FDM 11-45-10 Roadside Design Application - Improvement Strategy

February 15, 2023

10.1 Introduction

This procedure will serve to supplement existing FDM references with guidance specific to roadside design application for improvement strategies as defined in FDM 3-5-1.

The principal references for the development of roadside designs and the application of traffic roadside barriers and roadside hazard analysis are:

- FDM 11-45-20 - Roadside Hazard Analysis
- FDM 11-45-30 - Roadside Barrier Design Guidance

Roadside hazard analysis and treatment requirements will be categorized under three improvement strategies as described under FDM 11-45-10.2. Follow FDM 11-45-10.3 for roadside hazard analysis and treatment guidance.

Refer to FDM 11-45-10.4 for roadside hardware evaluation and treatment requirements. It provides guidance for the analysis and treatment of existing roadside hazards and barrier hardware for specific improvement strategies. Roadside barrier guidance in this procedure will be limited to:

- existing barrier condition
- terminal ends, and
- transition connections to rigid barriers

Note that guidelines in this procedure do not pertain to existing linear, non-Midwest Guardrail System (MGS)/Class A steel plate beam guard systems such as curved beam guard, bullnoses, concrete barrier, crash cushions and sand barrel arrays.

For new Energy Absorption Terminal (EAT) installations, the preferred grading referenced throughout this procedure is shown in SDD 14B44 (Midwest Guardrail System (MGS) EAT) and as described in FDM 11-45-30.4.1.3.

Follow FDM 11-45-20 and FDM 11-45-30 guidance for Modernization improvement projects.

10.2 Application of Improvement Strategy

Roadside hazard analysis (RHA) will be performed and treatments recommended based on the project improvement strategy:

- Perpetuation
- Rehabilitation
- Modernization

Refer to the project's Final Scope Document for the expected improvement strategy.

10.3 Roadside Hazard Analysis and Treatments

The degree of roadside hazard analysis and treatment will depend on the improvement strategy. Guidance is provided below for the various strategies.

Do not degrade roadside safety along the existing roadway corridor while finalizing the improvement's roadway typical cross-section and pavement structural needs. Pavement surface elevation increases should only be applied to the extent that the existing foreslopes or other cross-sectional features, such as shoulder slopes and widths, can be altered within the required range of design criteria. Foreslope adjustments will be confined within the existing subgrade shoulder points (i.e. shoulder foreslopes) with all Perpetuation and many Rehabilitation improvement projects. Roadside hazards include steep roadway foreslopes and fixed objects along a facility and as further described in FDM 11-45-20.

Adhere to Perpetuation and Rehabilitation guidance and its design flexibility under FDM 11-40 if needing to implement lower-end range shoulder widths and cross slopes. If countermeasure(s) are pursued, provide documentation in the Final Scope Certification (FSC). See FDM 11-4-3 for FSC guidance.

For all improvement projects, document final decisions and outcomes with roadside hazard analysis and treatments in the DSR.

10.3.1 Roadside Hazard Analysis/Treatment – Perpetuation Improvement Strategy

A roadside hazard analysis (RHA) generally will not be required for this strategy, including Preventative Maintenance (PM) projects. Re-evaluate roadside fixed objects and their potential removal/relocation with the next improvement project. Hazardous mailbox identification and evaluation is not required.

Conduct limited RHA for projects working on retaining walls, bridges, box culverts, or other structures (see FDM 11-45-20.3.3 for more discussion). Research shows that crashes near these features are more severe and more likely to occur. Installing safety hardware is more important at these locations. Examples are (the list is not all-inclusive):

- A road project has a "net project length exception" for a bridge (i.e. the bridge is not part of the road project). Include the bridge in the road project's RHA.
- A road project terminus is near a bridge or beam guard installation that connects to the bridge. Include the bridge and associated beam guard in the road project's RHA.

Even though a road project may not have originally planned to incorporate work on these features, a barrier system may need to connect to these features. Connecting road barriers to these features may need extra engineering.

10.3.2 Roadside Hazard Analysis/Treatment – Rehabilitation Improvement Strategy

At locations using S-2 Applications - Perform RHA per FDM 11-45-20 for S-2 area(s) within the improvement project corridor. S-2 areas include spot improvement(s) or other location(s) where three-dimensional roadway element(s) (i.e. alignment, profile, cross section) are improved with the project. Remove existing roadside hazards within the S-2 area(s) that qualify for removal under the RHA. An RHA along with a hazardous mailbox identification and evaluation is not required for adjacent S-1 area(s). Refer to FDM 11-1-10 for S-1 and S-2 application definitions.

Not all roadside hazards analyzed for elimination per FDM 11-45-20 qualify for removal. Refer to FDM 11-45-20.6.2 for the preferred roadside hazard treatment in order of desirability (e.g. removal, traversable, relocation, etc.) for qualifying hazards. Document these findings in the DSR.

10.3.3 Roadside Hazard Analysis/Treatment – Modernization Improvement Strategy

Perform RHA per FDM 11-45-20. Remove existing roadside hazards that qualify for removal per the analysis. Refer to FDM 11-45-20.6.2 for the preferred roadside hazard treatment in order of desirability (e.g. removal, traversable, relocation, etc.) for qualifying hazards. Roadside hazard analysis should be consistent with improvement strategy context.

10.4 Roadside Hardware Evaluation and Treatments

Replace existing wood post bullnoses and associated thrie beam, and downturned or blunt terminal ends, including breakaway cable terminals (BCTs) and modified eccentric loader terminal (MELT) systems, with appropriate anchorages, on all improvement projects.

Perform field assessment of existing roadside hardware per FDM 11-45-30.5 on all Perpetuation and Rehabilitation projects.

Apply the following roadside hardware guidance for all Perpetuation and Rehabilitation improvement projects:

- Replace/restore existing roadside hardware where determined to be operationally deficient/missing.
- Replace roadside hardware where the remaining service life is less than the improvement's pavement treatment service life. If the existing roadside hardware has a reasonable service life remaining, it is not mandatory to replace it, except as noted in the first paragraph of this section.
- Install or replace any roadside hardware identified as a safety countermeasure in the Safety and Operations Certification Document (SOCD). Refer to FDM 11-38 for Safety Certification Process (SCP) guidance. Also, document decisions in DSR.
- Install new beam guard Midwest Guardrail System (MGS) per FDM 11-45-30, if entire roadside hardware system is replaced. Determine guardrail length of need (LON) per FDM 11-45-30.3.1.2. Coordinate with the WisDOT project manager and the regional design oversight engineer, if installation is not achievable per calculated LON. Document justifications in the DSR.
- Replace unconnected or non-compliant beam guard transitions to rigid barriers per FDM 11-45-30.5.2.10.
- Replace existing non-EAT end treatments with EATs (see FDM 11-45-30.5.4). Existing EATs may be left in place if determined to be in good condition.
- Analyze preferred EAT grading for S-1 applications as described in FDM 11-45-30.4.1.3. Where

preferred EAT grading is not possible, refer to FDM 11-45-10.4.1 for guidance on end treatment grading for S-1 applications.

- Provide EAT grading for S-2 applications as described in FDM 11-45-30.4.1.3. Acquire right-of-way, if necessary, to accommodate preferred EAT grading for S-2 applications. See FDM 11-45-10.4.2 for additional right-of-way acquisition guidance. Refer to FDM 11-1-10 for S-1 and S-2 application definitions.

10.4.1 Guardrail and End Treatment Considerations for S-1 Applications

Evaluate whether preferred EAT grading installation is attainable per FDM 11-45-30.4.1.3. If preferred EAT grading is not possible, consider opportunities to slightly adjust the new EAT location from the existing end terminal location using optional applications per FDM 11-45-30.4.1.4. Apply guardrail length factor and cost ratio principles as needed. Some existing locations may already have reasonably flat shoulder foreslopes that can provide the desirable EAT grading within the existing right-of-way and with minimal to no additional grading. Ensure through the plan delivery process there are no utility impacts or environmental issues with any terminal end adjustments. Existing terminal ends adjacent to existing above-ground utilities or other objects (e.g. power poles, signs) are also good candidates for a slight terminal end location adjustment with the EAT installation.

As a last resort, install EATs per FDM 11-45-30.4.1.5 only when adjusting and providing acceptable EAT grading, as aforementioned referenced, is not feasible. The EAT offset from edge of shoulder may be reduced to zero feet (i.e. no flare) if grading for the EAT platform is non-practicable. Coordinate with the Region Maintenance section early in the scoping/design process to determine if a reduced offset would best serve the user's needs for this location. Shoulder width, approach alignment and adjacent driveway(s) are several factors, for example (not totally inclusive list), that may influence the final decision, as a no-flare EAT has a higher propensity for nuisance vehicular or maintenance equipment strikes.

The existing end terminal's longitudinal location can be replicated with the new EAT to take advantage of any existing level, widened shoulder. This may slightly reduce the installed guardrail's LON, as the EAT LON is over 53 feet. However, previous standards' LON calculations with blunt end terminals tended to estimate a conservative (i.e. longer) LON versus current estimated methodology.

For all EAT replacement installations, document in the DSR the EAT shoulder offset and longitudinal locations and associated grading decisions and the basis for these decisions, including any LON comparison of existing and new guard rail assemblies/terminal ends.

10.4.2 Right of way Acquisition Considerations

Right-of-way acquisition for:

- S-1 applications - if optional applications listed in FDM 11-45-10.4.1 do not eliminate the need for additional Real Estate, right of way should be acquired. Document any deviations from preferred or optional applications as justifications in the DSR.

- S-2 and S-3 applications - right of way acquisition will be required to attain proper beam guard system installation.

FDM 11-45-15 Roadside Barrier - General *February 18, 2020*

15.1 Introduction

FDM 11-45-15 and FDM 11-45-30 addresses various methods to reduce run off the road crash frequency and/or crash severity. This section of the FDM addresses run off the road crashes by providing:

- tools to aid in the selection of suitable treatments
- information on how to design various treatments
- commentary on common problems
- guidance on when to document decisions in the Design Study Report
- information on when an existing barrier system needs removal or spot improvements

Other sections of the FDM do provide guidance on roadside design. Some other sections of the FDM are (the list is not all-inclusive):

- 11-15-1
- 11-15-10
- 11-20-1

For some projects, other sections of the FDM may have modified guidance.

15.1.1 Run Off the Road Crash

A simple definition of a run off the road crash is: A crash where a vehicle has left its lane of travel and interacted with a fixed object, slope, ditch, or barrier system. Run off the Road crashes also include cross-median crashes, head-on crashes, rollover crashes, and sideswipe crashes from the opposing direction.

15.1.2 Causes of Run Off the Road Crashes

A driver experiences the following[i]:

- Commits at least one error every two minutes
- Is in a hazardous situation every two hours
- Has one or two near crashes a month
- Averages one crash every six years

A study into tree crashes showed the following reasons, in order of frequency of occurrence, for run off the road crashes[ii]:

- An avoidance maneuver
- A non-intentional traffic violation
- Mechanical failure

In the early 60's, General Motors found that professional drivers on their private test facility would make errors and run off the road because they are human.

The road or the environment may make it easier to have run off the road crashes. A location may show up as a hot spot for run off the road crashes. However, a significant portion of run off the road crashes are the result of human error and occur at random locations.

Steps are taken in other areas to reduce the frequency and results of human error (e.g. power tools have safety features…). So, a roadside should allow for some human error.

Several issues may limit how much the Department can account for human error on a given project or location. In these cases, staff are encouraged to ask for help and document their decision-making.

15.1.3 Preferred Treatment Sequence

In an ideal world, the roadside would be free of all possible objects that could injure a vehicle's occupants, other roadway network users, workers, and others. In the real world, it is not possible to develop a 100 percent risk free roadside. Some examples are (the list is not all-inclusive):

- A river is beside the road and cannot be moved.
- A stop sign or speed limit sign is needed.
- A retaining wall is needed
- A bridge pier is needed
- allow utilities within the right-of-way

Minimize the risk to the traveling public and others by using the preferred treatment sequence (in order of preference):

1. Remove hazard
2. Make hazard traversable
3. Move hazard
4. Use breakaway hardware
5. Shield hazard
6. Delineated

What treatment(s) to use depends on the following (the list is not all-inclusive):

- Nature of the hazard
    - A point hazard versus a series of point hazards versus a continuous hazard
    - Severity of hazard
    - Location of the hazard
- Function of the Hazard
    - Hazard is needed for operation of the road (e.g. stop sign versus a tree)
    - Structural need (e.g. bridge piers are not breakaway, but most traffic signs are)
- Benefit and cost of proposed treatment

- Consequence of Collision
  - Minor interaction with some hazards can cause significant injuries to a vehicle's occupants, other roadway network users, or community
- Nature of Work
  - Type of work within a project prevents the use of a treatment (e.g. a culvert-lining project probably will not move the culvert further away from the road).

Often, there is flexibility when selecting a treatment. After selecting a treatment, there may be less flexibility how to use the treatment. For example, a designer has determined to use a breakaway pole. The designer could have also had the pole removed, moved or shielded.

Once the designer has determined that the pole is to be breakaway, the pole should be designed so that breakaway features will work. Putting too much weight on a pole or installing a sign at the wrong height on a pole may negate the breakaway features.

Sections FDM 11-45-15.1.3.1 to FDM 11-45-15.1.3.6 have various examples of different roadside treatments. These examples are provided to show how various treatments can improve roadside safety. Some of these examples will use crash costs created in Roadside Safety Analysis Program (RSAP) v3. Crash cost is one variable, out of several variables, used to select a roadside treatment.

Other variables are not in the examples. Do not use these examples by themselves as design guidance. Additional analysis is needed at each location.

15.1.3.1 Remove Hazard

The AASHTO Roadside Design Guide points out that removing hazards is the most desirable roadside treatment. Removing a hazard reduces recorded crash frequency and severity. Vehicles will still leave the road. Potentially, no one has a serious injury, and the vehicle drives away. The Department will have no records of a crash.

Hazard removal typically focuses on fixed objects (e.g. poles, rocks, barrier systems). Flattening a hazardous slope could be a form of removal.

Figure 15.1 is an example how removing hazards (i.e. changing pole density) influences safety. Reducing the number of poles in an area can improve safety.

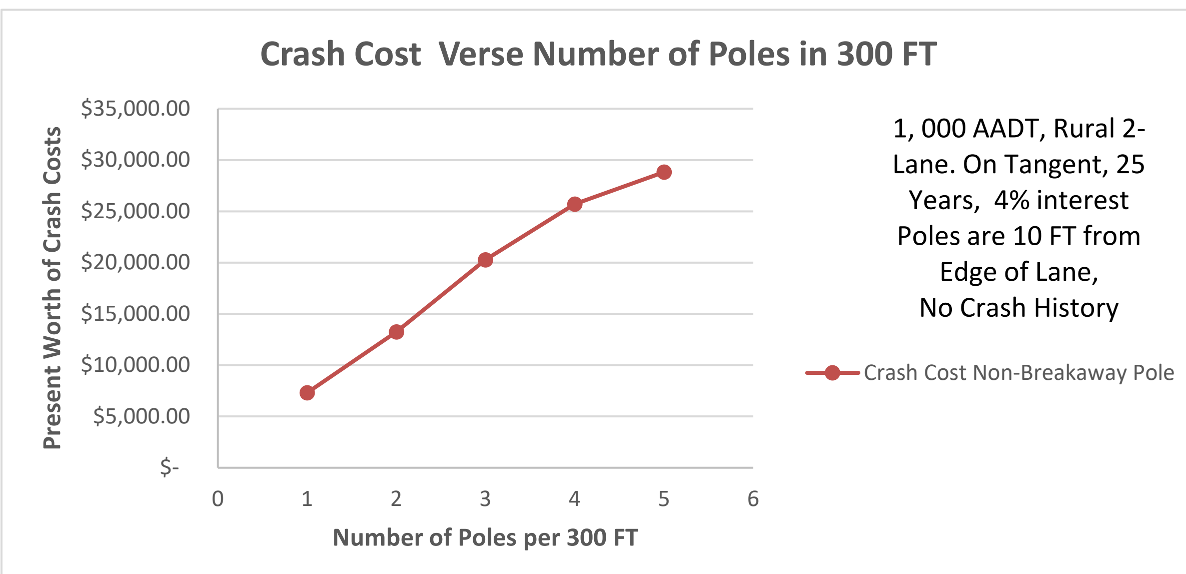

Figure 15.1 Influence of Removing Hazards From a Roadside[1]

Other potential methods of removing hazards could be (the list is not all-inclusive):

- Using drop inlets versus open culvert pipes in a median
- Removing barrier systems that are no longer needed (although this is recognized as difficult to do when considering public input)

[1] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

- Having utilities share poles or go underground

Removing hazards also eliminates long-term maintenance costs.

15.1.3.2 Make Traversable

The AASHTO Roadside Design Guide indicates that making a hazard traversable is the second most desirable treatment. Traversable slopes reduce recorded crash frequency and severity. Vehicles will still leave the road, but many vehicles will drive away, and occupants will have no serious injuries.

Traversability focuses on foreslopes, backslopes, ditches, and slopes parallel to the direction of travel (e.g. driveways, side roads, and median openings…).

Location of the slope relative to the road, and steepness of slope influences the safety performance.

Traversable slopes also reduce long-term maintenance.

Traversability is also an issue for safety hardware. Traversability of safety hardware will not reduce the number of recorded crashes. However, if safety hardware is non-traversable, crash severity may increase. This is discussed more under breakaway hardware (see FDM 11-45-15.1.3.4).

15.1.3.3 Move Hazard

Moving a hazard changes the frequency a hazard is hit. Therefore, a lower crash frequency increases safety. Crash severity does not change. Moving a hazard is not the most desirable roadside treatment. It is still possible to have a severe crash. The following sections will talk about various methods to move a hazard.

Moving hazards typically focuses on fixed objects (e.g. poles, rocks, barrier…). Other features may be moved. For example, moving a hazardous slope further from the travel lane can improve safety.

Occasionally, it may not be possible or reasonable to move a hazard. Some examples are (the list is not all-inclusive):

- A body of water
- A stop sign needs to be at a specific location
- Existing bridge abutment cannot be moved
- A light pole has to be able to light road

Other treatments may be more applicable for these hazards.

Moving hazards may reduce long-term maintenance. FDM 11-45-15.1.3.3.1 and FDM 11-45-15.1.3.3.2 discuss different ways a hazard may be moved.

In many cases, one or both methods of moving a hazard can be combined with other treatments to have a greater improvement on safety than one treatment alone. Some examples are (the list is not all-inclusive):

- Move hazards away from the traffic and switch to breakaway hardware
- Move hazards away from the traffic and remove unnecessary hazards
- Move hazards away from traffic, relocate hazard out of a curve and use breakaway hardware

15.1.3.3.1 Moving Hazards Away from Traffic

Several studies exist on how far a vehicle will travel perpendicularly from the edge of lane[2]. Figure 15.2 has data from one of these studies.

[2] GM, Kennedy and Hutchinson, Cooper, Sicking

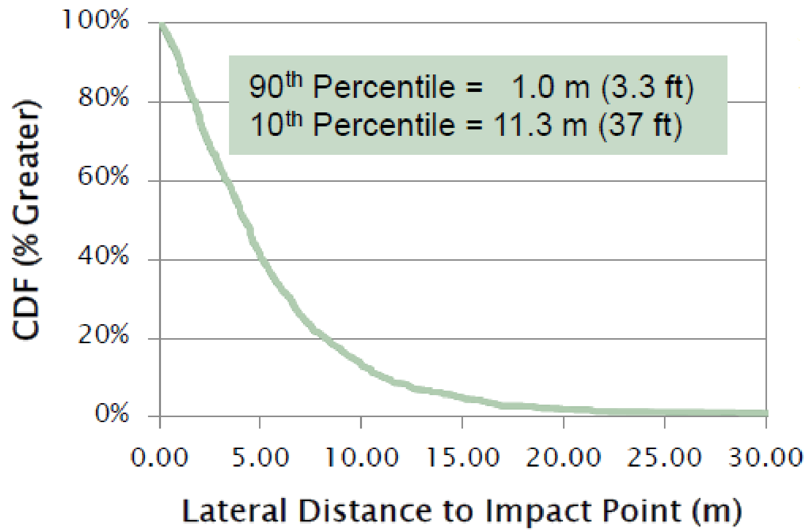

Figure 15.2 Vehicle Encroachment Distribution[iii]

Cumulative Distribution Function (CDF) showing percent of crash cases lateral trajectories exceeding given lateral distance. Figure 15.2 and other studies show that a significant percentage of vehicles will travel beyond a 30-foot (9 m) clear zone. Depending on the hazard and road, moving the hazard may provide sufficient safety improvement.

Figure 15.3 is an example, where moving trees further away from a road can increase safety. This example also shows how removing trees, even a few trees can improve safety. Combining the moving of trees farther from the roadway and decreasing the number of trees can improve safety more than using just one treatment alone.

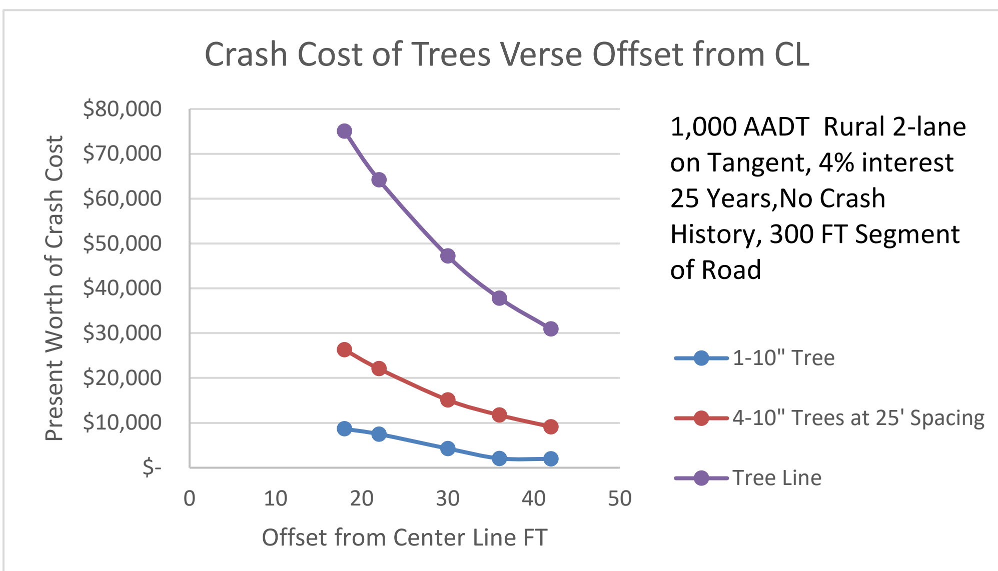

Figure 15.3 Influence of Removing Hazards From the Roadside and Moving Hazards Away From the Centerline[3]

Sometimes moving a hazard away from the road may not possible – an object may need to be closer to the road (ie. signs); it is not cost effective to move; or cannot be moved (river).

[3] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

Figure 15.4 Fatal Crash into Bridge Piers Just beyond the Clear Zone

Figure 15.4 shows a location where there was a fatal crash into the bridge columns, and they are noted to be just outside the clear zone.

In Figure 15.5, a project team determined that installing a barrier was unneeded because it would ruin the aesthetic view and the hazard (i.e. deep water) was beyond the clear zone. A few years after the road was reconstructed, beam guard was installed because of a fatal crash involving the deep water.

Before After

Figure 15.5 Fatal Crash Beyond the Clear Zone

15.1.3.3.2 Moving Hazard out of Areas Where Run Off the Road Crashes are Likely to Happen

Certain locations are more prone to have run off the road crashes. By simply moving hazards away from these locations, safety can be improved. For example, run off the road crashes are 3 times more likely to happen in a curve versus a tangent[iv]. By moving a hazard out of a curve, the crash frequency will be reduced.

The utility poles in the foreground of Figure 15.6 are in a series of poles along the edge of the freeway's clear zone. The foreground poles are more likely to be struck than the other poles because these poles are in a ramp gore. Vehicles tend to run off the road in ramp gores. Consideration should be given to moving these poles, and if not, shielding could be appropriate.

Figure 15.6 Location where run off the road is more likely to happen

Figure 15.7 Treatment Example[v]

Figure 15.7 is like Figure 15.6; the high mast light pole is beyond a normal clear zone. Project staff installed a sand barrel array to shield the high mast light pole. From a roadside design perspective, the design on Figure 15.7 is better than Figure 15.6.

15.1.3.4 Use Breakaway Hardware

Using breakaway hardware does not change the frequency of crashes. On average, crash severity is less. Because crash severity is reduced the overall safety is improved. However, breakaway hardware still can have serious crash outcomes (Figure 15.8). Typically, breakaway hardware is crashworthy.

Figure 15.8 Less than Desirable Crash Into Breakaway Hardware

Typically, light poles, signs, and similar hardware are breakaway[4]. Most roadside hardware provides a direct benefit for road users, and needs to be close to the road to work correctly.

Some hardware that directly benefits road users and has to be near the road does not need to be breakaway. This hardware typically falls into the following categories:

- Structurally Not Feasible
  - Examples (the list is not all-inclusive):
    - Bridge piers and abutments
    - Retaining walls
    - Sign bridges, overhead sign supports
- AASHTO Roadside Design Exception
  - Examples (List is all-inclusive):
    - Traffic signal
    - High mast lighting
    - Railroad gates, signals, and some supports
- Location Specific Safety Needs
  - Examples (The list is not all-inclusive):
    - Dropping a pole off a structure onto a road below
    - Dropping a pole where there is a significant concentration of pedestrians

Breakaway hardware needs to be traversable. Slopes leading to the breakaway hardware or around the breakaway hardware may have more strict requirements than “normal” traversable slopes. If a vehicle does not properly engage the breakaway hardware, the hardware may not work as expected.

Figure 15.9 shows how using breakaway hardware can improve safety. This figure also shows how moving breakaway hardware can improve safety. Combining breakaway hardware and moving hardware can have a greater safety benefit than one treatment alone.

[4] There are also breakaway utility poles and guy-wires.

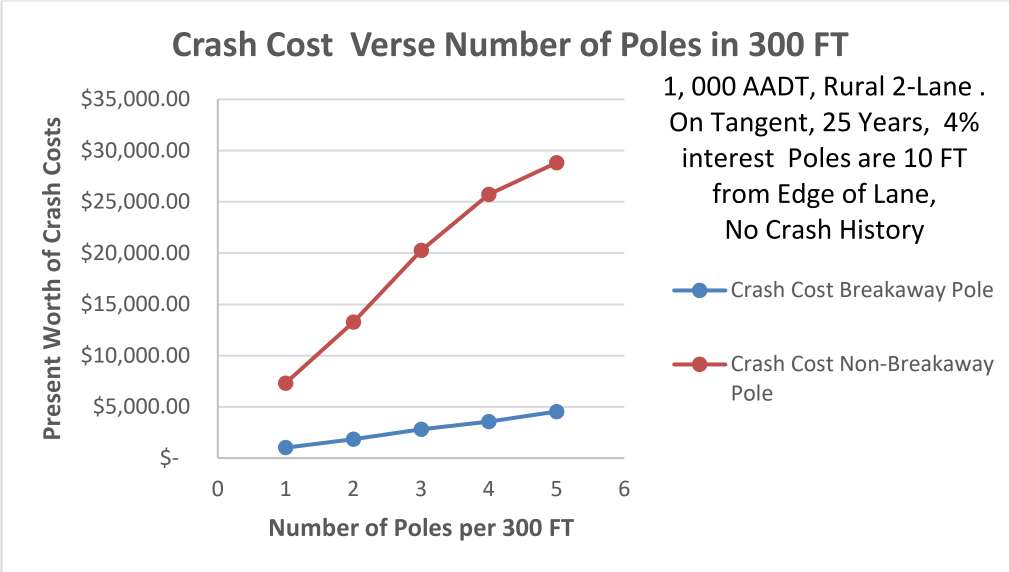

Figure 15.9 Crash Cost Breakaway Hardware[5]

15.1.3.5 Shielding

Shielding a hazard is less desirable because no barrier system is 100 percent effective, 100 percent of the time. Striking a barrier system can cause serious injury or death. Typically, barrier systems are crashworthy. Figure 15.10 is an example of a less than desirable crash into barrier system.

Figure 15.10 Less than Desirable Crash into Barrier System

Installing barrier systems typically increases crash frequency. In most cases, the severity of the crashes is lower.

Sometimes, the severity of a crash, consequence of collision, or cost to moving an object may make installing a barrier system the best choice. Figure 15.11 is an example that compares the crash cost of hitting a bridge's piers, crash cost of striking beam guard and the cost of moving a bridge's piers away from the road.

Figure 15.11 does not have other cost associated with building a bridge longer (e.g. right-of-way, earthwork). Likely the cost of building a longer bridge is higher than shown. This example does not address the need for

[5] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

structural protection of the bridge.

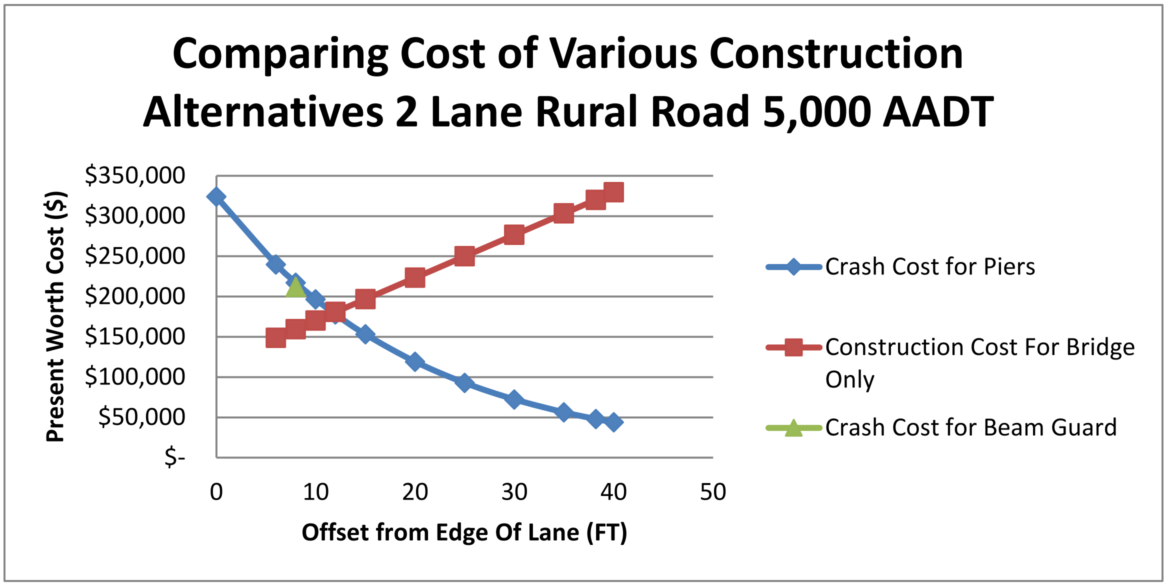

Figure 15.11 Cost Comparison of Various Pier Offsets [6]

Given the likelihood of a severe crash when hitting a bridge pier, installing a barrier system may be the preferred alternative. This could be true even in situations where the benefit cost of such an installation is low. See 11-45-20.3.5.7.4 for more information on when to shield bridge piers.

Sometimes, shielding may not be the best alternative. Figure 15.12 is an example of a two-lane rural road with the following characteristics:

- 55 mph
- 6 FT shoulder
- 30 FT clear zone with a 4:1 slope
- 1-mile segment of road
- 5,000 AADT
- The road is not a run off the road hot spot

Alternatives analyzed are:

- 30 FT clear zone
- 19 evenly spaced breakaway poles 25 FT from edge of lane
- 19 evenly spaced rigid poles 25 FT from edge of lane
- Beam guard at edge of shoulder to shield the poles

Analysis variables:

- 25-year analysis period
- 4% interest rate

[6] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

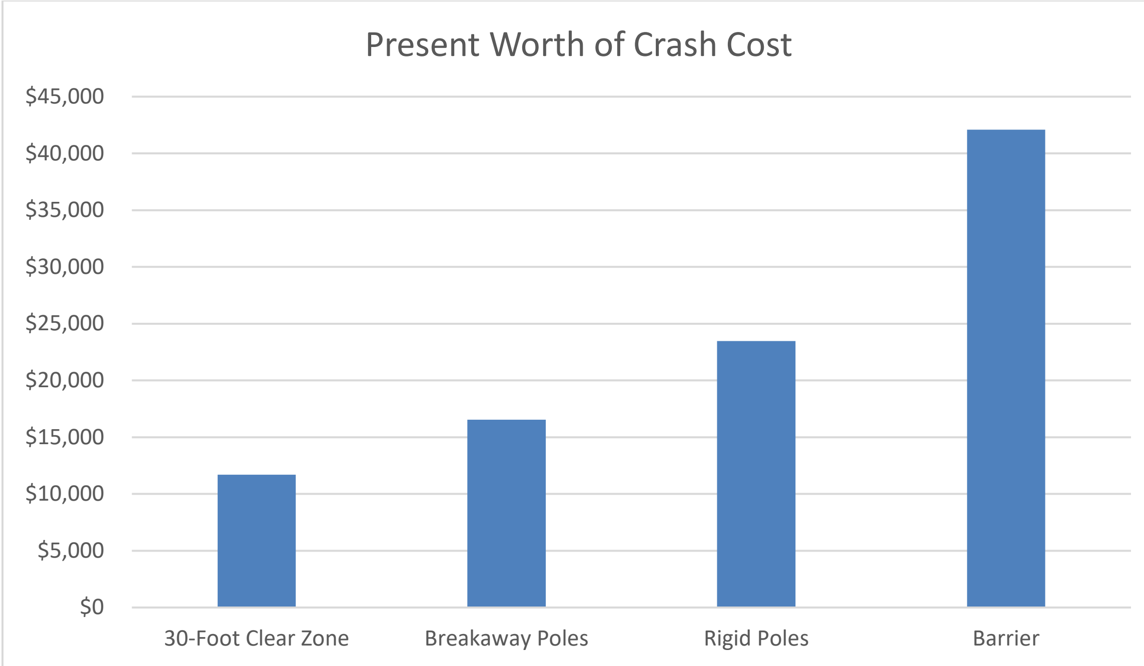

Figure 15.12 Roadside Alternative Crash Cost Comparisons [7]

For the example above, placing barrier may not be the most effective treatment. More information about the location, what the poles are being used for, consequence of collision, and other factors would need to be reviewed to determine what course of action to take.

15.1.4 Roadside Design and Aesthetics

AASHTO states the following:

> "While aesthetics are a concern, they should not be the controlling factor in the 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."[vi, vii]

The Roadside Design Guide also states:

> "Five factors should be considered in selecting a bridge railing: (1) performance, (2) compatibility, (3) cost, (4) field experience, and (5) aesthetics. Despite the relative importance placed on these factors, the capability of a railing to contain and redirect the design vehicle should never be compromised."[viii]

Another section of the Roadside Design Guide states:

> "Although there is no question that an aesthetic bridge railing in scenic areas or along park roads may be particularly important in response to public input, the safety performance of a railing should not be sacrificed."[ix]

As previously stated, installing a barrier system is less desirable than other roadside design treatments. Use caution when using aesthetics to justify not using a barrier system, or other more preferred roadside design alternatives.

15.1.5 Crashworthiness of Roadside Hardware

Crashworthiness tries to minimize the risk of injury from (the list is not all-inclusive):

- Deceleration forces
- Parts of the hazard penetrating the cab
- Deformation of vehicle cab
- Vehicle rollover
- Flying debris

Some types of roadside hardware have more requirements for crashworthiness. Some of these are (the list is not all-inclusive):

- Structurally adequate to redirect the design vehicle

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[7] Graph developed by RDSU staff utilizing Roadside Safety Analysis Program (RSAP) v3 with the noted parameters.

- Vehicle trajectory after a crash.

Using crashworthy hardware does not make an object risk free. Under some crash conditions, crashworthy hardware may not function as intended. This is because crashworthy roadside hardware is tested using several assumptions. Violation of crash testing assumptions could cause unexpected outcomes. Many of the variables that determine hardware performance's during a specific crash are not under the control of the design, construction, or maintenance staff.

The Department strives to install new hardware that conforms to the most current crash test standard. However, in some situations, it may not be possible to install new hardware that conforms to the current crash tested standard (the list is not all-inclusive):

- Not all the components needed in a barrier system meet the current standard
- Site, project, or other restrictions prevents installing hardware as it was crash tested

The Department addresses these less-than-ideal situations with published policies, or on a case-by-case basis. In less than ideal situations, the Department may (the list is not all-inclusive):

- Use roadside hardware tested to a lower or higher crash test level than it would normally use
- Use roadside hardware tested to an older crash test standard
- Adjust roadside hardware using computer modeling, other research, and expert opinion.
- Allow the use of non-crash tested hardware.

Some of the situations require the approval of BPD. Document a less-than-ideal situation in the Design Study Report. Other situations may require the approval of others in the Department. Coordinate with the WisDOT project manager and the regional design oversight engineer for assistance.

The Department has policies to address existing barrier system and some roadside hardware on projects. Existing barrier systems and roadside hardware is reviewed (see FDM 11-45-10.4). If reasonable, spot improvements or replacement may be implemented. Spot improvements may not meet the most current crash test standard. Spot improvements are based on (the list is not all-inclusive):

- Older crash tested hardware
- Adjust roadside hardware using computer modeling, other research, and expert opinion.

See other parts of the FDM for guidance for existing barrier systems and some hardware on projects.

15.1.6 High Angle Crash Locations

Longitudinal barrier systems (e.g. beam guard, concrete barrier…) are not designed for crashes greater than 25 degrees. Installing a longitudinal barrier system where a high angle hit can happen should be documented in the DSR. Examples where longitudinal barrier can be hit at a high angle are (the list is not all-inclusive):

- Top of a "T" intersection
- Median gap between bridges

Situations, like the top of a "T" intersection, a longitudinal barrier system may be the only choice available. For example, a lake is in the right-of-way near the top of a "T" intersection. On the other hand, removing a hazardous pole from the top of the "T" intersection is better than placing a barrier system.

Some bridges have beam guard installed in the median gap between bridges (See Figure 15.13). 90-degree crashes can happen here as well. The grading approaching a barrier system between bridges may prevent the barrier system from operating correctly. Many of the barriers installed at these locations are not crashworthy systems.

Avoid installing longitudinal barrier system in a median gap between bridges. Avoid using mowing and pedestrian concerns for installing a barrier in the median gap between bridges.

Figure 15.13 Beam Guard Installed in Median Gap Between Bridges

Other roadside hardware alternatives are better choices in the median gap between bridges. Some of these options are (the list is not all inclusive):

- Increasing the length of barrier along the road
- Flaring barrier along the road
- Thrie beam bullnose
- Flaring concrete barrier from both sides of the median and installing a crash cushion

The first two options may not prevent some vehicles from going between two bridges. However, this type of crash has a low probability. Review Length-of-Need discussion in FDM 11-45-30.3.1.2.

The last two options will likely prevent a vehicle from going between the bridges. Crash cushions and arrays are designed for some 90-degree hits. These alternatives may have other issues (e.g. drainage, longer barrier installations, cost maintenance…).

15.1.7 Request for Technical Assistance

Request for technical roadside design assistance should be directed through the regional project manager or others in the region. If there is a need for additional assistance, coordinate with the WisDOT project manager and the regional design oversight engineer.

Typically, request for technical assistance should include:

- AADT
- Speed
- Type of project
- Drawings or photos of the situation
- Deadline for a response

Other information may be requested.

15.1.8 Documentation of Roadside Design Decision

Provide a design justification (DJ) in Design Study Report when not following roadside design guidance in FDM 11-45-30 or other sections of the FDM. Documentation may be needed years after the design or construction and key decision makers may not be available.

Typical items that should have a DJ in the Design Study Report are (the list is not all-inclusive):

- Decision not to implement a warrant for a specific treatment. Some examples are:
    - not to shield the blunt ends of an existing bridge.
    - not to remove a tree that warrant removal.
- Decisions not to install crashworthy hardware as specified. Some examples are:
    - install barrier without adequate length-of-need.
    - not to provide grading for a barrier system.

    - modify a thrie beam approach transition.
- Decisions not to use crashworthy hardware. Some examples are:
    - install a sloped end treatment.
    - install a blunt end on the approach end of a barrier system.
- Decisions not to provide indicated plan information. Some examples are:
    - not provide individual construction details.
    - not provide soil boring information in plans for cable barrier project.
- Decision not to review or upgrading existing hardware. An example is:
    - not to adjust beam guard height.
- Decisions to use a non-typical installation of hardware. An example is:
    - to install a flared barrier system.
- Decisions to use special provisions or unique hardware.
- Decisions that require review, coordination with other groups, or additional engineering. Some examples are:
    - review a situation where other factors were required to make a treatment decision.
    - coordinate with Bureau of Structures about work near or attached to a structure.
    - decided they want to design a special concrete barrier transition.

