DEPARTMENT OF TRANSPORTATION

MASH Implementation for Bridges

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Contents

Introduction

A December 21, 2015 agreement between the American Association of State Highway Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) requires that for contracts on the National Highway System (NHS) with a letting date after December 31, 2019, only safety hardware evaluated using the 2016 edition of the *Manual for Assessing Safety Hardware* (MASH) criteria will be allowed for new permanent installations and full replacements for bridge railings.

"Railings" is used as a generic term in the specifications and includes traffic railings, combination railings, bicycle railings, and pedestrian railings. MnDOT further classifies railings as follows:

- Barriers – Concrete railings that have a non-vertical traffic face (e.g. - Type S).
- Parapets – Concrete railings that have a vertical traffic face and a brush curb (e.g. - Type P-4).
- Metal Railings – Steel Railings mounted on curbs, parapets, or the back of barriers (e.g. - Ornamental Metal Railing, Design T-4).
- Timber Railings – Bridge Standard Plans 5-397.175 & 176 include details for TL-2 and TL-4 timber railings for use on local bridges. These were tested in accordance with NCHRP 350 and can be employed until superseded by future MASH compliant standards.

MASH was originally published in 2009, with a second edition issued in 2016. MASH procedures were developed as a replacement for the testing procedures defined by NCHRP Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, which was originally published in 1993 and implemented in 1998. There were three reasons that the procedures were updated: updates to the vehicle fleet, removal of inconsistencies in impact condition criteria, and improving clarity in evaluation criteria.

The changes in the vehicular fleet have led to changes in the vehicles used for the testing. The test vehicles were updated between NCHRP 350 and MASH to reflect the current 85th percentile of the passenger vehicle fleet in the United States. For example, the loads for the single-unit van truck have changed from 18 kips with a center of gravity at 49 inches in NCHRP 350 to 22 kips with a center of gravity at 63 inches in MASH. The full comparison at all test levels is found in Table 1.

Previously, MnDOT standard practice for new installation has been to require bridge railings that meet NCHRP Report 350 Test Level 4 (TL-4) on bridges with design speeds greater than 40 mph and TL-2 on bridges with design speeds less than or equal to 40 mph. This document defines standard practice moving forward.

	Vehicle Characteristics	Small Automobiles		Pickup Truck	Single-Unit Van Truck	Van-Type Tractor-Trailer		Tractor-Tanker Trailer
NCHRP 350	W (kips)	1.55	1.8	4.5	18	50	80	80
	B (ft)	5.5	5.5	6.5	7.5	8	8	8
	G (in)	22	22	27	49	64	73	81
	Crash angle (θ)	20°	20°	25°	15°	15°	15°	15°
	Test Level	Test Speeds (mph)						
	TL-1	30	30	30	N/A	N/A	N/A	N/A
	TL-2	45	45	45	N/A	N/A	N/A	N/A
	TL-3	60	60	60	N/A	N/A	N/A	N/A
	TL-4	60	60	60	50	N/A	N/A	N/A
	TL-5	60	60	60	N/A	N/A	50	N/A
	TL-6	60	60	60	N/A	N/A	N/A	50
MASH	W (kips)	2.42	3.3	5	22	N/A	79.3	79.3
	B (ft)	5.5	5.5	6.5	7.5	N/A	8	8
	G (in)	N/A	N/A	28	63	N/A	73	81
	Crash angle (θ)	25°	N/A	25°	15°	N/A	15°	15°
	Test Level	Test Speeds (mph)						
	TL-1	30	N/A	30	N/A	N/A	N/A	N/A
	TL-2	45	N/A	45	N/A	N/A	N/A	N/A
	TL-3	60	N/A	60	N/A	N/A	N/A	N/A
	TL-4	60	N/A	60	55	N/A	N/A	N/A
	TL-5	60	N/A	60	N/A	N/A	50	N/A
	TL-6	60	N/A	60	N/A	N/A	N/A	50

Table 1: Bridge Barrier Test Levels and Crash Criteria for NCHRP 350 and MASH, where W is weight of the vehicle, B is the out-to-out wheel spacing on an axle, and G is the height of the vehicle center of gravity above the bridge deck

Safety Hardware System Components

The safety hardware system on and approaching a bridge consists of three components: the adjacent roadway system, the bridge railing, and the transition between the two. This document addresses the bridge railing and the bridge/roadway transition, together designated as the bridge railing system in this document. The guidance for the adjacent roadway system, including guidance for concrete barriers off bridges, such as median barrier, guardrail, and end terminals are the responsibility of the Design Standards Engineer.

