Chapter Thirteen

ROADSIDE SAFETY

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Chapter Thirteen
ROADSIDE SAFETY

This Chapter provides the designer with guidance on measures to reduce the number and/or severity of crashes when vehicles leave the traveled way.

The “forgiving roadside” concept, developed in the 1960s, has been a long-standing philosophy in Connecticut. As a result, many of ConnDOT’s State highways have been constructed to meet this design philosophy. In addition, guidance for installing roadside safety hardware has gradually evolved to reflect the results of crash test programs.

The American Association of State Highway and Transportation Officials (AASHTO) has incorporated many of the crash test results and roadside safety design concepts into the *Roadside Design Guide* (*RDG*).

Chapter Thirteen is a supplement to the *RDG*. Where there is a discrepancy between the two, Chapter Thirteen will take precedence.

13-1.0 DEFINITIONS

1. Recoverable Parallel Slope. Slopes that can be safely traversed, and upon which the driver of an errant vehicle has a reasonable opportunity to stop and return to the roadway. The Department considers slopes flatter than 1:4 and slopes of 1:4 without curbing at their top recoverable.

2. Non-Recoverable Parallel Slope. Slopes that are steeper than 1:4. Most drivers will not be able to recover and return to the highway. The Department has decided to treat this range of cross slopes as critical.

3. Critical Parallel Slope. Slopes upon which a vehicle is likely to overturn. Under the Department’s roadside criteria, slopes steeper than 1:4 and slopes of 1:4 with curbing at the top are critical.

These definitions vary slightly from those in the *RDG*.

13-2.0 CLEAR ZONES

13-2.01 Background

The clear zone concept was first established in the 1967 AASHTO report entitled *Highway Design and Operational Practices Related to Highway Safety*, known as the *Yellow Book* and revised in 1974. It provided the designer with a numerical value of 30 ft as the lateral extent needed for 80%-85% of run-off-the-road vehicles to recover. The 30-ft clear zone was predicated on the following set of conditions:

1. 60-mph vehicular speed,
2. tangent section, and
3. flat side slope.

If these conditions vary, the 30-ft clear zone should be adjusted accordingly. For example, at higher speeds, vehicles will travel farther before recovering; at lower speeds, vehicles will travel less before recovering.

Section 13-2.02 presents clear zone distances for various roadway conditions. The overall objective of these clear zone values is to achieve the 80%-85% target recovery area for run-off-the-road vehicles on any given roadway.

13-2.02 Application

The calculated clear zone widths presented in Figure 13-2A are recommended values and need not be achieved at all costs. The methodology used to determine the values in this chart are valid and provides the designer with a good frame of reference for making decisions to design safer roadside recovery areas. However, the designer must exercise judgment when applying the distances because they do not apply to every conceivable set of highway conditions. Each application of the clear zone distance must be evaluated individually.

When applying the clear zone distance, the designer must consider right-of-way availability, environmental concerns, economic factors, identification of potential hazards, safety needs and crash histories. The following items further describe the proper usage of the clear zone distances presented in Figure 13-2A:

1. Boundaries. The designer should not use the clear zone distances as boundaries for introducing roadside hazards such as bridge piers, non-breakaway sign supports or utility poles. These should be placed as far from the roadway as practical. Where roadside hazards must be placed along the highway, at a minimum they should be placed at the clear zone boundary and possibly shielded.

Design Speed	Design Year of ADT	Cuts or Fills (Negative Shelf)		Cuts or Fills (Positive Shelf)	
		1:6 or flatter	1:4	1:4	1:6 or flatter
40 mph or less	Under 750	7	7	7	7
	750-1500	10	12	10	10
	1500-6000	12	14	12	12
	Over 6000	14	16	14	14
45 – 50 mph	Under 750	10	12	8	10
	750-1500	14	16	12	14
	1500-6000	16	20	14	16
	Over 6000	20	24	18	20
55 mph	Under 750	12	14	10	10
	750-1500	16	20	14	16
	1500-6000	20	24	16	20
	Over 6000	22	26	20	22
60 mph	Under 750	16	20	12	14
	750-1500	20	26	16	20
	1500-6000	26	30	18	24
	Over 6000	30	30	24	26
65 – 70 mph	Under 750	18	20	14	14
	750-1500	24	28	18	20
	1500-6000	28	30	22	26
	Over 6000	30	30	26	28

Notes:

1. *All distances are measured from the edge of traveled way. See Section 13-2.02, Comment #5.*
2. *See Section 13-2.02, Comment #2, for application of clear zone criteria on fill slopes.*
3. *See Figure 5H for illustration of a cut section with a positive shelf. See Section 13-2.02, Comment #3, on cut slopes and ditch sections.*
4. *The values in the table apply to all facilities both urban and rural. See Section 13-2.02, Comment #4, for utility poles in urban areas.*

RECOMMENDED CLEAR ZONE DISTANCES (ft)

Figure 13-2A

2. Fill Slopes. Figure 13-2A provides clear zone values as a function of design speed, traffic volume, and the rate of fill slopes with a positive or negative shelf. Figure 13-2B illustrates the clear zone application on fill slopes with a negative shelf. Barn-roof fill slopes may be designed with two slope rates where the second slope is steeper than the slope adjacent to the shoulder. See Figure 13-2B(b). This design requires less right-of-way and embankment material than a continuous, flatter slope. Although a "weighted" average of the slopes may be used, a simple average of the clear zone distances for each slope is sufficiently accurate if the variable slopes are approximately the same width. If one slope is significantly wider, the clear zone computation based on that slope alone may be used.

3. Cut Slopes. Figure 13-2A also provides clear zone values as a function of design speed, traffic volume, and the rate of cut slopes with a positive or negative shelf. Figure 13-2C illustrates the clear zone application in a cut section. The designer must also reference Section 13-3.06 for guidance on the proper treatment of drainage features encountered within the clear zone.

   The outside limit of rounding for the backslope should be outside of the clear zone. This is illustrated in the typical section figures in Chapters Four and Five. When this is not achievable, the following approach should be used to calculate the clear zone for a ditch section:

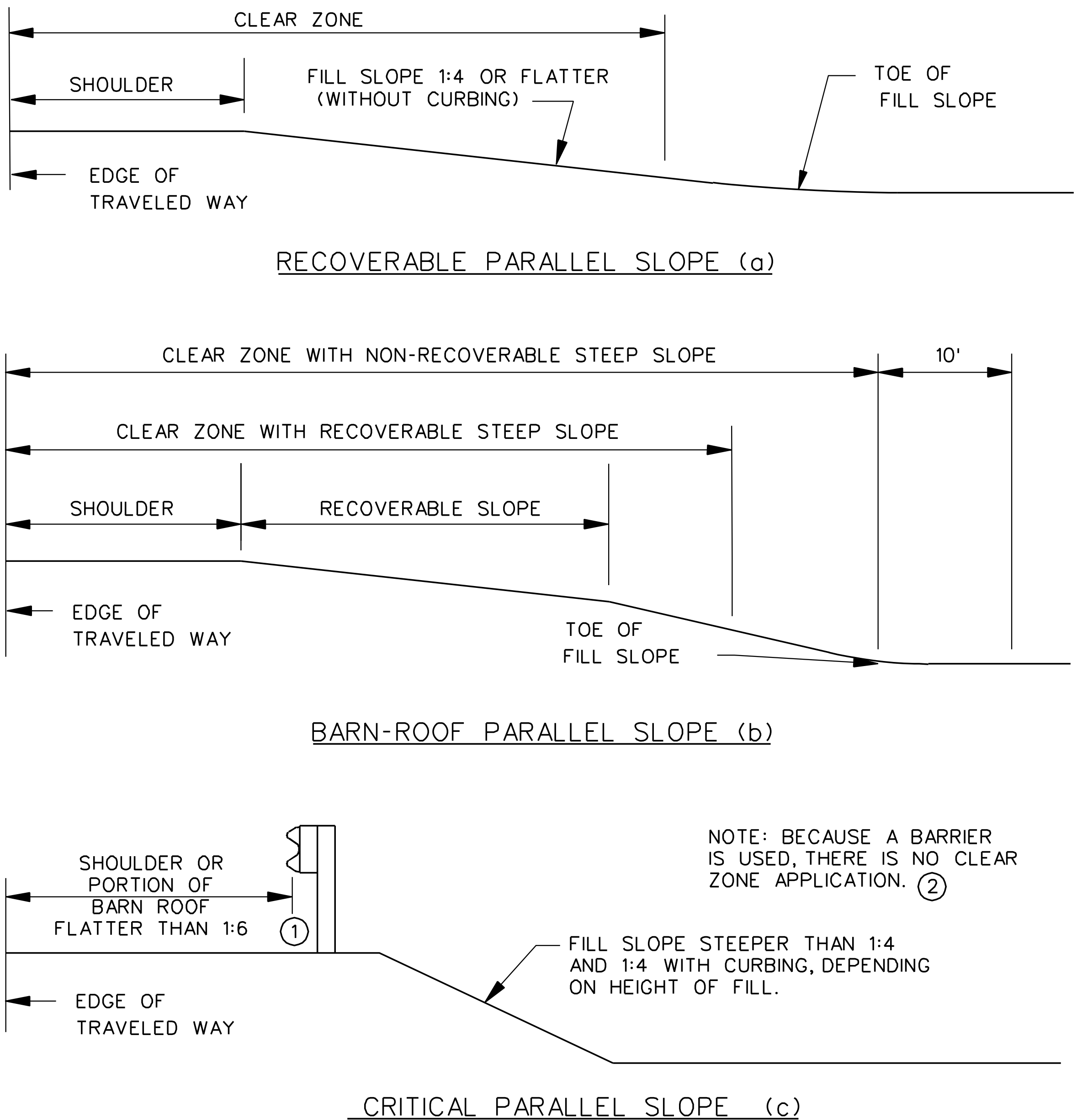
   a. Calculate the percentage of the clear zone from Figure 13-2A (negative shelf) available to the toe of the backslope.

   b. Subtract this percentage from 100 percent and multiply the results by the clear zone for the backslope from Figure 13-2A (positive shelf).

   c. Add the available clear zone to the toe of the backslope to the value determined in b. This yields the required clear zone from the edge of traveled way to a point on the backslope.

4. Urban Facilities. A minimum horizontal obstruction-free clearance of 1.5 ft should be provided as measured from the gutter line to any utility pole, sign or traffic signal pole. This distance is not considered a clear zone, but an operational offset. Clear zones to other fixed objects such as buildings should conform to Figure 13-2A. Refer to the Utility Setback and Design Exceptions Procedure in Section 13-2.04.

5. Auxiliary Lanes. For auxiliary lanes, such as climbing lanes, passing lanes, etc., the clear zone will be the same as for the mainline and will be measured from the outside edge of the auxiliary lane. The clear zone will not normally apply to left- and right-turning lanes at intersections. When evaluating crossover crash potential for undivided roadways, the clear zone will be measured from the left edge of the through traveled way.

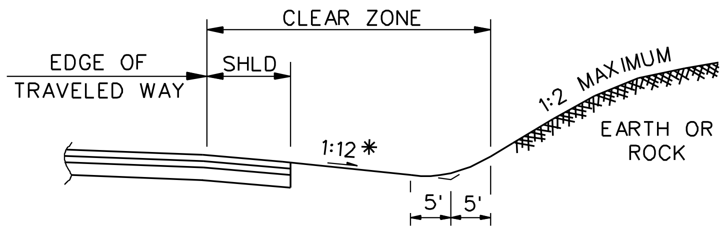


(1) WHEN GUIDERAIL IS NOT USED AND THE CLEAR ZONE EXTENDS BEYOND THE TOP OF THE SLOPE, A MINIMUM DISTANCE OF 10 FT WILL BE CLEARED AT THE TOE OF SLOPE.

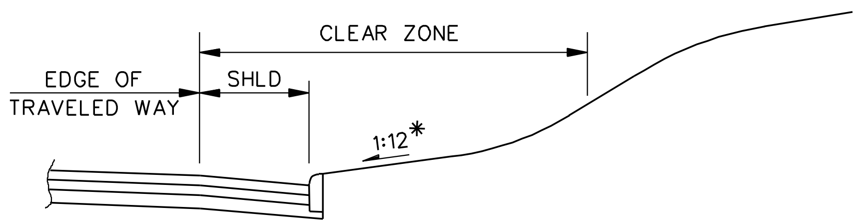
(2) SEE FIGURE 13-3A TO DETERMINE BARRIER NEED.

CLEAR ZONE APPLICATION FOR FILL SLOPES
(Negative Shelf)

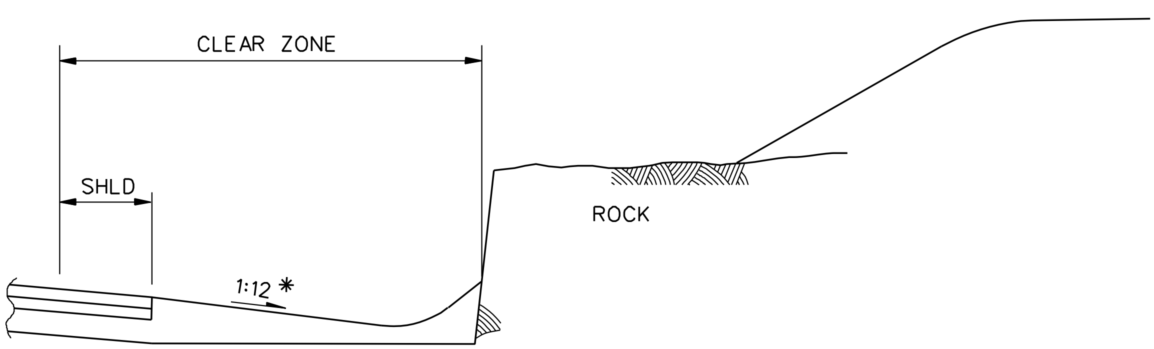
Figure 13-2B



ROADSIDE DITCH SECTION



POSITIVE SHELF



ROCK CUT SECTION

* 1:12 TYPICAL, 1:10 MAXIMUM

CLEAR ZONE APPLICATION FOR CUT SLOPES

Figure 13-2C

6. Horizontal Curves. Additional clear zone may be provided on the outside of horizontal curves by the use of curve correction factors that are included in the *RDG*. These increases should be considered only where crash histories indicate a need or where specific investigations indicate a high potential for crashes and where the increase to the clear zone is cost effective.

13-2.03 Rock Removal

Because of the often considerable expense in removing rock to meet roadside clear zone criteria, the Department has adopted a policy specifically for rock removal. If the costs and associated impacts with removing rock to meet the clear zone criteria in Figure 13-2A are reasonable, the designer should meet these criteria. If, however, there are significant negative impacts and/or the costs are major, the designer should evaluate the following factors:

1. Other Benefits. The rock removal may generate benefits other than those for roadside safety. These include:

   a. improving intersection sight distance;
   b. improving sight distance around horizontal curves; or
   c. improving any rock stability, ground water and/or icing problems.

   Any additional benefits should be considered when determining the extent of the rock removal.

2. Alternative Improvements. Where the designer determines that retaining the rock within the clear zone presents a significant roadside hazard, the designer should consider alternative improvements to rock removal. These include:

   a. installing a single-faced concrete barrier or guiderail, and

   b. providing a positive slope (with rounding at its toe) up to the face of the rock (1:4 or steeper) to provide limited vehicular redirection; see Figure 13-2C.

3. Application. If rock is within the clear zone and more than 18 ft from the edge of traveled way, the ConnDOT Design Exception Committee will review the case and will either:

   a. determine that rock removal is appropriate because of its crash potential, or
   b. grant a waiver of the clear zone criteria.

   Designers should also discern whether or not the rock is in a condition that may imperil the traveling public by flaking, falling or icing. If so, the designer should evaluate the need for and proper type of roadside barrier protection. This should be documented in the project file and verification sought from the Design Exception Committee.

13-2.04 Utility Setback and Design Exceptions Procedures

There will be many sites where it will be impractical to locate utility poles outside the clear zone. This is especially prevalent in urban projects but could apply to any project, depending upon the circumstances.

The following discussion provides the requirements for blanket design exceptions for utility poles located within the clear zone. Provided the criteria noted below is complied with and the utility company has justified, to the satisfaction of the Department, that its poles have been set back to the maximum extent practical, waivers will not have to be approved through the Design Exception Committee.

The project correspondence file should provide sufficient documentation that utility poles are set back in accordance with the criteria. It is suggested that the request for design approval include the following information:

1. Utility poles should be positioned outside the clear zone whenever practical.

2. A maximum utility pole setback of 10 ft (measured from the outside edge of the shoulder or the gutter line), irrespective of the clear zone, is permissible. This setback dimension is consistent with the capabilities of the utility company's installation and maintenance equipment. The maximum 10-ft setback is also consistent with the utility company's corporate strategy of providing a quick response to power outages, etc.

3. The Department may require a setback greater than 10 ft up to a maximum of 30 ft if conditions such as, but not limited to, a higher incidence of crashes related to the presence of utility poles exist.

4. Along urban highways, the Department will require poles to be placed as close to the right-of-way line as practical. Where sufficient space is available, poles must be placed in back of the sidewalk. If insufficient space is available, the Department may allow poles to be placed between the curb and sidewalk or as far from the curb as practical when there are no sidewalk considerations (minimum 1.5 ft behind the face of curb).

5. Design exceptions for utility poles within the clear zone are still required when it is the Department's position that the utility company is not locating its poles in accordance with these criteria.

13-3.0 GUIDERAIL WARRANTS

Determining the need for guiderail can be difficult and time consuming. Existing conditions may limit the designer's options thus increasing project cost, environmental impacts and right-of-way acquisitions. However, when economically and practically feasible, the designer should always attempt to eliminate the need for guiderail.

Section 1.2 of the *RDG* provides the designer with six design options, in order of priority, for redesigning the roadside to eliminate roadside obstacles and the need for guiderail. These steps should become an integral part of the preliminary design phase of all Department projects where applicable.

The following Sections illustrate where guiderail may be warranted.