The WisDOT project manager and the regional design oversight engineer have the responsibility of reviewing and approving a DJ. Questions about what needs a DJ and what documentation is needed should be directed toward the them.

15.1.9 Delineation of Roadways at Hazards

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

FDM 11-45-20 Roadside Hazard Analysis And Treatments — *February 15, 2022*

20.1 Introduction

Roadside Hazard Analysis (RHA) is a multi-step process of reviewing roadside hazards and locations of concern. The intent of RHA is to help staff:

- Create an accurate estimate during scoping or preliminary design.
- Limit redesign in later stages of the project
- Allow for more time to get technical help
- Allow for implementation of technical solutions
- Allow a quicker and more systematic review of roadside design decisions
- Allow more experienced staff to aid less experienced staff
- Help decide what clear zone to use for a project or a location

RHA has three phases:

1. Scoping/Preliminary Design
2. Design Study Report
3. Final Design

The scoping/preliminary design phase identifies roadside hazards and areas of concern that can have a significant influence on project type and what resources a project needs. This effort is accomplished during the Project Definition Phase – see FDM 3-1-10.

The Design Study Report phase has two steps. The first step creates a list of roadside hazards or locations of concern. The second step documents what roadside design methods are being used. This effort is accomplished during the Project Delivery Phase – see FDM 3-1-15.

The final design phase is a holistic review of the overall design. Identify new hazards or less than desirable situations, and discuss the use of non-standard roadside safety hardware.

This section will discuss the following:

- What projects need to use the RHA process?
- What is a hazard?

- What is an Area of Concern?
- How far from the road do I look for hazards or Areas of Concern?
- What documentation do I provide?
- Where does this documentation belong?

20.2 Roadside Hazard

One of the key functions of the RHA is to identify and decide on treatments for roadside hazards. FDM 11-45-20.2 discusses some of the most common roadside hazards along with known warrants. Not all possible hazards are listed.

The following roadside hazards need documentation in the RHA. Unless noted otherwise, the following hazards do not need to be documented in the scoping/preliminary design phase. Some situations, an early review of a hazard or hazards may have a benefit. Examples are (the list is not all-inclusive):

- A significant quantity of work is required (e.g. many culvert pipes need traversable grates).
- Work on an item will add significant cost (e.g. extend large culvert pipe).
- Right-of-way may be needed.

Document issues found during scoping/preliminary design in the Design Study Report phase.

20.2.1 Roadside Hazard Warrants

Warrants have been developed for various roadside situations. Many of the warrants present are based on results from crash tests, computer modeling, crash analysis, benefit cost analysis, or a combination of them.

20.2.2 Warrant Assumptions

Many of these warrants use an “average road.” An “average road” is:

- Built to a suitable standard
- Does not need to consider consequences of a collision
- Road is straight and level
- Road does not have a history of run off the road crashes

Unless noted otherwise, warrants use the following assumptions:

- Road is a two-lane highway
- Road has a speed of 50 to 55 mph
- Warrants do not include the interaction of hazards at a location. Examples are (the list is 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 road and the hazard are non-recoverable.
- The roadside hardware or barrier system can be correcty installed.
- The useful life of the barrier system is 20 to 25 years.
- The cost of installing a barrier system is near the statewide average cost.

20.2.3 Proper Application of Warrants

To properly apply the 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 the barrier system.
- for a design justification to a standard
- “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 made different assumptions to develop its warrant. Warrants may be in conflict. If there is a conflict, look to:

- Consult with an engineer trained and experienced in roadside design issues.
- Error on the side of driver safety.
  - Use a preferred roadside design treatment before a less desirable treatment.
  - If two shielding warrants conflict each other, provide shielding.
  - Look for other hazards nearby
  - Review Attachment 20.1, and Table 20.1

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

- A “Do Nothing” alternative for a lower speed road may not be suitable for a higher speed facility.
- A warrant for a two-lane road points to installing a barrier system, a freeway or expressway would likely warrant a barrier system.
- A warrant for a two-lane road points to not shielding a hazard, installing a barrier system may be correct on a freeway or expressway.

Many of the warrants do not consider consequence of collision. If there are significant consequences of collision, it is not appropriate to use these warrants to take no action. Discuss with the WisDOT project manager and the regional design oversight engineer.

20.3 Hazards

20.3.1 Slopes

Identify hazardous slopes during the scoping/preliminary design phase. Grading may need more right-of-way, drainage or environmental work. Slopes are either:

- Perpendicular to the direction of travel
  - Foreslope
  - Backslopes
- Parallel to the direction of travel
  - Driveway slopes
  - Side road slopes
  - Median crossovers
  - Ditch checks

Perpendicular slopes steeper than 4:1 are hazards. A vehicle will travel to the bottom of the slope. A vehicle on this steep of slope will engage:

- The backslope
- Fixed objects on the slope
- Fixed object at the bottom of the foreslope

Perpendicular foreslopes between 4:1 to 3:1 that lack the clear runout area at the toe of slope are hazards. See FDM 11-15 Attachment 1.9. Any ditch at the bottom of these foreslopes can cause the vehicle’s bumper to snag on the backslope of the ditch.

For perpendicular backslopes, see the discussion on ditches in the culverts and other associated drainage items section.

Slopes parallel to the direction of travel that are too steep will launch a vehicle into the air. Occasionally a parallel slope will cause a vehicle to flip over (rear bumper rotated over front bumper). Information in FDM 11-45-30.6.2 contains information on acceptable speed and maximum parallels slopes.

Occasionally, cross-drain pipes without the proper grading may have a hazardous parallel slope – see Figure 20.1, Figure 20.3 and Figure 20.4. A good parallel slope and traversable endwall is shown in Figure 20.2.

Figure 20.1 Parallel Slope Hazard

Figure 20.2 Good Parallel Slope and Traversable Endwall

Figure 20.3 Installation of a Traversable Culvert but Retaining Wall is a Hazard

Figure 20.4 Vehicle Hit a Hazardous Driveway Slope

It may be possible to decide if slopes are hazards by reviewing the as-built plans. However, unrecorded construction or maintenance, utility work, or natural erosion may have steepened slopes. Conduct a field review to verify what slopes are present along a road.

Perform an on-site visual survey with spot-measurements on the road to determine the following:

- Slope break points
- Extent of hazardous slope
- Ditch location

Spot-measurements are not a project's survey. These measurements are for identifying if hazardous slopes are present and roughly quantify the extent of the hazard. Use on-site visual survey and spot-measurements to answer the following questions about hazardous slopes:

- How long is the slope?
- How tall is the slope?
- How steep is the slope?
- How far from the edge of lane is the slope?
- Are there other hazards on or near the slope?
- Where is the slope located?

Without this information, it is difficult to decide a course of action.

At a minimum, use a 4-FT carpenters level and tape to measure slopes. Use the following guidance when measuring the slopes with a 4-FT carpenter level on projects without already completed or proposed future survey:

- Once every 500 feet
- Spot locations (e.g. driveways, near structures, drainage features, and transitions from cut to fills…).
- Parallel slopes need at least one measurement in the direction of travel.

On two-lane roads and in divided medians, parallel slopes have two approaches. One approach for each direction of travel.

20.3.1.1 Barrier Installation Warrant for Foreslopes

20.3.1.1.1 Roadside Design Guide – Foreslope Warrant

Attachment 20.2 is a warrant for shielding embankments.[x] Embankments falling within the shaded area are more of a hazard than installing a barrier system. This warrant is not based on:

- Fixed objects or other hazards on the slope
- A 3:1 slope that lacks a flat run-out area at the toe of the slope
- steep existing foreslopes.

20.3.1.1.2 FHWA Barrier Warrant for Low Volume and Low-Speed Roads Publication

Attachment 20.3 has warrants for shielding foreslopes based on Adjusted Traffic Factor (ATF), speed, slope rate, slope height, and offset from travel way.[xi]

This warrant does not automatically remove slopes that are shorter than the distance given or flatter than the slope given from shielding. Review flattening the slope before shielding a slope.

The following information will discuss proper application of this warrant. This warrant is based on crash severity and crash frequency on low speed, low AADT roads.

It is not proper to use these tables on roads with higher AADTs to justify leaving a hazard unshielded. If shielding is warranted in these tables, it is likely that shielding would be warranted on roads with higher AADTs or speeds. In many high-speed or higher AADT roads, other roadside treatments would be more desirable (e.g. remove, move, make traversable,...).

This warrant uses hazard type, ATF, speed, and offset from the road to decide if shielding should be used. The ATF value adjusts the vehicle encroachment rate for the effects of curves, traffic growth, and grade. Calculate ATF as follows:

$$\boxed{ATF = AADTxTGxHCxDG}$$

Where:

AADT= AADT

TG= Traffic Growth Factor (Attachment 20.3, Table A.1)

HC= Horizontal Curve Adjustment Factor (Attachment 20.3, Table A.2)

DG= Down Grade Adjustment Factor (Attachment 20.3, Table A.3)

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

The warrant has three classifications (1) Not Warranted, (2) Possibly Warranted, and (3) Warranted.

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

For roads that fall within the ranges in the tables, shield hazards that:

- Are within the Warranted column
- Are within Possibly Warranted columns on projects where there is a run off the road flag in Metamanager or if a Metamanager AK flag can be traced to run off the road crashes

On roads that fall within the Possibly Warrant column in the table, review locations that are within the Possibly Warranted column for shielding. Use Table 20.1 and Attachment 20.1 when considering shielding.

Table 20.1 Factors to Consider [xii]

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
Road 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

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

Warranted columns.

20.3.1.1.3 Traversable Grate for Hazardous Parallel Culverts Warrant

Hazardous parallel drains within the clear zone on roads with AADTs of 100 or greater warrant traversable endwalls.[xiii] See discussion in FDM 11-45-30.6.

20.3.2 Drainage Features

20.3.2.1 Culverts

Working on culverts and similar drainage features may need grading, right-of-way, and changes to existing barrier systems. Identify large drainage features early in the scoping/preliminary design phase.

Culverts or similar drainage features may need significant amount of grading or other work. Identify these culverts or drainage features early in the scoping/preliminary design phase.

If needed, coordinate with Bureau of Structures (BOS).

See FDM 11-45-30.6 for guidance on hazardous culverts and other typical hazards near culverts.

Other openings wider than 24 or 36 inches (depending on opening orientation to the road) are roadside hazards[xiv,8]. Examples are (the list is not all-inclusive):

- Inlets or manholes with no cover
- Three 12-inch culverts placed near each other
- Basins, drop structures, channels, (see Figure 20.5)
- culvert pipe headwalls (see Figure 20.6)

Figure 20.5 Width of Basin allowed Bumper Contact with Inside Wall[9]

[8] Opening smaller than 24 or 36 inches may be hazards for pedestrians and bikes.

[9] Wall of basin is approximately 1 foot tall. In the direction of travel, the inside dimensions of the basin is 10 feet. Contact with the wall caused excess decelerations.

Figure 20.6 Headwall for Culvert Pipe is a Hazard [xv] [10]

Improperly installed pipe grates (See Figure 20.7, Figure 20.8, and Figure 20.9) are hazards. For a traversable grate to work, the grate's bars need to be perpendicular to the direction of travel. Grates that do not have the correct hardware may not have the strength to support a vehicle. Review SDD 8F7 or SDD 8F8 for proper spacing and orientation of bars in a traversable grate.

Grate in Figure 20.8 is a hazard because the horizontal bar in the foreground is too far off the ground. This bar should be flush with the ground. A horizontal bar only 1 FT off the ground rolled a vehicle over during crash testing.

Figure 20.7 Pipes are Installed Parallel to Direction of Travel[11] Hazard

[10] 4-inch tall hazard on a 5-FT chord

[11] Ends of endwall are 4-inch tall hazards on 5-FT chords

Figure 20.8 Grate Does Not Extend to Bottom of Apron End Wall or Culvert[xvi] Hazard

Figure 20.9 Grate Should Have Covered All of the Opening[12] Hazard

20.3.2.1.1 Traversable Grate for Hazardous Cross-Drains Warrant

Hazardous cross-drains within the clear zone on roads with AADTs of 750 or greater warrant traversable endwalls.[xvii] See discussion in FDM 11-45-30.6.

20.3.2.1.2 Shielding Hazardous Cross-Drains or Cattle Passes Warrants

20.3.2.1.2.1 Shielding Hazardous Cross-Drains or Cattle Passes Warrant on Perpetuation and Rehabilitation Projects

Attachment 20.4 is a warrant for shielding hazardous cross-drains.[xviii] Locations that are on or below/right the line for the given box warrant shielding.

This warrant was developed for minor S-1 projects. It is not appropriate to use this warrant to justify installing a new drainage feature or cattle pass that is narrow. See discussion in FDM 11-45-30.6. Review more desirable treatments on S-2 and S-3 projects before shielding a hazard.

The warrant also assumes:

- Slopes near drainage feature or cattle pass are traversable
    - Slopes and culvert may need shielding
- Drainage feature or cattle pass is not a fixed object hazard (the e.g. headwall is not a 4-inch object on

[12] Head and sidewalls of the box culvert are 4-inch hazards on a 5-FT chord

5 foot chord hazard).

- Head wall may need to be shielded regardless of AADT.

- Hazardous water is not always present
  - Hazardous water may need to be shielded regardless of AADT.

20.3.2.1.2.2 Shielding Hazardous Cross-Drains or Cattle Passes Warrant on Rural Local Roads

More recent research shows that shielding a hazardous cross-drain can have a benefit cost ratio of 4 or more before 500 AADT.[xix] Some situations where these occur are:

- Road width less than 36 feet
  - Rural two-lane or rural one-lane road
    - AADTs of 250 or greater
    - Perpendicular slopes leading to the hazardous culvert are 2:1 or steeper
- Road width less than 36 feet
  - Rural two-lane or Rural one-lane road
  - With AADTs of 450 or greater
  - Perpendicular slopes leading to the hazardous culvert are 3:1 or steeper
- Road width of 36 feet or greater
  - Rural two-lane roads
  - With AADTs of 400 or greater
  - Perpendicular slopes leading to the hazardous culvert are steeper than 2:1

This research also shows that shielding hazardous cross-drains and cattle passes can have a benefit cost ratio of 2 or more in the following situations:[xx]

- Rural two-lane or one-lane road
  - Road has AADT of 250 or greater.
  - Slopes leading to the culvert are 2:1 or steeper

Shield when projects match conditions that have a benefit cost ratio of 4 or more. In areas, where run off the road crash frequency is high, shield hazardous cross-drains and cattle passes that match the conditions that have a benefit cost ratio of 2 or more. In areas, where run off the road crash severity is high, shield hazardous cross-drains and cattle passes that match the conditions that have a benefit cost ratio of 2 or more.

The consequence of a collision may suggest shielding as well. For example, the amount of drop from the culvert or the presence of deep water may make shielding a culvert the best treatment.

Review locations that match conditions listed for benefit cost ratio of 2. Use Table 20.1 and Attachment 20.1 when considering shielding these locations.

This research assumed:

- That no other hazard is present
- Analysis was done up to 500 AADT
- Highway's functional class is a rural local road
- 3:1 slopes have flat traversable areas at the toe of slope

Do not use this warrant to justify:

- Leaving hazardous cross-drains or cattle passes unshielded on higher AADT roads.
- Leaving hazardous cross-drains or cattle passes unshielded on higher functional roads.
- To install steeper slopes near a new cross-drain or cattle pass.

It may be proper to use this warrant to justify shielding hazardous cross-drain or cattle pass:

- On a higher AADT road
- On a road of higher functional class

Review more desirable treatments on higher functional class or AADT roads before shielding.

20.3.2.2 Ditches

Ditches that fall outside the typical ditch cross-sections in FDM 11-15 Attachment 1.11 are hazards. Non-traversable ditches can allow the bumper to engage the backslope. Engaging the backslope of the ditch can cause excessive deceleration or flip a vehicle. Ditches can also steer a vehicle into a fixed object (Figure 20.4).

20.3.2.3 Other Drainage Related Hazards

Identify water with a normal depth of 2 feet or more during scoping/preliminary design phase. If a vehicle rolls into the water this deep, occupant drowning is a higher risk.

Medium, heavy, and extra heavy riprap is a hazard. Riprap of this size can trip a vehicle or cause excessive deceleration.

Figure 20.10 Riprap is a Hazard[13]

20.3.2.3.1 Shielding Hazardous Water Warrant

Attachment 20.5 is a warrant for shielding hazardous water. See FDM 11-45-20.3.1.2 to use this warrant.

This warrant assumes the slopes between the water and the road are recoverable.

Figure 20.11 Shielding Hazardous Water

20.3.3 Structures - Bridges, Box Culverts, Large Drainage Conduit, Retaining Walls and Similar Features

A 2005 study of Kansas crash data indicated fatalities from hitting bridge parapets or barrier systems attached to the bridge are over-represented[xxi]. Research conducted on Iowa local bridges suggests that bridges narrower than the approaching road are more likely to have crashes than bridges as wide as the approaching road.[xxii]

Review the following structures during preliminary scoping/design (the list is not all-inclusive):

- Box culverts
- Bridges
- Retaining walls
- Large drainage conduits

Review the interaction of grading, other hazards, and barrier systems near these features.

Coordinate with BOS and the WisDOT project manager and the regional design oversight engineer. Structural

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[13] Individual rocks are 4-inch hazards on a 5-FT chord.

issues may limit options available, and what barrier systems can be used near these features.

Coordinate changes to these features with the road project. This limits impact on road users and allows for the correct installation of hardware.

Pay attention to the slopes that wrap-around a structure and blend into the slopes perpendicular to the direction of travel. These wrap-around slopes may increase the length of barrier because they are hazards.

***Figure 20.12 Bridge Rail*[14]**

Use only approved bridge parapet or road barrier systems on bridges, box culverts, retaining walls or large drainage conduits. In some existing situations, it may not be feasible to install an approved parapet or barrier system. If not feasible to install an approved parapet or barrier system, it is typically possible to improve an existing parapet or barrier system. The WisDOT project manager, BOS and the regional design oversight engineer will decide if an approved parapet design or changes to the existing parapet or barrier systems are needed.

20.3.3.1 Parapets

Review parapets on or connected to a bridge, retaining wall or other structure. Contact the WisDOT project manager and the regional design oversight engineer and BOS if parapet is not shown on:

- Standard detail drawings
- LRFD Bridge Manual
- Within BOS's standard detail drawings

The parapet may have crashworthiness issues. For example, parapet designs before 1964 may lack the strength to contain a crash.[xxiii] Parapets designed after 1964 may have enough strength, but the parapet may have other issues (e.g. snagging, pocketing...).

Some problems that parapets can have are (the list is not all-inclusive):

- Brush curb is present
- Elements of the parapet can allow snag during a crash
- Elements of the parapet can spear into the vehicle cab
- Elements of the parapet are missing or in poor condition
- Lack of connections between elements
- Parapet design prevents smooth redirection
- Parapet is not strong enough to absorb crash loads
- Fixed objects are too close to or on top of parapet
- Parapet lacks or has an insufficient transition from parapet to semi-rigid barrier system

Figure 20.13 has multiple issues that should be addressed during the scoping or preliminary design phase of a project. Some of the issues are:

- Brush curb is present
- Vertical elements of parapet may cause snag
- Height of horizontal element may be too low to contain a vehicle

[14] Note that this bridge parapet lacks appropriate thrie beam transition to beam guard.

- Structural strength of parapet elements and connections to bridge may not be strong enough
- Parapet has an insufficient transition from parapet to semi-rigid barrier

Figure 20.13 Brush Curb

Figure 20.14 Roadway Project Significant Damage to Bridge Railing

Review the quality and condition of the top, sides, and bottom of a deck that have parapets or barriers mounted to them. A deck that looks good on top may have issues on the sides or bottom. A weak deck can influence parapet or barrier performance (see Figure 20.15). Provide photos of the parapet and deck (i.e. top, bottom and side of deck) to the WisDOT project manager, regional design oversight engineer, and BOS.

Figure 20.15 Damage to Side of a Deck that May Influence Parapet Performance

Figure 20.16 Strength of Barrier Connection Critical to Barrier Performance and Structural Maintenance

Some sources of information that can help evaluate an existing parapet are:

- Chapter 6 of the 2006 Roadside Design Guide has pictures of inadequate parapets.
- FDM 11-45-30.5.3 has a discussion on concrete barrier issues that can apply to parapets (e.g. structural strength, smooth transitions).
- FDM 11-45-30.5.2.10 discusses transitions to parapets.
- CMM 1-45.12.5 has discussion and photos on potential snag issues and damage to the temporary barrier. This information can apply to parapets.
- CMM 6-25.3.4 has photos of damaged post, beams and blocks that can apply to parapets.
- Bridge Design Manual has standard parapet designs.

It can be difficult to fit crashworthy hardware on a structure when a driveway or intersection is nearby (e.g.150 FT). Identify these situations during scoping/preliminary design.

20.3.3.2 Blunt Ends

Blunt ends can sometimes be present on barrier systems, end of retaining walls, parapets, and other objects. Even some "sloped" bridge parapets are blunt ends. All blunt ends are significant hazards. Identify blunt ends that a vehicle can hit head on during scoping/preliminary design. See FDM 11-45-30 for more discussion on blunt ends.

20.3.3.3 Shielding Blunt End of Parapets or Railing Warrant

Blunt ends of parapets are significant hazards.[15]

Shield the blunt ends of parapets on roads with AADTs of 400 or greater, except as noted in Table 20.2.[xxiv]

Review Attachment 20.1 when deciding to shielding blunt ends on roads with AADTs between 150 and 399.[xxv].

Multiple research studies have shown that bridges narrower than the approaching road width are more likely to be hit. Shield the blunt ends of parapets on structures that are narrower than a road's normal width when AADT is between 150 and 399. Shield blunt ends of parapets on drainage features or cattle passes that are narrower than approaching road when AADTs is between 150 and 399.

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

Review FDM 11-45-20.3.3.4 and 11-45-20.3.3.5 for more information on bridges and barriers that approach bridges. Review FDM 11-45-30.5.2.10 and FDM 11-45-20.3.3 for more information about shielding blunt ends of parapets or railing.

20.3.3.4 Crashworthy Bridge Parapets and Railings Warrant

All bridge parapets and railings are to be National Cooperative Highway Research Program (NCHRP) 350 or Manual for Assessing Hardware (MASH) compliant. Refer to LRFD Bridge Manual 30.1 for more information. New bridge rail installations LET after December 31, 2019, need to meet MASH requirements.

It may not be reasonable to install a crashworthy parapet or railing on an existing structure. Often, safety improvements can be made to the existing parapet or railing. Coordinate with the WisDOT project manager, BOS, and the regional design oversight engineer.

Review FDM 11-45-20.3.3.3 and 11-45-20.3.3.5 for more information on bridges and barriers that approach bridges. Review FDM 11-45-30.5.2.10 and FDM 11-45-20.3.3 for more information about shielding blunt ends of parapets or railing.

20.3.3.4.1 Transitions to Bridges or Concrete Barrier Wall

The transition and end treatment shall be used based on Table 20.2 for the proposed posted speed.

[15] In one study, 58% of all fatal crashes on a bridge involved a vehicle hitting the blunt end of a parapet or railing [Michie, Jarvis, Bronstad, Maurices, Upgrading Safety Performance in Retrofitting Traffic Rails, FHWA-RD-77-40, 1976]. Another study compared the safety performance of bridges with exposed blunt ends to bridges with shielding [Gates, Tim, Noyce, Dave, Stine, Paul, TRB 2006 Annual Meeting CD-ROM, Safety and Cost-effectiveness of Approach Guardrail for Bridges]. Bridges with exposed blunt ends had 4.5 times more K and A crashes than bridges with shielding.

Table 20.2 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 Attachment 1.1, 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.

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

Research in Wisconsin shows that cross-median crashes, a specific subset of run off the road crashes, are more likely to occur near bridges. Research in Iowa suggests that 80 percent of their bridges have 2 or fewer parapet or railing crahes in 10 years.[xxvi]

If a bridge's parapet, railing or attached barrier system has more than two crashes in 10 years, the location has an issue with run off the road crashes. Improve roadside design near this bridge.

This is not a warrant to provide median protection shielding.

20.3.3.6 Bridge Piers

Crashes into bridge piers can have serious consequences. Identify piers as hazards early in the scoping or design process. See FDM 11-35-1 and FDM 11-45-30 for more information on piers.

20.3.3.7 Retaining Walls

Retaining walls are typically not designed for crash loads. A crash can cause damage to the retaining wall, or in the worst-case wall failure. Repairing a retaining wall can be expensive. A wall with a rough face [16]or edges can cause excessive vehicle compartment crush, rollover, or large deceleration force.

Identify retaining walls as a hazard when:

- The vehicle can leave the road and fall off an unshielded retaining wall.
- Barrier system on top of a retaining wall is in poor condition or substandard.
- The vehicle can leave the road and strike an unshielded retaining wall.

A chain-link fence is not considered a barrier system for vehicles.

20.3.3.8 Pedestrian Rails

Pedestrian railings using steel pipes with diameters of 2 inches or more are hazardous. Crash testing of a road sign using a single 2-inch diameter steel pipe caused excessive vehicle deceleration. Also, pedestrian rails can spear into a vehicle's passenger compartment[17]. In Figure 20.17, the pedestrian rail is a hazard to a vehicle. A pedestrian railing can prevent a pedestrian from evading a vehicle. See FDM 11-45-20.4.1 for discussion of Areas of Concern for more information.

Figure 20.17 The Pedestrian Rail is a Hazard[xxvii]

[16] Crash testing has indicated that sand blasted textures with a relief 3/8 of an inch or more can negatively affect crashworthiness of a concrete barrier system

[17] Top of railing is typically at 42 inches. Average eye height of a vehicle's occupants is 42 inches.

Figure 20.18 Pedestrian Rail Entered Cab of Vehicle

20.3.4 Signs and Poles

Signs and poles are fixed objects that engineers decide to install along a road. Traffic signals and railroad crossing warning devices are not hazards.[xxviii,18]

Luminaires may use non-breakaway hardware.[19] Identify these luminaires as hazards for RHA.

Table 20.3 contains a list of conditions for a sign or pole that would make the pole a hazard.

[18] See 2011 AASHTO Roadside Design Guide for more information

[19] Non-breakaway pole may be used in locations where dropping a pole on pedestrians, other road users or buildings is a risk.

Table 20.3 Signs or Poles

Issues	Condition	Discussion
Breakaway Feature	Type I signs are missing post clips, post clip bolts, washers or nuts) are hazards (see Sign Plate A4-6 and A5-2)	Post clip hardware allows the overhead sign to detach from the posts during a crash. During a crash, the clips temporarily delay the release of the sign. This delay prevents the sign from falling on the vehicle or causing excessive deceleration.
Breakaway features	Breakaway features are missing or are not installed correctly (see Figure 20.19 to Figure 20.24).	Sign or pole may not breakaway as intended (see discussion below).
Breakaway features	A sign is heavier, is larger than, located differently on a pole, or other hardware has been added to a pole than what was crash tested.	Signs that are heavier than what was crash tested can prevent the breakaway hardware from functioning or allow the sign to crash onto the vehicle. Signs that are larger than what was crash tested may enter a vehicle's cab. Adding mass or moving a mass can change the rotational inertia of a pole or sign. Changing the rotational inertia of a sign or pole may lock it into place versus rotating over the top of a vehicle. Sometimes, changes in rotational inertia can cause the pole to crush the vehicle's cab.
Breakaway features	Signs or poles that use weathering or Cor-Ten Steel (See Figure 20.25)	This steel can cause breakaway features to rust shut and not work.
Breakaway features	Steel poles with a diameter of 2 inches or more	Without changes that weaken the pipe or the use of breakaway features, pipes this size can cause a vehicle to decelerate too quickly.
Placement and Breakaway Features	Signs that do not conform to WisDOT's Sign Plates A3-1, A4-1, A4-2, or A4-3	Signs that do not follow these details have issues with proper sign placement, or the sign is not using breakaway hardware.
Placement	Breakaway features for a sign or pole is more than 4 inches tall on a 5-foot chord (See Figure 20.19, Figure 20.20, Figure 20.22 and Figure 20.31).	Grading near a sign or pole can cause the breakaway feature to become a snag hazard.
Placement	Sign or poles installed in poor soils, wet soils or near the bottom of a ditch are hazardous	Poor or wet soils may not allow breakaway features to engage. Ditch slopes can steer a vehicle into a sign or pole.
Placement	Signs or poles are within the working width, or the zone of intrusion of a barrier system	The vehicle may engage the sign or pole behind the barrier. See working width discussion in other sections of FDM 11-45-30.
Placement	Installing signs or poles within 70 feet of an EAT. See figure in CMM 6-26 and Figure 20.44	The vehicle may try to avoid the sign or pole and steer into the EAT. A vehicle may gate through the EAT and then hit the sign or pole.
Placement	Guy wires and poles are near the road.	Poles and guy wires are significant hazards. (See Figure 20.27 and Figure 20.28).
Placement	Grading leading to or around object can prevent object from working correctly	If vehicle engages breakaway pole too high, the pole may not work as designed (Figure 20.29)

Overhead sign supports, sign bridges, or message boards that do not follow guidance in FDM 11-55-20 are hazards.

Figure 20.19 Light Pole using Non-Breakaway Hardware[20]

Figure 20.20 The Footing is a 4-inch Hazard[21]

[20] Footing is a 4-inch tall object on a 5-foot chord hazard – see Figure 20.31

[21] This fixed object serves no purpose and should be removed.

Figure 20.21 Non-Breakaway Sign

Figure 20.22 Buried Breakaway Feature [xxix]

Figure 20.23 Breakaway Holes are too High[22]

[22] There are other issues with this sign and location. The sign should only have an arrow board on it (see discussion about the maximum size of sign on a breakaway feature). There also appears to be some edge drop issues from the paved shoulder to the gravel shoulder.

Figure 20.24 Breakaway Holes in the Wrong Location [xxx]

Figure 20.25 Cor-Ten/Weathering Steel Prevented Breakaway Hardware from Working [xxxi] [23]

Figure 20.26 Pole with Cabinet did not Breakaway [xxxii]

[23] Note that these signs need new steel posts and new footings.

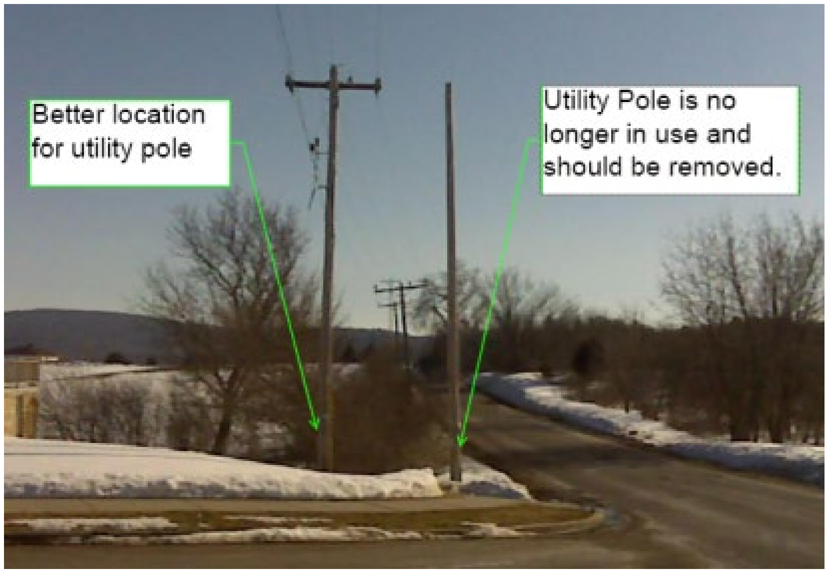

Figure 20.27 Utility Poles are Hazard

Figure 20.28 Guy Wire Cut Car into Two Pieces [xxxiii]

Figure 20.29 Grading Leads to Improper Pole Engagement [xxxiv]

Figure 20.30 Message Board is too Heavy for Breakaway Features[24]

20.3.5 Other Objects

Objects that are 4 inches tall on a 5-foot chord can cause a small vehicle to flip, rip open its' gas tank or decelerate the vehicle too quickly. See Figure 20.30 for a drawing of the 4-inch hazard on a 5-foot chord.

Breakaway hardware or other safety features not installed correctly can become a fixed object hazard as well. Within this procedure, various objects are fixed object hazards because of the 4-inch on a 5-foot chord criteria. It may not be possible to install a sign or pole without violating the 4-inch on a 5-foot chord criteria. Minimize the situations where an object is taller than a 4-inch on a 5-foot chord. See examples in Figure 20.32, Figure 20.33, and Figure 20.34.

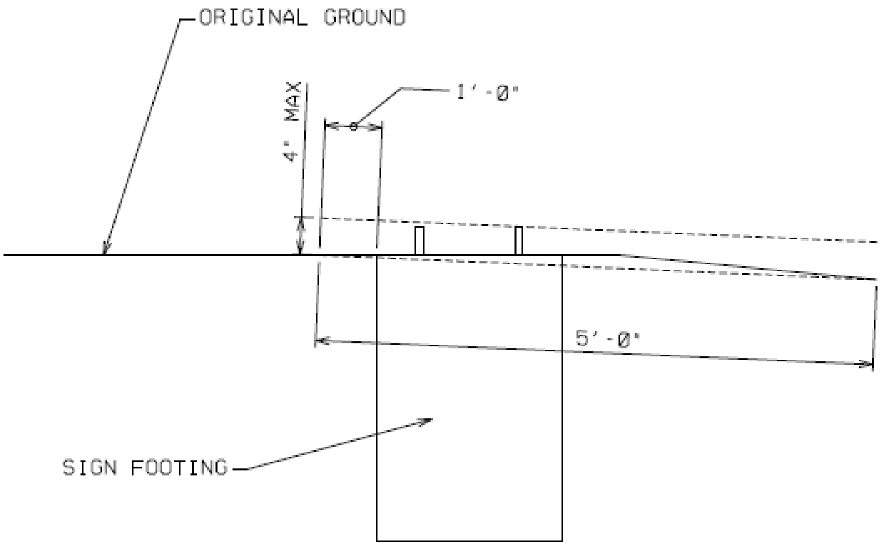

Figure 20.31 4-inch tall hazard on 5-foot chord

[24] Concrete foundation is a 4-inch tall hazard on 5-foot chord, and control box and power conduit are hazards. More than likely, the message board is not using the required breakaway clips. Message board is likely too heavy to allow proper operation of breakaway features.

Figure 20.32 Rock is a Fixed Object Hazard

Figure 20.33 Manhole is Fixed Object Hazard

Figure 20.34 Portions of Endwall and Culvert are 4-inch Hazard on 5-foot Chord

20.3.5.1 Trees

Preliminary results from NCHRP Project 17-43 shows the following:[xxxv]

- 50% of serious injury crashes are within 13 feet of road
- 50% of serious injury and fatal crashes with trees have a change of velocity near 22 mph (e.g... Hit tree at 22 mph and came to a full stop, or hit at 42 mph and leave the tree traveling 20 mph).

In another study, trees located in the median of urban/suburban roads had an increase in crash frequency and crash severity.[xxxvi]

A tree with a diameter of 4 inches or more, or will grow to be more than 4 inches in diameter, is a hazard. [xxxvii] Bushes or groups of closely spaced small trees with a group diameter of 4 inches or more are hazards.[xxxviii] Measure a tree's diameter 4 inches from the ground.[xxxix] Include stumps in hazardous tree identification.

Figure 20.35 is an example of what a vehicle crash looks like on a tree. Review existing trees for similar scars.

Woody limbs can become spearing hazards. In Figure 20.36, a branch from the shielded tree fatally speared an occupant of a vehicle.

Figure 20.35 Small Tree Crash

Figure 20.36 Trees speared vehicle's occupant[xl]

Figure 20.37 Smaller diameter tree fatality

Roadside landscaping and aesthetic issues can conflict with roadside design. Planting a small tree near traffic may not seem like a big issue during the design. However, the tree will grow into a long-term hazard that can cause significant injury or fatality. Even smaller diameter trees can contribute to fatalities – see Figure 20.37.

Removing existing trees is inexpensive, reduces run off the road frequency and severity. It may not be possible to remove all hazardous trees. Examples are (the list is not all-inclusive):

- A tangent section of a PM project within a suburban setting that does not have run off the road history.
- A tree or grove of trees is:
    - a documented "Witness Tree" for surveying
    - where a historically significant event took place[25]
    - a memorial to an important person, group, or historical event
    - a endanger/threatened tree species or habitat for endanger/threatened species
    - a documented exceptional example of a tree species [26]

[25] In these locations, the trees are part of the original historical setting.

[26] For an example, a given tree is the third largest white pine in the state.

- The road is[27]:
  - a rustic roadway
  - on the Great River Roadway network
- Other locations that it may be difficult to remove trees are:
  - scenic overlooks
  - historic properties
  - parks

Provide more discussion in RHA for a hazardous tree, or grove of trees, that needs to remain in-place.

20.3.5.1.1 Road Segment Warrant with High Rate of Tree Crashes

Attachment 20.6 has a threshold rate of tree crashes for various rural roads[xli]. If a road segment has a rate of tree crash greater than the values in Attachment 20.6, take corrective action. Trees are being hit more frequently than they should.

Break the project into quarter mile pieces. Use 3 to 5 years of crash reports to create the crash rate to compare to Attachment 20.6.

Review FDM 11-45-30.2.6, FDM 11-45-30.2.18 and FDM 11-45-20.3.5.1 for more information about trees. Do not use this warrant to override other warrants.

Other warrants indicate that it is cost effective to use other roadside design treatments on average roadway (i.e. roads without a high frequency of tree crashes). These other warrants combined crash severity and frequency.

20.3.5.1.2 Shielding of Hazardous Trees Warrant

Attachment 20.7 is a warrant for shielding hazardous trees. Refer to FDM 11-45-20.3.1.1.2 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.[xlii]

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

Typically, removing trees is the most desirable roadside design treatment.

Projects removing trees may need to include grubbing items to make sure that stumps are removed. Stumps not properly cut can be hazardous because they are taller than a 4-inch hazard on a 5 FT chord (see FDM 11-45-20.3.5).

Review FDM 11-45-30.2.5, FDM 11-45-30.2.18 and FDM 11-45-20.3.5.1 for more information about trees.

20.3.5.1.3 Tree Removal Warrant

On roads with AADTs as low as 125 the benefit cost ratio of tree removal is usually 4 or more.[xliv] Occasionally, removing trees can be justified when AADT is at 50 or lower. Removal depends on spacing of the trees, the diameter of the trees, and offset from the edge of lane to the trees.[xlv]

Typically, removing trees is less expensive than installing a barrier system. Removing trees is a more desirable roadside design treatment. Provide documentation when trees are remaining in-place.

Projects removing trees may need to include grubbing items to remove stumps.

Review FDM 11-45-30.2.5, FDM 11-45-30.2.6, FDM 11-45-30.2.18 and FDM 11-45-20.3.5.1 for more information about trees.

20.3.5.2 Mailboxes

Identify hazardous mailboxes during the RHA (see FDM 11-45-10.3 to determine when to perform an RHA). FDM 11-15-1 provides guidance on how designers are to treat hazardous mailboxes. See CMM 3-15.5 for a handout on mailboxes. Mailboxes mounted on barrier systems are hazards. Identify hazardous mailboxes during the RHA.

20.3.5.3 Fences

Chain-link fences with a top rail are a hazard[xlvi]. Top rails can be pipe or steel channels. Top rails can penetrate into vehicle cab. Identify hazardous fences.

[27] Statement is not to imply that trees will not be removed from these locations. Designers may need to be more selective on what trees are removed or may need more justification to remove trees (i.e. crash history).

20.3.5.4 Barrier Systems

Barrier systems are hazards. Identify barrier systems during the scoping/preliminary design phase. See FDM 11-45-30.5 for more information on reviewing barrier systems.

20.3.5.5 Vertical Drops

Identify vertical drops early in the scoping or early design as hazards for vehicles.

Vertical drops of 8 feet or taller are hazardous (see Figure 20.38)[28].

Drops of 6 feet or more combined with other hazards (e.g. water with a normal depth of 2 feet or more, riprap, drainage ditch or channel slopes) are hazards.

Vertical drops with high consequence of collision (see Attachment 20.1)

Figure 20.38 Vertical drop and water hazards are hazards

Drops of lesser height may be hazards for other users (e.g. bike and pedestrians...).

20.3.5.6 Planters, Monuments, and Similar Objects

Identify planters, monuments, and similar objects as hazards early in scoping and design.

These objects may allow (the list is not all-inclusive):

- Structural failure
- Blunt end Crash
- Snagging a vehicle
- Excessive cab crush
- Rollovers
- Large deceleration forces

[28] Vehicles have a tendence to flip or rollover when they traverse vertical drops of 8 feet or more.

