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2.9 IMPACT PROTECTION SYSTEMS

2.9.1 Introduction

Impacts due to waterborne and roadway traffic can cause severe damage to structures due to the high energy imparted to the structure. The structure's integrity is important since it is typically in use by the general public at the time of impact. Impact Protection Systems are structural appurtenances that are often located adjacent to structures, such as bridges and traffic operations support systems. The purpose of impact protection systems is to shield structures from collision damage while reducing the likelihood of severe injury to the vehicle occupants caused by a collision with an immovable object. Most systems reduce the severity of crashes by redirecting errant vehicles or vessels, and absorbing the energy of crashes. Redirection and energy absorption minimize injury to individuals and damage to the structures being protected.

It is recommended that Impact Protection Systems be inspected at the time the associated structure is inspected. WisDOT has created an assessment for tracking the condition of the exposed areas of waterway impact protection systems. The assessment is Dolphin and Fender System (Assessment 9290). It is the inspector's responsibility to examine the exposed surfaces of each assessment and determine its assessment state. Additional information may be on the inspection form from the underwater inspection. Refer to part 2 chapter 7 for additional information on the Dolphin and Fender System Assessment, and the Assessment State definitions.

2.9.2 Waterway Impact Protection Systems

2.9.2.1 Cell Dolphins

Cell Dolphins are typically constructed of a large-diameter steel casing pipe or interlocking steel sheet piles in a circular configuration. A typical cell dolphin is constructed by driving the casing / steel sheet piles into the soil and then filling with cell with concrete or granular material. If loose fill materials are used, a reinforced concrete or asphalt cap is typically placed on top to retain the fill. Settlement of the fill material may result in deterioration of the cap. Frequently, timber piles are driven around the perimeter of the cell for increased protection. Refer to Figure 2.9.2.1-1 for a view of a cell dolphin.

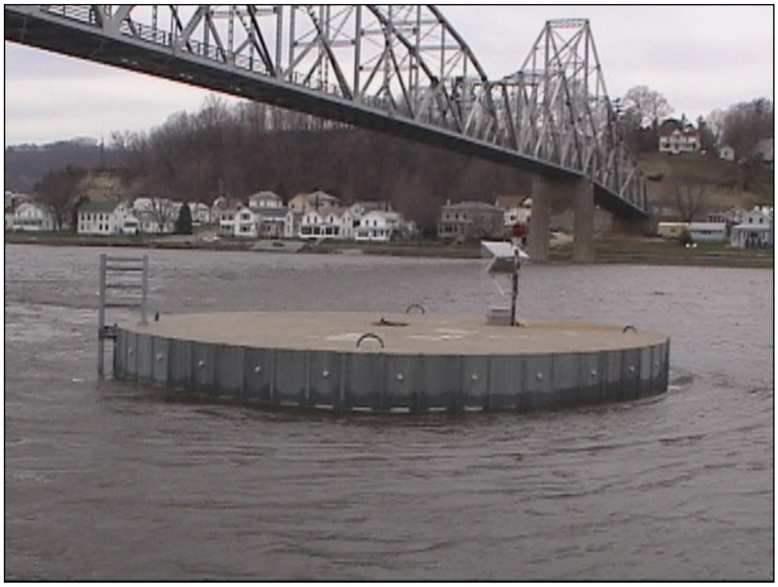

Figure 2.9.2.1-1: Cell Dolphin During Flood Conditions.

2.9.2.2 Pile Cluster Dolphins

Pile cluster dolphins are composed of groups of battered or vertical piles that are fastened or bound together at the top. Typical fasteners include chains, steel cables, wood chocks, bolts, and steel shells. Piles are typically timber, but composite and steel piles are also used. When steel piles are used, a cast-in-place concrete cap is generally used. Refer to Figure 2.9.2.2-1 for a view of a timber pile cluster dolphin.

Figure 2.9.2.2-1: Timber Pile Cluster Dolphins.