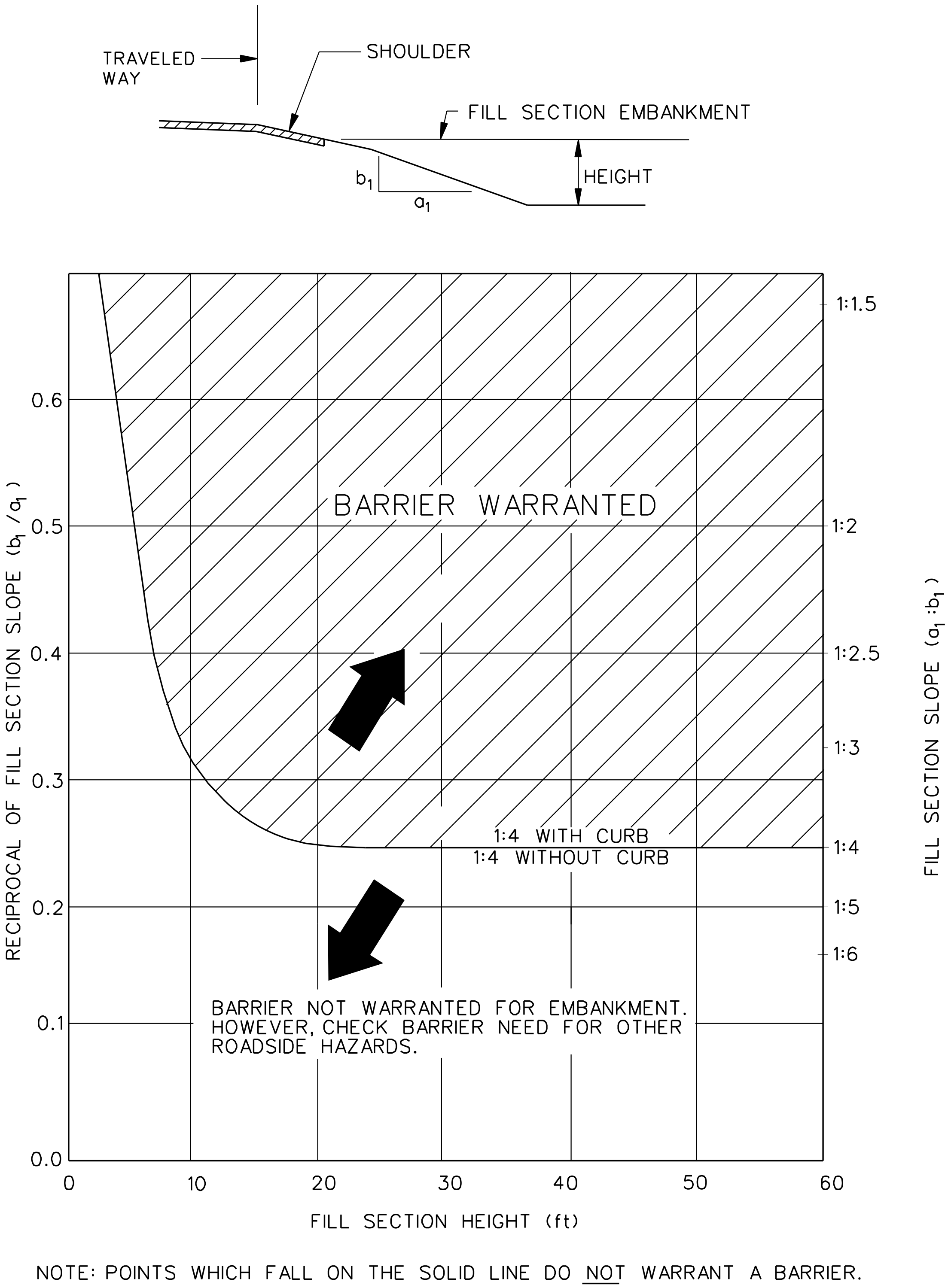
13-3.01 Embankments

The severity of the roadside condition depends upon the rate and height of the fill slope. Refer to Figure 13-3A for Comparative Risk Warrants for Embankments. This figure is revised from Figure 5.1 of the *RDG*. Depending on the height of fill slope, guiderail may be needed to shield a fill slope steeper than 1:4 and slopes of 1:4 with curbing. See Section 13-6.04 for curb and curb/barrier combinations. Guiderail is not required on fill slopes flatter than 1:4 if there are no roadside hazards within the clear zone as calculated from Section 13-2.0.

13-3.02 Roadside Hazards

The recommended clear zone distances for various roadway conditions presented in Section 13-2.0 should be free of any fixed objects and non-traversable hazards. Roadside hazards that may warrant guiderail include but are not limited to the following:

1. non-breakaway sign and luminaire supports,
2. concrete bases extending more than 4 in above the ground,
3. bridge piers and abutments at underpasses,
4. retaining walls and culvert end-walls,
5. trees with diameter greater than 4 in (at maturity),
6. rough rock cuts,
7. large boulders,
8. streams or permanent bodies of water,
9. stone fences, and
10. utility poles. *Note: It is not Department policy to design guiderail to protect the traveling public from utility poles. However, if guiderail is provided for other reasons and utility poles exist within the deflection of the proposed guiderail, strengthening of the guiderail for the utility poles is required.*



COMPARATIVE RISK WARRANTS FOR EMBANKMENTS

Figure 13-3A

These hazards in some instances may not warrant guiderail depending on their location. For example, to install guiderail to protect an errant vehicle from an isolated tree at the edge of a 30-ft clear zone may not be practical.

The designer should recognize that even barriers installed to deflect errant vehicles away from fixed objects may be hazards themselves. Preference should therefore be given to eliminating or relocating the fixed object or potential hazard rather than placing guiderail in front of it whenever possible.

13-3.03 Bridge Rails and Approaches

The leading and trailing ends of bridge rails normally warrant protection. The highway designer is responsible for determining the need for and design of the guiderail leading up to and trailing from the bridge rail; the bridge designer is responsible for the design of the bridge rail and details for guiderail attachment to bridge parapets. Figure 13-3B illustrates warrants for providing guiderail approaching a bridge rail. Refer to the Department's Guiderail Procedure for the disposition of existing leading end transitions to bridge parapets. Section 13-6.09.02 provides additional information on transitions. All bridge rails shall comply with the Department's *Bridge Design Manual*.

13-3.04 Bridge Piers, Abutments and Overhead Sign Structures

Structures should normally be placed outside the clear zone. However, many bridge piers and abutments are within the design clear zone and cannot be relocated. Where this occurs, guiderail protection is warranted. Where full-height abutments are immediately outside the clear zone, a leading end guiderail treatment may often be warranted. The following will apply:

1. High-Speed Facilities. On high-speed facilities (≥45 mph):

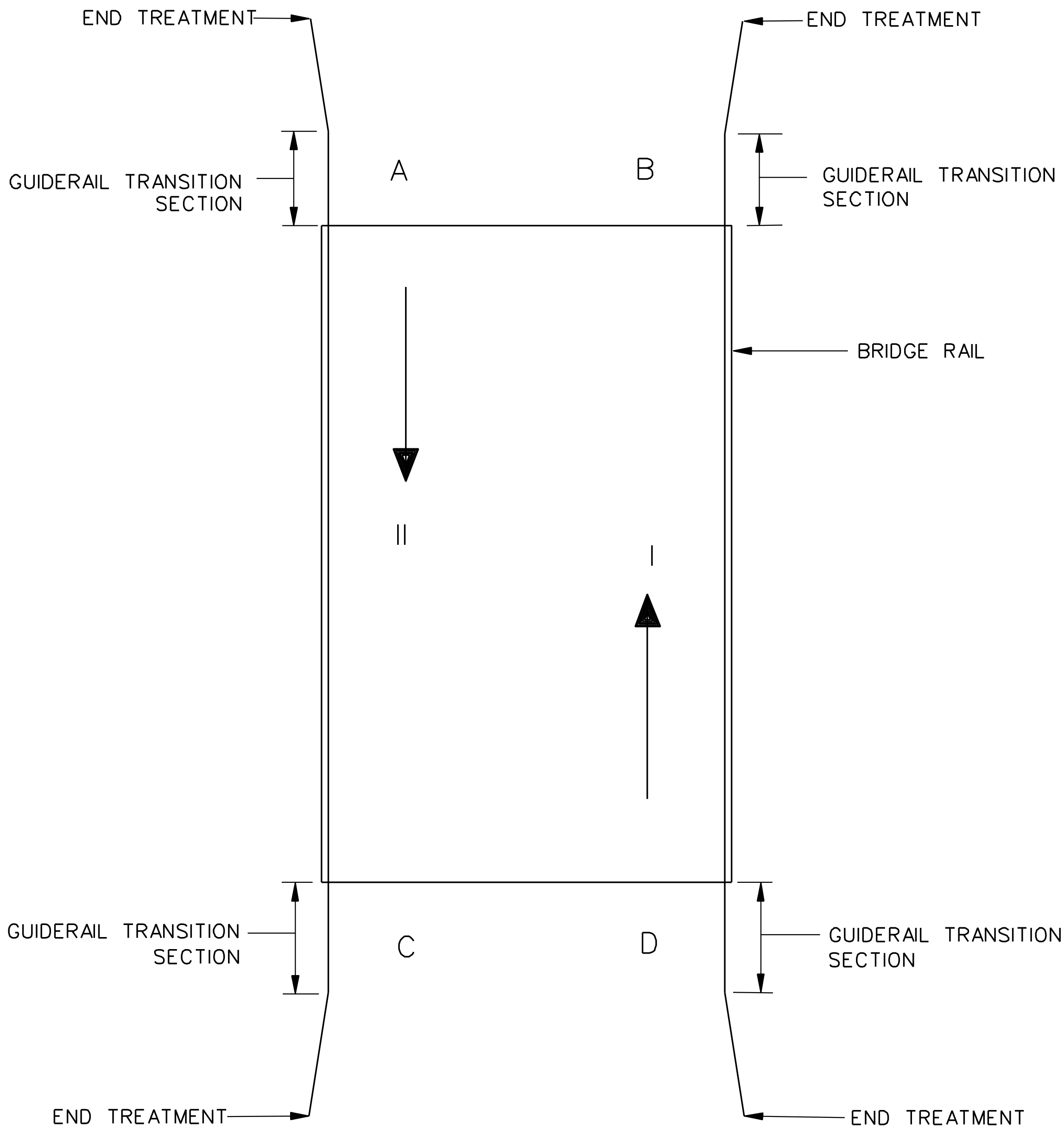
   a. Protect structures that are within the clear zone but are 10 ft or more from the outside edge of shoulder Consider installing a structurally independent 45-in high, F-shape PCBC.

   b. Protect structures that are within the clear zone but are located within 10 ft of the outside edge of shoulder with at least a structurally independent 45-in high, F-shape PCBC.

   c. Protect structures located less than 4 ft from the outside edge of shoulder with at least a structurally independent 45-in high, vertical faced wall.

   d. Structures within 3' of the outside edge of shoulder should be designed for a collision and be a continuous vertical faced barrier with approaching ends transitioned from a standard 45-in high, F-shape PCBC to a 54-in vertical face at the structure.

2. Low-Speed Facilities. On low-speed facilities (<45 mph), protect structures within the clear zone or that are 3 ft or less from the outside edge of shoulder with a guiderail system meeting the appropriate deflection requirements. Section 13-4.02 provides more information on the deflection parameters for various guiderail types.



TRAFFIC DIRECTION	LEADING END TRANSITION REQUIRED AT
I and II	A B C D
II Only	A B *
I Only	C D *

* FOR THESE CASES, TRAILING END TRANSITIONS MAY BE WARRANTED FOR THE TRAILING END OF THE BRIDGE.

WARRANTS FOR GUIDERAIL APPROACH TO BRIDGE RAIL
Figure 13-3B

13-3.05 Vertical Drop-Offs

An extended length of vertical drop-off, either along a fill slope or at the shoulder edge (e.g., retaining wall), typically warrants the installation of an unyielding barrier (e.g., concrete barrier) when the height of the vertical drop-off is 2.5 ft or greater. The single-faced, precast concrete barrier curb should not be used unless the area behind it can be backfilled. Normally, either the full-section precast concrete barrier curb or a cast-in-place retaining wall is used. Figure 13-3C provides additional details on where an unyielding barrier may be required.

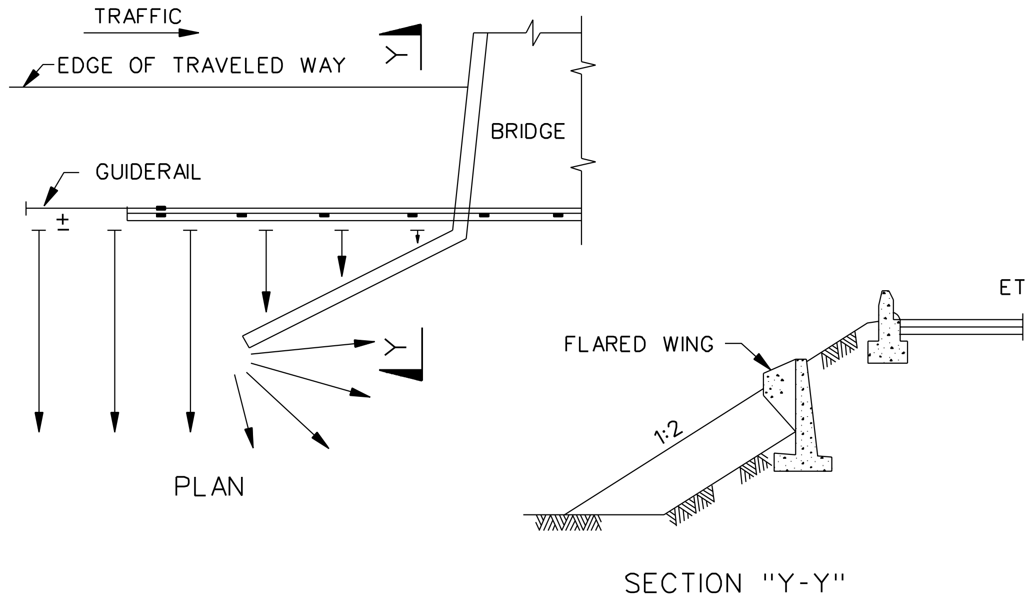
13-3.06 Roadside Ditches, Channels and Swales

If a vehicle departs the roadway and encounters ditches, channels or swales, the roadside configuration may introduce abrupt changes in vehicular direction that can result in destabilization of the vehicle. Figure 13-3D illustrates the relative traversability of various combinations of front slopes, ditch widths and backslopes for roadside channels, ditches and swales.

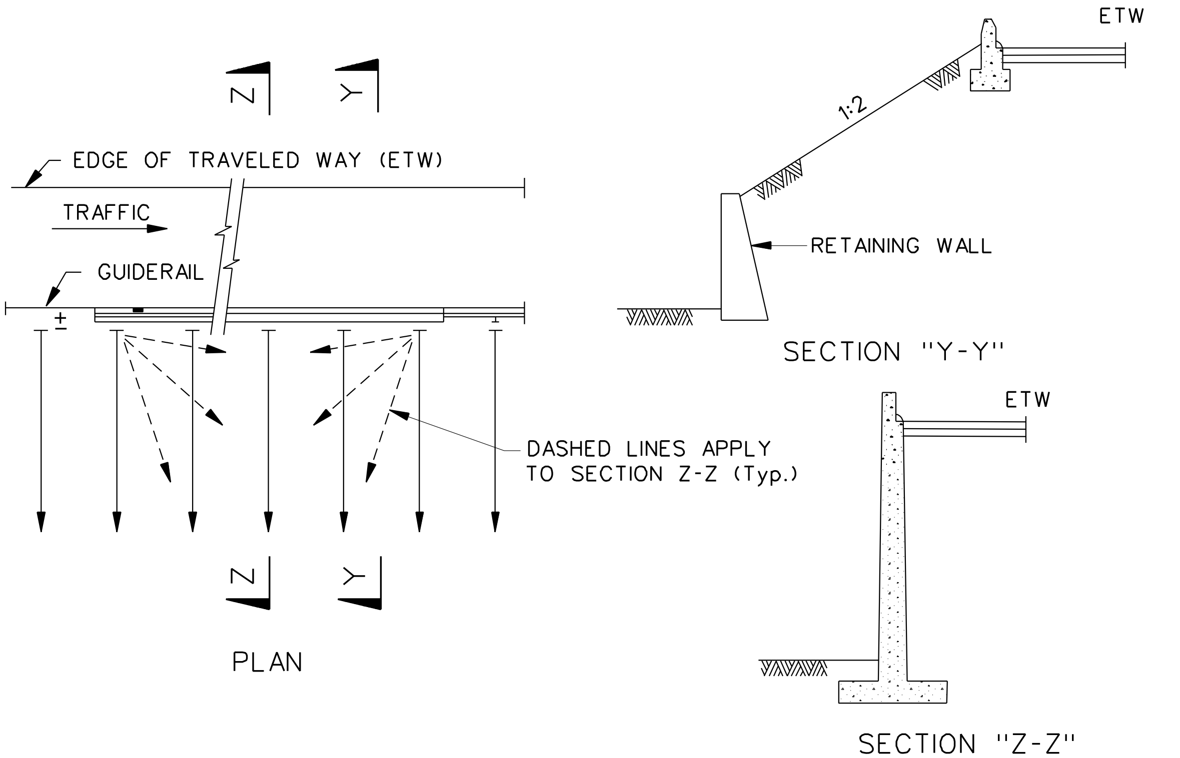
The typical section figures in Chapters Four and Five and Figure 13-2C illustrate the standard roadside swales in a cut section. For highways without curbs, the front slope is 1:12, the rounded ditch width is 10 ft and the backslope is variable but not to exceed 1:2. The typical sections also show that the outside limit of rounding for the backslope should be outside the clear zone distance determined from Section 13-2.0. Where this limit is within the clear zone, the designer should attempt to relocate the outside limit of rounding to beyond the clear zone.

Ditch sections that fall within Zone 1 in Figure 13-3D may warrant guiderail. However, the designer should consider the cost effectiveness of installing lengthy sections of guiderail to shield a ditch. This is not always desirable and may warrant revising the ditch cross section to eliminate the need for guiderail.

If the dimensions of an existing or proposed ditch section fall within Zone 2 in Figure 13-3D, the backslope should be flattened if practical. If this is not feasible, guiderail is not warranted because of the ditch cross section alone. In this Zone, guiderail is considered more of a hazard than the ditch itself and, therefore, may not be warranted.



