FDM 11-45-1 Traffic Barriers and Crash Cushions

October 5, 2011

FDM 11-45-1 is in the process of being rewritten and reorganized. As new guidance is published in FDM 11-45-2, it will supersede guidance in FDM 11-45-1.

1.1 Introduction

The principal reference for the development of roadside designs and the application of traffic barriers and crash cushions is the AASHTO Roadside Design Guide. This procedure will serve to supplement this reference with guidance specific to roadside design for WisDOT projects.

The Standards Development Engineer may be contacted for further guidance or information about the contents of this procedure (608) 266-2842.

1.2 Clear Zone Concept

Roadsides shall be designed to provide a reasonable opportunity for recovery of out-of-control vehicles. Ideally, this recovery area or "clear zone" should be free of obstacles and be reasonably flat. Width requirements for clear zones vary depending on traffic volume, design speed and side slope. Clear zone width requirements for new construction/reconstruction projects are included in FDM 11-15-1. The distances obtained from the curves and tables in this procedure represent the approximate center of a range of clear zone widths to be considered and are not precise distances to be held as absolute. Clear zone width requirements for resurfacing, restoration and rehabilitation (3R) projects are included in FDM 11-40-1. The clear zone widths prescribed represent minimum values; wider clear zones should be provided on 3R projects when practicable.

Roadside design should focus on the area within the clear zone but should not exclude consideration of any significant hazards outside this area.

1.3 Warrants

Roadside hazards that cannot be removed from the clear zone or otherwise made safe should be shielded by roadside barrier and/or crash cushions when cost effective and feasible considering specific site conditions and project circumstances.

Shielding hazards with roadside barrier or crash cushions should be considered only after determining that the following design options are not feasible:

- Removing the obstacle or redesigning it to be traversable.
- Relocating the obstacle to a point where it is less likely to be hit.
- Using a breakaway device to reduce the severity of the obstacle.

1.3.1 Roadside Barriers

Warranting information for roadside barriers is included in the Roadside Design Guide in the following figures and tables:

1. Page 5-3, Figure 5.1, Warrants for Fill Section Embankments.
2. Pages 3-3 through 3-5, Figure 3.1, Clear Zone Distance Curves; Table 3.1, Clear Zone Distances; and Table 3.2, Horizontal Curve Adjustments. These figures and tables are also included in FDM 11-15-1. Note: a clear zone width obtained from these curves and tables represents the approximate center of a range of widths to be considered and not a precise distance to be held as absolute.
3. Page 5-5, Table 5.1, Barrier Warrants for Non-traversable and Fixed Object Hazards.

1.3.2 Median Barrier

Figure 1.1 provides warranting criteria for the application of median barrier for new construction. Generally, the warrants are based on the probability of an out-of-control vehicle crossing the median and colliding with a vehicle in the opposing lane. This probability increases for higher ADT and narrower medians.

1.3.3 Median Barrier is warranted on new freeway construction:

- If median width < 60 feet, and the combination of Design ADT and median width falls within the area of Figure 1.1 which indicates that median barrier is warranted.

- To shield roadside hazards within the clear zone.

For situations other than new freeway construction, evaluate the need for median barrier on a case-by-case basis.

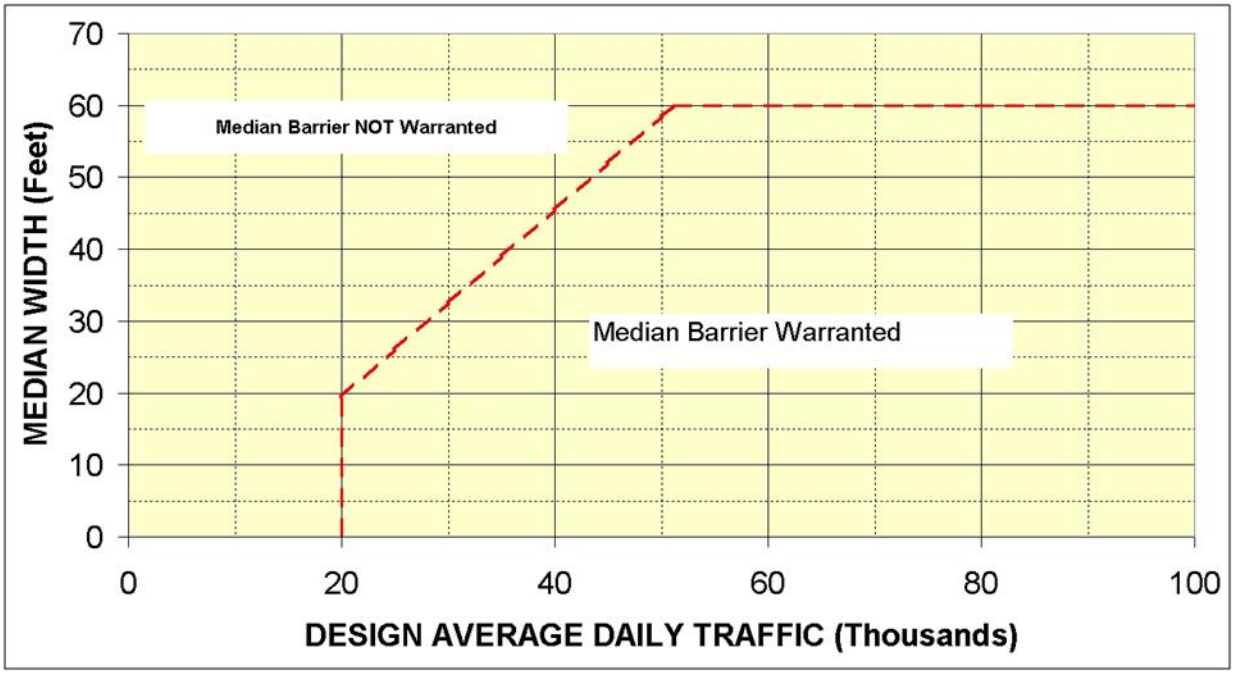

Figure 1.1. Freeway Median Barrier Warrants for NEW Construction *

* DO NOT USE this figure for determining allowable median width.

1.4 Design Application

Do not overlook the value of making mainline cross-drainage structures traversable through the use of pipe grates. Refer to the Roadside Design Guide, January 1996, pages 3-16 through 3-18 for pipe spacing and pipe material requirements. If mainline cross drains cannot be made traversable then shield them with beam guard.

1.4.1 Beam Guard End Treatments

The end(s) of traffic barrier exposed to oncoming traffic should reduce the chance to spear, vault, or roll a vehicle for head-on or angled impacts. In addition, the ends of steel plate beam guard must be anchored for the barrier to develop full tensile strength and re-directive capacity.

The preferred standard end treatment for the approach end of Steel Plate Beam Guard is an Energy Absorbing Terminal (EAT). There are two proprietary terminal items listed in FDM 19-1-5. This design is illustrated on Standard Detail Drawings SDD 14B24 and SDD 14B44.

The Energy Absorbing Terminal is designed to dissipate energy by reshaping w-beam guardrail as the extruder head is forced along the length of rail by the impacting vehicle. However, for angle hits on the end of the extruder, the system is designed to pivot or “gate” and allow the impacting vehicle to pass through to the back side of the barrier. When gating occurs, a clear, traversable runout is important behind the barrier system to allow the vehicle to come to a safe stop. When the extruder head is struck head-on or only at a slight angle, the vehicle may stay engaged to the extruder head for the entire deceleration. While the terminal is capable of absorbing tremendous amounts of energy through the reshaping of w-beam over the entire length of the terminal, many angle hits will result in only a short section of w-beam to be reshaped before the vehicle passes behind the extruder head and onto the run-out area.

WisDOT policy is to provide the Energy Absorbing Terminal on the traffic approach end of beam guard located within the clear zone of highways. Refer to FDM 11-45-2.5.4 to use down turn end treatments (SDD 14B17).

A Type 2 anchorage should be specified for the downstream traffic end of beam guard on divided highways and one-direction interchange ramps.

1.4.2 Special Situations

1.4.2.1 Short Radius

When there is insufficient space to provide the recommended length of beam guard between a structure and a side road (see Figure 1.2) consider the following.

1. If the structure is a box culvert with wing walls, provide a pipe grate between the wing walls to, and possibly beyond the theoretical clear zone. Provide about 2 ft of space between the flow line and the lowest pipe grate cross member to reduce nuisance maintenance cleaning.
2. If beam guard will be used then specify the standard bridge transition, SDD 14B20, with appropriate terminal treatment.
3. If beam guard is to be placed around the radius of an intersection (Refer to SDD 14B27).

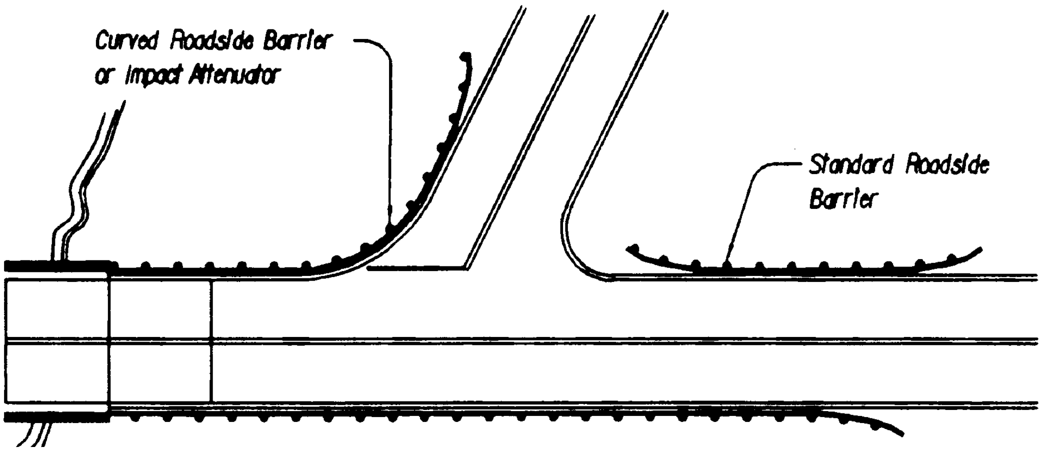

***Figure 1.2*: Beam Guard at Side Road**

Note: The standard barrier installation should be introduced as far from the structure as it would if the intersecting roadway were not present. Its use in conjunction with an appropriate treatment at the bridge itself significantly reduces risk to a motorist by narrowing the angle at which the curved barrier or crash cushion can be hit.

1.4.2.2 Curbed Roadways

A curb located between the traveled way and a traffic barrier can affect the impact performance of the barrier and result in an unpredictable crash. Therefore, new construction/reconstruction projects on rural highways with a design speed of 50 mph or more should avoid the use of curb where traffic barrier is required. EXCEPTION: short lengths of curb may be used to control drainage at bridge approaches. Where curb is necessary, it should be located behind or flush with the face of the beam guard railing. Furthermore, for curb/barrier combinations on highways with design speeds of 50 mph or more, the curb should be mountable and limited to a maximum height of four inches. This guideline also applies to 3R projects but only when curb replacement or removal is a planned part of the 3R improvement.

On highways with posted speed of 45 mph or more, provide a driveway curb cut (basically flat curb) out in front of the beam guard terminal. This driveway curb cut should extend from the third post, or length of need post, to 100 feet out in advance of the Energy Absorbing Terminal extruder head. In restricted areas where it may be difficult to provide 100 feet of driveway curb cut, a minimum of 30 feet is required out in front of the extruder head to prevent launching of the vehicle.

On highways with posted speed of 40 mph or less, provide a driveway curb cut (basically flat curb) out in front of the beam guard terminal. Extend this driveway curb cut from the third post, or length of need post, to 30 feet out in advance of the Energy Absorbing Terminal extruder head.

Do not allow fixed objects in the terrace behind the driveway curb, including but not limited to fire hydrants, light poles, signposts, trees or breakaway objects.

Barrier curb shall not be used in advance of an Energy Absorbing Terminal at any speed.

1.4.2.3 Beam Guard at Median Approach to Bridges

There are two alternative layouts for median side beam guard at approaches to bridges.

The first alternative is to use a Steel Thrie Beam Bullnose Terminal. It is shown on sheet "b" of the SDD 14B26. It may be used in any median wide enough to accommodate it.

A second alternative is the "Parallel" installation as shown on sheet "b" of SDD 14B18. It can be considered where the median width is over 50 feet. Provide end treatment as described under "Beam Guard End Treatments."

1.4.2.4 Transitions to Bridges or Concrete Barrier Wall

A transition section is required where a bridge parapet/railing, or a concrete barrier wall joins semi-rigid steel beam guard. "Steel Thrie Beam Structure Approach," shown on SDD 14B20, is the most common transition to the parapet/railing, or concrete barrier wall. Thrie beam is generally connected to some length of Class A beam guard and end treatment terminating with an energy-absorbing terminal. In some limited space conditions it may be appropriate to install a crash cushion or an impact attenuator as a transition to the blunt end of a bridge parapet/railing, or concrete barrier wall. Provide a thrie beam, crash cushion or impact attenuator transition in the following circumstances, and for various posted speeds in accordance with Table 1.2.

1. All projects on the National Highway System.
2. Projects classified as new construction or reconstruction.
3. Projects classified 3R with a design year AADT of 3,500 or more.
4. Projects classified 3R with a design year AADT less than 3,500 that involve beam guard replacement and application of the thrie beam transition is practical.
5. When a beam guard transition must be replaced, regardless of traffic volume, the thrie beam transition shall be used.

The transition and end treatment shall be used based on Table 1.2 for the proposed posted speed.

Table 1.2 Roadside barrier/end treatment required for bridge parapets/barrier walls.

	> 45 mph posted speed	= 45 mph posted speed	< 45 mph posted speed
Parapet or Barrier Wall Separates The Roadway From Sidewalk or Two-Way Shared Use Path. (See FDM 11-35 Attachment 1.1, Section CC.)	Yes	Yes	Yes
Rural & Undeveloped Transitional Areas.[1] (See FDM 11-35-1, Sections AA or BB.)	Yes	Yes	Yes, if no raised curb sidewalk/ path present. No, when a raised curb sidewalk/path is provided on approaches and structure, or when requested by community and agreed to by designer.
Urban & Developed or Developing Transitional Areas.[2] (See FDM 11-35 Attachment 1.1 Sections AA or BB.)	Yes	No, when a raised curb sidewalk/path is provided on approaches and structure, or when requested by community and agreed to by designer.	No, when a raised curb sidewalk/path is provided on approaches and structure, or when requested by community and agreed to by designer.

[1] *These areas are typically designed with a rural cross section and have a rural clear zone as provided in FDM 11-15 Attachment 1.9. Undeveloped transitional areas may have curb and gutter on the outside of the paved shoulder, however these areas will generally meet rural clear zone requirements.*

[2] *These areas have curb and gutter with a minimum lateral clearance of 2 feet from face of curb to the face of a fixed object. Typically there are power poles, fire hydrants, or trees etc. located within the clear zone according to FDM 11-15 Attachment 1.9. When a raised curb sidewalk/path is not provided on the structure use roadside*

barrier to shield the blunt ends of the parapet.

When a raised curb sidewalk/path is provided on a structure and no approach sidewalk/path is provided, the designer shall install a temporary asphaltic height transition, or ramp, on the roadway approach from the top surface of the sidewalk/path down to the level of the adjacent ground surface to eliminate the blunt end effect of the sidewalk/path. This transition height is typically 6 to 8 inches and shall extend approximately 10 feet in advance of the end of the sidewalk/path. This guidance applies to all posted speeds and all project locations. White, 4-inch, cross hatch pavement marking should be considered to delineate the ramp area.

Sloped concrete end terminals are not acceptable for posted speed greater than 25 mph or greater than 3,500 AADT.

See FDM 11-35-1 for guidance on using roadside barrier to shield columns under structures.

1.4.2.5 Beam Guard Over Low Fill Culverts

Refer to SDD 14B25, SDD 14B43 and FDM 11-45-2.5 for more guidance.

1.4.2.6 Low Volume Roadways

Roadside barrier is generally not cost-effective for highways which have a current traffic volume under 400 AADT[1]. Therefore, WisDOT policy is that beam guard will not be provided on highways-including bridge approaches-where the traffic volume is less than 300 AADT except when justified by severe roadside hazards and/or geometric conditions at the site. For example, beam guard may be cost-effective on low volume highways to shield roadside hazards within the clear zone such as steep drop offs, bodies of deep water, bridge rail ends located on the outside of sharp horizontal curves, especially when combined with steep gradients, or any roadside obstacle that has a significant accident history.

1.4.2.7 Delineation of Roadways at Hazards

Marker posts, delineators and appropriate signing may be used to alert motorists of highway alignment or roadside conditions where roadside barrier is not cost-effective and yet a safety hazard remains.

1.5 Barrier Design

1.5.1 Earthwork

> The grading guidance in this section is being reviewed. BPD recommends that individual construction drawing detailing the installation of certain components of a barrier systems are added to the plan. Grading guidance of this section is in the process of being rewritten. Recommend that desirable grading is provided for installations. See FDM 11-45-2 existing barrier section and SDD for more information.

Refer to SDD 14B25, SDD 14B44 and FDM 11-45-2.5 for more guidance on grading requirements at EATs.

Reference post #1 shall be used to identify the station location of the beam guard end treatment on the plan sheet and in the miscellaneous quantities. Consistency in identifying this location of the terminal is important only for the contractor.

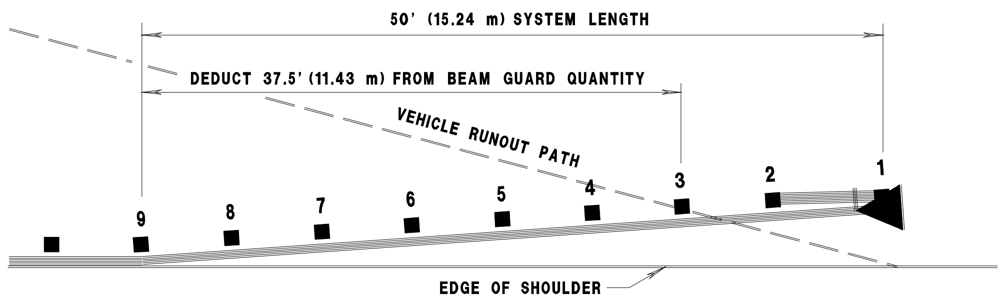

***Figure 1.7.* Beam Guard End Treatment (EAT)**

[1] NCHRP 214, Design and Traffic Control Guidelines for Low-Volume Rural Roads", John C. Clennon, Transportation Research Board, October 1979.

Figure 1.8 shows the length of need starts at post #5 on the End Treatment With Anchorage, SDD 14B17. In this case the entire 64' 4 3/4" length of the flared section shown in SDD 14B17 is paid for as Steel Plate Beam Guard, Class A but only the 25 ft portion that is full height can be included in the LON for beam guard. Therefore, the designer must increase the quantity of beam guard by 39' 4 3/4" to pay for the ramped down section after calculating the required LON for the guardrail.

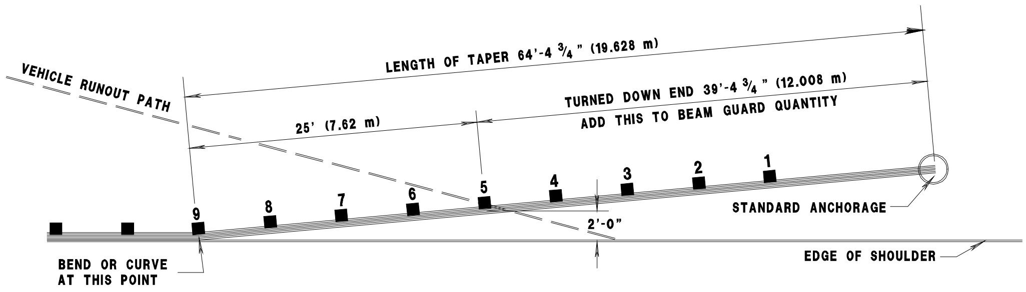

Figure 1.8. Beam Guard End Treatment (Anchorage)

For crash cushions and impact attenuators the length of need point is at the nose of the system. Therefore, the entire length of the crash cushion or impact attenuator can be deducted from the calculated length of need for the barrier, when another type of barrier is used in combination with crash cushions or impact attenuators. Many times the crash cushion and impact attenuators are stand-alone systems.

On divided highways with unidirectional traffic the LON should extend to the downstream edge of the hazard. See Figure 1.9. If this cannot be accomplished, refer to the Design Applications section for Special Situations. Class A beam guard should extend to the end of the hazard, then provide the Type 2 terminal.

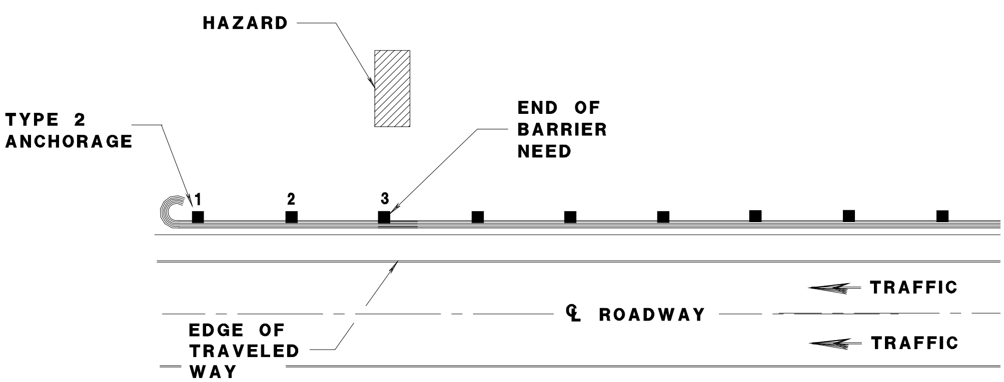

Figure 1.9. Length of Need Beyond Hazard for Divided Roadways

1.5.2 Beam Guard Deflection

The distance a barrier will deflect upon impact is a critical factor in the post spacing selection as well as in its placement, especially if the obstruction being shielded is a rigid object. The lateral distance is measured from the face of the rail to the face of the fixed object. Use Table 1.4 to determine appropriate post spacing, also see SDD 14B18.

Table 1.4 Design Deflections of W-Beam Barrier Systems

Lateral Distance to Fixed Object	Post Spacing
0 to 3'-6"	1'-6.75"
3'-6" to 4'-6"	3'-1.5"
4'-6" and over	6'-3"

** New construction and reconstruction projects shall provide a safety shape barrier wall from 25 ft in advance of the fixed object to the end of the fixed object. When it is not reasonable or cost effective to provide a barrier wall to the fixed object and the fixed object is within 3'-6" of the rail face, provide the 1'-6.75" post spacing 25 feet in advance of the fixed object as well as adjacent to the fixed object and also 25 ft beyond the fixed object. See SDD 14B20 for post spacing and beam guard requirements at bridge parapets or railing and rigid concrete barrier.*

Cable guard requires a clear lateral distance of 12 feet. Do not specify cable guard without involvement of staff from the Bureau of Project Development.

1.6 Crash Cushions and Sand Barrel Arrays

Where fixed objects cannot be removed, relocated, made breakaway, or shielded adequately by roadside barrier a WisDOT approved crash cushion or sand barrel array may be appropriate. They are often the only effective ways to shield narrow rigid obstacles.

A crash cushion is a manufactured product designed to absorb impact energy by deforming the components of the crash cushion. Typically crash cushions redirect errant vehicles that impact the side of them. Depending on the severity of the initial impact and the type of crash cushion used, a crash cushion may have the potential to protect from a second impact.

An array is a series of barrels filled with a sand and salt mixture. During an impact, an errant vehicle's momentum is dissipated by impacting various weighted drums in the array. Arrays typically do not allow for redirection of an errant vehicle during a side impact. Typically after an initial impact an array has limited to no capability to protect from a second impact.

