAL ALIGNMENT										
Maximum Grades		3%-5%	3%-5%	3%-5%	3%-5%	3%-5%	4%-6%	4%-6%	5%-7%	5%-7%
Crest Vertical Curves (K-values)*		193	151	114	84	61	44	29	19	12
Sag Vertical Curves (K-values)*		157	136	115	96	79	64	49	37	26

**K-values are based on stopping sight distance on level grades.*

ALIGNMENT CRITERIA FOR INTERCHANGE RAMPS

Figure 16.5C

16.5.4 Cross Section Elements

Figure 16.5D presents the typical cross sections for tangent and loop ramps. The following also applies to the ramp cross section:

1. Width. The total paved ramp width will be the sum of the ramp traveled way, the left shoulder and the right shoulder. For most ramps, the typical ramp traveled way is 16 feet. For locations with significant numbers of trucks and tight radii, consider widening the ramp shoulders. If the facility has unpaved shoulders, review the ramp shoulder criteria from the AASHTO *A Policy on Geometric Design of Highways and Streets* to determine the applicable ramp width. Assume the Case II and "C" design traffic conditions.

   The typical right-paved shoulder is 6 feet, and the typical left-paved shoulder is 4 feet in the direction of travel. The left shoulder-traveled way-right shoulder arrangement is illustrated in the ramp cross sections in Figure 16.5D. For multilane directional ramps, the cross sectional width is the same as the mainline design (e.g., 24-foot traveled way width plus shoulders); see Chapter 19.

2. Cross Slope. For tangent sections, the ramp traveled way is sloped unidirectionally at 2.08 percent towards the right shoulder. Shoulder cross slopes on tangent are typically 4.17 percent. The left shoulder is typically sloped away from the traveled way.

3. Curbs. Curbs should not be used on ramps with a design speed greater than or equal to 45 miles per hour. If curb and gutter is required for drainage, use sloping curb and place it on the outside edge of the full-width paved shoulders. See Sections 13.2.6 and 21.2.9 for information on the use of curbs.

4. Bridges and Underpasses. Carry the full width of the ramp (shoulders and travel lanes), across the bridge. See Chapters 13 and 19 when determining the clear ramp width for an underpass.

5. Side Slopes/Ditches. For the ramp proper, side slopes and ditches should meet the same criteria as for the highway mainline. Chapters 13 and 19 provide the applicable design information for side slopes and ditches.

6. Roadside Safety. Measure the clear zone from the edge of the traveled way on both sides of the ramp using the criteria in Section 14.3. Barrier warrants, selection and layout will be based on the criteria in Chapter 14.

7. Right of Way. The right of way adjacent to the ramp is fully access controlled and the right of way is typically fenced. See Chapter 30.

In Bullet 4, sentence corrected – Revised: 10-2004

GEOMETRIC DESIGN CRITERIA FOR FREEWAYS
(New Construction/Reconstruction)

Footnotes to Figure 19.3A

(1) Design Speed. In mountainous terrain, a minimum design speed of 55 miles per hour may be considered.

(2) Shoulder Width (Right). Where the directional distribution of trucks exceeds 250 DDHV, consider providing a 12-foot paved shoulder.

(3) Shoulder Width (Left). Where there are three or more lanes in one direction, provide a 10-foot left paved shoulder. If the directional distribution of trucks exceeds 250 DDHV, consider providing a 12-foot paved left shoulder.

(4) Travel Lane Cross Slope. On a six-lane highway crowned at the center line with CMB, use 2.08 percent for first two travel lanes adjacent to inside shoulder, use 2.78 percent for third lane breaking away from outside edge of second travel lane. See Figure 19.2B.

(5) Auxiliary Lane Cross Slope. For auxiliary lanes adjacent to two travel lanes sloped in the same direction, use a cross slope of 2.78 percent.

(6) Depressed Median Widths. In urban areas, existing 36-foot medians may be allowed to remain in place.