ROADSIDE BARRIER TREATMENT AT FLARED WINGS

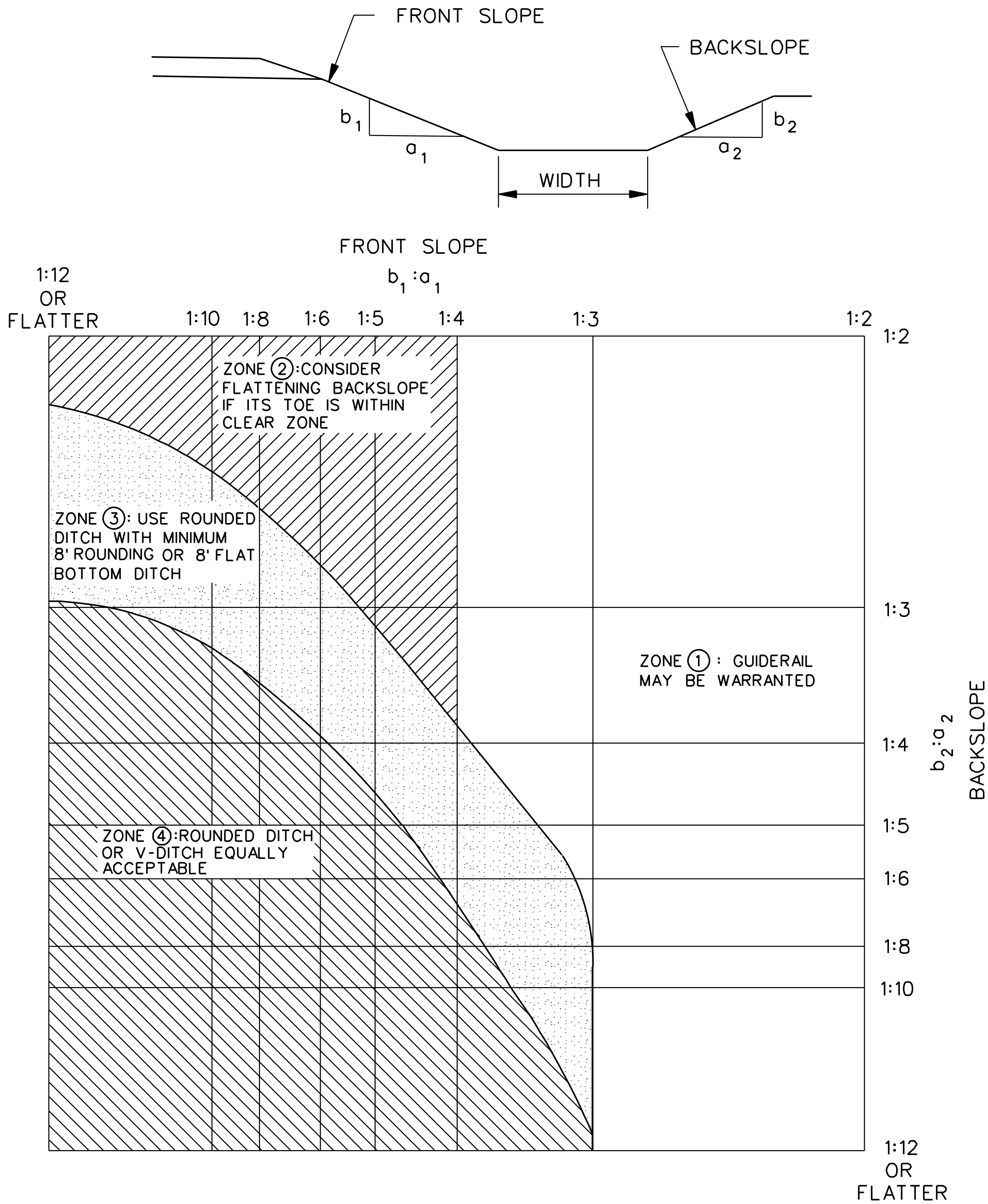


ROADSIDE BARRIER TREATMENT AT EMBANKMENT RETAINING WALLS

Note: An unyielding barrier is warranted for vertical drop-offs that exceed 2.5 ft.

BARRIER WARRANTS FOR VERTICAL DROP-OFFS

Figure 13-3C



Notes:

1. *Figure is based on impacts at 60 mph and 25 degrees.*
2. *Zones in figure are numbered indicating their relative hazard with Zone ① being the most hazardous.*

TRAVERSABILITY OF ROADSIDE DITCHES, CHANNELS AND SWALES

Figure 13-3D

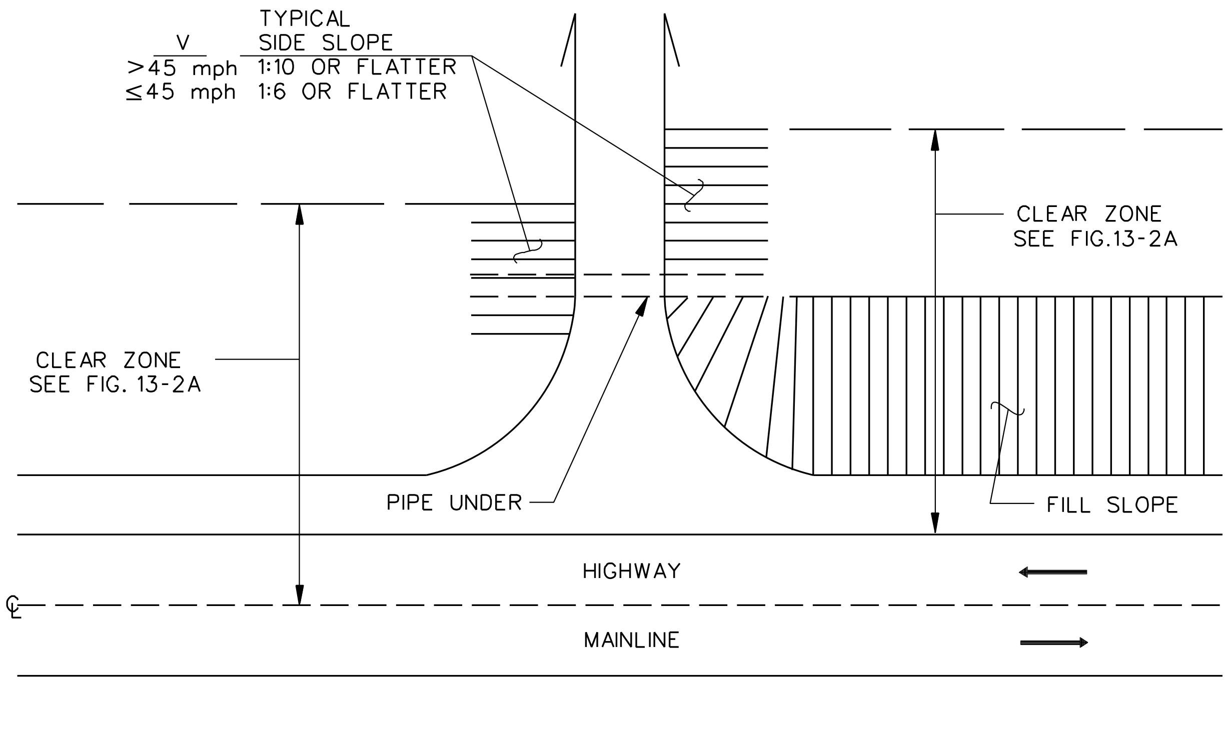
13-3.07 Transverse Slopes

Where the highway mainline intersects a driveway, side road or median crossing, a slope transverse to the mainline will be present. See Figure 13-3E. If a run-off-the-road vehicle at this location impacts the guiderail, the angle of impact will likely be close to 90 degrees. Even for relatively flat side slopes, this may result in vehicular vaulting; for steeper slopes the vehicular bumper may "catch" in the slope resulting in an abrupt stop and high occupant accelerations.

For these reasons, transverse slopes should be as flat as practical. For design speeds greater than 45 mph, the slope should be 1:12 typical or 1:10 maximum or flatter. For 45 mph or below, the slope should be 1:6 or flatter. If these criteria cannot be met practically, guiderail may be considered. The decision to use guiderail should be made on a case-by-case basis considering costs, traffic volumes, severity of the proposed transverse slope and other relevant factors. If guiderail is needed around the corners of intersecting roads or driveways, see Figure 13-6D for placement criteria on radii and Appendix A for design criteria of the "Washington Curved Guiderail Treatment."

13-3.08 High Tension Lines and Reservoirs

A 45-in precast or cast-in-place concrete barrier curb with the F-shape or box beam guiderail is the preferred means of shielding high tension line towers and water supply reservoirs. See Section 13-4.0 for a description of the box beam guiderail and Section 13-5.0 for a description of the F-shape barrier.



TRANSVERSE SLOPES

Figure 13-3E

13-4.0 ROADSIDE BARRIERS

FHWA has mandated that, as of October 1, 1998, all new installations of roadside safety hardware on the National Highway System (NHS) must meet, at a minimum, Test Level 3 (TL-3) crash testing criteria in National Cooperative Highway Research Program (NCHRP) Report 350 *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. This applies to roadside barriers (i.e., guiderail), impact attenuators, end treatments, bridge rails and guide-rail-to-bridge-rail transitions. The Department has adopted the TL-3 criteria as the minimum acceptable for new installations on all State-owned highways, whether on or off the NHS. Unless indicated otherwise, all guiderail types in Section 13-4.01 have met the TL-3 criteria in NCHRP Report 350.

13-4.01 Guiderail Types

Figure 13-4A presents the Department's preferred guiderail systems. The figure summarizes the hardware requirements for each system. The designer should reference the *Connecticut Standard Drawings* for detailed information on each system. The following Sections describe each system and its typical usage. In addition, several special roadside guiderails are described.

13-4.01.01 Three Cable Guiderailing (I-Beam Posts)

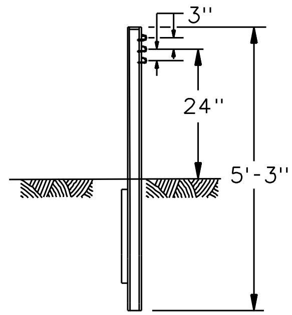
Three cable guiderailing is a weak-post flexible system with a large dynamic deflection. The tensile forces developed in the cable strands supply most of the resistance to impact. Upon impact, the cables break away from the posts, and the vehicle is able to knock down the posts as it is redirected by the cables. The detached posts do not contribute to controlling the lateral deflection. However, the posts that remain in place do provide a substantial part of the lateral resistance to the impacting vehicle and are therefore critical to proper performance.

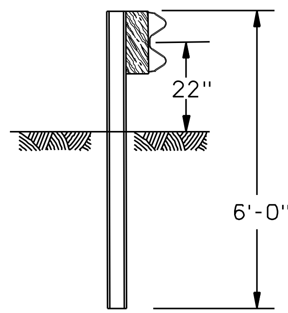
Three cable guiderailing is the most forgiving of the available systems because of its large dynamic deflection. It should only be used where a considerable length of the proper deflection distance is available behind the guiderail. Its use should be tempered by the following considerations:

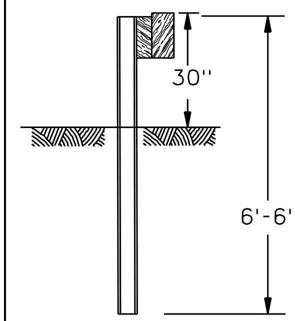
1. Transitions. Do not use three cable guiderailing for leading end transitions into bridge rails.

2. Slopes. Do not use three cable guiderailing on fill slopes steeper than 1:2, unless the distance between the back of the posts and the break in the fill slope is at least 8 ft.

3. Minimum Radius. Three cable guiderailing shall not be used on radii less than or equal to 440 ft. See Figure 13-6E for guiderail curvature criteria.





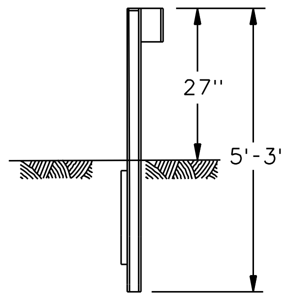


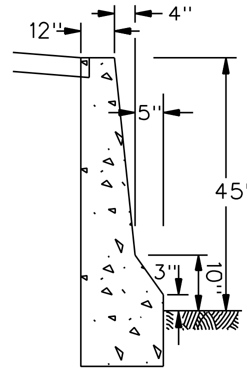
Type	Three Cable Guiderail	Metal Beam Rail (Type R-B 350)	Merritt Parkway Guiderail
AASHTO Designation	G1-a	G4(1S)	N/A
General Type	Weak-post (flexible)	Strong-post (semi-rigid)	Strong-post (semi-rigid)
Standard Post Spacing	16 ft – 0 in	6 ft – 3 in	10 ft – 0 in
Max. Dynamic Deflection	12 ft – 6 in	4 ft – 3 in	4 ft – 3 in
Post Type	S3 x 5.7 Steel with Soil Plate	W6 x 9 Steel	W6 x 15 Steel
Beam Type	Three 3/4″ dia. Steel Cables	Steel W. Section	6 in x 12 in Rough Sawn Timber
Offset Brackets	None	6 in x 8 in x 13 in Recycled Plastic Block Out	4 in x 8 in x 11 in Timber Block Out

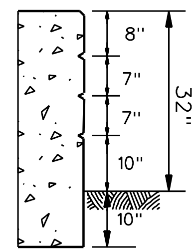
Note: Use recycled plastic block outs, approved by FHWA per NCHRP Report 350 TL-3 criteria, with R-B 350 guide rail systems. See Connecticut Standard Drawings. The Merritt Parkway Guide Rail is approved for use solely on the Merritt Parkway (See Section 13-4.01.08).

TYPICAL ROADSIDE BARRIER TYPES

Figure 13-4A







Type	Weak-Post Box Beam	F-Shape Concrete Barrier	Merritt Parkway Concrete Barrier
AASHTO Designation	G3	N/A	N/A
General Type	Weak-post (semi-rigid)	Safety Shape	Vertical Face - Aesthetic
Standard Post Spacing	6 ft – 0 in	N/A	N/A
Max. Dynamic Deflection	6 ft – 0 in	0 in	0 in
Post Type	S3 x 5.7 Steel Post with Soil Plate	N/A	N/A
Beam Type	6 in x 6 in x 0.19 in Steel Tube	N/A	N/A
Offset Brackets	None	N/A	N/A

TYPICAL ROADSIDE BARRIER TYPES

Figure 13-4A

(Continued)

4. Cable Tension. For three cable guiderail to provide full impact performance, the cables must be tensioned properly. Therefore, maintenance forces should ensure that the cable strands are tensioned properly at all times.

5. Minimum Length. The minimum length of three cable guiderailing on roads with design speeds greater than 45 mph, as measured between last end posts, is 200 ft. On roads with design speeds less than or equal to 45 mph, the minimum length is 150 ft with an 8 ft post spacing.

6. Systems. Where System 2 or 3 (see *Connecticut Standard Drawings*) is required, either install the entire run of rail using a single system or provide a 200 ft minimum length of the system.

13-4.01.02 Metal Beam Rail (Type R-I)

Like three cable guiderailing, the metal beam rail (Type R-I) is a weak-post flexible system. The tensile strength in the longitudinal W-beam will provide most of the resistance to the lateral forces of the impacting vehicle.

The Type R-I guiderail failed the TL-3 crash testing criteria in NCHRP Report 350. As a result, Department policy is that no new installations of this system will be allowed on any State-owned roadway. See Appendix A for latest Guiderail Procedure.

13-4.01.03 Metal Beam Rail (Type R-B)

The metal beam rail (Type R-B) is a strong post semi-rigid system with steel posts and steel block outs. The Type R-B guiderail failed the TL-3 crash testing criteria in NCHRP Report 350. As a result, Department policy is that no new installations of this system will be allowed on any State-owned roadway. See Appendix A for latest Guiderail Procedure.

13-4.01.04 Metal Beam Rail (Type R-B 350)

After the failure of metal beam rail (Type R-B) with steel block outs, FHWA tested a similar system with timber block outs that passed TL-3. Further tests were performed using recycled plastic block outs that passed TL-3 and were approved by FHWA. The Department has decided to use only recycled plastic block outs with FHWA approval for R-B 350 guiderail.

The maximum dynamic deflection of R-B 350 guiderail is much less than that of three cable guiderail. The deceleration forces on vehicular occupants when impacting R-B 350 are significantly higher than impacts with three cable guiderail. Thus, three cable guiderail is the preferred system. However, R-B 350 guiderail has significant maintenance advantages over the flexible rail. It can often safely sustain a second impact even after a major first impact. For this reason, R-B 350 guiderail should be strongly considered where a site has a history of frequent run-off-the-road incidents or where the greater deflection distance required for three cable guiderail is not available or is only available intermittently.

13-4.01.05 Thrie Beam 350

The Thrie Beam 350 passed the TL-3 crash test criteria in NCHRP Report 350. It is a strong post semi-rigid guiderail with a 20-in wide thrie-beam section, a W6 x 9 steel post, and a M14 x 18 steel block out with a notch cut out of the bottom of the web. This rail has a maximum dynamic deflection of 3 ft-4 in at a 6 ft-3 in post spacing. It may be used at selected sites on a case-by-case basis with approval of the Transportation Engineering Administrator.

13-4.01.06 Metal Beam Rail (6″ x 6″ Box Beam)

The box beam guiderail passed the TL-3 crash test criteria in NCHRP Report 350. It is a weak post semi-rigid guiderail with an S3 x 5.7 steel post and a TS 6 in x 6 in x 0.25 in steel box tube. This rail has a maximum dynamic deflection of 6 ft at a 6-ft post spacing. It may be used at selected sites on a case-by-case basis with approval of the Transportation Engineering Administrator; see Section 13-3.08.

13-4.01.07 Single-Faced Precast Concrete Barrier Curb (PCBC)

ConnDOT previously used the “Jersey Shape” PCBC. The Department’s choice, when installing new permanent PCBC, is the 45-in “F-shape.” The single faced F-shape PCBC may be used on the roadside in front of rigid objects where no deflection distance is available. If the rigid object is not continuous (e.g., bridge piers), the designer should backfill behind the PCBC.

Existing “Jersey Shape” PCBC may remain. However, designers should provide a proper transition where new construction meets existing. Refer to the *Connecticut Standard Drawings* for transition details.

13-4.01.08 Merritt Parkway Guiderail

The Merritt Parkway steel-backed timber guiderail combines aesthetic appeal (i.e., the timber longitudinal member) with acceptable safety performance (i.e., it passed the TL-3 crash testing criteria in NCHRP Report 350). The Department has approved this rail for use solely on the Merritt Parkway. However aesthetically appealing, this rail has a high maintenance and installation cost which precludes its widespread application on other State-owned roadways.

13-4.01.09 Merritt Parkway Barrier

The Merritt Parkway Barrier combines aesthetic appeal with acceptable safety performance (i.e., vertical wall barriers meet TL-3 crash testing criteria in NCHRP Report 350). The Department has approved this barrier for use solely on the Merritt Parkway.

