Research and Activities at Texas A&M Transportation Institute For Mash Bridge Railings

AASHTO Committee on Bridges and Structures
T-7 Technical Committee on Guardrail and Bridge Rail

June 25, 2019
Montgomery, Alabama
William Williams, P.E.
MASH Implementation for Bridge Rails

• AASHTO/FHWA Letter Dated January 07, 2016

Memorandum

Subject: INFORMATION: AASHTO/FHWA Joint Implementation Agreement for Manual for Assessing Safety Hardware (MASH)

From: Thomas Everett
Director, Office of Program Administration
Michael S. Griffith
Director, Office of Safety Technologies

To: Division Administrators
Directors of Field Services
Federal Lands Highway Division Directors

Date: JAN - 7 2016

In Reply Refer To: HSST

Purpose

The purpose of this memorandum is to share information regarding the American Association of State Highway and Transportation Officials (AASHTO)/FHWA Joint Implementation Agreement for the AASHTO Manual for Assessing Safety Hardware (MASH). Recently, the agreement was successfully balloted by AASHTO’s Standing Committee on Highways and approved by FHWA.

Information

On November 12th, 2015, FHWA issued a memorandum (http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/policy_memo/memo11215/) indicating that all modifications to NCHRP 350-tested devices will require testing under MASH in order to receive a Federal-aid eligibility letter from FHWA. In addition, a Federal Register Notice (https://www.federalregister.gov/articles/2015/11/13/2015-28753/manual-for-assessing-safety-hardware-mash-transition) was also issued regarding this action. This action provided a significant step forward to the implementation of MASH.

Through the AASHTO/FHWA partnership, the agreement was executed to define actions needed for full implementation of MASH over the course of several years. Per the agreement, the implementation of the forthcoming edition (anticipated Spring 2016) of the AASHTO Manual for Assessing Safety Hardware (MASH) will be as follows:

• The AASHTO Technical Committee on Roadside Safety will continue to be responsible for developing and maintaining the evaluation criteria as adopted by
AASHTO. FHWA will continue its role in issuing letters of eligibility of roadside safety hardware for federal-aid reimbursement.

- 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.
- 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 an upgrade to the safety hardware.
- For contracts on the National Highway System with a letting date after the dates below, only safety hardware evaluated using the 2016 edition of MASH criteria will be allowed for new permanent installations and full replacements:
  - December 31, 2017: w-beam barriers and cast-in-place concrete barriers
  - June 30, 2018: w-beam terminals
  - December 31, 2018: cable barriers, cable barrier terminals, and crash cushions
  - December 31, 2019: bridge rails, transitions, all other longitudinal barriers (including portable barriers installed permanently), all other terminals, sign supports, and all other breakaway hardware
- Temporary work zone devices, including portable barriers, manufactured after December 31, 2019, must have been successfully tested to the 2016 edition of MASH. Such devices manufactured on or before this date, and successfully tested to NCHRP Report 350 or the 2009 edition of MASH, may continue to be used throughout their normal service lives.
- Regarding the federal-aid eligibility of highway safety hardware, after December 31, 2016:
  - FHWA will no longer issue eligibility letters for highway safety hardware that has not been successfully crash tested to the 2016 edition of MASH.
  - Modifications of eligible highway safety hardware must utilize criteria in the 2016 edition of MASH for re-evaluation and/or retesting.
  - Non-significant modifications of eligible hardware that have a positive or inconsequential effect on safety performance may continue to be evaluated using finite element analysis.

Division Offices should discuss the MASH implementation agreement with state transportation agency partners and monitor the actions taken and progress towards the dates established in the agreement.

If you have any questions or comments, please contact Brian Fouch in the Office of Safety at (202) 366-0744.
Roadside Safety Pooled Fund

- Visit our roadside safety pooled fund website
- www.roadsidepooledfund.org
- Several states are members
- Work on key research areas pertaining to roadside safety
- Collection of valuable information on the testing of roadside safety hardware
- Database for current MASH approved Bridge Rails
Visit our MASH Database for MASH Approved Bridge Rails
The AASHTO Manual for Assessing Safety Hardware (MASH) is the new state of the practice for the crash testing of safety hardware devices for use on the National Highway System (NHS). It updates and replaces NCHRP Report 350.

MASH presents uniform guidelines for crash testing permanent and temporary highway safety features and recommends evaluation criteria to assess test results. This manual is recommended for highway design engineers, bridge engineers, safety engineers, researchers, hardware developers, crash test laboratories, and others concerned with safety features used in the highway environment.

