Fixing America's Surface Transportation Act

November 2017

Maintenance of Guardrail Systems

CATEGORY: Maintenance

ISSUE: Often times it is not immediately obvious when a w-beam guardrail or terminal is damaged to the extent that it may no longer function as intended. If the consequences of damaged hardware are not properly assessed, repairs may not be made in a timely manner, leading to poor crash performance and opening the responsible authority to possible legal action.

OBJECTIVE: To recommend general guidelines that enable maintenance personnel and contractors to determine when repairs to damaged or deteriorated guardrail and terminals are needed and how soon those repairs should be made. Also to provide guidance on when damaged guardrails and terminals should be upgraded, removed, or re-designed.

METHODOLOGY: Several typical "damage" scenarios for w-beam guardrails and terminals will be identified and best-practices will be presented for consideration. NCHRP Report 656, Criteria for Restoration of Longitudinal Barriers, will be summarized and referenced for more detailed information.

To function properly in an impact, guardrail must be able to reach its full tensile strength, have limited deflection, and minimize overrides and underrides. Guardrail terminals must be able to anchor the guardrail in side impacts and minimize crash severities in end-on impacts. The following sections identify the degrees of damage most likely to compromise the crash performance of these safety appurtenances.

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EXPECTED RESULTS:

Provide repair personnel with information that will allow them to evaluate barrier and terminal damage and to schedule appropriate repair, removal, upgrades, or redesign.

TYPES OF DAMAGE:

W-Beam Rail damage:

Perhaps the most catastrophic failure of a guardrail is vehicle penetration allowed by physical separation (rupture) of the rail element or over-riding the guardrail. Therefore, any damage that decreases the tensile strength of the w-beam should be considered a high-priority repair.

- Vertical tears in the W-beam (Photograph A) that extend to the top or bottom of the rail greatly reduce the capacity of the rail and create areas of high stress concentrations, both of which can cause the rail to tear completely through and allow vehicular penetration upon impact. Non-manufactured holes (e.g., those caused by crash damage, lug nut damage, or corrosion) in the rail element that intersect the top or bottom edges of the W-beam should also be considered a priority repair condition. Photograph B.
- Rail flattening with or without post deflection, increases the chances that an impacting vehicle will overturn upon contact and may increase the deflection distance. Any flattened panel that increases the W-beam section width to more than 18 inches (normal height is 12 inches) should be replaced.

Post / deflection damage:

If a section of barrier is struck a second time before repairs have been made, its performance may be uncertain, depending on the amount of original damage.

- If the barrier has been deflected more than 9 inches over a 25-foot length, its height has been reduced by 2 inches or more from its original height, or if any posts are missing or detached (Photograph C), prompt repairs should be made. These types of damage can result in greater vehicle instability in a crash, may leading to rollover, barrier rupture, or barrier overrides.

Terminal damage:

The most commonly used W-beam guardrail terminals are designed to transmit tensile forces in the rail to a cable and ground strut anchor system. This anchor keeps the rail in tension in a vehicular impact near the end of the barrier installation.

- If the end post is broken or if either the cable or steel bearing plate is missing (Photograph D), the anchorage is lost and any motorist striking the rail downstream from the terminal would likely penetrate the system rather than be redirected. Thus, if any of these components are deficient, repair work should be a very high priority.
- For those terminal designs that incorporate an energy-absorbing head, it is critical that this head be properly aligned and in position with the W-beam rail element so the rail will "feed" into it in any head-on crash. If the impact head cannot slide along the W-beam, its energy absorbing capacity is seriously compromised, probably resulting in a more severe crash. In Photograph E, the impact head and post #1 are misaligned, reducing or preventing its intended performance in an end-on impact.

A

B

C

D

E

Fixing America's Surface Transportation Act

Tech Brief

November 2017

Pre-Installation Field Review Team

CATEGORY: Design/Installation/Inspection

ISSUE: When crews install barrier systems (e.g., traffic barriers and terminals) exactly as shown on project plans, which may have been based on a limited survey of the site, the result can often be an installation that may not effectively shield the obstacle(s), may be too short or too long, may not shield obvious "secondary" obstacles in its immediate vicinity, or may not even be needed.

OBJECTIVE: Encourage all highway agencies to adopt a state-specific process and procedure to achieve the onsite review of a proposed barrier installations by a trained and experienced personnel who can identify and authorize any immediate adjustments needed to provide an optimal installation.