Both crash cushions and arrays are proprietary devices. Typically arrays can have barrels from different manufacturers intermixed, while crash cushions cannot intermix parts from different manufacturers.[1]

The approach ends of permanent blunt fixed objects, such as concrete barriers or bridge columns, within the clear zone, must be shielded. Concrete barrier ends should be protected with a beam guard barrier system (e.g. thrie beam, beam guard and EAT). If it is not possible to install beam a guard barrier system then a crash cushion or an array may be appropriate. In temporary work zones, if the approach end of a temporary barrier terminates within a clear zone and the speed of vehicles is greater than 35 mph provide a crash cushion or sand barrels.

Designers are to discuss selection of permanent crash cushions or arrays with local maintenance staff and Regional Operations. Proper long term operation of these systems depends on proper maintenance. It becomes more difficult, although not impossible, for local agencies to maintain multiple systems. Maintenance input may influence final design of a location, or selection process. However, maintenance concerns should not be the only factor in the selection process for a given location or project.

1.6.1 Design Criteria

The fundamental design criteria for designing a crash cushions or arrays are: Crash Test Condition, Area Requirements, Width, Grading, System Maintenance, and Object Marking Pattern. Include in the miscellaneous quantities the crash test condition, object marking pattern, and width requirements for each installation. Other sections within the plan need to show the area available for installation and associated grades near the crash cushion or array. Standard bid items will indicate system maintenance requirements for crash cushions.

It is recommended that the designer contact manufacturers for the most current design information on their product. This is especially true for laying out sand barrel arrays. Manufacturers' contact information can be found within the Department's Approved Product List.

1.6.2 Sand Barrel Considerations

Typically sand barrels are 3 feet in diameter and require 6-inch spacing between barrels. The barrels typically vary in height based on design function and manufacturers. The use of an array and may affect the site distance of turning vehicles in the vicinity of the array. Sight distance near the array is to be reviewed by the designer.

Indicate if the array is to be unidirectional (i.e. exposed to one way traffic) or bidirectional (i.e. exposed to two way traffic) in the Miscellaneous quantities. See the Roadside Design Guide Chapter 8, for additional guidance on placement of sand barrels.

Arrays are to be placed on asphalt or concrete pads, unless manufacturer's specification state otherwise. Show a pad for the array on the plan sheet, but it is the responsibility of the manufacturer to provide the actual design of the pad.

Arrays may be an option on lower AADT facilities, location with a lower probability of being struck, or local maintenance staff may not have other crash cushions to maintain.

1.6.3 Crash Test Condition

Table 1.5 indicates what crash test levels are to be used for various Design Speeds for crash cushions and arrays.

Table 1.5 Test Conditions

Speed MPH	Crash Test
<25	NA –Concrete Sloped End Treatment
≥25 to 45	TL-2
≥ 45	TL-3*

* In confined locations a TL-2 system may be installed for speeds of 45 MPH.

1.6.4 Area Requirements

Figure 1.10 and Table 1.6 provides two sets of dimensions for providing a crash cushion. The majority of crash cushions on the Department's Approved Products list will fit within the desirable dimensions.

Note that some manufacture's crash cushions are required to be anchored into the ground by use of a concrete/ asphalt pad or a backing block. Designers using the standard specifications do not need to provide details for pads and backing block or payment items. Exercise care when locating a crash cushion so a manufacturer has room to install footings or backing blocks. This is especially true when using temporary crash cushions (ie. one manufacturer need 7 inches of temporary asphalt to secure their crash cushion).

Minimum dimensions should only be used after analysis has been completed and discussions with Regional Operations have taken place. Minimum dimensions should not be used in areas where there is reduced shoulder width, because there will be limited room to install the crash cushion or to allow for maintenance of the crash cushion. Some manufactures' systems may not fit within minimum dimensions. Designer is to review manufactures' information to verify that a system can fit within a location.

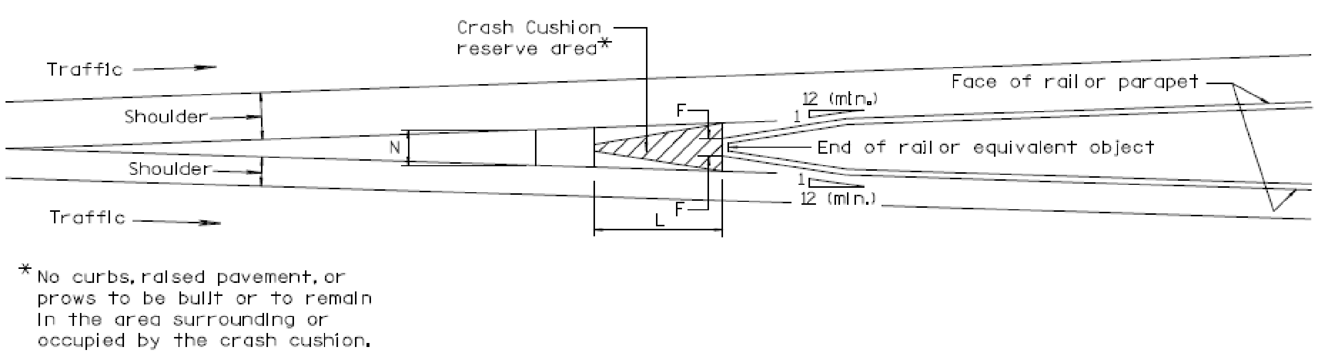

Figure 1.10 Area Requirements for Crash Cushions[2]

Table 1.6 Area Requirements for Crash Cushions3

	Minimum (FT)			Desirable(FT)		
Design Speed (MPH)	N	L	F	N	L	F
30	6	8	2	12	17	4
35	6	10	2	12	21	4
40	6	12	2	12	25	4
45	6	15	2	12	29	4
50	6	17	2	12	33	4
55	6	20	2	12	39	4
60	6	22	2	12	44	4
65	6	25	2	12	49	4
70	6	28	2	12	55	4

Note: Intermediate values in Table 1.6 are linear interpolations of data from AASHTO Roadside Design Guide Figure 8.4.

When proposing to use minimum area dimensions, document the impacts of using the desirable dimensions and provide justification for use of the minimum area in DSR or as an amendment to the DSR. When proposing to use the minimum dimension, designers are to consider the use of a low-maintenance crash cushion. Document why a low maintenance system is not being used in areas were minimum area is being provided.

It is desirable to use minimum area requirements for crash cushions installed in construction zones. If the minimum area cannot be provided at a construction zone installation, document why.

Sand barrel arrays require more room that a crash cushions to install. It is recommended that designers contact manufacturers to get the most current design information when to determine how much space is needed for an array.

1.6.5 Width Requirements

Providing the area in Figure 1.10 should be adequate for most crash cushion installations. However, with some projects, typically retrofit projects, the width near the back end of the crash cushion (i.e. dimension F) may be larger than what is indicated in Table 1.6. If a designer cannot install some other barrier system (e.g. concrete barrier) to narrow the back width, there are some crash cushions capable of spanning wider distances than indicated in Table 1.6, or the designer may install sand barrels. These situations require individual design and coordination with the manufacturers. If planning on using a specific manufacture's design a designer needs to complete Public Interest Finding (see FDM 19-1-5).

1.6.6 Grading

Grading in the leading to or alongside a crash cushion or array is not to be greater than 10:1. Curb and gutter will make it more difficult for crash cushions or arrays to perform as intended. Curb and gutter is not to be installed on the approaches to or alongside crash cushions or arrays installations.

It is desirable to remove curb and gutter near an existing crash cushion or array. 4-inch sloped face curb and gutter may remain in place if the crash cushion does not have a history or poor performance. If there is a history of poor performance it is desirable to remove curb and gutter. If curb is taller than 4-inch or vertical shaped, replace with 4-inch slope faced curb.

For existing installations, analysis on the need for existing curb and gutter, consequences of removing curb and gutter, existing crash cushion or array performance, and other alternatives considered. This analysis is to be included in the DSR or as an amendment to the DSR.

1.6.7 Maintenance Requirements

Some crash cushions are designed specifically to be easier or faster to repair. Typically these systems cost more to install than a standard crash cushion and are only to be used for permanent installations. Low maintenance systems are typically installed in areas where there is a significant chance of the crash cushion being struck, difficulties in repairing the device, or significant user delay because of maintenance activities.

Consider using a low maintenance crash cushion in the following situations:

- 2 or more impacts are happening within a year at a given location,
- Substandard geometry (alignment, profile or cross section) near the crash cushion,
- The roadway violates driver expectations,
- The designer has sufficient documentation showing that repairing a standard crash cushion would result in significant user delay,
- There is a significant crash exposure for the traveling public or maintenance staff.

Provide documentation on the criteria used when select maintenance requirements for a given crash cushion installation.

1.6.8 Object Marking Pattern

Indicate in the miscellaneous quantities, the object marking pattern required for a given installation. When an installation is on the left side of a one way road, indicate the use of marking pattern OM-3L. When the installation is on the right side of a one way or two way road, indicate the use of use pattern OM-3R. When the installation is in the median or in a gore between a ramp and the main line, indicate the use of OM-3C marking pattern. Manufacturers will provide the appropriate marking on the front of their specific systems to conform to the marking pattern indicated.

[1]Roadside Design Guide 3rd Edition 2006, with Updated Chapter 6, by the American Association of State Highway and Transportation Officials, Washington, D.C.

[2] From Roadside Design Guide, 2002, by the American Association of State Highway and Transportation Officials, Washington, D.C. Used by permission.

[3] Roadside Design Guide 3rd Edition 2006, with Updated Chapter 6, by the American Association of State Highway and Transportation Officials, Washington, D.C.

LIST OF ATTACHMENTS

Attachment 1.1	Beam Guard Terminal Earthwork

FDM 11-45-2 Roadside Barrier Design Guidance — *June 19, 2013*

FDM 11-45-1 is in the process of being rewritten and reorganized. As new guidance is published in FDM 11-45-2, it will supersede guidance in FDM 11-45-1.

Projects with PS&E due August 2011 or later are required to install MGS beam guard (MGS) for new beam guard installations. Some exceptions allowing the installation of new non-MGS beam guard may be granted by Bureau of Project Development (BPD). A few of these exceptions require minimum documentation (e.g. there is no short radius version of MGS designer would need to install non-MGS beam guard). Other exceptions require more documentation and discussion with Bureau of Project Development.

Projects on the NHS or subject to FHWA oversight review the use of MGS with FHWA.

Subsections 2.1 and 2.3.1 to 2.3.5 are blank and will have content added later.

2.1 (blank)

2.2 Warrants

Projects with PSE due Aug 2013 are required to use the new warrants. Projects with PSEs prior to August 2013 are encouraged but not required to use the new warrants. Projects with PSEs prior to August 2013 and are on NHS or subject to FHWA oversight are required to discuss with FHWA the implementation of the new warrants.

The following is a collection of warrants for various roadside design situations. Many of the warrants present are based on results from crash tests, computer modeling, crash analysis, and/or cost benefit analysis. It may be possible that an individual location may override a warrant. Limited project by project exceptions to override a warrant may be granted by BPD. However, these exceptions will be rare. Document the exception in the design study report (DSR).

2.2.1 Warrant Assumptions

Many of these warrants are based on an "average roadway". An "average roadways" is:

- Built to the appropriate standard
- Has an average crash frequency
- Has an average crash severity
- Does not need to consider consequences of a collision
- Roadway is straight and level

Unless noted otherwise, warrants use the following assumptions:

- Roadway is a two-lane highway
- Roadway has a speed of 50 to 55 mph
- Warrants do not include interaction of hazards at a location. Some examples are (not all inclusive):
  - A shielding warrant for a slope will not include influences of fixed objects on a slope.
  - A shielding warrant for a slope assumes that a 3:1 slope has a flat run out area at the bottom of the slope.
  - A shielding warrant for a culvert does not look at the interaction of other fixed objects or water near the culvert.
  - How curb and gutter may influence the performance of a barrier system, safety hardware or hazard.
  - A hazardous object is outside the area where shielding would be recommended, but slopes between the roadway and the hazardous object is non-recoverable.
- The roadside hardware or barrier system can be properly installed.
- The useful life of the barrier system is 20 to 25 years.
- The cost of installing a barrier system is near the state wide average cost.

2.2.2 Proper Application of Warrants

To properly apply warrants, use the roadside design treatment sequence. A warrant to shield a hazard requires review of other more desirable roadside design treatments first. If the warranted roadside treatment is not feasible, other roadside design treatments are to be reviewed.

A warrant does not:

- Automatically allow for improper installation of barrier system.
- Automatically allow for an exception to a standard.
- Automatically allow for "no action" to take place at locations where:
  - The frequency of run off the road crashes is high.
  - The severity of run off the road crashes is high.
  - The consequence of collision is high.

Warrants are from multiple sources. Each source may have different assumptions to develop its warrant. It is possible that warrants presented may conflict with one another. If there is a conflict between warrants, it is recommended that designers:

- Consult with an engineer trained and experienced in roadside design issues.
- Error on the side of driver safety.
  - A Warrant that uses a more preferred roadside design treatment should be used prior to a less desirable treatment.
  - Two shielding warrants conflict each other, provide shielding.
  - Look for other hazards nearby
  - Review Attachment 2.5

If a situation does not match the assumptions in the warrant, error on the side of safety of the traveling public. Some examples are (list not all inclusive):

- A "Do Nothing" alternative for a lower speed roadway may not be appropriate for a higher speed facility.
- If a warrant for a two lane roadway indicates that barrier system should be installed, it is likely that on a freeway and expressway would also warrant installation of a barrier system.

- If a two lane roadway warrant indicates that that a hazard does not need a barrier system, installing a barrier system still may be appropriate on an interstate, freeway or expressway.

2.2.3 Median Barrier on New Freeway Construction

This is an existing warrant and projects should be in compliance with this warrant.

Attachment 2.10 is a warrant for installing median barrier on new freeway. It may not be appropriate to use this warrant to install barrier on new expressways. The need to have access for cross roads is not taken into account with this warrant (e.g. intersection spacing, sight distances…).

2.2.4 Barrier Installation for Foreslopes

2.2.4.1 Roadside Design Guide

This is an existing warrant and projects should be in compliance with this warrant.

Attachment 2.11 is a warrant for shielding foreslopes.[i] Forslopes that fall within the shaded area are more of a hazard than installing a barrier system. This warrant does not include the following issues:

- Fixed objects or other hazards are on the slope.
- A 3:1 slope lacks a flat run out area at the toe of the slope.
- Slope is poorly compacted, graded, saturated, or has ruts.
- The warrant is not intended to allow for a project to steepen an existing foreslope.

2.2.4.2 FHWA Barrier Warrant for Low Volume and Low Speed Roads Publication

This is a new warrant.

Attachment 2.12 has warrants for shielding foreslopes based on Adjusted Traffic Factor (ATF), speed, slope rate, slope height, and offset from travel way.[ii]

This warrant does not automatically eliminate slopes that are shorter than the distance given or flatter than the slope given from shielding. Slope flattening should be reviewed prior to the decision to shield.

Warrants in this subsection and in some others subsections are from an FHWA Central Federal Lands publication. The following information will discuss proper application of these warrants. These warrants were based off crash severity and frequency on low speed, low AADT roadways.

It would not be appropriate to use these tables on roadways with higher AADTS to justify leaving a hazard unshielded. However, if shielding is warranted in these tables, it is likely that shielding would be warranted on roadways with higher AADTs or speeds. In many high speed or higher AADT situations other roadside design methods would be more desirable (e.g. remove, relocate, make traversable, etc.).

These warrants use type of hazard, ATF (adjusted traffic factor), speed, and offset from roadway to determine if shielding is needed. The ATF value adjusts the vehicle encroachment rate for curves, traffic growth and grade. ATF is calculated as follows:

$$ATF = AADTxTGxHCxDG$$

Where:

AADT= AADT

TG= Traffic Growth Factor (Attachment 2.12, Table A.1)

HC= Horizontal Curve Adjustment Factor (Attachment 2.12, Table A.2)

DG= Down Grade Adjustment Factor (Attachment 2.12, Table A.3)

Note: If project has projected AADT values, use projected AADT values and do not use TG Factor in calculations of ATF. If project does not have projected AADT value, use existing AADT and traffic growth factor.

The warrants have three classifications (1) Not Warranted, (2) Possibly Warranted, and (3) Warranted.

The Possible Warranted column has benefit cost ratios between 2 and 4. Warranted column has benefit cost ratios greater than 4.

Shield hazards that fall within the Warranted column. Shield hazards that fall within the Possibly Warranted columns on projects where there is a ROR flag in Metamanager or if a Metamanager AK flag in can be traced to

ROR crashes.

Many roadways on the STH network have speeds greater than the maximum speed in the provided tables. Provide shielding on roadways when the speed is greater than 50 mph and the ATF value falls within the Possibly Warranted or Warranted columns.

These warrants were developed using older severity values for barrier impacts. Since the development of the warrants, research has shown that barrier impacts are less severe than previously thought (e.g. beam guard impacts are about 50% less severe than previously thought). It is possible that ATF ranges for the Possibly Warranted and Warranted columns will be lower than what is indicated.

In other locations, the Possibly Warranted column requires site and project specific information to conduct a more detailed analysis. Use Table 2.1 and Attachment 2.5 when considering shielding. Document decision making process for Possibly Warranted hazards within the DSR.

Table 2.1 Factors to Consider [iii]

Consideration	Barrier is more warranted if:	Barrier is less warranted if:
Adjusted Traffic Factor	ATF is at the high end of range	ATF is at the low end of range
Roadway Cross Section	Section elements are more severe than assumed	Section elements are less severe than assumed
Size of hazard does not fit the assumption	Hazard is larger	Hazard is smaller
Hazard does not fit the description in the warrant table	Hazard is more severe	Hazard is less severe
Expected cost of Barrier	Expected costs will be low	Expected costs will be high
Multiple hazards exist at the site	Many additional hazards	
Operating speed	Likely to exceed design speed	At or below design speed
Crash history	Clear crash pattern	No crash pattern

2.2.5 Roadway Segment with High Rate of Tree Impacts

This is a new warrant.

Attachment 2.13 has a threshold rate of tree impacts for various rural roads[iv]. If a roadway segment has a rate of tree impacts greater than the values in Attachment 2.13, take corrective action. Attachment 2.13 requires the roadway to be broken up into quarter mile segments and 3 to 5 years of crash reports.

2.2.6 Shielding of Hazardous Trees

This is a new warrant.

Attachment 2.14 is a warrant for shielding hazardous trees. Refer to FDM 11-45-2.2.4.2 on how to use this warrant.

A tree with a diameter 4 inches or more or will grow to be 4 inches or more is a hazard. Measure a tree's diameter 4 inches from the ground.[v]

It is difficult to avoid impacting trees when the spacing between trees is less than 15 feet.[vi] Treat trees with spacing less than 15 feet as a group of trees.

Typically removal of hazardous trees is less expensive than installing a barrier system and is a more desirable roadside design option. If a tree cannot be removed, or shielded provide documentation in the DSR. Projects removing trees may need to include grubbing items to make sure that stumps are removed.

2.2.7 Shielding Blunt End of Parapets or Railing

This is a modification of an existing warrant.

Blunt ends of parapets are significant hazards. In one study 58% of all fatal impacts into barrier system on a bridge involved an errant vehicle hitting the blunt end of a parapet or railing.[vii]

Shield blunt ends of parapets on roadways with AADT of 400 or greater.[viii]

Review Attachment 2.5 for factors to consider when shielding blunt ends on roadways with AADTs between 150 and 399.[ix] Provide documentation of this analysis in the DSR.

Multiple research studies indicate that bridges that are narrower than the approaching roadway width are more likely to be struck. Shield the blunt ends of parapets on structures than are narrower than a roadway's normal roadway width when AADT is between 150 and 399. Shield blunt ends parapets that shield narrow drainage features or cattle passes on roadways with AADTs between 150 and 399.

Delineate blunt ends of parapets or railings on roadways with AADTs less than 150.

Review FDM 11-45-2.2.8 and 11-45-2.2.9 of this procedure for more information on about bridges and barriers that approach bridges. Review FDM 11-45-2.5.2.10 for more information about shielding blunt ends of parapets railing.

2.2.8 Crashworthy Bridge Parapets and Railings

This is a modification of an existing warrant.

All bridge parapets and railings are to be NCHRP 350 compliant. Refer to LRFD Bridge Manual Chapter 30.1 for more information.

In some cases, it may not be practical to install a crashworthy parapet or railing on an existing structure. In many of these cases, safety improvements can be made to the existing parapet or railing. Contact Bureau of Structures and Bureau of Project Development for assistance to improve existing parapets or railing that do not match current standards.

Review FDM 11-45-2.2.7 and 11-45-2.2.9 of this procedure for more information on about bridges and barriers that approach bridges. Review FDM 11-45-2.5.2.10 for more information about shielding blunt ends of parapets or railings.

2.2.9 Area with High Frequency of Run Off the Road Crashes by Bridges

This is a new warrant.

Research in Wisconsin has indicated that cross median crashes (a specific subset of run off the road crashes) are more likely to occur near bridges. Research in Iowa indicates that 80 percent of the bridges have 2 or fewer parapet impacts in 10 years.[x]

If a bridge's parapet or the barrier systems connected to the bridge has more than 2 impacts in 10 years, the location has an issue with run off the road crashes and additional steps should be taken to improve the roadside design in the area near this bridge. Provide documentation in the DSR.

This is not a warrant to provide median protection.

2.2.10 Traversable Grate for Hazardous Cross Drains

This is a modification of an existing warrant.

Hazardous cross drains within the clear zone on roadways with AADTs of 750 or greater warrant traversable endwalls.[xi] (Refer to discussion in FDM 11-45-2.6).

2.2.11 Traversable Grate for Hazardous Parallel Culverts

This is a modification of an existing warrant.

Hazardous parallel drains within the clear zone on roadways with AADTs of 100 or greater warrant traversable endwalls.[xii] (Refer to discussion in FDM 11-45-2.6).

2.2.12 Shielding Hazardous Cross Drains

This is a new warrant.

Attachment 2.15 is a warrant for shielding hazardous cross drains.[xiii] Locations that are on or below/right the line for the given dimension warrant shielding.

Warrant was developed for minor 3R projects. It is not appropriate to use this warrant to justify installing a new drainage feature or cattle pass than is narrow. (Refer to discussion in FDM 11-45-2.6). Reconstruction projects should look to use other more desirable roadside treatments prior to shielding.

Preliminary information from some more recent research indicates that it can be cost effective to shield smaller hazardous culverts and at lower AADTs than what is indicated. WisDOT will review this research once it is finalized.

Warrant also assumes:

- Slopes near drainage feature or cattle pass are traversable
- Drainage feature or cattle pass is not considered a fixed object hazard (e.g. head wall is not a hazard).

2.2.13 Shielding Hazardous Water

This is a new warrant.

Attachment 2.16 is a warrant for shielding hazardous water. Refer to FDM 11-45-2.2.4.2 on how to use this warrant.

This warrant assumes that the slopes between the water and the roadway a recoverable.

2.2.14 Shielding Fixed Objects

This is a new warrant.

Attachment 2.17 is a warrant for shielding fixed object. Refer to FDM 11-45-2.2.4.2 of this procedure on how to use this warrant.

This warrant is not appropriate for considering consequence of a collision (e.g. dropping an overhead sign onto a roadway). For overhead sign supports, sign bridges, mono tube signs follow guidance in FDM 11-55-20.

Shield or provide crash cushion for bridge piers and similar fixed objects when roadway's posted speeds 55 mph or greater and bridge pier is within the desirable clear zone distance.

2.2.15 Low-Volume Roadway

This is a modification of an existing warrant.