The implementation of the AASHTO Manual for Assessing Safety Hardware (MASH) by State DOTs will necessitate the examination and evaluation of roadside safety hardware currently being used by the State DOTs. It is already known that some currently used roadside safety hardware will not meet MASH requirements.
Hardware Tested

To filter available hardware devices, select the type of device, test level, eligibility letter, and if the device is proprietary/non-proprietary. If there are options available for the device selected they will appear to the right. Results are displayed below and can be selected for more information.

Device Types

Test Level

FHWA Eligibility Letter

Proprietary/Non-proprietary

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
<th>Proprietary/Non Proprietary</th>
<th>FHWA Eligibility Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoneguard barrier without pads</td>
<td>On both asphalt and concrete surface</td>
<td></td>
<td>B176C</td>
</tr>
<tr>
<td>Mobile Barrier Trailer</td>
<td>Extended, mobile, longitudinal barrier that provides a physical and visual wall</td>
<td></td>
<td>B178</td>
</tr>
</tbody>
</table>
Hardware Tested

The information provided in this database is for reference only. It is the responsibility of the user/designer to verify that the selected system meets current Federal eligibility and safety requirements.

To filter available hardware devices, select the type of device, test level, eligibility letter, and if the device is proprietary/non-proprietary. If there are options available for the device selected they will appear to the right. Results are displayed below and can be selected for more information.

<table>
<thead>
<tr>
<th>Device Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
</tr>
<tr>
<td>Breakaway Devices</td>
</tr>
<tr>
<td>- Luminaire Supports</td>
</tr>
<tr>
<td>- Mailboxes</td>
</tr>
<tr>
<td>- Sign Supports</td>
</tr>
<tr>
<td>Crash Cushion</td>
</tr>
<tr>
<td>Longitudinal Barriers</td>
</tr>
<tr>
<td>- Bridge Railings</td>
</tr>
<tr>
<td>- Cable Barriers</td>
</tr>
<tr>
<td>- Cast In Place Barriers</td>
</tr>
<tr>
<td>- Guardrails</td>
</tr>
<tr>
<td>- Median Barriers</td>
</tr>
<tr>
<td>- Portable Barriers</td>
</tr>
<tr>
<td>Terminals</td>
</tr>
<tr>
<td>Transitions</td>
</tr>
<tr>
<td>Work Zone</td>
</tr>
<tr>
<td>- Barricades</td>
</tr>
<tr>
<td>- Temporary Sign Supports</td>
</tr>
<tr>
<td>- Traffic Control Devices</td>
</tr>
<tr>
<td>- Truck-Mounted Attenuators</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
<th>Proprietary/Non proprietary</th>
<th>FHWA Eligibility Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>Anchored in concrete at ends.</td>
<td>Proprietary</td>
<td>B176C</td>
</tr>
</tbody>
</table>
Hardware Tested

The information provided in this database is for reference only. It is the responsibility of the user/designer to verify that the selected system meets current Federal eligibility and safety requirements. To filter available hardware devices, select the type of device, test level, eligibility letter, and if the device is proprietary/non-proprietary. If there are options available for the device selected they will appear to the right. Results are displayed below and can be selected for more information.

**Device Types**
- Bridge Railings

**Test Level**
- All

**FHWA Eligibility Letter**
- All

**Proprietary/Non-proprietary**
- All

**Bridge Railing Options**

**Material:**
- Combination
- Concrete
- Steel
- Timber

**Combo (Veh/Ped):**
- Yes
- No

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
<th>Proprietary/Non-proprietary</th>
<th>FHWA Eligibility Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>153-ft long reinforced concrete cantilevered deck and parapet. with</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TxDOT Type SSTR

Report Numbers: FHWA/TX-12/9-1002-5

Description:
TxDOT concrete single slope traffic rail (36° tall)

Test Level: 4

Barrier Type: Single Slope (10.8 deg)

MASH Test Number: 4-12

Proprietary/Non-proprietary: Non-proprietary

Pass/Fail: Pass

Sponsor: TxDOT

Dimensions

Height: 36°

Deck Thickness: 8"

Test Article Description

Material: Concrete

Mounting Type: Deck

Aesthetic: No

See Through: No

Retrofit: No

Combo. (Veh/Ped) No

Report(s):