13-4.02 Deflection Distance

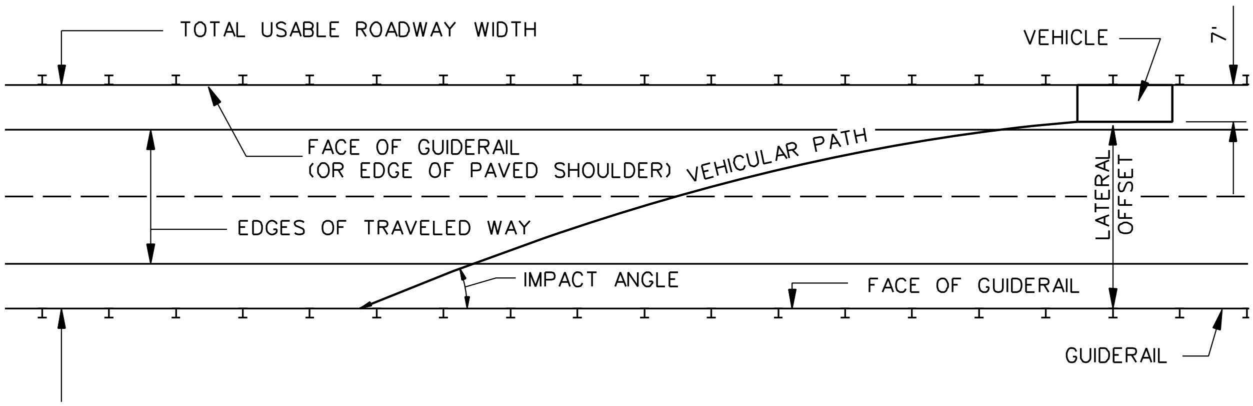
The “deflection distance” is defined as the lateral distance that the outside (side away from traffic) face of a barrier will deflect when struck by an errant vehicle before that barrier system stops the movement away from the road. Deflection for strong post systems is measured as the deflection from the back side of the posts to the face of the object. This distinction is made because weak post rail systems usually separate from the posts when struck, while strong post systems will usually remain attached. The clear distance to an obstruction must therefore include an allowance for the width of the strong post system. This clear distance for deflection is determined by the vehicular weight, speed, angle of impact and strength or rigidity of the barrier system.

The deflection distance is an important parameter for two reasons. First, it determines the magnitude of the lateral deceleration. Rigid systems, such as concrete barriers, produce essentially instantaneous lateral decelerations that are more likely to result in injuries. This difference is the major safety factor favoring the selection of flexible systems. The second reason that deflection distance is important is that it determines the space that must be maintained between the hazard and the barrier. If a hazard is allowed to remain or grow within the deflection distance of a barrier, the longitudinal movement of an errant vehicle can still carry it into the obstacle, even if the lateral movement has been arrested. The results of crash tests have been analyzed to develop a method for estimating the deflections that may be expected when a standard 4,500-lb vehicle strikes different types of barriers at different speeds and impact angles.

Figure 13-4D presents the deflection distances expected when various barrier systems are impacted at 60 mph with a standard 4,500-lb vehicle at 25 degrees. Vehicles traveling at lower speeds on narrow roadways with reduced lateral offsets tend to impact guiderail at flatter angles thereby creating a smaller deflection in the guiderail. For this reason, Figure 13-4B is used when needed to determine the maximum lateral offset for narrow roads. Figure 13-4C should be used to establish applicable reduction factors that may be used to decrease the normal dynamic deflection of guiderail when proposed for installation on lower speed, narrow roadways. Refer to the example problem in Figure 13-4C.

Department policy for selecting guiderail with respect to deflection needs is summarized below:

1. The barrier system with the largest acceptable deflection should be selected when a barrier is required.

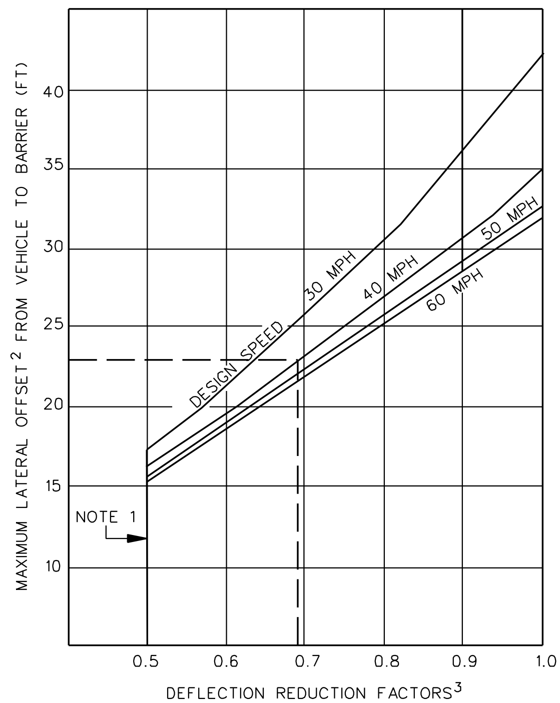


MAXIMUM LATERAL OFFSET
(For use with Figure 13-4C)

Figure 13-4B

Notes:

1. *Factors will not be less than 0.5.*
2. *As illustrated in Figure 13-4B.*
3. *Reduction factors are used at specific locations when a smaller deflection is needed on a lower speed roadway to protect motorists from immovable objects.*



Example:

1. *Determine that the maximum lateral offset (as defined in Figure 13-4B) equals 26 ft.*
2. *Determine that the guiderail's standard deflection (obtained from Figure 13-4D) is 8 ft.*
3. *Determine the design speed to be 50 mph.*
4. *From the graph in this figure, the reduction factor is 0.8.*
5. *Multiply 8 ft by 0.8 = 6.4 ft.*
6. *Use a reduced deflection of 6 ft, due to the narrow offset.*

DEFLECTION REDUCTION FACTORS

Figure 13-4C

Barrier Type	Post Type (Deflection Category)	Post Spacing (ft)	Standard Deflection[7] (ft)
Three Cable Guiderailing[2]	Weak Post (Flexible)	16′-0″[10] 8′-0″[8,11] 4′-0″[8]	12′-6″[5] 8′-0″[5] 6′-0″
Corrugated W-Beam Guiderail[3,12]	(Type R-I) Weak Post (Flexible)	12′-6″ 6′-3″ 3′-1½″	8′-0″[5] 6′-0″ 4′-6″
	(Type R-B 350) Strong Post (Semi-Rigid)	6′-3″ 3′-1½″ 1′-6¾″	4′-3″[6] 2′-6″[6] 1′-9″[6]
Box Beam Guiderail[4]	Weak Post (Semi-Rigid)	6′-0″ 3′-0″[9]	5′-0″ 4′-0″
Corrugated W-Beam Median[3,12]	(Type MD-I) Weak Post (Flexible)	12′-6″ 6′-3″	7′-0″ 5′-0″
	(Type MD-B 350) Strong Post (Semi-Rigid)	6′-3″	2′-0″
Box Beam Median[4]	Weak Post (Semi-Rigid)	6′-0″	5′-6″
Merritt Parkway Guiderail	(Type Merritt Parkway) Strong Post (Semi-Rigid)	10′-0″ 5′-0″ 2′-6″	4′-0″ 2′-6″ 1′-0″
Concrete Shapes	N/A	N/A	0

Notes:

1. *Standard impact was produced with a 4,500-lb test vehicle traveling at 60 mph impacting the barrier at a 25° angle.*
2. *Must be properly tensioned and anchored to limit deflection to values shown.*
3. *Must be properly anchored at both ends to limit deflections to values shown.*
4. *To develop beam strength must be a minimum length of 130 ft.*
5. *To minimize rollover problems, barrier systems with deflections of 8 ft or more should not be used adjacent to slopes steeper than 1:2.*
6. *Measured from back face of post.*
7. *Where extra long weak posts are required, these deflections should be multiplied by 1.3.*
8. *Split spacing achieved by use of backup posts bolted to cable.*
9. *Split spacing achieved by use of backup posts driven behind the rail but not fastened to it.*
10. *Recommended minimum length on roads with design speeds ≥ 45 mph excluding end anchors is 200'.*
11. *Recommended minimum length on roads with design speeds < 45 mph using 8' post spacing excluding end anchors is 150'.*
12. *To develop beam strength and tension in the rail, a minimum length of 50' excluding end anchors is recommended.*

BARRIER DEFLECTIONS FOR STANDARD[1] IMPACTS

Figure 13-4D

2. The deflection of the selected guiderail system must be less than the distance from the back of the guiderail post to the nearest hazard that cannot be removed or relocated.

All removable hazards must be removed from the area within the deflection distance of the selected guiderail. Maintenance work may be needed to prevent trees within the deflection distance from growing to more than 4-in in diameter. Because the Department cannot control development beyond the right-of-way (ROW) line, the selection of a barrier system should ensure that its deflection will not extend beyond the ROW.

The designer should note that when a vehicle impacts a barrier, the vehicle may lean over the top of the barrier and strike bridge piers, sign supports, light poles, etc., that have been placed behind the barrier and rise above it. If practical, fixed objects should be placed beyond the clear zone, instead of behind and above the barrier. Designers should refer to the *Connecticut Standard Drawings* for placement of PCBC adjacent to bridge piers, abutments and sign supports.

13-4.03 Disposition of Existing Guiderail

13-4.03.01 NHS Facilities

Refer to the latest Guiderail Procedure in Appendix A for disposition of existing guiderail systems on NHS facilities and the Merritt Parkway.

13-4.03.02 All Other Facilities

It is Department policy that all future and existing roadside safety hardware meet the crash testing requirements presented in NCHRP Report 350. Therefore, when any of the longitudinal barriers listed in the Guiderail Procedure in Appendix A are encountered within the limits of a project, designers should upgrade the guiderail to the new standards.

13-5.0 MEDIAN BARRIERS

13-5.01 Warrants

The following summarizes the Department's criteria:

1. Freeways. Median barrier is warranted on all medians of 66 ft or less. A median barrier may also be warranted on wider medians if a significant number of crashes have occurred.

   Medians may vary in width. If a section warrants a median barrier but a wider section does not, the barrier should be extended into the wider median by approximately 100 ft.

2. Non-Freeways. On lower-speed, lower-class highways, some judgment must be used. On highways without access control, the median barrier must terminate at each at-grade intersection, which is undesirable. In addition, lower speeds will reduce the likelihood of a crossover crash. On non-freeways, the designer should evaluate the crash history, traffic volumes, travel speeds, median width, alignment, sight distance and construction costs to determine an appropriate median barrier.

13-5.02 Median Barrier Types

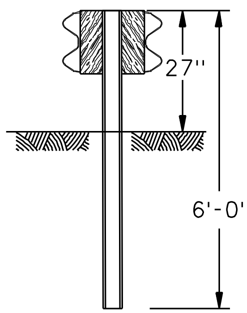
All new installations of median barrier on NHS roadways must meet the TL-3 crash testing criteria in NCHRP Report 350. Figure 13-5A presents the types of median barriers that are typically used by the Department. The figure summarizes the hardware requirements for each system. Unless indicated otherwise, all types have met TL-3 criteria in NCHRP Report 350. Section 13-5.03 provides additional guidance on the selection of median barriers.

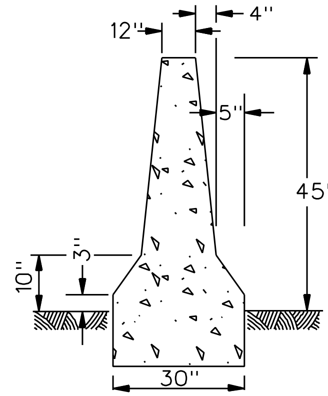
13-5.02.01 Metal Beam Rail (Type MD-I)

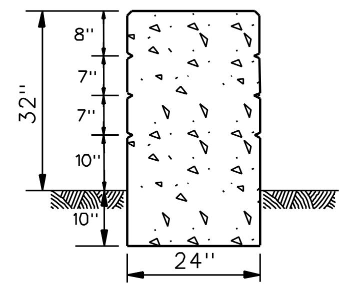
Metal beam rail (Type MD-I) is a weak-post flexible median barrier. Its performance is similar to metal beam rail (Type R-I). FHWA has tested Type MD-I guiderail at TL-3 and it passed. This barrier should only be used on relatively flat ground for optimum performance. In areas where maintenance has experienced a high number of impacts, use Type MD-B 350 in lieu of Type MD-I.

13-5.02.02 Metal Beam Rail (Type MD-B)

Metal beam rail (Type MD-B) is a strong-post semi-rigid system with steel posts and steel block outs. Its performance is similar to metal beam rail (Type R-B). FHWA has tested Type R-B guiderail at TL-3 and it failed. As a result, corresponding median Type MD-B has also been deemed a failure. Therefore, Department policy is that no new installations of this guiderail will be allowed on any State-owned roadway.





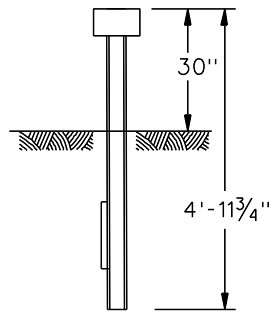
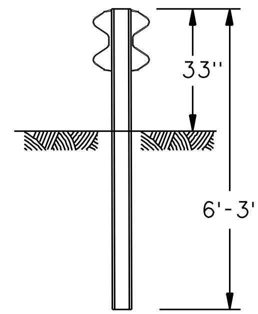
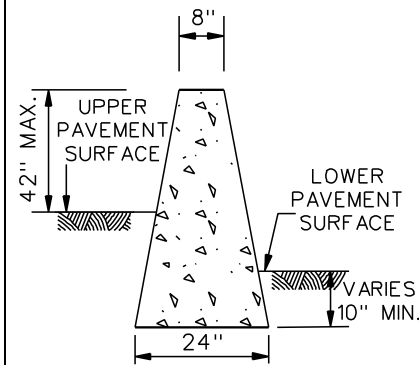


System	Metal Beam Rail (Type MD-B 350)	Double Faced PCBC F-Shape	Merritt Parkway Median Barrier
AASHTO Designation	SGM06a (Modified)	SGM10b (Modified)	N/A
General Type	Strong-post Semi-rigid	Rigid	Rigid
Standard Post Spacing	6 ft – 3 in	N/A	N/A
Deflection Distance	2 ft	0 in	0 in
Post Type	W6 x 9 Steel	N/A	N/A
Beam Type	Two Steel W Sections	N/A	N/A
Offset Brackets	Two 6 in x 8 in x 14 in Recycled Plastic Block Outs	N/A	N/A

Note: The Merritt Parkway Barrier has been designed for use solely on the Merritt Parkway where only passenger cars are present. It is not suitable for use where there are trucks allowed in the traffic mix. See the Connecticut Standard Drawings.

TYPICAL MEDIAN BARRIER TYPES

Figure 13-5A

			
System	Metal Beam Rail (Type 8″ x 6″ Box Beam)	Metal Beam Rail (Type MD-I)	Precast Concrete Barrier Curb (Single Slope)
AASHTO Designation	SGM03	SGM02	N/A
General Type	Weak-post	Weak-Post	Rigid
Standard Post Spacing	6 ft – 0 in	12 ft – 6 in	N/A
Deflection Distance	6 ft – 6 in	7 ft – 0 in	0 in
Post Type	S3 x 5.7	S3 x 5.7	N/A
Beam Type	8 in x 6 in x 0.25 in Steel Tube	Two Steel W-Beam Sections	N/A
Offset Brackets	N/A	N/A	N/A

Note: The Merritt Parkway Barrier has been designed for use solely on the Merritt Parkway where only passenger cars are present. It is not suitable for use where there are trucks allowed in the traffic mix. See the Connecticut Standard Drawings.

TYPICAL MEDIAN BARRIER TYPES

Figure 13-5A2

(Continued)

13-5.02.03 Metal Beam Rail (Type MD-B 350)

Metal beam rail (Type MD-B 350) is a strong-post semi-rigid median barrier with steel posts and recycled plastic block outs. Its performance is similar to metal beam rail Type R-B 350. MD-B 350 median guiderail is most applicable in medians with narrow or intermediate widths on non-freeways. One special application for MD-B 350 is to separate adjacent on/off ramps at interchanges.

13-5.02.04 Double-Faced F-Shape PCBC

As discussed in Section 13-4.01.07, the Department's choice for new permanent median PCBC is the 45-in F-shape. See the latest Guiderail Procedure in Appendix A. When installing median PCBC, the distance between the edge of traveled way and the concrete median barrier should not exceed 12 ft as illustrated in Figures 4I and 5K, except for the Incident Management section for urban freeways.

13-5.02.05 Merritt Parkway Median Barrier

Two individual roadside sections of the standard steel-backed timber guiderail discussed in Section 13-4.01.08 may be used in the median on the Merritt Parkway when the median is greater than 13 ft wide. Two individual roadside sections of System 2 shown in the *Connecticut Standard Drawings* may be used when the median is between 9 ft-6 in and 13 ft wide. Two individual roadside sections of System 3 shown in the *Connecticut Standard Drawings* may be used when the median is 6 ft-6 in to 9 ft-6 in wide. Ideally, designers should install the appropriate steel-backed timber guiderail system with the proper deflection needed for the site.

Where the median width is too narrow to accommodate the deflection of the steel-backed timber guiderail, the Merritt Parkway concrete median barrier will be used. See the *Connecticut Standard Drawings* for more details on its use and placement.

13-5.02.06 Metal Beam Rail (8″ x 6″ Box Beam)

Box beam median rail is a weak post, semi-rigid guardrail with an S3 x 5.7 steel post and a TS 8 in x 6 in x 0.25 in steel tube. The box beam rail passed the TL-3 crash test criteria in NCHRP Report 350. This rail has a maximum dynamic deflection of 5 ft-6 in at a 6-ft post spacing. It may be used at selected sites on a case-by-case basis with approval of the Transportation Engineering Administrator.

13-5.03 <u>Median Barrier Placement</u>

13-5.03.01 General

The ideal location for the median barrier is in the center of the median, which will provide a maximum clear recovery area for each direction of travel. The presence of excessive slopes or existing drainage in the center may make it impossible to locate a barrier there. Therefore, a median barrier should not be placed where the roadside slope up to the barrier exceeds 1:10. For a PCBC, the slope leading up to the barrier will be the shoulder slope. Existing median slopes greater than 1:10 should be flattened to a desirable 1:12 rate or maximum 1:10 rate.

13-5.03.02 Basic Application

Figure 13-5B illustrates three basic types of sloped medians. The following discusses each type; it assumes a median barrier is warranted:

1. For Cross Section I, the designer should determine if the individual slopes warrant protection based on the criteria in Section 13-3.0. If both slopes warrant protection (Illustration 1), guiderail should be placed at “b” and “d”. If one slope warrants protection, a median barrier should be placed to shield that slope. If neither slope warrants protection and both slopes are steeper than 1:10 (Illustration 2), a median barrier should be placed at “b” or “d”, whichever is shielding the steeper slope. If the slopes are 1:10 or flatter (Illustration 3), the median barrier should be placed slightly to one side of the center of the median so that it does not interfere with highway drainage.