Barrier systems are generally not cost-effective for highways which have a current traffic volume under 400 AADT.[xiv]

However, barrier systems can be installed under the following conditions:

- Crash frequency warrants a barrier system.
- Crash severity warrants a barrier system
- Consequences of a collision warrant a barrier system.

Generally, other warrants presented in this section will override this warrant.

Preliminary information from some more recent research indicates that it can be cost effective to shield or remove certain types of hazards on lower volume roadways. WisDOT will review this research once it is finalized.

2.3 (blank)

2.3.1 (blank)

2.3.1.1 (blank)

2.3.1.2 Length of Barrier

2.3.1.3 Length of Need

The length of a barrier system needed to shield a hazard is termed "length of need" or LON. Length of need is dependent on the location and size of the hazard, lateral distance from the direction of traffic, design speed, design traffic volume, and how far the roadside barrier is away from the edge of the traveled way and horizontal curve. Typically, LON provides sufficient distance for an errant vehicle to stop (i.e. end of barrier need point in Figures B and C) prior to hitting an object being shielded.

Install barrier systems that provide Length of Need (LON) to shield the primary hazard. Review installation of barrier for secondary hazard. If there are secondary hazards that require shielding (see Figure 2.1), provide shielding.

Document in Design Study Report (DSR) when LON is not being provided at a given location. Document barrier installations that are significantly longer than LON. Minor adjustments of a barrier's location to accommodate for hardware, grading, and other issues does not need documentation in DSR.

After barrier lengths are designed, if there are short gaps, the barrier should be connected as one continuous run of barrier. In general, gaps of 200 feet or less should be avoided.

Length of need to shield fill embankments where the roadway cross section is transitioning from cut to fill should generally begin in the cut section to shut off vehicle access to severe fill slopes behind the approach end of the barrier.

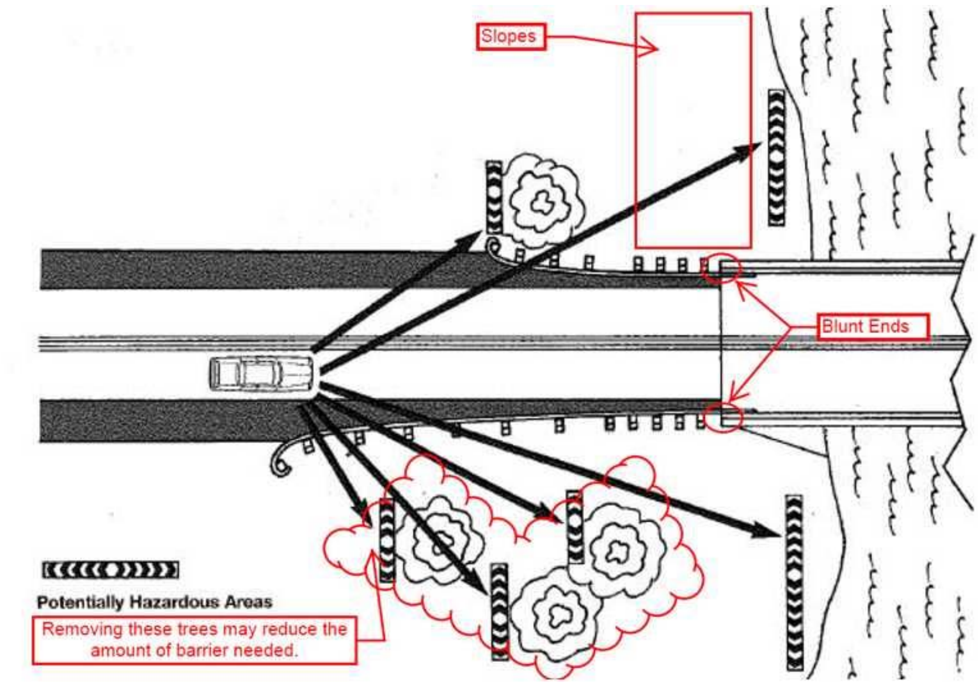

Figure 2.1 Hazard Identification[xv]

Length of need is calculated using runout values from Table 2.2 and Equation 1.[xvi] Equation 1 uses the parallel method from the Roadside Design Guide to calculate LON. The Roadside Design Guide has an equation that allows for a barrier to be flared away from the edge of lane. A flared barrier design typically reduces the amount of barrier being installed, but typically will require additional Right-of-Way and grading. The flared equation may be used under the following conditions:

- Grading from edge of lane to face of rail is 10: 1 or flatter slopes.
- Appropriate grading for the end treatment is provided (including runout areas”).
- End treatments are flared at the same rate as the barrier system.
- Use of the flared equation is documented in DSR.

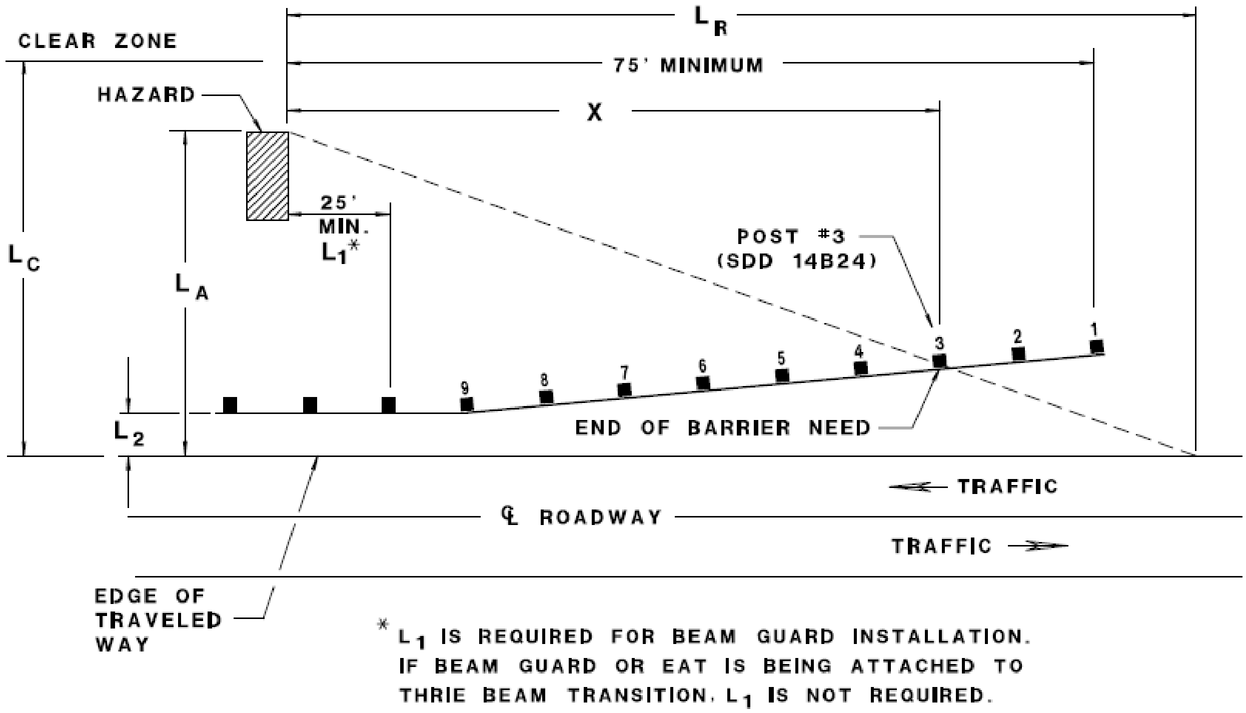

Figure 2.2 Near side LON Calculations

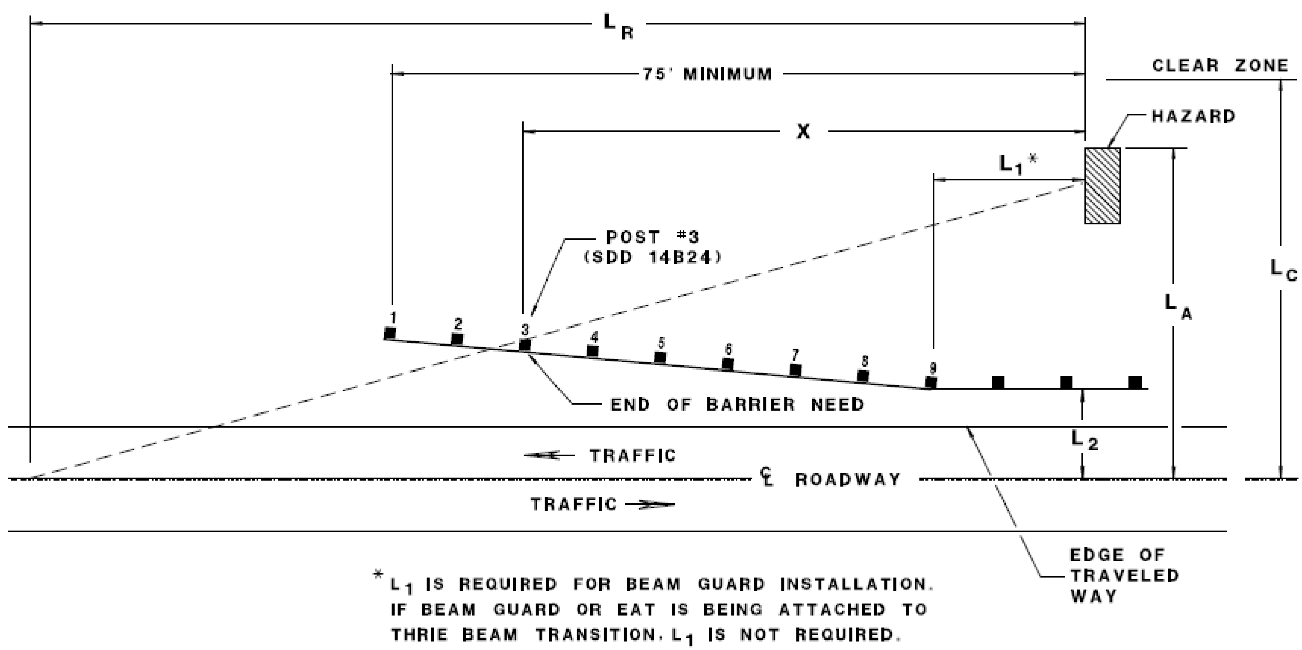

Figure 2.3 Far side LON Calculation

Using the LON equation, calculate the minimum distance from hazard to "end of barrier need (see Figure 2.2 and Figure 2.3). Depending on the barrier system and end treatment used the "end of barrier need" location may vary. Discussion of where the "end of barrier need" is located is in other sections of FDM 11-45-1 or FDM 11-45-2.

Table 2.2 Runout Lengths for Barrier Design (LR)[2]

Design Speed mph	AADT[3]			
	10,000 or more	**5,000 to 9,999**	**1,000 to 4,999**	**Less than 1,000**
80	470 ft	430 ft	380 ft	330 ft
75	415 ft	380 ft	335 ft	290 ft
70	360 ft	330 ft	290 ft	250 ft
65	330 ft	290 ft	250 ft	225 ft
60	300 ft	250 ft	210 ft	200 ft
55	265 ft	220 ft	185 ft	175 ft
50	230 ft	190 ft	160 ft	150 ft
45	195 ft	160 ft	135 ft	125 ft
40	160 ft	130 ft	110 ft	100 ft
35	135 ft	110 ft	95 ft	85 ft
30	110 ft	90 ft	80 ft	70 ft

Equation 1

$$X=\frac{(L_A-L_2)}{L_A/L_R}$$

L_2 = Distance from edge of lane to barrier

L_A = Distance from edge of lane to back of hazard

L_c = Distance from edge of lane to clear zone

L_R= Runout length per Table 2.2

X= LON = Minimum distance from hazard to end of barrier need.

Note:

Use L_A equal to L_C if there is no definable back of hazard or if there are multiple hazards within a given area (e.g. water hazard, a stand of trees, non-traversable slopes, non-recoverable slopes without runout distances…).

2.3.1.3.1 LON on Curves

The length of need equation is intended for tangent sections of roadway. On the outside of curves errant vehicles tend to take a tangential path. To determine LON on the outside of curves do the following:

1. With the given speeds and AADT find L_R
2. Draw on the plan a line that is tangent to the edge of lane to the greater of back of hazard or edge of clear zone.
3. Measure the distance of line constructed in step 2
4. Use the smaller length of either the L_R or the length of line constructed in step 2

On the inside of curves use L_R to locate the LON point for the barrier system being used. See Attachment 2.4 for an example.

For examples of LON, see the following attachments:

- Attachment 2.1: Example Problem 1: West Side of Structure
- Attachment 2.2: Example Problem 2: Rock Wall
- Attachment 2.3: Example Problem 3: Outside of Curve Cattle Pass
- Attachment 2.4: Example Problem 4: Inside of Curve Cattle Pass

[2] Table is based on 2011 Roadside Design Guide and linear interpolations.
[3] Use the greater of design AADT or current AADT.

2.3.2 (blank)

2.3.3 (blank)

2.3.4 (blank)

2.3.5 (blank)

Projects with PSE due August 2011 or later are required to use the guidance on concrete barriers single slope. Projects with PSEs prior to August 2011 are encouraged but not required to change to the new barrier design. Projects with PSEs prior to August 2011 and are on NHS or subject to FHWA oversight are required to discuss with FHWA about the implementation of concrete barrier single slope.

At the time of publishing concrete barrier guidance the following transition have not been fully developed:

Concrete Barrier Transition Type NJ42SF to S42

Concrete Barrier Transition Type NJ32DF to S32

Concrete Barrier Transition Type NJ42DF to S42

Concrete Barrier Transition Type NJ51DF to S42

Concrete Barrier Transition Type F42DF to S42

Concrete Barrier Transition Type F51DF to S42

Contact Bureau of Project Development (BPD) for details.

2.3.6 Concrete Barrier

Concrete barriers operate in a significantly different manor than flexible or semi-rigid barrier systems. Concrete barriers redirect impact energy verses absorbing energy[4].

The two main methods of redirecting impact energy are vehicle lift and vehicle deformation. During an impact, a vehicle will climb up the concrete barrier (i.e. converting kinetic energy into potential energy). Energy is also lost due to damage to vehicle components during impact (e.g. flattening or shattering body panels, bending vehicle frames, crushing of engine or drive train).

These two methods of redirecting energy cause impacts into concrete barrier systems to be more severe. (e.g. lifting a vehicle off the ground increases the chance of vehicle roll over, forces that cause vehicle deformation also can cause injury to vehicle occupants). On average, concrete barrier is twice as likely to produce an injury crash as a flexible barrier system.

It is important to distinguish between different concrete barrier shapes and heights. This is especially true if a new concrete barrier system has to match into an existing bridge or roadside barrier.

2.3.6.1 Shape

There are currently five different shapes of concrete barrier in Wisconsin: GM, NJ, F, Single Slope and Vertical (see Figure 2.4 for dimensions of GM, NJ, and F shapes). GM shaped barrier was originally designed in the 1970s, and has a tendency to roll smaller, lighter cars.

No new runs of GM shaped barrier are to be installed. Spot replacement of GM barrier that has been damaged or removed to facilitate installation or repair is acceptable (e.g. inlet underneath GM barrier requires repairing).

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[4] Frictional forces also are involved, but all barriers use frictional forces.

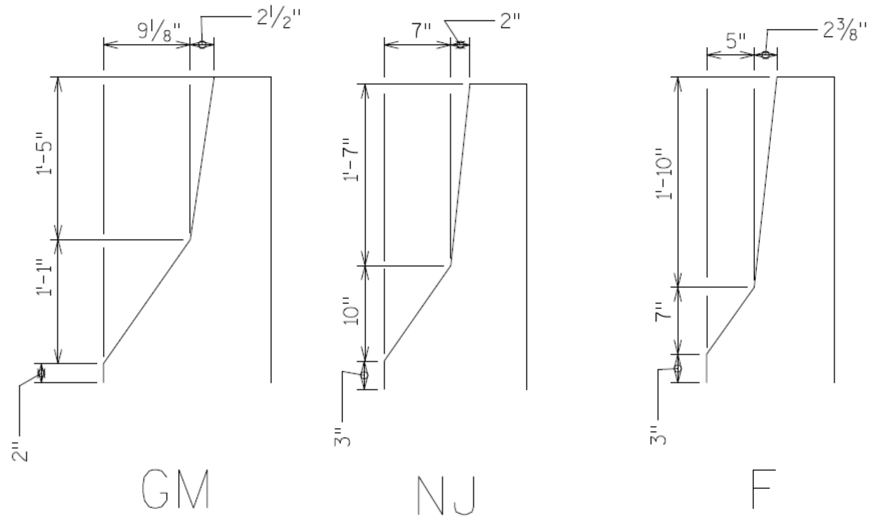

***Figure 2.4* Barrier Shape**

NJ shaped barrier has been the standard style of barrier for both roadways and bridges in Wisconsin for many years. Bureau of Structures (BOS) has used F shaped parapets on various bridges. Since the 1990's, SE region has used F shaped barriers on some roadways.

WisDOT has recently adopted the Concrete Barrier Single Slope (CBSS) design developed by Caltrans. The advantages of the CBSS design are:

- Lower maintenance cost
- Better crash performance
- More flexibility with overlay projects

Vertical shaped barrier may be found at various locations. For example, if removing an existing guardrail or thrie beam transition to concrete barrier, a vertical transition may be required to match the new CBSS into the existing concrete barrier. Minimize the use of vertical barrier.

Barriers that do not conform to: NJ, F, single slope, or vertical shapes are not acceptable. Changes to barrier shape to accommodate drainage, or placement of hardware on or near barrier is not desirable.

2.3.6.2 Concrete Barrier Height

Most existing installations of concrete barriers are 32 inches tall. Barriers that are 42 and 51 inches have been installed on some freeways and expressways (mostly SE region) and on various bridges.

The standard CBSS heights are in Table 2.3.

***Table 2.3* Standard Barrier Heights for Specific Types of Roadway**

Roadway	Standard Barrier Height (Inches)
Freeways and Expressways	42
STH	36
Local	36*

** Local road projects may use 32-inch tall CBSS if the local unit of government has provided a written request to use 32-inch CBSS. Within the written request, the local unit of government must acknowledge that overlays should not be placed near 32-inch CBSS and that recent crash testing has indicated that taller vehicles (i.e. single unit van trucks) have gone over 32-inch barriersxvii. Attach local unit of government's written request to the project's Design Study Report (DSR).*

Vertical-shaped barrier taller than 34 inches is acceptable between, and flush with, closely spaced bridge piers or other bridge substructures if there is not enough room to place a SSCB in front of the bridge piers or sub-structure. Vertical-shaped barrier taller than 34 inches is not desirable at other locations because of the increased risk of "head slap".

In specific situations, a barrier that is taller or shorter than Table 2.3 may be used, but additional documentation in the DSR is required. Coordinate early in the design process with Bureau of Project Development (BPD) on the use of a non-standard barrier height. Minimize the use of taller barrier.

Other issues to consider when selecting the appropriate height of CBSS are:

- Sight Distances
    - Stopping Sight Distance
    - Intersection Sight Distance
    - Decision Sight Distance
- Working Width
- Zone of Intrusion
- "Head Slap"
- Crash history

2.3.6.2.1 Sight Distances

Concrete barrier on the inside of a horizontal curve can obstruct stopping sight distance and/or decision sight distance (SSD and/or DSD). Taller barrier could possibly worsen the obstruction. If the available sight distance is less than the minimum required sight distance then an exception to standards is required.

A barrier within the required clear sight window of an intersection can obstruct intersection sight distance (ISD). If it is necessary to install barrier that obstructs required SSD, DSD and/or ISD then provide mitigation (e.g. more signs, bigger signs, pavement marking, more delineation). See FDM 11-10-5 for more discussion on sight distance.

2.3.6.2.2 Working Width

Working width is the combination of barrier width and either the maximum barrier deflection or the maximum distance a vehicle could extend behind the barrier (e.g. vehicle lean see Figure 2.10). See Figure 2.5 for more information on working width. If a barrier does not provide working width, an errant vehicle may engage the fixed object that the barrier was intended to protect.

Section 6.6.2 of the 2006 Roadside Design Guide states:

> "Appropriate Flare rates should be used for the approaching traffic side of the barrier and, if the deflection distance for the barrier cannot be provided, a transition may be necessary to stiffen the barrier in advance of the object."[5]

Section 6.6.2 also states:

> "If a concrete barrier is used, the barrier may be placed adjacent to the obstruction unless there is a concern for a high-center-of-gravity vehicle striking the obstruction when contact with the barrier causes the top of the vehicle to lean over the railing."

Provide working width for concrete barrier. Working width for concrete barrier is measured from the traffic side toe of barrier to the front face of hazard. See Table 2.3 for working width information for various heights and types of concrete barrier.

The majority of barrier impacts are from pick-up truck or smaller vehicles; however, larger vehicles do strike barriers. Design using working widths based on impacts from pick-up trucks or smaller vehicles unless:

- Crash history indicates larger vehicle impacts are frequent
- Consequence of a collision with fixed object is severe (e.g. light pole or sign bridge drops across lanes of travel on a freeway…)

When crash history indicates larger vehicles are impacting barrier contact BPD early in the design process. Different barrier designs may be required. Additional design effort will be needed. Document in DSR the justification of barrier designed for large vehicle impacts.

Typically, in locations where consequence of a collision is severe, use standard detail drawings and increase the height of barrier near the fixed hazards (e.g. sign bridges, light poles). Although the standard barrier will not withstand a critical hit by a vehicle larger than a pick-up truck (i.e. a very rare event), a taller standard barrier will provide some additional protection for less than critical impacts of a larger vehicle. Document in the DSR justification for barrier installed because of consequence of a collision.

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[5] i.e. provide working width.

The guidance in 2.3.6.2.2 for large vehicles does not apply to bridge substructures needing structural protection. See FDM 11-35-1 for guidance on structural protection for bridge substructures.

2.3.6.2.3 Zone of Intrusion

Figure 2.5 to Figure 2.9 show the differences between working width and Zone of Intrusion (ZOI). Table 2.4 has working width and ZOI values for various heights and types of barrier. ZOI is measured from the top, traffic side of barrier.

ZOI is a region within the working width where secondary hazards (e.g. breakaway signs…) traditionally have been placed. Some recent crash testing has indicated that secondary hazards could intrude into the vehicle cab. It is desirable that secondary hazards are not placed within the ZOI of a concrete barrier.

Many safety devices (sign poles, lights…) are designed to break away when a vehicle's bumper (typically between 18 to 23 inches off the ground) engages the safety device. If a safety device is placed on the top of a barrier, the upper part of the vehicle engages the safety device. The safety device may not breakaway as intended. For example, a breakaway device may cause excessive deceleration to the vehicle (i.e. increasing the probability of a serious crash).

When making a decision to install objects on top of the barrier, early coordination with BPD is required. Additional design effort may be needed. Additional documentation may be required in the DSR.