420020-9b_report

Other related crash tests

TxDOT 36° Tall SSRT Bridge Rail MASH Test No.3-11

Caitrans Single Slope Type 60 Median Barrier

Manitoba Constrained-Width Tall Wall Bridge Rail MASH Test No.5-12
Categories

01 Longitudinal Barriers
02 Work Zones
03 Crash Cushion
04 Terminals
05 Transitions
06 Breakaway Devices
PROJECT No. 20-07 / Task 395
MASH Equivalency of
NCHRP 350-Approved Bridge Railings
Research Objectives

• Identify and prioritize bridge rail systems
• Determine MASH equivalent test levels
• Determine whether individual bridge rails can be submitted to FHWA for determination of federal-aid reimbursement eligibility or whether testing is needed.
<table>
<thead>
<tr>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1. Identification and Prioritization</td>
</tr>
<tr>
<td>Task 2. Develop Methodology for Bridge Rail Analysis</td>
</tr>
<tr>
<td>Task 3. Analysis of Bridge Rails</td>
</tr>
<tr>
<td>Task 4. MASH Coordination Effort</td>
</tr>
<tr>
<td>Task 5. Eligibility Letters</td>
</tr>
<tr>
<td>Task 6. Presentations</td>
</tr>
<tr>
<td>Task 7. Final Report</td>
</tr>
</tbody>
</table>
Key MASH Considerations

- Structural Adequacy
  - Strength
- Rail Height
  - Stability
- Rail Geometry
  - Occupant risk
Simulation Study for MASH TL-3 Bridge Rail Analysis

• Finite element simulations were conducted to determine minimum rail height and lateral impact loads for MASH Test Level 3
  – Rigid vertical wall
  – MASH 2270P vehicle
### Global Equivalencies

**Stability**

<table>
<thead>
<tr>
<th>Test Level</th>
<th>NCHRP 350&lt;sup&gt;a&lt;/sup&gt;</th>
<th>MASH&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>27</td>
<td>29&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>36</td>
</tr>
<tr>
<td>5</td>
<td>42</td>
<td>42</td>
</tr>
</tbody>
</table>

<sup>a</sup> AASHTO LRFD Bridge Design Specifications, Section 13

<sup>b</sup> Resulting minimum rail height from simulation analysis
## Global Equivalencies

### Strength

<table>
<thead>
<tr>
<th>Test Level</th>
<th>NCHRP 350&lt;sup&gt;a&lt;/sup&gt;</th>
<th>MASH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TL-3</strong></td>
<td>54</td>
<td>24</td>
</tr>
<tr>
<td><strong>TL-4</strong></td>
<td>54</td>
<td>32</td>
</tr>
</tbody>
</table>

<sup>a</sup> AASHTO LRFD Bridge Design Specifications, Section 13

<sup>b</sup> Impact force and resulting height corresponds to 36 in tall barrier
Rail Geometry

• Rail geometry effects vehicle-barrier interaction
  – Post setback distance
  – Vertical clear opening
  – Contact surface area

• Increased impact severity increases snagging potential

• Applicability of AASHTO LRFD Bridge Design Specification relationships unknown
  – Different vehicles
  – Different impact conditions
Rail Geometrics

- AASHTO LRFD Bridge Design Specifications
  - Figures A13.1.1-2 and A13.1.1-3

Figure A13.1.1-2—Potential for Wheel, Bumper, or Hood Impact with Post

Figure A13.1.1-3—Post Setback Criteria
Global Equivalencies

- Rail Geometrics – Pickup Truck Crash Test Data

Post Setback Criteria

- 350 TL-3
- MASH TL-3
- 350 TL-4
- MASH TL-4
- MASH TL-5
- 350 Failed Tests
- MASH Failed Tests

Ratio of Rail Contact Width to Height vs. Post Setback Distance (in)

Not Recommended

Preferred

Oregon Bridge Rail (Crooked River)

T77

T131

Caltrans ST-10

NY (2-member)

T4(A) Bridge Rail

F411
Global Equivalencies

- Rail Geometrics – Pickup Truck Crash Test Data

![Graph showing vertical clear opening vs. post setback distance with data points and labels for different rail systems and potential levels.]