METHODOLOGY: Implement a mandatory field review of planned installations by a team consisting of a prime contractor representative and/or the guardrail installation superintendent/supervisor, project supervisor and FHWA transportation engineer (when appropriate). The ADOT inspector or other ADOT participants should be knowledgeable with barrier design and the crash performance of terminals.

Suggested Special Provision
for Pre-Installation Reviews

- Contractor to notify the construction Project Supervisor of the proposed barrier installation schedule.
- Project Supervisor to assemble review team and schedule pre-installation review.
- Prior to review, contractor or installer to mark planned locations for barrier, terminals and crash cushions.
- No installation to be done without authorization from the Project Supervisor following the review.
- Pre-installation review costs are considered incidental to the traffic barrier items.

A pre-installation review should have found that this placement of two terminal resulted in a gap in the median shielding and recommended an overlapping design treatment.

A pre-installation review should have found that this placement of two terminals created a situation where neither one could perform effectively if hit.

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EXPECTED RESULTS:

Barrier installations that are warranted and effectively shield all potential obstacles behind them and have terminals selected and located to minimize occupant injuries to the extent practicable if impacted.

By understanding that an impact into a non-energy-absorbing terminal can result in a vehicle travelling more than 150 feet behind and beyond the terminal, a review team could have recommended extending this barrier.

PROCESS:

1. Conduct pre-installation reviews on all projects that include barrier installation in the scope of work, including, but not limited to, federal oversight, freeway and expressway projects, and rehabilitation/maintenance/force account work as appropriate. Include a special provision for the pre-installation reviews in the project's contract documents.

2. The contracting agency will notify the prime contractor at the pre-construction conference that a traffic barrier pre-installation review should take place before installing any permanent barrier on the project.

3. Prior to the review, request that the contractor (or the guardrail subcontractor) place temporary markers designating the proposed limits of all barrier, terminals, and crash cushions to be installed on the project. Traffic control will be implemented as needed for this and the following activities.

4. Once the temporary markers are in place, the review team (see Methodology) will schedule the field review. Conduct this review early enough to allow sufficient time to make any necessary adjustments before the contractor begins work. Note: When practical, combine activities 3 and 4 as a single action.

5. The pre-installation review will consider the following items:
   - Is the barrier warranted or can the identified obstacle(s) be removed, relocated, or modified to eliminate the need for a barrier?
   - If warranted, is the barrier the appropriate length to shield the obstacle(s) effectively? Are there other hazardous terrain features or fixed objects that warrant shielding but were not considered in the original project scope?
   - Are there secondary obstacles in the immediate vicinity of the proposed barrier terminal that could be shielded by extending the barrier a reasonable distance?
   - If underground utilities are present, locate and mark them prior to or in conjunction with the field review in case barrier modifications become necessary to avoid them.
   - Is the appropriate terminal type (i.e., energy-absorbing or non-energy-absorbing) specified?
   - Are the approaches to the terminal properly graded to provide for maximum vehicle stability prior to an impact with the terminal?
   - Is there a minimum run-out area behind and beyond the terminal?
   - If on a side slope, is the barrier properly located to minimize the probability of vehicular override or underride?
   - If barrier is to be installed behind or in line with a curb, is it properly located or designed to minimize the probability of vehicular override or underride?
   - Is there any existing barrier within the project limits that should be removed?
   - If there is a gap in barrier runs of 200 feet or less; consider the field conditions and if it would be reasonable to close the gap?

6. As noted above, the composition of the review team should, at a minimum, include contractor or subcontractor personnel directly responsible for installing barrier on the project, the construction Project Supervisor, an ADOT roadside barrier expert, and an FHWA Transportation Engineer (on federal oversight projects). Participation by the agency's construction and design units is also encouraged. The final decision-maker on the team should be thoroughly familiar with barrier and terminal design principles and performance characteristics and have the authority to make on-the-spot modifications as needed.

7. Document all review findings in writing and signatures by all members of the review team. Use existing procedures to process major modifications (e.g., a different barrier type than originally specified). These types of modifications should become more infrequent after implementation of the review process.

8. Relay review findings to appropriate design and central office personnel so they can be used as lessons learned for future project designs.

Fixing America's Surface Transportation Act

Tech Brief

November 2017

Midwest Guardrail System (MGS)

CATEGORY: Design (The following information was developed using DRAFT ADOT proposed MGS standards.)