2.9.2.3 Fender Systems

The purpose of fender systems is to protect piers, bents, and other structural bridge members from impact damage due to docking or errant vessels. Fenders are usually positioned so that the horizontal angle of impact (channel navigation orientation) with respect to the fender line orientation is small. Fenders are designed to accept the forces from vessel impact while redirecting the course of the vessel. This reduces or eliminates the impact force upon the structure. Fender systems can be either supported independently or attached to the substructure unit. Fender systems can be composed of timber, rubber, composite, concrete, or steel.

Independently Supported

Independently supported fender systems typically consist of vertical or battered piles with horizontal members connecting the piles so the system acts as a unit. Some are installed between dolphins on either side of the structure they protect. Refer to Figure 2.9.2.3-1 for a view of an independently supported timber fender system.

Figure 2.9.2.3-1: Independently Supported Timber Fender System.

Substructure Supported

Substructure-supported fenders vary in type from simple rails, used as rubbing strips, attached directly to the substructure to more complex systems, which are designed to dissipate energy when struck by a vessel. The inspector should review the fender manufacturer's literature in order to be familiar with the individual components of this more complex system. Chains or bolts that fasten these complex systems to the substructure unit must also be inspected. Refer to Figure 2.9.2.3-2 for a view of a substructure-supported timber fender system.

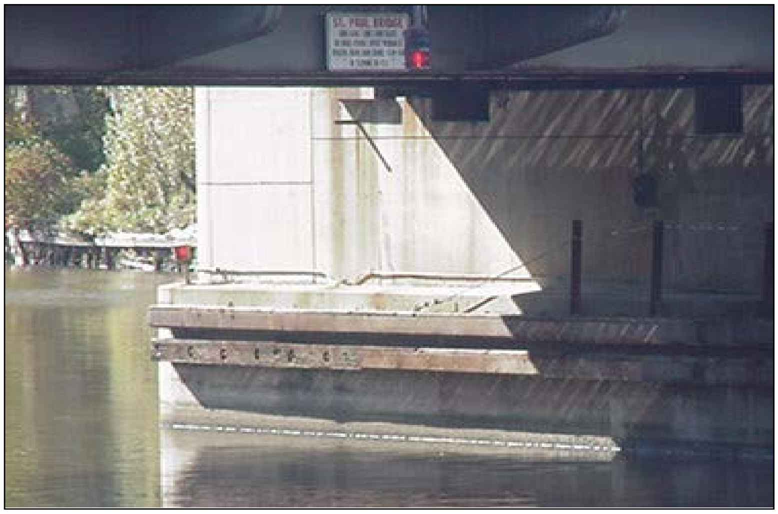

Figure 2.9.2.3-2: Substructure-Supported Timber Fender System.

2.9.2.4 Fender System Materials

A variety of materials are used either independently or in combination to create fender systems. The following items are materials typically used in the construction of fender systems.

Timber Fenders

Timber fenders are composed of vertical and/or horizontal timber members that are either attached to the substructure or are independently supported. Impact energy is absorbed by plastic deformation and crushing of the timber members. Timber members are an excellent choice for protection against minor collisions due to their low cost. However, timber fender system members for large-scale impacts would have to be extremely large and thus become both impractical and uneconomical.

Rubber Fenders

Rubber fenders are available in a wide variety of shapes. Rubber fender systems are attached directly to the concrete pier/abutment by bolts, or suspended in place using chains. Impact energy is absorbed by elastic deformation of the rubber elements through bending, compression, and shear.

Concrete Fenders

Concrete fenders are composed of hollow, thin-walled concrete boxes attached to the substructure. Typically, a timber fender is also attached to the outer face of the concrete fender. Impact energy is absorbed through the buckling and crushing of the concrete walls.

Steel Fenders

Steel fenders are composed of thin-walled members and bracing elements which form a box around, and are attached to, the substructure unit. Timber or composite facing is usually attached to the steel fender to prevent sparks during impacts from steel ships. Compression, buckling, and bending of the steel elements will absorb the impact energy.

2.9.2.5 Jetties

Jetties, or manmade protection islands, typically consist of sand or rock core. An outer layer of heavy rock armor is placed over the sand or rock core to protect the island from erosion due to wave, current, and ice action.