- Oregon Bridge Rail (Crooked River)
- T4(A) Bridge Rail
- T101
- F411
- NY (2-member)
Global Equivalencies

- Rail Geometrics – Small Car Crash Test Data

Post Setback Criteria

<table>
<thead>
<tr>
<th>Post Setback Criteria</th>
<th>350 TL-3</th>
<th>MASH TL-3</th>
<th>350 TL-4</th>
<th>MASH TL-4</th>
<th>MASH TL-5</th>
<th>350 Failed Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>350 TL-3</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>T202</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>350 Failed Test</td>
</tr>
<tr>
<td>MASH TL-3</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>T202</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>350 Failed Test</td>
</tr>
<tr>
<td>350 TL-4</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>T202</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>350 Failed Test</td>
</tr>
<tr>
<td>MASH TL-4</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>T202</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>350 Failed Test</td>
</tr>
<tr>
<td>MASH TL-5</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>T202</td>
<td>Preferred</td>
<td>Not Recommended</td>
<td>350 Failed Test</td>
</tr>
<tr>
<td>350 Failed Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Graph showing the ratio of rail contact width to height against post setback distance (in) with preferred and not recommended criteria.
Global Equivalencies

- Rail Geometrics – Small Car Crash Test Data

![Graph showing Snag Potential vs. Post Setback Distance (in)]

- Vertical Clear Opening (in)
- Post Setback Distance (in)
- High Potential
- Low Potential
- 350 TL-3
- MASH TL-3
- 350 TL-4
- MASH TL-4
- MASH TL-5
- 350 Failed Test
NCHRP Project 22-35 Underway

1.) Establish better Geometric Curves for MASH Test Levels 3 & 4 through LS-DYNA Simulations

2.) Select a matrix of rail offsets and spacings to better define these geometric relationships in LRFD Section 13.

3.) Crash testing effort is limited due to very limited funding for this project
Review & Assessment of Past MnDOT Bridge Barrier Types

- Minnesota has a total of 1.7 million feet of older barrier types on MnDOT Bridges
- Built in the 50’s through 80’s
- Designed based on the 10-kip loading
- Assess the strength and performance of these older barrier types with respect to MASH 2016.
- Use approach developed under NCHRP Project 20-07 Task 395
Percentages of Barrier Types on MnDOT Bridges

MnDOT Owned Barrier Types
05-17-2015

- Type G, 177,152 ft, 10%
- One Line, 226,221 ft, 13%
- Other, 284,699 ft, 17%
- Type J or F, 945,837 ft, 55%
- Vertical Parapet, 97,983 ft, 5%

Total Lineal Ft. of Barrier = 1,721,892
Project Tasks

• Task 1 – Site Visit to Review Barrier Types
• Task 2 – Barrier Analyses & Evaluations
• Task 3 – Barrier Methodology & Improvements
• Task 4 – Compile Technical Report
• Task 5 – Publish Technical Report
• Task 6 – Final Memorandum on Research Benefits & Implementation Steps
Typical J-Barrier with Metal Rail
Typical One Line Rail
Typical One-Line
One-Line with Metal Rail
Typical G-Barrier
MnDOT Barrier Assessments

- Grouped the critical barriers together.
- Developed detailed and comprehensive barrier analyses worksheets using MathCAD.
- Performed approximately 30 separate analyses for Task 2 on the different barrier types (just completed this month) to determine MASH equivalency.
- Working on Task 3 to determine what improvements/retrofits can be made to achieve MASH TL-3
# J-Barrier Sample Grouping & Assessments

<table>
<thead>
<tr>
<th>Group</th>
<th>Figure Title/Bridge No.</th>
<th>Critical Barrier?</th>
<th>Stability</th>
<th>Geometric</th>
<th>Strength</th>
<th>Overall Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Concrete and Steel Pipe Railing (Type J) With Separate End Post/5-397.112</td>
<td>Y</td>
<td>S</td>
<td>M</td>
<td>NS</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>Concrete and Steel Pipe Railing (Type J) With Integral End Post/5-397.113</td>
<td>N</td>
<td>S</td>
<td>M</td>
<td>S</td>
<td>S</td>
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<tr>
<td>B</td>
<td>Concrete Railing (Type J) With Separate End Post (w/o wearing course)/5-397.114</td>
<td>Y</td>
<td>S</td>
<td>S</td>
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<td></td>
<td>Concrete Railing (Type J) With Separate End Post (w/ wearing course)/5-397.114</td>
<td>N</td>
<td>S</td>
<td>S</td>
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<td>S</td>
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<td>Concrete Railing (Type J) With Integral End Post (w/o wearing course)/5-397.115</td>
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<td>C</td>
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<td>Concrete Railing (Type J) With Integral End Post (w/ wearing course)/5-397.115</td>
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<td>Concrete Railing (Type J) With Integral End Post/5-397.117</td>
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<td>Concrete Railing (Type J) With Separate End Post (North Railing)/19042 (5-397.120)</td>
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<td>D</td>
<td>Concrete Railing (Type J-SW) With Sidewalk And Separate End Post/5-397.118</td>
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<td></td>
<td>Concrete Railing (Type J-SW) With Sidewalk And Integral End Post/5-397.119</td>
<td>N</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>E</td>
<td>Concrete Railing (Type J) With Bridge Slab Sidewalk And Separate End Post/5-397.121</td>
<td>Y</td>
<td>S</td>
<td>S</td>
<td>NS</td>
<td>S</td>
</tr>
</tbody>
</table>
William P. Lane Bridge – MASH TL-4 Bridge Rail