Figure 20.39 Planter is not a crashworthy design[29]

20.3.5.7 Additional Warrants

20.3.5.7.1 Median Barrier on New Freeway Construction Warrant

Attachment 20.8 is a warrant for installing a median barrier on new freeways. It may not be proper to use this warrant to install a barrier on an expressway. The influence of crossroads was not considered in developing this warrant (e.g. intersection spacing, sight distances…). On a case-by-case basis, evaluate the need for a median barrier on non-freeway projects.

Do not use Attachment 20.8 for deciding allowable median width.

20.3.5.7.2 Retrofit Cross-Median Crash Warrant

Review crashes for cross-median crash (CMC) events using the most current 5 years of crash data. A minimum of three crashes are needed to do the analysis.

1. Calculate the distance between the farthest crashes in miles
2. Divide the total number of crashes by distance in step 1
3. Divide the number in step 2 by the number of years between crashes

If the value from step 3 is greater than 0.48 CMC/mile/year, take corrective action.

See FDM 11-45-30.8 for more information on cross-median crashes.

20.3.5.7.3 Shielding Fixed Objects Warrant

Attachment 20.9 is a warrant for shielding a fixed object. Refer to FDM 11-45-20.3.1.1.2 of this procedure on how to use this warrant.

This warrant is not appropriate for considering the consequence of a collision. For overhead sign supports, sign bridges, monotube signs, and message boards follow the guidance in FDM 11-55-20.

Shield bridge piers and similar fixed objects when the road's posted speeds is 55 mph or greater and object is within the desirable clear zone distance.

This warrant does not address the need for structural protection. See FDM 11-35-1 for guidance on structural protection.

20.3.5.7.4 Low-Volume Road Warrant

Barrier systems may not be cost-effective for highways that have a current traffic volume under 400 AADT.[xlvii]

However, review installing a barrier system under the following conditions:

- Crash frequency warrants a barrier system

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[29] Planter has various other roadside design issues. Curb and gutter in front of the planter can cause a vehicle improperly engage the planter. Texture of planter may cause excessive decelerations or vehicle rollover. Blunt ends of planter may cause significant deceleration.

- Crash severity warrants a barrier system
- Consequence of a collision warrant a barrier system

All other warrants presented in this section will override this warrant.

20.3.5.7.5 Strike Warrant

Review objects that have had three reportable crashes within a 5-year period. Desirably, remove the object.

20.4 Additional Areas of Concern

One of the functions of the RHA is to identify Areas of Concern. Areas of Concern are locations where: run off the road crashes are more likely to occur, crash severity is high, or the consequence of a collision is severe. See Attachment 20.1 for more discussion. Identify Areas of Concern during the scoping/preliminary design phase of a project.

The list of areas of concern in this subsection is not all-inclusive.

It may not be possible to address an Area of Concern with a project as it may not be reasonable to shield it. However, it may be possible to lessen the overall risk. Examples are (the list is not all-inclusive):

- Move bus stop out of a curve
- Remove hazards that are likely to be hit
- Provide signing
- Remove visual obstructions

20.4.1 Pedestrians

Areas of concern for pedestrians are:

- Locations where pedestrians would have no escape route or little time to react to a vehicle (See Figure 20.17 and Figure 20.40).
- Locations where there is often a high concentration of pedestrians (See Figure 20.41).[30]
- Locations where a vehicle would not normally expect to see a pedestrian (e.g. a hill or horizontal curve "hides" a pedestrian trail crossing on a rural road.).

Figure 20.40 Pedestrians have no Escape Route and Little Time to React to Vehicle

[30] The presence of a sidewalk does not indicate that there is a high pedestrian concentration.

Figure 20.41 University Avenue on UW-Madison Campus during Exchange of Classes

Other areas that could have frequent high pedestrian concentrations are (the list is not all-inclusive):

- Memorials
- Parks
- Scenic outlooks
- Trail crossings
- Athletic fields
- Playgrounds
- Transit shelters
- Schools
- Senior centers
- Medical facilities

The presence of these facilities does not automatically indicate there is a high pedestrian concentration. For example, a road may run along a school property but the road maybe far from the main entrance.

Consider the abilities of the pedestrians using the facility. For example, children in a playground may not be as focused or have the same ability to escape a vehicle as a group of college students waiting to cross a street.

20.4.2 Areas of Concern - Locations with High Run Off the Road Crashes

Areas of Concern for high run off the road crashes are:

- Areas with known high run off the road crash rates
    - Road segments with Metamanager run off the road flags
    - Other spot locations where crash reports show a run off the road problem
- Areas where research points to run off the road being more likely to occur

Review Attachment 20.1.

20.4.2.1 Curves

Research shows that curves are more likely to have run off the road crashes. In one study, 70% of fatal crashes occurred on or near the outside of horizontal curves.[xlviii] Other studies also show that vehicles are more likely to leave the road on curves. Curves that are likely to experience run off the road crashes are:

- An entrance curve that leads into a series of curves[xlix]
- A curve that is significantly sharper than other curves in the series (e.g. second curve in series is sharper than curves one, three or four)[l]

- Compound curves that have a ratio of 1.5 or more between radii[li, 31]
- Curves with advisory speed significantly lower than the approaching tangent roads' posted speed
- Sharp curves within or at the bottom of a steep grade

20.4.2.2 Other Locations

Other areas that are likely to experience run off the road crashes are (the list is not all-inclusive):

- Top of the "T" of a T intersection
- Areas alongside or downstream of a merge/diverge area
- A road segment where there is weaving
- Upstream of taper, taper and gore area of an off-ramp
- Gore area, taper and downstream of taper of an on-ramp
- Upstream and near a major fork
- Upstream and downstream of a bridge
- Areas with inadequate sight distance.

20.4.2.3 Areas of Concern-Locations that Violate Driver Expectation

Locations that violate a driver's expectations are likely to experience run off the road. Potential locations are (the list is not all-inclusive):

- Left hand off or on-ramps
- Sharp curves hidden by profile changes

Figure 20.42 and Figure 20.43 shows a road where driver expectation is violated. In Figure 20.42, a driver expects the road to go straight. However, Figure 20.43 shows the "straight" road is a side road and not the mainline.

Figure 20.42 Drivers Expect the Road to go straight

[31] This type of curve can be especially problematic for semi-trucks if they have to decelerate (i.e. loop ramps) and the first radius the truck encounters is the larger radius.

Figure 20.43 Main Road does not go Straight

20.4.2.4 Areas of Concern-Locations with High Consequence of a Collision

Review discussion in Attachment 20.1 on Consequence of Collision. The following are Areas of Concern for vehicles and other users of the road network (the list is not all-inclusive):

- See Vertical Drop section of this procedure
- Overhead sign, sign bridge, or other similar structure
- Message board

Other areas with high consequence of collision for the whole community are (the list is not all-inclusive):

- Power plants/substations
- Chemical plants/storage areas
- Natural gas/petroleum facilities

20.5 Area of Analysis

Identify all hazards and Areas of Concern within the area of analysis. Measure the width of the area of analysis like clear zone. It is measured from the edge of lane of travel toward the right-of-way. Measure the area of analysis differently when the edge of lane is not defined, or other lanes act as through lanes. Measure from the outside edge of lane or the flag of curb. Some examples when to measure from outside edge of lane or flag of curb are:

- Long auxiliary lane
- Unmarked parking
- Unmarked bike lane
- Wide curb lane

The width of the analysis area is the smaller of the following values:

- Distance to existing right-of-way or permanent easement
- Clear zone based on FDM 11-15 Attachment 1.9 and curve corrections in FDM 11-15 Attachment 1.10
- Distance to buildings that are to remain in-place

If existing right-of-way is less than the desirable clear zone distance and the project is not buying right-of-way, use existing right-of-way to limit the area of analysis. If a property or portion of a property cannot be bought within the project that is buying right-of-way, use existing right-of-way at that specific location to limit the area of analysis. Document in Design Study Report when using existing right-of-way to limit analysis instead of when the clear zone dimension indicated.

Include significant hazards that are just beyond the area of analysis. For example, include a cliff that is 1 foot outside the area of analysis in the RHA.

Break the road into segments with similar geometrics (e.g. number of lanes, lane width, shoulder width…), AADT and speed when documenting hazards. Cutting up a project this way allows for a simple comparison of exposure and crash severity without complicated analysis.

Treat median divided road as either a two-way road (e.g. one road running north, one running south) or as one road (e.g. northbound and southbound roads together). When documenting the median of divided highways as two, two-way roads, indicate which road has the median hazards.

20.6 Roadside Hazard Analysis (RHA) Documentation

20.6.1 Scoping/Preliminary Design

Use Attachment 20.10 during scoping/preliminary design. Discovering items in Attachment 20.10 may change the scope of the project.

List hazards found during the scoping/preliminary design in the Design Study Report phase of the RHA.

20.6.2 Design Study Report Phase

Use the form in Attachment 20.11 to document hazards for Design Study Report phase. Attach the form to Design Study Report. For some more complicated situations, provide additional documentation. Discuss with the WisDOT project manager and the regional design oversight engineer.

See FDM 11-45-15.1.3 for preferred roadside hazard treatment sequence.

Provide justification when shielding, delineating or not acting on a hazard. Address why more preferred methods of treatment are not being used.

Use caution when using construction or right-of-way cost to justify a treatment or lack of treatment. Cost justifications are to review maintenance and crash cost. Use Attachment 20.1 to help decision-making.

20.6.3 Final Design

During the final design, review plans looking for the following issues (the list is not all-inclusive):

- Plan has enough detail to allow for proper installation of safety hardware
- New hazards are not being created without justification
- New areas of concern have not been created without justification
- Interaction of grading, safety hardware, drainage features, and other aspects of the design do not interfere with safety hardware or other features - see Figure 20.44 and Figure 20.45.

By using the RHA and properly installing safety hardware, few issues should be found during the final design process. However, given the complexity of plans and the number of people involved in putting plans together issues can appear.

Figure 20.44 Drainage and Safety Hardware Installation Not Coordinated

Figure 20.45 ITS and Safety Hardware Installation Not Coordinated

Designers should strive to eliminate the issues above. If it is not possible to eliminate the issues above, coordinate with the WisDOT project manager and the regional design oversight engineer. Provide an amendment to the Design Study Report. Address why these issues cannot be eliminated.

LIST OF ATTACHMENTS

Attachment 20.1	Roadside Design Factors to Consider
Attachment 20.2	AASHTO's Warrant for Shielding Foreslopes
Attachment 20.3	FHWA Warrants for Shielding Foreslopes
Attachment 20.4	Shielding Hazardous Cross-Drains
Attachment 20.5	Shielding Hazardous Water
Attachment 20.6	Roadway Segments with High Tree Crash Rates
Attachment 20.7	Shielding Hazardous Trees
Attachment 20.8	Median Barrier Warrant for New Freeways
Attachment 20.9	Shielding Hazardous Fixed Objects
Attachment 20.10	Scoping/Preliminary Roadside Hazard Design Review List
Attachment 20.11	Roadside Hazard Analysis Sheet Template
Attachment 20.12	Roadside Hazard Analysis Sheet Example

FDM 11-45-30 Roadside Barrier Design Guidance — *November 15, 2023*

30.1

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30.2

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30.3 Barrier System Design

Improperly designed barriers systems may not work when needed. If a barrier system cannot be designed correctly, additional engineering is needed. The following contains basic guidance for almost all barrier systems. Specialty applications of barriers need additional engineering.

30.3.1 General Design Criteria

30.3.1.1 Working Width

Working width is combining barrier's width and either the maximum barrier deflection or the maximum distance a crash test vehicle extended behind the barrier (see Figure 30.16, Figure 30.22, Figure 30.37). Lack of working width could cause a vehicle to strike the hazard.

Provide working width for barrier systems.

As working width decreases, the likelihood of injury or death increases. From a general performance perspective, use barrier systems that use all available working width before using barrier systems with less working width (i.e. cable barrier over semi-rigid barrier, semi-rigid barrier over rigid barrier).

Occasionally, only a small section of an overall barrier system may need a reduced working width. Typically installing a small section of the barrier with reduced working width is more desirable than installing a whole barrier system with reduced working width (See Attachment 30.12).

Use proper transition between barrier systems with significant differences in working width. Examples are (the list is not all-inclusive):

- Beam guard systems and concrete barrier (SDD 14B20, or SDD 14B45)
- Beam guard with normal post spacing and quarter post spacing (see Attachment 30.12)
- Beam guard with half post or quarter post spacing to:
    - Short Radius System (SDD 14B27)
    - EATs (SDD 14B24 or SDD 14B44)
    - Long-Span (SDD 14B25 or SDD 14B43)
    - Type 2 Terminals (SDD 14B16 or SDD 14B47)

Where working width is measured depends on the barrier. Attachment 30.13 has a table of working widths for various barriers. This table also indicates where to measure working width. Figures 30.13 to Figure 30.21 show working width and Zone of Intrusion for a single slope concrete barrier. Most of the working widths are for Test Level (TL) -3 crash tests using NCHRP 350 or MASH crash test criteria.

Provide individual construction details showing reduced working width in spot locations. Identify the beginning/end of reduced working width, fixed object that has reduced the working width and overall length of barrier needing reduce working width.

For bidirectional traffic, reduce the working width of a barrier system 25 feet before and after the hazard' and along the hazard. Bidirectional traffic has two approaches. For unidirectional traffic, reduce working width 25 feet before the hazard, along the hazard and 12.5 feet down stream of the hazard.

Guidance on the amount of reduced working width assumes that the barrier system is installed at the edge of shoulder. Barriers installed further away from the edge of shoulder use different guidance.

See Attachment 30.12 for some examples on how to install beam guard with reduced working width

Lack of enough working width can cause a barrier installation to increase in length. See FDM 11-45-30.3.1.4 and Attachment 30.12 for more discussion. Use special provisions to pay for non-MGS beam guard with reduced working width (e.g. half post spacing, quarter post spacing).

Some of the barrier systems listed in Attachment 30.13 are rarely utilized in Wisconsin. Those barriers need approval by the WisDOT project manager and the regional design oversight engineer before use. Coordinate with them. More engineering may be required. Engineering may include special details, individual construction details, special provisions, and other efforts.

30.3.1.1.1 Working Width and Larger Vehicle Crashes

Most barrier crashes are from pick-up trucks or smaller vehicles; however, larger vehicles do strike barriers. Design the barrier systems based on hits from pick-up trucks or smaller vehicles unless:

- Crash history points to frequent larger vehicle hits
- Consequence of a collision is severe (e.g. light pole or sign bridge drops across lanes of travel on a freeway)

National research, using nine years of crash data, shows that 3% of reported barrier crashes involve vehicles larger than a pickup truck, SUV or van.[lii] Spots with more than 3% heavy vehicle crashes into a barrier or fixed object within 9 years may be candidates for a barrier with a higher crash test level.

A barrier with a higher test level may be needed because of a combination of issues. Adverse geometrics, large truck volume and significant consequence of collision may combine making it reasonable to install TL-5 or TL-6 barrier. Examples are (the list is not all-inclusive):

- A road has a steep downgrade followed by a sharp curve near a port with heavy truck traffic. On the outside of the curve is a school.
- Tanker trucks can have difficulties keeping control when there is a large algebraic difference in cross slope (e.g. when a shoulder breaks in the opposite direction of superelevated lanes)[liii].

Locations that do not meet the 3% in nine-year criteria and there is a consequence of a collision, may use taller standard single slope barrier. A taller standard barrier will not withstand a critical hit by a vehicle larger than a pickup truck. Large vehicle crashes are rare. A taller standard barrier will provide some additional shielding for less than critical crashes from a larger vehicle.

Coordinate with the WisDOT project manager and the regional design oversight engineer before using higher test level barrier. Plan for additional engineering. Coordinate early in the design.

Working widths for larger vehicles are bigger than the working width for pickup trucks. Barriers that are designed for larger vehicles are typically more expensive than a normal barrier. The extra working width and barrier cost can have significant influence on a project's design and cost.

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

30.3.1.2 Length-of-Need

The length of a barrier system needed to shield a hazard is called "length-of-need" or "LON". LON is dependent on:

- Location of hazard
- Size of the hazard
- Direction of traffic
- Design speed
- Design traffic volume
- Distance between edge of lane and barrier
- Distance between barrier and hazard
- Horizontal curve

Typically, LON provides enough distance for most cars and pickups to stop before striking the hazard. The distance between the Length-of-Need point of the barrier and hazard being shielded should free of other hazards.

Proper hazard identification is important. This is especially true by bridges or in other locations where there are secondary hazards.

Provide LON to shield the primary hazard. Review installations for secondary hazard. Review if secondary hazards can be removed or shielded (see Figure 30.1).

Document in a DJ barrier installations that are significantly longer or shorter than LON. Minor adjustments of a barrier's location to accommodate for hardware, grading, and other issues do not need documentation.

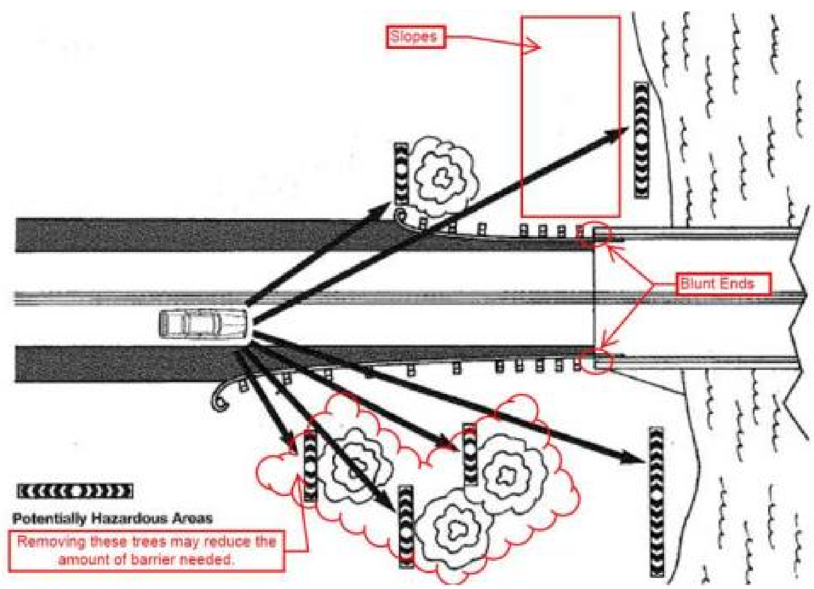

Figure 30.1 Hazard Identification [liv]

Calculate length-of-need using runout length values from Table 30.2 and Equation 1 (see below).[lv] Equation 1 uses the parallel method from the Roadside Design Guide. The Roadside Design Guide has an equation that allows a barrier system to be flared away from the edge of lane. Flaring a barrier system (which includes the beam guard plus the end treatment) reduces its overall length and will make it harder to hit the end terminal. Barrier systems that are flared will need more grading and may need additional right-of-way. See FDM 11-45-30.3.1.5 and Roadside Design Guide for more information on flaring barriers.

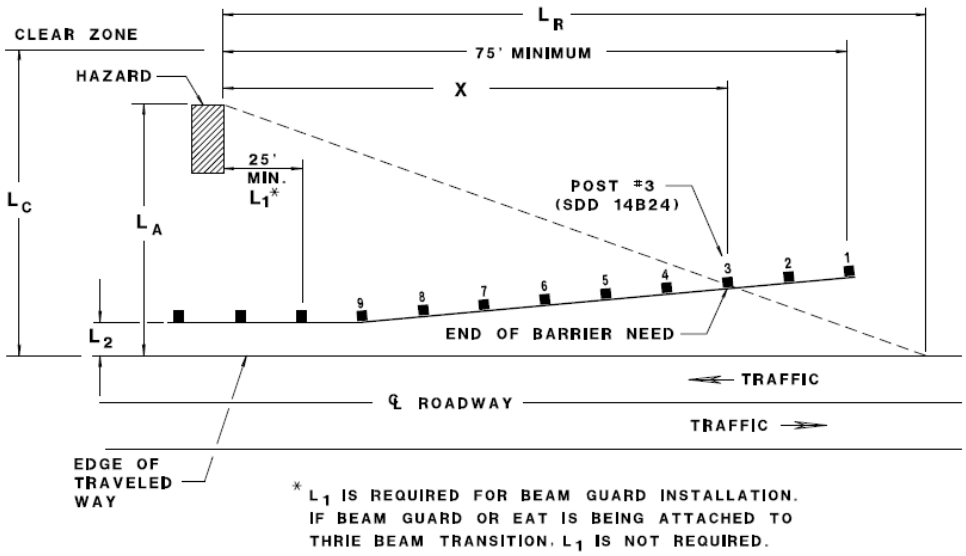

Figure 30.2 Near side Length of Need Calculations

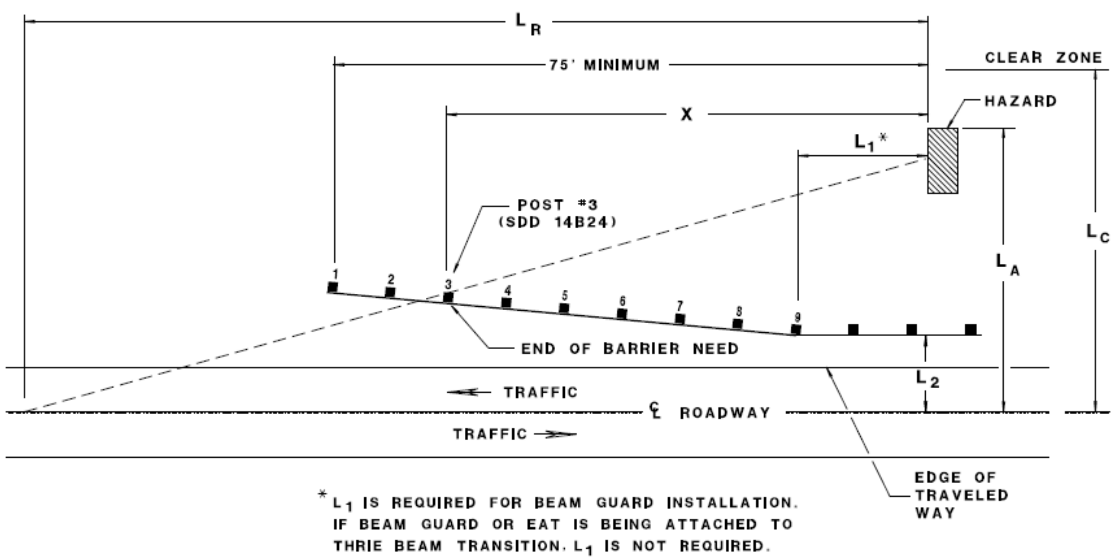

Figure 30.3 Far side Length of Need Calculation

Using the LON equation, calculate the minimum distance from hazard to “end of barrier need (see Figure 30.2 and Figure 30.3). Depending on the barrier system and end treatment used, the “end of barrier need” location may vary. Discussion on where the “end of barrier need” is located is in other parts of the FDM 11-45-30.

Table 30.2 Runout Lengths for Barrier Design (LR)[32]

Design Speed mph	AADT			
	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 30.2

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

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. Examples could be (the list is not all-inclusive):

- Water hazard
- A stand of trees
- Non-traversable slopes
- Non-recoverable slopes without runout distances

Secondary hazards by a bridge may increase the amount of barrier needed. At bridges, use clear zone in the length-of-need calculation (L_A= L_C) to protect water, road below, or steep slopes that wrap around the structure. The stationing of these secondary hazards may need to be used to calculate where a barrier is to begin.

When shielding a bridge pier or abutment, review if the slope that wraps around the structure is a hazard for the roadway on the bridge and the roadway below the bridge.

In high-speed narrow medians, setting L_a equal to the offset to the opposing structures median parapet may be reasonable. See Figure 5-45 of the 2011 AASTHO Roadside Design Guide for an example. Review if a thrie beam bullnose or crash cushion with concrete barrier is possible at this location before using a wider L_a. Document in a DJ the decision to use the distance between median parapets for L_a.

Verify location of a steep slope when calculating length-of-need. The transition between a traversable slope and a non-traversable slope may move during construction. Adding length to a barrier system to allow for proper shielding is acceptable. For example, a steep slope is at STA 10+00. A traversable slope is at STA 11+00. It is acceptable to assume that the steep slope starts at station 10+50. Extending the barrier may make it easier to install the grading for the end treatment.

Figure 5-47 in the 2011 AASTHO Roadside Design Guide provides an example on how to shield a hazardous slope. This example discusses the selection of appropriate L_a and L_c values, and the use of a buried-in-backslope terminal. For steep slopes within the clear zone, use clear zone value in the length-of-need calculation (L_a= L_c). The department does not use buried-in-backslope terminals.

Note the example in the Roadside Design Guide is shielding a 3:1 slope. A 3:1 slope may not need shielding (see FDM 11-15-1).

On multi-lane, one-way facilities assume that traffic is in the travel lane closest to the hazards when calculating length-of-need. Do not include the width of the travel lane or lanes in L_a, L_2, or L_c in the length-of-need calculations.

[32] Table is based on 2011 Roadside Design Guide and linear interpolations.

Travel lanes do not include turn lanes or taper to turn lanes in length-of-need calculations. Auxiliary lanes are typically not considered travel lanes for length-of-need calculations unless the auxiliary lanes perform more like through lanes. Auxiliary lanes need to extend some distance to act as a through lane.

Review if there are short gaps between different barrier systems. Close gaps of 400 feet or less.

30.3.1.2.1 LON on Curves

Length-of-need equation is for tangent sections of road. On the outside of curves, vehicles tend to take a tangential path. Determine LON on the outside of curves by:

1. utilizing the design speed and AADT, find L_R.
2. drawing a line that starts tangent from the edge of lane to the back of hazard or edge of the clear zone.
3. measuring line drawn in step 2.
4. using the smaller of either L_R or the length of the line determined in steps 2 and 3 and draw a tangent line from edge of lane to back of hazard or clear zone.
5. offset the edge of lane to the face of barrier.
6. LON is at the intersection of line from step 4 and offset edge line from step 5.

On the inside of curves, use L_R to locate the LON point for the barrier system. See Attachment 30.4.

For more examples of LON, see the following attachments:

- Attachment 30.1: Example Problem 1: West Side of Structure
- Attachment 30.2: Example Problem 2: Rock Wall
- Attachment 30.3: Example Problem 3: Outside of Curve Cattle Pass
- Attachment 30.4: Example Problem 4: Inside of Curve Cattle Pass

30.3.1.3 Individual Construction Detail Drawings

Individual construction details are site specific and used to minimize construction issues, communicate designer's intent, and to make it more likely that a barrier system will be installed appropriately. Provide individual construction details when there is a close interaction between grading, drainage, barrier system, hazards, underground obstructions, structures, or changes in working width.

Some examples are (the list is not all-inclusive):

- Figure 30.36 has a pole too close to the barrier system
- Figure 30.12 has a post driven through a culvert
- Figure 30.41 the thrie beam missing a post
- Figure 30.42 lacks proper grading near thrie beam transition. Flume does not capture water. There is slope erosion near structures.
- Figure 30.43 Within a year of construction the grading by the thrie beam transition is starting to fail because of water and improper grading.
- Figure 30.4 Drainage conflict with thrie beam transition

Figure 30.4 Inlet and Post Conflict

Some examples of when to provide individual construction details are (the list is not all-inclusive):

- End treatments
    - EAT
    - Crash cushion
    - Sand barrel array
- Beam guard
    - Long-spans
    - Short radius
    - Flared or tapered applications
    - Anchor Post Assemblies
- Thrie beam bullnoses
- Approach transitions to rigid barriers

Some locations are more likely to need individual construction details (the list is not all-inclusive):

- Areas with limited post embedment or post rotation is limited
    - Shallow fill box culverts (less than 5 FT of cover)
    - Large culverts that cross under semi-rigid barriers
    - Inlets or flumes near posts
    - Utilities near posts
    - Near footings
- Areas near structures
    - Bridge approaches
    - Bridge (e.g. piers, abutments, footings)
    - Slopes that wrap around structures
    - Barriers on top of retaining walls
    - Barriers shielding retaining walls
- Areas with reduced working width

Post location may also influence retaining wall design. For example, the reinforcement straps for an MSE wall may conflict with post placement. Typically, retaining wall designs cannot absorb crash loads without damage. Consult a structural engineer when placing a barrier system on or nearby a retaining wall. More discussion is in FDM 11-45-30.3.6.4.

A example of individual construction details are in Attachment 30.5.

Include the following in individual construction detail drawings (the list is not all-inclusive):

- Drainage pipes
- Cross-section/contours
- Hinge points
- Slope intercepts
- Structures (e.g. bridges, box culverts, retaining wall)
- Underground obstructions (e.g. utilities, rock)
- Post location and embedment,
- Curb and gutter changes,
- Radius of shop bent beam guard
- Fixed object or hazard
- Changes in curb and gutter
- Changes in working width

Use cross sections or more detailed earthwork analysis for complicated grading locations (e.g. wrapping slopes around a structure that has a transition to rigid barrier installed nearby). Perpetuation projects may need additional survey within the areas of replacement barrier system.

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 bid item use a table like Table 30.3. Add a note to miscellaneous quantities that points out that other items in the table are for bidding purposes only. Avoid adding other items into the grading and shaping bid item. Typically, other items (e.g. installing a pipe, other erosion control measures…) need more design.

Table 30.3 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.*

Provide termini for each location using grading item. Use discrete locations to identify where grading and shaping bid item is being used. For example, a given EAT may need the grading and shaping item, then stationing for the EAT is acceptable. In other locations a whole barrier system (EAT, beam guard, transition to rigid barrier) may need grading; the stationing for the whole barrier system can be used. Grading and shaping bid item can be used on all barrier systems.

30.3.1.4 Length of Barrier System

Do not use the guidance in this section to install barrier systems that are shorter than is required by Length-of-Need calculations or other reasons. This guidance is to point out:

- When short installations of barrier system needs documentation
- Lengths of barrier systems that should be avoided

A barrier system needs a minimum length to absorb crash loads, or to shield a hazard. Minimum length of a barrier system can depend on:

- Crash testing

- Traffic direction
- Expert opinion
- Computer modeling
- How other components of the barrier system work together

Potential issues with installing a barrier system that is too short are (the list is not all-inclusive):

- Barrier failure
- Pocketing
- Pulling foundation/soil tubes out of the ground
- Vehicles gating through terminal and hitting hazard
- Increased working width

Attachment 30.12 and Attachment 30.14 have some examples of how components of a barrier system or traffic direction can influence the minimum length.

Attachment 30.15 has “Recommended Minimum Barrier Lengths.”. Barriers shorter than the “Recommended Minimum Barrier Lengths” may not work as expected.

Concrete barrier and cable barrier shorter than “Recommended Minimum Barrier Lengths” may be acceptable,.

EATs and Type 2 Terminals set the minimum length of beam guard (see comment section of Attachment 30.15). Avoid installing beam guard shorter than the comment section in Attachment 30.15.

Specialty barriers have different length requirements that are not in Attachment 30.15. Some specialty barriers are (the list is not all-inclusive):

- Concrete barrier transitions
- Concrete barrier integral to bridge piers
- Long-span beam guard
- Thrie beam bullnose
- Transitions to rigid barrier

Review other sections or SDDs for more information.

Additional engineering may be required. The additional engineering could include special details, individual construction details, special provisions, documentation and other efforts.

30.3.1.5 Flaring Barrier Systems

Some barrier systems can have their position relative to the edge of lane change. Typically, the department does not install flared barriers (See FDM 11-45-30.4.1.7 for discussion on flaring EATs). In some circumstances, flaring a barrier system is done because the barrier system must (the list is not all-inclusive):

- match into and existing narrow bridge
- change offset to provide working width
- change offset to provide grading
- change offset to match changes in road’s cross-section
- have a shorter overall installation length

Most special applications of barriers, end treatments, or cable barrier cannot be flared. Examples are (the list is not all-inclusive):

- Long-Span beam guard
- Approach Transitions to rigid barriers or bridge parapet
- Type 2 End Treatments
- Short Radius
- Short Radius Terminal

A flared barrier system needs to absorb more crash energy than a normal barrier system. The flaring of a barrier causes the crash angle to be higher. As shown in Attachment 30.13, for the same crash test condition, flared MGS needs a larger working width than tangent MGS.

More engineering effort is required to install a flared barrier system correctly.

Avoid having sharp angles or abrupt changes in barrier system (see Figure 30.56). A vehicle can experience significant deceleration, snag, vaulting, rollover, or be abruptly redirected into traffic if it hits a sharp angle or abrupt change.

Most projects place the face of a barrier system at the edge of shoulder. Shifting a barrier system towards the lane may be possible at some locations. Typically, shifting a barrier’s location is done over a short segment of road, for a specific hazard. Decreasing the shoulder width may need a DJ.

A small section of the barrier system closer to the lanes may develop into a choke point for incident management or future construction. Use caution when reducing shoulder width over a long segment because the barrier system may cause operational issues. Possible examples are (the list is not all-inclusive):

- More crashes into the barrier system
- A plow is more likely to hit the barrier system
- Less shoulder room for disabled vehicles
- Less shoulder room for maintenance operations
- Less room for future construction

Attachment 30.20 has some example layouts of shifting beam guard location closer to the lane. The AASHTO Roadside Design Guide has examples flaring barrier systems away from the lane. Review guidance in FDM 11-45-30.

The department does not install flared cable barrier systems. There has been no research on how flaring a cable barrier will work during a crash.

Provide individual construction detail drawings when shifting barrier location.

30.3.1.5.1 Grading for Flared Installations

Grading from the edge of lane to the face of most barrier systems is 10:1 or flatter (see 11-45-30.3.2.5.7 for cable barrier grading guidance). Grading behind the barrier system follows other requirements listed in the FDM. A flared barrier system without suitable grading may not perform as intended. Some examples of poor barrier performance are (the list is not all-inclusive):

- Vehicle rolls over before striking the barrier
- Vehicle vaults over the barrier
- Barrier moves too much during crash

Grading requirements for end treatments, crash cushions, or sand barrel arrays do not change if these systems are outside the clear zone.

30.3.1.5.2 Flare Rate

According to AASHTO's Roadside Design Guide, the usable flare rates for barrier systems depends on speed, barrier system offset, and barrier system type. Barrier systems that are closer to a lane may cause the vehicle to slow or shift positions with in the lane. Barriers that are closer to a lane use flatter flare rates to mitigate changes in vehicle speed and position.

Use flare rates in Table 30.4 for Concrete Barriers, Class A Beam Guard, and other non-MGS semi-rigid barriers. Flare rates that are flatter than the values in Table 30.4 are acceptable.

Table 30.4 Shy-line and Flare Rates for Different Barriers

Design Speed	Shy Line Offset	Within Shy-line	Outside of Shy-Line	
MPH	**FT from edge of Lane**	**Semi-Rigid and Rigid**	**Max. for Rigid**	**Max. for Semi-Rigid**
80	12	No information available		
75	10			
70	9	30:1	20:1	15:1
60	8	26:1	18:1	14:1
55	7	24:1	16:1	12:1
50	6.5	21:1	14:1	11:1
45	6	18:1	12:1	10:1
40	5	16:1	10:1	8:1
30	4	13:1	8:1	7:1

Shy-Line offset or distance from the edge of travel lane is typical, but not required design criteria for barrier system placement. Some early research indicated that traffic might shift location and slow down if a barrier system started abruptly close to the road. If choosing between providing shy-line offset or working width, provide working width.

Avoid using flare rates steeper than the outside shy-line maximum values in Table 30.4.

30.3.1.5.3 Flare Rate for MGS

Normal post spacing of MGS was crash tested using flare rates steeper than the values in Table 30.4. The flare rates for MGS and working widths for TL-3 applications of MGS are in Attachment 30.13. Flatter flare rates are acceptable with MGS. MGS may use the shy-line offsets from Table 30.4.

These flare test were done using NCHRP 350 testing criteria and have not been tested to MASH criteria. The small car had significant damage after striking MGS with a 5:1 flare. It is recommended that designers limit using MGS with 5:1 flare rate.

30.3.2 Cable Barrier

In recent years, WisDOT has been installing cable barrier on freeways and expressways to limit cross-median crashes (CMC). Most existing roadside installations of cable barrier are strong post installations that are not crashworthy. See Figure 30.33 for an example of a low-tension cable barrier system.

The department is not installing cable barrier on the outside of roads. More information on cable barrier's performance and proper installation is required before the department would use cable barrier on the outside of a road. Coordinate with the WisDOT project manager and the regional design oversight engineer if considering installing cable barrier on the outside of a road.

Use the following when installing proprietary cable barrier system:

- SDD 14B52
- Standardized Special Provision Spec 613-010
- Bid items:
    - 613.1100.S (Cable Barrier Type 1)
    - 613.1200.S (Cable Barrier End Terminal Type 1)

Approved Product List

The proprietary nature of the cable barrier systems makes designing cable barrier different from other barriers systems. The Department depends more on the manufacturer's knowledge of their system. Some of the guidance that is in the FDM, Standard Detail Drawings or the Standardized Special Provision will overrule manufacturer's recommendations. Examples are (the list is not all-inclusive):

- Manufacturers have tested cable barriers with large line post spacing, but the Department limits the maximum post spacing to 15 FT.

- Some manufacturers have provided connection hardware that is weaker than the cable. Using a weaker connection can allow barrier failure.
- Some manufacturers have crash tested cable barriers on steeper slopes than the design guidance. Research that is more recent suggests that it may be more difficult for a vehicle to engage a cable barrier on steep slopes.

The cable barrier market is competitive. Contact the manufacturer for the most current information on their system. Designers should verify with the WisDOT project manager and the regional design oversight engineer before using the manufacturer's recommendations.

30.3.2.1 Cable Barrier Selection

WisDOT's policy is to have at least two different cable barrier manufacturers in each county. Two systems are used so that there is competitive bidding. See Approved Products List for what systems are available in each county. If a county has no system listed, contact the WisDOT project manager and the regional design oversight engineer . The regional design oversight engineer will provide you with guidance on what systems to use. Contact them early in the design process. They will review existing information on cable barriers and update the approved products list.

If a county no longer wishes to use one of the cable barrier systems approved, provide documentation to the WisDOT project manager and the regional design oversight engineer stating the reasons a specific cable barrier system is no longer desired.

Design cable barrier installations using the "worst" features of either cable barrier system. Examples are (the list is not all-inclusive):

- "Cable Barrier System A" has a 25% greater working width than "Cable Barrier System B". Use "Cable Barrier System A's" working width to layout cable barrier.
- "Cable Barrier System B's" length-of-need point is further downstream than "Cable Barrier System A's "length-of-need point. Use "Cable Barrier System B's" length-of-need point to layout cable barrier.

By designing for the "worst" feature of either cable barrier system, both manufacturers can bid the project.

30.3.2.2 Components of a Cable Barrier System

There are three major components of a cable barrier system: the line posts, steel cable, and the cable barrier terminal.

Line posts consist of the following parts: reinforced concrete foundation, steel sleeve, steel post, and connection hardware. The reinforced concrete foundation and steel sleeve allow for quick removal and replacement of damaged posts. Steel posts hold the cables at the proper height to capture the vehicle and absorb some crash energy by breaking or yielding when hit. Connection hardware holds the cables at the proper height to allow for proper contact and interlocking of the cable into the vehicle.

Cables and cable splice hardware transfers most of the crash's energy to the cable barrier end terminals.

Cable barrier end terminals transfer the crash energy to the ground. Cable barrier end terminals are crashworthy and have more design requirements (see FDM 11-45-30.3.2.5.1, and FDM 11-45-30.3.2.5.2).

30.3.2.3 Use of Mow Strips with Cable Barrier

Install cable barrier without mow strips. Other methods of weed control are more cost-effective. If line posts are properly located and designed for the soil conditions present, there is little need for mow strips. Mow strips will increase a project's cost, make installation of the cable barrier more difficult, increase long-term maintenance, or create difficulties for future projects.

30.3.2.4 Cable Barrier to Beam Guard Connections

Avoid connecting a cable barrier to EAT or beam guard. Coordinate with the WisDOT project manager and the regional design oversight engineer when connecting cable barrier to EAT or beam guard. More engineering and special provisions may be needed.

Manufacturers have various designs to connect cable barrier to a EAT or beam guard. These connections have FHWA eligibility letters. Many of these connections are not crash tested. Manufacturers are basing their designs from a generic low-tension cable barrier crash test.

Although the generic low-tension system passed crash testing, there are some concerns about the stability of the vehicle. Adding more tension to the cable barrier would likely increase vehicle instability.

Other states have noticed that cable barrier connected to EAT or beam guard have caused damage to the EAT, or the beam guard. These states also have had difficulties repairing these connections, EATs, or the beam guard. Maintenance staff would need to stockpile more parts and have additional training to maintain these special cable connections.