2.9.2.6 Floating Protection Systems

Various types of floating systems are used to provide structure protection. Several of these systems include:

Cable Net Systems

Ships are stopped by a system of cables anchored to the bottom of the waterway and suspended by buoys located in front of the bridge piers.

Anchored Pontoons

Large floating pontoons are anchored to the bottom of the waterway in front of the bridge piers to absorb vessel impact.

Camels

Camels are circular members that float adjacent to the substructure. They are typically constructed of composites or timber.

2.9.3 Roadway Impact Protection Systems

Vehicle barrier systems are discussed in 16 5 and 11-45-1 of the Wisconsin Department of Transportation (WisDOT) Facilities Development Manual (FDM). The primary purpose of these systems is to protect the traveling public from severe injury caused by vehicular impact with rigid objects. They are also used to keep vehicles from driving down steep slopes, into waterways, or to separate oncoming traffic. This section will discuss the condition assessment of appurtenances that guard structures from vehicular impact.

2.9.3.1 Cable Guard

A cable guard is considered a semi-rigid impact protection system because it is designed to absorb the energy of vehicles through deformation of the system. Cable guard is comprised of a series of horizontal steel cables attached to vertical steel posts that are driven into the ground to provide anchorage. The cables are anchored to concrete blocks located underground at either end. When vehicles strike the system, the tensioned cables catch and redirect the vehicle away from the structure or hazard the system protects. Refer to Figure 2.9.3.1-1 for a view of a cable guard.

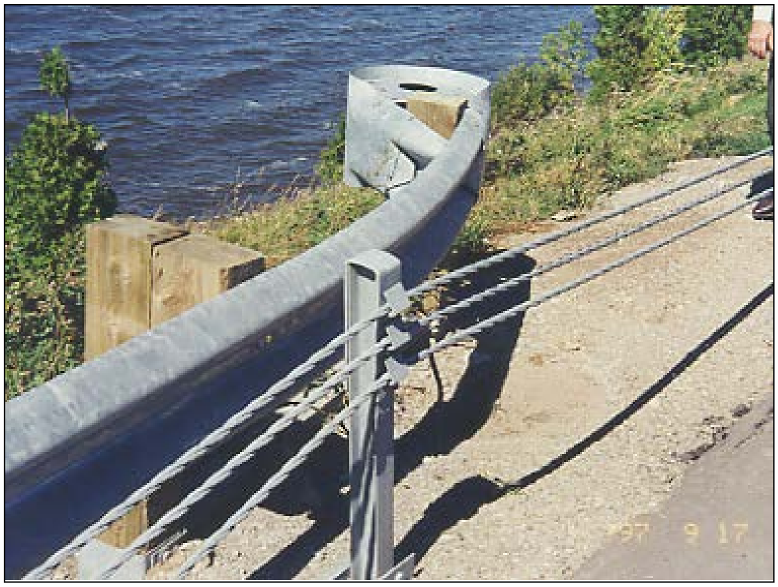

Figure 2.9.3.1-1: Section of Cable Guard Next to a Steel Plate Beam Guard.

2.9.3.2 Steel Plate Beam Guard

A beam guard is considered a semi-rigid impact protection system because it is designed to absorb the energy of vehicles through deformation of the system. Beam guard is comprised of corrugated horizontal steel rail sections that are bolted to vertical steel or wood posts driven into the ground to provide anchorage. When vehicles strike the system, the rails bend and develop tension to catch and redirect the vehicle away from the structure or hazard that the system protects. Refer to Figure 2.9.3.2-1 for a view of a newly installed beam guard.

