MDT Bridge Rail Design and Selection Guidance

Purpose

The purpose of this document is to provide guidance on bridge rail use and on the selection of railing for the Montana Department of Transportation (MDT) Bridge Bureau and consultants employed by MDT. It is for new bridges and for bridges being rehabilitated where railing replacement is appropriate. This document provides direction in becoming compliant with the joint agreement between the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) requiring all new safety hardware installations on National Highway System (NHS) facilities to be evaluated using the 2016 edition of the Manual for Assessment of Safety Hardware (MASH). Implementation deadlines are outlined per AASHTO and FHWA agreements located at this address: https://design.transportation.org/mash-implementation/

This guidance is intended to be used in conjunction with Guidelines for Nomination and Development of Pavement Projects and the Bridge Rail Agreement. Implementing MASH roadside hardware is a fluid and incremental process. As such, this document should be checked for revision updates as design strategies are developed and crash-tested systems become increasingly available. Similarly, for rehabilitation projects many eras of bridge rail and approach rail must be combined with MASH-tested hardware and this guidance is intended to provide uniform treatment of rail revisions as they are developed.

MASH Background

The AASHTO MASH is a testing criterion for roadside hardware which updated and supersedes the previous standard called NCHRP 350. Test vehicles were updated to what is being produced and sold today, which means an increase in weight and changed center of gravity. Impact conditions were modified to more correctly represent actual conditions and test speeds were increased as well. The MASH document provides uniform guidance for testing highway safety features to assess the safety performance of those features. This guidance utilizes the latest advancements in the knowledge and technology of roadside safety testing and evaluation and includes classifications of crash-test levels with specified vehicle, speed, impact angle and impact location for each level.

Identify Crash Loads used for MASH

LRFD Bridge Design Spec currently outlines NCHRP 350 crash loads in Appendix 13 (LRFD A13). The MDT Bridge Bureau recognizes that LRFD may underrepresent loads generated by MASH-level testing (especially for TL-4 and above). At this time, Bridge Bureau has utilized the following load schedule for designing elements that must resist MASH TL-4 forces:

Table 3.9 Summary of Magnitude, Distribution and Application of the MASH TL-4 Impact Loads.

Design Forces and Designations	Barrier Height (in.)			
	36	39	42	Tall
F_t Transverse (kip)	67.2	72.3	79.1	93.3
F_L Longitudinal (kip)	21.6	23.6	26.8	27.5
F_v Vertical (kip)	37.8	32.7	22	N/A
L_L (ft)	4	5	5	14
H_e (in.)	25.1	28.7	30.2	45.5

N/A= not applicable

Per MASH EQUIVALENCY OF NCHRP Report 350-APPROVED BRIDGE RAILINGS (http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07(395)_FR.pdf):

As MASH level loads are better established, more sources will become available to better define demands. Designers are encouraged to seek the most current publications for guidance.

Bridge Approach Sections

Coordinate with Road Design on the bridge approach section. Currently, the only MASH compliant bridge approach section used by MDT is the Midwest Guardrail System (MGS) Thrie Beam Bridge Approach Section. See DWG. NO. 606-23A & 23B.

The MGS bridge approach section will be attached directly to the sloped face of MDT Single Sloped Concrete Barriers (36" and 42" height), face of jersey barrier retrofit, and sloped face of concrete barrier retrofits or existing or new concrete parapets.

Two additional approach sections are being developed and standard details will be released upon completion of crash tests:

1. MGS Thrie Beam Approach connected to Type Open Bridge Rail 42"
2. Box Beam Approach connected to Type Open Bridge Rail 42"

The new MDT Single Sloped Concrete Barrier (SBR-SS36 and SBR-SS42) and the Open Bridge Rail (SBR-OR42) will be discussed further in depth later in this guidance.

Lastly, MDT has not selected a MASH tested roadside concrete barrier (RCB). No crash tested details exist to connect the current RCB shape to concrete bridge rail. Where RCB connects to SBR-SS36 and SBR-SS42 bridge rail, a transition section will have to be developed. Bridge Bureau should design this connection to resist NCHRP 350 crash loads per LRFD A13.

Bridge Rail Stationing

Pay limits for bridge rail and the MGS Thrie Beam Approach Section overlap. To reduce confusion, do not include bridge end rail stationing on plans for both retrofit and new structures.

New Bridges

The intent is to install MASH TL-4 bridge rail on all new bridges let after the implementation deadline. For bridges that require unique treatments, an acceptable MASH alternative may not currently exist and designers should use the RSH and companion documents to determine a permissible solution. For example, drift prone bridges may require the use of W830 bridge rail until a MASH tested system is available or off-system structures may end up utilizing an old standard. Any rail systems that are not MASH tested should be documented in the SOW report.

MDT Bridge Bureau is implementing two MASH barrier types: Single Sloped Concrete Barrier and Open Bridge Rail. The Open Bridge Rail is intended to be the primary bridge rail after the approach sections are crash tested. In the interim, the Open Bridge Rail is available for use with a parapet and is at the discretion of each district to install open rail or concrete barrier.