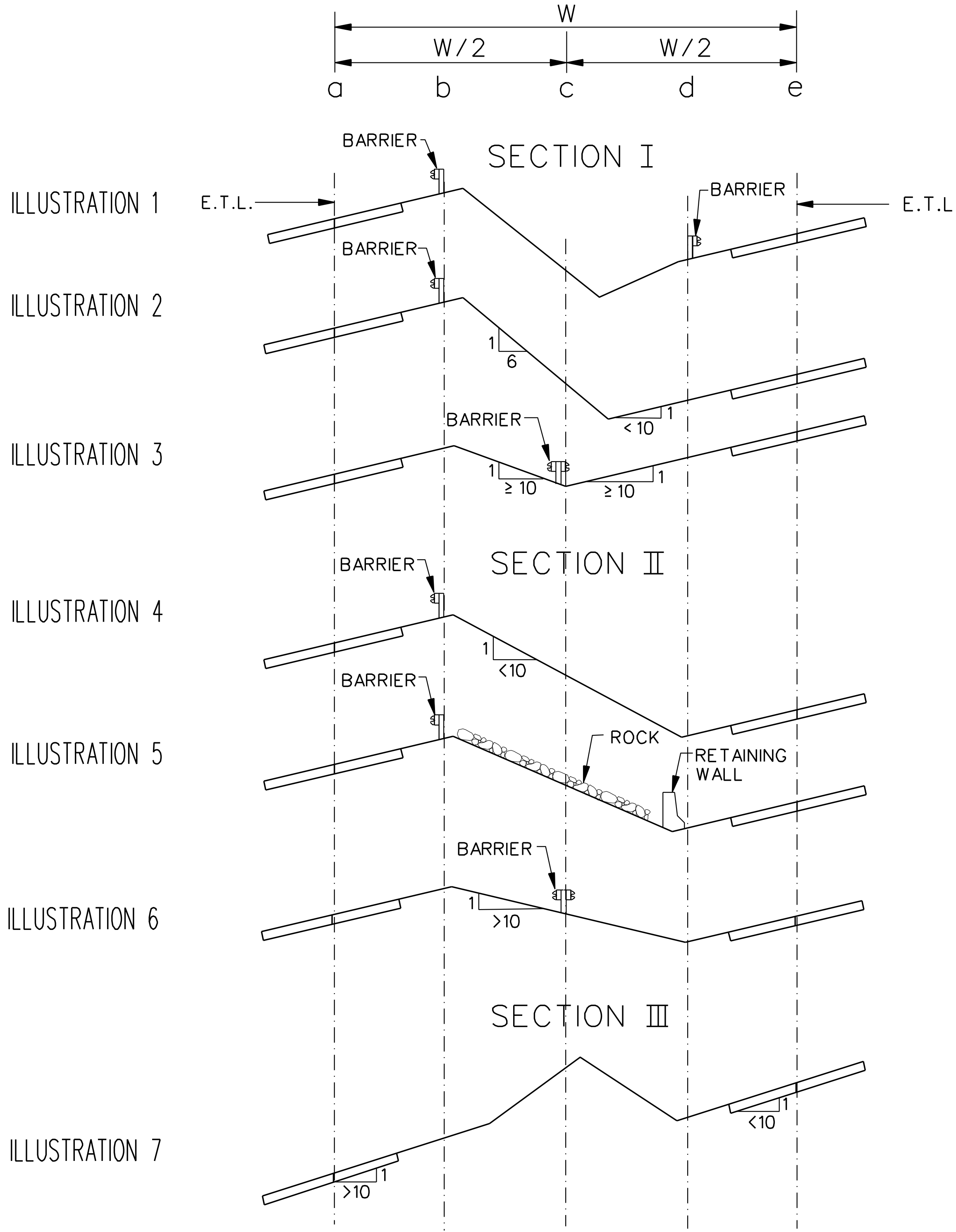
2. For Cross Section II, the slope in the median will determine the proper treatment. If the slope is between 1:10 and 1:4 (Illustration 4), the median barrier should be placed at “b.” If the median slope is 1:4 or steeper, guiderail at “b” is the only necessary treatment. If the median slope is a roadside hazard (e.g., rough rock cut) (Illustration 5), guiderail should be placed at both “b” and “d.” If the median slope is 1:10 or flatter (Illustration 6), the median barrier should be placed in the center of the median.

3. For Cross Section III (Illustration 7), the redirective capacity of the median slope will determine the proper treatment. If the median slope is 1:4 or steeper and $\geq$ 3 ft in vertical height, no roadside nor median barrier is necessary. If the median slopes are flatter than 1:4 and/or $<$ 3 ft in vertical height, the median barrier should be placed at the apex of the cross section.

13-5.03.03 Divided Median Barriers

It may be necessary to intermittently divide a median barrier. The slope criteria in Section 13-5.03 or a fixed object in the median may require this. The median barrier may be divided by one of these methods:

1. An F-shaped PCBC may encase a fixed object.



SLOPED MEDIANS

Figure 13-5B

2. A single-faced F-shaped PCBC may be used on both sides to shield a fixed object. Backfilling may be necessary.

Metal beam rail MD-B 350 may be split into two separate runs of guiderail passing on either side of the median hazard (fixed object or slope).

If a median barrier is split, the design should adhere to the acceptable flare rates (Figure 13-6A). Where practical, the flare rate should be 50:1.

The designer should note that, when a vehicle impacts a barrier, the vehicle may lean over the top of the barrier and strike bridge piers, sign supports, light poles, etc., that have been placed on top of or immediately behind the barrier. Note that a vertical faced concrete barrier helps to reduce vehicle lean over the top of the barrier. If practical, fixed objects should be placed on the outside of the highway beyond the clear zone, instead of on top of or immediately behind the PCBC. When using a 45” F-shape PCBC a 4’ minimum set back from the face of the curb line to the face of the obstruction should be provided. Where a 4’ set back for the F-shape barrier cannot be met a 45” tall vertical faced barrier can be used with a 3’ minimum set back from the curb line to the face of the obstruction. When a PCBC is transitioned to a vertical faced barrier for this purpose, a transition section should be used on the leading end followed by 100’ of vertical barrier prior to the fixed object. The vertical faced barrier should then be carried past the fixed object with one additional section of barrier.

13-5.04 <u>Glare Screens</u>

Headlight glare from opposing traffic can be bothersome and distracting. Glare screens can be used in combination with median barriers to eliminate this problem. The Department has not adopted specific warrants for the use of glare screens.

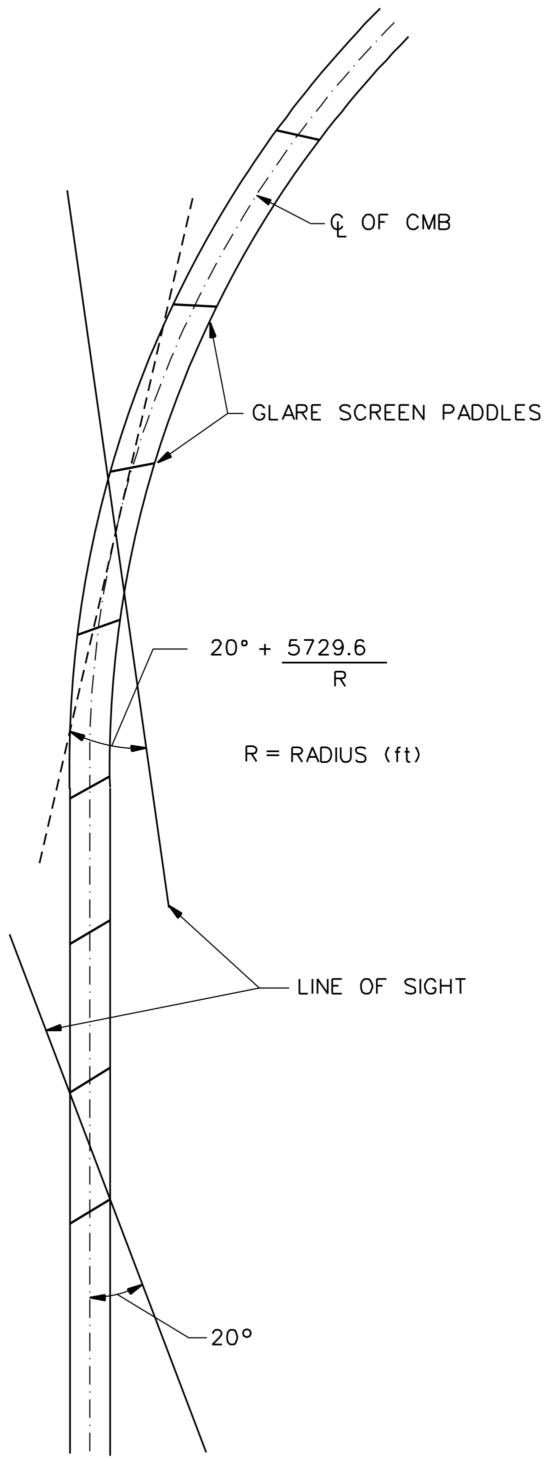
The typical application, however, is on urban freeways with narrow medians and high traffic volumes or between on/off ramps at interchanges where the two ramps adjoin each other. Here, the sharp radii of curvature and the narrow separation may make headlight glare especially bothersome. Designers should consider the use of glare screens at these sites especially if the Department has received a significant number of public complaints.

Blocking headlight glare can be achieved in several ways:

1. Vegetation can be used; however, the designer should not introduce hazardous fixed objects in a narrow median.

2. Several commercial glare screens are available. Considering both effectiveness and ease of maintenance, the paddle glare barrier may be the best choice. These are a series of plastic paddles that are usually mounted to a PCBC.

Glare screens should be designed for a cutoff angle of 20^{o}. This is the angle between the median centerline and the line of sight between two vehicles traveling in opposite directions. The glare screen should be designed to block the headlights of oncoming vehicles up to the 20^{o}



CUTOFF ANGLE FOR GLARE SCREENS

Figure 13-5C

cutoff angle. On horizontal curves, the design cutoff angle should be increased to allow for the effect of the curvature on headlight direction. See Figure 13-5C. The criteria is:

Cutoff Angle = 20^{o} + 5729.6/R
where R = Curve radius, ft.

The designer should also evaluate the impact of a glare screen on horizontal sight distance on curves to the left. The screen could significantly reduce the available middle ordinate for stopping sight distance. See Section 8-2.0 for a discussion of sight distance at horizontal curves.

13-5.05 Disposition of Existing Median Barriers

13-5.05.01 NHS Facilities

See the latest Guiderail Procedure in Appendix A for disposition of existing median barriers on the NHS facilities and the Merritt parkway.

13-5.05.02 All Other Facilities

It is Department Policy that all future and existing roadside safety hardware meet the crash testing requirements presented in NCHRP Report 350. Therefore, when any of the longitudinal barriers listed in the Guiderail Procedure are encountered within the limits of a project, designers should upgrade the guiderail to the new standards.

Temporary median Jersey-shaped PCBC may be used for temporary traffic control during construction, as shown in the *Connecticut Standard Drawings*.

13-6.0 GUIDERAIL LAYOUT

13-6.01 Length of Need

The Department's criteria for determining the length of need is found in the AASHTO *Roadside Design Guide*, Section 5.6.4.

13-6.02 Flare Rate

It may be necessary to laterally relocate a run of guiderail to terminate the end anchorage outside the clear zone or to meet a bridge parapet. This lateral relocation may increase the angle of impact on the guiderail. Therefore, guiderail flare rates should be based on Figure 13-6A.

13-6.03 Lateral Placement

Guiderail should be placed as far as practical from the edge of the traveled way. This will minimize the chance that it will be struck. The following factors should be considered when determining guiderail lateral placement:

1. The dynamic deflection distance of the guiderail, as shown in Figure 13-4D, should be met. The zone of intrusion of a vehicle getting above and behind the rail should also be considered.

2. At a minimum, 2 ft should be provided between the back of the guiderail post and the break in the fill slope. This will provide the necessary soil resistance for the post. In addition, on fill slopes steeper than 1:2, three cable guiderailing should not be installed unless the distance between the back of the post and the break in the fill slope is at least 8 ft. In rare locations where a 2-ft shelf behind the rail is not practical, a 7-ft long post should be used.

3. Drivers tend to "shy" away from continuous longitudinal obstacles along the roadside, such as guiderail. Therefore, the minimum lateral guiderail offset without curbing should be based on Figure 13-6B.

13-6.04 Curbs and Curb/Barrier Combinations

When the tires of an errant vehicle strike a curb, the impact tends to bounce the vehicle upwards which may contribute to vaulting or penetration of the rail. This problem is increased when curbs are located between 1 ft and 10 ft in front of guiderail. When the destabilizing or vertical bounce of the vehicle acts in combination with the longitudinal barrier, undesirable results may occur. Crash tests have shown that the use of any barrier/curb combination where high-speed, high-angle impacts are likely should be discouraged. Where there are no feasible

Design Speed (mph)	Flare Rate for Barrier Inside Shy Line	Flare Rate for Barrier Beyond Shy Line	
		Rigid	Flexible/Semi-Rigid
30	13:1	8:1	7:1
40	16:1	10:1	8:1
45	18:1	12:1	10:1
50	21:1	14:1	11:1
55	24:1	16:1	12:1
60	26:1	18:1	14:1
70	30:1	20:1	15:1

BARRIER FLARE RATES

Figure 13-6A

Design Speed (mph)	Shy Line Offset (ft)
30	3.5
40	5.0
45	5.8
50	6.5
55	7.3
60	8.0
70	10.0

MINIMUM LATERAL OFFSET FOR GUIDERAIL WITHOUT CURBING
(from Edge of Traveled Way)

Figure 13-6B

alternatives, the designer should consider using a curb no higher than 4 in and consider stiffening the guardrail to reduce potential deflection. Other measures that usually prove satisfactory are bolting a W-beam to the back of the posts, reducing post spacing, double-nesting the rail or adding a rubrail. A case-by-case analysis of each situation considering anticipated speeds and consequences of vehicular penetration should be used.

The following criteria will apply for curb and curb/barrier combinations on high-speed (V $\geq$ 45 mph) roadways:

1. Curbing of any height is not permitted for use in conjunction with either concrete barriers or attenuating devices. See Bridge Design for exceptions at abutments.

2. Curbing should not be used in gore areas or wide medians. Existing curbing should be removed wherever practical.

3. When curbing is necessary for drainage control on high-speed roadways, a maximum height of 4 in may be used. W-beam guiderail will be installed with the face of the rail flush with the face of the curbing and the height of the rail measured from the gutter line. However, where railing is behind a sidewalk, measure it from the top of the sidewalk. See the *Connecticut Standard Drawings* for 4-in park curbing.

4. Curbing must not be placed along high-speed highways to shield pedestrians. Curbing is ineffective as a barrier and, at high speeds; vehicles that contact curbing are at an increased risk of departing the traveled way and encroaching into areas frequented by pedestrians.

5. Due to the propensity for vehicles to vault or roll over W-beam guiderail when used with curbing, the allowable guiderail deflection should not exceed 4 ft.

6. Three cable guiderail when used with curbing shall be placed a maximum of 1 ft from the face of curbing. The installation height will be measured from the pavement surface.

7. See the Guiderail Procedure and *Connecticut Standard Drawings* for transition curbing at bridge parapets.

The following criteria will apply to curb and curb/barrier combinations on low-speed (V < 45 mph) roadways:

1. Curbing of any height is not permitted for use in conjunction with either concrete barriers or attenuating devices. See Bridge Design for exceptions at abutments.

2. For general guidance, curbs may be used in low-speed situations where justified by present or anticipated pedestrian traffic. Use of vertical faced curbing should be avoided. The preferred curb choice is the park curb.

3. When curbing is used in conjunction with any guiderail type, the face of rail should be placed no more than 1 ft from the face of curbing.

4. When a sidewalk is present, the guiderail should typically be placed with the rail element flush with the back of the sidewalk.

13-6.05 Placement on Slopes

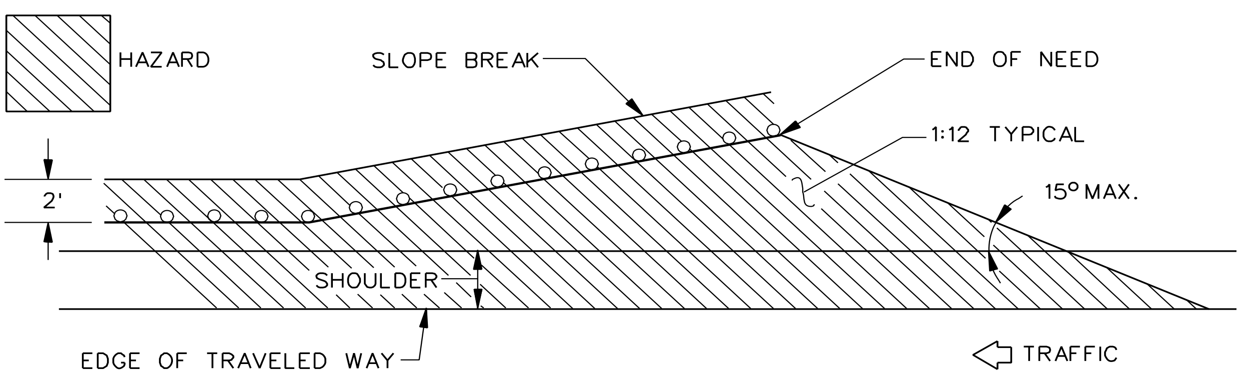
If guiderail is improperly located on slopes, an errant vehicle could impact the rail too high or too low, causing destabilization of the vehicle. Therefore, the following criteria will apply:

1. W-beam guiderail should not be placed on a cut or fill slope steeper than 1:10. This also applies to the areas in front of the flared section of guiderail, if used. See Figure 13-6C.

2. Three cable guiderail may be placed on slopes between 1:10 and 1:6 when needed (i.e., barn-roof sections). It has been demonstrated through crash test evaluation that the cable engages vehicles better than other rail systems for this range of slopes.

13-6.06 Minimum Length and Guiderail Gaps

Short runs of guiderail have limited value and should be avoided. As a general rule, the three cable guiderailing should have at least 200 ft of length at full height. Type R-B 350 guiderail should have at least 85 ft of length at full height. Likewise, short gaps between runs of guiderail are undesirable. In general, gaps less than 200 ft between guiderail termini should be connected into a single run. However, this may not be possible on roadways with numerous driveway openings. Whenever possible, removal of the need for guiderail should be investigated to prevent short runs of guiderail or multiple short gaps of guiderail.



Note: When the hazard being shielded is greater than or equal to 15 ft from the traveled way, a slope of 1:6 in front of the rail may be considered. Provide a 1:10 maximum slope in all other cases; see the AASHTO Roadside Design Guide, Section 5.6.2.2.

SLOPES IN FRONT OF GUIDERAIL

Figure 13-6C

13-6.07 Treatment at Intersecting Roads and Driveways

Guiderail runs on non-freeway facilities must often be interrupted by intersecting roads and driveways. Figure 13-6D presents the typical treatment that should be used for terminating guiderail at intersecting roads and driveways. When using this figure, the designer should consider the following:

1. Studies have shown that there is an increased chance for vehicles to impact this type of guiderail installation at 90° Because of the potential for high-angle impact; three cable guiderailing should not be used.