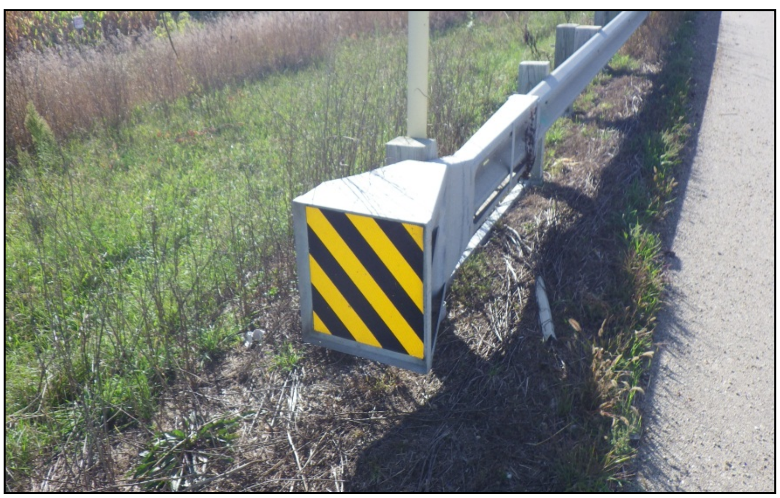

Figure 2.9.3.2-1: Newly Installed Beam Guard.

2.9.3.3 Crash Cushions and Impact Attenuators

A crash cushion is considered a semi-rigid impact protection system because it is designed to absorb the energy of vehicles through deformation of the system. In Wisconsin, impact attenuator arrays (sand-filled barrels) and accordion style steel beam guards with compressible cartridges and cylinders are used in areas where space limitations prevent the use of beam guard systems. These systems are also designed to safely redirect vehicles that do not contact the system head on. Refer to Figure 2.9.3.3-1 for a view of an impact attenuator system and Figure 2.9.3.3-2 for a view of a crash cushion.

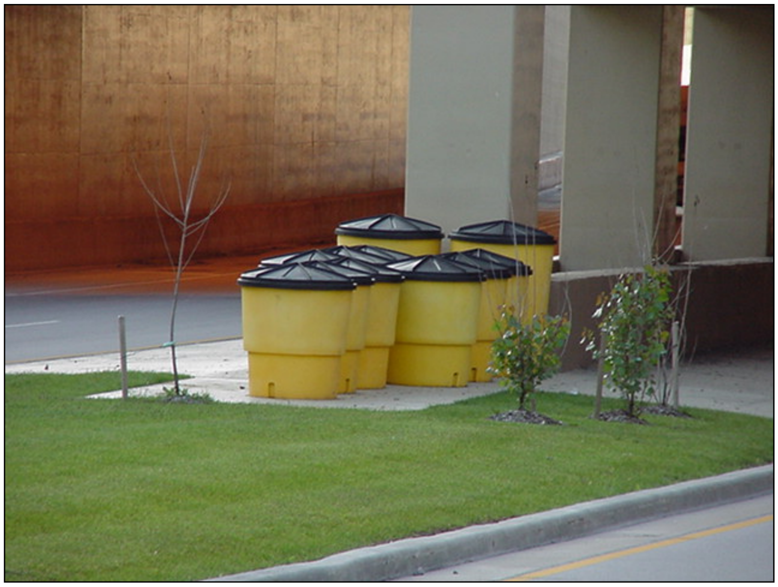

Figure 2.9.3.3-1: Impact Attenuator System.

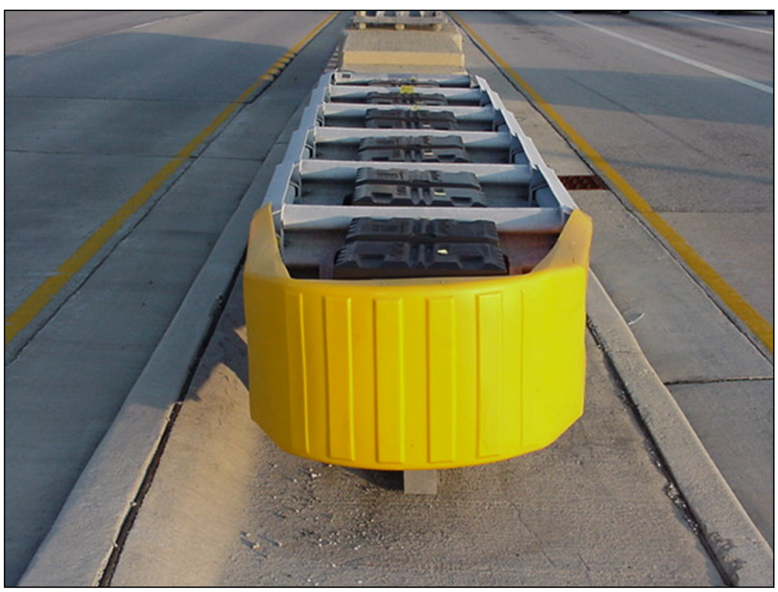

Figure 2.9.3.3-2: Crash Cushion.