(7) Flush Median Widths (CMB). In urban areas, existing 12-foot to 14-foot medians may be allowed to remain-in-place. Where adding travel lanes to an existing median less than 48 feet, the left-shoulder may be less than 10 feet.

(8) Side Slopes (Cut Section). Cut rock slope may vary based on a detailed geotechnical investigation.

(9) Clear Zone. The clear zone will vary according to design speed, traffic volumes, side slopes and horizontal curvature.

(10) New and Reconstructed Bridge Widths. Clear roadway bridge widths are measured from face to face of parapets or rails. Bridge widths are normally defined as the sum of the approach traveled way width plus total shoulder width right and left.

(11) Existing Bridge Widths to Remain in Place. Clear roadway bridge widths are measured from face to face of parapets or rails. Bridge widths are normally defined as the sum of the approach traveled way width plus total shoulder width right and left.

(12) Vertical Clearance (Freeway Under).

a. The clearance must be available over the traveled way, shoulders, and any anticipated future widening.
b. Table value includes allowance for future overlays.

Bullets 3, 10, 11, and 12a – Revised: 10-2004

Design Element		Manual Section	Design Speed				
			75 mph	70 mph	65 mph	60 mph	55 mph
* Stopping Sight Distance **(1)**		10.1	820′	730′	645′	570′	495′
* Minimum Radii (e_{max} = 8%)		11.2.3	2215′	1820′	1485′	1205′	965′
* Superelevation Rates		11.3	8%	8%	8%	8%	8%
* Horizontal Sight Distance		11.4	38′	36′	35′	34′	32′
* Vertical Curvature **(2)** (Minimum K-values)	Crest	12.5	312	247	193	151	114
	Sag		206	181	157	137	115
* Maximum Grade **(3)**	Level	12.3.1	3%	3%	3%	3%	4%
	Rolling		4%	4%	4%	4%	5%
	Mountainous		N/A	5%	5%	6%	6%
Minimum Grade **(4)**		12.3.2	Desirable: 0.5% Minimum: 0.0%				

* Controlling design criteria (see Section 9.2).

(1) Stopping Sight Distance. Table values are for passenger cars on level grade.

(2) Vertical Curvature. The K-values are based on stopping sight distances. See Section 19.2.4.

(3) Maximum Grade.

a. Rural. With wide medians where two roadways are on independent alignments, downgrades may be 1 percent steeper.
b. Urban. Grades 1 percent steeper may be used for restricted conditions.

(4) Minimum Grade. Check flow lines of the outside ditches to insure adequate drainage.

ALIGNMENT CRITERIA FOR FREEWAYS
(New Construction/Reconstruction)

Figure 19.3B

GEOMETRIC DESIGN CRITERIA FOR RURAL TWO-LANE PRINCIPAL ARTERIALS
(New Construction/Reconstruction)

Footnotes for Figure 20.1D

(1) Travel Lane Width. On reconstructed arterials, an existing 22-foot traveled way may be retained based on an engineering study.

(2) Shoulder (Total Width). Where guardrail is required, increase the shoulder width an additional 3.5 feet.

(3) Shoulder Cross Slopes. For paved shoulders greater than 2 feet, the shoulder cross slope should be 4.17 percent

(4) Clear Zone. The clear zone will vary according to design speed, traffic volumes, side slopes and horizontal curvature.

(5) New and Reconstructed Bridges (Clear Roadway Width). Clear roadway bridge widths are measured from face to face of parapets or rails. Bridge widths are normally defined as the sum of the approach traveled way width plus total shoulder width right and left.

(6) Existing Bridges to Remain in Place. HS-20 capacity structure may be retained if it is not deficient.

(7) Vertical Clearance (Arterial Under).

a. The clearance must be available over the traveled way, shoulders and any anticipated future widening.
b. Table value includes allowance for future overlays.