Concrete Barrier

Select Type Single Slope 36" concrete barrier (SBR-SS36B and SBR-SS36R) when Open Rail is not suitable such as when the bridge is over a highway or railroad. A Type Single Slope 42" concrete barrier (SBR-SS42) is available for use on a case by case basis (e.g. in locations with high speed, high truck traffic on a curved alignment). There are bid items for both rails. They are as follows: "*36 IN SS Concrete Barrier Rail – BR*" and "*42 IN SS Concrete Barrier Rail – BR*". Currently, the LRFD Deck Design spreadsheet and the Bridge Apps Suite are not updated to include these barrier shapes.

Barrier capacity for the SBR-SS36 is comparable to the previous jersey barrier rail (SBR-BRR) but deck overhangs should be checked until the LRFD Deck Design spreadsheet is updated. Design bridge deck overhangs to accommodate SBR-SS42 barrier capacity. (Note that the topic of capacity protecting the deck overhang is currently under review by the bureau and designers are encouraged to seek the latest information.)

Bridge roadway width for SBR-SS36 and SBR-SS42 is the distance from toe of barrier to toe of barrier.

Concrete Barrier Cover Plate

Bridges with a barrier gap exceeding approximately 4 inches at an expansion joint should utilize a cover plate across the gap. For most gaps, a ¼ inch thick plate shaped to match the top and face of the single slope barrier is adequate to prevent vehicle snagging. This plate should be recessed and may be and installed with threaded inserts. For large expansion gaps, a thicker plate might be required. An example of a recessed cover plate can be found here: Recessed Cover Plate

New Bridges Designed with Jersey Shaped Concrete Rail

Some new structures have been designed with the previous standard concrete barrier (SBR-BRR) and will be let before the MASH implementation deadline. Therefore, this detail is intended to be short lived and is used in a few circumstances to implement MGS roadside rail. Use the 6-foot bridge barrier end

connection detail for jersey barrier to MGS approach railing. Design the transition piece to withstand NCHRP 350 crash loads per LRFD A13.

See link for details: SBR-BRR Modified to accept MGS Thrie Beam

Example of reinforcing: Modified BRR End Example

Bridge width for SBR-BRR is measured from toe of rail and roadway width is measured from face of rail (4" setback from toe of rail).

Open Bridge Rail

Type Open Bridge Rail 42" (SBR-OR42) is intended for primary use. If the Open Bridge Rail system is to be used before the approach details are available, the MGS Thrie Beam Approach Section may be connected to a concrete parapet cast either on the bridge deck or as part of a turnback wingwall. This configuration is not considered favorable for drift prone locations. Do not use Type Open Bridge Rail when the bridge is over highways or railroads or where connection to roadside concrete barrier rail is required. For these cases, select a single slope concrete barrier.

This rail is tested to MASH TL-4 and is available with and without pickets. Only use pickets when they are specifically documented in the Scope of Work (SOW) report. This may occur when aesthetic enhancements are being considered within a municipality or when installed adjacent to sidewalk. See drawing SBR-OR42-PK.

The bid item for open bridge rail is "*42 IN Open Rail – BR*". This bid item includes all costs associated with installing the standard barrier (e.g. steel tube and post, curb, and associated hardware). Where a concrete parapet is required, use the bid item "*42 IN Open Rail Parapet - BR*" which also includes the cost of the parapet shoe. For jobs utilizing pickets with this rail, add the bid item "*42 IN Open Rail Picket – BR*" to account for additional cost of fabricating and installing the picket panels onto the standard barrier.

Bridge roadway width for SBR-OR42 and SBR-OR42-PK is the distance from face of curb to face of curb.

Bridge Locations with Drifting Issues

Until such time the Type Open Bridge Rail 42" is available with an accompanying box beam approach, select W830 Bridge Rail (SBR-W830) and Box Beam Bridge Approach Sections (DWG. NO. 606-53) when drifting is a known issue. Document this decision in the SOW report.

Bridge roadway width for SBR-W830 is the distance from face of curb to face of curb.

Bridge Rail Across Stub Abutments

For most typical structures, the bridge approach rail is permitted to deflect with bridge movements. In unique cases where excessive deflections would inhibit performance of the approach rail, a turnback wingwall should be added to extend the bridge rail past the deck expansion joint. This wingwall must be of adequate size to resist the vehicle impact load and to anchor a terminal bridge rail panel that accommodates a barrier expansion joint (refer to the expansion splice detail for open rail or evaluate need

for cover plate on concrete barrier). An example of a stub abutment wingwall can be found here: Stub Abutment Wingwall.

Bridge Rehabilitation Projects

Treatment of bridge rail is split into two categories. Rails tested to NCHRP 350 and bridge rails not meeting these criteria.

Rehab Projects with Bridge Rail Tested to NCHRP 350

Bridge approach sections tested to NCHRP 350 may remain in place, but their use should be coordinated with Road Design. MDT bridge rails standards that meet NCHRP 350 criteria and are not required to be replaced. This applies to the following bridge rails:

- W740
- W830
- SBR-BBR
- T101

When a MASH approach section is to be used, then modify the ends of these systems to accept an appropriate bridge approach section as shown in the MDT Detailed Drawings.