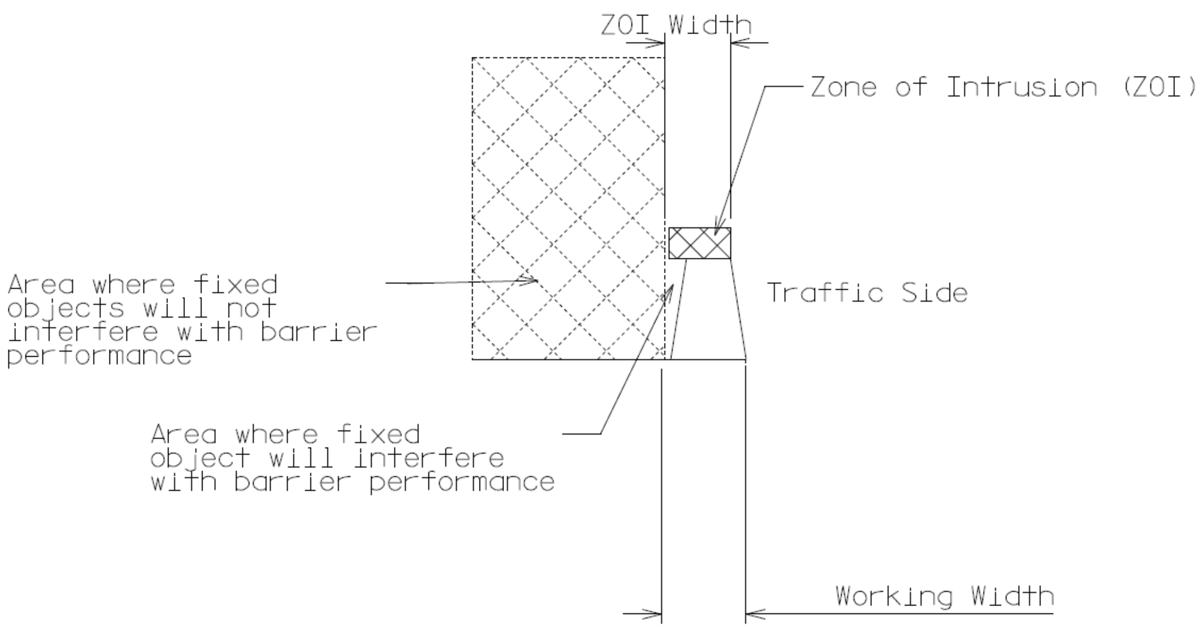

Figure 2.5 Zone of Intrusion and Working Width

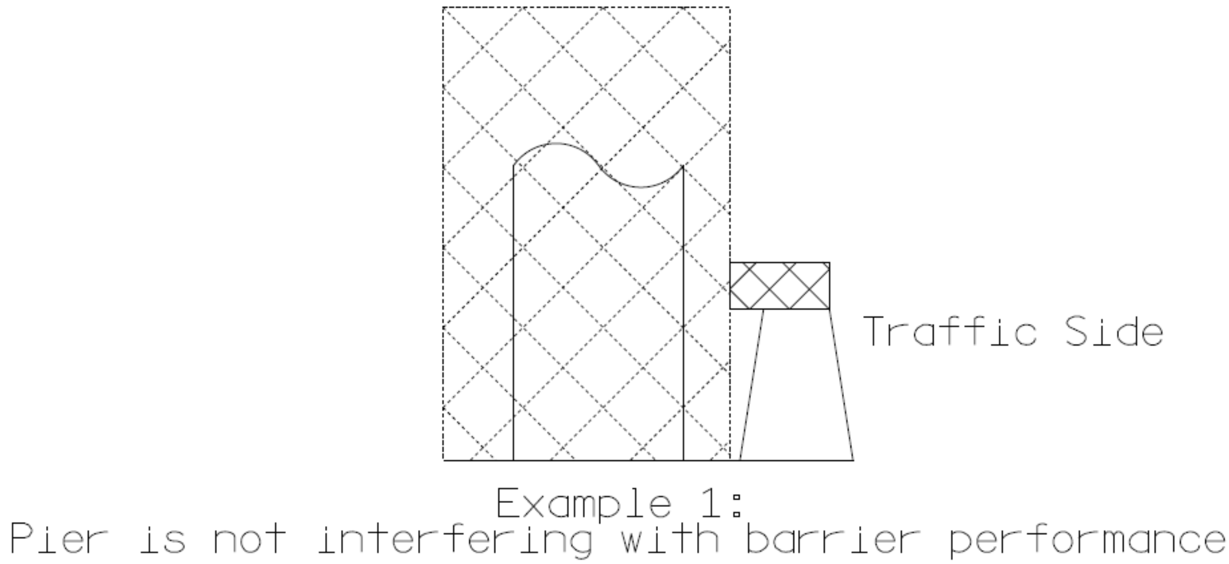

Figure 2.6 Example 1

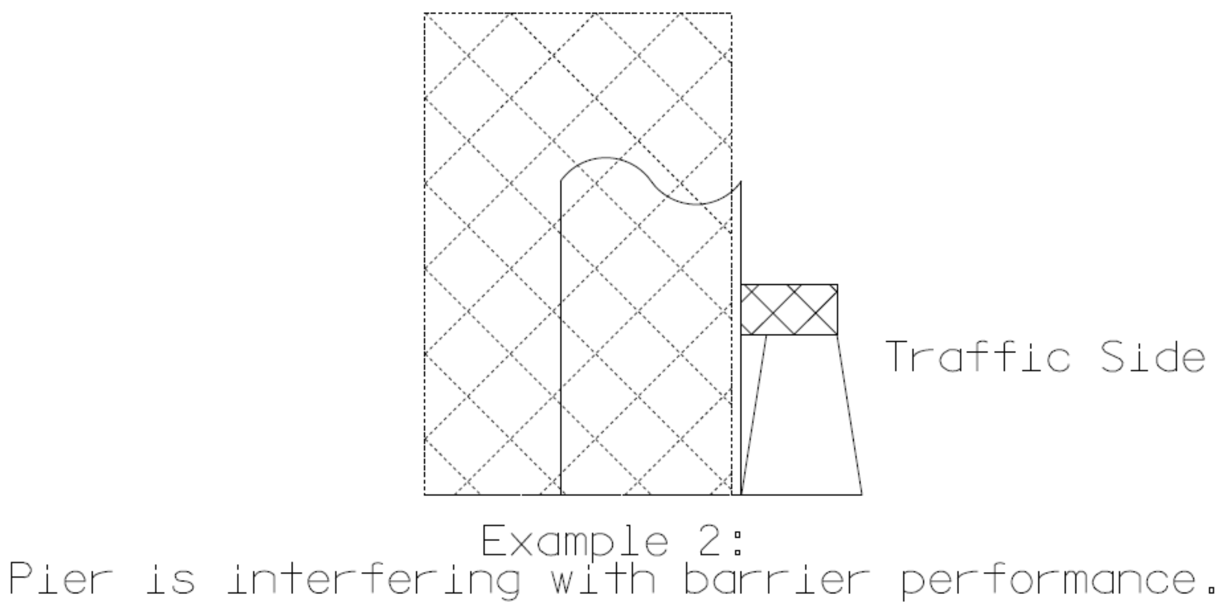

Figure 2.7 Example 2

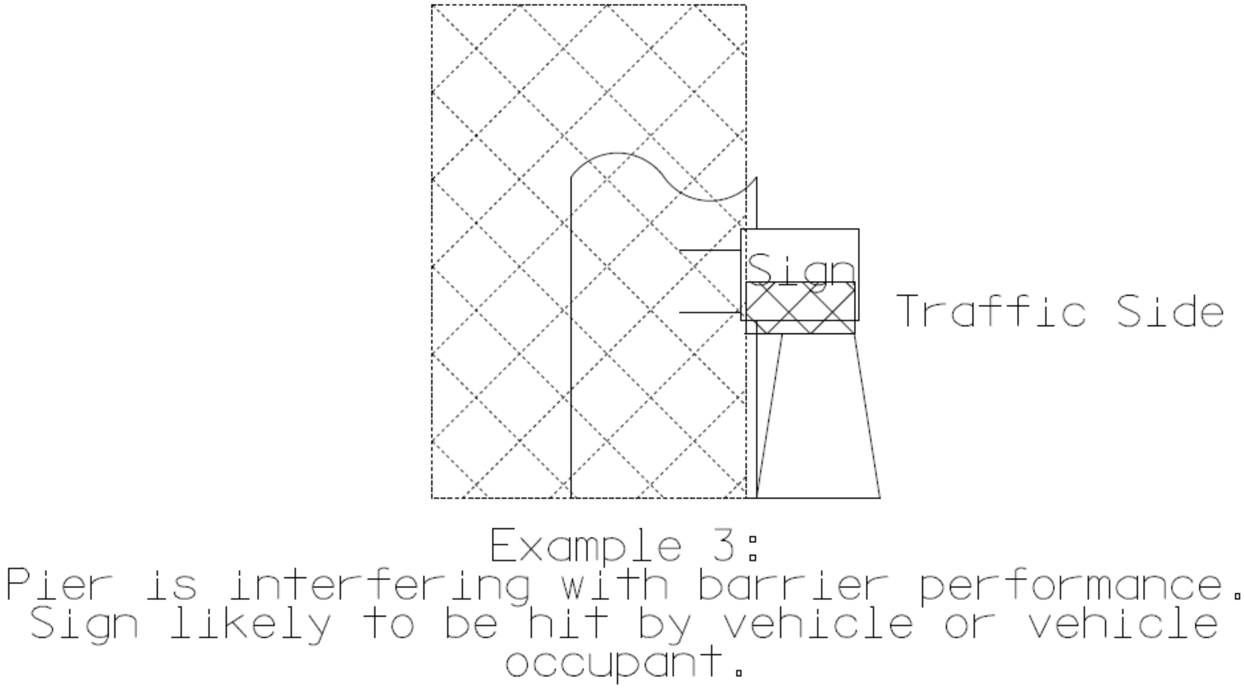

Figure 2.8 Example 3

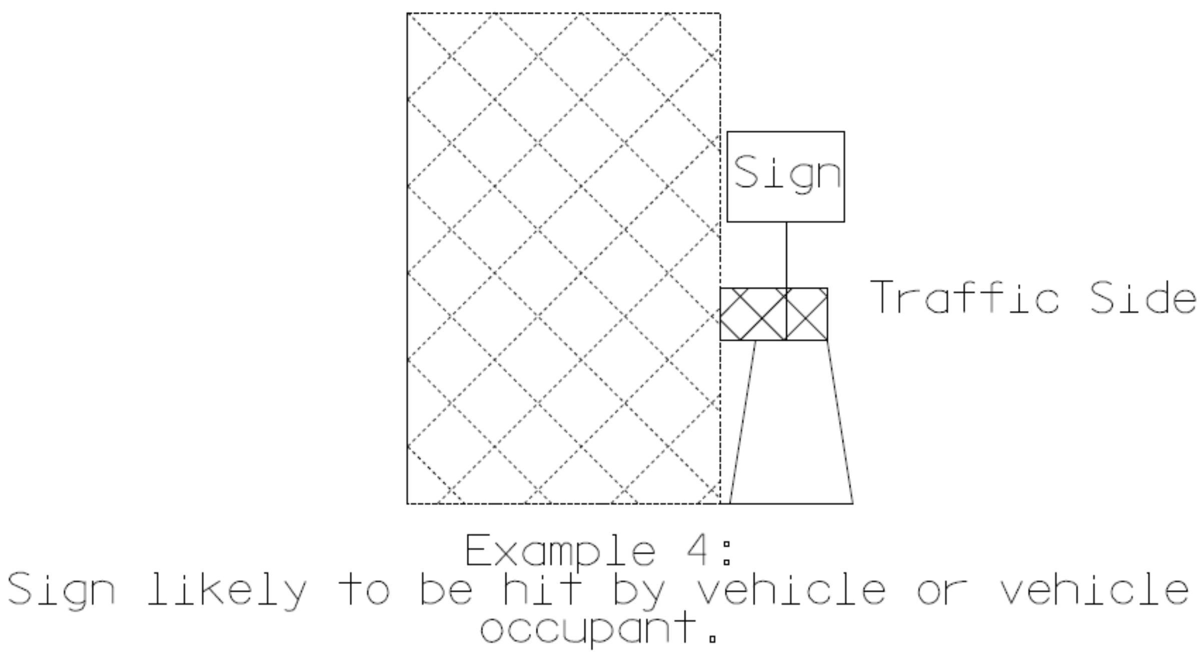

Figure 2.9 Example 4

Table 2.4 Concrete Barrier Working Widths and ZOI Dimensions[xviii]

Concrete Barrier	Working Width (Inch)	ZOI Width (Inch)
32" CBSS	27	21
36" CBSS	27	21
42" CBSS	27	21
56" CBSS	24	6
32" Vertical Concrete Barrier	24	24

2.3.6.2.4 Head Slap

"Head slap" is a condition where an occupant's head is outside the cab of a vehicle during impact and contacts concrete barrier's face (See Figure 2.10). Head slap become more of an issue when smaller vehicles impact taller barriers.

Figure 2.10 Crash test showing occupant head out of vehicle[xix]

2.3.6.2.5 Crash History

Taller barriers may be warranted if crash history indicates smaller vehicles (i.e. cars, pick-up trucks, SUVs…) have:

- Vaulted over barrier
- Traveled along top of the barrier
- Engaged objects on the barrier
- Engaged objects that are behind barrier

Taller barrier may be warranted if there is a crash history of larger vehicles striking barrier.

2.3.6.2.6 Glare/Gawking Screen

Typically, glare screens should not be installed in medians wider than 20 feet, or in locations where there is ambient lighting. Ambient lighting includes roadway lighting, high-mast lighting, or neighboring properties provide significant lighting. If a median is greater than 20 feet, analysis is required.

Contact BPD early in the design process since they will review the installation of a glare or gawking screen on a case-by-case basis. Project staff will need to:

1. Document there is a need for glare or gawking screen,
2. Develop multiple alternatives to address the glare or gawking problem,
    a. What is the effectiveness of an alternative at blocking glare or gawking?
    b. What is the cost of providing glare or gawking alternative?
3. Document the justification within the DSR.

If there is a counter directional traffic on a frontage road next to a main line, a glare screen may be appropriate.

2.3.6.3 Components of a CBSS System

CBSS systems have the following components:

- Standard Barrier Sections
- End Anchors
- Transitions
    - Shape
    - Height

Review barrier design for adequate space to use the different components of the CBSS system. (see 2.3.6.4.6). If SDDs will not fit a given location, coordinate early in the design process with BPD. It is the designer's responsibility to develop crashworthy designs for unique situations.

2.3.6.3.1 Standard Barrier Sections

Of all the components of a CBSS system, the standard barrier section is the most frequently used and simplest section. A standard section of CBSS requires less reinforcement steel than other components of concrete barrier system because impact forces are distributed in two directions (see Figure 2.11) and over long distances.

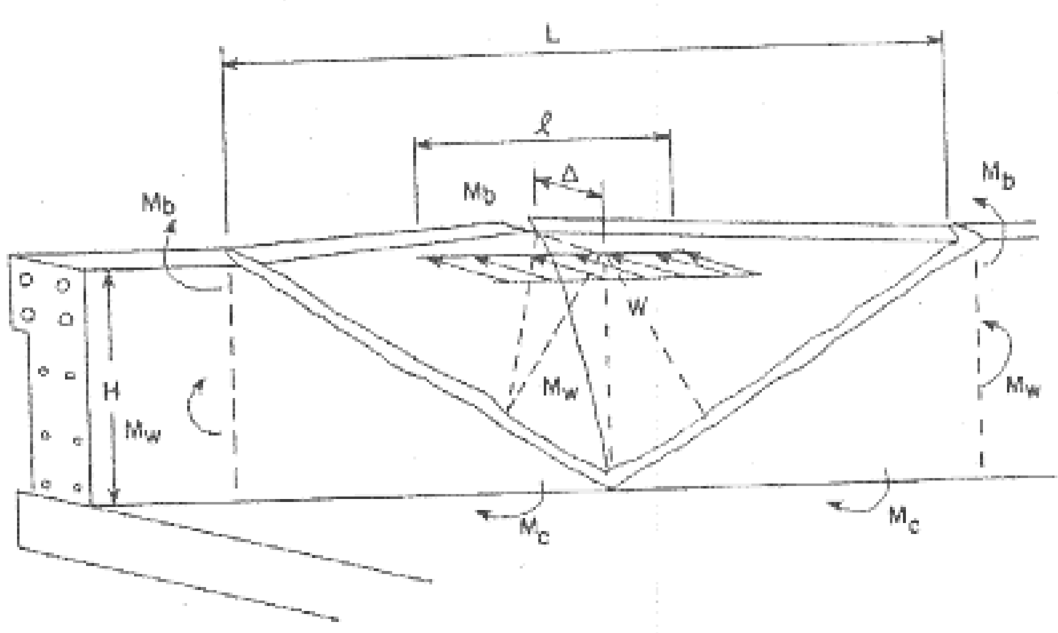

Figure 2.11 Forces in Normal Barrier Section[xx]

The CBSS standard section does not require a footing. Do not tie the CBSS standard section into the shoulder with reinforcement.[6] The CBSS standard section may be set on a few inches of asphalt[xxi]. Extend shoulder pavement structure under CBSS. Pay for shoulder extension with shoulder items. CBSS does not require the shoulder to extend behind the barrier. Place a note on the plans when there is less than 1 foot between the back

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[6] If a barrier is rigidly tied to the shoulder then impact forces may damage the shoulder. In addition, shoulder and barrier may expand and contract differently. This may cause cracks in the barrier and/or shoulder.

of CBSS and a rigid object.[7] Include bid items for reflector and brackets.

During construction of long runs of CBSS, a contractor may use a cold joint to connect to previous day's pour (See notes on SDD 14B32). However, the overall barrier run must have end anchors (see 2.3.6.3.2)

2.3.6.3.2 End Anchors

End anchors require additional vertical steel and footings to absorb impact loads and to prevent the anchor from rotating during an impact (in Figure 2.12 impact forces cannot travel in both directions). End anchors use a cold joint[8] to connect to standard CBSS. When using SDDs, it is not necessary to detail the use of a cold joint.

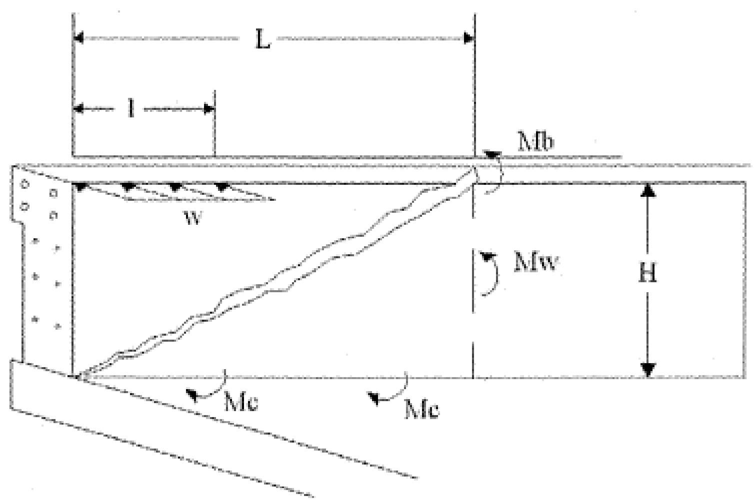

Figure 2.12 Forces in End Section[xxii]

There are two types of end anchors for CBSS: thrie beam anchors and normal end anchors. The department does not pay for anchors separately, because the anchor length is included in the length of the CBSS.

The thrie beam anchor is designed to prevent an errant vehicle's front wheel from snagging the barrier. Do not install curb and gutter near a thrie beam anchor. On taller thrie beam anchors, the top of the thrie beam anchor is sloped to prevent a vehicle from leaning over and snagging on the top of the anchor. Indicate in plan (e.g. plan view) where thrie beam anchors are required and include appropriate SDD (SDD 14B33) in plan set.

Normal end anchors are used when there is an expansion joint needed in a barrier run (e.g. on both sides of the sign bridge) or on the downstream end of a one-way roadway. When using SDD 14B32, it is not necessary to indicate that a normal end anchor is needed. However, there could be a project specific need that would require the use of normal end anchor (e.g. an expansion joint is needed at a specific location, traffic control staging requires a normal end anchor…). In these situations, indicate on the plan were additional normal end anchors are needed.

Review grading and drainage near end sections. Although a particular location may satisfy the length of need for a barrier system, the location may not provide sufficient room for grading needed for other components of the barrier system (e.g. crash cushion, sand barrier array, or steel thrie beam structure approach), or may have other drainage issues that require additional work. This is a concern if the barrier is installed near a tall cut section, or in other areas where there is significant drainage needed near the barrier system. CBSS may have to be lengthened to provide appropriate space for proper drainage or other roadside hardware.

2.3.6.3.3 Transitions

CBSS may need to connect to taller or different shaped barriers. Typically, transitions require additional vertical steel and footings to absorb impact loads and to prevent the barrier from rotating during an impact.

It is important to review what transitions are needed for a given project early in the scoping or design phase. For example, if a new barrier is to match into a barrier that had an existing thrie beam transition, a vertical faced

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[7] When there is less than 1 foot between fixed object and back of barrier, it may be difficult to perform finishing work.

[8] A cold joint has sufficient length of reinforcement steel extended beyond the previous concrete pour to allow the end section reinforcement to properly tie into the previously place reinforcement. This allows for the distribution of impact energy.

transition is required. Use "each" items to pay for shape transitions. Indicate in plan (e.g. plan view and MQ sheets) the location of shape transitions.

There are two types of height transitions: double cold joint and the expansion joint design. Typically, designers would use the double cold joint transition detailed on SDD 14B32**.** The double cold joint details allow impact force to be transmitted in both directions (i.e. the height transition acts like a normal barrier section). Double cold joint height transitions are included in the cost of normal CBSS. Indicate in plan (e.g. plan view) the location of double cold joint height transitions.

The expansion joint height transition designs, SDD 14B9 are intended for locations where it is not possible to transmit forces in both directions (e.g. the bridge has parapets of one height, and the roadway has barrier of a different height) or there is not sufficient length of barrier to absorb an impact. Pay for the expansion joint height transition as an each item. Indicate in plan (e.g. plan view and MQ sheets) the location of expansion joint height transition.

2.3.6.4 Unique Situations

2.3.6.4.1 Short Sections of Barrier

The minimum length for the standard CBSS is 40 feet (end of end anchor to end of the end anchor). Lengths shorter than 40 feet require the use of the CBSS Short Section (Concrete Barrier, Type B, SDD 14B34). These barriers are more robust and can absorb impact within the total length of the barrier.

The minimum length of installation of CBSS Short Section varies depending on the number and type of anchors required:

- If two thrie beam anchors are needed (e.g. bidirectional traffic), then the minimum installation length of CBSS Type B is 31 feet (end of the thrie beam anchor to other end of the thrie beam anchor).
- If one thrie beam anchor is needed (e.g. one-way traffic), CBSS Type B then the minimum installation length is 21 feet.
- If no thrie beam anchor is needed (e.g. a sign bridge is close to a bridge), then the minimum installation length of CBSS Type B is 10 feet.

2.3.6.4.2 Fixed Object Protection

SDD 14B32 provides two details on how to install barrier near fixed objects. Use fixed object protection when using a single run of barrier and fixed object require protection.

These details provide for extra steel, use of fill material and a small footing. Pay for fixed object protection using linear feet. Indicate in plan (e.g. plan view and MQ sheets) the location of fixed object protection. Include bid items for reflectors and brackets.

Other designs (e.g. integrating a sign bridge or light pole into the barrier run), have to integrate the impact forces into the structural design of the fixed object. The majority of impacts on a barrier are from vehicles of pick-up truck size or smaller (see 2.3.6.4.6).

Taper rates in the transition at large or small fixed objects may be adjusted using Table 5.7 "Suggested Flare Rates for Barrier Design" in 2006 AASHTO Roadside Design Guide. Provide construction details and special provisions. Include special bid items for design. Include bid items for reflectors and brackets.

2.3.6.4.3 Median Widening

If a single run of CBSS has to widen to match into double runs of CBSS, use sections A-A and B-B of SDD 14B32b transitions at large or small fixed objects as a guide. Taper rates in the transition at large or small fixed objects may be adjusted using Table 5.7 "Suggested Flare Rates for Barrier Design" in 2006 AASHTO Roadside Design Guide. Provide construction details and special provisions matching a single run of CBSS to a double runs of CBSS. Include bid items for reflectors and brackets.