• 4.3 mile dual span bridge over the Chesapeake Bay east of Annapolis, Maryland
• Connects the Eastern Shore with mainland western shore
• Named after William P. Lane 52\textsuperscript{nd} Governor of Maryland
• Commonly known as Chesapeake Bay Bridge
• Original bridge built in 1952
• New bridge rail meeting MASH TL-4 is planned
William P. Lane Bridge
William Preston Lane Memorial Bridge
US 50/301 over the Chesapeake Bay
Anne Arundel/Queen Anne's Counties
Owned by the Maryland Transportation Authority
Overview of MASH TL-4 Requirements

• **3 Tests in the MASH TL-4 Matrix**
  – MASH Test 4-12 -10,000S, Single Unit Truck
    • 22,000 lbs. (10,000 kg)
    • 56 mph (90 km/hr) @ 15 degrees impact angle
  – MASH Test 4-11 - 2270P, Pickup Truck
    • 5000 lbs. (2270 kg)
    • 62 mph (100 km/hr) @ 25 degrees
  – MASH Test 4-10 - 1100C, Small Car
    • 2425 lbs. (1100 kg)
    • 62 mph (100 km/hr) @ 25 degrees

• **All tests performed @ Critical Impact Points**
Details of the Test Installation
Deck Details - Elevation
(from Field Side)

Section C-C
Scale 1 : 10

Rebar, Ø5/8"
@ 8" in Deck
unless otherwise indicated

L-bar

J-bar

Anchor Bar
See 2a

Deck rebar clearance is 1-1/2"
on each side of the joints.

Detail D
Scale 1 : 10

2a. Weld Anchor Bars to existing rebar (not shown here) protruding from Apron at 18" spacing.
2b. All rebar is grade 60. Minimum lap length for #5 bars is 18-3/4".
2c. 3/4" Chamfer at back edges of the deck as shown.
2d. Concrete strength is 5000 psi.
Deck Details - Plan

Detail E
Scale 1 : 30
Typ all Sections

Rebar clearance is 1-1/2" on each side of the joints.

Conduit, 3/4" EMT x 10"
for Field Side Anchors

Conduit, 1-1/4" EMT x 10"
for Traffic Side Anchors

5" - Typ for J- and L-bars

Rebar, Ø6/8" x 14'-9"

Adjust rebar spacing as needed to avoid Sleeves.

Detail F
Scale 1 : 20

L-bar Typ

J-bar Typ
**Parapet Section**

Plan View

- Symmetric about C

Elevation View

- 2 sp @ 6" 12"

- 5 sp @ 10" 50"

- 3 sp @ 4" 12"

- 4 sp @ 7" 28"

- Rebar, φ 3/4" x 14'-9"

- Bolt, 7/8 x 15" hex A325 galvanized (4 @ each Post location)

**5a.** Concrete strength is 5000 psi.
Section H-H
Scale 1 : 7

Scupper Stirrup
Total rebar length ≈54 15/16"  

Parapet Stirrup
Total rebar length ≈61 9/16"

6a. The numerals in hexagons indicate the quantity needed for each Parapet segment. The length dimensions are given as a reference only. The individual dimensions take precedence in the event of a conflict.
7a. The numerals in hexagons indicate the quantity needed for each Parapet segment.
Rail Details
Sections I-I and H-H are typical for each Rail type

Elevation View
Center Section

Elevation View
End Section

Section J-J
Scale 1:8

8a. Galvanize Rail and Splice Sections after all fabrication is complete.
Instrument Placement
Total of 12 strain gauges and 4 load cells

Section A-A

Strain gauge location on transverse rebar
Load Cell locations B1-B4 on Anchor Bolts