ISSUE: Standard strong-post W-beam, referred to in Arizona as w-beam guardrail (G4), has been one of the most widely used traffic barriers in the United States. Recent testing with today's high center of gravity vehicles however has shown it to be near or at its performance limits in high speed, high angle roadside crashes. A new non-proprietary design, the Midwest Guardrail System (MGS) has been successfully crash-tested, both under NCHRP 350 and MASH at Test Level 3 (TL-3), and being adopted by ADOT as their preferred system.

OBJECTIVE: To provide information on the MGS and some of its design flexibility to ADOT design engineers and other personnel who may have responsibilities for designing, installing, inspecting, or maintaining this design. ADOT currently has DRAFT standard drawings and specifications available that were developed in conjunction with implementing MGS guardrail system by January 2018 in Arizona.

METHODOLOGY: This Technical Brief will describe the MGS characteristics and identify the types of locations for which variations of the design have been successfully crash-tested. For additional information please see the FHWA website at http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/ and the Midwest Roadside Safety Facility Pooled Fund website at http://mwrsf-qa.unl.edu/.

BASIC MGS DESIGN: The major differences from the standard guardrail are the shifting of the W-beam rail splices from the posts to mid-span between posts, and the raising of the rail height to 31". This provided a stronger system and a better performance with higher center-of-gravity/bumper height pick-up vehicles.

MASH TL-3 Test of MGS Transition to Thrie-beam

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EXPECTED RESULTS:

Provide ADOT design engineers and others with summary information on the Midwest Guardrail System (MGS).

MGS uses the same steel or wood post and rail element (with five holes punched) as the standard guardrail; the wood post is 6′ long. The blockout is now 12″ deep (versus the 8″ on the standard system). The standard MGS (6′-3″ post spacing) resulted in a somewhat increased dynamic deflection when MASH tested. (Reference: FHWA letter B-212, dated 06/10/11). ADOT will select their specific criteria when the new system is adopted. ADOT requires the shoulder be widened and paved 2′ – 8″ from normal width of shoulder, this allows for the rail face to be placed over the paved roadway section.

MGS SOIL BACKING: Standard guidance for installation of guardrail (MGS and G4) is a minimum 10H:1V into the face of the rail, and 2 ft. minimum of 10H:1V behind the post, which is also the ADOT proposed requirement. When this is not practical to provide, the MGS has been successfully crash-tested to MASH with the standard 6′ post placed right at the slope break point. (Reference: FHWA letter B-211, dated 06/10/11).

MGS WITH CURBS: Although previously tested under NCHRP 350, the standard MGS system with curb has not yet been successfully crash tested under MASH at TL-3; current ADOT guidance is to use a (embankment) curb height no greater than 4″, when curbing cannot be avoided, shown on ADOT proposed Standard Drawing, C-10.01 with face of rail flush with face of curb. For lower speed locations, the MGS system has been successfully tested to MASH at TL-2 when located 6 feet behind the face of a 6-inch high vertical concrete curb (Reference: FHWA letter B-133, dated 03/01/05).

MGS LONG-SPAN GUARDRAIL AND OMITTED POST: As with standard guardrail (G4), an MGS design has been developed for use when guardrail posts must be "left out", e.g., when the guardrail crosses a low-fill culvert. Unlike standard guardrail (G4) missing post designs, the MGS system does not require nested rail in the clear span. Testing has shown that a single post can be omitted without any additional modification (i.e. no weakened wood posts or nesting). For 2 and 3 missing posts , three CRT posts with standard post spacing are placed on each side of the span (25-foot maximum) to reduce any snagging potential. Since larger deflections can be expected, nothing protruding more than 4″ should be allowed behind the rail to avoid "tripping" the vehicle (Reference: FHWA letter B-189, dated 03/20/09). ADOT proposed standard for deflection are somewhat more restrictive. Adequate length, 50 ft. or more of standard MGS must extend on either side of the gap to maintain tension in the system. Terminal must not be placed any closer than 50 ft., from the rear of the system, to any omitted post installation. Omitted post designs should ONLY be used in standard guardrail runs and should be separated by a minimum of 50 ft, between additional missing post situations. Missing post should not be used with terminal or transition designs.

MGS TRANSITION DESIGN: The MGS system is compatible with most existing Thrie-beam to rigid barrier/bridge railing transition designs with the use of a non-symmetrical W-beam to Thrie beam 10-gauge transition section and a modified post layout upstream of the Thrie-beam. Steel or wood posts can be used. The recommended design was successfully crash-tested under MASH criteria (References: FHWA letters B-231, dated 01/27/12 and B-236, dated 05/30/12).