Bullets 5 and 7a – Revised: 10-2004

Design Element				Manual Section	Design Criteria		
Design Controls	Design Forecast Year			9.6.2	20 Years		
	Design Year Traffic (ADT)			9.6.3	**0 to 400**	**400 to 2000**	**Over 2000**
	*Design Speed (maximum)	Level		9.5.2	60 mph		
		Rolling			50 mph		
		Mountainous			40 mph		
	Access Control			9.8	Controlled by Regulation		
	Level of Service			9.6.4	C		
Cross Section Elements	*Travel Lane Width			13.2.3	11′ **(1a)**	11′	12′ **(1b)**
	*Shoulder Width **(2a)**			13.2.4	6′ **(2b)**	6′ **(2b)**	8′
	Auxiliary Lanes	Lane Width		13.2.5	11′	11′	12′
		Shoulder Width			6′	6′	8′
	Cross Slope	*Travel Lane		13.2.3.3	2.08%		
		Auxiliary Lane		13.2.5	2.08%		
		*Shoulder		13.2.4.3	8.33%		
	TWLTL Width			21.2.7	15′		
Roadway Slopes	Side Slopes	Cut Section	Foreslope	13.3.1	4H:1V		
			Ditch Type		V-Ditch		
			Back Slope		4H:1V to 2H:1V		
			Rock Cut		0.25H:1V		
			0′ – 10′		4H:1V		
			> 10′		2H:1V		
	Clear Zone			14.3	**(3)**		
Bridges	New and Reconstructed Bridges	*Structural Capacity			HL-93		
		*Clear Roadway Width **(4)**		13.5.1.1	34′	34′	40′
	Existing Bridges to Remain in Place	*Structural Capacity			H-15		
		*Clear Roadway Width		13.5.1.1	22′	24′	28′
	*Vertical Clearance (Collector Under) **(5a)**	New/Replaced Overpassing Bridges **(5b)**		12.6	16′-0″		
		Existing Overpassing Bridges			16′-0″		
		Pedestrian Bridges			18′-0″		
		Overhead Signs			17′-6″		
	Clearance (Collector Over)	*Railroads		12.6	23′-0″		
		Underpass Width		13.5.2	Traveled Way plus Clear Zone		

* Controlling design criteria (see Section 9.2).

GEOMETRIC DESIGN CRITERIA FOR RURAL TWO-LANE COLLECTORS

(New Construction/Reconstruction)

Figure 20.1E

GEOMETRIC DESIGN CRITERIA FOR RURAL TWO-LANE COLLECTORS
(New Construction/Reconstruction)

Footnotes for Figure 20.1E

(1) Travel Lane Width.

a. Where the design speed is 40 miles per hour or less and the ADT is less than 250 vehicles per day, 10-foot travel lanes may be considered.
b. On reconstructed collectors, an existing 22-foot traveled way may be retained based on an engineering study.

(2) Shoulder Width (Total Width).

a. Where guardrail is required, increase the shoulder width an additional 3.5 feet.
b. For ADT's less than 1500 vehicles per day, the shoulder width may be reduced to a minimum roadway width of 30 feet.

(3) Clear Zone. The clear zone will vary according to design speed, traffic volumes, side slopes and horizontal curvature.

(4) New and Reconstructed Bridges (Clear Roadway Width). Clear roadway bridge widths are measured from face to face of parapets or rails. Bridge widths are normally defined as the sum of the approach traveled way width plus total shoulder width right and left.

(5) Vertical Clearance (Collector Under).

a. The clearance must be available over the traveled way, shoulders, and any anticipated future widening.
b. Table value includes allowance for future overlays.