30.3.2.5 Design Requirements

30.3.2.5.1 LON Point for Cable Barrier End Terminals

Like EATs, vehicles can pass through the beginning of the cable barrier end terminal with little or no decrease in speed. Contact the manufacturers for the most current information on the LON point for their cable barrier end terminals.

Use LON procedures in FDM 11-45-30.3.1.2 when shielding a fixed object (see Attachment 30.16) with cable barrier. Desirably, where CMC is an issue, cable barrier terminals would overlap the LON of other barrier systems. Attachment 30.16, Attachment 30.17, Attachment 30.18 have some examples of overlapping LON. Next choice would be to extend cable barrier to a point beyond where CMC are likely to occur.

30.3.2.5.2 Shielding Cable Barrier End Terminals

Cable barrier end terminals are crashworthy. However, it is desirable to shield cable barrier end terminals with other barrier systems. Crashes to a cable barrier end terminal can make a whole installation of cable barrier inoperative and cause expensive repairs. For example, a vehicle can bend the connection plate on the footing. To fix the connection plate, the whole footing would need to be removed and replaced.

30.3.2.5.3 Factors that Influence Working Width of Cable Barrier

Each cable barrier system has a different working width.

Manufacturers will provide working width information based on crash testing. As the distance between cable barrier end terminals increases, working width will increase. A typical road application of cable barrier is longer than most test installations. It is likely that real-world cable barrier working width is larger than what the manufacturers report. To find out if cable barrier is an alternative for a location, assume a working width of 12 feet.

There is a direct relationship between line post spacing and working width. The larger the distance between lines posts the larger the working width.

The maximum line post spacing WisDOT uses is 15 feet[33]. Do not use larger line post spacing because of concerns with:

- Increased working width
- Difficulties keeping cable heights relative to the road's profile
- Increased likelihood of penetration of the cable barrier.

Most cable barrier manufacturers use 15 feet for their normal line post spacing. Some manufacturers use normal line post spacing as low as 10 feet.

Use reduced line post spacing to reduce working widths at spot locations (e.g. a long run of normally spaced cable barrier needs reduced post spacing near a sign bridge). See FDM 11-45-30.3.2.5.1 on how to design for reduced line post spacing by a fixed object.

Some current crash tests with reduced line post spacing have shown significant damage to crash test vehicles (e.g. A-pillar of the vehicle partially cut through, windshield cut through, holes in floorboard.). Avoid reducing line post spacing to less than 7 feet.

Crashes on the convex side of a curved cable barrier installation can cause a temporary loss of cable tension. This loss of tension will create a larger working width (See Figure 30.5). Provide more room to allow the increased working width on curves when placing the cable barrier on the convex side of the median (See Attachment 30.17).

Avoid installing cable barrier on curves with a radius of 1,300 feet or less when a vehicle can hit the convex side of the cable barrier[lvi]. Review using another barrier system. The WisDOT project manager and the regional design oversight engineer may grant DJ's for cable barrier installed on a radius of 1,300 feet or less and the convex side of the cable can be struck.

For curve installations that cannot have a convex crash, the minimum radius to install cable barrier is 500 FT or the minimum radius the manufacturer allows. Radii less than 500 FT or less than the manufacturer's recommendation should use a different barrier system.

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[33] State Guidelines for Cable Barriers"; FHWA; April 2016

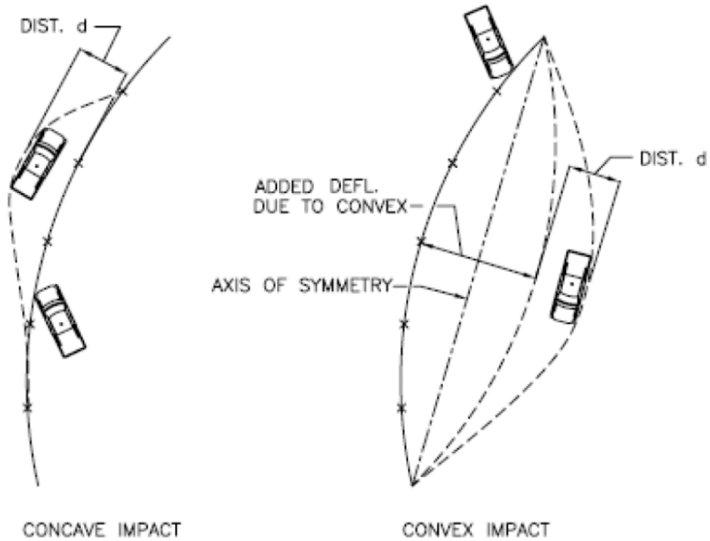

Figure 30.5 Concave verses Convex Crashes on Cable Barrier [lvii]

30.3.2.5.3.1 Designing Working-Width of Cable Barrier

Typically for median applications, the cable barrier's working width would not use more than 1/2 of the total shoulder width. For example, if a vehicle from the far side of the median hits the barrier. This vehicle should not pass beyond the 1/2 point of the median shoulder.

Provide working width for large fixed objects (e.g. piers, overhead sign supports, sign bridges, drainage features). Sometimes, the designer may need to use other barrier systems with reduced working width or more than one installation of cable barrier to shield large fixed objects. Attachment 30.16 has some examples. Review the need for structural protection in FDM 11-35-1.

Provide the following in the plan:

- Where working width is measured to:
  - Examples are:
    - cable barrier to the middle of the shoulder
    - cable barrier to the edge of lane
    - cable barrier to large fixed object
- Value or values of the cable barrier's working width
- Location or locations where the working width is different (e.g. reduced post spacing is used near a sign bridge, but the rest of the barrier system will have a larger working width).

Provide individual construction details for location changes in working width.

Install small breakaway devices outside the working width of the cable barrier. Small breakaway signs may have restrictions on where signs can be placed. Review signs with region's traffic staff. Determine if there are unnecessary signs or if signs can be moved outside the working width of the cable barrier.

30.3.2.5.4 Soils Information

Cable barrier is more sensitive to soil conditions than other barrier systems. Provide soils information on all projects with cable barrier installations. Manufacturers design their foundations with the soils information in the plan and how their system transfers energy. Not providing soil information could cause cable barrier to malfunction or the cable barrier could become a hazard. Projects that do not provide soils information can experience significant delay and cost increases.

Include soil boring information in plan sheet(s) for each cable barrier end terminal. Sometimes, nearby cable end terminals may be able to use one soil boring. For example, each side of a maintenance crossover needs a cable barrier end terminal; one soil boring may provide enough information to design the cable barrier.

Place boring near end terminal locations.

Information from a manufacturer indicates that soil boring should be a minimum of 15 feet deep in good soils. If the soils are soft, the boring need to be a minimum of 20 feet deep. Individual manufacturers vary on what information the soils information is needed. Some of the information that could be required are:

- Water table (if present)

- Soil type and general description
- The following tests should be conducted at standard intervals:
    - Dynamic Cone Penetrometer
    - Standard Penetration Test
    - Shear Vane

Discuss with regional soils engineer what soil testing needs to be conducted.

If a regional soils engineer decides an alternative source of information is acceptable, make this information available to the contractor. For example, soil boring for a nearby bridge is representative of conditions near cable barrier terminal. Show in the plan that other sources of information are available. Point out whom to contact for soil information. Place contact information on the cable barriers individual construction detail drawings.

30.3.2.5.5 Cable Barrier and Curb

Avoid installing curb and gutter by a cable barrier. Curb and gutter will change the vehicle's trajectory or could trip vehicle into the cable barrier.

If a cable barrier must have adjacent curb, use the following curb styles (in order of most desirable to least desirable):

1. Driveway curb
3. 4-inch sloped curb

30.3.2.5.6 Median Width for Installation of Cable Barrier

Use cable barrier in medians that are 48 feet or wider[34]. A design justification is needed for median widths between 40 feet and 48 feet. Working width issues and cable barrier placement relative to ditch may make it difficult to install a cable barrier in medians that are 48 feet or narrower. There may also be concerns of having maintenance staff working in narrow medians (e.g. Does a lane need to be shut down? Are the hours of work restricted?).

There may be working width problems with using one cable run in a median. For example, for nearside hits a cable barrier needs to be placed close to the lane of travel to avoid a working width issue with a sign bridge. The working width for an opposite side hit on the same cable barrier is in the lane of travel. The designer may need to install cable barriers on both median edges of shoulder to avoid the working width problem at this location. Another option would be to install two different barrier systems.

Cable barrier is not typically installed in medians that are 70 feet or wider unless one of the following conditions are present:

- There is known cross-median crash (CMC) history (see FDM 11-45-20.3.5.7.3).
- Department's CMC Hotspot Analysis shows there is a cross-median crash issue at a location.
- Analysis has shown that cross-median crashes are likely to occur (See FDM 11-45-30.8.1)

30.3.2.5.7 Median Grading

Predicting the path of a vehicle in a simple "V" or flat bottom ditch is difficult. The more complicated the median cross-section, the more difficult it is to predict vehicle trajectory. If it is difficult to predict vehicle trajectory, then it is difficult for any barrier system to capture a vehicle.

Install a single run of cable barrier on 6:1 slopes or flatter. Consider using slopes flatter than 6:1 for cable barriers. Flatter slopes may allow future work on the road to proceed without requiring adjustments to the cable barrier. Median ditch for a single run of cable barrier is to be a 6:1 to 6:1 traversable ditch or flatter.

Avoid having multiple grading break points within the median. Even if these break points are traversable or flatter than 6:1 (e.g. 6:1 slope goes to 8:1 then 7:1). The break points make it more difficult to predict a vehicle's path through a median.

Installing cable barrier or other barrier systems on both sides of the median shoulder may be a better treatment. Examples are (the list is not all-inclusive):

- A significant amount of earthwork is required to get appropriate slopes
- Median ditch already has drainage problems
- Large drainage features would require a significant amount of modification
- A significant number of fixed objects are in the median

[34] Other barrier system can be used on wider medians.

If a project cannot get the suitable median grading or other issues are making it difficult to install two barrier systems at the edge of median shoulder, coordinate with the WisDOT project manager and the regional design oversight engineer.

When using two runs of cable barriers at the edge of shoulder (i.e. where beam guard is installed), grade slopes behind cable barrier to 4:1 or flatter. During a crash, the vehicle will traverse the area behind the cable barrier.

Conduct field survey for all cable barrier installations. Create cross-sections at a minimum of 100 FT intervals. Provide additional cross-sections near drainage features or other locations with grade changes. These grade changes can influence cable barrier height. Projects that have relied on “As Built Plans” or Typical Sections have had significant construction problems, delays and cost over runs..

Adjust drainage features to install cable barrier. This work typically includes (the list is not all-inclusive):

- Grading around drainage features
- Regrading of ditches
- Adjusting the height of inlets
- Installing traversable grates, or drop inlets
- Removal of 4-inch tall hazards on a 5 FT chord
- Extending drainage features

See FDM 11-45-30.6 for discussion on roadside design for drainage features. Problems with drainage features may make it more difficult for cable barriers to work. For example, if a vehicle hits a culvert, flips over, hits the cable barrier, and then penetrates the cable barrier.

Pay attention to grading in the following areas:

- Curve and transitions
- Narrow medians
- Other cross-sectional transitions
- Special ditches
- Flat medians

Drainage concerns or maintenance work may have caused adjustments to the existing grading.

30.3.2.5.8 Placement in Median

FHWA’s research shows that vehicles can go under the cable barrier when the cable barrier is too close to a median ditch bottom. At a minimum, place cable barrier at least 8 feet up from a median ditch bottom.

Cable barrier should be no closer than 8 feet from a ditch bottom (see SDD 14B52). Other factors can influence how far from the ditch bottom the cable barrier can be. Examples are (the list is not all-inclusive):

- Working width
- Likelihood of being hit
- Room for maintenance staff

Placing cable barrier away from median ditch keeps the cable from wet or poor soils. Installing cable barrier up a slope also lessens the likelihood that line post will freeze into line post footings.

It can be easier to measure from the edge of lane or other feature to locate cable barrier. If the median ditch is hard to define or meanders, grade the ditch or move the cable barrier closer to the travel lane.

Place cable barrier at a constant offset from the ditch. Show in the plan where the cable barrier is located in the median.

There has been no crash testing of flared cable barrier.

30.3.3 Beam Guard

This section discusses the design of new installations of beam guard and some new installations of special applications of beam guard. Beam guard includes Class A Beam Guard (SDD 14B15), and MGS (SDD 14B42). Some special applications of beam guard are (the list is not all-inclusive):

- Reduced working width
    - Reduced Post Spacing
- Reduced grading
    - Longer posts at half post spacing
- Reduced embedment
    - Long-Span
    - Anchor Post Assemblies Top Mounted

Besides the general beam guard guidance provided, special applications of beam guard may have additional design guidance in other sections of the FDM.

Some guidance in this section may apply to other semi-rigid barrier systems. Other semi-rigid barriers may have additional design guidance in other sections of the FDM. Examples of this are (the list is not all-inclusive):

- Thrie Beam Bullnoses
- Thrie Beam Transitions
- Short Radius

Some of the guidance in this section can apply to beam guard end treatments. End treatments have additional design guidance in FDM 11-45-30.4.

Identify new installations of beam guard and special applications of beam guard and other semi-rigid barrier systems in the plan.

Some special applications of beam guard need individual construction details. Some standard installation of beam guard may need individual construction details. See other parts of 11-45-30 for more information.

30.3.3.1 General Design Issues with Beam Guard

The following subsections deal with common design issues associated with beam guard beyond those listed in the design criteria found in FDM 11-45-30.3.1. Information provided may be useful to designing special applications of beam guard, other semi-rigid barrier systems, or end treatments as well.

30.3.3.1.1 Class A or MGS

Install MGS based systems for all new beam guard installations.

Individual construction details may be required.

Some of the information in this subsection may be applicable to existing beam guard systems.

30.3.3.1.2 Beam Guard Anchorages

Nearly ½ the crash force is transferred to the beam guard's anchorages.[lviii] Without proper anchorage, a vehicle may pass through a beam guard system. Lack of anchorages can defeat the purpose of having beam guard. Figure 30.6 shows how much an anchor can move during a crash in the middle of a beam guard installation.

Figure 30.6 Upstream (top) and Downstream (bottom) End Anchors after Crash Test

Proper anchorages for beam guard are:

- Beam guard end treatments
    - EATs
    - Type 2
- Approach or Departure transitions to a rigid barrier and the rigid barrier.
- Crash cushion

See other sections of the FDM for guidance on anchorages.

Provide anchorages for semi-flexible barrier systems.

30.3.3.1.3 Proper Grading for Beam Guard

Grading for beam guard includes:

- from lane to beam guard
- behind the beam guard post
- for anchorages

For beam guard to work, grading from edge of lane to the beam guard must allow for proper vehicle engagement. Grading from edge of lane to beam guard is typically not an issue because the shoulders are usually 10:1 or flatter. However, standard detail drawings may not work when beam guard is installed in the following situations (the list is not all-inclusive):

- down a foreslope

- up a backslope
- on an uneven slope
- on a shoulder that breaks away from superelevation[lix]

Soil behind the post helps to absorb crash loads. Changes to the soil behind the post will influence performance. Figure 30.7 shows the estimated decrease in energy absorbed when there is less grading behind the post.[lx]

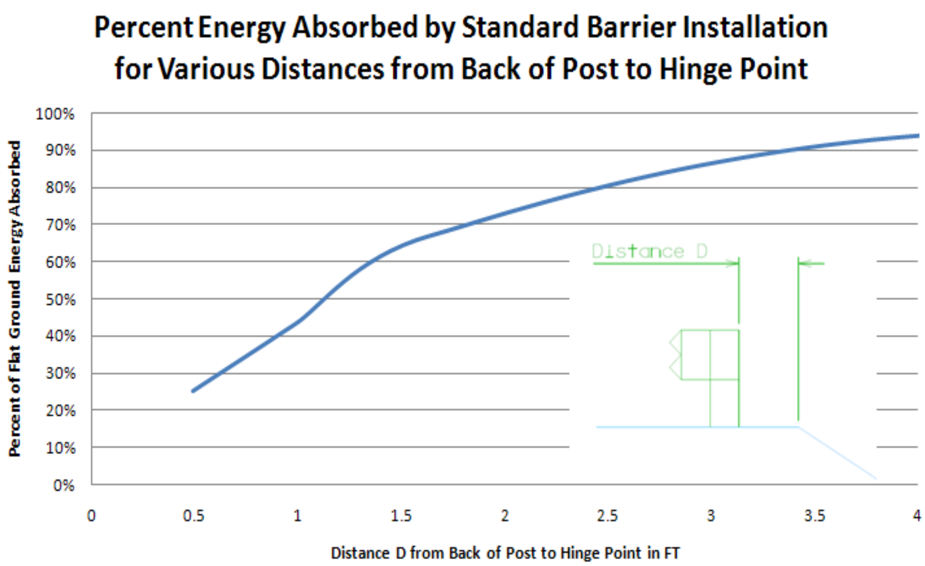

Figure 30.7 Energy Absorbed by Post During an Impact for Various Soil Conditions[lxi]

When normal grading is not an option by the posts, try the following:

- Install long post with reduced spacing – see SDD's for MGS Type K or Class A LHW
- Use concrete barrier
- Shift beam guard location to allow proper installation

MGS Type K and Class A LHW make up for the lack of soil behind the beam guard. See FDM 11-45-30.3.1.5 on adjusting beam guard location to allow proper installation.

Lack of grading near anchorages can cause beam guard to fail or move too much during a crash (see Figure 30.6). Too much movement can lead to beam guard failure or expensive repairs.

Review guidance on the grading and shaping bid items for barrier systems in FDM 11-45-30.5.

If there are issues with the grading design, coordinate with the WisDOT project manager and the regional design oversight engineer.

30.3.3.1.4 Post Rotation and Embedment

All beam guard applications, and other semi-rigid barrier use post rotation to absorb crash energy. In some crashes, beam guard end terminals use post rotation.

Beam guard posts with limited rotation break earlier than a post that can rotate through the soil. A broken post will not absorb as much energy as a post that can rotate in the soil.

Figure 30.8 Photos of Post Rotation[lxii]

Underground obstacles can limit post rotation. Occasionally, the underground obstacle may become damaged because of post rotation. See Attachment 30.20 for guidance on how close underground obstacles can be. It does not address damage to the underground obstacle from installation or performance of the barrier system. This is covered in other parts of this sub-procedure. Some underground obstacles have additional guidance in the following subsections, and may have different requirements than what is in Attachment 30.20.

Occasionally a post or foundation/soil tube may hit a shallow solid object (e.g. rock, buried concrete, breaker run) during installation. In some cases, posts have been cut shorter to avoid hitting objects below ground. In other cases, posts or foundation/soil tubes have had the bottom damaged (see Figure 30.9).

Figure 30.9 Foundation/Soil Tube Damaged from Shallow Obstacles

Cutting or damaging the bottom of a post or foundation/soil tube reduces embedment depth. Reduced embedment depth limits how much energy can be absorbed (see Figure 30.10).

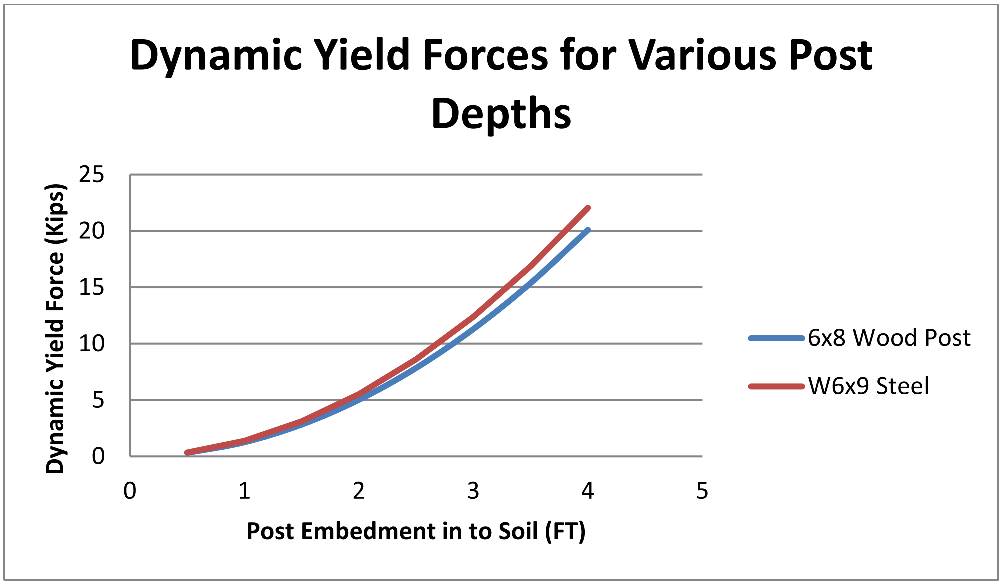

Figure 30.10 Energy Absorb by Post for Various Depths[35]

Do not use Figure 30.10 to change beam guard designs. Other factors do influence beam guard performance.

Crash energy is transferred from the sides of the posts to the soil. Soil support under the post does not help absorb energy. There have been failed crash tests using lesser post embedment.

A barrier system may not work as intended without proper embedment. If the clear cover is 5 FT or less, extra engineering is required. Special applications of beam guard, other semi-rigid barrier systems, and end terminals need more embedment depth.

The following sections provide methods for dealing with common issues that interfere with post rotation and embedment.

30.3.3.1.4.1 Mow Strips

Concrete, asphalt, or other similar objects can reduce post rotation.[lxiii, lxiv] It has been observed:

- Failed beam guard crash test in asphalt mow strips less than 3 inches deep when box-outs are not provided.
- Beam guard post failing early in bogie tests when 2 inches or less of hand packed asphalt is placed around post
- Foundation/soil tubes causing significant damage to concrete and asphalt mow strips when no leave out is provided.

If a mow strip is needed, use SDD 14B28 for crashworthy mow strip alternatives.

Most semi-rigid barrier systems, beam guard end terminals, and specialty barrier applications can use the mow strip alternatives in SDD 14B28. Include individual construction details if changing the layout of SDD 14B28.

It may not be cost-effective to install mow strips or other devices near beam guard or semi-rigid barrier systems to control weeds. Delaware Department of Transportation evaluated different weed control methods under beam guard.[lxv] They reviewed hand mowing, herbicides, special grass plantings, and some commercially available weed barriers. The commercially available weed barrier systems were some form of plastic barrier placed under the beam guard. The cost of the commercially available weed barriers ranged from $1,700 to $2,500 per 100 FT of beam guard. Delaware's research shows that weed barrier systems are the most costly form of vegetative control under beam guards when annualized over 10 years.

Use caution when selecting emulsified asphalt mow strips. Emulsified asphalt mow strips may not be able to prevent heavy erosion. Avoid locations that are sensitive to overspray or pooling of emulsified asphalt. Examples could be near (the list is not all-inclusive):

- Environmentally sensitive locations
- aesthetic treatments

[35] AASHTO MASH 2016

- property owner's flowerbed
- high pedestrian concentration

Installing a mow strip to prevent erosion may only shift the erosion from paved/gravel shoulder edge to other locations (e.g. mow strip/grass foreslope edge). Use other measures to control erosion (e.g. installing a flume, erosion mat). Review drainage and erosion concerns when installing a mow strip. Verify quantity of run-off and potential for erosion when using a mow strip. Curb and gutter may be a more viable alternative to control water flow.

30.3.3.1.4.2 Shallow Rock

Shallow rock is an obstacle typically found that interferes with post rotation or embedment. See FDM 11-45-30.3.3.1.4 for more discussion. Standard Spec 614 and SDD 14B15 and SDD 14B42 have information on how to deal with shallow rock. The normally used methods should take care of most rock and post conflicts. The department typically does not pay for rock excavation for beam guard, special applications of beam guard, and other semi-rigid barrier system.

Be aware of locations where guidance on rock excavation may not be the best answer. Examples are (the list is not all-inclusive):

- If the pavement structure is less than 2 FT (measured at edge of lane) and the road placed on shallow rock
    - Special modifications are needed to the standard detail drawing
- When a road must cut down rock to install road pavement, subgrade, or subgrade improvements
    - Because rock is already being remove, it may be more cost effective to cut additional rock out for the barrier system
- Breaker or pit run materials in subgrade improvements are near posts
    - Providing special detail that stops installing pit run or breaker run just short of the barrier system.
    - Verifying that there is sufficient cover over the subgrade treatment to install barrier system
- Overhead utilities may cause problems with rock removal
    - Contractor may be prevented from using large equipment to drill the holes.

Additional engineering is needed for situations like this. Coordinate with statewide or regional soils engineer, the WisDOT project manager, and the regional design oversight engineer for these situations.

30.3.3.1.4.3 Surface Object that Prevent Rotation

Avoid placing surface objects near post that prevent post rotation (e.g. rip rap, asphalt millings, fill slopes, flumes). Remove objects that prevent post rotation.

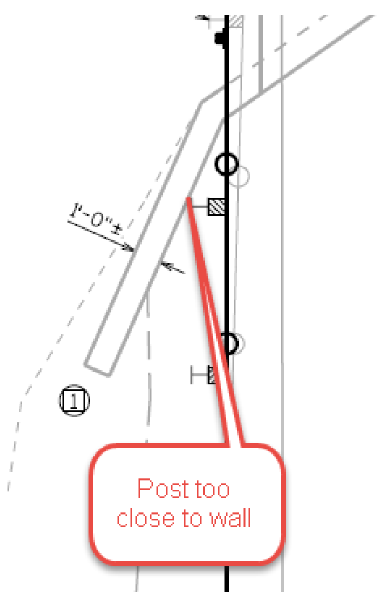

Figure 30.11 Wing of Box Culvert Prevents post Rotation

30.3.3.1.4.4 Other Obstacles

Occasionally, existing drainage systems or other utilities have been damaged during installation of beam guard. During design, identify all post conflicts with buried utilities, storm sewers, culverts, and structures.

In Figure 30.12, a beam guard post was driven through a culvert pipe. A storm two years after construction caused a failure near the edge of shoulder. In another case, a post driven through a culvert has caused a road to flood.

Figure 30.12 Post Driven Into a Culvert

It is unknown how the beam guard in Figure 30.12 will work in a crash. .

Some potential conflicts are (the list is not all-inclusive):

- Drainage features
- Cattle passes
- Retaining walls
- Bridge abutments
- Pier footings
- Utilities

Possible solutions are (the list is not all-inclusive):

- Shifting beam guard location relative to the lane
- Shifting a beam guards location upstream or down stream
- Switching to concrete barrier
- Using a special application of beam guard
- Adding blocks to an installation of beam guard

Occasionally, just shifting beam guard upstream or downstream may help avoid some underground conflicts. Attachment 30.20 has examples how shifting beam guard upstream or downstream can avoid conflict. Post spacing does not change in a shifted beam guard system. Provide individual construction details when shifting beam guard.

Sometimes, typical MGS without one post (i.e. 12.5 FT span) can be used to bridge over an obstacle. These installations have additional requirements. Some of these requirements are (the list is not all-inclusive):

- A minimum of 2 FT of flat ground is behind all other beam guard posts in the installation
- Enough room both upstream and downstream of 12.5 FT span (See SDD 14B42)
- Individual construction details to locate the missing post are in the plan
- The missing post is in a tangent installation of beam guard

Use caution when near the maximum span length. Do not use this detail for spans greater than 12.5 FT. Use the Long-Span details (see FDM 11-45-30.3.3.3.

Do not use the missing post detail when curb and gutter is near the missing post location or within (the list is not all-inclusive):

- an end terminal
- an approach transition to a rigid barrier
- a special applications of MGS
- Class A beam guard

Although not the most desirable alternative, details that add blocks to an installation (SDD 14B15 and SDD 14B42) may be used to avoid underground conflicts.

30.3.3.1.5 Curb and Gutter

Curb and gutter can negatively influence how beam guard and other semi-rigid barrier systems work. Curb and gutter are likely to influence barrier performance by:

- Preventing vehicles from properly engaging beam guard
- Loading the post bolt to rail connection causing a rail tear and allowing vehicle penetration.

To minimize these issues, SDD 14B15 provides guidance on proper placement of curb and gutter and Class A beam guard. Use Table 30.5 to decide what combinations of Class A beam guard and curb to use.

Table 30.5 Class A Beam Guard and Curb Combinations

Speed	6-Inch Vertical	4-Inch Sloped Face Curb
<35	Standard Class A	Standard Class A
≥35 to <45	Nested Installation (i.e. Type NW)	Standard Class A
≥45	Not Permitted	Nested Installation (i.e. Type NW)

MGS Beam guard has been TL-3 crash tested with 6-inch vertical curb and gutter in front of the rail (see SDD 14B42). This testing allows MGS to use curb on high-speed roads. The MGS SDD show only one curb type. Other standard curbs shapes can be used with MGS. Special curbs 6 inches or less may be used with MGS. Discuss the use of curb with the WisDOT project manager and the regional design oversight engineer. Curb is in front of MGS to lessen the likelihood that a snowplow will scrape the beam guard’s rail.

At 45 mph or less MGS can be placed further away from the face of curb. The additional design requirements to place MGS further back from the face of curb are:

- Face of rail is 4 to 12 feet behind the face of curb
- Grading between MGS and curb is 10:1 or flatter
- Top of Rail is 31 to 32 inches above the top of the curb

Note: approach transitions and end terminals have not been tested further back from the face of curb.

30.3.3.1.6 Pay Quantities for Beam Guard

Once the overall length of the barrier system has been determined, anchorage types are selected, and working width is checked, calculate pay quantities.

To calculate the pay quantity for beam guard, subtract EAT length from the overall length of the barrier system. The length of a Type 2 end treatment is included in the overall length of a barrier to determine the linear foot quantity for beam guard.

Pay for special applications of beam guard within the total length of a barrier system (e.g. long-span, Type K,…) with separate bid items. Subtract the length of special applications of barrier from the overall length of the barrier system to determine the linear foot quantity for beam guard.

30.3.3.1.7 Other Considerations

Beam and thrie beam railings are typically manufactured in 25 FT or 12.5 FT lengths. Look to use multiples of 12.5 FT when installing beam guard and thrie beam systems. Odd lengths of rail may be required. For example, a shorter piece of beam guard will allow a beam guard to avoid a driveway. It is possible to order odd lengths of beam guard, but it is not recommended. Standard Spec 614 has contract language on how to field cut, punched, and galvanized railings.

Place a note in the individual construction detail showing that a rail needs to be field cut, punch and galvanize. No note is needed in the plan if the odd lengths of rail are on an SDD.

30.3.3.2 Short Radius Systems

Installing a short radius system is not a desirable option. Review and document other options before installing a short radius system (see 11-45-30.9 for more discussion).

Review using a short radius system early in scoping or design. Short-radius systems may need right-of-way, grading or additional work on drainage features.

There are times when an intersection or driveway prevents a normal barrier system from being installed tangent to the mainline. A short radius system may be used.

A short radius system consists of:

- Radius Components
  - Curved beam guard rail
  - Controlled Releasing Terminal (CRT) posts
  - Grading
- Non-Radius Components
  - Beam guard rail height transition
  - Anchorage

Short radius systems do not neatly fit into one category of roadside hardware (i.e. beam guard, sand barrier array, end treatment…). A short radius system uses many of the same parts as beam guard. It can act like beam guard under certain crash conditions. Examples are (the list is not all-inclusive):

- Post rotation
- Maintaining rail tension
- Redirection of vehicles in some crashes

Short radius systems can act like a sand barrel array under certain crash conditions. Both the short radius systems and a sand barrel array need to limit deceleration to minimize injury. A vehicle is likely to stop within a short radius system like what happens in a sand barrel array (see Attachment 30.24).

However, a short radius system cannot perform like a sand barrel array. For example, vehicles can gate through a sand barrel array. Typically, a short radius system cannot allow a vehicle to gate through. Usually, there are hazards close to the short radius system (e.g. steep slopes, water…).

Historically, it has been difficult for short radius systems to perform adequately during a crash test. Some crash tests have failed because it:

- Launched vehicles into the air
- allowed the beam guard rail to go over a small car's hood and enter the vehicle cab through the windshield.
- caused anchor failures (see Attachment 30.24)
- caused rail failures

See SDD 14B27 (Class A) and SDD 14B53 (MGS) for information on short radius systems. The SDDs uses information from some NCHRP 230 crash testing and expert opinion. Some research done by the Texas Transportation Institute (TTI) suggests a similar system is NCHRP 350 TL-2 compliant[lxvi]. TTI performed no crash testing to determine NCHRP 350 compliance.

This section does not address the design of bullnose systems. Review SDD 14B26 or other sections of 11-45-30 to design thrie beam bullnose. See guidance in FDM 11-45-30.5.2.11 for existing bullnose design information.

See FDM 11-45-30.5.2.12 for guidance for existing bent beam guard.

30.3.3.2.1 Required Design Documentation and Construction Details

Provide individual construction detail drawings for short radius systems. Attachment 30.24 and other sections of 11-45-30 for more information.

Following is a list of design documentation and construction details needed for a short radius beam guard system (the list is not all-inclusive):

- System type
- Design speed
- Radius
- Cross hatch the no fixed object placement zone
- Drainage concerns

- Barrier length along tangents
- Anchorage selection
- Grading

30.3.3.2.1.1 System Type

All projects will use the MGS version of the short radius system. Lettings before December 31, 2017, may have used either the Class A or the MGS version.

30.3.3.2.1.2 Design Speed

Installing a short radius system is not the preferred alternative on roads with design speeds of 45 mph or more.

Consider the utilization of short radius beam guard system on roads with a design speed of 45 mph or less after analyzing, removing, or moving side roads and driveways.

30.3.3.2.1.3 Radius

Radii when using the SDDs are between 8 FT and 149 FT. Rails within this range are shop bent. Use straight rail sections for radii 150 FT or greater. Do not use the short radius details for radii greater than 150 FT.

Installing a short radius system on an oversize-overweight truck route may need more engineering. Turning radii for these vehicles can be large (Figure 30.13). A short radius system may limit movement of oversize–overweight trucks, or become damaged by these vehicles. See other sections of the FDM for information on design vehicles and oversize-overweight vehicles.

Figure 30.13 Truck Hung Up on Thrie Beam Transition and Short Radius

If designing for a larger vehicle, review if moving short radius systems further away from the edge of shoulder allows for large vehicle movement. Provide proper grading when designing for large vehicle movement.

Manufacturers can bend beam guard rail to the nearest foot. Manufacturers typically stock bent rails between radii of 10 and 50 FT in 5 FT increments. Picking a radius that is typically stocked may lessen the cost of the system. However, the radius needs to fit the location.

Show the radius and total length of bent beam guard in the plan.

An installation may need an odd length of beam guard to fit a location. See FDM 11-45-30.3.3.1.7 for more information.

Short radius systems may partially block sight distance. Review sight distances.

30.3.3.2.1.4 Fixed Object Placement

When a vehicle strikes a short radius system, the vehicle typically stops behind the initial rail position. See Attachment 30.24 for more information.

On the short radius SDDs, the hatched area should be free of fixed objects. The vehicle may interact with the fixed object after hitting the short radius. Hitting the short radius system and the hazard may have unintended results.

Figure 30.14 Utility Pole Will Prevent Proper Operation of Short Radius System [lxvii]

Objects typically not acceptable in the hatched area are (the list is not all-inclusive):

- Utility poles (see Figure 30.14) or cabinets
- Control boxes for signals or lights
- Lights
- Trees
- Overhead sign supports and sign bridges
- ITS poles

Move or remove fixed objects. Short radius may require utility coordination.

There may not be a choice but to put a fixed object in the hatched area in the SDDs or Attachment 30.24. For example, a side road likely needs a stop sign. Document in the DSR why the fixed object is necessary, cannot be removed, or moved. Indicate actions taken to minimize the risk during a crash. For example, installing a smaller stop sign on a 4x6" breakaway post is better than installing a large overhead sign support at the same location.

30.3.3.2.1.5 Drainage Concerns

Avoid installing short radius system near curbs or flumes. Flumes within the short radius system are problematic. Curb and flumes may cause the short radius system not to work. Use other methods to control drainage (e.g. mow strips or drop inlets).

If curb must be used, use the following curb and gutter (in order of preference):

- Driveway curb and gutter with a maximum height of 2 inches
- 4-inch sloped curb and gutter

Review post locations for underground conflicts.

30.3.3.2.1.6 Length of Barrier on Tangents

Review FDM 11-45-30.3.1.1, short radius SDDs, Attachment 30.24 and other SDDs to decide if there is enough room to install a short radius system. The minimum length of tangent beam guard on the side road or driveway is found on the SDD. Attachment 30.24 shows what can happen when too little barrier is along the side road or driveway.

30.3.3.2.1.7 Anchorage Selection

Possible anchorages for short radius system could be (the list is not all-inclusive):

- Short Radius End Treatment
- Rigid barrier with approach transition
- EATs

Guidance for most end terminals is in other sections of 11-45-30 or SDDs. This section concentrates on when to use the short radius terminal.

The short radius end terminal is not crash tested. Use the short radius end terminals on roads with a posted speed of 35 mph or less.

The short radius terminal may look like a type 2 end terminal. Do not interchange these terminals. The short radius terminal has an extra-long cable connection and additional hardware that allow the rail to rotate on the post. Allowing the beam guard rail to rotate around the last post maintains rail tension and prevents the rail from ripping apart.

30.3.3.2.1.8 Grading

The maximum grade from the edge of lane to the face of a short radius system or short radius terminal is 10:1. Flatter grades are acceptable. Short radius system and short radius terminal require 2 FT of flat grading behind the posts (see SDDs).

Grading in the hatched area on the SDDs would be traversable. The area behind the rail is where the vehicle ends up after a crash. However, it is not required that this area be traversable.

Extend culvert pipes to get proper grading for short radius system. On side roads with low fills, the posts for the short radius system may conflict with underground obstacles. For example, a culvert may interfere with post installation. See FDM 11-45-30.3.3.1.4 for more information.

30.3.3.2.2 Short Radius Layout

Recommended steps to layout Short radius systems are:

1. Layout a radius that fits the location and other requirements of a short radius system.
2. Review turn template of larger vehicles and adjust radius as needed.
3. Review if adequate grading can be provided
4. Break radius into individual 12.5’ sections of rail
5. Determine if odd length rail is required.
6. Locate splice joints and CRT post on drawing

30.3.3.3 Long-Span Beam Guard

SDD 14B24 for Class A or SDD 14B43 for MGS can be used to span larger culverts or other underground obstacles. The maximum distance between post 1 to post 1 in the long-span system is 25 FT. SDD 14B24 and SDD 14B43 can be used for shorter spans. Detail the span length in the plans.

Use caution when near the maximum span length. Posts may conflict with culvert walls or other structural features. Verify that a long-span system can fit the location early in scoping and design. WisDOT is aware of a failed crash test with longer span lengths[lxviii].

Long-span beam guard is more sensitive to grading than normal beam guard. Provide 2 FT of flat grading behind the posts of a long-span system. Review grading requirements early in scoping and design.

Do not use curb and gutter near a long-span beam guard. Headwalls of culverts are to be flush with the ground line. Curb and headwalls may cause vehicle instability or cause a rail to fail.

When the part of the long-span that is over the underground obstruction is hit, the vehicle will travel over the underground obstruction (i.e. working width). For example, if the underground obstruction is a culvert, the vehicle will traverse over the culvert opening. In essence, the vehicle will be partially suspended in the air by the beam guard rail. See Attachment 30.25 for some examples. It is acceptable to have the vehicle travel over the culvert opening. However, it is not acceptable to have other objects within the working width (e.g. poles, trees, signs).

A long-span beam guard needs beam guard up and downstream to work as intended. See SDD 14B43 for the minimum beam guard length needed both upstream and downstream for a long-span beam guard. Review that there is adequate room upstream and downstream of the long-span beam guard early in scoping or design.

The beam guard adjacent to a long-span system should be normal 6 FT 3 inch post spacing or have a similar working width. Going directly to a system with more or less working width could cause performance issues for the long-span beam guard. Avoid going directly from a long-span beam guard to a short radius system without some normal beam guard with 6 FT 3 inch post spacing between these two systems.

Do not flare a long-span system. Flare beam guard before or after long-span system (see Attachment 30.20).

Provide individual construction details for long span installations.

Occasionally, a single beam guard post may be skipped in an MGS beam guard (see FDM 11-45-30.3.3.1.4.4).

30.3.3.4 Anchor Post Assemblies

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30.3.4 Thrie Beam

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30.3.5 Transitions to Rigid Barriers

This section will discuss the use of transitions to a rigid barrier. Transitions to rigid barrier are:

- Steel Plate Beam Guard Structure Approach (SDD 14B20)
- Midwest Guardrail System (MGS) Thrie Beam Transition (SDD 14B45).

Normal beam guard is too flexible to connect directly to a rigid barrier. Some crashes with beam guard directly connected to a rigid barrier can allow the vehicle to hit the rigid barrier's blunt end (See Figure 30.57, Figure 30.64 and Attachment 30.21). Transitions need to be gradually stiffened to match the working width of the rigid barrier. A vehicle can have excessive deceleration or vaulting if working width does not gradually stiffen.