MGS TERMINALS: Several terminal designs have been modified so they can be used to terminate the 31-inch high MGS design. These changes generally involve shallower embedment of the original terminal posts so the terminal railing matches the 31-inch height of the MGS design and corresponding related adjustments. Several proprietary terminals have been successfully tested under MASH guidelines for use with the MGS system. See current FHWA Eligibility website at https://safety.fhwa.dot.gov/roadway_dept/countermeasures/reduce_crash_severity/listing.cfm?code=cushions and Arizona approved product list at https://azdot.com.

Fixing America's Surface Transportation Act

Tech Brief

November 2017

In-Service Evaluation of Barrier Systems

ISSUE: Before a traffic barrier, terminal, or crash cushion can be installed on a public road, devices must meet requirements of standardized crash tests, and be included on ADOT's Standard Drawings or Approved Products List (APL). Even so, each barrier type, terminal, and crash cushion has unique installation requirements, different crash performance, and varying degrees of required maintenance/repair during its service life. Unless real world information on these variables is uniformly collected and analyzed statewide, it is possible that the most cost-effective devices are not always selected for use at specific locations and that some devices may not be performing as well in the field as expected.

OBJECTIVE: To inform field personnel to the importance of collecting data on the performance and repair costs associated with safety hardware involved in a crash, as well as an assessment of possible installation issues and degradation due to environmental conditions such as weather, age, climate.

METHODOLOGY: Some state DOTs currently require a field review at locations where any serious crash involving roadside hardware has occurred. A similar review may be appropriate where a barrier, terminal, or crash cushion requires repair following an impact. The type of information to be collected varies, depending on the type of barrier system impacted. Recommended data items to record for each barrier system are listed below.

TRAFFIC BARRIERS:

The primary traffic barriers used that require repair after a crash are cable barriers, box-beam, thrie-beam and w-beam guardrail. Each system can be used as a roadside barrier or as a median barrier. It is recommended to collect and record the following information when these barriers are damaged:

- Identify the type of barrier.
- Evaluate the condition of barrier components (posts, blockouts, rail, etc.) that were damaged and for degradation due to environmental conditions.
- If there is a crash report available, obtain a copy to determine the extent of occupant injuries, the vehicle type and impact conditions (i.e., estimated speed and impact angle), and the final resting position of the vehicle. (If there is no police report, one may conclude the impact was minor and the vehicle was driven from the scene). Did the barrier contain and redirect the impacting vehicle?

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EXPECTED RESULTS:

The information collected as part of this effort will aid ADOT Design engineers with the selection and placement of barrier systems and recognize deficiencies that may compromise performance.

- Measure the distance from the edge of the travel lane to the face of the barrier.
- Identify and record any installation issues such as slopes and/or curbs from the edge of the shoulder to the barrier face, the flare rate if any, slope immediately behind the barrier, deviation from standard drawing, etc.
- Record the height of the barrier upstream and downstream of the damaged area. For cable barrier, identify the manufacturer and measure the height of each cable adjacent to the damaged section and the post spacing.
- Was the barrier a current or obsolete design? Look for things such as steel blockouts or rectangular washers on the face of w-beam barriers. Also note if w-beam rail splices were at the post or mid-span between posts as well as the post spacing.
- Measure the permanent deflection and if the barrier was shielding a vertical fixed object, record the available deflection distance.
- Provide photos of the damaged and adjacent barrier sections.
- Record the extent of damaged barrier and the estimated cost along with any anticipated difficulties with the replacement or repair.

TERMINALS/CRASH CUSHIONS:

There are several types of terminals and crash cushions used throughout the country along with existing systems that no longer meet the current testing criteria. It is recommended to collect and record the following information when these systems are damaged:

- Identify the type of terminal or crash cushion damaged and obtain a copy of the crash report if one was completed.
- If there is a crash report available, determine the extent of occupant injuries, the vehicle type and impact conditions (i.e., estimated speed and impact angle), and the final resting position of the vehicle.

- Identify any installation concerns such as stub height, flare rate, grading, runout area behind terminal, presence of curbs or other objects, missing or nonconforming parts or other deviations from the standard drawings or manufacturer's guidance.
- Identify any secondary impacts or rollover that may have occurred after impact with the terminal or crash cushion. Was this the result of inadequate length or clear area?
- Did the system perform as intended?

- Provide information of the condition of the system as a result of the impact and/or due to environmental issues such as weathering, age, climate, etc.
- Determine if there were any installation issues such as compliance with the manufacturer's drawings, proper site preparation, etc.
- Provide photos of the damaged installation and surrounding conditions.
- Record the estimated cost and any anticipated difficulties to repair or replace a crashworthy system, or to upgrade to State's typical maintenance practices.