Bullets 4 and 5a – Revised: 10-2004

Design Element		Manual Section	Design Speed						
			40 mph	45 mph	50 mph	55 mph	60 mph	65 mph	70 mph
*Stopping Sight Distance **(1)**		10.1	305′	360′	425′	495′	570′	645′	730′
Passing Sight Distance		10.2	1470′	1625′	1835′	1985′	2135′	2285′	2480′
Intersection Sight Distance **(2)**		10.4	445′	500′	555′	610′	665′	720′	775′
*Minimum Radii	e_{max} = 8%	11.2.3	–	–	–	965′	1205′	1485′	1820′
	e_{max} = 6%		510′	660′	835′	–	–	–	–
*Superelevation Rate **(3)**		11.3	6%	6%	6%	8%	8%	8%	8%
*Horizontal Sight Distance **(4)**		11.4	23′	24′	27′	32′	34′	35′	36′
*Vertical Curvature (K-values) **(5)**	Crest	12.5	44	61	84	114	151	193	247
	Sag		64	79	96	115	136	157	181
*Maximum Grade	Level	12.3.1	5%	5%	4%	4%	3%	3%	3%
	Rolling		6%	6%	5%	5%	4%	4%	4%
	Mountainous		8%	7%	7%	6%	6%	5%	5%
Minimum Grade **(6)**		12.3.2	0.5%						

*Controlling design criteria (see Section 9.2).

(1) Stopping Sight Distance. Table values are for passenger cars on level grade.

(2) Intersection Sight Distance. Table values are for passenger cars for assumed conditions described in Figure 10.4C.

(3) Superelevation Rate. See Section 11.3 for superelevation rates based on e_{max}, design speed and radii of horizontal curves.

(4) Horizontal Sight Distance. Table values provide the necessary middle ordinate assuming the maximum radii and stopping sight distance.

(5) Vertical Curvature (K-Value). K-values are based on the level stopping sight distances.

(6) Minimum Grade. Longitudinal gradients of 0 percent may be acceptable on some pavements that have cross slopes that insure adequate drainage. Special ditch grades may be necessary to insure proper project runoff management.

ALIGNMENT CRITERIA FOR RURAL ARTERIALS

Figure 20.1F

Design Element			Manual Section	Design Criteria
Bridges	New and Reconstructed Bridges	*Structural Capacity		HL-93
		*Clear Roadway Width	13.5.1.1	**(8)**
	Existing Bridges to Remain in Place	*Structural Capacity		HS-20
		*Clear Roadway Width	13.5.1.1	**(8)**
	*Vertical Clearance (Arterial Under) **(9a)**	New/Replaced Overpassing Bridges **(9b)**	12.6	17′ - 0″
		Existing Overpassing Bridges		16′ - 0″
		Pedestrian Bridges		18′ – 0″
		Overhead Signs		17′ – 6″
	Clearance (Arterial Over)	*Railroads	12.6	23′ – 0″
		Underpass Width	13.5.2	Traveled Way Plus Clear Zone

*Controlling design criteria (see Section 9.2).

GEOMETRIC DESIGN CRITERIA FOR SUBURBAN/URBAN ARTERIALS
(New Construction/Reconstruction)

Figure 21.3A

(Continued)

GEOMETRIC DESIGN CRITERIA FOR SUBURBAN/URBAN MULTILANE ARTERIALS

(New Construction/Reconstruction)

Footnotes to Figure 21.3A

(1) Parking Lane Width. A parking lane width as narrow as 10 feet may be acceptable.

(2) Auxiliary Lane Cross Slope. For auxiliary lanes adjacent to two travel lanes sloped in the same direction, use a cross slope of 2.78 percent.

(3) Shoulder Cross Slope. For paved shoulders greater than 2 feet, the shoulder cross slope should be 4.17 percent.

(4) Bicycle (Lane Width). For design speeds greater than 45 miles per hour, bike lane width should be increased in accordance with AASHTO *Guide for the Development of Bicycle Facilities*.

(5) Curb and Gutter (Type). If curb and gutter is used on streets with design speeds greater than 45 miles per hour, place the curb and gutter outside of the shoulder and use a sloping curb.

(6) Side Slopes. Generally on curb and gutter sections, a maximum slope of 2H:1V is used.

(7) Clear Zone. The clear zone will vary according to design speed, traffic volumes, side slopes and horizontal curvature.