2.3.6.4.4 Retaining Walls

There are two designs for retaining walls: median and roadside. Use median retaining wall design when the barrier is between two roadways of different height. The median design has a maximum wall height of 3 feet (See SDD 14B32). Indicate in plan (e.g. plan view and MQ sheets) the location of median retaining wall. Earthwork associated with median retaining walls is included in the cost of the median retaining wall. Include bid items for reflectors and brackets.

If the required height of median retaining walls is greater than 3 feet, a structural design is required. Design taller median retaining wall not only to retain soil and other loads, but also impact loads (see 2.3.6.4.6).

Insert construction details, special provision, and special bid items for median retaining walls taller than 3 feet. If the use of taller median retaining walls require significant earthwork or special earthwork, include earthwork bid items. Include bid items for reflector and brackets.

The roadside retaining wall does not have a maximum fill height (see SDD 14B41). However, a soils or structural engineer is required to review the location to see if SDD14B41 is appropriate. Indicate in plan (e.g. plan view and MQ sheets) the location of roadside retaining wall. Soils or structural engineer is to determine gradation of select borrow.

If SDD 14B41 is not structurally adequate for a given location, structural design is required (see 2.3.6.4.6). Insert construction details, special provision, and special bid items for special roadside retaining walls.

Pay for associated earthwork for retaining wall with separate items (e.g. common excavation, rock excavation, select borrow). Include bid items for reflectors and brackets. Insert special provision for select borrow.

Review drainage behind the retaining wall. Water should not flow over the top of the barrier wall. Pay for drainage items associated with retaining wall with separate items (e.g. inlets, inlet covers).

2.3.6.4.5 Use of CBSS on Bridges

The CBSS may be used on a bridge in a non-outer parapet application (See SDD 14B32). An example of this situation would be when a barrier is required to separate an on or off ramp or CD lane from main line lanes on a bridge deck (see Figure 2.13). Separating vehicle travel lanes from a multi-use path or pedestrians still requires a crashworthy bridge parapet (see Figure 2.14).

When using a crashworthy barrier on a bridge, coordinate with BOS early in the design process. Indicate on plan the location of this barrier, use SDD 14B32**,** and insert a special provision, and special items for this barrier. Include bid items for reflectors and brackets.

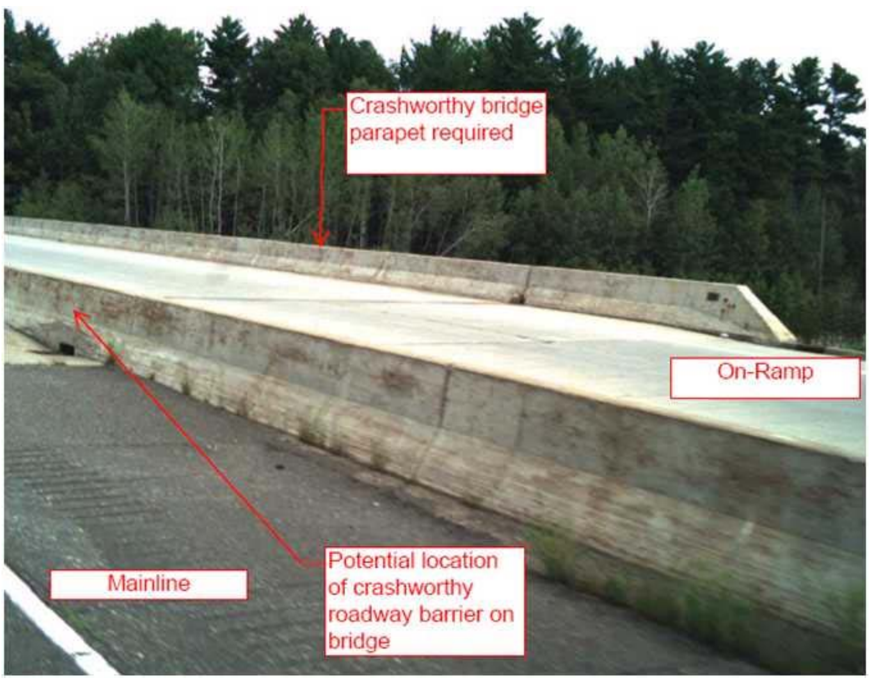

Figure 2.13 Crashworthy Barrier on Bridge

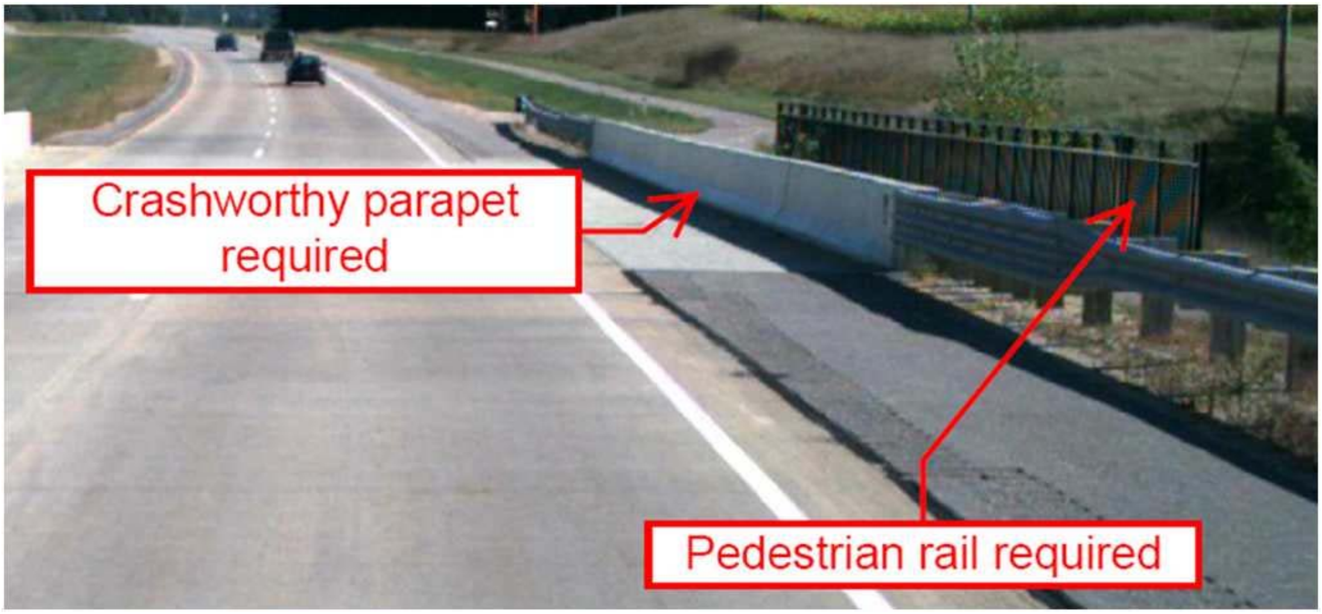

***Figure 2.14* Crashworthy Parapet on Bridge**

2.3.6.4.6 Other Situations

Use standard barrier as much as possible. Use of non-standard barrier may increase barrier cost (e.g. contractor may have to purchase a special shoe for the paver, or use traditional formwork to install barrier). Contractors may not be able to slip-form vertical barriers

However, there may be other situations where the SDDs may not fit a given location (e.g. closely placed parallel bridges on super elevations, not enough room for the transitions) or fixed objects are incorporated into a barrier system (e.g. sign bridges, light poles). In these situations, barriers or fixed object designs are required to:

- Have sufficient reinforcement for:
    - Shrinkage and temperature steel
    - Contain a TL-3 impact loads (See AASHTO LRFD Manual Chapter 13)
    - As necessary contain other loads (wind loads, dead loads…)
    - Vertical steel and associated footings to prevent barrier rotation during impact
- Provide clear cover for steel
- Provide working width (See FDM 11-45-2.3.6.2.2)
- Use crashworthy shape (See FDM 11-45-2.3.6.1)
- Allow for smooth redirection
- Be free of snag points
- Limit potential for vehicle vaulting
- Limit potential for flying debris

Coordinate early in the design process with BPD on the use of non-standard barrier. Structural analysis will be required. Place additional documentation in DSR justifying the use of special barriers or special transitions.

Provide constructible designs that are structurally and functionally adequate. Construction details, special provisions and special bid items will be needed.

2.3.6.5 Concrete Barrier Placement

The minimum required offset from edge of driving lane to face of barrier (at the toe) is the greater of shoulder width or the required horizontal clearance. WisDOT's practice on some high-speed divided highways has been to place concrete barrier 2-feet beyond the edge of shoulder (i.e. shy distance).

Shy distance is desirable, but not required design criteria for barrier placement. If a designer has to choose between providing shy distance or working width (see FDM 11-45-2.3.6.2.2) provide working width.

2.3.6.6 Median Barrier

Concrete barrier is typically installed in medians that are 40 feet or less. It is desirable to install two runs of concrete barrier. The advantages are:

- Fixed objects (e.g. signs, light poles, sign bridges, bridge piers…) can be located between the barriers and are less likely to be hit.[9]
- Fixed object designs are not required to accommodate impact loads
- Snow storage
- It is less likely that a vehicle will penetrate or over top barriers and end up in opposing traffic.

In general, it is desirable to use two runs of barrier when:

- 4-lane A3 roadway's median width is 19 feet or greater
- 6-lane A3 roadway's median width is 31 feet or greater

A single run of concrete median barrier may be appropriate for some projects. Provide documentation within DSR for using one run of median barrier. Factor to consider include:

- Insufficient room for two runs (shoulder width, shy distance to barrier, width of hazard, working width)
- No or few fixed objects in median
- Construction staging and work zone traffic control.

2.5 Existing Barrier System Evaluation

A significant amount of research has been invested into making barrier systems as safe as practical.[10] However, there can be collisions into a barrier system that have serious consequences. Because of this, it is important to review the need and quality of existing barrier systems.

In September of 1994 a technical memo from FHWA indicated:

> "We [i.e. FHWA {emphasis added}] believe that roadside hardware selected by a highway agency to improve safety should do so and that agencies must provide due care in not allowing inappropriate devices to remain indefinitely. Consequently, we [FHWA {emphasis added}] expect the selection and maintenance of roadside safety hardware will be key elements of a State's safety management system, with the objective of assuring that current crashworthy designs will be employed where appropriate."[xxiii]

The 2006 Roadside Design Guide states:

> "If the feature requiring shielding cannot be eliminated, the designer must assess the adequacy of the barrier installation. If the barrier is essentially non-functional (i.e., it cannot reasonably be expected to function satisfactory under most expected impacts) it should be upgraded to current standards."[xxiv]

Document in the Design Study Report (DSR) the following:

- The quantity of existing barrier systems,
  - Where are existing barrier systems located?
  - What type of barrier systems are on the project?
- The need for the existing barrier systems:
  - Can other roadside design methods be used to reduce the severity or frequency of collisions?
- The quality of barrier systems:
  - What hazard does the barrier system shield?
  - Is the barrier crashworthy?
  - How does this barrier system compare to the current standards?
- What is the past performance of the barrier system?

Without this information it is difficult to judge what action is appropriate (e.g. remove, spot improvement or replace existing barriers systems). Except for certain preventative maintenance (see PM Agreement) projects, not reviewing existing barrier systems is below minimum standards. Limited project by project exceptions for barrier systems review may be granted by Bureau of Project Development (BPD). These exceptions will be rare. Document the exception in DSR.

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[9] See working width discussion in FDM 2.3.6.2.2

[10] A barrier system is all of the components needed to prevent an errant vehicle from impacting a hazard. A simple example of a barrier system would require all hardware shown on the standard detail drawings for beam guard, end treatments (separate SDD drawings), proper placement of the barrier relative to hazard and grading. Installing beam guard without all the other components (e.g. EAT, grading…) may degrade the beam guard's performance.

After determining that a barrier system is required, analyze the existing barrier system. Use Attachment 2.5 Roadside Design Factors to Consider and guidance provided in this sub-section to determine if spot improvements or full replacement of a barrier system is required.

It can be difficult to determine what action is appropriate (e.g. do I modify this barrier or replace it?). BPD has tried to provide clear guidance when it can (e.g. remove beam guard with 12 foot 6 inch post spacing). Many situations will require the professional judgment of an experienced engineer trained in roadside design. In general, BPD recommends:

- Installing barrier systems as indicated in the Standard Detail Drawings (SDDs) and Facility Development Manual (FDM).[11]
- Fully replace barrier systems instead of performing a significant amount of spot improvements.
- Flexibility for an existing barrier system does not apply to newer installations of the same type of barrier system. Some examples are:
  - Existing beam guard has a range of acceptable heights. It is not appropriate to use this range of heights for new Midwest Guardrail System (MGS) beam guard installations.
  - Retrofitting a concrete sloped end treatment to shield an existing blunt end has more flexibility than installing a new concrete sloped end treatment for a new hazard.
- Remove barrier systems that are no longer needed[12].
- Remove or modify curb on approaches to or adjacent to a barrier systems.[13]
  - It is desirable to do the following (in order of preference):
    - Remove curb and gutter.
    - Use driveway curb and gutter.
    - Use 4-inch sloped face curb.

Some of the design guidance for new barrier systems can be used to judge existing barrier systems (e.g. length of need, grading, working width[14]...). Additional guidance on existing barrier systems can be found in the following sub-sections. Guidance in this sub-section is applicable to roadside barriers systems. Some of the guidance may be applicable to parapets on or attached to structures. Contact Bureau of Structures (BOS) for guidance when working with parapets attached to structures or barriers used for structural protection.

A significant number of crashes occur in work zones. Replace or perform spot repairs on existing barrier systems that are in marginal condition prior to shifting traffic closer to or increasing traffic adjacent to existing barrier systems.

Document the following in the DSR:

- Not reviewing existing barrier systems.
- Leaving a barrier system that is no longer needed in place.
- Installing a “modified” barrier system to fit a given location.[15]
- Not applying spot improvements or replacing a substandard barrier system.
- When applicable, not modifying existing curb or installing 4-inch sloped face curb.

Other items within this sub-section may require additional documentation within, as an attachment, or as an amendment to the DSR.

An individual construction drawing detailing the installation of a barrier system may be required[16]. Typically, an individual construction drawing is required when there is close interaction between grading, drainage, barrier system, hazards, underground obstructions, or structures. If these interactions are not addressed during the

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[11] Limited project by project exceptions allowing modification of barrier system may be granted by BPD. However, these exceptions will be rare. Document the exception in DSR.

[12] Barriers are hazards and require maintenance.

[13] Some modifications may allow a barrier system to be installed by curb. See SDDs and FDM for details.

[14] Working width is the combination of barrier width and either the maximum barrier deflection or the maximum distance a vehicle could extend behind the barrier. If a barrier does not provide working width, an errant vehicle may engage the fixed object that the barrier was intended to protect.

[15] Limited project by project exceptions allowing modification of barrier system may be granted by Bureau of Project Development (BPD). However, these exceptions will be rare. Document the exception in DSR.

[16] This guidance is recommended for both new barrier systems and retrofitting old barrier system installations.

design, a barrier system or other features may not be installed correctly or perform as intended (e.g. Figure 2.22 Thrie beam is missing a post to install a flume. Figure 2.18 lacks appropriate grading near thrie beam transition). A construction project may experience delay or costly change orders. An example of an individual construction drawing is in Attachment 2.6. See following sub-sections or SDDs for more information.

Individual construction details are site specific. Include the following in individual construction details: drainage structures (e.g. inlets, pipes, ditches) cross section/contours, hinge points, slope intercepts, structures (e.g. bridges, box culverts, retaining wall…) and underground obstructions (e.g. utilities, rock…). Typically, contours are required for complicated grading situations (e.g. rapping slopes around a structure that has a transition to rigid barrier installed nearby…). Other items that may be in individual construction details are: post location and embedment, curb and gutter changes, radius of shop bent beam guard, fixed object, changes in working width, installations near driveways, etc.

Some barrier systems may have components that can be salvaged and reused. Coordinate with regional operation staff if components are to be salvaged. Provide local unit of government contact within plan.

Both removal and salvage items for barrier systems include language requiring the contractor to restore the site. For example, no additional items are required for filling holes left by old posts being removed or salvaged. Earthwork items may be required if performing modification to a site to install a new barrier.

If a barrier system is within the grading limits of a contract, incorporate the grading for the barrier system into the standard bid items. If the barrier system is not within the grading limits of a contract, use grading and shaping standard bid item for the barrier system's earthwork.

When using the grading and shaping standard bid item use a table similar to Table 2.5. Add note to miscellaneous quantities indicating that the other items are for bidding purpose only. It is not recommended to include other items into the grading and shaping bid item. Typically, other items (e.g. installing a pipe, erosion control…) require additional design.

***Table 2.5* Barrier System Grading, Shaping, and Finishing**

Location	Excavation Common*	* Borrow	* Salv. Topsoil	* Fert. Type (-)	* Seeding	* Mulching	Each
	C.Y.	C.Y.	S.Y.	CWT.	L.B.	S.Y.	
Sta.__ to Sta.__							
Totals							

* *Items & Quantities listed for Bid Information Only. Show the quantities and units clearly in the table.*

List all items of work and round up the quantities for individual items and note them as "For Bid Information Only." Provide termini for each individual location where grading item is being used. Use discrete locations to identify where grading and shaping. For example, a given EAT location or a whole barrier system (EAT, beam guard, transition to rigid barrier.) The standard bid item for grading and shaping can be used with all different types of barrier systems.

2.5.1 Flexible Barriers

Replace low-tension cable barrier systems installed in non-median locations (See Figure 2.15). Typically, these systems are not crashworthy, have fixed objects within a barrier's working width or have grading issues.

Typically, median cable barrier installations are installed at cross median crash locations. Coordinate with BPD prior to removing or working near median cable barrier. Grading, cable barrier placement, drainage structures, and soil conditions can influence cable barrier performance. Some modifications of the cable barrier may be required.

Working width of cable barrier is measured from the traffic side of the cable. Many variables can impact the working width of a given installation. Discuss cable barrier working width with BPD.

It is recommend that curb and gutter near cable barrier systems is removed.

Forward questions about cable barrier to BPD. Special provisions and construction details are required when working on cable barrier. Typically individual construction details are needed for interaction with drainage structures, and areas of reduced working width.

Figure 2.15 Strong Post Low-Tension Cable Barrier to be Replaced

2.5.2 Semi-Rigid Barriers

Non-MGS beam guard (See SDD 14B15, SDD 14B25), MGS beam guard (See SDD 14B42, SDD 14B43), transitions to rigid barrier[17], bullnoses and curved beam guard are considered semi-rigid barrier systems.

General guidance (e.g. damaged components, missing components, washer between rail and bolt head, working width, LON…), can be applied to almost all semi-rigid barriers systems. However, there are some differences between systems (e.g. depending on speed, non-MGS beam guard requires modification and specific types of curb. MGS does not require modifications or special types of curb). What will work with one barrier system may not work with a different system. Know what barrier systems are within a project.

Working width for semi-rigid barrier installations is measured from traffic face of rail to front of hazard. Special applications of semi-rigid barrier may have different or additional requirements.

Some situations that require individual construction details are (See FDM 11-45-2.5):

-Installation of beam guard (non-MGS and MGS) next to or on top of underground obstruction, drainage features, or box culverts.

-Installation of beam guard (non-MGS and MGS) near retaining wall.

-Installation of beam guard (non-MGS and MGS) near a spot location with reduced working width.

-Installation of long span beam guard (non-MGS and MGS).

-Installation of transitions to rigid barrier systems (non-MGS and MGS).

-Installation of thrie beam bullnoses.

-Installation of curved beam guard.

-Installation of short radius beam guard.

Show post location and embedment on individual construction details when working next to or on top of an underground obstruction, drainage feature, or structures. Individual construction detail may be required to show dimensions of mow strip and changes of working width changes.

Only runs of semi-rigid barrier systems that do not require any grading, including end treatments, do not need individual construction details.

[17] Rigid barriers includes bridge parapets and concrete roadway barriers.

CMM 6-25 has examples of semi-rigid barrier that requires repair. Table 2.6 is an example of a miscellaneous quantity sheet using semi-rigid repair items. Use the limits of semi-rigid barrier installation to identify where work is required (e.g. from post number one of an EAT to post number one of an EAT, or post number one of an EAT to end of thrie beam transition…). Additional location accuracy is not required.

Table 2.6 Example Miscellaneous Quantity Sheet

Location	204.0165 Removing Guardrail LF	614.0400 Adjusting Steel Plate Beam Guard LF	614.0920 Salvaged Rail LF	614.0950 Replacing Guardrail Posts and Blocks Each	614.0951 Replacing Guardrail Rail and Hardware LF
2+00 to 3+00 LT		35		--	25
3+00 to 7+35 RT		150		75	100
8+00 to 10+50 LT	250				
15+00 to 19+00 RT			600		
Total	**250**	**185**	**600**	**75**	**125**

2.5.2.1 Adjustment of Steel Rail Height

Top of rail for existing non-MGS beam guard is between 27 3/4 to 29 inches.[xxv] Top of rail for existing MGS beam guard is between 27 3/4 to 32 inches.[xxvi,xxvii] Top of thrie beam rail is plus or minus 1 inch of the rail height indicated in the applicable standard detail drawing. Standard spec 614 provides guidance on adjusting rail height.

Verify top of rail's height once every 50 feet. Measure the rail's height at mid-span locations. Do not measure rail height on damaged rail sections.

Document in DSR that rail heights have been reviewed. Adjustment item (614.0400) may be used by itself or with other spot improvement items.

2.5.2.2 Replacement of Steel Rail

Replace torn, dented, flattened, and kinked rails. Replace rails with additional holes punched into them or rails with structural rust (i.e. not small locations of surface rusting). Use steel rail replacement item (614.0951). Indicate in plan when thrie beam is being replaced using the replacement of steel rail item. If Shop bent rail is needed, provide radii in plan (See FDM 11-45-2.5.2.12). Do not use steel rail replacement item on EATs because they are proprietary products.

2.5.2.3 Replace Posts and Block

Replace posts or blocks that are rotten or damaged. Replace or adjust blocks that are 1½ inch above or below the rail. Use replace block and post item (614.0950). Do not use replace post and block item on EATs. EATs are proprietary products. Use a special provision to replace blocks and posts in EATs

2.5.2.4 Straightening Blocks or Posts

Straighten posts or blocks that are out of plumb. Straighten posts that are more than 6 inches out of plumb.[xxviii] Use the adjust item (614.0400) for straightening blocks or posts.

2.5.2.5 Other Hardware Issues

The following issues require special provisions:

- Remove washers installed between the head of a bolt and traffic side of steel rail.[xxix,18]
- Replace delineators that are missing.

[18] A washer in this location can cause semi-rigid barrier to fail.

- Rails are not lapped in the proper direction (see SDD 14B15)[19].

2.5.2.6 Use of Salvage or Removal Bid Item

Use salvage and removal bid items separately. Use removal item (204.0165) if contactor is to dispose of all components.

Use salvage item (614.0920) to reclaim metal components. It is not the intent of the standard specification to reclaim wood materials. Once a post is installed and cut to proper height, it may be difficult to reuse the post in another installation. Exposure to the elements may weaken a wood post.

Use a special provision in the following situations:

- Reclaiming all semi-rigid barrier components (e.g. metal and wood components).
- If the contractor is to remove hardware, others are to select what hardware is to be reclaimed, and then have the contractor remove the remaining hardware from the construction site.

Removing semi-rigid barrier can facilitate other work or can allow for a better finished product. For example, an overlay project can add a significant amount of shoulder material. Removing the beam guard can allow proper compaction of new shoulder material and proper compaction can reduce shoulder erosion.

Review grading near soil or foundation tubes. These tubes provide strength for a whole semi-rigid barrier system.

2.5.2.7 Grading for Semi-Rigid Barriers

All semi-rigid barrier systems use soil to absorb impact energy. Some semi-rigid barrier systems can be modified to accommodate locations with reduced grading. Other semi-rigid barrier systems do not have the same flexibility. Grading options for semi-rigid barrier systems can be found on the appropriate SDD, or discussed in the following sub-sections. See discussion in FDM 11-45-2.5 on providing earthwork in plans near barrier systems.