Existing Jersey Barrier

Where MGS Bridge Approach Section is to be installed, modify existing jersey barrier to accommodate MGS Thrie Beam Approach Section as shown here: MGS to Existing Jersey Barrier

Rehab Projects with Bridge Rail Not Passing NCHRP 350 Criteria

This section outlines the current bridge rail retrofit designs. Bridges with outdated rail should be retrofitted to mimic the geometry and desired behavior of MASH tested systems. It should be noted that the retrofit barrier designs often have capacities that exceed the capacity of many older deck overhangs. MDT Bridge Bureau has accepted the potential for deck damage in the event of a significant vehicle impact.

For Bridge Rehabilitation projects (work types 230, 231, 232) revise bridge rail, attach an appropriate bridge rail approach section, then immediately transition to existing roadside rail. In cases where MASH systems are connected to existing roadside rail there is potential for post spacing conflicts that may require additional detailing effort. On a project-specific basis, some sites may warrant full replacement of the roadside guardrail.

On all rehab projects, coordinate bridge approach sections with Road Design. Barrier ends should be modified to accept a MASH transition where possible. In situations where a MASH approach is not practical, use of older standards or modified MASH transition is permitted (e.g. continued use of T101 Timber Rail Revisions). In rare instances where concrete barrier ends are recast and a non-MASH approach section is used, install additional sleeves in the modified barrier end to accept future installation of the MGS Thrie Beam Bridge Approach Section.

Existing Post and Beam Railing on Curb

1. **Concrete barrier** – Cast a single slope concrete barrier on existing curb. Use a 36" tall barrier measured from finished surface to top of rail and with a slope matching that of the curb face. See example here: 36" Single Slope Concrete Retrofit Barrier
2. **Thrie beam rail** – Select thrie beam bridge rail when there are concerns about extra weight on an existing structure from a concrete barrier or a faster installation time than concrete barrier is needed. Thrie beam retrofit is preferred when there are voids in the curb sections on the deck such as that shown in Section B-B on the old SBR-T4 drawing, but the concrete barrier retrofit may also be used. Use the bid item "*Revise Bridge Rail – Thrie Beam*" for this work. See link for plan set using thrie beam railing on voided curb: Thrie Beam on Existing Curb

Existing Concrete Rehab Barriers on Curb

For bridges already retrofitted with a single slope concrete barrier, modify the barrier ends to accept the MGS Thrie Beam Approach Section as shown: End Modification for Existing Rehab Barrier

For projects that require a streamlined implementation or require minimal traffic control, an acceptable installation method is as follows: Drill 2" holes and epoxy in 1.5" galvanized pipe sleeves in order to facilitate direct connection to the MGS Thrie Beam Approach Section to the existing concrete barrier.

In some cases, a retrofit jersey shape was cast on curb. If adequate clearance allows, attach MGS Thrie Beam Approach sections directly to the face of the rail as shown: Retrofit Jersey Shape Cast on Curb

Timber Rail

Follow the preferred course of action listed below for rail revisions on timber bridges. Document decisions made in the Scope of Work document.

1. If MGS Thrie Beam Approach Sections are planned, considering using thrie beam railing across the bridge. The bid item is "*Revise Timber Bridge Rail – Thrie Beam*". An example of this revision may be found here: Revise Timber Bridge Rail. It should be noted that the drilled shaft anchor posts for timber rail revisions are no longer required for this detail.

2. Where it is not practical to connect a MASH transition to the bridge rail, continued use of the T101 timber rail revision is permitted (BRSTDTRR). Continue to use the Drilled Foundation Anchor Post detail for the bridge approach rail (BRSTDXDS).

3. Where box beam bridge rail is required use the bid item is "*Revise Timber Bridge Rail – Box Beam*". Bolt box beam to the timber deck and transition to roadside box beam using DWG. NO. 606-53. An example of this revision may be found here: Box Beam on Timber Bridge. When the MASH tested box beam approach section becomes available, this detail may need to be modified for situations where the existing approach section is not tested to NCHRP 350.

Approach Slab Conflicts

On rehabilitation projects, if an existing structure has approach slabs, they may conflict with the MGS Thrie Beam Approach Section rail posts and possibly box beam approach section rail posts. Approach slabs known to have conflicts include the Type 39-14.

Follow the preferred course of action listed below when an approach slab is present and in conflict with bridge approach rail posts.

1) Remove approach slabs if there are settlement issues or if Maintenance has concerns with them. For pavement preservation projects, this may not be an option as well as on projects with minimal traffic control. Mill/fill projects and reconstruction projects lend themselves to slab approach removal. If no settlement or other Maintenance issues exist, leave the slabs in place.
2) Extend barrier to the end of the approach slab.
3) Modify the approach slab to accept the new rail posts. An example of this modification can be found here: Typical Approach Slab Conflict Detail
    a. Use the bid item titled, "*Modify Bridge Approach Slab*" with a measurement of "Each" for each corner of the approach slab being modified.
    b. Include the special provision titled, "*Modify Bridge Approach Slab*" to describe the work in the project special provisions.