(8) Bridge Widths. Clear roadway bridge widths are measured from face to face of parapets or rails. Bridge widths are normally defined as the sum of the approach traveled way width, right and left shoulders and median width, where applicable. For curbed sections, the clear roadway width will be the curb-to-curb width plus the sidewalk width on one or both sides.

(9) Vertical Clearance (Arterial Under).

a. The clearance must be available over the traveled way, shoulders, and any anticipated future widening.
b. Table value includes allowance for future overlays.

Bullet 9a – Revised: 10-2004

GEOMETRIC DESIGN CRITERIA FOR SUBURBAN/URBAN COLLECTORS

(New Construction/Reconstruction)

Footnotes to Figure 21.3C

(1) Parking Lane Width. A parking lane width as narrow as 8 feet may be acceptable.

(2) Auxiliary Lanes. For auxiliary lanes adjacent to two travel lanes sloped in the same direction, use a cross slope of 2.78 percent.

(3) Shoulder Cross Slope. For paved shoulders greater than 2 feet, the shoulder cross slope should be 4.17 percent.

(4) Bicycle (Lane Width). For design speeds greater than 45 miles per hour, bike lane width should be increased in accordance with AASHTO guidelines.

(5) Curb and Gutter (Type). If curb and gutter is used on streets with design speeds greater than 45 miles per hour, place the curb and gutter outside of the shoulder and use a sloping curb.

(6) Clear Zone. The clear zone will vary according to design speed, traffic volumes, side slopes and horizontal curvature.

(7) Bridge Widths. Clear roadway bridge widths are measured from face to face of parapets or rails. Bridge widths are normally defined as the sum of the approach traveled way width, shoulders and median width, where applicable. For curbed sections, the clear roadway width will be the curb-to-curb width plus the sidewalk width on one or both sides.

(8) Vertical Clearance (Collector Under).

a. The clearance must be available over the traveled way, shoulders, and any anticipated future widening.
b. Table value includes allowance for future overlays.

Bullet 8a – Revised: 10-2004

Design Element		Manual Section	Design Speed			
			30 mph	35 mph	40 mph	45 mph
*Stopping Sight Distance **(1)**		10.1	200′	250′	305′	360′
Decision Sight Distance **(2)**		10.3	490′	590′	690′	800′
Intersection Sight Distance **(3)**		10.4	335′	390′	445′	500′
*Minimum Radii	e_{max} = 6%	11.2.3	275′	380′	510′	660′
	e_{max} = 4%		305′	425′	565′	735′
*Superelevation Rate **(4)**		11.3	4% or 6%	4% or 6%	4% or 6%	4% or 6%
*Horizontal Sight Distance **(5)**		11.4	22′	23′	24′	25′
*Minimum Vertical Curvature (K-values) **(6)**	Crest	12.5	19	29	44	61
	Sag		37	49	64	79
*Maximum Grade **(7)**	Level	12.3	9%	9%	9%	8%
	Rolling		11%	10%	10%	9%
	Mountainous		12%	12%	12%	11%
Minimum Grade		12.3	Des.: 0.5% Min.: 0.3% Curb and Gutter			

*Controlling design criteria (see Section 9.2).

(1) Stopping Sight Distance. Table values are for passenger cars on level grade.

(2) Decision Sight Distance. Table values are for a stop on an urban road, Avoidance Maneuver B, as described in Figure 10.3A.

(3) Intersection Sight Distance. Table values are for passenger cars for assumed conditions described in Figure 10.4C.

(4) Superelevation Rate. See Section 11.3 for superelevation rates based on e_{max}, design speed and radii of horizontal curves. The 6 percent superelevation rate should only be used on suburban collectors.

(5) Horizontal Sight Distance. Table provides the necessary middle ordinate, assuming the maximum radii and stopping sight distance.

(6) Vertical Curvature (K-values). K-values are based on level stopping sight distances.