Determination of Adequacy for Use

There are three criteria that must be met for a bridge railing system to be considered adequate for use: stability, geometry, and strength. Stability is met by satisfying minimum height requirements. Geometry is met by satisfying snagging requirements. Snagging can lead to vehicle instability, occupant compartment damage, and excessive acceleration on drivers and passengers, among other undesirable consequences. Finally, strength is determined by evaluating the structural capacity of the elements of the bridge railing system.

MnDOT practice for determination of MASH compliance is to self-certify bridge railing systems for use on Minnesota bridges that meet the stability, geometry, and strength requirements. This process will be done through the Bridge Standards and Research Unit and the Design Standards Unit, with standards approval by the Bridge Office Research and Development (R&D) Committee and/or the Design Advisory Committee. For a bridge railing system to be used, it will need to meet the requirements of self-certification. This is a long standing MnDOT practice that will be defined more clearly in this document.

MnDOT will use one of the following methods to determine when and where a bridge railing system is appropriate to use.

1. Eligibility letter issued by the Federal Highway Administration (FHWA)

In a May 26, 2017 update to the process for requesting eligibility letters, FHWA changed the requirements for issuance of an eligibility letter. Now, all crash tests in the suite recommended by MASH must be complete for consideration of an eligibility letter.

2. Letter issued by a certified facility

MnDOT will accept a letter from a certified facility, such as the Midwest Roadside Safety Facility (MwRSF) or the Texas Transportation Institute (TTI) stating that a bridge railing system meets MASH. Those facilities can perform simulations, modeling, and evaluation of the test results. An advantage to this process over an FHWA eligibility letter is that not every test in the suite of MASH recommended tests may be required based on the professional experience of the facility experts.

3. Comparable geometry and strength by analysis

A bridge railing system with a structural strength equal to or higher than required by MASH and that also meets MASH geometry and stability requirements can be considered acceptable. For example, a barrier that has the same geometry as one that has an FHWA eligibility letter can be used on the MnDOT system with different rebar size and spacing, provided its strength exceeds the MASH criteria. If the computed strength does not exceed the theoretical static equivalent force based on MASH criteria but analysis demonstrates that it exceeds the computed strength of the original MASH crash-tested barrier, it is also deemed acceptable.

4. Other agency standards

Other agency standards may be used on the MnDOT system, provided the original developer used one of the above methods for determining adequacy. The process of "borrowing" from other agencies is more challenging than it was previously, because many more owners are opting to self-certify rather than getting FHWA approval. For MnDOT to use a system developed by another agency, documentation showing the development process and that it was consistent with MnDOT requirements is imperative.

Process

Any bridge railing system that will be used on Minnesota bridges must follow one of the processes above. Systems that will be used regularly may be developed into standard plans. Bridge railing systems that will be used on a single or very few projects, such as bridge railings with special aesthetic designs or historic features, must be reviewed by the Bridge Standards Engineer and the Design Standards Engineer to confirm that an adequate process was followed.

New Installation

For all projects let after December 31, 2019, all installations of bridge railing systems on new bridges or existing structures where the barrier is replaced must meet MASH 2016 criteria. For speeds 45 mph and lower, TL-2 is acceptable; for speeds over 45 mph, TL-4 is required. When TL-4 railings are required on bridges, the bridge/roadway transition rails on approach panels may be TL-3. Where TL-2 bridge railings are acceptable on the bridge, a TL-2 bridge/approach transition railing is acceptable on the approach panel. Although the FHWA/AASHTO agreement only requires bridge railing systems on bridges on or over the National Highway System (NHS) to meet the MASH requirements, MnDOT requires it for all MnDOT system bridges.

On very low volume roads (ADT<500) with no crash history, the use of a TL-3 bridge railing system on a high-speed roadway is acceptable when there are no TL-4 railings that can be used. Additionally, for bridges that are eligible for or are on the National Register of Historic Places, TL-3 bridge railing systems are acceptable when no historically appropriate TL-4 railing is available.

Bridge railing systems on retaining walls are required to follow the same test level requirements as those located on bridge decks based on the speed of the roadway adjacent to the bridge railing. Bridge railing systems on wingwalls can be the same as what is required on the approach panel. However, on very long or tall wingwalls located on high-speed roadways, extend the TL-4 bridge railing to within 20 feet of the end of the wingwall. Bridge railing beyond this length can be designed to meet TL-3.