2.9.3.4 Concrete Barrier Walls

A concrete barrier wall is considered a rigid impact protection system because it is not designed to absorb the energy of vehicles that strike it. Instead, concrete barrier is designed to safely redirect errant vehicles. Refer to Figure 2.9.3.4-1 for a view of a concrete barrier wall.

Figure 2.9.3.4-1: Concrete Median Barrier Wall.

2.9.3.5 Concrete Crash Walls

Concrete crash walls are supplementary structural elements designed to resist the high-energy impacts associated with impacts from trucks and trains. These walls are located in advance of, and adjacent to, the structure to redirect vehicles that would strike structural elements susceptible to failure from impact. Refer to Figure 2.9.3.5-1 for a view of crash wall installed at an overpass bridge as part of a highway upgrade.

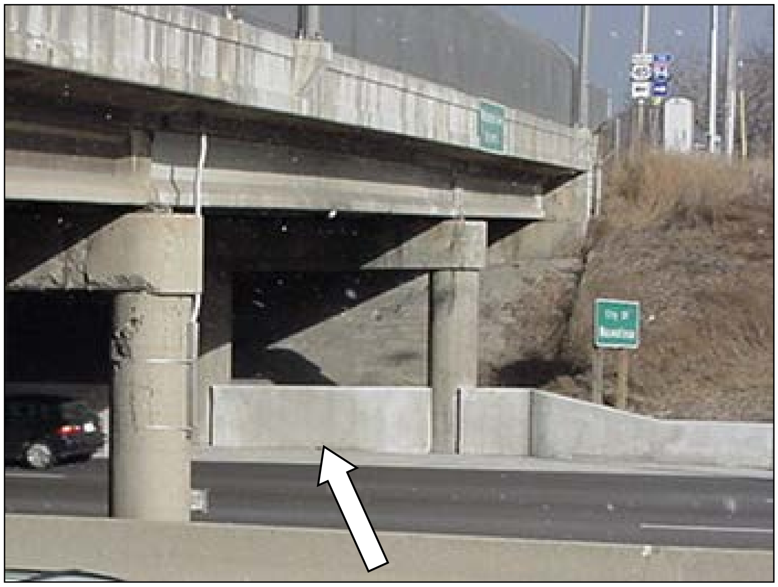

Figure 2.9.3.5-1: Concrete Crash Wall Along an Overpass Bridge Pier.

2.9.4 Inspection of Impact Protection Systems (Water)

While noticeable above water deterioration should be noted during routine inspections of the structure, the primary inspection would be conducted during the underwater inspection of the substructure since the inspector-diver will have closer access to all surfaces.

2.9.4.1 Inspection of Cell Dolphins

The steel sheet piling or steel casing should be inspected for corrosion, cracking, and sheet pile joint separation. Special attention should be given to areas in the splash zone where corrosion is usually most significant. The steel sheet piling should be examined for tightness of the interlocks, any seepage of loose fill materials, alignment, lateral movement, plumbness, and impact damage. The cell dolphin should also be inspected for a spalled cell cap, broken or missing cleats, and damaged fenders that may be present. Scour at the channel bottom should also be investigated by sounding the channel in the general area of the dolphin. The remaining thickness of the steel should be determined through non-destructive testing and the pile length recorded to compare inspection findings with previous inspections. Any timber piles surrounding the steel cell dolphin should be inspected according to the methods describes in Section 2.9.4.2. Refer to Figure 2.9.4.1-1 for a view of cell dolphin deterioration.

Figure 2.9.4.1-1: Cell Dolphin Deterioration.