(7) Maximum Grades. Short lengths of grades (e.g., less than 500 feet), one-way downgrades and low-volume collectors may be up to 2 percent steeper.

ALIGNMENT CRITERIA FOR SUBURBAN/URBAN COLLECTORS

Figure 21.3D

Design Element			Manual Section	Design Criteria			
				Group 1	**Group 2**	**Group 3**	**Group 4**
Bridges	New and Reconstructed Bridges	*Structural Capacity		HL-93			
		*Clear Roadway Width	13.5.1.1	**(7)**	**(7)**	**(7)**	**(7)**
	Existing Bridges to Remain in Place	*Structural Capacity		H-10 to H-15	H-10 to H-15	H-10 to H-15	H-10 to H-15
		*Clear Roadway Width	13.5.1.1	**(8)**	**(8)**	**(8)**	**(8)**
	*Vertical Clearance (Local Roads Under) **(9a)**	New/Replaced Overpassing Bridges **(9b)**	12.6	16′ - 0″	16′ - 0”	16′ - 0″	16′ - 0”
		Existing Overpassing Bridges		14′ - 0″	14′ - 0”	14′ - 0″	14′ - 0”
		Pedestrian Bridges		17′– 0″	17′ – 0″	17′– 0″	17′ – 0″
		Overhead Signs		17′ – 6″	17′ – 6″	17′ – 6″	17′ – 6″
	Clearance (Local Roads Over)	*Railroads	12.6	23′ – 0″	23′ – 0″	23′ – 0″	23′ – 0″
		Underpass Width	13.5.2	Approach Roadway Width Including Sidewalks, Where Applicable.			Traveled Way Plus Clear Zone

*Controlling design criteria (see Section 9.2)

GEOMETRIC DESIGN CRITERIA FOR SECONDARY AND STATE "C" ROADS
(New Construction/Reconstruction)
(Continued)

Figure 22.3A

GEOMETRIC DESIGN CRITERIA FOR SECONDARY AND STATE "C" ROADS
(New Construction/Reconstruction)

Footnotes to Figure 22.3A

(1) Design Forecast Year. Table values are desirable. For rural roads, the design year may be current traffic volumes. For urban streets, the minimum design year is 10 years.

(2) Design Speed.

a. Design speed is not a major factor for Group 1 roads and streets. Select a design speed based on available right of way, terrain, likely pedestrian presence, adjacent development and other area controls.
b. Group 4 roads may be designed for 45 miles per hour on selected rural routes and "C" projects, if agreed upon during the Design Field Review.

(3) Shoulder Width. Shoulders should be increased by 3.5 feet where guardrail is used.

(4) Auxiliary Lane Width. The auxiliary lane width should be the same as the adjacent travel lane.

(5) Bicycle Facilities Lane Width. If curb and gutter is provided, provide a 5-foot width from the face of curb. For design speeds greater than 45 miles per hour, the bike lane width should be increased in accordance with AASHTO *Guide for the Development of Bicycle Facilities*.

(6) Clear Zone.

a. Desirably provide a 7 to 10 foot clear area from the edge of traveled way for rural roads. Curbs do not have a significant redirection capability. Obstructions behind a curb should be located at or beyond the minimum clear zone distances. Where minimum recommended clear zones cannot be provided, locate fixed objects as far from traveled way as practical, desirable 5.5 feet but in no case closer than 1.5 feet from the face of curb.
b. The clear zone will vary according to design speed, traffic volumes, side slopes and horizontal curvature. In addition, guardrail will be installed at bridge ends and along fill slopes steeper than 4H:1V exceeding 10 feet in height.

(7) New and Reconstructed Bridge Widths. See Section 22.2.6

(8) Existing Bridge Widths to Remain in Place. See Section 22.2.6

(9) Vertical Clearance (Local Roads Under).

a. The clearance must be available over the traveled way, shoulders, and any anticipated future widening.
b. Table value includes allowance for future overlays.

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