Elevation View
Field side
This view links Bars and Bolts to gauge indicators. See Section A-A for gauge locations. "A" indicates lower bars and "C" indicates upper bars.
Installation of Strain Gages
Installation of Strain Gages
Photos During Deck Construction
Photos of Test Installation
Installation of Load Cell Washers
Critical Impact Points

Plan View

Strain Gauge Location

Dimensions from C of Rail Splice

60" [5.0ft]

43-3/16" [3.6ft]

51-5/8" [4.3ft]

15.0°

Impact Path
4-12 Box Van

25.0°

Impact Path
4-10 Car

Impact Path
4-11 Pickup

Elevation View

Post Numbers

1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20

Joint Numbers

1  2  3  4  5  6  7  8  9
Performed Test 4-12
MASH Test 4-12, 56 mph, 15 Degrees
MASH Test 4-12 Acceptable
Photos After Test 4-12
Performed MASH Test 4-11, 62 mph, 25 degrees
MASH Test 4-11 Acceptable
Post Test 4-11 Photos
Performed MASH Test 4-10, 62 mph, 25 degrees
MASH Test 4-10 Acceptable
Post Test 4-10 Photos
Strain Gage/Load Cell Layout
Force in Anchor Bolts

40 kips x 11” x 4 / 42” = 42 kips each side = approx. 82 kips
Force in Transverse Rebar in Deck

25kips * 12"/5" * 5 5/8"/12 = 28 kip*ft / ft (extreme bending in slab @ joint)
William P. Lane Bridge Rail

- William P. Lane combination concrete and metal bridge rail met all the requirement of MASH TL-4.
- Information from the deck and barrier instrumentation currently being used to design the deck for the bridge.
- Currently working on an “all-steel” design for the middle long span.
TL-3 TXDOT Type T631 Bridge Rail
Objective

• Design on a new bridge rail to meet the crash requirements of MASH TL-3
• Perform full scale crash testing on the new design
• Design needed for 8” Thick concrete deck and minimize deck damage crash loads
T631 TL-3 TRAFFIC SIDE VIEW

11 GAGE A1011 SS GRADE 33 BENT BACK-UP PLATE (EA. POST)

5/16" DIA. x 2" LG. A307 BOLT w/ 1 3/4"x1 3/4"x1/8" PLATE WASHER

S3x5.7 POST @ 3'-1 1/2" O.C.

12 GAGE W-BEAM GUARDRAIL ELEMENT (12'-6" LGTH.)

3'-1-1/2" (TYP.)

31"

18-7/8"

5/8" DIA. A325 ANCHOR BOLTS 10 1/2" LG. W/ 6 3/4"x8"x1/4" THK. ANCHOR PLATE

8"
GUARDRAIL PLATE WASHER DETAILS

5/16" DIA. x 2"
A307 GUARDRAIL BOLT

A36 ANCHOR PLATE DETAILS
S3x5.7 POST ISO VIEW

8″x8″x5/8″ THK.
ASTM A529
GRADE 55
BASEPLATE

2-1/2″
R1/2″
5/8″
1/8″
2-1/2″
2-1/2″

11 GAGE THK (SHEET STEEL) A1011 SS GRADE 33 BENT BACKUP PLATE

1″
5/8″
5/8″
5/8″ TYP.
Photos of the Test Installation
• **Test Parameters**
  – Test Designation: MASH 3-11
  – Test Vehicle: 2270P
  – Impact Speed: 62.6 mph
  – Impact angle: 25.0 deg
  – Impact Location: 13.6 ft upstream of rail splice at Post 24

• **Test Results (PASS)**
  – Met all the risk criteria of MASH Test 3-11
  – Rideddown Accel. 5.1 g’s
  – Occupant Impact Velocity 4.7 m/s
After Test Photos
• Test Parameters
  – Test Designation: MASH 3-10
  – Test Vehicle: 1100C
  – Impact Speed: 62.2 mph
  – Impact angle: 25.6 deg
  – Impact Location: 9.8 ft upstream of rail splice at Post 30

• Test Results (PASS)
  – Met all the risk criteria of MASH Test 3-10
  – Rideddown Accel. 10.0 g’s
  – Occupant Impact Velocity 8.1 m/s
Conclusions & Recommendations

• T631 Bridge Rail met all the performance requirements for MASH Test Level 3.
• No deck damage was observed from either of the two tests performed.
• Bolted bent back-up plates performed well.
• The T631 is currently in use for TL-3 application on TXDOT bridges.
TXDOT T1W 32-Inch Bridge Rail
Research Problem