Approach transitions (i.e. traffic goes from beam guard toward rigid barrier) are more critical than departure transitions (i.e. traffic goes from rigid barrier towards beam guard).

On roads with bidirectional traffic:

- A bridge would have four approach transitions.
- A road with a concrete barrier on one side of the road would have two approach transitions and no departure transitions.
- A road with concrete barrier on both sides of a road would have four approach transitions and no departure transitions

On roads with unidirectional traffic:

- A bridge would have 2 approach transitions and 2 departure transitions
- A road with a concrete barrier on one side of the road would have one approach and one departure transition.
- A road with a concrete barrier on both sides of a road would have two approach transitions and two departure transitions.

Approach transitions can be installed on the downstream end of a rigid barrier on a one-way road. However, it is not necessary.

Approach transitions use closer post spacing, nested rails, and posts with deeper embedment than a typical beam guard installation. Approach transitions are more sensitive to changes in grading than typical beam guard. Provide individual construction details.

Do not flare or bend a transition.

Thrie beam transition posts need to rotate in soils.

Attachment 30.22 provides guidance on how to layout approach and departure transitions to a rigid barrier. This guidance concentrates on MGS. Some of the comments apply to Class A transitions.

Use semi-rigid barrier system's working width for the transition working width.

Grading and drainage are more of a concern with approach transitions. Review grading and drainage near transitions. See Figure 30.58, Figure 30.59, and Figure 30.60 for common grading and drainage problems.

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.

30.3.6 Concrete Barrier

Concrete barriers work in a different manner than flexible or semi-rigid barrier systems. Concrete barriers redirect crash energy versus absorbing energy.

The two main methods of redirecting crash energy are vehicle lift and vehicle crush. During a crash, a vehicle climbs the concrete barrier. Climbing up the barrier converts kinetic energy into potential energy. Energy is lost because of damage to the vehicle during a crash. Crashes into concrete barrier are more severe because:

- Lifting a vehicle off the ground increases the chance of vehicle roll over
- Forces that crush a vehicle can injure a vehicle's 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 needs to match into an existing bridge or roadside barrier.

30.3.6.1 Shape

There are five different shapes of concrete barrier in Wisconsin: GM, NJ, F, Single Slope and Vertical (see Figure 30.15 for the difference in various shapes). GM shaped barrier was designed in the 1970s and tends to roll smaller, lighter cars.

Do not install new runs of GM shaped barrier. Spot replacement of damaged barrier is acceptable. Replacing of GM shaped barrier to aid installing or repairing of other facilities is acceptable. For example, an inlet underneath GM shaped barrier needs repair. Replacing a small segment of GM shaped barrier to aid in the repair of the inlet is acceptable.

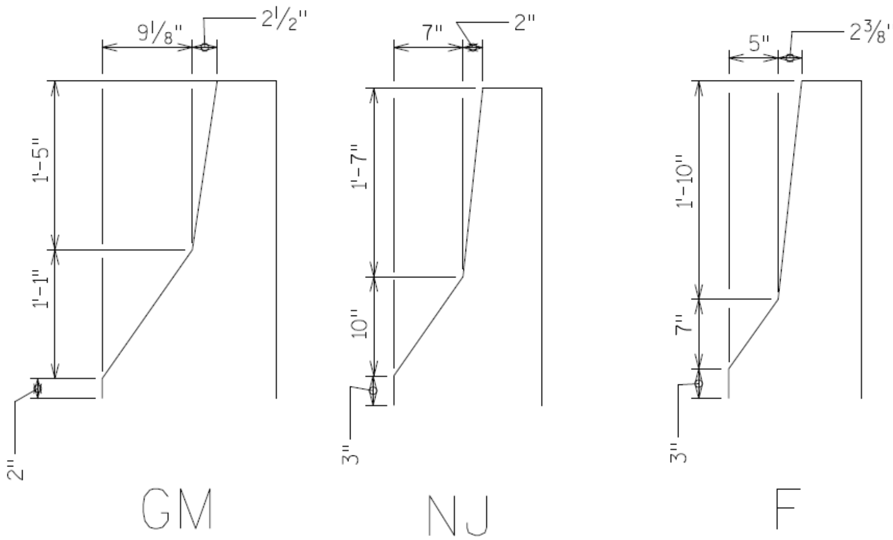

Figure 30.15 Barrier Shape

NJ shaped barrier has been the standard style of barrier for both roads 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 roads.

Since 2010, WisDOT has used the Concrete Barrier Single Slope (CBSS) developed by Caltrans. Advantages of the CBSS design are:

- Lower maintenance cost
- Better crash performance
- More flexibility with overlays

Vertical shaped barrier may exist at various locations. For example, vertical shaped barrier is likely to be at an approach transition to a concrete barrier. Minimize the use of vertical barrier.

Barriers that do not conform to NJ, F, single slope, or vertical shapes are not acceptable. NJ, F, single slope and vertical shaped barriers have been crash tested. It is not desirable to change barrier shape for drainage, or to allow placement of hardware on or near barrier.

30.3.6.2 Concrete Barrier Height

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

The standard CBSS heights are in Table 30.6.

Table 30.6 Standard Barrier Heights for Specific Types of Road

Road	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 recognize that overlays should not be placed near 32-inch CBSS. MASH crash testing has shown that taller vehicles (i.e. single unit van trucks) have gone over 32-inch barriers[lxix]. Attach local unit of government's written request to the project's Design Study Report.*

Vertical shaped barrier taller than 34 inches is acceptable between bridge piers or other bridge substructures. The vertical barrier should be flush with the face of pier or substructure. Vertical-shaped barrier taller than 34 inches is not desirable at other locations because of the increased risk of "head slap". Limit the use of taller or shorter barrier.

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

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

30.3.6.2.1 Sight Distances

Concrete barrier on the inside of a horizontal curve can obstruct stopping sight or decision sight distance (SSD or DSD). A barrier within the clear sight window of an intersection can obstruct intersection sight distance (ISD). If the available sight distance is less than the minimum sight distance, a shorter barrier may be acceptable.

If it is necessary to install barrier that obstructs SSD, DSD or ISD then provide mitigation. See FDM 11-10-5 for more discussion on sight distance.

30.3.6.2.2 Vacant

This section intentionally left blank.

30.3.6.2.3 Zone of Intrusion

Figure 30.17 to Figure 30.21 show the differences between working width and Zone of Intrusion (ZOI). Table 30.7 has the working width and ZOI values for various heights and types of barrier. Measure ZOI from the top, traffic side of the barrier.

ZOI is a region within the working width where secondary hazards (e.g. breakaway signs…) have been placed. Secondary hazards have entered the vehicle cab during testing and real world crashes. Avoid placing objects within the ZOI of a concrete barrier (see Figure 30.16).

Figure 30.16 Vehicle Interactions with Object on Barrier

Many safety devices (sign poles, lights) are designed to break away when a vehicle's bumper engages it. A safety device on the top of a barrier engages the top of the vehicle. The safety device may not work as intended. For example, a crash test done by Caltrans of a sign post mounted on top of a single slope barrier drove the hood of the pickup truck into the vehicle cab.[lxx]

Coordinate with the WisDOT project manager and the regional design oversight engineer when installing an object on top of a concrete barrier. More engineering may be required.

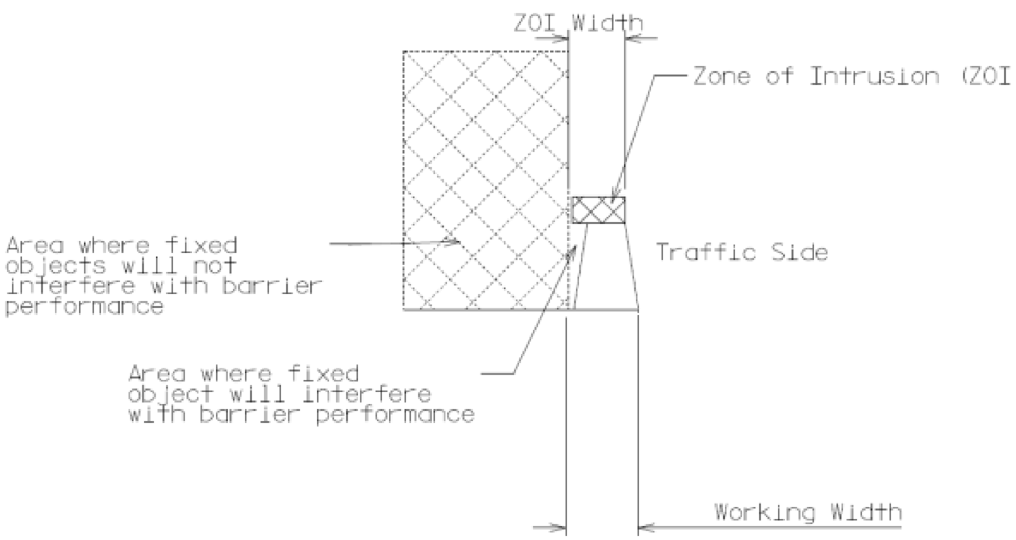

Figure 30.17 Zone of Intrusion and Working Width

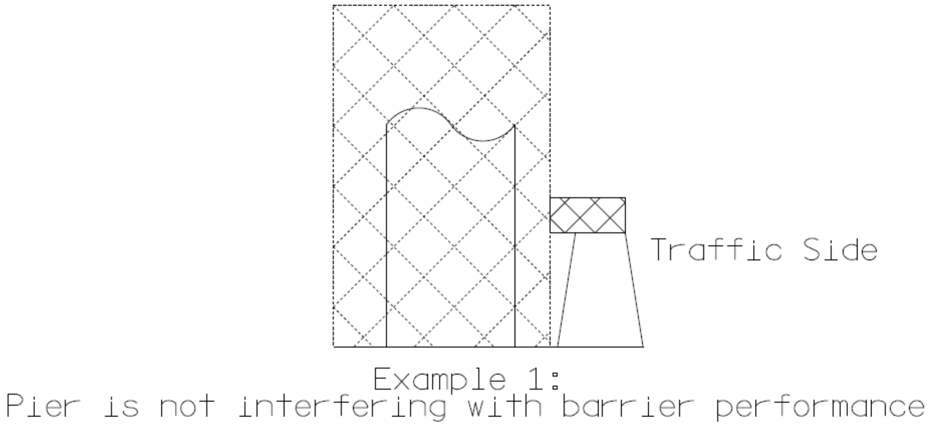

Figure 30.18 Example 1

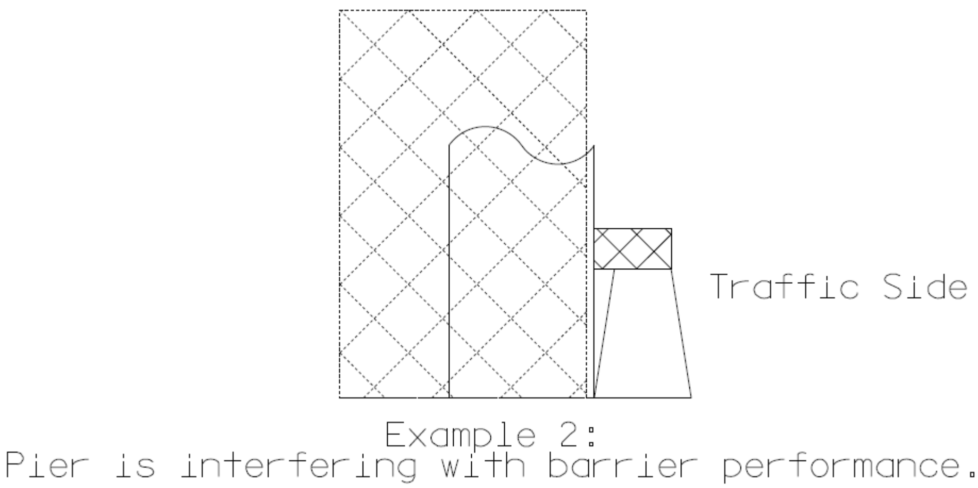

Figure 30.19 Example 2

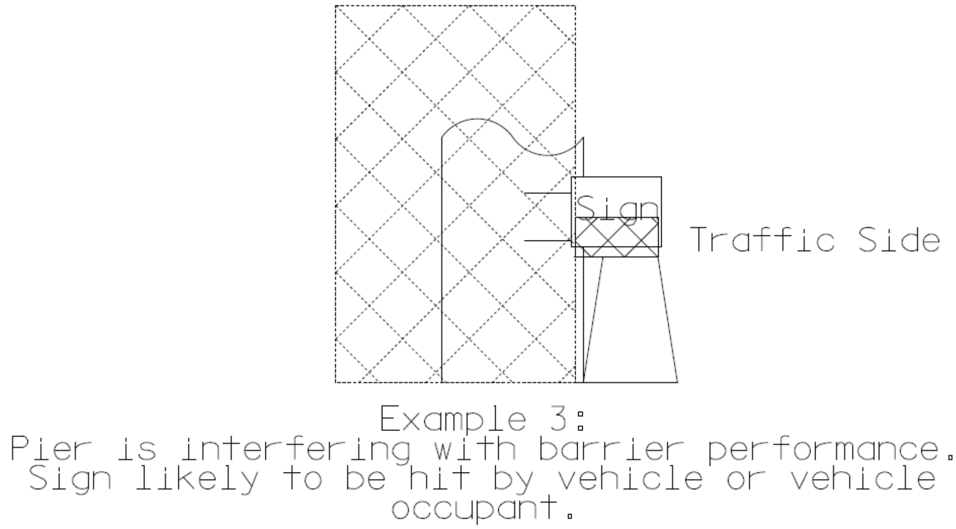

Figure 30.20 Example 3

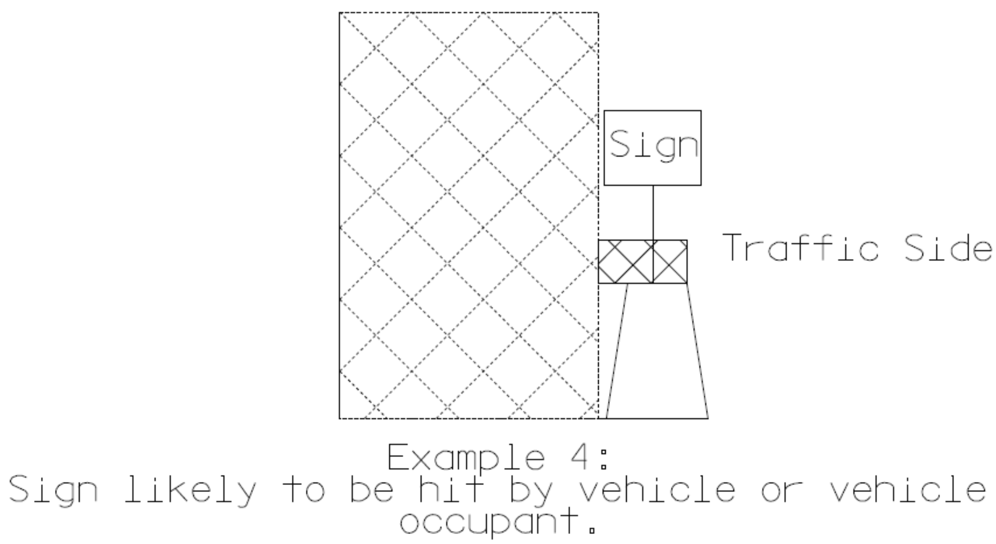

Figure 30.21 Example 4

Table 30.7 ZOI Dimensions[lxxi]

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

30.3.6.2.4 Head Slap

"Head slap" is a condition where an occupant's head is outside the cab of a vehicle during crash and it hits the concrete barrier or object on top of the barrier (See Figure 30.22). Head slap is more of an issue when smaller vehicles crash into taller barriers.

Figure 30.22 Crash test showing occupant's head out of vehicle [lxxii]

30.3.6.2.5 Crash History

Taller barriers may be used if crash history suggests passenger vehicles 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 used if there is a crash history of larger vehicles striking barrier. See FDM 11-45-30.3.1.1 for more discussion.

30.3.6.2.6 Glare/Gawking Screen

Avoid installing glare screens in medians 20 feet or wider, or in locations with ambient lighting. Ambient lighting includes roadway lighting, high-mast lighting, or neighboring properties provide significant lighting. Provide analysis when installing glare or gawk screen. Coordinate with the WisDOT project manager and the regional design oversight engineer.

Project staff will need to:

1. Document that 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 each alternative at blocking glare or gawking?
    b. What is the cost of providing glare or gawking alternative?

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

SHRP2 report points to taller permanent barriers not being cost effective at reducing non-recurrent congestion.[lxxiii]

30.3.6.3 Parts of a CBSS System

CBSS systems have the following parts:

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

Review if a location has room to install different parts of the CBSS system. If SDDs do not fit a given location, coordinate with the WisDOT project manager and the regional design oversight engineer. Designer is responsible for developing crashworthy designs for these unique situations (see FDM 11-45-30.3.6.4.6).

30.3.6.3.1 Standard Barrier Sections

Of all the parts of a CBSS system, the standard barrier section (i.e. the middle section of the concrete barrier system) is the most often used and simplest section. A standard section of CBSS needs less reinforcement steel than other parts of the concrete barrier system. This is because crash forces are distributed in two directions, (see Figure 30.23) and over a longer distance.

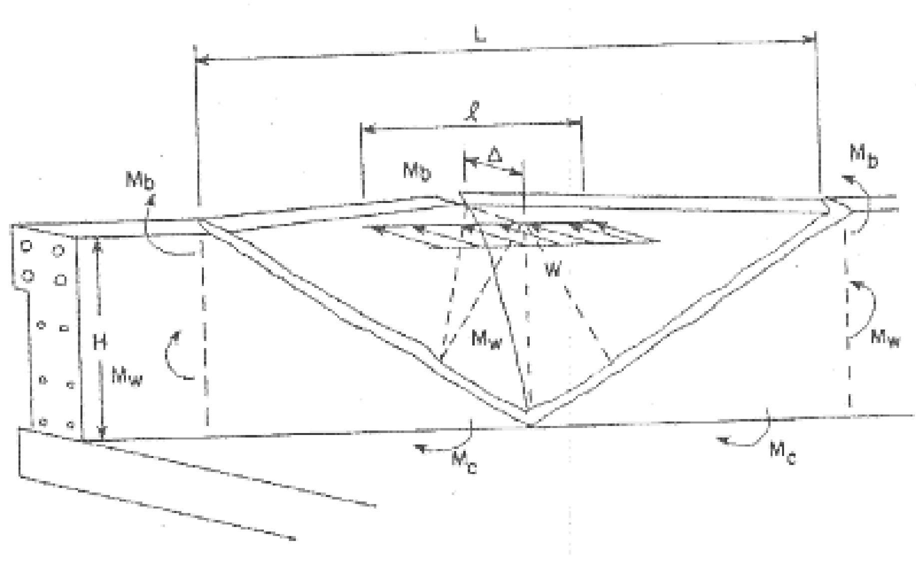

Figure 30.23 Forces in Normal Barrier Section[lxxiv]

The CBSS standard section does not need a footing. However, a concrete pad is placed under the barrier to limit crack propagation. The minimum pad dimensions are on SDD 14B32.

The cost of installing the CBSS includes the pad. The concrete pad extends behind the barrier to help provide a stable foundation under the concrete barrier.

Review grading behind the concrete barrier for stability and erosion concerns. Loss of soil stability can cause the barrier to slide out of position and form a snag point. Provide 1 foot of flat grading behind the concrete barrier on fill slopes.

Put a note in the plan when there is less than 1 foot between the back of concrete barrier and a rigid object.[36] Include bid items for reflectors and brackets.

A contractor may use a cold joint to connect to a previous day's pour (See notes on SDD 14B32). However, the overall barrier run must have end anchors, or expansion joint transitions at the terminals of the barrier system (see FDM 11-45-30.3.6.3.2).

30.3.6.3.2 End Anchors

End anchors need vertical steel and footings to absorb crash loads and to prevent the anchor from rotating (in Figure 30.24 crash forces cannot travel in both directions). End anchors use a cold joint[37] to connect to standard CBSS. It is not necessary to detail the use of a cold joint with the SDD.

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

[37] 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 crash energy.

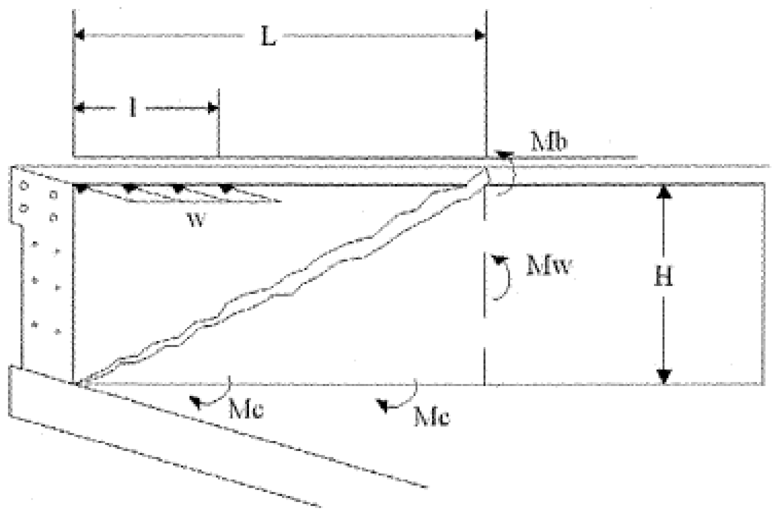

Figure 30.24 Forces in End Section [lxxv]

There are two types of end anchors for CBSS: thrie beam anchors and normal end anchors. Do not pay for anchors separately, because anchors are needed for the normal barrier section to work. Include anchor length in the pay length of the CBSS.

The thrie beam anchor is designed to prevent a vehicle's front wheel from snagging the barrier. It is not necessary to install curb and gutter near a thrie beam anchor. Review SDD 14B45 when installing curb and gutter. 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. Show in the plan (e.g. plan view) where thrie beam anchors are and include proper SDD (SDD 14B33) in the plan set.

Use normal end anchors when an expansion joint is needed in a barrier run (e.g. on both sides of the sign bridge) or on the downstream end of a one-way road. There may be a project specific reason that would cause the use of typical end anchors. Examples are (the list is not all-inclusive):

- A specific location needs an expansion joint
- Traffic control staging needs a normal end anchor

Review grading and drainage near end sections. A location may satisfy length-of-need, it may not have room for other barrier system parts, or it may have drainage issues (e.g. crash cushion, sand barrier array, or steel thrie beam structure approach). CBSS may have to be longer to provide space for proper drainage or other roadside hardware when installing barrier in a cut section, or in other areas where there is a drainage needed.

Stability of the soil by the anchor is important. The anchor provides resistance to crash loads along the whole run of the concrete barrier. If an end anchor shifts, it may form a snag point. For example, an end anchor for a barrier may no longer be flush with a bridge parapet. Provide 1 foot of flat grading behind the concrete barrier on fill slopes.

30.3.6.3.3 Transitions

CBSS may need to connect to taller or different shaped barriers. These sections of concrete barrier are called transitions.

Review the need for transitions early in design. A new barrier matching into an existing thrie beam transition may need a vertical faced transition. Use "each" items to pay for shape transitions. Show the location and shape transitions in the plan views and MQ sheets.

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**.** Double cold joint height transitions act like a normal barrier section by being able to transfer crash energy in both directions. Include the length of the double cold joint height transitions in the cost of the tallest barrier installed.

Use expansion joint height transition, SDD 14B39, at locations where it is not possible to transfer forces in both directions. Some examples are

Roadway barrier is not allowed to tie into a bridge parapet

A bridge parapet is a different height than the roadway barrier

Pay for the expansion joint height transition with an "each" item. Show the expansion joint height transitions in the plan views and MQ sheets.

Shape transitions are shown on the following SDDs:

- SDD 14B35
- SDD 14B36
- SDD 14B37
- SDD 14B38
- SDD 14B40

Pay for shape transition with an “each” item.

Review the stability of the soil near transitions. If a transition shifts, it may form a snag point. Provide 1 foot of flat grading behind the transition on fill slopes. This grading will help stabilize the transition on fill slopes.

30.3.6.4 Unique Situations

30.3.6.4.1 Short Sections of Barrier

The minimum length for the standard CBSS is 40 feet (end of end anchor to end of the end anchor). When lengths are shorter than 40 feet use Concrete Barrier, Type B, (i.e. SDD 14B34). These barriers are more robust and can absorb crashes within the total length of the barrier.

The minimum length of CBSS Short Section depends on the anchors used:

- When using two thrie beam anchors, the minimum length is 31 feet (end of the thrie beam anchor to the other end of the thrie beam anchor).
- When using one thrie beam anchor (e.g. one-way traffic), the minimum length is 21 feet.
- When using no thrie beam anchor (e.g. a sign bridge is close to a bridge), then the minimum length is 10 feet.

30.3.6.4.2 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 in a median and there is a fixed object installed in the median.

These details provide for additional steel, use of fill material and a small footing. Pay for fixed object protection using linear feet. Show the location of fixed object protection in the plan views and MQs.

Include bid items for reflectors and brackets.

Other designs (e.g. integrating a sign bridge or light pole into the barrier run), must account for the crash forces in the structural design of the fixed object. Many crashes on a barrier are from vehicles of pick-up truck size or smaller (see FDM 11-45-30.3.6.4.6).

The designer may adjust taper rates in the transition at large or small fixed objects using Table 30.4. When adjusting taper rate, provide construction details and special provisions. Include special bid item. Include bid items for reflectors and brackets.

30.3.6.4.3 Median Widening or Narrowing a Hazard for a Crash Cushion/Array

Use sections A-A and B-B of SDD 14B32-b transitions at large or small fixed objects as a guide on how to transition from a single run of median barrier to two runs of median barrier. Use the same sections to narrow a hazard to allow for the installation of crash cushion or sand barrel array. Designer may adjust the taper rates using Table 30.4.

Make the height of concrete barrier 32 inches where the crash cushion or array is installed. Combine height and width transitions together to minimize the number of transitions near the crash cushion or array. During a crash, a vehicle can lean over and strike the edge concrete barrier taller than 32 inches. Provide end anchorage for changes in median width and crash cushions and arrays. Review guidance on crash cushions and arrays for back width (FDM 11-45-30.4.4).

Provide structural analysis and design of median widening, or narrowing a hazard, for crash cushions or arrays (see FDM 11-45-30.3.6.4.6).

Provide individual construction details, special bid items, and special provisions. Include bid items for reflectors and brackets.

30.3.6.4.4 Retaining Walls

There are two designs for concrete barrier retaining walls: median and roadside. Use median retaining wall design when the barrier is between two roads of different height. The median design has a maximum wall height of 3 feet (see SDD 14B32). Show the location of in median retaining wall in the plan (e.g. plan view and MQ sheets). 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 height of median retaining walls is greater than 3 feet, provide a structural design. Design taller median retaining wall to retain soil, other loads, and crash loads (see FDM 11-45-30.3.6.4.6). Show in the Miscellaneous Quantities the maximum median retaining wall height for each installation.

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 needs significant earthwork or special earthwork, include earthwork bid items. Include bid items for reflectors and brackets. Show in plans the maximum height of the median retaining wall for each installation.

A study conducted by TTI showed that a minimum of 35 to 60 feet of median barrier was needed to prevent movement during a crash. [lxxvi] BOS indicates a minimum of 60 feet of median retaining wall is required to prevent movement of the barrier during a crash.

Note: it may not be possible to slip-form the median retaining wall from the low side road.

Avoid using median retaining wall barrier design on the outside of the road. Contact BOS and Technical Services (TS) soil staff for help.

The roadside retaining wall does not have a maximum fill height (see SDD 14B41). A soils or structural engineer is to review the location to see if SDD 14B41 is suitable. Show the location of roadside retaining wall barrier in the plan (e.g. plan view and MQ sheets). Soil or structural engineer is to decide the gradation of structural backfill.

If SDD 14B41 is not structurally acceptable, provide a design (see FDM 11-45-30.3.6.4.6). Insert construction details, special provision, and special bid items for special roadside retaining walls.

Design roadside barriers (SDD 14B41) and other retaining wall barriers to prevent overturning or sliding during a crash.

Pay for associated earthwork for roadside 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).

Normal retaining walls are not barrier systems. Retaining walls may not have a crashworthy surface, shape, or strength. A report by TTI using computer modeling of a NCHRP-350 TL-4 crash states, “panels alone cannot resist direct impact of such severity.”[lxxvii]

Repairing a damaged retaining wall may be difficult. Review the consequences of retaining wall failure from a crash. Provide additional engineering when using a retaining wall as a barrier.

30.3.6.4.5 Use of Concrete Barrier Single Slope (CBSS) on Bridges

Designer may use CBSS on a bridge in a non-outer parapet application (See SDD 14B32). Figure 30.25 is an example of CBSS on a bridge deck. Separating vehicles from a multi-use path or pedestrians needs a crashworthy bridge parapet (see Figure 30.26).

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

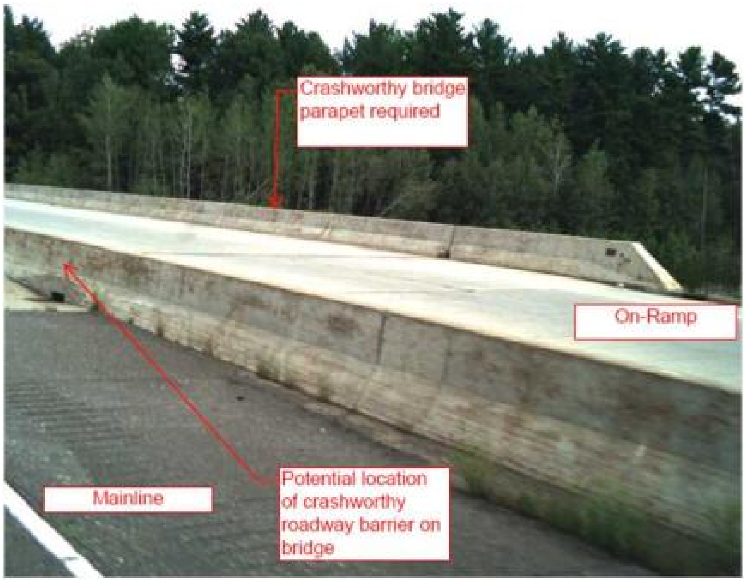

Figure 30.25 Crashworthy Barrier on Bridge

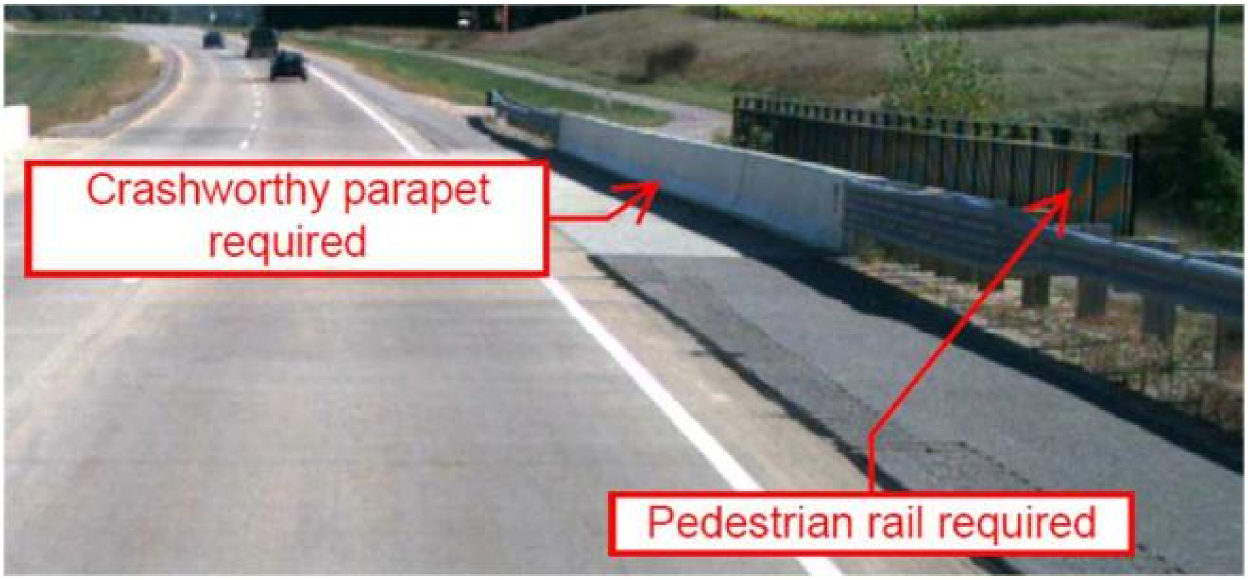

Figure 30.26 Crashworthy Parapet on Bridge

30.3.6.4.6 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 tall vertical barriers.

There may be situations where SDDs may not fit. In these situations, design barriers or fixed objects to:

- Have enough reinforcement for:
  - Shrinkage and temperature steel
  - Contain TL-3 crash 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 a crash
- Provide clear cover for steel
- Provide working width (See FDM 11-45-30.3.1.1)
- Use crashworthy shape (See FDM 11-45-30.3.6.1)
- Allow for smooth redirection
- Be free of snag points
- Limit potential for vehicle vaulting
- Limit potential for flying debris

Coordinate with the WisDOT project manager, the regional design oversight engineer and BOS when using a non-standard barrier. Provide structural analysis. Avoid abrupt angles that could concentrate crash loads on the vehicle, abrupt redirection (see Figure 30.57), or snag the vehicle.

Provide constructible designs that are structurally and functionally adequate. Use construction details, special provisions, and special bid items.

30.3.6.5 Concrete Barrier Placement

At a minimum, place the CBSS toe either at the shoulder width or the horizontal clearance width, whichever is greater. On some high-speed divided highways, CBSS has been placed 2-feet beyond the edge of shoulder (i.e. shy distance). See FDM 11-45-30.3.1.5 for discussion on flare and shy-line for concrete barrier. See FDM 11-45-30.3.1.1 for information on working widths.

30.3.6.6 Median Barrier

Typically, use a concrete barrier in medians 40 feet or less. Wider medians may use a concrete barrier.

In narrow medians, install two runs of concrete barrier. Advantages of two runs are:

- Fixed objects (e.g. signs, light poles, sign bridges, bridge piers…) placed between the barriers are less likely to be hit.
- Fixed objects do not need to accommodate crash loads
- Snow storage

- A vehicle is less likely to penetrate or go over two barriers

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

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

A single run of concrete median barrier may be acceptable for some projects or locations.. Include the following:

- Lack of room for two runs
- No or few fixed objects in median
- Construction staging and work zone traffic control

If using a single run of median barrier and a large object placed on top of the barrier, design each object using FDM 11-45-30.3.6.4.6. Provide concrete end anchors next to the large object on top of the barrier.

This design prevents crash loads from the barrier damaging the large object. Maintenance staff does not need to replace a large object on top of the barrier if the nearby barrier is damaged.

30.3.6.7 Extending Concrete Barrier

Occasionally, existing concrete barrier may need to be extended. Portions of the existing end anchorage will need to be removed. If end anchorages are not modified there may be issues with snag or barrier failure. Review SDD 14B32 sheet E and FDM 11-45-30.3.6.4 for single slope barriers.

Older safety shaped barrier may need to be extended a few hundred feet. Some options are:

- Removal of the 6.5 FT safety shape to vertical shaped transition (see SDD 14B22 sheet B).
    - Vertical steel within this area may need to be removed. Horizontal steel should remain to tie in the new barrier (see Attachment 30.23). Special details and special provisions may be required.
- Use a vertical to single slope transition and install single slope barrier
- Detail that a contractor needs to install the 6.5 FT safety shaped to vertical transition abutting the existing safety shape transition.

30.4 End Treatments

End treatments provide strength for the entire barrier system. Review guidance in FDM 11-45-30.5.4.

Provide individual construction details for end treatments and cross-sections. End treatments may not fit without individual construction details in the plan. Sometimes, improperly installed end treatments can degrade the strength of an entire barrier system.

Some end treatments are proprietary products and are on an approved products list. Avoid placing multiple end treatments near each other (see discussion in FDM 11-45-30.4.1.2).

Avoid aesthetic reasons to justify not installing a crashworthy end terminal correctly. Review FDM 11-45-30.1.4.

Research shows that beam guard terminal crashes are: [lxxviii]

- 2.5 times more likely to cause driver injury when compared to crashes into beam guard.
- NCHRP 350 compliant terminals are about 5 times safer than striking other terminal designs.
- End terminals are twice as likely to cause rollover crashes as striking beam guard.

30.4.1 Energy Absorbing Terminals (EAT)

EATs are attached to the end of beam guard, are proprietary, and crashworthy. With other hardware, an EAT can shield the blunt end of a concrete barrier.

Install EATs when a vehicle could have a head-on crash with the blunt end of a semi-rigid barrier. If an EAT cannot be installed, review other crashworthy options.

Downstream ends of a beam guard installation on a one-way road may use an EAT. These locations typically use a Type 2 terminal.

CMM 6-26 contains more information on construction problems faced installing an EAT.

During a head-on crash, an EAT can absorb a significant amount of energy by reshaping the rail. Angle hits between the head and post 3 will result in limited reshaping of a short section of rail before the vehicle passes behind the EAT and barrier. For crashes beyond post 3 (e.g. post 4, 7), an EAT works like normal beam guard. To shield a hazard, the end of barrier need (i.e. LON point) is post 3 of the EAT (see FDM 11-45-30.3.1.2).

SDD 14B24 is the EAT SDD for Class A beam guard. SDD 14B44 is EAT SDD for MGS beam guard. Use the EAT with the correct beam guard (e.g. MGS EAT with MGS, EAT with Class A). Identify EAT location in the plan by using the station and offset of post 1.

Usually, the department installs TL-3 EATs. In some locations, installing a TL-2 EAT may be acceptable.. Use special details and special provisions when installing a TL-2 EAT. Coordinate with the WisDOT project manager and the regional design oversight engineer early in the design.

EATs cannot accommodate the following modifications (the list is not all-inclusive):

- Bending the rails to a radius
- Different post spacing than shown on the SDDs
- Connecting to beam guard with significantly reduced working width without some intermediate beam guard (see FDM 11-45-30.3.1.1)
- Connecting to a rigid barrier without a transition.
- Connecting to a short radius system without a normal section of beam guard before the EAT.
- Installing with nested rail within the EAT.
- Installing railing or planks on the backside of the EAT.
- Using longer posts

Coordinate with the WisDOT project manager and the regional design oversight engineer about adjusting an EAT to fit a location.

30.4.1.2 Fixed Object Placement and EATs

Figure 30.27 is a plot where test vehicles came to rest after hitting various end treatments at 62 mph. This figure also includes AASHTO's Roadside Design recommended 75-foot by 20-foot area that should be traversable and free of fixed objects (i.e. yellow area). Crash testing is conducted under controlled conditions. In the real world, vehicles may travel further than Figure 30.42.

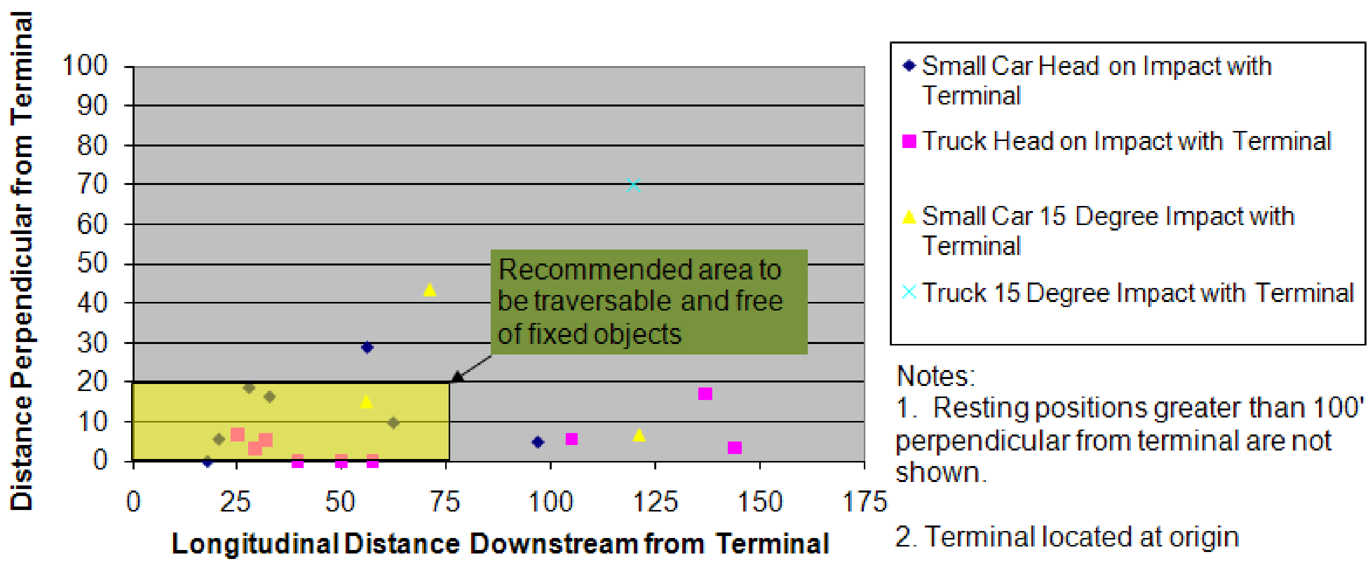

Figure 30.27 Final Resting Position of Test Vehicle after Hitting End Treatments

Figure 30.28 Hazard within Area End Treatment Gates

Avoid placing objects, even breakaway hardware, just behind an EAT (i.e. yellow box). Desirably a vehicle would engage one object during a crash. Crashes into multiple objects are complicated and are more likely to have negative results. In Figure 30.28, the rock face will likely be struck by a vehicle after gating through the EAT.