Protect vehicles when crossing bridge culverts that do not extend far enough to have a recoverable slope in the entire clear zone. Bridge railing systems for culverts are chosen by the roadway designer and can be MASH TL-3.

When a railing system and moment slab are present to prevent vehicles from reaching a drop-off adjacent to a retaining wall, railing systems on moment slabs are required to follow the same test level requirements as those located on bridge decks based on the speed of the roadway adjacent. When the railing system is being used to

protect a pier from a potential impact, use a MASH TL-5 railing system in compliance with the provisions of AASHTO LRFD Article 3.6.5. Other situations may be evaluated on a case-by-case basis.

Temporary barrier on bridges and temporary bridges may use MASH TL-3 barriers for high-speed traffic.

MnDOT has published bridge standards for several types of MASH compliant railing systems including;

- 36", 42", and 54" single slope barriers (Type S) (Standard plans 5-397.138 – 5-397.143)
- 36", 42", and 54" split median single slope barriers (Type S) (Standard plans 5-397.144 – 5-397.146)
- 36", 42", and 54" solid median single slope barriers (Type S) (Standard plans 5-397.147 – 5-397.149)
- Structural tube railing (T-1) mounted on concrete parapet (P-2) (Standard plans 5-397.157(A) – 5-397.157(H))
- Concrete parapet (P-1) (low speed) (Standard plans 5-397.166(A) – 5-397.166(H))
- Concrete parapet (P-4) (high speed) (Standard plans 5-397.173(A) – 5-397.173(D))

Existing Structures

Existing structures are a much more complex issue with regards to bridge railing system test levels. Most existing bridge railings that would be required to meet MASH TL-4 will not meet that threshold due to having a height less than 36 inches. Requiring these bridge railings to be upgraded to meet a TL-4 level is not a financially viable option, because nearly every project would require upgrading barriers. Therefore, MnDOT has taken a risk-based approach to determine how to manage in-service bridge railing performance. Historically, the MnDOT Bridge Preservation and Improvement Guidelines (BPIG) allowed flexibility in allowing barriers designed at a 10-kip load, with no snagging potential, in good condition, and meeting a minimal height to be left in-place. This guidance has been replaced by MnDOT Technical Memorandum 22-03-B-01 which includes an update to Chapter 9 "Bridge Barrier and Endpost" of the MnDOT Bridge Preservation and Improvement Guidelines (BPIG) which incorporates the following MASH criteria:

- When a bridge railing system does not meet at least MASH TL-3 stability, geometric, shape, and strength requirements for roads with a posted speed limit greater than 45 mph, modify the railing to meet at least MASH TL-3 or replace the bridge railing system with one meeting the crash-tested shape and strength requirements for new bridges.
- When a bridge railing system does not meet at least MASH TL-2 stability, geometric, shape, and strength requirements for roads with a posted speed limit of 45 mph or lower, modify the bridge railing system with one meeting MASH TL-2 stability, geometrics, shape, and strength requirements or replace it with one meeting the crash-tested shape and strength requirements for new bridges.

Complete details for assessing existing railings are included in Chapter 9 and the appendices of the BPIG.

Transitions

Guardrail Connection to Existing Structures

On preservation projects, section 10C of the MnDOT Facilities Design Guide provides guidance on when and how to upgrade W-beam guardrail to Type 31. Many projects that upgrade guardrail also want to upgrade the connection to the existing end post. If the existing end posts need to be replaced to accommodate the new

guardrail, projects become substantially more expensive, traffic disrupting, and time consuming. These upgrades often necessitate a significant amount of replacement of approach panel and barrier to make the transition. Existing bridges with MASH TL-3 compliant Type F and Type J barriers consist of more than half of the length of all barriers on the MnDOT bridge inventory. MnDOT standard roadway plan 5-297.695 provides details for connecting new Type 31 guardrail to existing bridges with Type J or F barriers.

The solution for connecting an existing G barrier, one-line railing, or vertical parapet to a Type 31 guardrail includes removing the end of the existing barrier and recasting a transition to a Type S or vertical parapet shape that is compatible with the Type 31 connection. Refer to chapter 9 of the BPIG for additional guidance and examples for reconstructing an end post.

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