2.9.4.2 Inspection of Pile Cluster Dolphins

The timber piling should be inspected for rot, fire damage, impact damage, and lateral movement. Special attention should be given to the tops of the piles and the areas in the splash zone where section loss is common. Scour at the channel bottom should also be investigated by sounding the channel in the general area of the dolphin. The soundness of the timber may be determined by incremental coring, but care should be taken to plug any holes created with treated hardwood dowels. Wire rope and connection bolts that secure the piles should be examined for corrosion. Any missing or loose bolts and wires should be noted. Refer to Figure 2.9.4.2-1 for a view of pile cluster dolphin deterioration.

Figure 2.9.4.2-1: Pile Cluster Dolphin Deterioration.

2.9.4.3 Inspection of Fender Systems

All piles of fender systems should be inspected in the same manner as presented in Section 2.9.4.2. Timber, concrete, and steel members should be inspected for their typical material deficiencies. All members should be examined for collision damage. Connections should be examined for loose and/or corroded bolts. Rubber fender systems should be inspected for loose or broken support chains. Pier supported fenders should be checked for adequate attachment to the pier. Refer to Figure 2.9.4.3-1 for a view of a failed rubber fender system. All failed fenders systems should be noted in the inspection report.

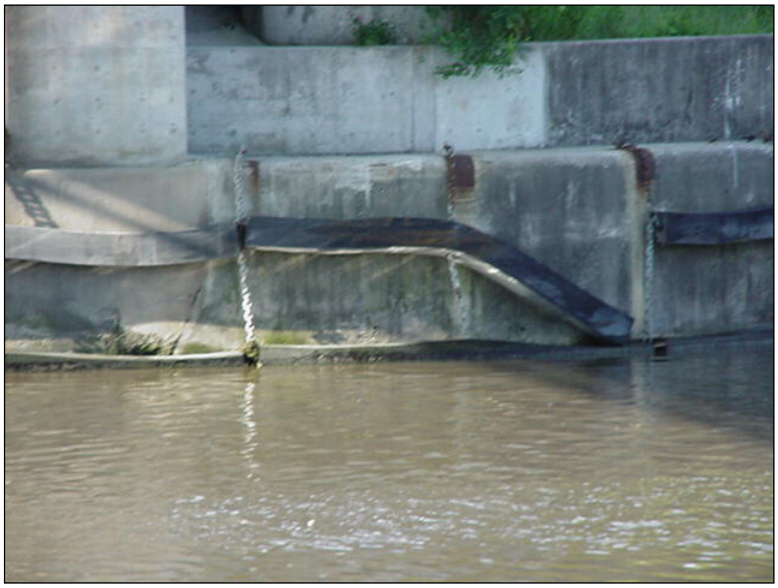

Figure 2.9.4.3-1: Failed Rubber Fender System.

2.9.4.4 Inspection of Jetties

Island protection systems should be examined for collision damage that may have displaced the heavy rock armor layer exposing the sand or rock core beneath it. The island should also be examined for scour.

2.9.4.5 Inspection of Floating Protection Systems

Cable net systems should be examined for deterioration or breaks in the netting that could weaken the system. Buoys should be examined to ensure that they are floating as intended and that they are not cracked.

Anchored pontoons should be examined for collision damage. Pontoons should be examined to insure that they are floating as intended and that they are not cracked.

2.9.5 Inspection of Impact Protection Systems (Land)

Neither elements with defects nor assessments have been incorporated into Wisconsin's structure inspection program for these roadway traffic safety systems, but due to their importance in protecting the structures from vehicular impact their condition should be evaluation during structure inspection. Conditions are documents under the structure inspection notes of the structure inspection. Any concerns or maintenance actions are relayed onto the roadway maintenance engineer in charge of the roadway corridor.

2.9.5.1 Inspection of Cable Guard

The horizontal steel cables and vertical steel posts should be inspected for corrosion and collision damage. All loose or missing connections should be noted as well as material deterioration in the connections. Anchorages should be secure at both ends of the system, as well as at the intermediate steel posts throughout the system. Cable guards should also be inspected for excess sag in the cables. The distance to the structure or hazard, which the system is protecting, should be checked. This distance should be a minimum of 12 feet away from the cable guard system. Refer to Figure 2.9.5.1-1 for a view of a cable guard next to a beam guard.