Avoid placing objects just upstream of an EAT (about 75 feet). Objects upstream of an EAT can (the list is not all-inclusive):

- Funnel vehicles towards the EAT
- Cause a crash into multiple objects
- Cause a non-tracking crash into the EAT

Non-tracking crashes into an end treatment are more likely to have negative results. Figure 30.29 has a breakaway sign too close to the EAT.

Figure 30.29 Fixed Object may Funnel Vehicle into EAT

In some situations, (e.g. urban areas, low speed), the area that AASHTO shows free of fixed objects and traversable grading may be difficult to achieve.

Review placement of objects near EAT before PS&E. If there are conflicts, adjust the location of the object or EAT, or use different hardware.

EATs, like many other end treatments, are designed to work independently. Avoid placing two EATs, or other end treatments, near each other (See Figure 30.30). Crashes like Figure 30.31 can have less than desirable outcomes.

Figure 30.30 End Treatment Placed Near Each Other[lxxix]

Figure 30.31 Results of Placing End Treatments Near Each Other[lxxx]

Other end treatments are more suitable where there is little room between barrier systems. Examples are:

- Thrie beam bullnoses
- Crash cushions
- Special semi-rigid barrier end terminals

Coordinate with the WisDOT project manager and the regional design oversight engineer, early in the design process, when end treatments are close to each other (typically 25 feet or less). Provide additional engineering, special details, and special provisions.

30.4.1.3 EAT Grading

In 2004, FHWA released a memorandum that highlights the importance of advance, adjacent and run-out grading for EATs (see Figure 30.32).[lxxxi] Advance grading allows a vehicle to avoid hitting the EAT or allows the vehicle to engage the EAT properly. Adjacent grading provides stability for the vehicle during crash and provides structural strength to the whole barrier system. Run-out grading provides an area for a damaged vehicle to stop before hitting a fixed object. The tree in Figure 30.32 may be struck by a vehicle that hit the EAT, and then gates through the EAT.

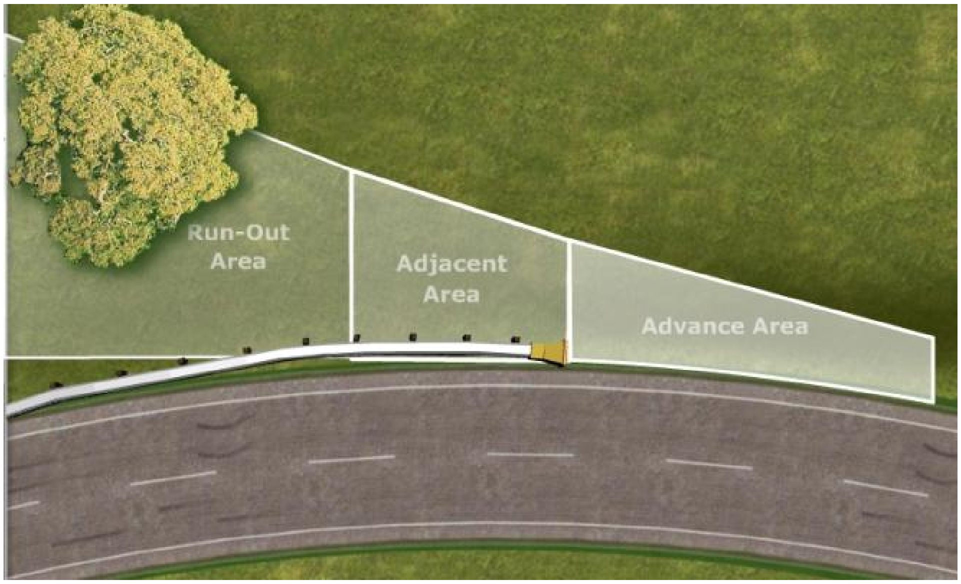

Figure 30.32 EAT grading Locations[lxxxii]

AASTHO suggests the desirable grading would be the yellow area in Figure 30.32. WisDOT does allow changes to the EAT grading (see SDD 14B24 and SDD 14B44). The area bounded by roadside clear zone, hinge point between posts 1 through 5 of the EAT and gradeline should conform to clear zone requirements. Grading for the additional area shown in the 2011 AASHTO Roadside Design Guide is not required (see Figure 30.32), but is a best practice.

Insert cross-sections at posts 1, 5, 9 and the beginning of approach taper into the plan. Review how various slopes blend into each other near EAT. Make transitions from one slope to another as smooth as practical. The blending of slopes will help minimize vehicle instability before and after hitting an EAT.

Removing or reducing earthwork at an end treatment may influence how the barrier system will work (see FDM 11-45-30.4.1.4 and FDM 11-45-30.4.1.5). Review FDM 11-45-30.3.1.3 to use grading and shaping barrier system item.

The soil outside the road's core may not be suitable. Consult with the Region's Soils Engineer. Review the need to bench the EAT's earthwork into existing road's slope. Remove unsuitable material before building EAT's fill. If benching existing slope, show benches in the cross-sections and add a note to construction details. Show the removal of unsuitable soils in the cross-sections as well.

Review drainage and right-of-way near EAT early in the scoping or design. See if more right-of-way is needed. If EAT grading interferes with ditch drainage, review installing a parallel culvert pipe (see FDM 11-45-30.6). Sometimes, a parallel culvert pipe may reduce the need for right-of-way and allow for proper grading near the EAT.

30.4.1.4 Extending Barrier Installation for EAT Grading

Minor shifts in EAT's location to account for transitions, and rounding up to get an even number of rail sections does not need documentation. Shielding of a secondary hazard, or to avoid having fixed objects within the area near the EAT needs documentation. Installing an EAT without grading needs a designer to evaluate and document moving the EAT to a different location.

If it is not possible to get the preferred grading, use the following options (in order of preference):

1. Provide alternative grading at first EAT location (See 2011 Roadside Design Guide Figure 8.3 for alternative grading).
2. Extend barrier to a location where desirable grading can be provided.
3. Extend barrier to a location where alternative grading can be provided.
4. Install EAT with substandard grading.

Flaring a barrier system may allow for a shorter overall barrier length and proper grading. See FDM 11-45-30.3.2.4 for information on flaring a barrier system.

When extending a barrier to allow grading, use one of the following methods (in order of preference):

1. Length Factor.
2. Cost Ratio.
3. Other Factors.

30.4.1.4.1 Length Factor

If it is not feasible to provide grading for the EAT near the end of barrier point (LON), multiply the length of barrier system by 1.6. This new value represents the maximum length the barrier system may be extended using the length factor method.[38]

Example:

Given:

Barrier run length is 312.5 FT

Extension factor 1.6

It is not feasible to provide grading at the desirable location.

Find:

Maximum distance designer may extend barrier to provide grading.

Max length of barrier run =312.5*1.6= 500.

Use any location between 312.5 to 500 FT in front of the hazard that allows for grading.

30.4.1.4.2 Cost Ratio

If grading for the EAT cannot be provided within the length factor range, extend barrier using the cost ratio method. If the total cost of EAT installation at the desirable location, divided by the total cost of extending the barrier to provide grading is greater than 6, extend the barrier to provide grading. The ratio uses the relative severity of hitting a barrier system versus hitting an EAT.[lxxxiii]

Example:

Given:

Barrier run length is 312.5 feet

Length Factor 1.6

It is not feasible to provide grading at the desirable location (i.e. 312.5 FT before the hazard).

The maximum length of the barrier using length factor method is 500 FT before the hazard.

It is not feasible to provide grading at any location from 312.5 to 500 FT before the hazard.

Find:

Does a location 650 FT before the hazard satisfy the cost ratio requirements?

The cost to provide more barrier and EAT measured from the desirable location (i.e. 312.5 feet before the hazard) to 650 feet before the hazard= $5,000

The cost of providing EAT and grading at desirable location (i.e. 312.5 feet before the hazard) = $15,000.

Cost Ratio= $15,000/$5,000=3

Cost Ratio is less than 6; it is not feasible to extend the barrier to a location 650 FT before the hazard.

30.4.1.4.3 Other Factors

There may be significant impacts preventing proper grading of a terminal. Consider how a terminal works with other needs of the road and its' surroundings.

Coordinate with the WisDOT project manager and the regional design oversight engineer early if using some other factor to justify not installing EAT grading. Show the scope of the impact of grading the EAT. Include an analysis of the other methods of altering an EAT's location.

Avoid aesthetic reasons to justify not designing the installation of an EAT accordingly. Review FDM 11-45-30.1.4.

The WisDOT project manager and the regional design oversight engineer may grant case-by-case DJ's to install EATs without grading.

30.4.1.5 Substandard Grading

The department does not want to install EATs without the proper grading. However, there may be situations where moving or providing proper grading for an EAT is not feasible. In these cases, providing a crashworthy end treatment with substandard grading is better than using a non-crashworthy end treatment.

Consider installing substandard grading for an EAT only after reviewing other EAT locations. Eliminate grading

[38] Length factor is based on the average ratio of L_r values in AASHTO's 2006 Roadside Design Guide divided by the L_r values in the FDM.

in the following order of preference:

1. Reduce or remove EAT flare.
2. Reduce grading between EAT head and hinge point to 2 feet.
3. Review if installing a parallel culvert pipe with traversable grate and fill can reduce the need to flatten run out path slopes.
4. Reduce slope beyond the hinge line to 3:1.

See FDM 11-45-30.4.1.7 to reduce or remove EAT flare.

Reducing grading between the EAT head hinge point may make it more difficult for a vehicle to be stable during a crash. Reducing grading to less than 2 feet can weaken the entire semi-rigid barrier system.

Research conducted by Midwest Roadside Safety Facility (MwRSF) shows that recommended grading reduces the chances of rollover after hitting an EAT.[lxxxiv] The report also indicated 3:1 slopes could be used in the runout areas if the soil is firmly compacted[lxxxv]. Using 3:1 slopes may reduce flexibility for future projects. Review 3:1 slopes for a flat spot at the toe of slope and fixed objects on the slopes or at the toe of slope.

Approach taper may be steepened to 4:1.

30.4.1.6 Curb and Gutter near EAT

There has not been crash testing with an EAT installed near or behind curb and gutter. In areas with curb and gutter, it is desirable to install driveway curb 100 FT before the EAT head. In a constricted location, use a minimum of 25 feet before an EAT head[lxxxvi]. Extend driveway curb to post three of the EAT. Review drainage near EAT.

Locate driveway curb in the plan (i.e. individual construction detail). If providing paving details or curb and gutter details, locate driveway curb for EATs on these sheets. Typically, one contractor installs curb and gutter, and another contractor installs the EAT. There may be communication issues between contractors or project staff if this information is not in the plan.

30.4.1.7 Flare EAT

Install EATs tangent or flared from a road. The maximum flare rate for an EAT attached to tangent beam guard is on SDD 14B24 or SDD 14B44.

If beam guard is flaring away from the road, install the EAT without additional flare. For example, beam guard is flared 15:1 from the road. Flare the EAT at 15:1 from the road.

In urban and suburban/transitional areas, it can be difficult to get space for EATs. EAT offset from flow line of the curb can be reduced to 1 FT in these areas. Any offset less than 1 FT will more than likely lead to hits by snowplows. The EAT's head may extend beyond the flow line of the curb. Avoid reducing the flare rate in rural areas. Discuss with local government and regional maintenance staff before reducing the flare rate.

Provide information in the plan when no or reduced offset is used for an EAT.

30.4.1.8 Foundation/Soil Tubes for EATs

Review discussion in FDM 11-45-30.3.3.1.4 for more information on post rotation embedment.

EAT foundation/soil tubes are embedded nearly 6 FT into the ground. Designers may move EAT to accommodate tube installation (e.g. flare barrier system, install longer barrier system).

Where 6 FT of embedment is difficult, even if the designer relocates the end terminal, manufacturers may have special designs that could be used. If using a manufacturer's special design coordinate with the WisDOT project manager, the regional design oversight engineer, the manufacturer, and maintenance staff. Additional engineering, special provisions, special bid items, and drawings may be needed.

30.4.2 Downturned Ends, Blunt Ends, BCTs, MELTs, and Sloped Concrete End Treatments

Downturned end treatments (see Figure 30.64), sloped concrete end treatments (see Figure 30.74) blunt ends (see Figure 30.61, Figure 30.62), BCTs (Figure 30.63) and MELTs (Figure 30.65) are not crashworthy. These end treatments can launch vehicles into the air, decelerate a vehicle too quickly or spear into the cab. If considering their use, coordinate with the WisDOT project manager and the regional design oversight engineer.

30.4.3 Type 2 End Treatments

These end treatments are installed at locations where a vehicle cannot have a head-on crash or where it is unlikely to be hit. Some examples are:

- Downstream end of a beam guard installed in a wide median on a freeway or expressway
- Downstream end of a one-way road

See SDD 14B16 (Class A) and SDD 14B47 (MGS) for more information.

Computer modeling indicates that some crashes will gate through the MGS Type 2 (see Figure 30.48). Use this guidance for designing all Type 2 end treatments.

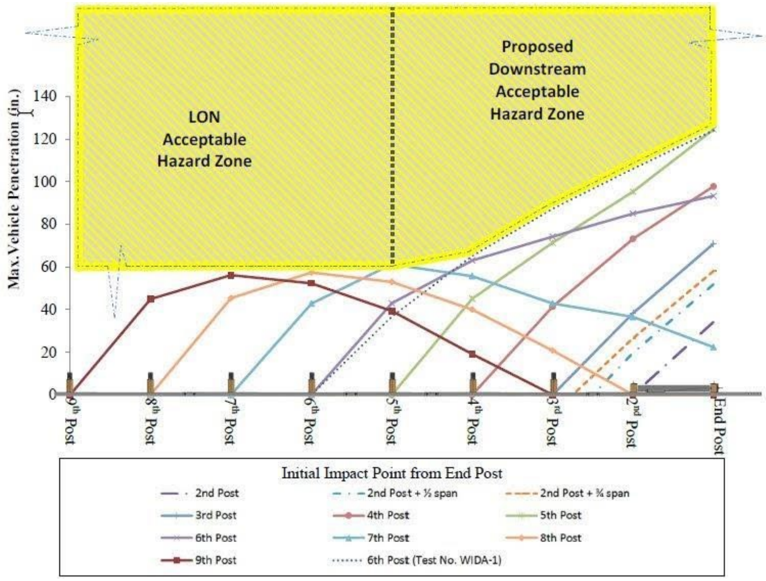

Figure 30.33 MGS Type 2 Computer Modeling

Options available to the designer are:

- If the hazard is close to the beam guard, extend beam guard 39.5 feet beyond the hazard and place a Type 2 end treatment.
- If the hazard is farther from the beam guard, the end treatment can have the same station as the hazard (see Figure 30.33).

For example, if a fixed object (e.g. pole) is 15 feet behind the beam guard. It is possible to have the end post of the Type 2 end treatment flush with the end of the fixed object hazard.

For some hazards, avoid installing a Type 2 end treatment within 39.5 FT of the hazard. Examples are (the list is not all-inclusive):

- Steep slopes
- Water
- Cliffs
- Areas of Concern for Pedestrians
- Areas with High Consequence of Collision

In general, avoid allowing a vehicle to gate through the Type 2 terminal and interact with a hazard.

Show the location of end post of a Type 2 end treatment in the plan.

Transition from curb and gutter to driveway curb and gutter between post 6 and 7 in Figure 30.33. Extend driveway curb and gutter 32 feet downstream of the end post.

Provide additional cross-sections for a Type 2 end treatment.

Provide grading behind the posts for the Type 2 end treatment. Lack of grading by the Type 2 end treatment may weaken barrier system. See FDM 11-45-30.3.3.1.3 and SDDs for more information about grading..

See discussion in FDM 11-45-30.4.1.8 for more information on foundation/soil tubes.

30.4.4 Crash Cushions and Sand Barrel Arrays

Where fixed objects cannot be removed, moved, made breakaway, or shielded by roadside barrier use a WisDOT approved crash cushion or sand barrel array. See approved product list for acceptable hardware. Use other barrier systems before using a crash cushion or sand barrel array. Sand barrel arrays and crash cushions are often the only effective ways to shield narrow, rigid hazards.

During a head-on crash, the crash cushion absorbs energy by deforming the components of the crash cushion. When a crash cushion is hit on the side, it will redirect a vehicle. Depending on crash severity and crash cushion, a crash cushion may have the potential to shield a second crash or be put back into service quickly.

An array is a series of barrels filled with a mixture of sand and salt. During a crash, the vehicle’s momentum is dissipated by hitting various weighted drums in the array. Arrays do not allow for redirection of a vehicle. After a crash, an array has limited to no capacity to shield a second crash.

Arrays can have barrels from different manufacturers intermixed. Crash cushions cannot intermix parts from different manufacturers.

In work zones, shield temporary barrier ends within the clear zone when the posted speed is 30 mph or greater with a crash cushion or array.

Discuss the selection of permanent crash cushions or arrays with local maintenance staff. Proper maintenance is important for crash cushions to work correctly. Maintenance input may influence final design of a location or the selection of a system. Maintenance concerns should not be the only factor in selecting of a permanent crash cushion.

30.4.4.1 Design Criteria

Fundamental design criteria for crash cushions or arrays are:

- Crash test condition
- Area requirements
- Back width
- Grading
- System maintenance
- Object marking pattern
- Object being connected to
- Location of traffic
- Direction of traffic

Include this information in the miscellaneous quantities for each installation.

Length-of-need point for most crash cushions is within 2 feet of the crash cushion's nose or first metal diaphragm. Often, the length-of-need point of a crash cushion may not matter. For example, a crash cushion is protecting the blunt end of two barriers in a gore.

Length-of-need point for arrays is the first barrel.

Provide individual construction details for each crash cushion and array. Include the following (the list is not all-inclusive):

- Width and length available for installation
- What the array or crash cushion is shielding

Include cross-sections or contours near crash cushions and arrays in the plan.

Standard bid items show crash cushion system maintenance requirements.

Avoid using special provisions for crash cushions. In the past, some problems with special provisions for crash cushions have been (the list is not all-inclusive):

- Critical parts missing from contract documents
- Problems with consistency between special provisions
- Conflicts between standard bid items or other project's special provisions
- Specifying a product that is not required/allowed

These issues have caused delays, increases in project costs, and have led to less than desirable installations.

30.4.4.1.1 Sand Barrel Considerations

Department policy is to limit the use of permanent sand barrel arrays. Use arrays at locations where crash cushions cannot reasonably fit. Sand barrel arrays are typically more expensive to maintain, and in certain crashes not as safe as a crash cushion. For example, arrays allow vehicles to gate through, and vehicles can hit the heaviest barrel first. See system maintenance discussion.

The barrels typically vary in height based on design and manufacturer. An array may affect the sight distance of turning vehicles. Review sight distance near the array. State if the array is unidirectional (i.e. exposed to one-way traffic) or bidirectional (i.e. exposed to two-way traffic) in the miscellaneous quantities. In the Miscellaneous Quantities, state the crash test level for each array. See Chapter 8 in AASHTO Roadside Design Guide for more guidance on arrays.

Place arrays on asphalt or concrete pads. Show a pad for the array in the plan. The manufacturer is responsible for pad design. Provide enough room to install an array.

When providing space for an array use the following guidance:

- Provide minimum offset from last few rows of barrels and end of hazard (see Figure 8-40 of 2011 AASHTO Roadside Design Guide)

- 6 inches of space between barrels
- Barrels are 3 FT wide

Desirable new arrays would also include:

- For bidirectional arrays, install some barrels to reduce the severity of reverse direction crashes (see Figure 8-41 of 2011 Roadside Design Guide).
- Angle arrays toward traffic (see Figure 8-42 of 2011 Roadside Design Guide).

Show in the plan that additional barrels are being used to reduce reverse direction crashes or if the array is angled towards traffic.

30.4.4.1.2 Crash Test Level

Use Table 30.8 to select crash test levels for crash cushions and arrays. Put the crash test level in the plan for each crash cushion or array.

Table 30.8 Test Conditions

Speed (MPH)	Crash Test Level
≤25	NA –Sloped Concrete End Treatment
>25 to 45	TL-2
≥ 45	TL-3 *

*Most manufacturers use an 8-inch deep concrete pad to anchor a crash cushion. Some manufacturers allow the use of asphalt for temporary crash cushions. If the hazard is 4 or more feet in width, a temporary crash cushions needs a concrete pad. Confined locations, a TL-2 system may be used for speeds of 45 MPH.

30.4.4.1.3 Area Requirements

Figure 30.34 show the general components and the relationship of pad dimensions to the generic crash cushion. Most crash cushions on the Department's Approved Products list will fit within the dimensions of Table 30.9.

Crash cushions need to be anchored into the ground. Most manufacturers use a concrete or asphalt pad. Sometimes crash cushions use a backing block. Designers using the standard specifications do not need to provide details or payment items for pads or backing blocks.

Lack of room for the pad or backup block may hinder the operation of the crash cushion. Table 30.9 an estimate of the concrete pad's width and length.

Review the pad's location for underground conflicts. It is difficult to install or maintain a crash cushion with limited room. Review manufacturers' information to verify that a system will fit.

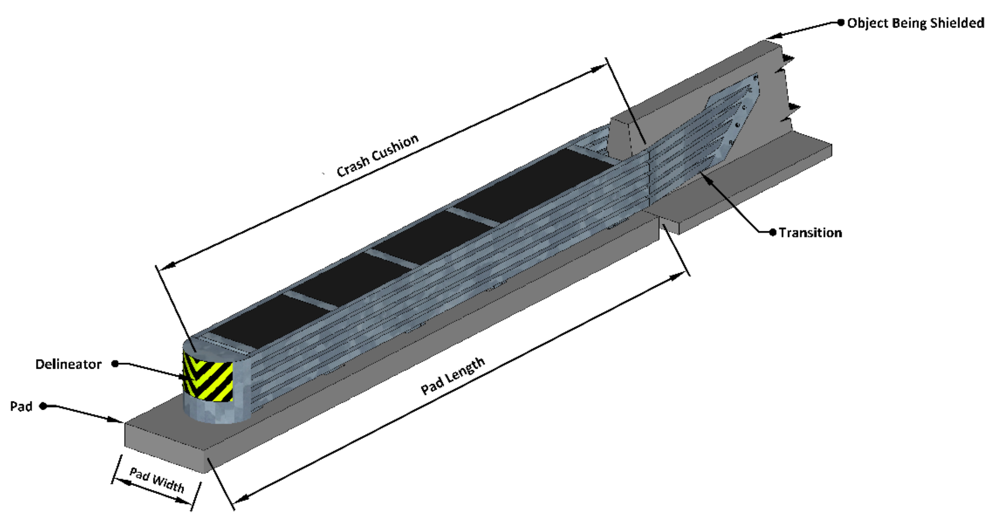

Figure 30.34 Area Requirements for Crash Cushions[lxxxvii]

Table 30.9 Area Requirements for Crash Cushions

	Pad Dimensions (FT)	
Test Level	**Width**	**Length**
TL-2	4	15
TL-3	4	26

Document when values less than the values in Table 30.9. Type of work, the amount of room for a crash cushion, or pad requirements may limit the effectiveness of a crash cushion. However, installing a crash cushion may be the best available option.

30.4.4.1.4 Back Width Requirements

Back width is the width of the hazard being shielded. Typically, crash cushions are as wide as or wider than the hazard, they are shielding.

Table 30.9 should allow most crash cushions to be installed. Objects that are 2 FT or wider may need an sand barrel array or be tapered to a narrower width. Wider crash cushions will cost more to repair than standard sized crash cushions. Also there are no wider crash cushions that are tested to MASH 16.

Limit the use of wider crash cushions to locations where it is not feasible to taper the back width of the hazard to the values in Table 30.9. Use concrete barrier that tapers to the widths in Table 30.9 to minimize the cost of future repairs. See FDM 11-45-30.3.6 for guidance on narrowing a hazard with a concrete barrier.[39] In addition, there are no MASH-16 wider crash cushions on the department's approved product list.

Typically, using beam guard or thrie beam to taper a hazard is acceptable when using beam guard or thrie beam to shield the hazard. Beam guard or thrie beam tapers will require more room than concrete barriers and may have other special requirements. Beam guard and thrie beam tapers may be more expensive to repair. Coordinate with the WisDOT project manager and the regional design oversight engineer when using beam guard or thrie beam to taper a hazard.

Typically, on retrofit projects, the back width may be larger and it may be more difficult to taper the hazard down. Manufacturers can provide wider crash cushions or use an array.

Use the outermost limits of the hazard to determine back width. If two barriers are near each other, use the distance from outside toes of the barriers for back width. If a hazard is near a barrier, use the distance from the outer toe of the barrier to the outside edge of the hazard for back width.

30.4.4.1.5 Grading

Provided 10:1 or flatter grading leading to, alongside, and under a crash cushion or array. Include grading items in the plan. Crash cushions may use the grading and shaping standard bid item. See FDM 11-45-30.3.1.3 for more information on the grading and shaping bid item.

Curb and gutter will make it more difficult for crash cushions or arrays to work as intended. Avoid installing curb and gutter leading to, or alongside of a crash cushion or array. If curb and gutter is needed by a crash cushion or array on a project that is not new construction or reconstruction, use 4-inch sloped curb.[lxxxviii]

30.4.4.1.6 Maintenance Requirements

Some crash cushions are designed specifically to be easier, faster, or less expensive to repair. These 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. Low-maintenance crash cushions are usually more expensive than a normal crash cushion.

If there is no crash data available, or the crash data indicates that there has been 4 or more years between crashes on a crash cushion, use (in order of preference):

1. Desirable maintenance criteria tables in Attachment 30.11.
2. Less than desirable maintenance criteria tables in Attachment 30.11.

If a crash cushion has experienced less than 4 years between crashes, use a low-maintenance crash cushion. Other issues may factor into the selection of a low-maintenance crash cushion. Some of the issues are (the list is not all-inclusive):

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[39] Figure 2.47 indicates that a "12:1 taper (Min)". Flatter tapers (e.g. 20:1, 15:1) are acceptable.

- User delay
    - The road is at capacity, and it is not feasible to repair cushion during the off-peak time or at night.
- Exposure to the traveling public or maintenance staff
    - Geometric or cross-section issues near the crash cushion (e.g. there is little to no shoulder, a high-volume ramp gore requires a crash cushion).
- Violation of driver expectations
    - Geometric issues are present (e.g. left-hand off-ramp, curve hidden by hill…).

Look for locations that have high crash frequency and it is difficult to maintain the crash cushion. Using a crash cushion with some residual capacity may be suitable. Locations like this have one or more crashes within a week. Coordinate with the WisDOT project manager and the regional design oversight engineer for assistance. Special provisions may be needed.

30.4.4.1.7 Object Marking Pattern

Show in the miscellaneous quantities the object marking pattern required for a given installation. Manufacturers will provide the marking on the front of their crash cushion.

For permanent installations:

- When the installation is on the left side of a one-way road, use marking pattern OM-3L (W5-58L sign plate).
- When the installation is on the right side of a one-way or two-way road, use marking pattern OM-3R (W5-58R sign plate).
- When the installation is in the median or a gore between a ramp and the mainline, use marking pattern OM-3C (W5-58M sign plate).

For temporary work zone installations:

- When the installation is on the left side of a one-way road, use marking pattern OM-3L (WO5-58L sign plate).
- When the installation is on the right side of a one-way or two-way road, use marking pattern OM-3R (W05-58R sign plate).
- When the installation is in the median or a gore between a ramp and the mainline, use marking pattern OM-3C (W05-58M sign plate).

Include correct WisDOT sign plates in the plan.

30.4.4.1.8 Direction of Travel

There are two traffic directions: unidirectional (e.g. outside shoulder of a one-way road, gores between the ramp and mainline...) or bidirectional (e.g. temporary barrier divides north and southbound traffic, narrow median installation in a freeway or expressway). Provide direction of travel in the plan.

Different hardware or different layouts are used depending on traffic direction. For example, bidirectional traffic needs a transition from temporary barrier to the crash cushion. Lack of this information in the plan may cause a crash cushion not to function adequately.

30.4.4.1.9 Traffic Location

Traffic can be on one side (e.g. temporary barrier is on the outside shoulder) or have traffic on both sides (e.g. gore between ramp and mainline, gore between east bound and west bound mainline). Traffic location may influence crash cushion hardware.

30.4.4.1.10 Object Crash Cushion Shields

Type of object can influence crash cushion or crash cushion's layout. Typical hazards are the blunt ends of the temporary barrier and permanent barrier. There may be some other hazards as well. Identify what to shield and the crash cushion's location in the plan.

30.4.4.2 Miscellaneous Quantities Sheet

Below is a sample miscellaneous quantity sheet for crash cushions and sand barrel arrays.

Table 30.10 Crash Cushion Miscellaneous Quantity Sheet

Location	614.0800 Crash Cushions Permanent	614.0805 Crash Cushions Permanent Low-Maintenance	614.0905 Crash Cushions Temporary	Back Width FT	Object Marking Pattern	Crash Test Level	Traffic Direction	Traffic location	Crash cushion shields
354+13, 30' R	--	1	--	4	OM-3C (W5-58M)	TL-3	Unidirectional	L and R	permanent concrete barrier in ramp gore
50 "c"+67 10' L	1	--	--	2	OM-3C (W5-58M)	TL-2	Bidirectional	L and R	permanent concrete barrier in median
10 "temp"+15 R	--	--	1	4	OM-3R (W05-58R)	TL-3	Bidirectional	L and R	gore between temporary lanes single temporary barrier
357+80 45 L	1	--	--	2	OM-3L (L5-58L)	TL-3	Unidirectional	L	permanent concrete barrier on shoulder
Total	2	1	1						

30.4.4.3 Other Crash Cushion Considerations

Occasionally, a crash cushion must be left in place and a future project will remove it. Typically, this is because of traffic staging on large multi-contract projects. It is recommended that permanent crash cushion items are used.

The temporary crash cushion bid item uses some older crash cushions. These crash cushions may have high repair costs. During the time between projects, county forces will be responsible for maintenance. Repair crews are more familiar with the crash cushions on the permanent crash cushion list. It is also easier to get replacement parts. The future project can remove the crash cushion.

Standard specifications require the contractor to attach the crash cushion to the object being shielded. Sometimes it is not proper to attach a crash cushion to an object. For example, traffic is temporarily closer to a metal pole during construction. Use a special provision to modify standard specifications for these locations.

Avoid placing crash cushions near each other or having a fixed object installed near a crash cushion (see discussion in FDM 11-45-30.4.1.2).

Do not add bid items to repair crash cushions during construction. In most cases, the department does not pay for repairing temporary crash cushions. Standard specification 614 already requires the contractor to "immediately" repair a damaged crash cushion. In part 1 of the Standard Specification, the contractor is responsible for maintaining the safety of the traveling public.

30.5 Existing Barrier System Evaluation

A significant amount of research has been invested into making barrier systems reasonably safe. However, there can be crashes into a barrier system that have serious outcomes. 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."[lxxxix]

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."[xc]

The 2016 FHWA/AASHTO MASH Implementation Agreement states:

> "Agencies are urged to establish a process to replace existing highway safety hardware that has not been successfully tested to NCHRP Report 350 or later criteria."[xci]

The same FHWA/AASHTO agreement also states:

> "Agencies are encouraged to upgrade existing highway safety hardware to comply with the 2016 edition of MASH either when it becomes damaged beyond repair, or when an individual agency's policies require and upgrade to safety hardware."[xcii]

Document the following:

- The quantity of existing barrier systems,
  - Where are existing barrier systems located?
  - What barrier systems are on the project?
- The need for the existing barrier systems:
  - Can the use of other roadside design methods reduce the severity or frequency of crashes?
- 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 determine what action to take (e.g. remove the hazard, spot improvement of barrier, or replace existing barriers systems). Except for certain projects (see FDM 3-5-5), not reviewing existing barrier systems requires a DJ.

After deciding that a barrier system is needed, analyze the existing barrier system. Use Attachment 20.1, Table 30.1, and guidance provided in this subsection to decide if spot improvements or full replacement is needed.

Roadway Design Standards Unit (RDSU) recommends:

- Installing barrier systems as shown in SDDs and FDM.
- Fully replace barrier systems instead of performing a significant amount of spot improvements.
- Flexibility for existing barrier system does not apply to newer installations. Examples are:
  - Existing beam guard has a range of acceptable heights. It is not correct to use this range of heights for new beam guard installations.
  - Retrofitting a sloped concrete end treatment to shield an existing blunt end has more flexibility than installing a new sloped concrete end treatment for a new blunt end.
- Remove barrier systems that are no longer needed[40].
- Remove or modify curb on approaches to, or alongside an existing barrier systems.[41]
  - Do the following (in order of preference)[42]:
    - Remove curb and gutter
    - Use driveway curb and gutter

[40] Barriers are hazards and require maintenance.

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

[42] Contractors have access to equipment that makes removal of the head of curb easier to do.

    - Use 4-inch sloped face curb
  - Shorten barriers that are longer than needed.[43]

Some of the design guidance for new barrier systems can be used on existing barrier systems. Some examples are length-of-need, grading, and working width. More guidance on existing barrier systems is in the following subsections. Guidance in this subsection applies to roadside barriers systems. Guidance may apply to parapets on structures. Contact BOS for guidance on existing parapets.

A significant number of crashes occur in work zones. Replace or do spot repairs on existing barrier systems before shifting traffic closer to or increasing traffic near existing barrier systems.

Document the following:

- Not reviewing existing barrier systems.
- Leaving a barrier system that is no longer needed in-place.
- Leaving a “modified” barrier system in-place.[44]
- Not applying spot improvements or replacing a substandard barrier system.
- Not reviewing Length-of-Need
- Not modifying existing curb or installing 4-inch sloped face curb near a barrier system.

Other issues within this subsection may need additional documentation in the DSR.

When needed, provide individual construction details to retrofit existing barrier systems.

Barrier systems may have parts that can be salvaged. Coordinate with regional maintenance staff. Provide local unit of government contact within the plan.

Both removal and salvage items have language telling the contractor to restore the site. No additional bid items are needed to fill holes left by the contractor removing posts. If installing a new barrier at the same location, earthwork items may be needed.

30.5.1 Flexible Barriers

Replace low-tension cable barrier systems installed in non-median locations (See Figure 30.35). Typically, these systems are not crashworthy, have fixed objects within a barrier’s working width, or have grading issues.

Coordinate with the WisDOT project manager, the regional design oversight engineer and maintenance personnel before removing or working near median cable barrier. Review grading, cable barrier placement, drainage structures, and soil conditions. Those items can influence performance.

Review FDM 11-45-30.3.2 for more information on cable barrier.

Desirably, remove curb and gutter near cable barrier systems.

[43] This assumes that the barrier was not lengthened to shield other hazards or to allow for proper grading for the EAT.

[44] The WisDOT project manager and the regional design oversight engineer may grant case-by-case design justifications (DJ) allowing modification of barrier system. Document the DJ in Design Study Report.

Figure 30.35 Strong Post Low-Tension Cable Barrier to be Replaced

30.5.2 Semi-Rigid Barriers

Semi-rigid barriers include:

- Non-MGS beam guard (See SDD 14B15)
- MGS beam guard (See SDD 14B42)
- Transitions to rigid barrier[45]
- Bullnoses
- Curved beam guard

General guidance can be applied to almost all semi-rigid barriers systems and special applications of semi-rigid systems. Examples are (the list is not all-inclusive):

- Damaged parts
- Missing parts
- Washer between rail and bolt head
- Working width
- LON
- Grading

There are some differences between systems. Examples are (the list is not all-inclusive):

- Depending on speed, normal non-MGS beam guard needs adjustments and specific types of curb
- Normal MGS does not need adjustments or special types of curb
- Special application of beam guard may need a special curb or cannot use curb

What works for one barrier system may not work for another system. Know what barrier systems are within a project.

In many cases, specialty applications of a barrier system has more design requirements than normal barrier system. Examples are (the list is not all-inclusive):

- MGS long-span cannot have curb installed by it.
- Regardless of speed, non-MGS long span cannot have curb installed by it.

Some circumstances may need individual construction details.

CMM 6-25 has examples of semi-rigid barrier that need repair. Table 30.11 is an example of a miscellaneous quantity sheet for semi-rigid repair items. Use the limits of the barrier installation to identify where to use bid items. For example, show stationing from post number one of an EAT to post number one of an EAT in the plan.

[45] Rigid barriers includes bridge parapets and concrete road barriers.

Table 30.11 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**

30.5.2.1 Adjustment of Steel Rail Height

Top of rail for existing non-MGS beam guard is between 27 3/4 to 29 inches.[xciii] Top of rail for existing MGS beam guard is between 27 3/4 to 32 inches.[xciv,xcv] Top of thrie beam rail is plus or minus 1 inch of the rail height 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. Do not measure rail height on damaged rail sections or at locations where erosion or other grade abnormalities would cause errors in height measurements.

Use caution when the majority of a barrier system is using the maximum height adjustment.

Use adjustment item (614.0400) by itself or with other spot improvements.

30.5.2.2 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). Show in plan when replacing thrie beam with the replacement item. Provide radii in the plan when replacing bent rail (See FDM 11-45-30.5.2.12).

Review thrie beam bullnose rail replacements. These rails may be bent and have slots. Use rail number or rail number and letter to show what rail to replace.

Do not use steel rail replacement item on EATs. EATs are proprietary products and may need special rails.

30.5.2.3 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).

Posts in foundation/soil tubes are important for the entire semi-rigid system. Replace damaged post in soil tubes. Use replace block and post item (614.0950). Show in the plan that posts being replaced is in a foundation/soil tube for bullnoses and Type 2 end treatments. Include appropriate SDDs in plan so contractors can order the correct posts.

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.

Do not use 'replace post and block' item for anchor post assemblies.

30.5.2.4 Straightening Blocks or Posts

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

30.5.2.5 Other Hardware Issues

The following issues need special provisions:

- Removing washers installed between the head of a bolt and traffic side of steel rail[xcvii,46]
- Replacing delineators that are missing
- Lapping rails in the correct direction (see SDD 14B15 or SDD 14B42) [47]
- Remove signs, mailboxes, and other objects mounted to beam guard

Figure 30.36 Sign Mounted on Beam Guard

30.5.2.6 Use of Salvage or Removal Bid Item

Use salvage and removal bid items separately. Use removal item (204.0165) if the contractor is to dispose of all parts.

Use salvage item (614.0920) to reclaim metal parts. The standard specification is not set up to reclaim wooden parts. Installing and cutting a post to proper height may make it difficult to reuse the post. Exposure to the elements may weaken wooden parts.

Use a special provision when (the list is not all-inclusive):

- Reclaiming all semi-rigid barrier parts (e.g. metal and wood)
- The contractor is to disassemble hardware. Others select what hardware they wish to have. Finally, the contractor is to dispose of the remaining hardware.

Removing a semi-rigid barrier can help other work or allow for a better-finished product. For example, an overlay project can add shoulder material. Removing the beam guard can allow proper compaction of the shoulder material.

30.5.2.7 Grading for Semi-Rigid Barriers

Review grading of existing semi-rigid barrier. Modify grading or semi-rigid barrier when grading is missing. See 11-45-30.3.1.3 for discussion of grading and shaping item. Review FDM 11-45-30.3.3.1 for more discussion on grading and other issues important to semi-rigid barriers and special applications of semi-rigid barriers. See grading options for semi-rigid barrier systems in other parts of 11-45-2, or on the SDDs.

Review grading near foundation/soil tubes. These tubes provide strength for the whole semi-rigid barrier system. Visual gaps between tube and soil reduces the amount of energy the anchors can absorb. Small gaps should have soil replaced and compacted around the tube. Replace foundation/soil tubes when a soil gap is one inch or more. Provide special provisions to reset foundation/soil tubes or replace soil around the post.