Visual gaps between soil tubes (or foundation tubes) and soils around the tube reduce the amount of force the anchors can absorb. Small gaps should have soil replaced around the tube and compacted. Replace soil tubes when a soil gap is one inch or more. If there are issues with gaps around soil tubes, provide special provision to either reset soil tubes or replace soil around post.

2.5.2.8 Beam Guard

Beam guard is one of the most frequently encountered barrier systems. Use Excel analysis program(Attachment 2.7), Table 2.7 and Table 2.8 to determine if replacement or spot improvements are required. Issues in Table 2.6 require new beam guard. Other issues not in Table 2.6 may impact the decision to install new beam guard. Replace non-MGS beam guard with most current standard.

[19] In temporary conditions (e.g. a unidirectional roadway has become bidirectional), it is not necessary to change rail lap direction.

Table 2.7 Issues that Warrant New Barrier System

Situation	Issue	Discussion
Project	A new hazard requires shielding.	Install the most current standard.
	Other work on the project requires removal of beam guard.	Install the most current standard.
Beam Guard Installation	Current beam guard has 12 foot 6 inch post spacing.	This type of installation is not crashworthy.
	Beam guard has had poor past performance.	A new barrier system may have better performance.
	Beam guard has a w-beam backup plate installed at posts.[20]	W-beam backup plate may prevent rail separation from post during impact (see Figure 2.16).
	Beam guard has washer installed between the bolt head and the front face of the rail (see Figure 2.21).	A washer in this location may reduce the effectiveness of the beam guard.[21]
	Top of steel rail is less than 21 ¾ inches tall.	It is not possible to adjust rail to acceptable height.
	Cost of spot improvements is greater than the depreciated value of the existing barrier system (see Excel analysis program).	It is less expensive to install a new barrier system.

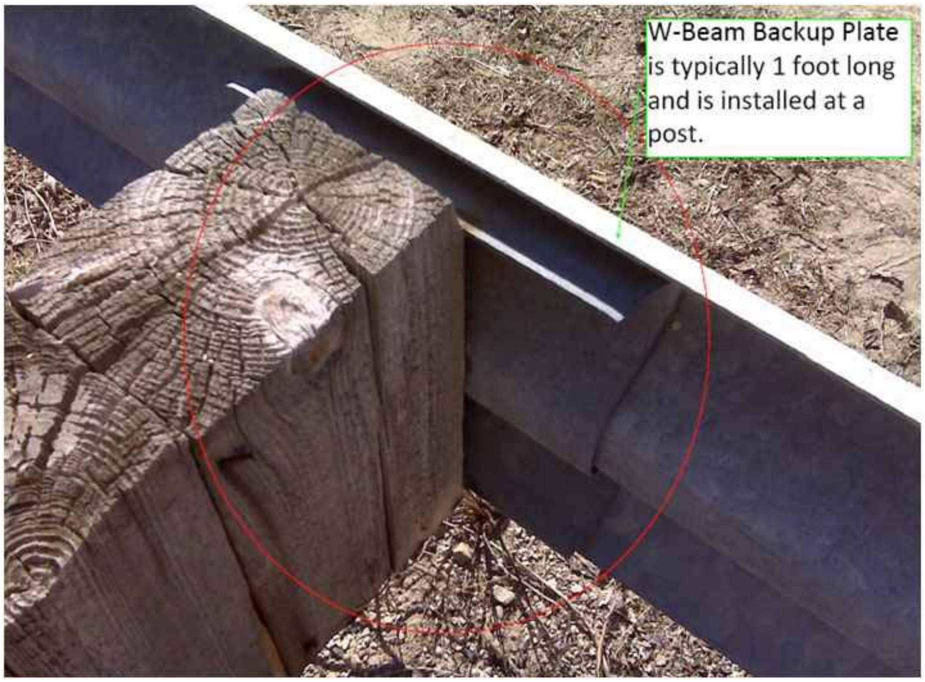

Figure 2.16 W-Beam Backup Plate

Table 2.8 is a list of situations that would require at least spot improvements and may require replacement. Replacement of beam guard depends on the magnitude and accumulated affect of spot improvements. Other

[20] The last time that the w-beam backup plate was included in a standard detail drawing was 1981.

[21] The last time that the washer was included in a standard detail drawing was 1985.

issues not in Table 2.8 may influence the decision to upgrade or to replace beam guard.

***Table 2.8* Issues that Warrant Spot Improvements of Beam Guard**

Situation	Issue	Discussion
Beam Guard Installation	Non-MGS beam guard has curb and gutter installed near it (see backside of SDD 14B15 for alternatives).	Curb and gutter have a detrimental influence on beam guard performance.
	Beam guard posts are pinned in asphalt, millings, or concrete (see backside of SDD 14B15 for alternatives).	Pinned posts increase the likelihood of beam guard failure (See SDD 14B28)
	Beam guard has insufficient working width (see Figure 2.17).	Beam guard can direct an errant vehicle into the fixed object (see Figure 2.18) or vehicle can lean over barrier and strike a fixed object.
	Lack of the 2 foot of grading behind beam guard with 6 foot 3 inch post spacing.	Lack of soil behind posts increase the likelihood of beam guard failure (see backside of SDD 14B15 for alternatives).
	Steel rail or wooden planks are used to control erosion or water (see Figure 2.19)	Steel rail or wooden planks limit post rotation
	Non-MGS Beam guard is flared at a rate steeper than the values in 2006 Roadside Design Guide Table 5.7.	Flaring barrier steeper than what is recommended increases the likelihood that the barrier will not function as intended.
	Beam guard posts or blocks are missing, out of plumb, or damaged.	Missing or out of placed hardware can influence barrier performance.
	Steel rail is Weathering or Cor-Ten steel.[22]	This type of steel makes it difficult to perform maintenance on.
	Steel rail is damaged.	Weakened rail may not function as intended.

[22] Weathered or Cor-Ten steel is specially designed to have a stable rust surface that does not require painting. This type of steel was used for a while as an aesthetic treatment.

***Figure 2.17* Utility Pole placed within Working Width of Barrier**

***Figure 2.18* Beam Guard Directed Errant Vehicle into Utility Pole**[xxx,23]

[23] More than likely, the beam guard was installed to shield the bridge pier. If the beam guard was not there the errant vehicle, more than likely, would have missed the utility pole.

Figure 2.19 Wood planks limit post rotation

The following situations require additional engineering to determine what action should be taken:

- Beam guard is on slopes steeper than 10:1.
- Beam guard is over a drainage feature (e.g. bridge, box culverts, culverts, pipes…).[24]
- Beam guard is shielding an errant vehicle from going over the top of a retaining wall or other structure.[25]
- The majority of a barrier installation requires the maximum height adjustment.
- If a project has a service life greater than 15 years (see duration discussion in Attachment 2.5).
- Will future projects be able to provide improvements to existing barrier systems?

To determine working width for normal non-MGS beam guard installations add 19.25 inches (i.e. 8 inch post, 8 inch block, 3.25 inch rail thickness) to the lateral distance values in FDM 11-45-1.5.2. Adjust working width if additional blocks are added to beam guard installation. See SDD 14B25 for working width requirements for non-mgs long span application.

Provide individual construction drawing showing reduced working width in spot locations. Identify the beginning/end of reduce working width, fixed object that has reduced working width and overall length of barrier requiring reduce working width. Reduce working width is to be provided 25 feet prior to hazard and along hazard. For unidirectional traffic, provide reduce deflection 12 1/2 feet beyond hazard. Bidirectional roadways have two approaches.

If working width is being reduced by one method (e.g. standard post spacing to half post spacing) no additional design is required. If working width is being reduced by two or more method (e.g. standard post spacing to half post spacing, half post spacing to quarter post spacing), provide 25 feet of each intermediate method to reduce working width prior the next method to reduce working width (e.g. 25 feet half post spacing between the standard post spacing and the quarter post spacing). This procedure would be followed on the approach and departure of the installation. Provide individual construction detail for a working width reduction of 2 units or more.

Lack of sufficient working width can cause a barrier installation to increase in length. For example, it is not

[24] A previous construction project may have installed shorted posts, used other methods to mount the beam guard to the drainage structure or used a long span beam guard design. Consult with BOS and a structural engineer.

[25] The consequences of a collision (i.e. a vehicle goes over the beam guard) may require a different barrier system. Retaining wall may need to be designed to accommodate impact loads. Consult with BOS and a structural engineer.

possible to reduce working width for end treatments. A hazard along a unidirectional roadway requires 12 1/2 feet of reduced post spacing longitudinally beyond a hazard. After the 12 1/2 feet of reduced post spacing, then a type 2 end treatment is installed. Other specialty applications typically do not permit modifications to reduce working width.

Use special provisions to pay for non-MGS beam guard with reduced deflection (e.g. half post spacing, quarter post spacing…)

2.5.2.9 MGS

Much of the guidance for non-MGS beam guard can apply to MGS beam guard (MGS). In some situation, MGS may be installed with curb and gutter. If MGS lacks appropriate grading behind the post, install MGS type K. Working width information for MGS systems will be provided for on future SDDs. Although it is possible, BPD does not recommend intermixing of MGS and Non-MGS systems.

MGS system may be flared at a maximum rate of 5:1. However, additional working width is required when flaring MGS.

2.5.2.10 Treatments near Rigid Barriers-Transitions

There are 3 types of treatments near beginning and end of existing rigid barriers:

- Unconnected beam guard (see Figure 2.20)
- Beam Guard Transition to Rigid Barrier (See Figure 2.21)
- Thrie beam transitions (See SDD 14B20, and Figure 2.22)

Figure 2.20 Unconnected Beam Guard[xxxi]

Figure 2.21 Beam Guard Transition to Rigid Barrier[26]

Figure 2.22 Thrie Beam Missing Posts

There are different options to modify barriers near a rigid barrier. The options depend on: type of treatment (see Figure 2.20 through Figure 2.22), direction of travel, what deficiencies are present, speed, and crashworthiness of the rigid barrier. Approach transitions (i.e. transition from a more flexible barrier to a rigid barrier) are more critical than departure transitions (i.e. transition from a more rigid barrier to a more flexible barrier).

Review parapets on or connected to a bridge, retaining wall or other structure. If parapet is not shown on: standard detail drawings, LRFD Bridge Manual, or within BOS's standard detail drawings, coordination with BOS and BPD is required. There may be crashworthiness issues with the parapet. For example, parapet designs prior to 1964 may not have sufficient strength to contain an impact.[xxxii] Parapets designed after 1964 may have sufficient strength, but the parapet may have other issues (e.g. snagging, pocketing...).

[26] Installation is not crashworthy. Installation lacks sufficient strength.

Additional design effort may be needed to evaluate the parapet or develop alternative retrofit designs. It is recommended that this coordination occur early in the design or scoping process. The crashworthiness of a parapet can have a significant impact on a project's scope.

Review location for other hazards besides the blunt end of the rigid barrier. If possible, remove the other hazards and focus on shielding or delineating the blunt end of the rigid barrier[27].

If an existing installation does not have at least 2 feet of grading behind the existing posts, options are (in order of preference):

1. If there is sufficient right of way, provide 2 feet of grading behind the posts.
2. If there is not sufficient right of way or there is a restriction preventing the use of the right of way, install a retaining wall. Or extend rigid barrier to a location that would allow for proper grading for the transition to rigid barrier.

A retaining wall may have to be designed to accommodate impact loads (See AASHTO LRFD Bridge Design Guide Chapter 13 for load information). Post location may also influence type of retaining wall. For example the reinforcement straps for MSE wall may conflict with post placement. Consult a structural engineer to determine type of retaining wall and if wall has to accommodate impact loads.

If required, a structural engineer is to design retaining wall for impact loads. Use TL-3 impact loads on roadways with design or operating speeds of 45 mph or greater. Use TL-2 impact loads on roadways with design or operating speeds less than 45 mph.

Use semi-rigid barrier system's working width for transition to rigid barrier's working width. Review guidance on providing individual construction details (See FDM 11-45-2.5 and FDM 11-45-2.5.2)

Use standard semi–rigid barrier adjustments bid items to provide spot improvements or replacement on transitions (See FDM 11-45-2.5.2). Depending on situation and location special provisions may be needed. Transitions to rigid barrier may also use the grading shaping item.

Figure 2.23 Problematic Thrie Beam Transition to Rigid Barrier

Figure 2.23 has a thrie beam transition to rigid barrier that has the following issues: post pinned into position by asphalt, lack of grading behind posts and insufficient post embedment.

[27] Delineating a roadside hazard is the least desirable roadside design option and requires documentation in DSR.

2.5.2.10.1 Unconnected Beam Guard

Unconnected beam guard near a rigid barrier is a significant hazard (i.e. Figure 2.20). Not only is the blunt end of the rigid barrier a concern, but the beam guard installed near the blunt end is a concern. Unconnected beam guard is an issue on the approach and departure ends of a rigid barrier.

All beam guard end treatments installed in a similar manner as Figure 2.20 will allow a vehicle to hit the blunt end of a rigid barrier. An example of end treatment allowing a vehicle to impact a blunt end of a rigid barrier is in Figure 2.24. The end treatment in Figure 2.20 is a potential spearing hazard for an errant vehicle. An end treatment, similar to one pictured in Figure 2.20**,** may not provide the whole beam guard installation with sufficient strength to contain a vehicle.

Figure 2.24 Unconnected Beam Guard Gated or Directed Errant Vehicle in to Blunt End[xxxiii]

Desirably, protect blunt end with a crash cushion or sand barrel array. A sloped end treatment may be used (see FDM 11-45-2.5.6). If guard rail is required to protect other hazards, desirably a thrie beam transition to rigid barrier would be used. In certain circumstances a beam guard transition to rigid barrier may be used (see FDM 11-45-2.5.9.2).

2.5.2.10.2 Beam Guard Connected to Rigid Barrier

Connecting beam guard to a rigid barrier is an improvement over an unconnected beam guard installed near a rigid barrier. However, critical impacts may allow an errant vehicle to impact the end of the rigid barrier. Beam guard connections may experience pocketing during an impact (see Figure 2.25) or other failures during an impact.

***Figure 2.25* Pocket Formed by Vehicle Impacting Beam Guard Connected to Parapet**[xxxiv,28]

However, there may be situations where a special beam guard transition to rigid barrier could be used (See SDD 14B46). A beam guard transition to rigid barrier is more than just connecting standard beam guard to a rigid barrier. The beam guard transition uses additional posts and nested beam guard to stiffen the connection to rigid barrier similar to a thrie beam transition.

A beam guard transition to a rigid barrier is not as desirable as installing a thrie beam transition to rigid barrier. BPD is trying to strike a balance between allowing minor projects (e.g. overlays, projects with less than 10 years of service life…) to proceed, and providing an improvement to roadside safety (i.e. providing at least some protection for minor impacts).

To determine if a beam guard transition is a suitable alternative, review the following variables: existing site conditions, speed, AADT and duration (i.e. how long an installation will be in service).

Some existing site conditions where a beam guard transition would be appropriate are:

- Beam guard is already attached to the structure.
- Rigid barrier has holes in it that allows beam guard transition to attach to the rigid barrier.
- Projects with 10 or fewer years of service life.
- Roadway segment does not have ROR flag in metamanager.
- Installation is in a location where ROR is not likely.

Some existing site conditions where a beam guard transition would not be appropriate are:

- New rigid barrier is being installed.
- Rigid barrier has holes for thrie beam transition to rigid barrier.
- Roadway segment has ROR flag in metamanager.
- Installation is in a location where ROR is more likely (e.g. curves, areas that violate driver expectations…).
- Projects with more than 10 years of service life.

Table 2.9 provides guidance on speed, AADT, and some existing site conditions. If roadway does not match criteria listed in Table 2.9 or other criteria within this sub-section replace with most current thrie beam transition.

[28] If a barrier contains a vehicle, as in figure 2.5, the occupants can experience excessive deceleration forces. Excessive deceleration forces can cause significant injuries or fatalities.

***Table 2.9* Roadway Conditions for Beam Guard Retrofit** [29]

Design or Operating Speed[30]	AADT	Action	
<45 mph	Any	If rigid barrier ends abruptly (i.e. blunt end), a beam guard transition may be a permanent application.	If rigid barrier has a "sloped concrete end section" (see SDD14b20-c), the beam guard transition is only to be used on projects with 10 or fewer years service life.
≥45 mph to ≤50 mph	≤20,000	Use beam guard transition on projects with short service life of 10 years or less.	
>50 mph to ≤55 mph	≤4,000		
>55	All	Replace beam guard with most current thrie beam transition.	

Other conditions for the beam guard transition are:

- Rigid barrier is NJ, F or vertical shaped.
- Bridge does not have brush curb (see Figure 2.26).
- Top of beam guard rail can be attached to rigid barrier at 27 3/4 inches.
- Bridge rail is not W or M.

Follow guidance in the introduction of this sub-section on curb and gutter (FDM 11-45-2.5). Review SDD 14B4 (SDD being developed) or additional information on the beam guard transition to rigid barrier.

***Figure 2.26* Brush Curb**

Provide documentation in DSR when using beam guard transition. Projects with long service life are to install thrie beam transitions (See Duration discussion in Attachment 2.5). If a designer cannot determine if a beam guard or a thrie beam transition is appropriate, BPD recommends installing the thrie beam transition.

2.5.2.10.3 Thrie Beam Transitions

Since 1990, thrie beam transitions to rigid barriers have been installed by the department. Since its inception, the thrie beam transition drawings have had various changes. The preferred alternative is to install a thrie beam transition to rigid barrier as shown in standard detail drawings.

Existing non-MGS installations that have the following may remain in place:

- Posts:

[29] Table adapted from: Keller, Eric, Faller, Ronald, Sicking, Dean, Polivka, Karla, Rohde, John: "Guideline for Attachments to Bridge Steel Beams and Median Barriers" Midwest State's Regional Pooled Fund Research Program, MwRSF Research Report No. TRP-03-98-03, February 2003

[30] Select the higher of the two.

  - Quarter post spacing (i.e. 1 foot 6 3/4 inches) for the first 6 posts upstream of the rigid barrier.
  - Half post spacing (i.e. 3 foot 1 1/2 inches) for the next 4 posts upstream of the quarter post spacing).
- Steel thrie beam:
  - 12 1/2 feet of nested thrie beam rail upstream of the rigid barrier.
  - A minimum of 12 1/2 feet of standard thrie beam rail following the nested thrie beam rail.

It is desirable to replace missing posts within the thrie beam transition. Posts may conflict with drainage structures. BPD is conducting research on this issue. Until the research is published, relocate drainage structures to allow for post installation. Provide justification in DSR if missing posts cannot be installed.

Existing curb and gutter may remain in place. Review guidance provided in SDD 14B20.

2.5.2.11 Bullnoses

WisDOT has used at least three different bullnoses designs. Only the thrie beam bullnose design has been successfully crash tested. The three system are:

- Downturned end treatment bullnose (See Figure 2.27)
- Bent beam guard bullnose(See Attachment 2.8)
- Thrie beam bullnose (SDD14B26)

Replace downturned end treatment bullnoses and bent beam guard bullnoses. Limited project by project exceptions to allow downturned end treatments and bent beam guard bullnose may be granted by BPD. These exceptions will be rare. Document the exception in DSR.

Review thrie beam bullnose installations for other issues that may impact performance (e.g. grading, working width, curb and gutter, fixed objects too close to rail 1 of bullnose…). Review guidance provided in SDD 14B26. Review guidance on providing individual construction details (See FDM 11-45-2.5, FDM 11-45-2.5.2, and SDD14B26)

For existing installations, follow guidance in the introduction of this sub-section on curb and gutter (See Attachment 2.5).

Figure 2.27 Downturned Bullnose Design

2.5.2.12 Curved Beam Guard

Curved beam guard is any beam guard that has to be shop bent.[31] In general, WisDOT does not want to use curved beam guard because of cost, longer repair time, and crashworthiness issues. However, site specific or

[31] Radii 150 feet or less require shop bending.

project related issues may permit the use of a curved beam guard. For example, a collision into curved beam guard may be more desirable than a collision with a hazard.

Replace curved beam guard with radii 36 feet or less with the short radius system (see SDD 14B27). If curved beam guard with radii of 36 feet or less is not going to be replaced with short radius system document in DSR.

Desirably, radii greater than 36 feet would be removed or the location would be modified to use the short radius system. If it is not feasible to install short radius system, document in DSR.

On existing curved beam guard installations, follow guidance in the introduction of this sub-section on curb and gutter (See Attachment 2.5). For grading and curb guidance for new installations of the short radius system, review the backside of SDD 14B27. Review guidance on providing individual construction details (See Attachment 2.5, FDM 11-45-2.5.2, and SDD 14B26).

The short radius system may require additional right of way. Review right of way needs early in project's design.

Figure 2.28 Problematic Short Radius with installation Problems

The installation in Figure 2.28 has the following issues: not using CRT post in radius, insufficient length of tangent beam guard along the low volume road, wrong end treatment, and use of curb and gutter.

2.5.3 Concrete Barriers

WisDOT has used various shapes of concrete barriers (See FDM 11-45-2.3.6). Issues in Table 2.10 require new concrete barrier. Other issues not in Table 2.10 may also impact the decision to install new concrete barrier.

Table 2.10 Issues that Warrant New Concrete Barrier

Situation	Issue	Discussion
Project	A new hazard requires shielding.	Install the most current standard.
	Other work on the project requires removal of a whole run of concrete barrier.	Install the most current standard.
	Structural protection is required (FDM 11-35-1).	LRFD impact loads require special barrier designs.
Concrete Barrier	Barrier is GM shaped.	GM shaped barrier has not passed NCHRP 350 criteria.
	Concrete barrier does not match NJ, F, single slope or vertical shapes (See FDM 11-45-2.3.6).	Barrier shape is a non-crash tested design.
	Concrete barrier is flared at a rate steeper than the values in 2006 Roadside Design Guide Table 5.7.	Flaring barrier steeper than what is recommended increases the likelihood that the barrier will not function as intended.
	Overlays greater than 3 inches have been placed adjacent to a NJ, and F shaped barrier (see Figure 2.29).	NJ and F shaped barriers were designed to accommodate up to 3 inches of overlays.
	Single slope barrier has a height less than 32 inches (see Figure 2.29).	Single slope barrier less than 32 inches may have difficulties redirecting larger vehicles.

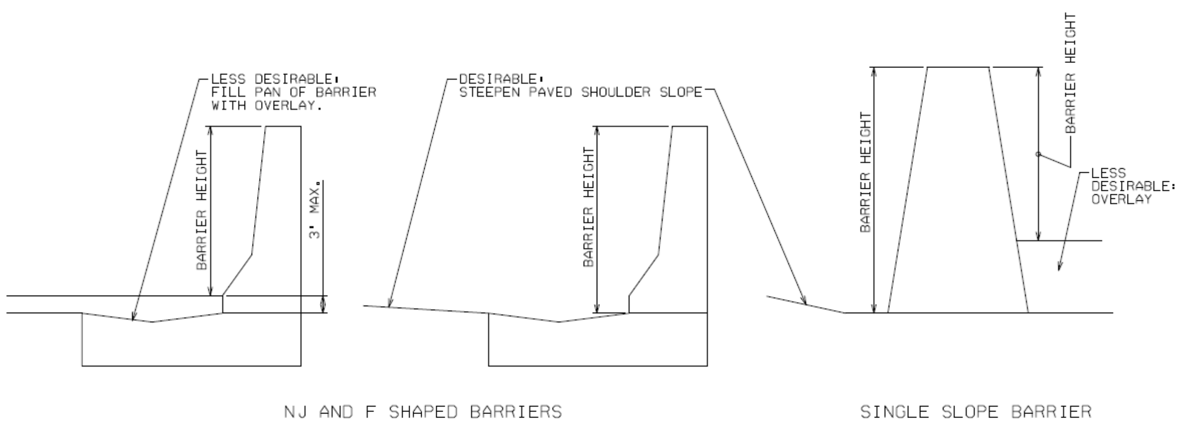

Figure 2.29 Overlays near NJ, F, Single Slope Barriers

Table 2.11 is a list of situations that would require at least spot improvements and may require replacement. Replacement of concrete barrier depends on the magnitude and accumulated affect of spot improvements. Other issues not in Table 2.11 may also impact the decision to use spot improvements or fully replace concrete barrier.