• Assess the Performance of the TXDOT T1W Bridge Rail according to MASH Test Level Three (TL-3) requirements.
Objective

- Existing bridge rail in TXDOT Inventory
- Evaluated the strength of this 32-inch bridge rail design for TXDOT a few years back for MASH TL-3
- Crash Test design with respect to MASH TL-3 Specifications
- Have a metal post and beam bridge rail that meets MASH TL-3 for use on TXDOT bridges
MASH Test Matrix

• MASH Test 3-11
  – 2270P, 62 mph, 25 deg
• MASH Test 3-10
  – 1100C, 62 mph, 25 deg
Details of the TXDOT Type T1W 32-Inch Bridge Rail

Test Installation

Plan View

Elevation View

Detail B
Scale 1 : 20

Section A-A
Scale 1 : 20

Section C-C
Scale 1 : 10

Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground

Project #493468-4 TXDOT T1W Rail
2019-06-18

Drawn by GES Scale 1.200 Sheet 1 of 7 Test Installation
Rail and Sleeve Details

T1W Rail
HSS 6” x 2” x 1/4”
ASTM A500 Grade B (see 4a)

Plan View
∅ 1” both Faces

Elevation View
∅ 1-1/16” Typ x 4 Field Side only

Section D-D
Scale 1 : 5

T1W Rail Sleeve
ASTM A36 Steel

Plan View
Elevation View

Section E-E
Scale 1 : 3

Typ 3/16
R3/16

4a. ASTM A-1085 is an acceptable substitute. Contractor shall specify which grade was used, and shall provide material certs for all steel components, including hardware.
5a. Place two V-bars centered at each Post location spaced @ 6” as shown. 6” spacing is typical for all V-bars.
6a. Secure each Tie Bar to existing rebar (not shown here) protruding from the runway with a minimum 3" weld. Maximum spacing is 18".
6b. All rebar is grade 60, and contractor shall provide material certs. Minimum rebar lap is 19" for #4 bars and 24" for #5 bars.
6c. All rebar dimensions are to center of bar unless otherwise indicated by "cvt" (cover).
6d. Chamfer top edges of Curb and field side edges of Deck 3/4" each way as shown.
6e. Concrete shall be TxDOT Class S (4000psi).
Photos of The Test Installation
Performed MASH 3-11 on August 1, 2018
Post MASH Test 3-11 Photos
MASH 3-11 Results

- 2270P Vehicle contained and redirected (nicely)
- Impact Conditions - Speed: 62.0 mph, Angle 25.0 deg.
- Met all the requirements for MASH Test 3-11
- Test was a PASS!
Performed MASH Test 3-10 on August 3, 2018
MASH Test 3-10 Video
Post MASH Test 3-10 Photos
MASH 3-10 Results

• 1100C Vehicle contained and redirected (nicely)
• Impact Conditions - Speed: 61.9 mph, Angle 24.8 deg.
• Met all the requirements for MASH Test 3-10
• Test was a PASS!
Conclusions & Recommendations

• The TXDOT Type T1W 32-Inch Bridge Rail meets all the performance criteria for MASH TL-3.
• The T1W Bridge Rail design is currently in use on TXDOT bridges!
TXDOT C1W 42-Inch Bridge Rail
Research Problem

- Assess the Performance of the TXDOT C1W Bridge Rail according to MASH Test Level Four (TL-4) requirements.
Objective

• 42-inch high TXDOT C1W
• Existing bridge rail in TXDOT inventory.
• Helped in evaluating the strength and performance of the design with respect to MASH TL-4
• Crash Test new design with respect to MASH TL-4 Specifications
• Have a metal post and beam bridge rail that meets MASH TL-4 for use on TXDOT bridges
MASH Test Matrix

- MASH Test 4-12
  - 10000S, 56 mph, 15 deg
Details of the TXDOT Type T1W 32-Inch Bridge Rail
5a. Place two V-bars centered at each Post location spaced @ 6” as shown. 6” spacing is typical for all V-bars.
6a. Secure each Tie Bar to existing rebar (not shown here) protruding from the runway with a minimum 3" weld. Maximum spacing is 18".

6b. All rebar is grade 60, and contractor shall provide material certs. Minimum rebar lap is 19" for #4 bars and 24" for #5 bars.

6c. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

6d. Chamfer top edges of Curb and field side edges of Deck 3/4" each way as shown.