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

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

30.5.2.8 Beam Guard

Beam guard is the most often used barrier system. Use Excel spreadsheet (Attachment 30.6), Table 30.12, and Table 30.13 to decide if beam guard is to be replaced or have spot improvements. Install new beam guard for issues in Table 30.12. Other issues not in Table 30.12 may influence the decision to install new beam guard.

Table 30.12 Issues that Warrant New Barrier System

Situation	Issue	Discussion
Project	A new hazard needs shielding.	Install the current standard.
	Other work on the project needs the beam guard removed.	Install the current standard.
Beam Guard Installation	Current beam guard has 12-foot 6-inch post spacing.	This installation is not crashworthy.
	Beam guard has had poor past performance.	A new barrier system may have better performance.
	At the post, beam guard has a w-beam backup plate.[48]	The w-beam backup plate may prevent rail and post separation during a crash (see Figure 30.40).
	Beam guard has a washer installed between the bolt head and the front face of the rail (see Figure 30.42).	A washer may prevent rail post separation.[49]
	Top of steel rail is less than 24-3/4 inches tall.	It is not possible to adjust rail to an acceptable height.
	The 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.
	Total installation length (end treatments plus beam guard) is 75 FT or less. [50]	Shorter lengths of beam guard have not been crash tested. Fixed objects that are shielded by short beam guard still can be hit (see FDM 11-45-30.3.1.4).
	Beam guard is being used as a barrier system and retaining wall	See Attachment 30.26 for examples
	Beam Guard Class B is installed	Connecting beam guard directly to a 6x8 wood post allow for too much tire snag during an crash. Post spacing for Class B is 12.5 FT, which is too far apart to be effective. Often Beam Guard Class B was installed at locations where a vehicle can have a 90-degree crash.

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

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

[50] This length of beam guard only applies to terminal, beam guard, and terminal designs. Other designs (e.g. EAT, thrie beam transition and bridge parapet; EAT, beam guard, long-span, beam guard and EAT…) have different length requirements.

Figure 30.37 W-Beam Backup Plate

Table 30.13 is a list of situations that need at least spot improvements and may need replacement. Replacement of beam guard depends on the size and collective influence of spot improvements. Other issues not in Table 30.13 may influence the decision to use spot improvements or to replace beam guard.

Table 30.13 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 FDM 11-45-30.3.3.1.5).	Curb and gutter have a negative influence on beam guard performance.
	Beam guard posts cannot freely rotate in asphalt, millings, or concrete (see FDM 11-45-30.3.3.1.4).	Pinned posts increase the likelihood of beam guard not working as intended.
	Beam guard lacks working width (see Figure 30.38).	Beam guard can direct a vehicle into the fixed object (see Figure 30.37), or vehicle can lean over the barrier and strike a fixed object. See FDM 11-45-30.3.1.1
	Lack of grading behind beam guard with 6-foot 3-inch post spacing (See FDM 11-45-30.3.3.1.3).	Lack of soil behind posts increases the likelihood of beam guard failure.
	Steel rail or wooden planks are used to control erosion, water or right-of-way (see Figure 30.40)	Steel rail or wooden planks limit post rotation
	Improperly flared beam guard (see FDM 11-45-30.3.1.5)	Barrier flared improperly may not work as intended.
	Beam guard posts or blocks are missing, out of plumb, or damaged.	Missing, damaged, or out of placed hardware can influence barrier performance.
	Steel rail is Weathering or Cor-Ten steel.[51]	This steel makes it difficult to perform maintenance on.
	Total installation length (end treatments plus beam guard) is 175 FT or less. [52]	Beam guard is typically crash tested using 175 FT of barrier. Fixed objects shielded with shorter lengths of beam guard may be hit (see FDM 11-45-30.3.1.4). Review barrier for length-of-need.
	Beam guard is installed without anchorages	Beam guard uses anchorages to absorb energy.
	Steel rail is damaged.	Weakened rail may not work as intended.
	Lack of transition between beam guards with significantly different working widths (see FDM 11-45-30.3.1.1).	Beam guard may form a pocket when struck.
	Objects installed on top of beam guard (e.g. signs, mailboxes)	Beam guard is not tested with objects on top of it. These objects may penetrate the vehicle cab. Plastic delineators are acceptable when attached to block or post.

[51] 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.

[52] This length of beam guard only applies to terminal-beam guard- terminal designs. Other designs (e.g. EAT, thrie beam transition and bridge parapet; EAT, beam guard, long-span, beam guard and EAT) have different length requirements.

Figure 30.38 Utility Pole placed within Working Width of Barrier

Figure 30.39 Beam Guard Directed Vehicle into Utility Pole[xcviii,53]

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

Figure 30.40 Wood planks limit post rotation

The following situations need additional engineering to decide what action to take (this list is not all-inclusive):

- Beam guard is on slopes steeper than 10:1.
- Beam guard is over a drainage feature (e.g. bridge, box culverts, culverts, pipes).[54]
- Beam guard is shielding a vehicle from going over the top of a retaining wall or other structure.[55]
- Most of a barrier installation needs the maximum height adjustment.
- If a project has a service life greater than 15 years (see duration discussion in Attachment 20.1).

30.5.2.9 MGS Attaching to Existing Class A

Although it is possible, BPD does not recommend intermixing of MGS and Non-MGS systems. There has been no crash testing of this connection.

30.5.2.10 Treatments Near Rigid Barrier-Transitions

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

- Unconnected beam guard (see Figure 30.41)
- Beam Guard Transition to Rigid Barrier (See Figure 30.42)
- Thrie beam transitions (See SDD 14B20, SDD 14B45 and Figure 30.43)

[54] A previous construction project may have installed shorter posts, used other methods to mount the beam guard to the drainage structure, or used a long-span beam guard design.

[55] 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 crash loads.

Figure 30.41 Unconnected Beam Guard [xcix]

Figure 30.42 Beam Guard Transition to Rigid Barrier

Figure 30.43 Thrie Beam Missing Posts

There are different choices to update barriers near a rigid barrier. The choices depend on (the list is not all-inclusive):

- Type of treatment (see Figure 30.41 through Figure 30.43)
- Direction of travel
- What deficiencies are present
- Speed
- 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. Coordinate with the WisDOT project manager, the regional design oversight engineer and BOS if parapet is not shown in:

- Standard detail drawings
- LRFD Bridge Manual
- BOS's standard detail drawings

The parapet may have crashworthiness issues. For example, a parapet designed before 1964 may lack the strength to contain a crash.[c] Parapets designed after 1964 may have enough strength, but the parapet may have other issues (e.g. snagging, pocketing...).

Provide additional engineering to evaluate the parapet or develop alternative retrofit designs. Coordinate with the WisDOT project manager and the regional design oversight engineer and BOS early in the design or scoping. Crashworthiness of a parapet can have a significant influence 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[56].

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

Provide individual construction details.

Use standard semi rigid barrier adjustments bid items to provide spot improvements. Special SDDs have been developed to retrofit transitions to rigid barriers when posts are missing and cannot be reinstalled (SDD 14B48, SDD 14B49, SDD 14B50 and SDD 14B51). These special SDDs are designed for class A thrie beam

[56] Delineating a roadside hazard is the least desirable roadside design treatment and requires documentation in Design Study Report.

transitions.

Transitions to rigid barrier may also use the grading shaping item.

Figure 30.44 Problematic Thrie Beam Transition to Rigid Barrier

Figure 30.45 New Thrie Beam Transition with Drainage Problems

Figure 30.38 has a thrie beam transition to a rigid barrier. This transition has the following issues: post pinned into position by asphalt, lack of grading behind posts and inadequate post embedment.

Transitions were not designed to be curved or flared away from the road. Coordinate with the WisDOT project manager and the regional design oversight engineer when there are curved or flared installations. Provide additional engineering and special bid items.

Some older parapets were constructed with a notch in the parapet (see Figure 30.46). Approach transition SDDs have had notes on them telling contractors to install a wood block. In many cases, the block has not been installed. Use the ‘replace block’ bid item, appropriate transition SDD, and add a note in the plan pointing to the location needing a block.

In Figure 30.47, the existing combination rail has a horizontal crack, that should be discussed with BOS.

Figure 30.46 Missing Wood Block is a Snag Point

Figure 30.47 Damage to Parapet and Height of Parapet Issues

30.5.2.10.1 Unconnected Beam Guard

Unconnected beam guard near a rigid barrier is a significant hazard (i.e. Figure 30.41). The beam guard 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 like Figure 30.41 will allow a vehicle to hit the blunt end of a rigid barrier. An example of an end treatment allowing a vehicle to hit a blunt end of a rigid barrier is in Figure 30.48.

The end treatment in Figure 30.41 is a potential spearing hazard for a vehicle traveling in the opposite direction. An end treatment, like the one pictured in Figure 30.41**,** may not provide the beam guard enough strength to contain a vehicle. Review FDM 11-45-30.3.3.1.2, FDM 11-45-30.4.4, and 11-45-30.3.5.

Figure 30.48 Unconnected Beam Guard Gated or Directed Vehicle into Blunt End[ci]

If there is no other object to shield, but the blunt end, review using a crash cushion or sand barrel array. A sloped end treatment may be used on low speed roads (see FDM 11-45-30.5.6). If beam guard is needed to shield other hazards, use a thrie beam transition to a rigid barrier. In certain circumstances, a beam guard transition to rigid barrier may be used (see FDM 11-45-30.5.2.10.2).

30.5.2.10.2 Beam Guard Connected to Rigid Barrier

Beam guard connections may experience pocketing (see Figure 30.10 and Attachment 30.21) or other failures during a crash.

Figure 30.49 Pocket Formed by Vehicle Hitting Beam Guard Connected to Parapet[cii]

There may be situations where a special beam guard transition to rigid barrier could be used.

A beam guard transition to a rigid barrier is not as desirable as installing a thrie beam transition to the rigid barrier. BPD is trying to balance between allowing minor projects to advance, and providing an improvement to roadside safety.

Coordinate with the WisDOT project manager and the regional design oversight engineer if considering the use of a beam guard transition to rigid barrier.

30.5.2.10.3 Thrie Beam Transitions

Since 1990, thrie beam transitions to rigid barriers have been installed by the Department. The thrie beam transition drawings have had various changes. The preferred method 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:
  - 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 typical to replace missing posts within the thrie beam transition. Posts may conflict with drainage structures. Move drainage structures to allow for post installation. Review discussion about approach transition retrofits in FDM 11-45-30.5.2.10.

Existing curb and gutter may remain in-place. Review guidance provided in FDM 11-45-30.3.5.

Some thrie beam transitions to single slope barrier are missing the connector plate detailed in SDD 14B45. Without these plates installed, a tire may snag on the blunt end of the thrie beam anchorage. To install plates, use a special provision and SDD 14B45. Write special provision to install the connector plate and reset approach transition.

If using the 'replace rail' item, note that a thrie beam rail or thrie beam transition piece is being replaced in the miscellaneous quantities.

30.5.2.11 Bullnoses

WisDOT has utilized at least four different bullnose designs. Only the steel post thrie beam bullnose design has been successfully crash tested to MASH The four systems are:

- Downturned end treatment bullnose (See Figure 30.50)
- Bent beam guard bullnose (See Attachment 30.7)
- All Wood Post Thrie Beam Bullnose (SDD SSD 14B26 Version 1-3)
- Steel Post Thrie Beam Bullnose (SDD14B26 Version 4 to present)

Replace downturned end treatment bullnoses, bent beam guard bullnoses, and all wood post thrie beam bullnoses. Steel post thrie beam bullnoses may remain in-place if they are installed correctly and are in good working order. Review thrie beam bullnose installations for other issues that may influence performance (e.g. grading, working width, curb and gutter, fixed objects too close to rails 1 and 2 of bullnose, missing or damaged components).

Remove curb on the approach to, and along the side of bullnoses. 'Grading at Bullnose' drawing in SDD 14B26 sheet A has the approximate area where curbs should be removed. If curb cannot be removed follow guidance in the beginning of FDM 11-45-30.

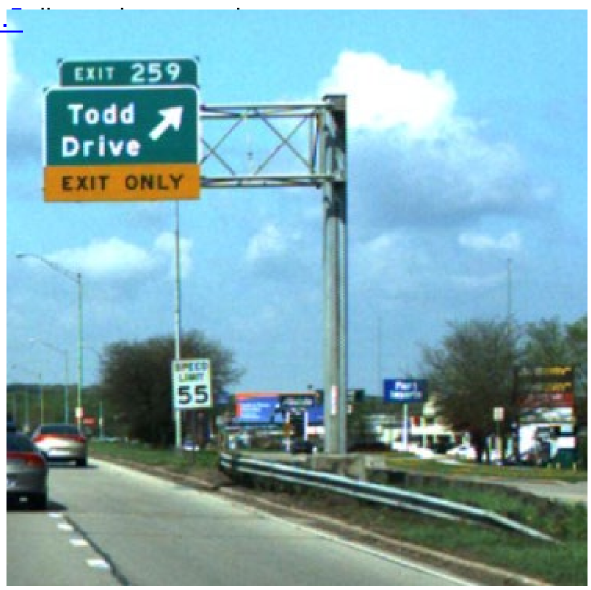

Figure 30.50 Downturned Bullnose Design

Vehicles hitting the nose of the bullnose need the area behind the rail to stop. Figure 30.51 and Figure 30.52 show the final resting place of some crash test vehicles.

SDD 14B26 shows where objects should not be placed within a thrie beam bullnose. Remove objects, even if they are breakaway, from this area. The trees in Figure 30.53 will cause a bullnose not to work correctly.

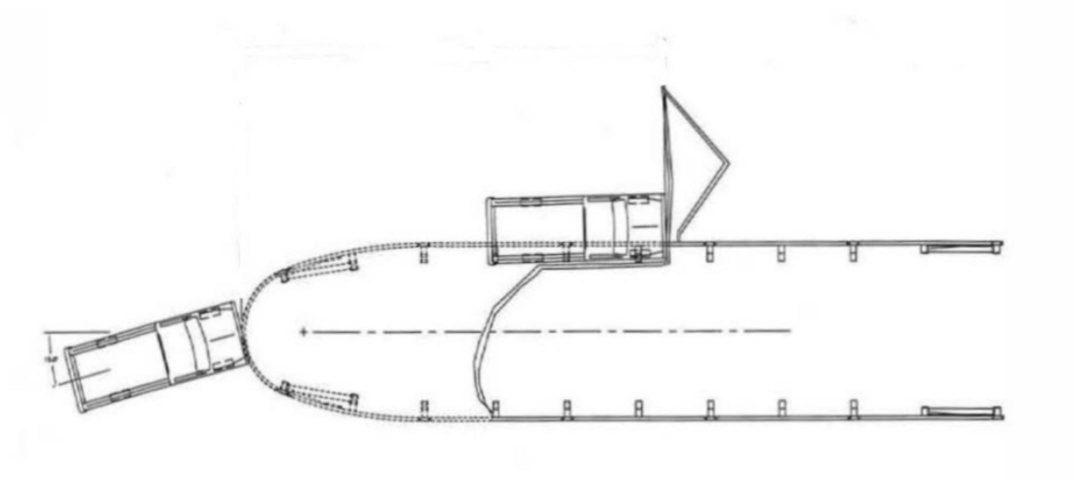

Figure 30.51 Offset Nose Crash Test with Pick-up Truck[ciii]

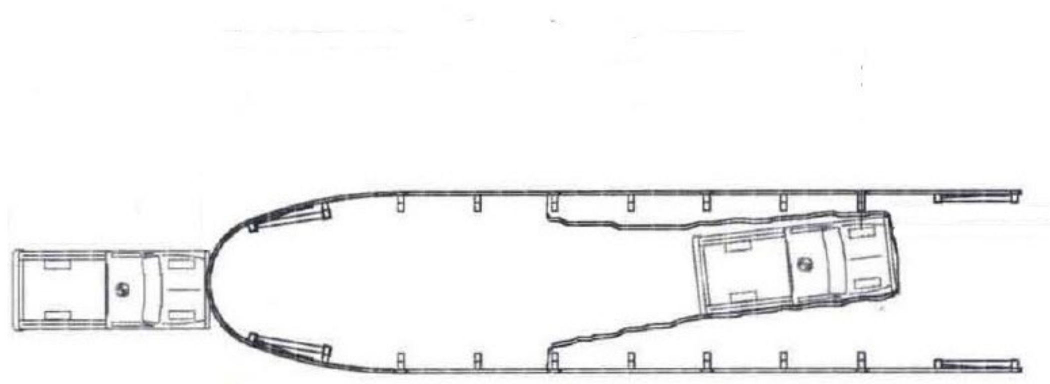

Figure 30.52 Head-on Crash Test with Pick-up Truck[civ]

Figure 30.53 Trees placed within Bullnose

Remove objects that are within the working width of the sides of the thrie beam bullnoses.

30.5.2.12 Curved Beam Guard

Curved beam guard is any beam guard that is bent to a radius.[57] In general, WisDOT does not want to use curved beam guard because of cost, longer repair time, and crashworthiness issues. However, site specific or project related issues may allow the use of a curved beam guard. For example, crashing into curved beam guard may be more desirable than crashing into a different hazard.

Review curved beam guard with radiuses 150 feet or less. Use SDD 14B27, SDD 14B53, and 11-45-30.3.3.2 to review existing hardware. Implement spot improvements or full replacement of curved beam guard sections that do not match SDDs or FDM. Replace short radiuses that are less than 8 FT with a larger radius system or other hardware.

Provide individual construction details.

The short radius system may need more right-of-way. Review right-of-way early in design.

Figure 30.54 Problematic Short Radius with installation Problems

The installation in Figure 30.54 has the following issues:

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

- Not using CRT post in radius
- Not enough beam guard along the low volume road
- Wrong end treatment
- curb and gutter

30.5.3 Concrete Barriers

WisDOT has used various shaped concrete barriers (See FDM 11-45-30.3.6). Issues in Table 30.14 require a new concrete barrier. Other issues not in Table 30.14 may influence the decision to install a new concrete barrier.

Table 30.14 Issues that Warrant New Concrete Barrier

Situation	Issue	Discussion
Project	Shielding a new hazard.	Install the current standard.
	Other work requires the removal of a whole run of concrete barrier.	Install the current standard.
	Structural protection is needed (FDM 11-35-1).	LRFD crash loads need special barrier designs.
Concrete Barrier	The barrier is GM shaped.	GM shaped barrier has not passed NCHRP 350 testing.
	Concrete barrier does not match NJ, F, single slope or vertical shapes (See FDM 11-45-30.3.6).	Barrier shape is a non-crash tested design.
	A concrete barrier flare rate is too steep. See FDM 11-45-30.3.1.5.	Barrier flared too steep may not work as intended.
	Overlays greater than 2 inches adjacent to a NJ, or F shaped barrier (see Figure 30.55).	NJ and F shaped barriers can allow up to 2 inches of overlays.[cv]
	Single slope barrier with a height less than 32 inches (see Figure 30.55).	Shorter single slope barriers may have difficulties redirecting larger vehicles.

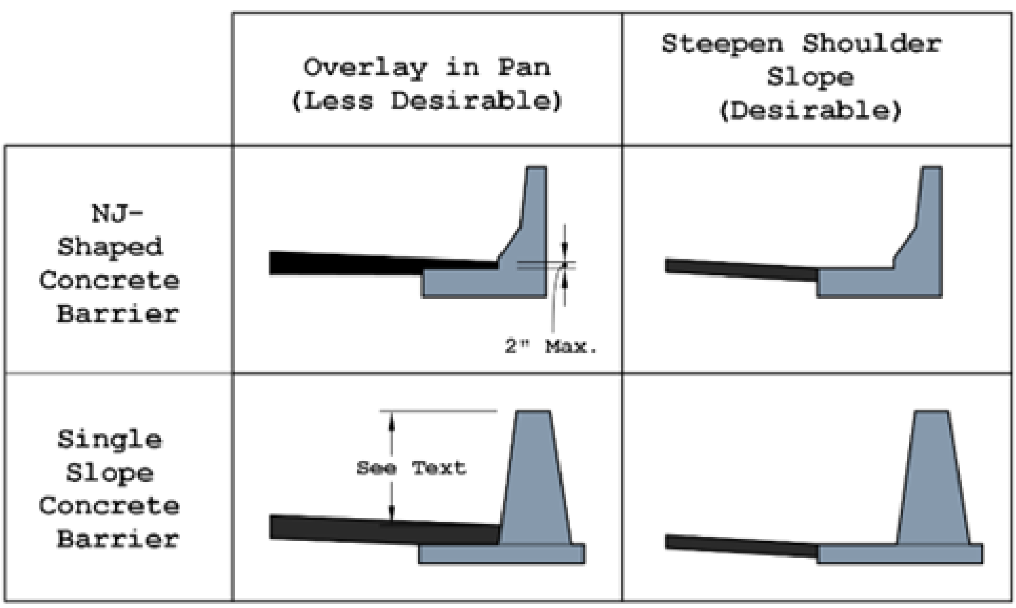

Figure 30.55 Overlays near NJ, F, and Single Slope Barriers

Vehicles can vault over or hit objects just behind shorter concrete barrier. From a roadside design perspective, it is more desirable to steepen paved shoulder slopes when overlaying near concrete barrier. Steepening the shoulder slopes can maintain the height of the barrier.[58] Sometimes combining milling with steeper shoulders will minimize or prevent reducing the height of concrete barrier. It may not be possible to steepen shoulder slope to avoid reducing concrete barrier height.

Overlays alongside the barrier (Left side of Figure 30.55) may cause drainage issues. To address potential drainage issues it may be necessary to adjust inlets or use inlet risers.

The minimum height of single slope barrier with overlays is 36 inches on freeways and expressways with a design speed greater than 45 mph. On other roads, single sloped concrete barriers with overlays can have a a height of 32 inches . Replace any single slope barrier with a height less than 32 inches.

An existing 3 inch overlay adjacent to a safety shaped barrier may remain in place based on an analysis of barrier crashes.

- Barrier induced rollovers are 6% or less.
- Crash where the vehicle did not roll over before impact.
- After impact the vehicle did not strike another object and then roll over.
- Vaulting over the barrier, vehicle resting on top of, vehicle strikes object on top of or behind barrier 5%

Avoid reducing barrier height in the following locations:

- Fixed objects are close to the barrier
- Consequences of a collision is severe
- Pick-up trucks or smaller vehicles have ridden on top of, hit fixed objects on the barrier or vaulted over the barrier
- Crash history of large vehicle crashes into a barrier

Table 30.15 is a list of situations that would need at least spot improvements and may need the concrete barrier to be replaced. Replacement of concrete barrier depends on the size and collective influences of spot improvements. Other issues not in Table 30.15 may also influence the decision to use spot improvements or fully replace concrete barrier.

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

Table 30.15 Issues that Warrant Spot Improvements

Situation	Issue	Discussion
Project	The project needs to partially remove concrete barrier to make repair work easier.	Shorter sections of concrete barrier can be replaced in kind
Concrete Barrier Installation	Police reports show that vehicles are vaulting over, riding on top of, or striking objects behind, on top of the barrier.	See discussion below.
	Concrete barrier has open cracks that extend through the barrier (see Figure 30.59 through Figure 30.61).	Concrete barrier with open cracks may fail during a crash or launch projectiles at other vehicles or pedestrians.
	A concrete barrier has exposed or rusted reinforcement.	The concrete barrier is structurally weak and may fail during a crash.
	A concrete barrier is tipping over or faulting (see Figure 30.56).	The concrete barrier may snag a vehicle during a crash.
	Sections are more than 2 inches offset from each other (See CMM 1-45.12.5.9 for examples).	The concrete barrier may snag a vehicle during a crash
	A concrete barrier has an opening greater than 4 inches long (See CMM 1-45.12.5.9 for examples).	The concrete barrier may snag a vehicle during a crash.
	A concrete barrier has open gaps (see Figure 30.58).	The concrete barrier may snag a vehicle during or fail during a crash.
	A concrete barrier has abrupt changes in cross-sectional area (see Figure 30.57).	The concrete barrier may cause rapid deceleration or launch vehicle into opposing lanes.
	Curb and gutter is in front of a concrete barrier.	Concrete barrier may not work as intended when curb is in front of it.
	A concrete barrier has a blunt end.	Blunt ends not a crashworthy.

Issues like Figure 30.56, will need limited engineering effort (i.e. remove the barrier and replace with new). Other issues, like Figure 30.57, Figure 30.58, Figure 30.59 and barrier openings (see CMM 1-45.12.5.9), will need more engineering effort. Coordinate with the WisDOT project manager and the regional design oversight engineer early in design.

Review FDM 11-45-30.5 for guidance on curb. Review FDM 11-45-30.3.6 for guidance on concrete barrier design.

Special provisions and construction details may be needed.

Use bid item 204.0157 to remove the concrete barrier. Use this bid item to remove transitions, standard sections of concrete barrier and concrete anchorages.

Acceptable repairs to concrete barrier depend on (the list is not all-inclusive):

- Extent of the repair
- What part of the concrete barrier system needs work
- Type of barrier

The extent of repairs may be minor. For example, repairing cracks on the concrete barrier (damage like Figure 30.59 through Figure 30.61), may not provide structural strength for critical crashes. Repairing cracks may help reduce future deterioration of the barrier, limit snag, limit the size of barrier fragments from a crash, and provide some shielding for less than critical crashes.

Issues like Figure 30.59 through Figure 30.61 may be only a few feet of repair. Other issues, such as Figure 30.56 may be hundreds of feet long.

Issues like Figure 30.57 can cause excessive deceleration, damage to object on barrier, and abruptly redirect a vehicle back into the lanes of travel. Modification to situations similar to Figure 30.57 will need more engineering.

Repairs near the end of a concrete barrier, transition, or bridge parapet may need vertical steel. Not providing vertical reinforcement near the end of the barrier may lead to barrier failure. Not adjusting the shape of a barrier could lead to wheel snag, excessive deceleration, or vehicle rollover. Situations like this may require removal of an end or transition.

Review FDM 11-45-30.3.6.4 and SDD 14B32 to SDD 14B41 when repairing single slope barrier and transitions.

Single slope barrier, SDD 14B32 sheet E provides guidance on how to repair or replace sections standard single slope barrier.

Use details like Attachment 30.22 to fully replace middle sections of older safety shaped concrete barrier designs.

Provide additional engineering, special details, individual construction details, special provisions when doing improvements to existing concrete barrier. Coordinate with the WisDOT project manager and the regional design oversight engineer early in the design.

Figure 30.56 Concrete Barrier Tipping Over

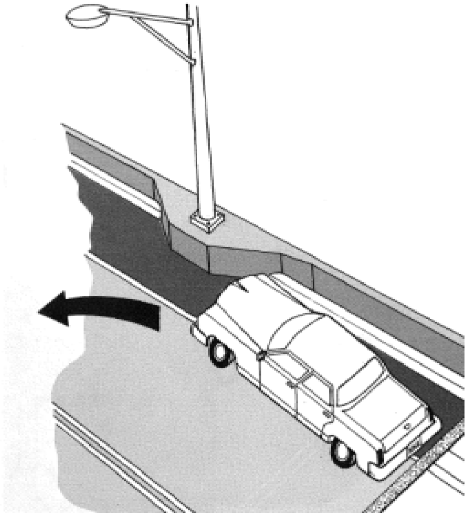

Figure 30.57 Cross-Sectional Changes in Barrier[cvi]

Figure 30.58 Opening in barrier that can snag a vehicle [cvii]

Figure 30.59 Cracked Concrete Barrier Needing Repair

Figure 30.60 Cracked Concrete Barrier Needing Repair

Figure 30.61 Cracked Concrete Barrier Needing Repair

30.5.4 End Treatments

Review guidance in FDM 11-45-30.4.

Replace existing downturned (Figure 30.65) or blunt terminal ends (see Figure 30.62 and Figure 30.63), including breakaway cable terminals (BCTs) (see Figure 30.64) and modified eccentric loader terminal (MELT) systems (see Figure 30.66), with appropriate anchorages.

SRT-350 terminals (Figure 30.67) may remain in-place if they are in good working order and installed correctly.

Figure 30.62 Blunt Ends

Figure 30.63 Blunt Ends [59]

Figure 30.64 BCT terminal [cviii]

Figure 30.65 Downturned End Treatment

[59] 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.

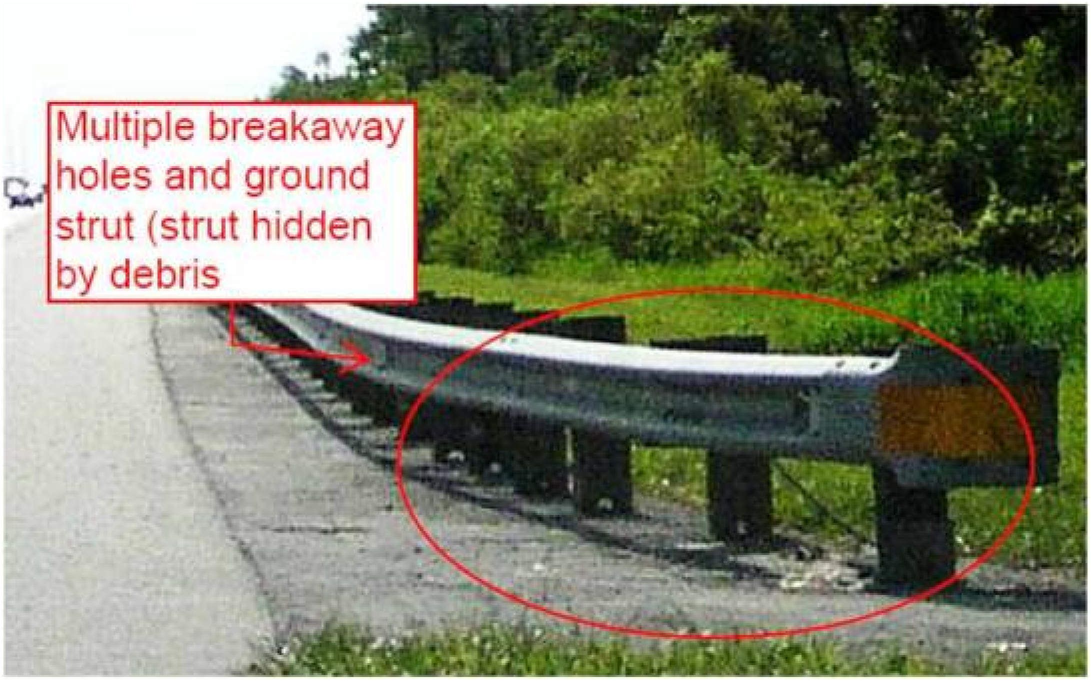

Figure 30.66 MELT [cix]

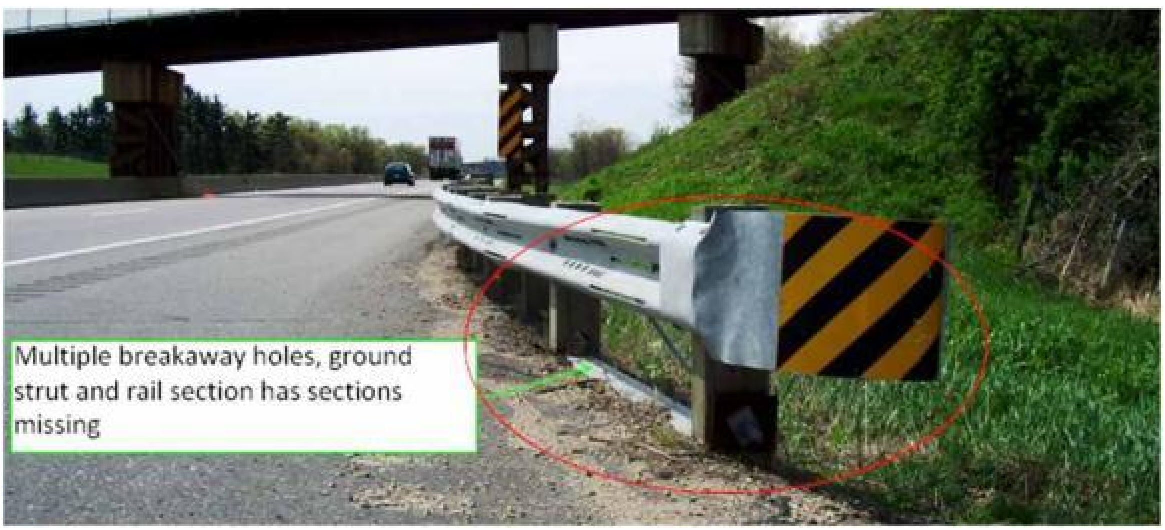

Figure 30.67 SRT-350 [cx]

Older NCHRP 350 crashworthy EATs may remain in-place if they are in good working order:

- ET-2000 (See Figure 30.68)
- SKT-350 (See Figure 30.69)
- ET-Plus (See Figure 30.70)

Figure 30.68 ET-2000

Figure 30.69 SKT-350

Figure 30.70 ET-Plus

If an older EAT is not in working order, replace with a newer crashworthy terminal.

Review existing terminals for proper grading, hardware, and rail height, reflective sheeting and EAT. The terminals uses the same height and height tolerance as the semi-rigid barrier it is attached to. Provide appropriate grading. See appropriate section of FDM for guidance on grading. Coordinate with the WisDOT project manager and the regional design oversight engineer if there is an issue with grading.

Replace existing beam guard end terminals that are too close to one another (see Figure 30.30).

Beam guard end terminals are not designed for backside hits.

Review FDM 11-45-30.4.1.6 for guidance on curb and gutter placement near existing beam guard end terminals. Consider sawing the head of the curb, if full removal is not necessary.

Provide individual construction detail drawings for beam guard end terminals retrofits.

Extend beam guard far enough downstream to prevent a vehicle from gating through Type 2 end terminal and hitting a hazard (see FDM 11-45-30.4.3).

A broken post in an end treatment may limit the effectiveness of a barrier system. Review end treatments for broken posts and replace these posts. Use special provisions, special detail drawings of the post, and indicate where a post is to be replaced. Note that posts within the EAT are proprietary. These post need to come from the manufacturer. A project may need to have multiple special provisions to replace posts for various beam guard end treatments.

Remove objects attached to beam guard end terminals (e.g. signs, mailboxes…). An object attached to beam guard end terminal could penetrate into the vehicle cab.

Figure 30.71 Sign Mounted to Post 2 of and EAT

Beam guard end terminals using a cable attached to a foundation/soil tube need to review cable tension. The cable transfers crash forces to soil tubes. Slack cables may allow too much rail movement during a crash.

Visual gaps between foundation/soil tubes and soils around the tube reduces the amount of energy the beam guard system can absorb. Small gaps should have soil replaced around the tube and compacted. Replace foundation/soil tubes when a soil gap is one inch or more. If there are issues with gaps around foundation/soil tubes, provide special provision fix the foundation/soil tube problem.

30.5.5 Crash Cushions and Sand Barrel Arrays

Issues in Table 30.16 need new crash cushions or sand barrel arrays. Other issues not in Table 30.16 may also influence the decision to install a new crash cushion or sand barrel array.

Table 30.16 Issues that Warrant New Crash Cushion or Sand Barrel Array

Situation	Issue	Discussion
Project	A new hazard needs shielding.	Install the current standard.
	Other work needs the crash cushion or array removed.	Install the current standard.
Crash Cushion or Sand Barrel Array Installation	The crash cushion is a GREAT (see Figure 30.72 and Figure 30.73).	GREAT does not meet the current crash test standard.
	Crash cushion or array was installed before October 1, 1998.	Systems installed before this date do not meet current crash test standards.
	Crash cushion or array has had poor past performance.	A newer crash cushion or array may perform better.

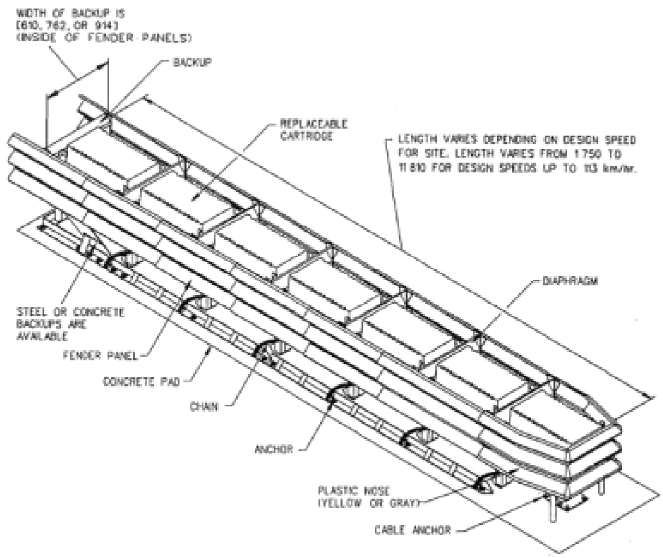

Figure 30.72 GREAT Crash Cushion[cxi]

Figure 30.73 Photo of GREAT installation

Table 30.17 is a list of situations that would need at least spot improvements and may need replacement. Replacement depends on the size and collective influence of spot improvements. Other issues not in Table 30.17 may also influence the decision to provide spot improvements or fully replace a crash cushion or array.

Table 30.17 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.	A paved surface anchors the crash cushion. The crash cushion may not work without a paved surface.
	Paved surface is in poor condition	A paved surface anchors the crash cushion. The crash cushion may not work without a paved surface.
	The crash cushion is not anchored into a paved surface.	If the crash cushion is not anchored into a paved surface the crash cushion may not work.
	Curb and gutter is on the approach or alongside the crash cushion or array.	Curb can have negative influences on performance.
	Grading from the edge of lane to the crash cushion or array is steeper than 10:1. Grading under the array or crash cushion is 10:1 or flatter.	A vehicle may not engage the crash cushion or array correctly.
	The array is 10 or more years old.	Older barrels are likely to fail because of exposure to UV rays. (e.g. yellow barrels look more like gray barrels or barrels are brittle)
	Connections between the object being shielded and crash cushion are missing.	Lack of a transition may allow the object that crash cushion is shielding to be hit. Transitions are needed on both sides of the crash cushion.
	Crash cushion or array has missing, improperly installed, or damaged parts.	The system may not work.

Review FDM 11-45-30.4.4 for more guidance on crash cushions or arrays.

Remove curb and gutter before and along arrays and crash cushions. Use driveway curb. If driveway curb cannot be used, use a 4-inch mountable curb.[cxii]

Review existing arrays using procedures in 2011 Roadside Design Guide, or manufacturer's most current array information. Replace arrays that are not to the NCHRP 350 crash test standard. If it is not possible to fit a new array into an existing location, review the use of a crash cushion.

Review arrays for:

- Minimum distance between barrels
- Minimum distance from barrels to object being shielded
- Correct number of barrels
- Correct weight of sand at the correct location
- Rock salt is mixed with sand

Existing barrels warp over time and may not accept new lids. Replace older warped barrels. If most of the barrels in an array need replacement, replace the whole array.

If feasible, adjust existing arrays using the following guidance:

- For bidirectional, arrays install some barrels to reduce the severity of reverse direction crashes (see Figure 8-41 of 2011 Roadside Design Guide).
- Angle arrays toward traffic (see Figure 8-42 of 2011 Roadside Design Guide).

Figure 30.74 Problematic Sand Barrel Array

Figure 30.74 is a problematic array. The array has the following issues: curb and gutter, no pad, and a damaged barrel.

Use special provisions to refurbish crash cushions. Include the name of the manufacturer, the name of the specific crash cushion. Point out what work the crash cushion needs in the special provisions. If multiple systems are within a project, use different special provisions for each crash cushion. Provide individual construction details when grading, installing a pad or a back-up block, or adjusting curb near a crash cushion.

Use special provision to repair individual barrels within an array. Provide individual construction details showing which barrel to replace and its' weight. Reference WisDOT's Product Approval List for arrays when using a special provision.

Use standard bid item to replace the whole array. Provide individual construction details when grading, installing a pad, or adjusting curb near array.

30.5.6 Sloped Concrete End Treatments

Replace approach sloped concrete end treatments with a crashworthy option. As previously stated, the Department does not want to install or leave sloped end treatment in areas where crashworthy treatments are feasible.

There could be existing site specific issues that may allow a sloped end treatment to be retrofitted at a location (i.e. slope end treatment is better than an exposed blunt end and sight restriction prevent installing a crashworthy option). Coordinate with the WisDOT project manager and the regional design oversight engineer when retrofitting a sloped end treatment.

Retrofitting in a new sloped end treatment into an existing location when all the following criteria exist:

- Design speeds are 40 mph or less
- Other road features prevent the proper installation of crash tested hardware
- Barrier has LON to protect roadside hazards
- 10:1 or flatter grading is present leading to and alongside the sloped end treatment

Sloped concrete end treatment will require additional engineering, special details and special provisions. See FDM 11-45-30.3.6.4.6 and Attachment 30.8 for guidance. Attachment 30.8 has an acceptable sloped concrete end section. Other "sloped" concrete sections that do not match the barrier design in Attachment 30.8 (such as Figure 30.75 or SDD 14B20 sheet c) are considered blunt ends.