Table 2.11 Issue that Warrant Spot Improvements

Situation	Issue	Discussion
Project	Project requires the partial removal of concrete barrier installation to facilitate work on project.	Replace long sections of concrete barrier with most current concrete barrier standard.
Concrete Barrier Installation	Police reports indicate that vehicles are vaulting over, riding on top of, or striking objects behind/on top of barrier.	See discussion below.
	Concrete barrier has open cracks that extend through the barrier (see Figure 2.33, 2.34 and 2.35).	Concrete barrier with open cracks may fail during an impact or launch projectiles at other vehicles or pedestrians.
	Concrete barrier has exposed or rusted reinforcement.	Concrete barrier is structurally weak and may fail during an impact.
	Concrete barrier is tipping over or faulting (see Figure 2.30).	Concrete barrier may snag a vehicle during an impact.
	Individual panels are more than 2 inches offset (See CMM 1-45.12.5.9 for examples).	Concrete barrier may snag a vehicle during an impact.
	Concrete barrier has opening greater than 4 inches long (See CMM 1-45.12.5.9 for examples).	Concrete barrier may snag a vehicle during an impact.
	Concrete barrier has open gaps (see Figure 2.32).	Concrete barrier may snag a vehicle during an impact or fall during an impact.
	Concrete barrier has abrupt changes in cross sectional area (see Figure 2.31).	Concrete barrier may cause rapid deceleration of vehicle or launch vehicle into opposing lanes or air.
	Curb and gutter is placed in front of concrete barrier.	Curb can have negative influences on barrier performance.
	Concrete barrier has a blunt end.	This is not a crashworthy end treatment.

Reducing barrier height can make it more likely that a vehicle could vault over concrete barrier or hit objects just behind the barrier. From a roadside design perspective, it is more desirable to steepen paved shoulder slopes near concrete barrier because it does not reduce the overall height of the barrier[32]. It may not always be possible to steepen shoulder slope to avoid reducing the overall height of the barrier. Overlays directly adjacent to a barrier (Left side of Figure 2.29) may also cause drainage issues.

The recommend minimum height for single slope concrete barrier on freeways or expressways with design or operating speeds greater than 45 mph is 36 inches. Single sloped concrete barriers with height of the barrier 32 inches may acceptable on other facilities. Document changes in barrier height in DSR.

Avoid reducing barrier height in the following locations:

- Fixed objects are placed close to the barrier.
- Consequences of a collision are severe.
- Pick-up trucks or smaller vehicles have ridden on top of, hit fixed objects on the barrier or vaulted over the barrier.
- Collision history of large vehicle impacting a barrier.

Some issues in Table 2.11 may not improve overall concrete barrier performance. Addressing these issues limit negative influences on concrete barrier. For example, repairing cracks on concrete barrier (damage similar to

[32] Review other sections of FDM about maximum shoulders slopes and maximum algebraic difference in slopes.

Figure 2.33 through Figure 2.35), may not provide structural strength for critical impacts. Repairing cracks may help reduce future deterioration of the barrier, limit snag, or limit size of barrier fragments from an impact. Additional design effort may be required when designing spot improvements.

Issues similar to Figure 2.33 through Figure 2.35 may be only a few feet long and more than likely not provide structural capacity. Other issues, such as Figure 2.30 or the need to provide working width may be 100's of feet long and more than likely provide structural capacity.

Some issues, such as Figure 2.30, will require limited engineering effort (i.e. remove barrier and replace with new). Other issues, similar to Figure 2.31, Figure 2.32, Figure 2.35 and barrier openings (see CMM 1-45.12.5.9), will require more engineering effort. Coordinate with BPD early in the project development.

Follow guidance in the introduction of this sub-section on curb and gutter (see FDM 11-45-2.5). Review FDM 11-45-2.3.6 for additional guidance on concrete barrier design.

Depending on work being performed, special provisions and construction details may be needed.

Figure 2.30 Concrete Barrier that is Tipping Over

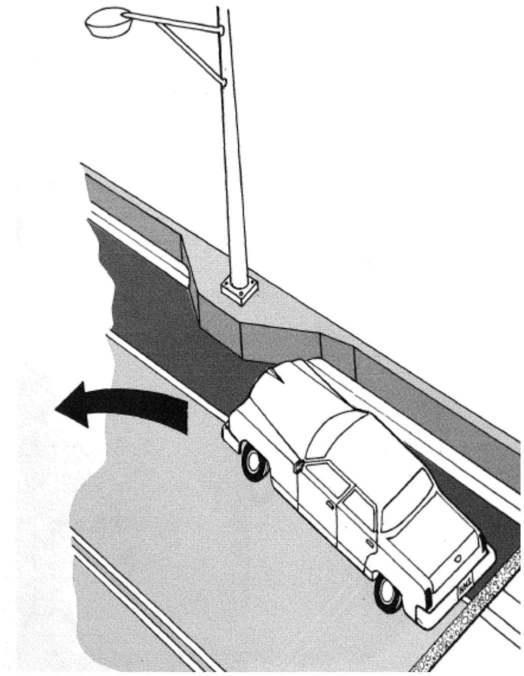

Figure 2.31 ***Cross Sectional Changes in Barrier***[xxxv]

Figure 2.32 ***Opening in barrier that can snag a vehicle***[xxxvi]

Figure 2.33 Cracked Concrete Barrier Needing Repair

Figure 2.34 Cracked Concrete Barrier Needing Repair

Figure 2.35 Cracked Concrete Barrier Needing Repair

2.5.4 End Treatments

Upgrade approach blunt ends (see Figure 2.36 and Figure 2.37), all BCT's (Figure 2.38), and all downturned ends (Figure 2.39) to EATs.

Limited project by project exceptions for downturned ends may be granted by BPD. These exceptions will be rare. Document the exception in DSR. In many cases, an EAT can be designed to accommodate a location.[33] BPD is aware of two situations that would allow the use of a downturned end treatment. These situations are:

- A project is using a non-standard beam guard system and the only end treatment that can be attached is a downturned end.
- A combination of unique topography and roadway geometry allows for the installation of a downturned end.[34]

Coordinate early in the design process with BPD to determine if a downturned end is appropriate. Additional design effort, special details, individual construction details, and special provisions are required.

MELT terminals (Figure 2.40) are acceptable in locations where: the design speed or operating speed is 45 mph or less, the terminal is installed correctly, and the MELT is in working order[35]. If one of these conditions is not met, remove the MELT and replace with EAT. SRT-350 terminals (Figure 2.41) may remain in place provided that they are in good working order and installed correctly.

[33] In many cases an EAT without proper grading is more desirable than a downturned end. However, not providing grading for EAT would require documentation in DSR.

[34] BPD is aware of only one such location in the state.

[35] Note the MELT requires a "parabolic flare" from the edge of shoulder.

Figure 2.36 **Blunt Ends**

Figure 2.37 **Blunt Ends**[36]

[36] Besides the blunt ends the beam guard also has the following issues: improper steel posts, overall barrier length is not sufficient to protect hazard and utility pole is a hazard.

Figure 2.38 **BCT terminal**[xxxvii]

Figure 2.39 **Downturned Ends**

Figure 2.40 **MELT**[xxxviii]

Figure 2.41 **SRT-350**[xxxix]

Review existing EATs for proper grading, hardware, steel rail height, reflective sheeting and EAT marker posts. EAT height and height tolerance is the same as semi-rigid barrier's it is attached to. Review backside of SDD 14B24 and SDD 14B44 for grading and other design information on EATs.

EATs attached to flared barrier installations should be installed tangent to the flared barrier. For example the barrier is flared at 16:1 the EAT should use a 16:1 flare. Steepening the flare rate of the EAT (e.g. 16:1 barrier flare plus and additional 2:1 for the EAT) may increase the likelihood of EAT not functioning as intended.

EAT's are proprietary devices. Write special provision to have the contractor provide replacement parts made by the manufacture. Have special provision indicating location, manufacture, and system (ET-2000, ET-2000 Plus, SKT-350…). Use the salvage items in Standard spec 614 to salvage end treatments.

Provide individual construction drawings for EATs (See FDM 11-45-2.5 and FDM 11-45-2.5.2). Review FDM 11-45-1.4.2.2 for guidance on curb and gutter near EATs. Review the need for breakaway or fixed object placed near EAT and working width.

2.5.5 Crash Cushions and Sand Barrel Arrays

Issues in Table 2.12 require new crash cushions or sand barrel arrays. Other issues not in Table 2.12 may also impact the decision to install a new crash cushion or sand barrel array.

Table 2.12 Issues that Warrant New Crash Cushion or Sand Barrel Array

Situation	Issue	Discussion
Project	A new hazard requires shielding.	Install the most current standard.
	Other work on the project requires removal of crash cushion or array.	Install the most current standard.
Crash Cushion or Sand Barrel Array Installation	Crash cushion is a GREAT system (see Figure 2.42 and Figure 2.43).	This system does not meet current crash test standard.
	Crash cushion or array was installed prior to October 1, 1998.	Systems older than this date are not to current crash test standards.
	Crash cushion or array has had poor past performance.	A newer system may have better performance.

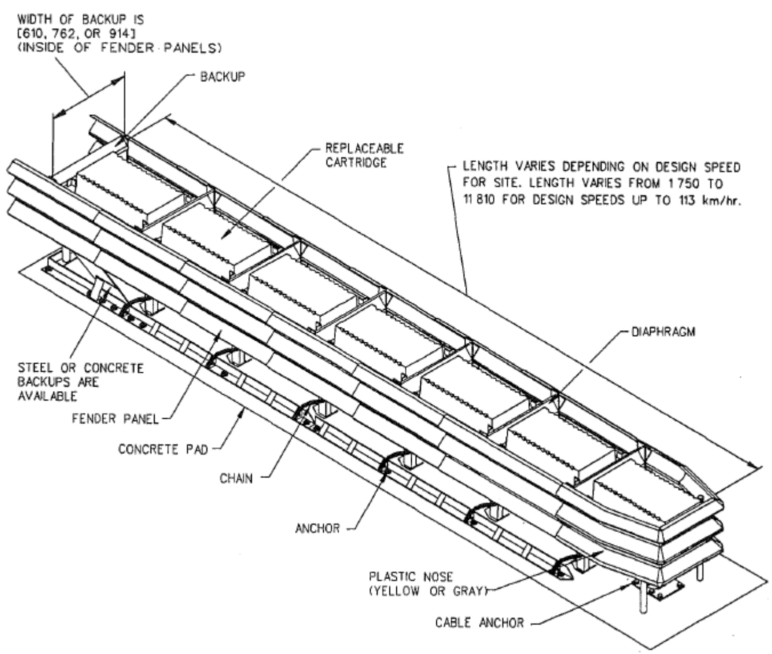

Figure 2.42 GREAT Crash Cushion[xl]

Figure 2.43 Photo of GREAT installation

Table 2.13 is a list of situations that would require at least spot improvements and may require replacement. Replacement depends on magnitude and accumulated affect of spot improvements. Other issues not in Table 2.13 may also impact the decision to provide spot improvements or fully replace and crash cushion or array.

Table 2.13 Issues that Warrant Spot Improvements Crash Cushion or Array

Situation	Issue	Discussion
Crash Cushion or Sand Barrel Array Installation	Cushion or array is not on a paved surface.	Systems are required to be on a paved surface.
	Crash cushion is not mounted to a backup block or anchored into a paved surface.	Without one of these attachments the crash cushion may not absorb impact energy.
	Curb and gutter is on the approach or adjacent to a crash cushion or array.	Curb can have negative influences on performance.
	Grading from edge of lane to crash cushion or array is steeper than 10:1.	Vehicle may not engage the crash cushion or array correctly.
	Array is 10 or more years old.	Older barrels are more likely to have a non-impact failure because of exposure to UV rays.
	Crash cushion or array has missing, improperly installed, or damaged components.	Systems may not function as intended.

Review FDM 11-45-1.7 for additional guidance on crash cushions or arrays.

Discuss with crash cushion manufacturer the need for a back up block or pad for crash cushion. If needed, update delineation of crash cushion.

Older arrays may not be designed to most current crash testing standards. Review existing layouts by using procedures in 2006 Roadside Design Guide, or manufacture's most current array layouts. Replace arrays that are not to current crash test standards. If it is not possible to fit a new array into an existing location, review if a crash cushion could be installed.

If array is designed to current crash test standard, review arrays for: proper position of barrels, correct number of barrels, weight of barrels, and that rock salt is mixed with sand. Existing barrels have a tendency to warp over time and may not accept new lids. Older warped barrels may have to be replaced. If the majority of barrels in an array require replacement, replace whole array.

Figure 2.44 Problematic Sand Barrel Array

Figure 2.44 is a problematic array installation. This installation has the following issues: use of curb and gutter, barrels are not on a pad, and a damaged barrel.

Use special provisions to refurbish crash cushions. Include name of manufacture, the name of the specific system and indicate what work is required in special provisions. If multiple systems are within a project, use different special provisions for each system. Provide individual construction drawings when grading, installing pad or back up block, or modifying curb near crash cushion.

Use special provision to repair individual barrels within an array. Provide individual construction drawings indicating which barrel is to be replaced, it location, and weight. When using a special provision reference WisDOT's Product Approval List (PAL).

Use standard bid item to replace whole array. Provide individual construction drawing when grading, installing pad or back up block, or modifying curb near array.

2.5.6 Sloped Concrete End Treatments

No known concrete sloped end treatment has passed all crash testing requirements. In general, the department does not want to install sloped concrete end treatments. Guidance provided below is for retrofitting a concrete sloped end treatment into an existing location on minor projects (i.e. projects with less than 15 years of service life).

Approval of Bureau of Project Development is required to install a concrete sloped end treatment. Approvals will be rare. In many cases, it is possible to install crashworthy hardware (e.g. crash cushions, sand barrel arrays, transition to rigid barrier with EAT…)[37]. Avoid using aesthetical concerns to justify the retrofitting of a sloped end treatment.

AASHTO indicates the following:

"While aesthetics are a concern, they should not be the controlling factor in selection of a roadside barrier. Even in environmentally sensitive locations such as recreation areas and parks, it is important that the barrier be selected crashworthy as well as visually acceptable"[xli]

There could be existing site specific or project related issues that may allow a sloped end treatment (i.e. slope

[37] In some case, it may be better and EAT without grading than to install a sloped end treatment.

end treatment is better than an exposed blunt end). Retrofitting in a new sloped end treatment into an existing facility requires the following:

- Design or operating speeds are 40 mph or less.
- Other roadside features prevent the proper installation of crash tested hardware.
- Barrier has sufficient LON to protect roadside hazards or the only hazard is the blunt end of a rigid barrier.
- 10:1 or flatter grading is present leading to an adjacent to the sloped end treatment.

Desirably no curb or gutter should be installed leading into or adjacent to the sloped end treatment. Follow guidance in the introduction of this sub-section on curb and gutter (See FDM 11-45-2.5).

Attachment 2.9 has an acceptable sloped concrete end section. Other "sloped" concrete sections that do not match the barrier design in Attachment 2.9 (e.g. such as Figure 2.45 or SDD 14B 20 sheet c) are considered blunt ends. Shield, replace, or delineate blunt ends of concrete barrier.[38]

Attachment 2.9 is a concrete sloped end treatment designed to match into a 32-inch F shaped barrier. To match into a taller barrier, extend slope to reach appropriate height. To match into a different shaped barrier, use similar geometry and transition to desired shape. Generally, the length of the barrier will be 20 feet or longer (depending on height of barrier matching into). Provide overall geometry details, overall steel details, cross sections, and bent bar details. See FDM 11-45-2.3.6.4.6 for more information.

***Figure 2.45* A "Slope" End Treatment that needs Replacement**

Coordinate with BPD when retrofitting a sloped end treatment. Construction drawings and special provisions will be required.

2.6 Drainage Features and Cattle Passes

Projects with PSE due Aug 2013 are required to use the new guidance. Projects with PSEs prior to August 2013 are encouraged but not required to use the guidance. Projects with PSEs prior to August 2013 and are on NHS or subject to FHWA oversight are required to discuss with FHWA about the implementation of the guidance.

Drainage features like (list not all inclusive): culverts, bridges, large drainage conduits have unique challenges that can make it difficult to select an appropriate roadside treatment option. Cattle passes can have many of the

[38] Note that delineating a hazard is the least desirable roadside design option. Provide documentation in DSR when delineating a roadside hazard.

same roadside design issues as drainage features and will be discussed in this section.

Drainage features or cattle passes can be a hazard depending on orientation, number of drainage features and size. Drainage features or cattle passes with diameters greater than the value listed in the table below are hazards.

Table 2.14 Drainage Feature or Cattle Size [xlii]

Pipe Orientation to Roadway	Number of Culverts	Culvert diameters or box culvert opening width (inches)
Perpendicular	1	36
	2 or more	30
Parallel	1	24
	2 or more	All multi-culvert runs are hazards

A drainage feature or cattle pass can become a hazard, regardless of size of drainage feature or cattle pass, if a portion a of the structure can snag the undercarriage of an errant vehicle (e.g. 4 inch object on a 5-foot chord) or the vehicle bumper can impact the structure (e.g. headwall, pipe sticks out of slope, etc.).

In addition, other objects near a drainage feature or cattle pass can be hazards (refer to Figures 2.47 and 2.48). Some examples are:

- Water [39]
- Slopes
  - Leading to and departing from drainage feature.
  - Slopes that blend into drainage feature.
- Ditches
  - Non traversable roadway's ditches.
  - Drainage ditches' slopes (i.e. non-roadway ditches).
  - Blending slopes:
    - Roadway backslopes and drainage ditch slopes.
    - Foreslopes and drainage feature or cattle pass.
- Other fixed object hazards.
- Overall drop from structure to ditch bottom.[40]

Other hazards typical increase the traveling public's crash exposure (refer to Figure 2.46).

[39] Water 2 feet or deeper.
[40] Vertical drops of 8 feet or more are hazardous. Vertical drops of 6 feet or more combined with other hazards (e.g. rip rap or water) are hazardous.

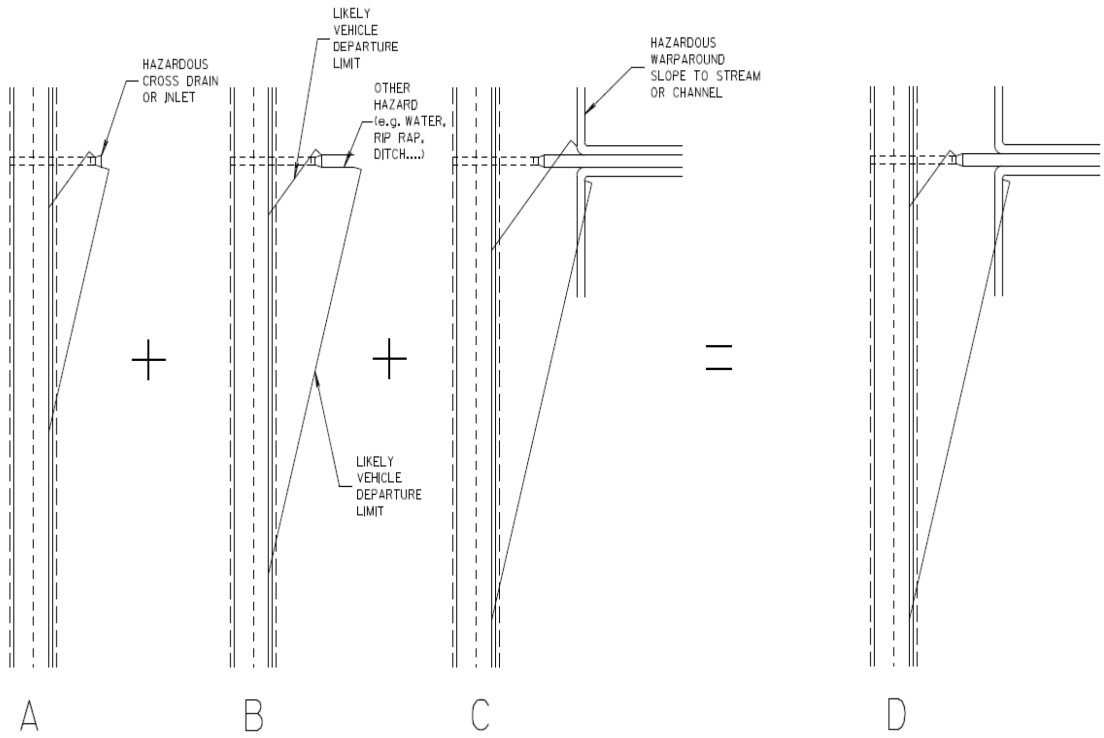

Figure 2.46 Likely Exposure Limits for Errant Vehicles to Hazards (one direction of travel only)

Figure 2.47 Water and Culverts are Hazards

Figure 2.48 Overall height of this box culvert would require shielding. Edge of box culvert is just beyond clear zone.

The following subsections are written assuming the drainage feature or cattle pass is in good structural condition. When reviewing structural adequacy, it is important to review where safety hardware or a barrier system will attach to the drainage feature. If there are questions about the structural condition of the drainage feature or cattle pass contact Bureau of Structures.

Provide individual construction drawing for installing a barrier system or safety hardware near hazardous drainage features or cattle passes (refer to discussion in FDM 11-45-2.5). If cross sections are not provided, the barrier system or safety hardware may not work as intended.

FDM 11-45-2.6 is written for 3R, 4R, or new construction projects. The provided guidance may be applicable to some Preventative Maintenance (PM) projects. Typically, the type of work being performed in the PM project will influence what roadside treatment is being used. Some examples are listed in Table 2.15 (list is not all inclusive).

Table 2.15 Potential Roadside Treatment Options for Hazardous Drainage Features or Cattle Pass for PM Projects

Type of PM Project or Work Being Performed	Traversable Grate	Extend, Remove or Relocate	Shield	Delineate
Drainage Restoration Project	X	X	X	X
Restoring grading near drainage feature or cattle pass	X	X	X	X
Restoring or installing Rip Rap			X	X
A barrier system shielding a hazardous culvert can be removed by installing a traversable grate without acquiring additional R/W	X			
Project is crack sealing and upgrading signage				X

It is recommended that Regional staff review the PM project with Bureau of Project Development Project Services Section early in the scoping phase or design phase. If a hazardous condition for a drainage feature or cattle pass cannot be adequately addressed as within a PM project, then a future project should be program to correct this hazard.

2.6.1 Cross Drainage Features and Cattle Passes

This section deals with drainage features and cattle passes that are installed perpendicular or skewed to the direction of mainline travel. Options available for cross drainage features and cattle passes (in order of preference are):

1. Traversable grates
2. Extending removing or relocating cross drain
3. Installing a barrier system
4. Delineate

2.6.1.1 Traversable Grates

From a roadside design perspective, traversable grates are the most desirable option. In general, traversable grates have lower installation and crash costs than other alternatives. Traversable grates can have a lower maintenance cost than a barrier systems.

Traversable grates can have issues with clogging, requiring right of way, or grading. Issues with clogging can be minimized by installing a traversable grate on the upstream end of the drainage feature. If a traversable grate is not installed on the upstream end of the drainage feature, it is difficult to detect if the cross drain is clogged with debris. It is also more difficult to clean out debris from inside a cross drain.