2. The guiderail should be flared away from the main road to allow sufficient sight distance for vehicles on the intersecting road or driveway.

3. The slope between the main line and the guiderail should not exceed 1:10.

4. The end treatments should meet the criteria in Section 13-7.0.

5. The designer should ensure that the treatment reflects the applicable safety considerations for the intersecting road or driveway.

6. On intersecting roads and driveways with design speeds of $V \leq 50$ mph, designers should investigate the possibility of using the “Washington Curved Guiderail Treatment.” See Appendix A for design criteria and the *Connecticut Standard Drawings*.

7. Curbing should not be used in the area where guiderail is flared for the sight line.

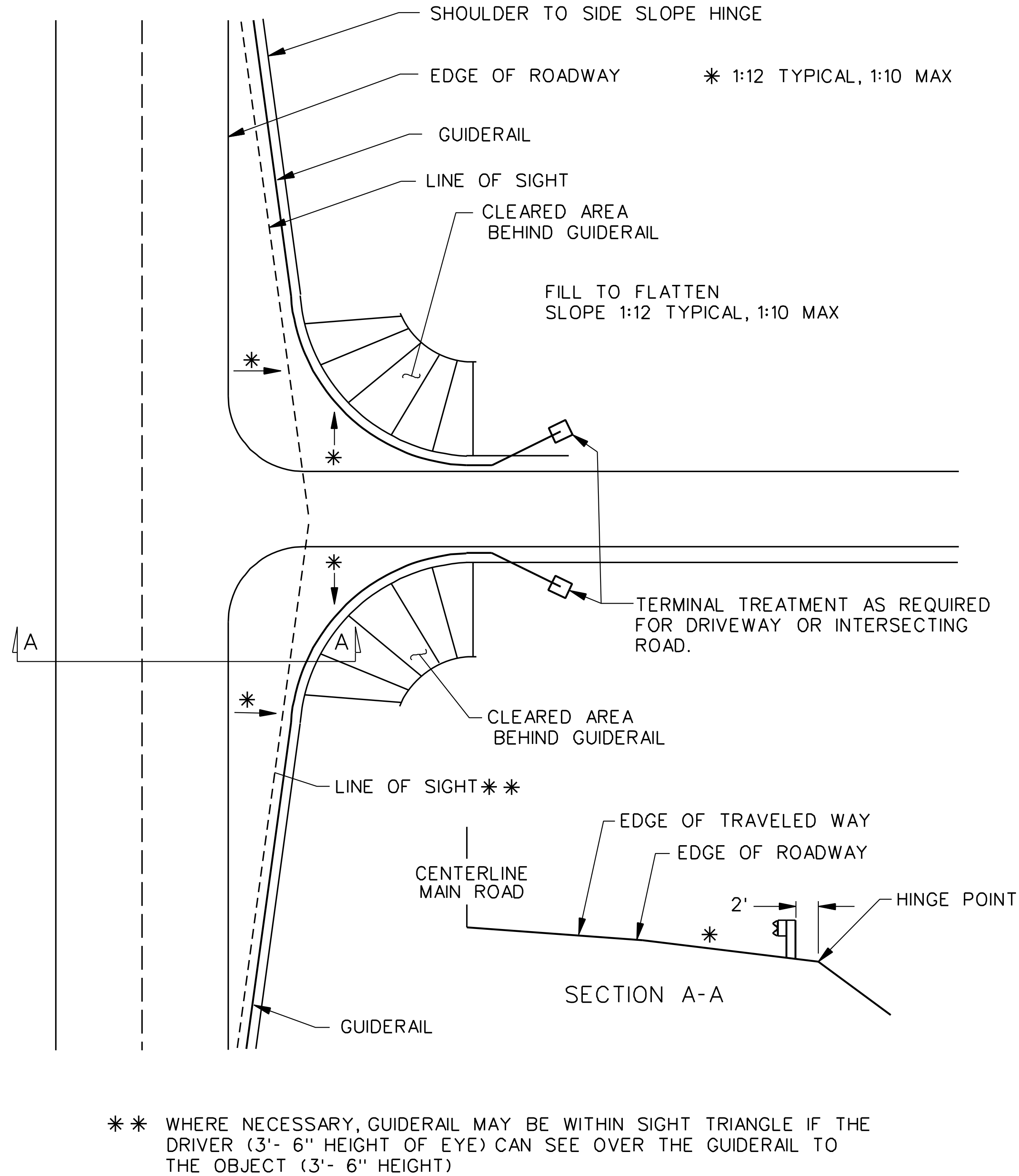
13-6.08 Guiderail Curvature Criteria

Guiderail must sometimes be placed on the inside of radii at, for example, interchange ramps. This condition presents a problem when standard post spacing’s are used because a vehicle may impact the guiderail at close to 90° Therefore, the post spacing on the inside of radii must be decreased. The criteria for guiderail post spacing on the inside of radii is presented in Figure 13-6E.

13-6.09 Transitions

13-6.09.01 Transitions Within Same Type System

Where conditions allow, designers should always choose the guiderail with the largest dynamic deflection possible. The available distance between the guiderail and the hazard will govern this selection. However, there may be sites where this distance is interrupted by short sections where the available deflection distance is less. The desirable treatment, if practical, is to stiffen



Note: See Appendix A for the Washington Curved Guiderail Treatment for application at sharp radii where V ≤ 50 mph.

GUIDERAIL TREATMENT AT INTERSECTING ROADS AND DRIVEWAYS

Figure 13-6D

Radius of Curve	Curved Guiderail Treatment For ≤ 50 mph
R > 720 ft	3 cable @ 16-ft post spacing Type R-B 350
720 ft ≥ R ≥ 440 ft	3 cable @ 12-ft post spacing Type R-B 350
R ≥ 35 ft	Type R-B 350
R = 35 ft, 25.5 ft, 17 ft or 8.5 ft	Refer to Washington Treatment Details

Note: R-B 350 guiderail must be shop fabricated for radii less than or equal to 150 ft. Three cable guiderail should not be used for radii less than 440 ft. For radii less than 440 ft, use R-B 350.

CRITERIA FOR GUIDERAIL CURVATURE

Figure 13-6E

the existing guiderail by tightening up the post spacing through the section of reduced deflection distance. Transitions for metal beam rail are illustrated in the *Connecticut Standard Drawings*, and reduced post spacing for different rail types are listed in Figure 13-4D.

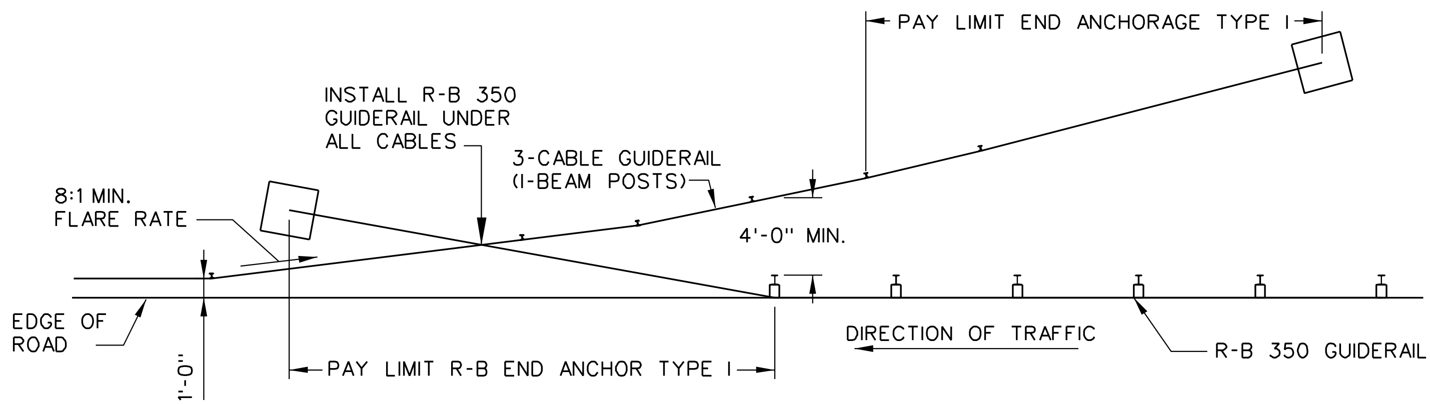
13-6.09.02 Transitions Between Systems

Figures 13-6F, 13-6G and 13-6H illustrate the various transition treatments between two different systems. Normally, overlap transitions between two different guiderail types are undesirable. However, they may be necessary, for example, when a new guiderail meets a different type of existing guiderail of considerable length. See the *Connecticut Standard Drawings* for illustrations of R-B 350 guiderail transitions to bridge parapets.

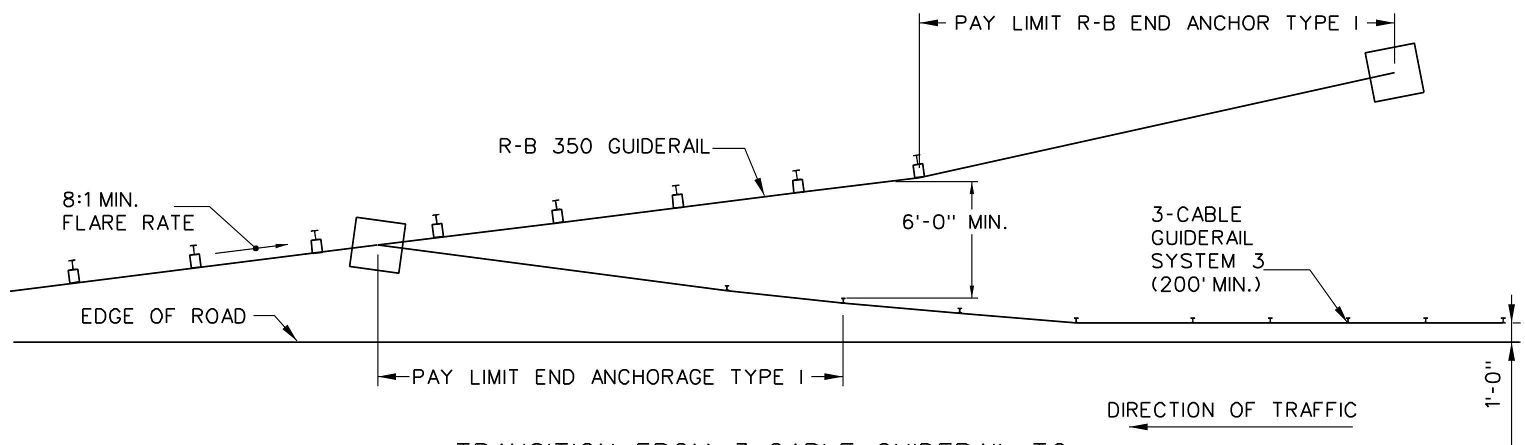
From	To	Transition By	Reference
R-B 350 R-B 350 R-B 350	Parapet/Barrier 3-cable R-I	Leading End Rail Overlap Rail system	Standard Drawings Figures 13-6G & 13-6H Standard Drawings
Parapet/Barrier	R-B 350	Trailing End Rail	Standard Drawings

GUIDERAIL TRANSITIONS

Figure 13-6F



TRANSITION FROM R-B 350 GUIDERAIL TO
3-CABLE GUIDERAIL

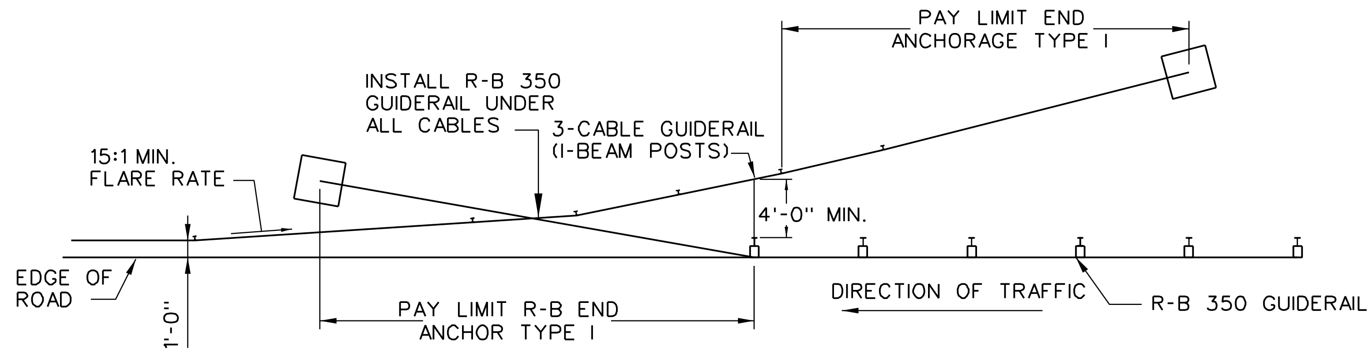


TRANSITION FROM 3-CABLE GUIDERAIL TO
R-B 350 GUIDERAIL

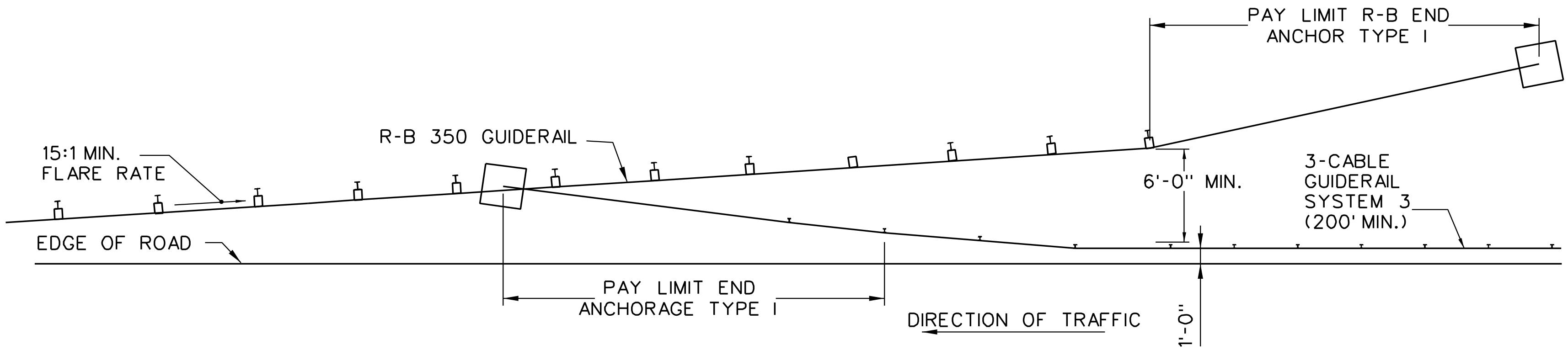
Note: Transitions are overlapped to prevent the errant vehicle from overrunning the lapped rail and being released into the area of concern. Grading in the transition area should be 1:12 typical, 1:10 maximum.

TRANSITIONS BETWEEN DIFFERENT RAIL TYPES
(V <45 mph)

Figure 13-6G



TRANSITION FROM R-B 350 GUIDERAIL TO
3-CABLE GUIDERAIL



TRANSITION FROM 3-CABLE GUIDERAIL TO
R-B 350 GUIDERAIL

Note: Transitions are overlapped to prevent the errant vehicle from overrunning the lapped rail and being released into the area of concern. Grading in the transition area should be 1:12 typical, 1:10 maximum.

TRANSITIONS BETWEEN DIFFERENT RAIL TYPES
(V $\geq$ 45 mph)

Figure 13-6H

13-6.10 Pavement for Railing

In general, herbicides will be used to control growth under the railing. However, bituminous concrete will be used under the railing 1) when the railing is within a public water supply watershed area, 2) at the approaches to bridges over streams and rivers for a minimum length of 50 ft. and 3) when the river or stream is less than 50 ft. from the edge of road and paralleling it. The application of herbicide is the responsibility of the Office of Maintenance and will not be included in construction contracts. Public water supply watershed areas can be located in the "Atlas of the Public Water Supply Sources and Drainage Basins of Connecticut," D.E.P. Bulletin No. 4.

Pavement for railing may be used under the W-beam End Terminals, as specified in the Guiderail Procedure. See the Department Standard grading details for impact attenuators.

13-6.11 Placement on High Fills with Sidewalk and Utility Pole Lines

Theoretically, the preferred location for guiderail is behind the sidewalk with the utility pole line located at the guiderail deflection distance plus 1 ft. In most locations, the pole would then be placed at least 15 ft from the edge of the roadway. This is beyond the practical distance for which utility lines can be easily maintained and would increase the likelihood of the lines being too close to buildings. In practice, the utility poles will usually be placed within a utility strip/snow shelf between the street and the sidewalk. In high-speed areas where there are few driveway breaks requiring guiderail between the street and the walk, consideration should be given to placing the rail adjacent to the curb and the utility poles immediately behind the walk. See Utility Pole Placement Policy in Section 13-2.04.

13-7.0 IMPACT ATTENUATORS AND END TREATMENTS

13-7.01 General

Impact attenuators may be categorized as either inertial or compression systems. Inertial systems are designed to transfer the kinetic energy of a vehicle to a series of yielding masses. Sand barrel arrays are a typical example. Compression systems are designed to absorb the energy of the vehicle by the progressive deformation or crushing of the elements of the system. W-beam end terminals are a typical example.

13-7.01.01 Definitions

Designers are encouraged to fully understand the following definitions before specifying impact attenuators:

1. Critical Impact Point (CIP). For a given test, the CIP is the initial point of vehicular contact along the longitudinal dimension of a feature judged to have the greatest potential for causing a failure.

2. Length of Need (LON). That part of a longitudinal barrier or terminal designed to contain and redirect an errant vehicle.

3. Impact Attenuators. A device designed primarily to safely stop a vehicle within a relatively short distance.

4. Redirective Impact Attenuator. A device designed to contain and redirect a vehicle impacting downstream from the nose of the cushion.

5. Non-Redirective Impact Attenuator. A device designed to contain and capture a vehicle impacting downstream from the nose of the cushion.

6. Gating Device. A device designed to allow controlled penetration of the vehicle when impacted between the nose and the beginning of the LON of the device.

7. Non-Gating Device. A device designed to contain and redirect a vehicle when impacted along its entire length.

13-7.01.02 Impact Attenuators

As with all roadside safety appurtenances, impact attenuators used on the State-owned highway system must satisfy NCHRP Report 350 criteria (TL-3 minimum). When determining the appropriate type of impact attenuator, the designer should refer to the latest Guiderail Procedure for Department-approved systems.