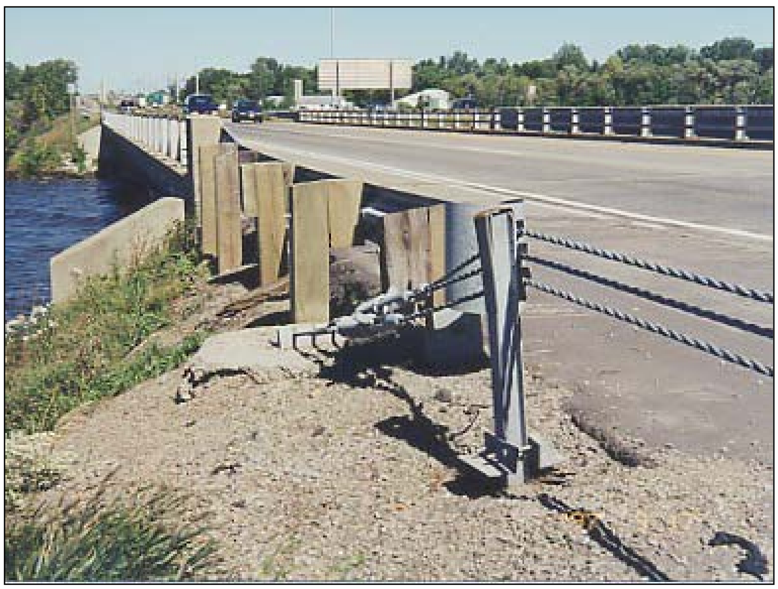

Figure 2.9.5.1-1: Cable Guard Next to a Beam Guard.

2.9.5.2 Inspection of Steel Plate Beam Guard

The inspector should check the vertical posts for material deterioration, collision damage, anchorage and adequate spacing. The steel rail should be inspected for material deterioration and collision damage. Connections should be inspected for material deterioration. Loose or missing bolts should also be noted. Note that portions of the steel rail are not designed to be bolted to the posts in specific areas near the attenuator. Standard details can be obtained through the Wisconsin Department of Transportation (WisDOT) Facilities Development Manual (FDM) for reference on beam guard design. The distance to the structure or hazard, which the system is protecting, should be checked. Refer to Figure 2.9.5.2-1 for a view of a damaged beam guard.

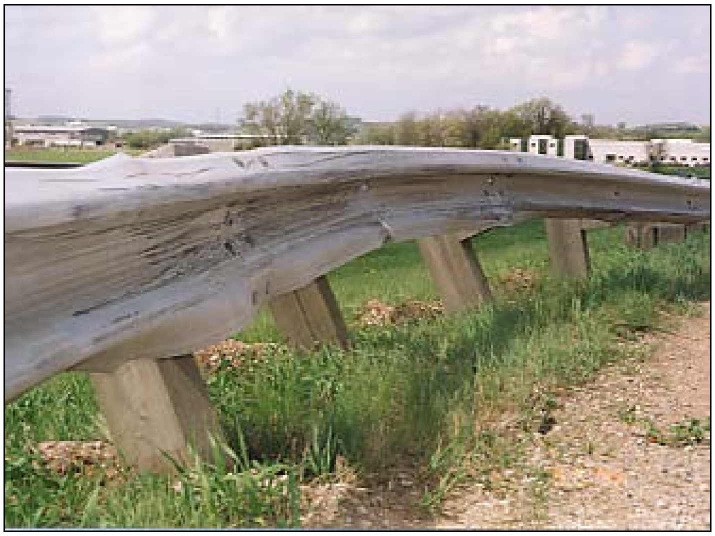

Figure 2.9.5.2-1: Beam Guard that was Damaged During a Collision.