6e. Concrete shall be TxDOT Class S (4000 psi).
Photos of The Test Installation
Performed MASH 4-1 on October 17, 2018
MASH Test 4-12 Video
Post MASH Test 4-12 Photos
MASH 4-12 Results

• 10000S Vehicle contained and redirected (nicely)
• Impact Conditions - Speed: 56.0 mph, Angle 14.0 deg.
• Met all the requirements for MASH Test 4-12
• Test was a PASS!
Conclusions & Recommendations

• The TXDOT Type C1W 42-Inch Bridge Rail was successful for MASH Test 4-12.
• TXDOT is currently implementing this design on TXDOT bridges!
Questions?

• Contact Information:
William Williams, P.E.

w-Williams@tti.tamu.edu

979-317-2707

Thanks!
TL-3 TXDOT Type T222 Bolt-Down Bridge Rail
Objective

- Design on a new bolt-down bridge rail to meet the crash requirements of MASH TL-3
- Perform full scale crash testing on the new design
- Design needed for 6” Thick concrete deck
3a. Rebar shall be grade 60. Laps for #4 rebar shall be minimum 15".
3b. Concrete shall be TxDOT Class C (3000 psi).
3c. Chamfer edges 3/4" as shown.
T222 Section Details

- 3/4" DIA. FULLY THREADED ASTM A-193 B7 ROD 8" LG.
- EMBED. 6 IN. W/ HILTI RE500 ADHESIVE

**Plan View**
- Plate, 12" x 3/4"
- ASTM A36 Steel

**Elevation View**
- Φ 5/8"
- 29"
- 12"
- 3/4"
4a. Rebar shall be grade 60. Laps for #4 rebar shall be minimum 15".
4b. Concrete shall be TxDOT Class C (3600 psi).
4c. Chamfer edges 3/4" as shown.
Shear Plate Details

- Diameter: 7/8" x 2
- Slot: 7/8" x 2-1/8" TYP x 2
- Plate: 6" x 3/4" ASTM A572 Grade 50

Scale 1:5
Test Installation Details

Installation - Plan

Plate Washer for Shear Plate
Washer, 3/4 lock
Nut, 3/4 hex
See 1b
Anchor Rod, Ø3/4” x 8”
ASTM A-193 B7 all-thread rod

Impact Path

25°

Installation Parts

<table>
<thead>
<tr>
<th>#</th>
<th>Part Name</th>
<th>QTY.</th>
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<tbody>
<tr>
<td>1</td>
<td>Barrier</td>
<td>3</td>
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<tr>
<td>2</td>
<td>Bolt, 1” x 10 hex</td>
<td>24</td>
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<tr>
<td>3</td>
<td>Nut, 1” heavy hex</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>Nut, 1” heavy hex jam</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>Shear Plate</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Anchor Rod</td>
<td>8</td>
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<tr>
<td>7</td>
<td>Washer, 3/4 flat</td>
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</tr>
<tr>
<td>8</td>
<td>Washer, 3/4 lock</td>
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</tr>
<tr>
<td>9</td>
<td>Nut, 3/4 hex</td>
<td>8</td>
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<tr>
<td>10</td>
<td>Plate Washer for Deck</td>
<td>48</td>
</tr>
<tr>
<td>11</td>
<td>Plate Washer for Shear Plate</td>
<td>4</td>
</tr>
</tbody>
</table>

Detail A

Scale 1 : 10
TYP both joints

1a. Core Ø1-1/4” holes in deck for Anchor Bolts. Percussion drilling is not permitted.

1b. This hardware is on Slotted Side of the Shear Plate. The Plate Washer may be replaced with a standard 3/4” flat washer on the round hole side of the Shear Plate. Install Anchor Rods with Hiili RE500 epoxy according to manufacturer’s instructions, minimum 6” embedment in Concrete.
• **Test Parameters**
  – Test Designation: MASH 3-11
  – Test Vehicle: 2270P
  – Impact Speed: 64.4 mph
  – Impact angle: 25.5 deg
  – Impact Location: 51.5 inches upstream of bolted rail splice at 1/3 point

• **Test Results (PASS)**
  – Met all the risk criteria of MASH Test 3-11
  – Rideddown Accel. 3.6 g’s
  – Occupant Impact Velocity 6.6 m/s
Conclusions & Recommendations

• T222 Bridge Rail met all the performance requirements for MASH Test Level 3.
• The shear expansion plates located between the barriers performed well.
• Recommend the T222 be used for TL-3 application on TXDOT bridges.