Fixing America's Surface Transportation Act

Tech Brief

November 2017

Maintenance of High Tension Cable Barrier

CATEGORY: Maintenance

ISSUE: High tension cable barrier (HTCB) has proven effectively to reduce the frequency and severity of median crossover crashes. Currently, only approved propriety systems are eligible for Federal funding by the FHWA. The systems below meet all full-scale crash testing conducted under NCHRP Report 350 or AASHTO MASH 09 guidelines and are on ADOT Approve Product List (APL).

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Like all barriers, it is important to properly design, install, and maintain HTCB for the best performance. To function properly in an impact, a HTCB must be able to gradually redirect or arrest an impacting vehicle by cable deflection, which minimizes forces on the vehicle and its occupants. To obtain the desired results, the cables must be properly tensioned and and at the correct heights above the ground.

OBJECTIVE: To provide ADOT maintenance personnel with general guidance regarding maintenance and repair of high-tension cable barrier systems. Maintenance can be divided into two areas—routine maintenance and repairs after crashes. For maintenance and repair procedures for specific systems, personnel should receive manufacturer-based training and keep on-hand and use the manufacturer's installation and repair manual.

METHODOLOGY: After striking a high-tension cable barrier, a motorist is oftentimes able to drive away from the crash scene, leaving no documentation, such as a police crash report. Therefore it is important to have frequent field inspections by maintenance and other personnel to identify damaged locations and to aid in timely repairs to maintain optimal performance. This would include both drive-by assessments for obvious impact damage as well as checking cable tension.

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EXPECTED RESULTS:

To Provide ADOT repair personnel charged with repair and maintenance of HTCB with guidance on appropriate repair and maintenance of HTCB.

Cable Inspections: It is important that crews routinely check tension, even in the absence of an impact (photograph A), as per manufacturers' recommendations. This is particularly important during the first few years following cable installation. Cables can lose tension because of construction stretch, temperature changes, anchor creep, fitting slippage, and/or previous impacts elsewhere in the same run of HTCB. Maintenance personnel should also check the tension and inspect the individual cables for kinks or broken strands as part of routine maintenance (at least annually), and also following any repair, in accordance with manufacturer guidelines.

In situations where there is an impact and the vehicle becomes tangled in the cable (photograph B), it is important to keep the cable intact. In many situations, the vehicle can be removed by pulling it in the opposite direction from which it hit the system. Maintenance personnel (as well as emergency responders) should consider cutting the cables only under life-threating situations and other alternatives for loosening the cables are not feasible Alternatives to cutting the cable include:

- Loosen cables at the turnbuckles.
- Cut a turnbuckle rather than a cable. This alternative requires removing the adjacent posts on either side of the turnbuckle.

Note: Before cutting a turnbuckle, ensure all personnel are clear of the cable. Cut the center of the turnbuckle between two undamaged posts away from the impact area. Contact manufacturers for any specific considerations for their particular system.

Posts Inspections: Posts can be installed in cast-in-place concrete sockets, precast concrete sockets, or with driven posts. Systems installed using socketed posts, possibly in conjunction with a continuous mow strip, will facilitate removal and replacement of damaged posts. In most impacts, only the posts are typically damaged (photograph C). If enough posts have been hit or if the damaged section is along a roadway curve, the cables may be on the ground (photograph D) and maintenance personnel should expedite repairs to ensure a fully effective barrier. Damaged posts can present a spearing hazard should a secondary impact occur; crews should remove damaged or bent-over posts to eliminate the spearing potential and appropriately delineate the area to warn the motorist as soon as practical after the discovery/notification of the impact. Complete repairs in a timely manner to maintain the systems optimal performance. It is recommended that a District maintain a supply of posts for the high-tension cable barrier systems used in the district for use as needed.

Anchorage Inspections: Anchorage designs for high-tension cable barrier are unique in that impact to an anchor releases tension in long sections of barrier, making it ineffective. For this reason, locate anchors in areas where they are least likely to be struck. Offsetting the downstream and upstream anchors at a median crossover or introducing an anchor near the downstream end of a bridge rail can minimize terminal impacts. Some terminal designs anchor each cable separately (photograph E), so tension is retained in some cables when only one anchor post is released. However, most designs use a single anchor point and all tension is lost upon impact. Therefore, repair of the anchorage and resetting the cable should be a high priority.


A


B


C


D


E