Attachment 30.8 is a sloped concrete end treatment designed to match into a 32-inch F shaped barrier. To match into a taller barrier, extend slope to reach correct height. To match into a different shaped barrier, use similar geometry and transition to shape needed. The length of the sloped concrete end treatment will be 20 feet or longer. The length of the sloped concrete end treatment depends on the height of barrier matching into it.

Flare the sloped concrete end treatment. Extend slope concrete end treatments to limit the likelihood that a vehicle will ride up the sloped end treatment and interact objects nearby.

No curb or gutter should be leading into or alongside the sloped concrete end treatment. See FDM 11-45-30.5 for guidance on curb and gutter.

Figure 30.75 A “Sloped” End Treatment that Needs Replacement

Provide individual construction detail drawings and special provisions.

30.6 Drainage Features and Cattle Passes

Drainage features like culverts, bridges, large drainage conduits, and similar features have unique challenges. These challenges can make it difficult to select a roadside treatment. Cattle passes or similar features can have the same roadside design challenges. This section will discuss common challenges and potential roadside design treatments for these features.

Drainage features or cattle passes can be a hazard depending on orientation, the 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 30.18 Drainage Feature or Cattle Pass Size [cxiii]

Pipe Orientation to Road	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

If a part of the structure snags the undercarriage of a vehicle or the vehicle’s bumper can hit the structure, the culvert is a hazard. The culvert is a hazard regardless of the opening size. Examples are (the list is not all-inclusive):

If a vehicle can fall into the culvert opening and hit the inside of a wing wall (see Figure 20.5)

If a headwall can snag the undercarriage of a vehicle (see Figure 20.6 and Figure 20.34)

Drainage features that are equal to or smaller than the values listed in Table 30.18 are not roadside hazards. However, consider treating smaller parallel drainage features. Treating smaller parallel drainage features is a best practice.

Also, other objects near a drainage feature or cattle pass can be considered a hazard (refer to Figure 30.77 and Figure 30.78). Examples are (the list is not all-inclusive):

- Water [60]

[60] Water 2 feet or deeper.

- Slopes
    - Leading to and departing from drainage feature.
    - Slopes that blend into drainage feature.
- Ditches
    - Non-traversable road's ditches.
    - Drainage ditches' slopes (i.e. non-road ditches).
    - Blending slopes:
        - Road backslopes and drainage ditch slopes.
- Other fixed object hazards.
- Overall drop from structure to ditch bottom.[61]

Other hazards typically increase the traveling public's crash exposure (refer to Figure 30.76) and may influence what treatments are used near the culvert. Some examples are (the list is not all-inclusive):

- Shielding may be a better option if there is deep water present
- A traversable grate may be a better option than extending a culvert if there is adequate existing grading

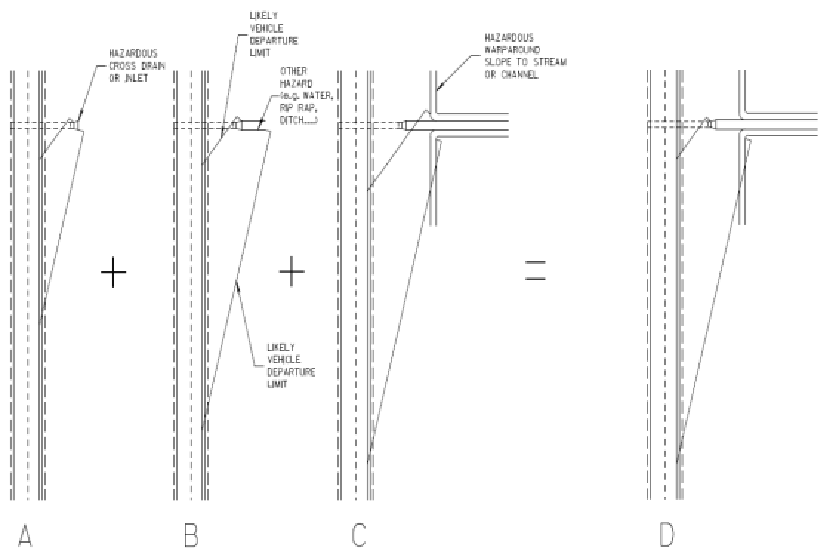

Figure 30.76 Likely Exposure Limits for Vehicles to Hazards (one direction of travel only)

[61] Vertical drops of 8 feet or more are hazardous. Vertical drops of 6 feet or more combined with other hazards (e.g. riprap or water) are hazardous.

Figure 30.77 Water and Culverts are Hazards

Figure 30.78 Overall height of this box culvert would need shielding. Edge of box culvert is just beyond clear zone.

Some of the alternatives to treat drainage features and cattle passes may need hydraulic analysis. See FDM Chapter 13 for more information.

Provide individual construction details for barrier systems or safety hardware near drainage features or cattle passes.

Use FDM 11-45-30.6 on perpetuation, rehabilitation and modernization projects. Guidance may apply to some Preventive Maintenance (PM) projects. The type of work within the PM project influences what roadside treatment is used. Some examples are in Table 30.19 and it is not all-inclusive.

Table 30.19 Roadside Treatment for Drainage Features or Cattle Pass on PM Projects

Type of PM Project or Work Being Performed	**Traversable Grate**	**Extend, Remove or Move**	**Shield**	**Delineate**
Drainage Restoration Project	X	X	X	X
Restoring grading near drainage feature or cattle pass	X	X	X	X
Restoring or installing riprap			X	X
Removing a barrier system for a culvert and installing a traversable grate	X			
Project is crack sealing and upgrading signage				X

Coordinate early with the WisDOT project manager and the regional design oversight engineer to decide on a roadside treatment. If a drainage feature or cattle pass cannot be addressed within a PM project, program a future project to address the issue.

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

30.6.1 Perpendicular Drainage Features (Cross Drains) and Cattle Passes

This subsection deals with drainage features and cattle passes that are perpendicular or skewed to the direction of mainline travel. Treatments available are (in order of preference):

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

30.6.1.1 Traversable Grates

From a roadside design perspective, traversable grates are the recommended treatment. In general, traversable grates have lower installation and crash costs than other treatments. Traversable grates can have a lower maintenance cost than a barrier system.

Do not install traversable grates on cross-drains for navigable waterways.

Review hydraulic capacity of cross-drains before installing traversable grates.

Refer to FDM 11-45-30.2.10 for a warrant on using traversable grates for perpendicular drainage features (cross drains).

See SDD 8F8 for traversable cross drain culvert grates. Steel traversable culvert grates can be used with concrete culverts. SDD8F8 has a “Steel Adapter Sleeve for Concrete Pipe” drawing.

It is not possible to mix traversable cross-drain culvert grates of SDD 8F8 with traversable parallel grates of SDD 8F7. The number of bars, bar orientation, and bar spacing is different.

Traversable grates in SDD 8F8 have a wide bar spacing that minimizes the likelihood of a drainage feature being clogged by small objects. To minimize the risk of a large object clogging a drainage feature, install a traversable grate on the upstream end of the drainage feature. Install a traversable grate on the upstream end of a pipe even if it is beyond the clear zone.

Document the decision, in the DSR, not to install a traversable grate from SDD 8F8 because of maintenance concerns.

Traversable grates on SDD 8F8 are not appropriate for cross-drains or similar features with significant skew. Provide additional engineering, special details and special provisions. Contact the WisDOT project manager and the regional design oversight engineer for more information.

Significantly larger drainage features can have specially designed traversable grades similar to what is in SDD 8F8. Provide additional engineering, special details and special provisions. Coordinate with the WisDOT project manager and the regional design oversight engineer early in design.

Figure 30.79 Larger Traversable Grate[62]

Inlets with appropriate inlet covers could also be used to make a drainage feature traversable. Normal inlet covers may be more prone to clogging. A number of different inlet types could be used to make a drainage feature traversable. Median inlets can be used along a roadside to make a drainage feature traversable. Slopes may need to be adjusted similar to what is in SDD 8C8.

Mortar rubble masonry endwalls (older standard), or concrete masonry endwalls (SDD 8F10), may need special provisions, and individual construction drawings to use a traversable grate. Coordinate with the WisDOT project manager and the regional design oversight engineer.

Provide grading for traversable grates. On projects with significant grading, match the new traversable foreslope.

For projects doing spot improvements, a traversable grate may need individual construction detail drawings and cross-sections. Attachment 30.9 shows typical grading limits for a culvert extension, but can be used as a guide to define the area that needs grading for a traversable cross-drain.

Do not rely on a generic drawing like Attachment 30.9 as the sole source of grading information for installing a traversable grate.

30.6.1.2 Extend, Remove or Move Perpendicular Drainage Features (Cross Drains) or Cattle Pass

In general, extending cross-drains or cattle passes will have higher construction costs and will result in lower crash costs than placing traversable grates. Extending a smaller drainage feature is simpler and less costly than extending a larger feature. Extending a large cross-drain or cattle pass is more likely to need coordination with BOS, environmental work, review of hydraulic capacity, right-of-way, and grading.

Review using a traversable grate before extending a cross-drain. Extending a culvert or cattle pass may be the best treatment 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, riprap...). In some case, shielding may be a better treatment than extending a cross-drain or cattle pass.

If extending a cross-drain or cattle pass use the desirable clear zone value adjusted for AADT, speed, and curvature. See FDM 11-15 Attachment 1.9 and 1.10.

Provide grading for cross-drain or cattle pass extensions. For projects doing spot improvements, pipe extension may need individual construction detail drawings and cross-sections. Attachment 30.9 shows typical grading limits for a culvert extension. Do not rely on a generic drawing like Attachment 30.9 as the sole source of

[62] Final grading by grate not completed. Bottom of grate has a hinge to allow for easier maintenance.

grading information. Check drainage. Avoid making a non-traversable “hump” of soil over pipe extension (see FDM 11-45-30.6.2.1).

Remove unnecessary cross-drains or cattle passes. FDM 11-55-10 addresses unnecessary cattle passes. Installing a drop inlet can “remove” a cross-drain.

Occasionally, cross-drains or cattle passes can be moved. For example, moving a cattle pass out of a curve to a tangent section will reduce crash frequency. When relocating a cross-drain or cattle pass, extend the new cross-drain or cattle pass to the desirable clear zone distance.

30.6.1.3 Barrier Systems

Review using more desirable treatments before shielding.

Barrier systems can shield other roadside hazards near cross-drains or box culverts. Previous roadside design treatments may not be able to address other hazards.

Refer to FDM 11-45-30.2.12 for warrants to shield larger culverts.

Some difficulties with installing barrier systems are (the list is not all-inclusive):

- Lack of cover over the cross-drain or cattle pass.
- Lack of room between posts for drainage feature or 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.
- Maintaining a barrier system
- Barrier system may make a structure too narrow

Lack of soil cover can limit barrier alternatives available (see FDM 11-45-30.3.3.1.4). Treatments for a low fill situation are:

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

Barrier systems need length up station and down station to shield hazards. If there are driveways or side roads within 125 feet of the cross-drain, or a cattle pass, it may be difficult to install a barrier system. Options are:

- Move driveway or cross street
- Move cross drain or cattle pass
- Taper semi-rigid barrier (see FDM 11-45-30.3.1.2 and FDM 11-45-30.3.1.5)
- Install a short radius system

Figure 30.80 Culvert by Driveway

The cattle pass in Figure 30.80 has both a driveway very close, little cover over the culvert and little to no room on top to install a barrier system. These issues combine to make it difficult to install a barrier system. It is likely that without some extension of the cattle pass, a barrier system may be difficult to install.

All barrier systems need some grading. Grading near the cross-drain or cattle pass may prevent using a given barrier system. For example, existing location may not have the room to install grading per typical MGS design.

If these options cannot fit a location, coordinate with the WisDOT project manager and the regional design oversight engineer. Additional engineering, individual construction details, and special provisions may be needed.

Coordinate with BOS when attaching a barrier to a box culvert or cattle pass. Some examples of why coordination is needed are (the list is not all-inclusive):

- Barrier system influences structural rating
- Attaching to box culvert or cattle pass needs structural analysis
- Condition of box culvert or cattle pass may influence hardware selection.

Provide additional engineering. Special provisions and individual construction details may be needed.

Discuss with maintenance staff and BOS before bolting through a box culvert with permanent water in it.. See SDD 14B51 to attach beam guard to a shallow fill box culvert.

30.6.1.4 Delineate

If other roadside design treatments are not feasible, delineate a hazardous cross-drain or cattle pass within the clear zone. Use SDD 15A7. Refer to MUTCD 2C.63 and 2C.65.

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

30.6.2 Parallel Drainage Features

Parallel drainage features are typically access points to the highway (e.g. driveway, side road, median crossover).

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

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

30.6.2.1 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 cross-drain grates.

Do not install traversable grates on parallel drains for navigable waterways.

Review hydraulic capacity of parallel drains before installing traversable grates.

Review FDM 11-45-30.2.11 for a warrant to install traversable grates on parallel culverts.

Refer to SDD 8F7 for information on traversable grates for parallel culverts. Steel traversable culvert grates can be used with concrete culverts. SDD 8F7 has a “Steel Adapter Sleeve for Concrete Pipe” drawing.

It is not possible to mix traversable cross-drain culvert grates of SDD 8F8 with traversable parallel grates of SDD 8F7. The number of bars, bar orientation, and bar spacing is different.

In general, parallel drainage features are less likely to clog than cross-drains. Grates in SDD 8F7 are less likely to be clogged by small objects. To minimize the risk of a large object clogging a drainage feature, install a traversable grate on the upstream end of the drainage feature.

Inlets with appropriate inlet covers could also be used to make a drainage feature traversable. Normal inlet covers may be more prone to clogging. A number of different inlet types could be used to make a drainage feature traversable. Median inlets can be used to make a parallel drainage feature traversable. Slopes may need to be adjusted similar to what is in SDD 8C8.

Mortar rubble masonry endwalls (older standard), or concrete masonry endwalls (SDD 8F10), may need special provisions, and individual construction drawings to use a traversable grate. Coordinate with the WisDOT project manager and the regional design oversight engineer.

Provide grading for traversable grates. Provide individual construction details and cross-sections for traversable grate. See Attachment 30.10 for example. Do not rely on a generic drawing like Attachment 30.10 as the sole source of grading information. Select traversable grate and transverse slope using the following table:

Table 30.20 Maximum Parallel Slope to the Direction of Travel [cxiv] [cxv]

Posted Speed (mph)	Maximum Parallel Slope to the Direction of Travel
<35	4:1
≥ 35 to <60 *	6:1
≥60 *	10:1

* 20:1 is more desirable for freeways, expressways, and divided highways.

Flatter slopes are acceptable. Inlets using 10:1 or flatter slopes may have to be cast-in-place. Drop inlets may be a more desirable option.

Flatter slopes are recommended in the medians of freeway, expressways and other divided highways. Vehicle trajectory after hitting steeper slopes in median slope could launch vehicle into opposing traffic.

Other locations may have slopes perpendicular to the direction of travel. Examples are (the list is not all-inclusive):

- a parallel drainage feature sticking out of the foreslope
- median berm near a thrie beam bullnose installation.

These locations may need flatter slopes than what is in the table above.

30.6.2.2 Remove or Move Structure

Remove parallel drainage features that are no longer needed. One possible way of "removing" a parallel drainage features is to combine closely spaced parallel drainage features into one feature.

Installing a culvert and inlet between driveways or side roads can remove a drainage feature and associated slope.

It may be possible to move a parallel drainage feature to a location where run off the road crashes are less frequent. Review Figure 3-11 of 2011 Roadside Design Guide.

30.6.2.3 Barrier Systems

It can be difficult to install a barrier system to protect a parallel drainage feature and associated slopes. Use a short radius system to wrap beam guard around the parallel drainage feature and associated slopes.

In some situations a structure is too close to install any barrier system. In other cases, project staff may have to use hardware that they wouldn't "normally" use. Coordinate with the WisDOT project manager and the regional design oversight engineer.

If a short radius system does not fit, designer may put a "break" in the barrier system[63]. A break may allow some vehicles to hit a hazard.

30.7 Safety Edge

Safety edge is a wedge of pavement added to the outside edge of a lane with no paved shoulder or outside edge of a paved shoulder. See Figure 30.81.

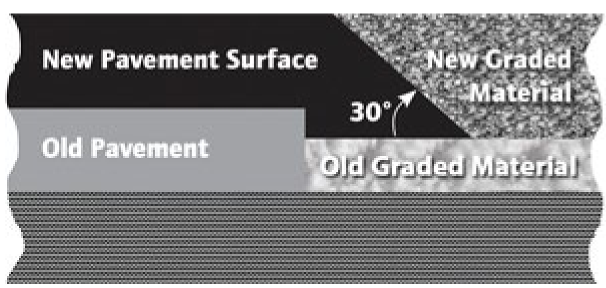

Figure 30.81 Cross-Section of Safety Edge [cxvi]

Safety edge can mitigate run off the road crashes caused by edge drop between the paved surface and gravel shoulder. An edge drop as little as 2.5 inches can cause a driver to oversteer when they try to reenter the pavement.[cxvii] Eventually, when the vehicle's tires climb the edge, the vehicle will shoot abruptly across its' lane

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

and strike oncoming traffic.

Many states are reporting better pavement performance near a safety edge. Some of the pavement benefits are a decline of edge line cracking, better compaction, and less damage from construction traffic.

Safety edge can be installed on HMA and concrete pavements. WisDOT is installing safety edge on HMA projects. Safety edges are created by adding a wedge maker to the paver.

CMM 6-70 has more information about safety edge.

30.7.1 Policy

Install safety edge on HMA pavements with 0 to 3 feet of paved shoulder. Install safety edge on temporary roads that are in-service over the winter or will be in-service for a year or more.

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.

30.7.2 Design Information

Standard Spec 450.3.2.11 contains language on where to install safety edge. SDD 14B29 contains information on how to build safety edge. Use special provisions for safety edge on wider paved shoulders. If not installing a safety edge on a roadway that matches the criteria use a special provision.

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

30.8 Cross-Median Crash (CMC)

A cross-median crash (CMC) is when a vehicle travels through a median and enters or passes beyond the lanes of the opposing direction of travel. A CMC crash can involve single or multiple vehicles.

Review methods to limit median encroachments before installing a barrier system. Potential methods to reduce the severity and frequency of a median encroachment are (the list is not all-inclusive):

- Widen shoulders
- Widen median*
- Flatten median slopes
- Change ditch from a “V” to trapezoidal ditch
- Minimize the use of horizontal curves with a radius 3,000 FT or less*
- Minimize the use of grades 4% or steeper*
- Increase separation between on- and off-ramps between interchanges
- Increase decision sight-distance
- Simplify or remove weaving areas*
- Lengthening speed-change areas
- Improve merge and diverge areas*
- Limit or remove left hand on and off-ramps*
- Edge line improvements
- Install or update shoulder rumble strips
- High friction treatment
- Improve delineation
- Improve visibility at ramps
- Speed reduction techniques
- Repairing edge drops from lane to paved shoulder and shoulder to gravel
- Safety Edge

* These methods are typically only available for new or reconstruction projects.

If a significant number of CMCs occurs during wet weather, ice, or snowy conditions, review:

- Superelevation
- Pavement cross slope
- Faulting pavement
- Pavement ruts
- Standing water on road

- Maintenance activities in poor weather

Review the mitigation methods for CMC crashes. Use mitigation methods with barrier system..

Review NCHRP 790 Appendix D for the effectiveness of the some of the potential mitigation methods.

The department has two methods to decide if a segment has potential CMC issues:

- Locations where CMC crash are statistically likely (See FDM 11-45-30.8.1)
- Locations where existing crash history shows CMC are happening (See FDM 11-45-30.8.2)

30.8.1 Likely CMC Locations

Cross-median crashes are most likely to occur at the following locations[cxviii, cxix]:

- Downstream of bridge*
- Downstream of on-ramps*
- Curves with radius of 3,000 FT or less
- Curves to the right*
- Downgrades of 4% or greater
- Closely spaced on and off-ramps between interchanges

* Locations are statistically significant based on Wisconsin data. Other locations are from NCHRP Report 790

Install median barrier systems at locations above on perpetuation and rehabilitation projects. Providing barriers at these locations is a proactive measure to prevent future CMC.

Attachment 30.17 and Attachment 30.18 has information on common barrier systems installations for CMC.

It is likely that other run off the road crashes are happening at CMC locations. Avoid placing fixed objects, or other hazards in locations were CMC is likely.

30.8.2 Department's CMC Hotspot Analysis or CMC Warrants

CMC crash rate may identify a hotspot. Use warrant in FDM 11-45-20.3.5.7.3 or the Department's CMC Hotspot Analysis. See Regional Safety Engineer for more information for Department's CMC Hotspot Analysis.

It can be difficult to identify where to stop treating CMC. Use the following methods to decide where to end treating CMC.

30.8.2.1 Logical Termini

Logical termini are highway features such as:

- Interchanges
- Grade separations
- Median openings
  - Median intersections
  - Maintenance crossovers
  - Permanent crossovers
- Road transitions to urban lower speed road
- Medians wider than 70 feet and AADT is less than 90,000 AADT*.

* If the median is 70 feet or wider and has CMC history (see FDM 11-45-30.8.2), install a median barrier. If the existing AADT is greater than 90,000 and the location has CMC (see FDM 11-45-30.8.2) install a median barrier.

Extend barrier system to logical termini when:

- Next segment has CMC history (see FDM 11-45-30.8.2)
- Within 2,000 feet of logical termini

30.8.2.2 Road Similarity

Extend barrier systems into areas where the road has similar road characteristics. Road segments with similar characteristics share (the list is not all-inclusive):

- Number of lanes
- Lane width
- Shoulder width
- Traffic characteristics
- Median width

30.8.3 Median Opening

Review existing median openings or crossings where CMC is likely to occur, or there is a history of CMC crashes. Each median opening left in-place can allow a CMC crash. Avoid placing new median openings in locations where there is a history of CMC, or CMC is likely to occur.

See Figure 6.16 in the 2011 AASHTO Roadside Design Guide to design an opening in barrier systems. Attachment 30.19 shows a median opening design for cable barrier.

30.8.4 Barrier Systems for CMC

Many of the attachments listed in FDM 11-45-30.8 use a single run of cable barrier to prevent CMC. Other barrier systems or other layouts of standard barrier could be used.

There are a few double-faced barrier systems that can be installed as a single run in the median. These systems typically have lower working widths and may fit into narrower medians. Double faced barrier systems can be hit from both directions. One drawback of these double-faced systems is that grading to the barrier needs to be 10:1 or flatter. Many of the double-faced barrier systems will need additional engineering, special details, and special provisions.

A design team may decide to install two barrier system in the median because (the list is not all-inclusive):

- Grading for one barrier system disrupts median drainage too much.
- Excessive grading
- Fixed object density and placement

LIST OF ATTACHMENTS

Attachment 30.1	Example Problem 1: West Side of Structure
Attachment 30.2	Example Problem 2: Rock Wall
Attachment 30.3	Example Problem 3: Outside of Curve Cattle Pass
Attachment 30.4	Example Problem 3: Inside of Curve Cattle Pass
Attachment 30.5	Example Beam Guard Plan Sheet
Attachment 30.6	Beam Guard Analysis
Attachment 30.7	Beam Guard Bullnose
Attachment 30.8	Sloped Concrete End Treatment
Attachment 30.9	Grading Area for Hazardous Cross-Drain
Attachment 30.10	Grading Area for Hazardous Parallel Drain
Attachment 30.11	Crash Cushion Selection Tables
Attachment 30.12	Length of Barrier and Working Width Examples
Attachment 30.13	Barrier Working Width Table
Attachment 30.14	Barrier Length Examples
Attachment 30.15	Minimum Barrier Length Table
Attachment 30.16	Shielding Large Fixed Objects in a Median with Cable Barrier and Other Barrier Systems
Attachment 30.17	Median Cable Barrier on a Curve
Attachment 30.18	Median Cable Barrier by an Interchange or Bridge
Attachment 30.19	Median Cable Barrier by a Maintenance Cross Over
Attachment 30.20	Underground Obstructions and Shifting Beam Guard
Attachment 30.21	Crash Test Photos Sequence Beam Guard Attached to Rigid Barrier
Attachment 30.22	Thrie Beam Transitions to Rigid Barrier Installations
Attachment 30.23	Partial Removal of a Middle Section of an Older Barrier Section Details
Attachment 30.24	Short Radius
Attachment 30.25	Long-Span
Attachment 30.26	Beam Guard Retaining Wall
Attachment 30.27	Beam Guard Terminal Earthwork

FDM 11-45-40 Fencing

February 18, 2020

40.1 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.

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.

40.2 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[64].
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

40.3 WisDOT Policy for Expressways

Department policy is to generally not fence expressways[65] including facilities designated as expressways under s. 84.295 stats, and expressways with multi-use paths., and to minimize fencing in those locations where 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.

40.3.1 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

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

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

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 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.

40.3.2 Location of Expressway Fencing

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[66]. 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 the 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.

40.4 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.

40.4.1 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.

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

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 collector than the other fence types.

40.4.2 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.

40.5 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.

40.6 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.

40.7 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 11-45-50 Bicycle Facilities *February 18, 2020*

See FDM 11-46-15.

FDM 11-45-99 References February 18, 2020

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[i] 2006 FHWA webinar on Human Factors

[ii] A.J. Zeigler and Others, “Guide to Management of Roadside Trees”, FHWA-IP-86-17, 1986

[iii] Final Report RSAP V3.0.0 NCHRP 22-27 Roadside Safety Analysis Program (RSAP) Update;

Ray Malcom, Carrigan Christine, Plaxico Chuck, Miaou Shaw-Pin, Johnson, T; RoadSafe, Oct 2012

[iv] Glennon, et al; 1985; FHWA

[v] 2014 Hybrid Roadside Design Class

[vi] A Guide for Achieving Flexibility in Highway Designs, 2004, AASHTO
[vii] Roadside Design Guide 4rd Edition 2011

[viii] Roadside Design Guide 4rd Edition 2011

[ix] Roadside Design Guide 4rd Edition 2011

[x] Roadside Design Guide 4rd Edition 2011

[xi] Stephens, Louis, “Barrier Guide For Low Volume and Low Speed Roads”, FHWA-CFL/TD-05-009, FHWA Central Federal Lands Highway Division

[xii] Stephens, Louis, “Barrier Guide For Low Volume and Low Speed Roads”, FHWA-CFL/TD-05-009, FHWA Central Federal Lands Highway Division

[xiii] Ross, Hayes, Sicking, Dean, Hirsch, T.L., Cooner, Harold, Nixion, John, Fox, Samuel, Damond, C.P., Safety Treatments of Roadside Drainage Structures” Transportation Research Record 868

[xiv] 2006 AASHTO Roadside Design Guide

[xv] 2007 NHI Roadside Design Class

[xvi] 2007 NHI Roadside Design Class

[xvii] Ross, Hayes, Sicking, Dean, Hirsch, T.L., Cooner, Harold, Nixion, John, Fox, Samuel, Damond, C.P., Safety Treatments of Roadside Drainage Structures” Transportation Research Record 868

[xviii] Wolford, Dan, Sicking, Dean, “Guardrail Need: Embankments and Culverts, Transportation Research Record 1599.

[xix] Schrum, Kevin; Lechtenber, Karla; Faller, Ron; Stolle, Cody; Sicking, Dean; Cost-effective Safety Treatments for Low-Volume Roads” MwRSF ReportTRP-03-222-12; 08/24/2012

[xx] Schrum, Kevin; Lechtenber, Karla; Faller, Ron; Stolle, Cody; Sicking, Dean; Cost-effective Safety Treatments for Low-Volume Roads” MwRSF ReportTRP-03-222-12; 08/24/2012

[xxi] Hurt, M., Schrock, S. D., and Rescot, R., “Review of crashes at bridges in Kansas”, Proceedings of the 2009 Mid-Continent Transportation Research Symposium, Iowa, August 2009.

[xxii] Bigelow, Jake, Hans, Zachary, Phares, Brent, “Bridge Rail and Approach Railings for Low-Volume Roadways”, TRR number 2262

[xxiii] 2006 AASHTO Roadside Design Guide

[xxiv] Gates, Tim, Noyce, Dave, Stine, Paul, TRB 2006 Annual Meeting CD-ROM, Safety and Cost-effectiveness of Approach Guardrail for Bridges.

Gates, Tim, Noyce, Dave, Stine, Paul, TRB 2006 Annual Meeting CD-ROM, Safety and Cost-effectiveness of Approach Guardrail for Bridges.

[xxv] Gates, Tim, Noyce, Dave, Stine, Paul, TRB 2006 Annual Meeting CD-ROM, Safety and Cost-effectiveness of Approach Guardrail for Bridges.

[xxvi] Albuquerque, Francisco, Sicking Dean, Evaluation of the In-Service Safety Performance of Safety-Shape and Vertical Concrete Barriers, TRP 03-259-11.

[xxvii] 2007 NHI Roadside Design Class

[xxviii] 2006, AASHTO Roadside Design

[xxix] Photo Source: Matt Rauch

[xxx] Photo Source: Matt Rauch

[xxxi] Photo Source: Matt Rauch

[xxxii] 2012 Photo from FHWA presentation by Frank Julian

[xxxiii] 2010 FHWA One day Course on Roadway Departure

[xxxiv] 2009 NHI Roadside Design Presentation

[xxxv] Gabler, Clay PowerPoint Presentation, “Early findings from NCHRP 17-43 Analysis of Tree and Pole Crashes” 1/24/2011

[xxxvi] Sullivan, Edward, Daly, James; “Investigation of Median Trees and Collisions on Urban and Suburban Conventional Highways in California”, TRR 1908.

[xxxvii] 2006 AASHTO Roadside Design Guide

[xxxviii] 2006 AASHTO Roadside Design Guide

[xxxix] 2007 NHI Roadside Design Class

[xl] 2007 NHI Roadside Design Class

[xli] Zeigler, A.J. and Others, Guide to Management of Roadside Trees, FHWA-IP-86-17, December 1989

[xlii] 2007 NHI Roadside Design Class

[xliii] Schrum, Kevin, Stolle, Cody, Lechtenberg, Karla, Johnson, Erin, Sicking, Dean, Faller, Ron, Howard, Chris, Cost Effective Treatments of Common Low-Volume Roadways, TRP-03-222-09

[xliv] Schrum, Kevin; Lechtenber, Karla; Faller, Ron; Stolle, Cody; Sicking, Dean; Cost-effective Safety Treatments for Low-Volume Roads” MwRSF ReportTRP-03-222-12; 08/24/2012

[xlv] Schrum, Kevin; Lechtenber, Karla; Faller, Ron; Stolle, Cody; Sicking, Dean; Cost-effective Safety Treatments for Low-Volume Roads” MwRSF ReportTRP-03-222-12; 08/24/2012

[xlvi] MacDonald, L.N., FHWA Memorandum “Top Rails on Chain-link Fence”, 2/5/1991

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

[xlviii] “Priorities for Roadside Hazard Modifications: A Case Study on 300 Fatal Roadside Object Crashes”, Insurance Institute for Highway Safety, March 1976
[xlix] 2011 AASTHO Roadside Design Guide

[l] 2011 AASHTO Roadside Design Guide

[li] 2011 AASTHO Roadside Design Guide

[lii] Gabauer, Douglas, “Real-world Performance of Longitudinal Barrier Struck by Large Trucks”, Transportation Research Record 2309

[liii] Griffith, Michael, Geometric Design Considerations for Prevention of High Center of Gravity Commercial Vehicles Rollovers-NTSB Recommendations Resulting from 2009 Indianapolis, IN crash, FHWA Memo, 11/30/2012

[liv] Improving Highway Safety At Bridges on Local Roads and Streets, FHWA October 1998

[lv] Wolfred, Dan, Sicking, Dean, Transportation Research Record No. 1528 “Current Research on Roadside Safety Features.” 1996

[lvi] Marzouguo, Dhafer, Mahadevaiah, Umashankar, Tahan, Fadi, Kan, Cing Dao, McGinnis, Richard, Power, Richard’ NCHRP 711 “Guidance for the Selection, Use, and Maintenance of Cable Barriers Systems”; 2012; TRB

[lvii] Nauman M. Sheikh, Dean C. Alberson and Linda S. Chatham;" The State-of-the-Practice of Cable Barrier Systems Paper"; TRB 2008

[lviii] Dean Sicking, "Great Lakes Safety Hardware Workshop Handout" March 1996

[lix] Stout, D; "Traffic Barrier on Curves, Curb, and Slopes"; FHWA-93-01; March 1993

[lx] Manual for Assessing Safety Hardware 2009 AASHTO

[lxi] Pernetti Mariano, Scalera Salvatore; "Effects of Post-To-Foreslope Distance On Containment Capacity Of A H1 Safety Barrier"; TRB 2008 Annual Meeting CD-Rom; TRB 2008

[lxii] Nicholas A. Weiland, Ronald K. Faller, Robert Bielenberg, John D. Reid, Dean Sicking, and Karla Lechtenberg; "Minimum Effective Guardrail Length of the MGS"; TRP-03-276-13; 2013

[lxiii] AASHTO 2011 Roadside Design Guide

[lxiv] FHWA Memo W-Beam Guardrail Installations in Rock and in Mowing Strips, March 10, 2004

[lxv]Roads and Bridges April 2013, "Guards Lose Cover" by Susan Barton

[lxvi] Akram, Abu-Odeh, Kang-Mi Kim, Dean Alberson; "Evaluation of existing T-Intersection Guardrail Systems for Equivalency with NCHRP Report 350 TL-2 Test Conditions"; report Number 405160-10; TTI; August 2010

[lxvii] 2014 NHI Roadside Design Class Presentation

[lxviii] Dylan Meyer, John Reid, Karla Lechtenberg, Robert Bielenberg, Ronald Faller; "Increased Span Length for the MGS Long-Span Guardrail System Part II: Full-Scale Crash Testing"; MwRSF Reort number TRP-03-339-17 ;2017

[lxix] Polivka, Karla, Sicking, Dean, Beielenberg, Bob, Faller, Ron, Rohde, John, Reide, John, Coon Brian, Performance Evaluation Of The Permanent New Jersey Safety Shape Barrier - Update To NCHRP 350 Test No. 4-12 (2214NJ-2), MwRSF Report TRP-03-178-06

[lxx] Caldwell, Christopher; "Investigation of the Crashworthiness of Barrier Mounted Hardware: Barrier Mounted Sign and Sign Post; FHWA/CA10-0644, June 2011

[lxxi] Email Correspondence Between MwRSF and Erik Emerson

[lxxii] Rosenbaugh, Scott; Sicking, Dean; Faller, Ron: "Development of a TL-5 Vertical Faced Concrete Median Barrier Incorporating Head Ejection Criteria" Midwest States' Regional Pooled Fund Research Program, MwRSF Research Report No. TRP-03-194-07, December 2007

[lxxiv] Rosenbaugh, Scott; Sicking, Dean; Faller, Ron: "Development of a TL-5 Vertical Faced Concrete Median Barrier Incorporating Head Ejection Criteria" Midwest States' Regional Pooled Fund Research Program, MwRSF Research Report No. TRP-03-194-07, December 2007

[lxxv] Rosenbaugh, Scott; Sicking, Dean; Faller, Ron: "Development of a TL-5 Vertical Faced Concrete Median Barrier Incorporating Head Ejection Criteria" Midwest States' Regional Pooled Fund Research Program, MwRSF Research Report No. TRP-03-194-07, December 2007

[lxxvi] Dobrovolny, Chiara, Brackin, Michael, Arrington, Dusty; Single Slope Median Walls for Grade Separations; 405160-33/35; Jan 2013

[lxxvii] Abu-Odeh, Akram, Kim, Kang-Mi, Williams, Williams, Patton Chris; *Crash Wall Design for Mechanically Stabilized Earth (MSE) Retaining Walls Phase I : Engineering Analysis and Simulation*; TTI; 405160-15; March 2011

[lxxviii] Johnson, Nicholas and Gabler, Hampton, "Injury Risk Posed by side impacts on Non-tracking Vehicle into Guardrails", TRB 2377; TRB 2013

[lxxix] FHWA Video, "Guidelines for the Selection of W-beam Barriers Terminals", FHWA

[lxxx] FHWA Video, "Guidelines for the Selection of W-beam Barriers Terminals", FHWA

[lxxxi] Baxter, John*, Guidelines for the Selection of W-Beam Barrier Terminals,* FHWA, 10/26/2004

[lxxxii] FHWA's *Guidelines for the Selection of W-Beam Barrier Terminals*

[lxxxiii] Mak, King, Sicking Dean, *Roadside Safety Analysis Program (RSAP) User's Manual; NCHRP; June 2002*

[lxxxiv] Paulsen, Tony, Sicking, Dean, Holloway, James, *Embankment Widening and Slopes for Energy Absorbing End Terminals*, MwRSF Report TRP-03-126-02

[lxxxv] Paulsen, Tony, Sicking, Dean, Holloway, James, *Embankment Widening and Slopes for Energy Absorbing End Terminals*, MwRSF Report TRP-03-126-02

[lxxxvi] Riser Nicholas, Sicking Dean, Reid John, Faller Ronald, Rohde John, Polivka Karla*, Bridge Rail and Transitions for Pedestrian Protection*, MwRSF Report TRP-03-127-03.

[lxxxvii] 2011 AASHTO Roadside Design Guide

[lxxxviii] 2011 AASHTO Roadside Design Guide

[lxxxix] Carlson, Dean, *Traffic Barrier Safety Policy and Guidance*, FHWA Technical Memo, 9/29/1994

[xc] Roadside Design Guide 3rd Edition 2006, with Updated Chapter 6

[xci] Thomas Everett; FHWA –AASHTO Joint Implementation Agreement for Manual for Assessing Safety Hardware (MASH); FHWA Memo; 1/7/2016

[xcii] Thomas Everett; FHWA –AASHTO Joint Implementation Agreement for Manual for Assessing Safety Hardware (MASH); FHWA Memo; 1/7/2016

[xciii] Nicol, David, Roadside Design: Steel Strong Post W-Beam Guard Steel Beam, FHWA Technical Memo 6/17/ 2010.

[xciv] 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

[xcv] Nicol, David, Roadside Design: Steel Strong Post W-Beam, FHWA Technical Memo, 6/17/2010

[xcvi] Carolyn Hampton, Douglas Gabauer, Hampton, Gabler, "Limits of Acceptable Steel beam and Post Deflection in Crash-damaged Strong-Post W-beam Guard Steel Beam", TRB 2010 Annual Meeting CD

[xcvii] FHWA Technical Memo, Corrugates Sheet Steel (W-Beam) Guardrail, T5040.23, March 13,1984

[xcviii] 2006 NHI Roadside Design Class

[xcix] 2006 NHI Roadside Design Class

[c] 2006 AASHTO Roadside Design Guide

[ci] 2006 NHI Roadside Design Class

[cii] W-Beam Guardrail Repair A Guide For Highway And Street Maintenance Personnel, FHWA 11/1/2008

[ciii] Robert, Bielenbert, John, Reid, Ronald, Faller, John, Rhode, Dean, Sicking, Eric, Keller, Jim, Holloway, Lora, Supercheck; "Phase III development of a Bullnose Guardrail System for Median Applications"; MwRSF; TRP-03-095-00; 2000.

[civ] Robert, Bielenbert, John, Reid, Ronald, Faller, John, Rhode, Dean, Sicking, Eric, Keller, Jim, Holloway, Lora, Supercheck; "Phase III development of a Bullnose Guardrail System for Median Applications"; MwRSF; TRP-03-095-00; 2000.

[cv] Charles, McDevitt; "Basics of Concrete Barriers"; Public Roads Volume 63 No. 5; March/April 2000

[cvi] Improving Highway Safety At Bridges on Local Roads and Streets, FHWA October 1998

[cvii] 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

[cviii] Oregon Department of Transportation

[cix] 2006 NHI Roadside Design Class

[cx] Photo from Linda Richardson

[cxi] Design Construction and Maintenance of Highway Safety Features and Appurtenances User Manual, FHWA, FHWA-HI-97-026, June 1997

[cxii] 2011 AASHTO Roadside Design Guide

[cxiii] 2011 AASHTO Roadside Design Guide

[cxiv] 2011 AASHTO Roadside Design Guide

[cxv] 2007 NHI Roadside Design Class

[cxvi] FHWA safety edge website

[cxvii] FHWA Safety Edge Website, http://www.fhwa.dot.gov/everydaycounts/technology/safetyedge/intro.cfm

[cxviii] NCHRP Report 790 Factors Contributing to Median Encroachment and Cross Median Crashes, Hardwood, Douglas, Gilmore, David, Graham, Jerry, O'laughlin, Mitchell, Smiley, Alison, Smahel, Thomas; TRB; 2014

[cxix] TOPS LAB Presentation