2.9.5.3 Inspection of Crash Cushions and Impact Attenuators

Crash cushions should be inspected for collision damage and functionality. The barrels or cells of the attenuator system should be inspected for cracking or leakage of the material from the inside the barrel. Refer to Figure 2.9.5.3-1 for a view of a damaged impact attenuator.

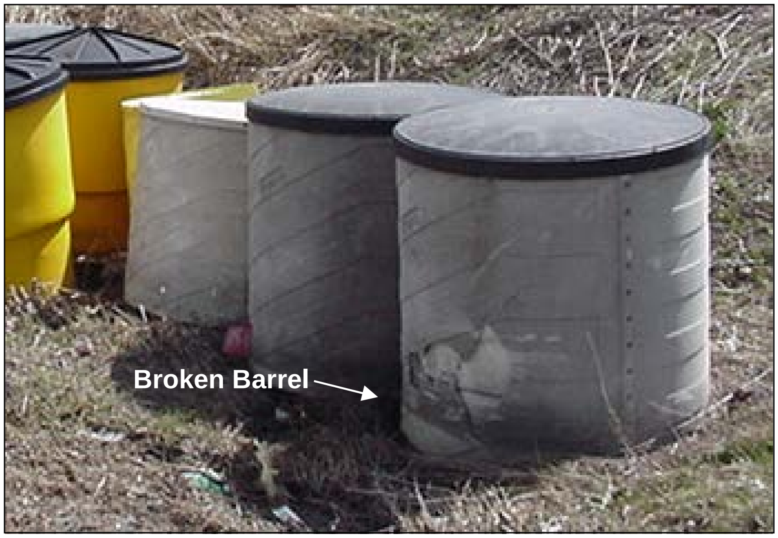

Figure 2.9.5.3-1: Damaged Impact Attenuator.

2.9.5.4 Inspection of Concrete Barrier Walls

The inspector should check concrete barrier walls for collision damage and deterioration. The barrier should be secure and capable of performing its designed intent. Tipping or settling portion of the barrier wall may create snag points that would catch rather than redirect a vehicle if struck. These should be noted on the inspection form. Deterioration and spalling should also be noted. Refer to Figure 2.9.5.4-1 for a view of a concrete barrier wall.

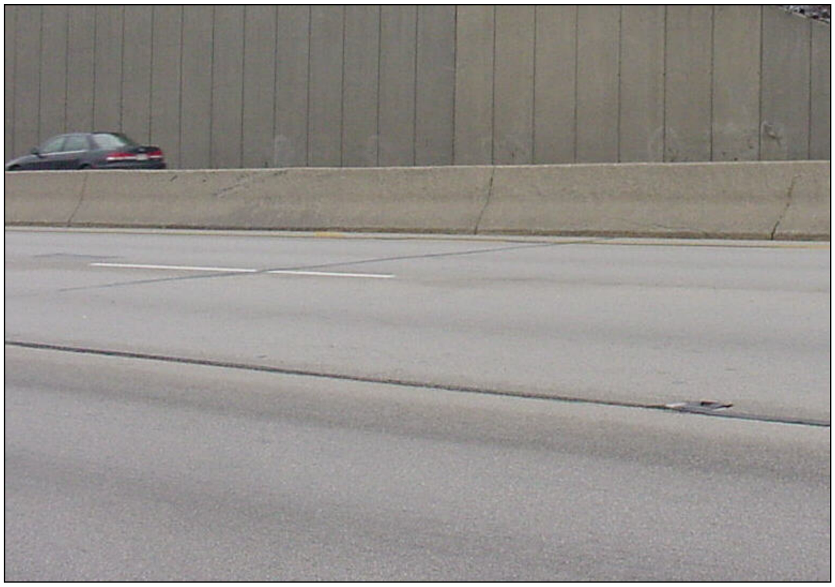

Figure 2.9.5.4-1: Concrete Median Barrier Wall.

2.9.5.5 Inspection Of Concrete Crash Walls

Concrete crash walls should be inspected for collision damage and material deterioration. Tipping or settling portions of the barrier wall may create snag points that would catch rather than redirect a vehicle if struck. These should be noted on the inspection form. Any spalling of the concrete should also be noted in the inspection form.

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