Not installing traversable grates because of maintenance concerns requires additional coordination with Bureau of Project Development (BPD). Document the decision not to install a traversable grate because of maintenance concerns in the DSR.

Do not install traversable grates on cattle passes or cross drains for navigable waterways.

Review hydraulic capacity of cross drains prior to installing traversable inlet. Not installing a traversable inlet because of hydraulic concerns requires documentation in DSR.

Refer to FDM 11-45-2.2.10 traversable grates for the warrant on traversable inlet.

Generally, it is not possible to intermix cross drain traversable culvert grates with parallel traversable grates because the number of bars, bar orientation, and spacing for the bars are different.

For most cross drain culverts, the traversable grate details can be found on SDD 8F8. Concrete culverts are to use steel traversable culvert grates (refer to Steel Adapter Sleeve for Concrete Pipe drawing on SDD 8F8).

Type 8,9,10 inlets may be modified to provide the correct slope to allow it to be traversable (refer to SDD 8C5). Larger box culverts, mortar rubble masonry endwalls (SDD 8F9), or concrete masonry endwalls (SDD 8F10), may require special provisions, special construction details and coordination with BPD.

Concrete inlets may require additional information in the plan to allow the contractor to construct the inlet and associated slopes.

Provide grading for traversable grates. Installation of traversable grate may require a site specific construction detail or cross sections (refer to Attachment 2.18 for an example). Do not rely on a generic drawing similar to Attachment 2.18 as the sole source of grading information.

2.6.1.2 Extending, Removing or Relocating of Cross Drain or Cattle Pass

In general, extending cross drains or cattle passes will have higher initial construction costs and will result in lower crash costs. Extending smaller hazardous cross drains or cattle passes is simpler than extending a larger drainage features or cattle passes. Extending a large cross drain or cattle pass is more likely to require coordination with a structural engineer, environmental work, review of hydraulic capacity, right of way and grading.

Review the use of a traversable grate prior to extending a cross drain. Extending a culvert or cattle pass may be the best option when installing a new cross drain or cattle pass, or performing a significant amount of work on an existing cross drain or cattle pass. Other hazards may limit the effectiveness of extending a cross drain or cattle pass (e.g. overall drop, water, rip rap, etc.).

Extend hazardous cross drain or cattle passes to the desirable clear zones values adjusted for AADT, speed and curvature in the following situations:

New construction of:

- Roadway project near cross drain or cattle pass
- Cross Drain or cattle pass

Reconstruction of:

- A roadway and the project is purchasing right of way near cross drain or cattle pass
- Cross drain or cattle pass

Areas with run off the road crash history.

On 3R projects, extend existing hazardous cross drains, or cattle passes to the minimum of the following: desirable clear zone values adjusted for AADT, speed and curve or 30 feet.

Not extending hazardous cross drains or cattle passes requires documentation in the DSR. Not extending hazardous cross drains or cattle passes to the distances above requires documentation in the DSR.

Provide grading for cross drain or cattle pass extension. The extension of a box culvert or cattle pass may require a site specific construction detail or cross sections (refer to Attachment 2.18 for an example). Do not rely on a generic drawing similar to Attachment 2.18 as the sole source of grading information. Check drainage and traversablilty of slopes, ditches and blending slopes.

In some rare situations cross drains or cattle pass that are no longer required and can be removed. There could also be situations where a drop inlet could be installed to "remove" a cross drain. FDM 11-55-10 contains design guidance on what to do with a cattle pass that is no longer in use.

In some rare situations cross drains or cattle passes can be relocated. Relocate a cross drain or cattle pass to a location where run off the road crashes are less frequent (e.g. move the cattle pass out of a curve and into a tangent section). When relocating a cross drain or cattle pass, extend the new cross drain or cattle pass to the desirable clear zone distance.

2.6.1.3 Barrier Systems

Typically, barrier systems increase crash frequency and decrease crash severity. If other roadside design alternatives are not feasible then a barrier system may be a viable alternative. Barrier systems can be designed to shield other roadside hazards that previous alternatives cannot address.

Refer to FDM 11-45-2.2.12 for warrants to shield larger culverts.

Some difficulties with installing barrier systems are:

- Lack of cover over the cross drain or cattle pass.
- Lack of room between posts for drainage feature of cattle pass.
- Lack of room before or after the cross drain or cattle pass to install a barrier system.

- Lack of room to get proper grading for barrier system.
- Structural issues with cross drain or cattle pass.
- Being able to maintain a barrier system.

Lack of cover becomes a concern when there is less than 5 feet of fill over the top of a cross drain or cattle pass. Options for low fill situation could be:

- Long Span Beam guard
- Attaching to the structure
- Rigid barrier system

Lack of room between posts becomes a concern in a low fill situation and the width of the cross drain or cattle pass is close to the span length between posts. Depending on cross drain or cattle pass width and skew it may not be possible to install standard semi-rigid barrier. Options for this situation could be:

- Long Span Beam guard
- Attaching to structure
- Rigid barrier system

Barrier systems require length up station and down station of a cross drain or cattle pass in order to shield the hazard or hazards. If there are driveways or side roads within 125 feet of the cross drain or cattle pass it may be difficult to properly install a barrier system. Options for this type of situation are:

- Move driveway or cross street
- Taper semi rigid barrier (refer to FDM 11-45-2.3.1.3 for length of need discussion)
- Install a short radius system.

If these options cannot fit a given location, additional design and coordination with BDP is required. Documentation in the DSR is required.

Almost all barrier systems require some grading (even if it is just for end treatments). In case of semi-rigid barriers, grading provides structural strength to the barrier system. Grading near the cross drain or cattle pass may prevent the use of a given barrier system (e.g. designer cannot get grading near post for proper installation of midwest guardrail system (MGS K).

In some cases, adding a barrier system on top of a box culvert or cattle pass may require contact with Bureau of Structures. A barrier system may influence the structural rating; attaching or bolting through the deck of a box culvert may require structural analysis; condition of box culvert or cattle pass may not allow for proper connection. Additional engineering will be required.

Do not bolt through a cross drain with permanent water in it without discussing with maintenance staff. Provide documentation of maintenance staff discussion in DSR. Contact BPD when bolting through the deck of a box culvert for crashworthy details. Special provisions will be required.

2.6.1.4 Delineate

If other alternative roadside design are not feasible, delineate a hazardous cross drain or cattle pass with the clear zone (refer to SDD 15A7). Also refer to MUTCD sections 2C.63 and 2C.65. Provide documentation in DSR when using delineating a hazardous cross drain or cattle pass.

Use flexible marker post for culvert pipe (SDD 15A3) for non hazardous cross drains and cattle passes.

2.6.2 Parallel Drainage Features

Parallel drainage features are typically located at an access point (e.g. driveway, side road, median crossover, etc.). Other locations may also have slopes that are perpendicular to the direction of travel and have a parallel drainage feature (e.g. a median berm near a thrie beam bullnose installation).

Options available for parallel drainage features are (in order of preference):

1. Traversable Grates
2. Relocate or remove structure
3. Installing a barrier system
4. Delineate

2.6.2.1 Traversable Grates

Installing traversable grates for parallel drainage features is the preferred roadside treatment. Parallel traversable grates have the same benefits and issues as traversable grates installed on cross drains (refer to FDM 2.6.1.1 discussion).

Parallel drainage features are less likely to experience difficulties with clogging as cross drains. If a traversable grate is installed, install a traversable grate on the upstream end of the drainage feature.

Generally, it is not possible to intermix cross drain traversable culvert grates with parallel traversable grates because the number of bars, bar orientation, and spacing for the bars are different.

Do not install traversable grates on parallel drain for navigable water ways.

Refer to FDM 11-45-2.2.11 (Traversable Grate for Hazardous Parallel Culverts) for warrant to install traversable grates on hazardous parallel culverts.

Refer to SDD 8F7 for information on traversable grates for most parallel culverts. Type 8,9,10 inlets may be modified to provide the correct slope to allow traversablility (refer to SDD 8C5). Larger box culverts, mortar rubble masonry endwalls (SDD 8F9), or concrete masonry endwalls (SDD 8F10), may require special provisions, special construction details and coordination with Bureau of Project Development and Bureau of Structures.

Provide grading for proper installation of a traversable grate. Installation of traversable grate may require a site specific construction detail or cross sections (refer to Attachment 2.19 for an example). Do not rely on a generic drawing similar to Attachment 2.19 as the sole source of grading information. Select the appropriate traversable grate and transverse slope based on the following table:

***Table 2.16* Maximum Perpendicular Slope**[xliii] [xliv]

Posted Speed (mph)	Maximum Perpendicular Slope
<35	4:1
≥ 35 to <60	6:1
≥60	10:1

Grade slopes near the traversable grate to the values shown in the above table. Flatter slopes are permissible. Not installing a traversable grate or providing appropriate grading requires documentation in DSR.

2.6.2.2 Relocate or Remove Structure

In some rare situations a parallel drainage feature is no longer required and can be removed. If an access point is removed, remove the drainage feature and its associated grading. One possible way of “removing” a parallel drainage features is to combine closely spaced parallel drainage features into one feature.

In other situations, it may be possible to relocate a parallel drainage feature. Relocate the new parallel drainage feature to a location where run off the road crashes are less likely to occur (refer to Figure 3-11 of 2011 Roadside Design Guide).

2.6.2.3 Barrier Systems

It can be difficult to install a barrier system to protect a parallel drainage feature and its associated slopes. In some situations, a short radius system (SDD 14B27) can be used to wrap beam guard around the parallel drainage feature and its transverse slopes.

If a short radius system is not feasible, it may be possible to provide a “break” in the barrier system[41]. However, this break would allow some errant vehicles to hit the hazards. Designing a break in the barrier system requires discussion in the DSR.

2.6.2.4 Delineate

Guidance for this section is to be added at a future date.

2.7 Safety Edge

Safety edge is a sloped wedge of pavement added to the outside edge of a lane (assuming no paved shoulder) or outside edge of a paved shoulder (refer to Figure 2.49 below).

[41] Instead of designing one continuous barrier system, there would be two independent barrier systems with a gap between them.

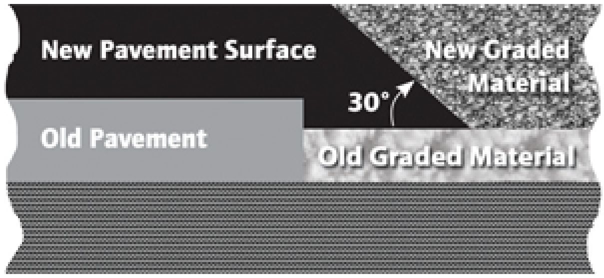

***Figure 2.49* Cross Section of Safety Edge**[xlv]

Safety edge can mitigate run off the road crashes due to edge drop between the paved surface and the gravel shoulder. An edge drop as little as 2.5 inches can cause a driver to over steer in an attempt to reenter the pavement.[xlvi] Eventually, when the vehicle's tires climb up the edge, the vehicle will shoot abruptly across its' lane and enters into oncoming traffic.

Many states are reporting better pavement performance near the safety edge. Some of the pavement benefits are: reduced edge line cracking, better compaction, less damage to pavement edge due to construction traffic.

Safety edge can be installed on HMA and concrete pavements. At this time, WisDOT is installing safety edge on various HMA projects through the state. Safety edges are created by adding a wedge maker to the paver.

CMM 6.70 (future home for a current construction note) has additional information about safety edge.

2.7.1 Policy

Install safety edge on HMA pavements (e.g. HMA overlay, new construction, reconstruction…) with no paved shoulder or HMA paved shoulder of 3 feet or less. Install safety edge on temporary roads that are in-service over the winter or will be in-service for a year or more.

Provide documentation in the DSR when not installing safety edge on a roadway that matches the previous criteria. Avoid using concerns about "gravel dropping away from safety edge" as justification for not installing safety edge.

It is optional to provide safety edge on wider HMA shoulders.

2.7.2 Design Information

Standard Spec 450.3.2.11 contains language on where to install safety edge. SDD 14b29 contains information on how to construct safety edge. No additional information is needed in the plan for standard application of safety edge. Special provisions are required when using safety edge on wider paved shoulders or when not installing a safety edge.

The "top" of the safety edge is to be located at edge of paved shoulder or lane. If the safety edge is not properly located the widths of the shoulder or lane may be too narrow.

Review stability of shoulder. Soft shoulders or poorly graded shoulders may need additional work to provide stability for safety edge and new pavement. If the project is not building a new pavement, review FDM 19-7-1.2 on preparing foundation and shaping shoulders bid items. Use these items if applicable.

Calculate additional HMA quantities for safety edge and add the quantity to the overall quantities. Typically safety edge adds less than 1 to 2% to the overall HMA quantities.

xi. Carlson, Dean, Traffic Barrier Safety Policy and Guidance, FHWA Technical Memo, 9/29/1994
xii. Roadside Design Guide 3rd Edition 2006, with Updated Chapter 6
xiii. Nicol, David, Roadside Design: Steel Strong Post W-Beam Guardsteel beam, FHWA Technical Memo 6/17/ 2010.
xiv. Polivka, K.A. Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., Holloway, J.C., Bielenberg, R.W., and Kuipers, B.D., "Development of the Midwest Guardrail System (MGS) for Standard and Reduced Post Spacing and in Combination with Curbs", TRP-03-139-04, September 2004
xv. Nicol, David, Roadside Design: Steel Strong Post W-Beam, FHWA Technical Memo, 6/17/2010
xvi. Carolyn Hampton, Douglas Gabauer, Hampton, Gabler, "Limits of Acceptable Steel beam and Post Deflection in Crash-damanged Strong-Post W-beam Guardsteel beam", TRB 2010 Annual Meeting CD
xvii. FHWA Technical Memo, Corrugates Sheet Steel (W-Beam) Guardrail, T5040.23, March 13,1984
xviii. 2006 NHI Roadside Design Class
xix. 2006 NHI Roadside Design Class

xx. 2006 AASHTO Roadside Design Guide
xxi. 2006 NHI Roadside Design Class
xxii. W-Beam Guardrail Repair A Guide For Highway And Street Maintenance Personnel, FHWA 11/1/2008
xxiii. Improving Highway Safety At Bridges on Local Roads and Streets, FHWA October 1998
xxiv. Huijser, M. P. , McGowen, P, Clevenger, A.P. and Ament, R, “Wildlife-vehicle Collision Reduction Study: Best Practices Manual”, FHWA, FHWA-HEP-09-022, October 2008
xxv. Oregon Department of Transportation
xxvi. 2006 NHI Roadside Design Class
xxvii. Photo from Linda Richardson
xxviii. Design Construction and Maintenance of Highway Safety Features and Appurtenances User Manual, FHWA, FHWA-HI-97-026, June 1997
xxix. A Guide for Achieving Flexibility in Highway Designs, 2004, AASHTO

LIST OF ATTACHMENTS

FDM 11-45-5 Fencing *August 31, 2006*

5.1 General

Fencing along a highway serves primarily to prevent vehicles, people and animals from entering onto highway right-of-way where they may cause a hazard to traffic. Fencing is especially important along freeways where drivers are traveling at high speeds and expect complete protection from all forms of roadside interference. Fencing is used in urban areas to separate pedestrians from vehicle traffic in special situations where there would be a safety benefit such as along school grounds and parks or to channel pedestrians to pedestrian structures.

Fencing may be deferred until needed or possibly eliminated at locations where access to the highway is blocked by rough topography, dense vegetation, or a natural barrier such as a body of water or a river.

Fencing is normally not required along the outside of frontage roads unless the abutting property was fenced prior to highway construction. Such fencing would normally be part of right-of-way negotiations.

If an adjacent property owner requests the installation of a fence, for example to contain domestic animals or to keep multi-use path users off private property, it is the property owner’s responsibility to construct and maintain the fence on their property. Unless the property owner's fence already existed, it is unlikely that WisDOT would participate in the cost of the fence. If WisDOT does participate in the cost of any fence constructed on private property, the designer shall coordinate with the Region Real Estate Section to include fencing in the right-of-way negotiations.

In very rare instances it may be appropriate, such as meeting a compelling safety need or addressing a demonstrated land encroachment issue, to construct a second fence on the outside of a multi-use path but on WisDOT right-of-way.

Note: Refer to FDM 11-35-1 for guidelines for protective screening of overpass structures. This is technically a fence but does not serve the same purpose as the fencing discussed in this procedure.

Refer to FDM 11-55-5 for barriers on top of retaining walls.

5.2 WisDOT Policy for Freeways

Department policy is to fence along freeways, designated and non-designated, except where such fencing would not be effective or essential for access control. The following guidelines are provided for application of this policy:

1. Fence along freeways with no multi-use path shall be located along the right-of-way line, generally 3 feet inside the right-of-way line.
2. Fence along freeways with multi-use paths adjacent to the facility shall be located between the roadway and the multi-use path. This fence shall be installed near the edge of the path shoulder and outside the clear zone of both the roadway and the multi-use path[42].
3. Fencing should be provided between frontage roads and the freeway, or ramps, unless other barriers are used to control access.
4. Fencing of planned freeways which will be built in stages and operate initially as a two lane highway should be constructed to the extent possible with the construction of the first roadway

5.3 WisDOT Policy for Expressways

Department policy is to generally not fence expressways[43] including facilities designated as expressways under s. 84.295 stats, and expressways with multi-use paths., and to Minimizeminimize fencing in those locations where it fencing is deemed necessary. Expressways are generally defined as divided highways with at-grade intersections and usually having a posted speed of 50 mph or greater.

5.3.1 Exceptions to Department's Expressway Fencing Policy

While the Department's general policy is to not fence expressways, there may be some locations where fencing is needed:

1. Where there is a demonstrated history of right-of-way encroachment problems, or there is a strong expectation they will occur in the future. Typical problems include land use encroachment or illegal use of motorized vehicles.
2. Where there is a perceived or demonstrated potential for an unsafe condition related to the highway right-of-way. Generally, this potential is likely to occur in an urban or suburban setting, and may include the following conditions:
    - Existing residential areas or areas zoned residential where development is expected to occur within five years. As a general rule, fence should be evaluated where 20 or more residences exist or are clearly planned within 500 feet of the right of way for a distance of 500 feet along the highway.
    - Along the entire frontage of abutting school property.
    - Along sidewalks to channel pedestrians over pedestrian structures.
    - Along the entire frontage of official city, county, state or federal parks or preserves with due consideration to aesthetics and the desires of local officials.
    - Along steep embankments or drop offs such as a box culvert opening adjacent to a sidewalk.
    - Other areas where pedestrian traffic is present or anticipated such as playgrounds, sports fields

[42] The clear zone for a multi-use path is normally 3 feet minimum beyond the edge of traveled way.

[43] Expressways are generally defined as divided highways with at-grad intersections and usually having a posted speed of 50 mph or greater.

and golf courses.

- Where a local government requests the fence and participates in its funding.

The decision to provide fencing along an expressway whether it is separating the roadway from a multi-use path, a frontage road, a deterrent to land use encroachment, safety or other reasons should be made by the Region on a case-by-case basis.

5.3.2 Location of Expressway Fencing

Department policy is to generally not fence expressways, including expressways with multi-use paths, and to minimize fencing in those locations where it is deemed necessary. If an exception to this policy is needed to satisfy the WisDOT concerns identified above, there are two locations to install fence:

1. When there is not a multi-use path along the expressway, the fence shall be located along the right-of-way line, generally 3 feet inside the right-of-way line.

2. When there is a multi-use path along the expressway the fence may be located either along the right-of-way line, or between the multi-use path and the expressway. When the fence is installed between the expressway and the path it should be located adjacent to the path shoulder, and outside the clear zone of the highway and the multi-use path[44]. Fence location is determined as follows:

   2.1. Fence along the right-of-way line when there is a compelling safety need to control access or prevent encroachment to the path and the highway.

   2.2. It may be appropriate to fence between the highway and the multi-use path at locations where access to the path from the adjacent property is acceptable, such as:
   - A frontage abutting school property
   - Other areas where pedestrian traffic is present or anticipated such as playgrounds and sports fields
   - Steep embankments or drop offs such as a box culvert located between the path and highway.

The fence may be alternately located at the right-of-way line for a certain section of a project; and then, located between the multi-use path and the highway at other sections. This discontinuity of the fence is considered acceptable.

5.4 Fencing Types

Selection of fence type depends primarily on the character and density of adjacent development and cost of installation and maintenance. In general, chain link fence should be installed in urban/suburban areas and woven wire or high-tensile fence in rural areas. Consideration may be given to improving the aesthetics of chain link fence by adding a colored epoxy coating.

5.4.1 Chain Link Fence

Chain link fence should be installed in urban and suburban areas. It should be considered where the following conditions exist adjacent to the highway right of way:

1. Existing residential areas or areas zoned residential where development is expected to occur within five years. As a general rule, chain link fence should be evaluated where 20 or more residences exist or are clearly planned within 500 feet of the right of way for a distance of 500 feet along the highway.

2. Along the entire frontage of abutting school property.

3. Along sidewalks to channel pedestrians over pedestrian structures.

4. Along the entire frontage of official city, county, state or federal parks or preserves with due consideration to aesthetics and the desires of local officials.

5. Along steep embankments or drop offs such as a box culvert opening adjacent to a sidewalk.

6. Other areas where pedestrian traffic is present or anticipated such as playgrounds, sports fields and golf courses.

Chain link fence should not be used where it may restrict sight distance, particularly on curves. In addition, chain link fence can result in additional snow drifting in some locations and it is more of a trash and waste paper

[44] The clear zone for a multi-use path is normally 3 feet minimum beyond the edge of traveled way.

collector than the other fence types.

5.4.2 Woven Wire or High Tensile Wire Fence

Woven wire or high tensile wire fence should be installed where chain link fence is not warranted and where the following conditions exist:

1. Areas that are rural in character. Note: Standard woven wire and high tensile wire fence are not adequate to retain livestock. This application requires special fencing that should be provided by the property owner and subject to right of way negotiations.
2. Urban and suburban areas where improvements along the right of way are infrequent and future development is not anticipated.

Transitions between fence types may change within a relatively short length due to existing or planned land use. Transitions should be planned to occur at logical points such as at an interchange or bridge; for expressways the transition may also be at a cross road intersection.

5.5 Gates

Gates along freeways should be provided only where necessary to allow access by maintenance personnel. Each gate must be provided with a lock and keys in accordance with maintenance policy or preference. All gates on the Interstate system, including those for maintenance purposes, require FHWA approval.

Gates along expressways may be provided to allow access by maintenance personnel, at field entrances, and when requested by the property owner at the main entrance to the farm or residence.

5.6 Design Standards

Design details for each of the fence types are shown on standard detail drawings in Chapter 16.

The standard detail drawing for chain link fence and the standard specifications recognize a range of fence heights from four to eight feet. The desirable height is six feet because it is sufficient to discourage people from attempting to climb over the fence. Special circumstances may warrant installation of shorter fence. For example, a tall fence may reduce sight distance at interchanges or be objectionable to property owners for a variety of reasons.

High tensile wire fence is an effective rural fence that is economical to build. However, this fence requires periodic maintenance to assure wire tension and this may add to its life cycle cost. Also, the fence can be hazardous to deer, which can become entangled and trapped in the top wires as they try to leap over it.

Woven wire fence is a good general-purpose rural fence, which may be specified as an equal alternate to high tensile wire fence or specified exclusively.

5.7 References

For further reading on this subject, refer to the AASHTO publication; "An Informational Guide on Fencing Controlled Access Highways" dated November 1990. The laws relative to fencing are contained in Chapter 90 of the Wisconsin Statutes.

FDM 11-45-10 Bicycle Facilities — October 5, 2011

This portion of the FDM has been transferred to FDM 11-46-15.

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