13-7.01.03 Impact Attenuator Selection

Impact attenuators are most often installed to shield fixed-point hazards that are close to the traveled way. Examples include exit gore areas, bridge piers and non-breakaway sign supports.

The selected impact attenuator must be compatible with the specific site characteristics. This includes a consideration of:

1. the width of the hazard to be shielded,
2. the need for redirective capability,
3. the anticipated frequency of impact,
4. any attenuation capacity after impact,
5. the initial cost of the system,
6. maintenance of the impact attenuator,
7. any required base structure,
8. any required transitions, and
9. any runout clear area required.

13-7.01.04 Impact Attenuator Design

Once an impact attenuator system has been selected, the designer must ensure that its design is compatible with the traffic and physical conditions at the site. All of the Department approved impact attenuators are patented; therefore, the designer should contact the manufacturer of the system for assistance. The following presents additional information on the design of impact attenuators:

1. <u>Deceleration</u>. For all safety appurtenances, the occupant impact velocity measured during full-scale crash tests determines acceptable vehicular deceleration. These are discussed in detail in NCHRP Report 350 *Recommended Procedures for the Safety Performance of Highway Features.* The impact attenuator should be designed to meet the recommended acceptance limits for deceleration.

2. <u>Impact Speed</u>. To determine the length and/or layout of an impact attenuator, the appropriate design speed must be selected. Figure 13-7A presents the criteria for selecting the initial impact speed for designing the impact attenuator.

3. <u>Placement</u>. Several factors should be considered in the placement of a impact attenuator:

    a. <u>Level terrain</u>. All impact attenuators have been designed and tested for level conditions. Vehicular impacts on devices placed on a non-level site could result in an impact at the improper height that could produce undesirable vehicular behavior. Therefore, the impact attenuator should be placed on a level surface or on a cross slope not to exceed 5%.

Highway Design Speed (V) (mph)	Impact Attenuator Impact Speed (mph)	
	Freeways	Non-Freeways
$V \geq 45$	60	60
$V < 45$	--	45

IMPACT SPEED FOR IMPACT ATTENUATORS

Figure 13-7A

b. Curbs. Curbs in front of or along the side of an impact attenuator can induce vehicular vaulting. This may result in impacts at an improper height or in other undesirable vehicular behavior. Therefore, no curbs shall be designed for new projects at proposed impact attenuator locations. On projects where existing impact attenuators are present with curbing, the curbing shall be removed and drainage redesigned where necessary.

c. Surface. A paved bituminous or concrete pad may be needed under some of the impact attenuators. The manufacturer's recommendations will prevail.

d. Elevated Structures. There is some concern that the unanchored inertial systems may walk or crack due to the vibration of an elevated structure. This could adversely affect its performance. Therefore, designers should locate gore areas, etc., to avoid the use of impact attenuators on a structure.

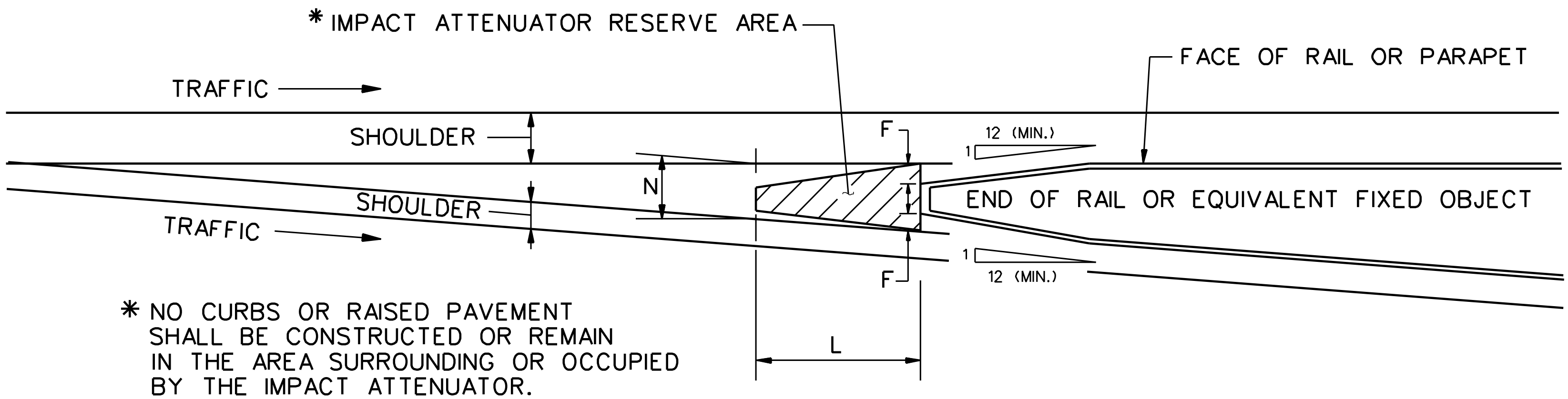
e. Reserve Area. The designer should, as early as practical in the project design process, determine the need for and approximate dimensions of an impact attenuator. This will avoid late changes that could significantly affect the project design. Figure 13-7B provides recommended criteria for the impact attenuator reserve area.

13-7.02 End Treatment Selection

Guiderail end treatments present a potential roadside hazard if not properly selected, designed and installed. Department policy is that all new end treatments installed on the State-owned highway system must meet the NCHRP Report 350 criteria (TL-3 minimum). This Section discusses those treatments that are acceptable for use.

13-7.02.01 End Treatment Design

For the leading ends of metal beam rail Type R-B 350 guiderail, the following will apply:



Design Speed on Mainline (mph)	Dimensions for Impact Attenuator Reserve Area (feet)								
	Minimum						Preferred		
	Restricted Conditions			Unrestricted Conditions					
	N	L	F	N	L	F	N	L	F
50	6	17	2	8	25	3	12	33	4
55	6	20	2	8	30	3	12	39	4
60	6	23	2	8	35	3	12	44	4
65	6	25	2	8	40	3	12	50	4
70	6	28	2	8	45	3	12	55	4

RESERVE AREA FOR IMPACT ATTENUATOR IN GORES

Figure 13-7B

1. End Anchorage Outside Clear Zone. The preferred end treatment is to flare the guiderail to outside the clear zone and use the End Anchorage Type I. See the *Connecticut Standard Drawings* for details of the Type I end anchorage.

2. Earth Cut Slope and Rock Cut Slope Anchorages. Wherever practical, use these anchorages for the R-B 350. They eliminate the possibility of an errant vehicle striking the terminal end or running behind the terminal. The *Connecticut Standard Drawings* illustrate the details for these anchorages with the R-B 350.

3. Terminal Within Clear Zone (NHS). If a crashworthy end terminal is needed to anchor W-beam guiderail within the clear zone, designers should choose an impact attenuator from the approved list in the latest Guiderail Procedure in Appendix A. When the recommended length of need is not attainable due to intersecting roads or driveways and when the use of an impact attenuator or three-cable guiderail is inappropriate, a radius rail with a Type II end anchor may be placed down the driveway. In some cases, an easement for placement of the anchor may be required. See Section 13-6.07 for details and sight line requirements.

4. Terminal Within Clear Zone (Non-NHS). As with NHS roadways, designers should strive to anchor W-beam guiderail by extending the anchor outside the clear zone and/or anchoring the end in an earth cut slope or rock outcrop. An impact attenuator may be used as a last option only if all grading requirements and design features can be obtained. Refer to Department grading plans for impact attenuators. If the above options are not appropriate, designers may consider regrading the roadside so that a proper anchor can be installed. See Figure 13-6C for guiderail treatment at intersecting roads and driveways.

For the trailing ends of metal beam rail Type R-B 350 guiderail, the following will apply:

1. Undivided Facilities (NHS). The above criteria for the approach ends of Type R-B 350 also apply to its trailing end on a two-way facility and on an undivided multi-lane facility.

2. One-Way Roadways (NHS and Non-NHS). These include interchange ramps and one roadway of a divided facility. In these cases, the trailing end of Type R-B 350 may be the End Anchorage Type I placed within the clear zone. The rationale is that the end anchorage cannot be impacted head on.

13-7.02.02 Three Cable Guiderail

It is not necessary to place the end anchorage outside of the clear zone. An End Anchorage Type I end treatment is used for three cable guiderail; see the *Connecticut Standard Drawings*.

13-7.02.03 Merritt Parkway Guiderail

See the *Connecticut Standard Drawings* and the latest Guiderail Procedure in Appendix A for acceptable end treatments.

13-7.02.04 Metal Beam Rail (Type MD-B 350)

The Department uses these types of terminal treatments for the Type MD-B 350:

1. End Anchorage Type I. This treatment is used when the median metal beam rail can be flared to a point outside the clear zone or to another safe location. The details for this terminal type are illustrated in the *Connecticut Standard Drawings*.

2. Terminal End Treatments. There are several types of special end treatments available for median metal beam rail. These end treatments are used where the terminal end for the median rail cannot be flared to a point outside of the clear zone (e.g., in narrow medians).

The selection of the appropriate end treatment will be based on a case-by-case assessment considering initial cost, maintenance, grading requirements, etc. See the Guiderail Procedure in Appendix A for the Department-approved list.

When the median rail extends down an on/off ramp to a T intersection, an MD-B End Anchorage Type I may be used. The anchor shall be placed so that the sight line is not compromised and that clear zone requirements for the intersecting road are met.

13-7.02.05 Concrete Median Barrier

A variety of situations exist on Connecticut roadways where the leading ends of concrete barriers require end treatments. See the Guiderail Procedure in Appendix A for the Department-approved impact attenuator list.

13-7.02.06 Metal Beam Rail (Type Box Beam)

When terminating box beam guiderail, the following will apply:

1. If the box beam guiderail end treatment is being installed within the design clear zone, use the WYBET impact attenuator.

2. If the box beam guiderail end treatment is being installed outside the design clear zone, see the *Connecticut Standard Drawings* for end treatment details.

13-8.0 REFERENCES

3. *Roadside Design Guide*, AASHTO, 2002.

4. G*uide for Selecting, Locating, and Designing Traffic Barriers*, AASHTO, 1977.

5. *A Supplement to A Guide for Selecting, Locating, and Designing Traffic Barriers*, Texas Transportation Institute, March, 1980.

6. *Safety Design and Operational Practices for Streets and Highways*, FHWA, May, 1980.

7. FHWA-IP-83-4 *A Procedure for Determining Frequencies to Inspect and Repair Highway Safety Hardware*, December, 1983.

8. Research Report 67-1 *New Highway Barriers, The Practical Application of Theoretical Design*, New York Department of Public Works, May, 1967.

9. NYSDOT-ERD-76-RR38 *Testing of Highway Barriers and Other Safety Appurtenances*, New York State Department of Transportation, December, 1976.

10. Transportation Research Record 970, “Development of Proposed Height Standards and Tolerances for Light-Post Traffic Barriers,” James E. Bryden, 1984.

11. “A Roadside Design Procedure,” James Hatton, Federal Highway Administration, January, 1974.

12. FHWA/NY/RR-80/83 *Crash Tests of Sharply Curved Light-Post Guide Rail*, New York State Department of Transportation, July, 1980.

13. NCHRP Report 150 *Effect of Curb Geometry and Location on Vehicle Behavior*, Transportation Research Board, 1974.

14. NCHRP Report 158 *Selection of Safe Roadside Cross Sections*, Transportation Research Board, 1975.

15. NCHRP Synthesis 66 *Glare Screen Guidelines*, Transportation Research Board, December 1979.

16. NCHRP Report 350 *Recommended Procedures for the Safety Performance of Highway Features*, Transportation Research Board, 1993.

17. *Impact Attenuators — Selection and Design Criteria*, FHWA, 1975.

18. “Impact Attenuators, Safety Systems,” Technical Notebook, Energy Absorption Systems, Inc.

Appendix A

Appendix A presents the following:

1. Guiderail Procedure.

2. FHWA Technical Advisory T5040.32 “Curved W-Beam Guardrail Installations at Minor Roadway Intersections.”

Guiderail Procedure

When the American Association of State Highway and Transportation Officials and Federal Highway Administration's (AASHTO-FHWA) agreement regarding the National Cooperative Highway Research Program (NCHRP) Report 350 was published in 1997, the Department developed a procedure for its implementation dated December 1, 1997. The following procedure will supersede that guiderail procedure.

It has always been Department practice to attempt to provide the traveling public with a forgiving roadside. Although a forgiving roadside is not always possible, every effort should be made to eliminate the need for railing. When all means to remove the need for railing have been exhausted, designers should refer to the following procedure and Chapter 13 of the Department's Highway Design Manual (HDM). When special instances arise that are not addressed in this procedure, the appropriate Division Manager must approve alternative designs.

Section 13-A.01: National Highway System (NHS) and State Roadways with Design Speeds ≥ 45 mph and/or Traffic Volumes > 6000 vpd and all Freeway Ramps

13-A.01.a **Railing:** All new roadside safety appurtenances installed on NHS and State roads, as noted above, must meet the testing criteria found in NCHRP Report 350 Test Level 3 (TL-3) or better.

1. When any of the longitudinal barriers requiring removal, as listed below, are within the limits of a project, and their need cannot be eliminated, the railing shall be replaced with a barrier chosen from the approved longitudinal barrier list:

Longitudinal Barriers Requiring Removal:
a) Two-cable on wood posts.
b) Three cable with steel brackets on steel or wood posts.
c) R-I W-beam guiderail on weak steel posts.
d) R-B and MD-B W-beam guiderails with the steel blockouts.

Approved Longitudinal Barriers:
a) Three Cable Guiderailing (I-Beam Posts), TL-3.
b) MD-I W-beam guiderail on weak steel posts, TL-3.
c) R-B 350 and MD-B 350 W-beam guiderail with polyethylene blockout, TL-3.
d) 45 in F-shaped Precast Concrete Barrier Curb (PCBC), TL-5.
e) 6 in x 6 in roadside box beam, TL-3.*
f) 6 in x 8 in median box beam, TL-3.*
g) Thrie-beam 350 guiderail with modified steel blockout, TL-4+. *
h) Innovative Barriers. See Section 13-A.01.e.

* Note: These barriers may only be used with the written permission of the Transportation Engineering Administrator.

Guiderail Procedure

2. New installations of R-I, R-B and MD-B guiderail are prohibited.

3. New R-B 350 guiderail including systems, anchors and transitions installed on limited access highways and ramps shall use 10 gauge W-beam rail elements. Standard Drawings have been revised to include this change.

4. Existing guiderail types R-I, R-B and MD-B shall be eliminated, replaced or converted to R-B 350 or MD-B 350. See Department Specifications.

5. Avoid gaps less than 200 ft between guiderail end anchors.

13-A.01.b Anchors:

1. Leading-end, turned-down end anchors, except three cable guide railing (I-Beam Posts), are no longer allowed within the clear zone. Refer to HDM Section 13-2 for clear zone applications. Existing leading end anchors within the limits of a project in the clear zone shall be either flared away from the roadway to meet clear zone requirements, anchored into an earth cut slope, attached to a rock face or, as a last option, installed with an impact attenuation system. When proposing an impact attenuation system, refer to the attached chart for design parameters and the Department's Standard Drawings for grading requirements. There shall be no curbing in front of, or fixed objects in the vicinity of, any impact attenuation system.

2. Remove all existing leading-end blunt ends and terminate the rail using an appropriate end treatment chosen from Section 13-A.01.b1 above.

3. Pavement for railing shall be used only within public water supply watershed areas and at the approaches to bridges over waterways. In all other areas and when the water course is greater than 50 ft from the road and paralleling it, use processed aggregate under railing. Some impact attenuators require a deck structure, and others may be installed with processed aggregate or pavement for railing.

4. Trailing-end, turned-down end anchors for W-beam guiderail may continue to be placed within the clear zone on divided or one-way roadways. On bi-directional roadways, the trailing-end, turned-down end anchor shall be placed outside the clear zone. The clear zone, in this case, is measured from the centerline of the road to the last post before the turndown. The concrete anchor for the turndown shall then be measured and placed as shown on the Department's Standard Drawings.

5. When the recommended length of need is not attainable due to intersecting roads or driveways and when the use of an impact attenuator or three cable guiderail is inappropriate, a radius rail with a Type II end anchor may be placed down the driveway. In some cases, an easement for placement of the anchor may be required. Refer to the HDM Section 13-6.07 for details and sight line requirements.

Guiderail Procedure

13-A.01.c Guiderail to Bridge Rail Transitions:

1. The R-B 350 transition to a vertical-shaped bridge parapet and a Jersey-shaped bridge parapet have successfully met NCHRP Report 350 guidelines.

2. All existing bridge rail transitions not meeting NCHRP Report 350 requirements within the limits of a project shall be converted to one of the R-B 350 guiderail transitions. A deficient approach guiderail is one where the rubrail is not attached to the parapet, where the system improperly transitions strength, or where the system is completely unattached.

3. The R-B 350 trailing-end bridge attachment shall only be designed for single-direction roadways. All four corners of a bridge on a bi-directional roadway shall be treated as an approach end regardless of clear zone requirements.

13-A.01.d Curbs and Curb/Barrier Combinations:

1. The standard curb used on high-speed, high-volume NHS or State roadways shall be the 4-in bituminous concrete park curbing shown in the Department Standard Drawings.

2. When W-beam guiderail is installed without curb, it may be placed 1 ft or more from the edge of pavement only on slopes 1:10 or flatter. If the rail is installed within 2 ft of the edge of shoulder, the rail height is measured from the shoulder slope extended to the rail. If the rail is installed beyond 2 ft from the edge of shoulder, the rail height is measured from the ground directly below the rail. Deflection requirements must be adhered to at all times.

3. When W-beam guiderail is installed with curb, install it flush with the face of curb and measure the rail height from the pavement surface. If curb and sidewalk are present and the rail is placed behind the sidewalk, measure the rail height from the top of sidewalk. Deflection requirements must be adhered to at all times.

4. The use of granite stone transition curbing (gstc) has been discontinued. Existing gstc may remain in place if a 4-in reveal at the parapet can be obtained to accommodate the R-B 350 Jersey-shaped Attachment. If the existing curb does not have a 4-in reveal, replace it with the Department standard curb. When installing the R-B 350 Vertical Shape Attachment, measure the rail height from the top of curb.

13-A.01.e Innovative Barriers:

1. Section 328 of the NHS Act entitled Roadside Barrier Technology requires that 2.5% of all barrier installed on the NHS beginning with calendar year 1996 to be innovative. The term barrier, as used in Section 328, includes both temporary and permanent median and roadside barrier, but excludes guiderail. The following is a list of NCHRP Report 350 approved innovative barriers. Designers should review and investigate the possibility of using them in their projects:

Guiderail Procedure

Innovative barriers for Permanent Locations:
42 in high (or higher) Jersey-Shaped PCBC.
42 in high (or higher) F-Shaped PCBC. (Dept. standard is 45 in)
42 in high (or higher) Vertical-Shaped PCBC.
42 in high (or higher) Single-Sloped PCBC.

13-A.01.f Concrete Barriers:

1. Due to the superior performance during crash tests, FHWA has deemed the F-Shape PCBC as the preferred barrier shape. Therefore, 45-in F-Shape PCBC shall be used for new construction to provide positive median separation on limited access highways or when needed on the roadside. Replacement of existing Jersey Shape PCBC within the limits of a project is not required.

2. Temporary median Jersey-shaped PCBC may continue to be used for maintenance and protection of traffic during construction.

13-A.02 Merritt Parkway

13-A.02.a Railing:

1. The Merritt Parkway Guiderail (MPGR) has successfully met NCHRP Report 350 TL-3 guidelines and is approved exclusively for use on the Merritt Parkway. Any existing longitudinal barrier requiring replacement within the limits of a project shall be replaced with the MPGR. Refer to Section 13-A.01.a for the list of longitudinal barrier requiring replacement.

13-A.02.b Anchors:

1. A crashworthy end treatment is not available for MPGR. Use one of the following applications to anchor the leading-end:

a) Anchor the rail to a rock face.
b) Bury the anchor in an earth cut slope.
c) Place the anchor outside the clear zone and bury the end.
d) Bury the anchor in a built-up berm. (Use only as a last option.)

13-A.02.c Guiderail to Bridge Rail Transitions:

1. The MPGR transition to a bridge rail has been successfully crash tested to meet NCHRP Report 350 TL-3 guidelines. It was tested with gstc and is currently the only place where new gstc can be installed. Refer to Department Standard Drawings and the HDM Sections 13-4 and 13-5 for more information.

Guiderail Procedure

13-A.03 State Roadways with Design Speeds < 45 mph and Traffic Volumes < 6000 vpd

13-A.03.a Railing:

1. Existing metal beam rail (type R-I and R-B) does not need to be replaced provided that it meets length of need and deflection requirements. The rail shall be extended if the length of need is inadequate. All other new installations of guiderail should meet the testing criteria in NCHRP Report 350.

2. Replace rail such as two-cable on wood posts and three cable with steel brackets on wood or steel posts according to Department standards, even if the run of rail extends beyond the project limits. If obsolete rail extends down a municipally maintained roadway, the Engineer may investigate transition between two rail types along the local road.

13-A.03.b Anchors:

1. Review existing anchors for location and type. Extend the anchor to meet clear zone requirements or anchor it into an earth cut slope or rock face. Use an impact attenuator only if all grading requirements and design features can be obtained. Refer to standard grading plans for proper installation. If the railing can be extended up to an additional 200 ft to provide proper anchorage, this should be done instead of installing an impact attenuator. Types R-I and MD-I guiderail needing an impact attenuator will require 25 ft of strong post transition before installing the impact attenuator.

2. Do not terminate guiderail at a second rail type unless a transition meeting Department standards can be applied. Refer to HDM Section 13-6.09.02 and Figure 13-6G. Never transition or terminate guiderail at a critical juncture such as at the radii of intersections.

3. If the above options are not appropriate, designers may consider regrading the roadside so that a proper anchor can be installed. Refer to Figure 13-6D in the HDM for guiderail treatment at intersecting roads and driveways.

13-A.03.c Guiderail to Bridge Rail Transition:

1. Unconnected top rail and/or rubrail for bridge-approach guiderail transitions shall be connected with an approved transition design meeting the requirements of NCHRP Report 350. See Department Standard Drawings. Existing bridge-approach guiderail transitions for types R-I or R-B are acceptable provided any rubrail is also attached.

Guiderail Procedure

13-A.04 Scenic Roadways

1. For installations on scenic roads, the designer will have the option of using ASTM A-588 steel, “weathering steel” rail elements and posts for metal beam rail, and weathering steel posts for three cable guiderail (I-beam posts). Where there is a large body of water, such as major rivers and lakes adjacent to a scenic roadway or within the roadway fill slope, the designer has the option of using galvanized or weathering steel box beam rail elements and posts. If the body of water is a potable reservoir, Section 13-3.08 of the HDM governs.

13-A.05 Local Roadways

1. Municipalities are encouraged to use current Department guiderail standards and procedures for their roadside safety appurtenances. Refer to Chapters Two, Four, Five and Thirteen of the HDM.

13-A.06 General

1. When a designer considers using three cable guiderail (I-beam posts), crash history should be investigated. If the crash history shows a significant number of crashes have occurred, designers should consider using R-B 350 guiderail instead. In this case, R-B 350 guiderail may be more appropriate because it may remain in service after a hit whereas the three cable guiderail may not.

Guiderail Procedure

CHARACTERISTICS OF IMPACT ATTENUATION SYSTEMS
December 2006
ALL SYSTEMS HAVE FHWA APPROVAL PER NCHRP REPORT–350 TEST LEVEL III

System	Manufacturer or Distributor	W-beam End Terminal	Crash Cushion	Hazard Location	Trans. to Rigid System Required	Std. Width	Std. Length	Deck Structure Required	Bi-direct Capable	Redirect Capable	Comments
TYPE A IMPACT ATTENUATION SYSTEMS											
FITCH UNIVERSAL MODULE BARRELS	Distributed by TRANSPO 1-800-321-7870	no	yes	Roadside, Median & Gore	no	6.5' to unlimited	18' to 40'	no	yes	no	Primarily used as a temporary barrier
ENERGITE III (BARRELS)	Distributed by TRANSPO 1-800-321-7870	no	yes	Roadside, Median & Gore	no	6.5' to unlimited	18' to 40'	no	yes	no	Primarily used as a temporary barrier
TYPE B IMPACT ATTENUATION SYSTEMS (TANGENTIAL)											
SKT-350	Distributed by Road Systems Inc. 1-815-464-5917	yes	no	Roadside and *Median	yes	2'	50'	no	yes only if head of system is placed outside clear zone for opposing direction of traffic	yes	*Use in a median where the opposing travelway is > 30' away. Site grading req'd.
ET-2000	Manufactured by Syro/Trinity 1-800-321-2755	yes	no	Roadside and *Median	yes	2'	50'	no	yes only if head of system is placed outside clear zone for opposing direction of traffic	yes	*Use in a median where the opposing travelway is > 30' away. Site grading req'd.
BEAT	Distributed by Road Systems Inc. 1-815-464-5917	no	no	Roadside	yes	6" Box Beam with Impact Head at a 50:1 offset	14'	no	yes only if head of system is placed outside clear zone for opposing direction of traffic	yes	This system is used to terminate a 6" x 6" Box Beam Guiderail. Specific grading and material specifications req'd.
WY-BET	Manufactured by Syro/Trinity 1-800-321-2755	no	no	Roadside	yes	6" Box Beam with Impact Head at a 50:1 offset	48'-2"	no	yes only if head of system is placed outside clear zone for opposing direction of traffic	yes	This system is used to terminate a 6" x 6" Box Beam Guiderail. Specific grading and material specifications req'd.
TYPE B IMPACT ATTENUATION SYSTEMS (FLARED)											
FLEAT 350	Distributed by Road Systems Inc. 1-815-464-5917	yes	no	Roadside	yes	2'	37.5'	no	no	yes	W-beam Terminal site grading required.
SRT - 350 (Ross-350)	Manufactured by Syro/Trinity 1-800-321-2755	yes	no	Roadside	yes	18”	37.5'	no	no	yes	*W-beam Terminal site grading required

Guiderail Procedure

CHARACTERISTICS OF IMPACT ATTENUATION SYSTEMS
December 2006
ALL SYSTEMS HAVE FHWA APPROVAL PER NCHRP REPORT–350 TEST LEVEL III

System	Manufacturer or Distributor	W-beam End Terminal	Crash Cushion	Hazard Location	Trans. to Rigid System Required	Std. Width	Std. Length	Deck Structure Required	Bi-direct Capable	Redirect Capable	Comments
TYPE B IMPACT ATTENUATION SYSTEMS (MEDIAN/GORE)											
BRAKE-MASTER	Distributed by TRANSPO 1-800-321-7870	yes	yes	Roadside, *Median and Gore	yes	2'	32'-8"	yes	yes	yes	*Median width 20' or more. Site grading req'd.
C-A-T	Manufactured by Syro/Trinity 1-800-321-2755	yes	yes	Roadside, Median and Gore	yes	2.3'	30'	no	yes	yes	Site grading req'd.
ADIEM 350	Manufactured by Syro/Trinity 1-800-321-2755	no	yes	Roadside, Median and Gore	yes	2.3'	30'	yes	yes	yes	Use to shield fixed objects 2' wide.
BEAT-MT	Distributed by Road Systems Inc. 1-815-464-5917	no	no	Roadside, Median and Gore	yes	8" Box Beam with impact head at a 50:1 offset	32'-3"	no	no	yes	This system is used to terminate a 8" x 6" Box Beam Guiderail. Specific grading and material specifications req'd.
WY-BET (MD)	Manufactured by Syro/Trinity 1-800-321-2755	Box Beam Terminal	no	Roadside, Median and Gore	yes	8" Box Beam with impact head at a 50:1 offset	48'-2"	no	no	yes	This system is used to terminate a 8" x 6" Box Beam Guiderail. Specific grading and material specifications req'd.
TYPE B IMPACT ATTENUATION SYSTEMS (NON-GATING)											
REACT 350 Family	Distributed by TRANSPO 1-800-321-7870	yes	yes	Roadside, Median & Gore	yes	3' to 10'	15.5' to 30.5'	yes	yes	yes	Primarily used in locations where a high # of accidents have occurred on high speed high volume roadways
SCI100GM Family	Distributed by Onsite Inc. 1-860-669-3988	Yes	Yes	Roadside, Median & Gore	no if under 24'-9" and no reverse direction traffic	2' to 10'	21'-6" to 47'	Yes	Yes	Yes	Primarily used in locations where a high # of accidents have occurred on high speed high volume roadways
QUAD-GUARD Family	Distributed by TRANSPO 1-800-321-7870	yes	yes	Roadside, Median & Gore	yes	2' to 7.5'	5.7' to38.7'	yes	yes	yes	Primarily used to shield fixed objects
TAU II	Barrier Systems 1-856-424-8186	yes	yes	Roadside, Median & Gore	yes	2'	5.3' to 28'	yes	yes	yes	Primarily used to shield fixed objects
TRACC	Manufactured by Syro/Trinity 1-800-321-2755	yes	yes	Roadside, Median & Gore	yes	2.6'	20'	yes	yes	yes	Unit is shipped completely assembled
TYPE C or NC IMPACT ATTENUATION SYSTEMS											
CIAS	Ram Welding Co. Naugatuck CT. 1-203-729-2289	no	yes	Roadside, Median & Gore	Back up Support Required	6.5'	18.25'	yes	yes	yes	Non-Proprietary wide crash cushion
NCIAS	Ram Welding Co. Naugatuck CT. 1-203-729-2289	no	yes	Roadside, Median & Gore	Back up Support Required	3'	30'	yes	yes	yes	Non-Proprietary narrow crash cushion

TECHNICAL ADVISORY

CURVED W-BEAM GUARDRAIL INSTALLATIONS AT MINOR ROADWAY INTERSECTIONS

T 5040.32
April 13, 1992

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1. PURPOSE. To transmit information on two different operational designs of curved guardrail for radii between 8½ and 35 feet, as well as a specialized application of an 8½ foot radius curved guardrail. These new designs have been successfully crash tested and are acceptable for new construction, as well as for improving safety at existing sites. These designs are most appropriate for use on low volume highways.

2. BACKGROUND

   a. Often roads or driveways intersect a highway close to the end of a bridge or other immovable, restrictive features of the highway. To shield both the end of the bridge and the steep embankment, a strong post W-beam guardrail curved around the radius is typically used. Often, these installations have not been effective when the curved section of the barrier has been hit at higher speeds. A vehicle which impacts the barrier under such conditions will generally vault over or penetrate the guardrail; or, in the event that the vehicle is contained by the guardrail, the resulting decelerating forces often exceed the recommended limits for occupant safety. In many of these situations, it is not practical to change the site conditions by relocating the intersecting roadway further away from the bridge end in order to allow room for a standard approach guardrail. It was, therefore, necessary to develop a curved guardrail installation which would substantially improve the safety at these sites.

b. A cooperative research program between the Washington State Department of Transportation and the Federal Highway Administration was undertaken to design improved curved guardrail approaches and transitions. Subsequently, Yuma County in Arizona tested and developed a stiffer 8½-foot radius curved guardrail for sites where canals or other features such as drainage are close to the guardrail. Both systems are intended primarily for use on lower-speed through roadways intersected by low-speed, low-volume roads, driveways, or maintenance rights-of-way.

3. <u>SUMMARY</u>

a. This information can be used to enhance highway safety in certain locations where it is desirable to use curved strong post guardrail sections. This information is appropriate for use in new construction and for improving or upgrading existing curved guardrail installations.

b. The curved sections have been successfully crash tested within the performance limits detailed in this Technical Advisory. Crash tests also indicated that these sections have limitations and should not be used in situations which vary excessively from the conditions (such as grading, layout, or vehicle speed) under which these successful crash test results were obtained.

c. Adherence to detail is important. Guardrail section layout and construction details such as rates of curvature, use of breakaway Controlled Releasing Terminal (CRT) posts, adequate deflection zone behind curved guardrail and appropriate end anchorages are elements which can critically affect performance.

d. The recommended designs and details listed below are shown in the attached drawings:

(1) <u>Figure 1</u>: Curved W-Beam Guardrail Installation for an 8½-foot radius.

(2) <u>Figure 2</u>: Curved W-Beam Guardrail Installation for a 35-foot radius.

(3) <u>Figure 3a</u>: Special Anchor Details.

(4) <u>Figure 3b</u>: Special Anchor Details.

(5) <u>Figure 4</u>: Yuma County, AZ, Curved W-Beam Guardrail Installation for an 8½-foot radius.

4. RECOMMENDATIONS

a. The curved guardrail designs detailed in this Technical Advisory should be considered for use in new construction projects as appropriate. Existing curved guardrail installations may also be replaced or upgraded as the opportunity becomes available.

b. These curved guardrail designs are for radii of 8½ feet and 35 feet. Crash test results and technical experience indicate that this system will also perform satisfactorily with other intermediate radii as noted in the table on Figure 1. Situations which require a curved guardrail installation which falls beyond this range of radii should be designed individually and not subjected to a “make it fit” misapplication of these details.

5. RELATED TECHNICAL INFORMATION

a. The following details are essential to proper system performance in the field:

(1) Breakaway CRT posts are used within the curved “nose” of the guardrail installation. Wood blockouts are not used on the CRT posts. The W-beam rail in the curved area is attached directly to the CRT post with a button-head bolt which has no washer. This is done to have the posts break away in the curved nose area and thus separate from the rail. This minimizes rotation of the rail during impact and minimizes the likelihood that a vehicle will vault over the guardrail upon impact.

(2) For the 8½-foot radius layout (Figure 1), the guardrail is not bolted to the one CRT post at the center of the curved nose area. This allows the center post to easily separate from the guardrail upon impact, and facilitates guardrail deflection without having this bolt ripping or snagging the W-beam rail section.

(3) A flat approach to the curved guardrail installation is necessary in order to ensure proper performance of the system. The slope in front of the installation should not exceed 15:1. If the installation is on a superelevated section, analysis should be performed in order to evaluate the potential for vaulting of an errant vehicle.

(4) The embankment slope should break at least 2 feet behind the post (so that the post will have adequate bearing strength when hit). It is desirable that the embankment slopes behind the guardrail not be steeper than 2:1. Successful crash tests were done on installations with 2:1 slopes behind the guardrail.

(5) Considerable deflection of the W-beam guardrail can be expected with higher speed impacts on the curved guardrail portion of the installation. Therefore, the

area behind the curved portion of the guardrail, shown as the cross-hatched areas on Figures 1, 2 and 4, must be kept free of fixed objects.

b. These curved guardrail installations are not appropriate for use in all situations. To avoid misapplication, the designer should be aware of the following limitations:

(1) When used in close proximity to a bridge with a rigid bridge rail, these design layouts require an adequate space between the curved guardrail installation and the bridge end (approximately 25 feet) to place a crashworthy W-beam transition from the W-beam guardrail to a rigid bridge rail.

(2) Since the special end anchor shown in Figures 3A and 3B has not been crash tested as a guardrail terminal, its use should be limited to low-speed, low-volume facilities with a stop condition such as intersecting driveways or service-type roadways. For most intersecting public highways, the curved guardrail installation should be either terminated along the intersecting roadway with an acceptable terminal system, or connected to an existing guardrail system.

(3) The special end anchor system was developed for use when it is necessary to end the guardrail system immediately after the curved section. This end anchor uses many components from the breakaway cable terminal design. It also includes another cable to connect the steel foundation of the next-to-last post to the end post anchoring cable system. One novel feature incorporated is a pivoting pipe section which is placed over the end post and improves rail performance by allowing it to swivel as it is deflected by a car. This special end anchor is not a crashworthy terminal for high speed highways. Therefore, as stated previously, its use should be limited to driveways or service roadways.

(4) In the high speed crash tests, some heavy debris was observed flying about in the area behind the impact. Judgment must be used when installing these sections where people are likely to be present in the area behind the curved section.

c. Curved guardrail installations of the Washington State design having radii of 8½ feet and 35 feet were successfully crash tested, but it should be noted that the 35-foot radius installation did not perform adequately when impacted at 60 MPH by a large vehicle (4740 lbs.). Satisfactory results were obtained for the 35-foot radius installation when a test was performed at a reduced speed of 50 MPH with the large vehicle. Two intermediate radii (17 feet and 25½ feet) are provided in Figure 1. Installations having a different radius between 8½ feet and 35 feet must be specially detailed so as to use only full lengths of W-beam rail, and to shop bend only full sections of rail. Any such intermediate radius designs must incorporate all other critical details and post types and locations as shown on the attached Figures 1 and 2 in order to be considered acceptable.

(1) It is important to note that the Yuma County design shown in Figure 4 was successfully crash tested at 50 mph. Radii larger than 8½ feet should not be used without further testing.

(2) All of the attached designs are based on an intersection angle of 90 degrees. If field conditions vary excessively from 90 degrees, it will be necessary to specially detail a curved guardrail section so that the curved rails will fit the intersection geometry, and that only full sections of W-beam rail will be shop bent for installation.

d. The attached drawings, in a format suitable for use on the Intergraph CAD system, are available from the Federal Highway Administration, Office of Engineering, Geometric and Roadside Design Branch, HNG-14, 400 Seventh Street, S.W., Washington, D.C. 20590.

/s/ Thomas O. Willett

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Director, Office of Engineering

/s/ R. Clarke Bennett

R. Clarke Bennett
Director, Office of Highway Safety