MwRSF Research on Bridge Railings & Transitions

Bob Bielenberg
Midwest Roadside Safety Facility
Assistant Director Roadside Safety Division
Manager – Midwest Pooled Program

AASHTO T-7 Technical Committee
Burlington, Vermont

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Research Project Overview

• Development of an Optimized MASH TL-4 Concrete Bridge Rail
• Nebraska: Cost-Efficient, TL-2 Bridge Rail for Low Volume Roads
• Ohio/Illinois: MASH TL-4 Steel-Tube Bridge Rail and Guardrail Transition
• Iowa: DOT Combination Bridge Separation Barrier with Bicycle Railing
• TL-3 Development of a Standardized Concrete Buttress for MGS Thrie Beam Transitions
• Nebraska: 34-In. Tall Thrie-Beam Approach Guardrail Transition
• Wisconsin: Evaluation of a Culvert-Mounted, Strong-Post MGS to MASH TL-3
• NCHRP 22-34: Determination of Zone of Intrusion Envelopes under MASH Impact Conditions for Rigid Barrier
Optimized TL-4 Concrete Bridge Rail

• Objective
  ▪ Develop an optimized, concrete bridge rail to MASH TL-4 safety performance standards

• MASH TL-4
  ▪ Increased rail height
  ▪ Increased impact loads
General Barrier Geometry

- **39” Tall**
  - 36” to satisfy MASH TL-4
  - 3” future overlay

- **Single Slope Front Face**
  - Vehicle stability
  - Near vertical 1:19.5

- **Vertical Back**
  - Sloped back acceptable
  - Reduced width more critical

- **Top Barrier Width**
  - 8” minimum for rebar bends
Bridge Rail Optimization

- Design loads – NCHRP 22-20(2)
  - 80 kip lateral load applied over 48” length
  - 33” load height (30” + 3” overlay)
  - Analysis with Yield Line Theory
- Design variables
  - Barrier width
  - Longitudinal bar size and quantity
  - Stirrup size and spacing
- Estimated costs for materials and installation labor
- Optimize based on strength, cost, weight, and deck loading
Optimized Rail Configuration

- **Strength**
  - \( \text{Rw} = 80.8 \text{ kips} \)

- **Cost**
  - \$39.00 per linear ft

- **Weight**
  - 380 lb/ft

- **Deck loading**
  - \( \phi_{Mc} = 8.6 \text{ (k-ft)/ft} \)

- **Head ejection envelope configuration also developed**
Deck Design

- DOT bridge deck survey responses
  - 8” thick
  - Up to 5’ overhang
  - Clear cover: top-2.5”, bottom-1”
- Design per AASHTO LRFD Section 13.4
  - Critical design for impact load and barrier capacity
  - Longitudinal distribution of $F_t$
  - Evaluation should provide insight on future bridge deck design
Future Work

- Optimized TL-4 bridge rail planned for testing in July 2018
  - Test no. 4-12 (10000S)
  - 39” tall rail with 3” overlay ➔ 36” rail height
- Summary report
  - Design methodology
  - Full-scale testing
  - Exterior and end section details
TL-2 Bridge Rail for Rural Roads (NE)

- **Objective**
  - Develop low cost, MASH TL-2, bridge rail for use on low-volume roads
  - Side-mounted posts
    - Limit deck encroachment
    - Avoid damage during snow removal
    - Deck edges must be flat for formwork
Bridge Deck Options

- Precast Slab Deck
  - 12” minimum thickness
- Cast-in-Place Slab
  - 7” minimum thickness
- Both utilize channel along deck edge
Bolted Socket Attachment

- Coupling nuts & threaded rods cast into deck
- A325 bolts attach to channel (nuts)
Test No. N2BR-1

- 7” CIP Deck
- Ø7/8” rods, coupling nuts, and bolts
- C7x9.8 Channel
- S3x5.7 posts @ 75” spacing
Test No. N2BR-1
Test No. N2BR-1
TL-2 Bridge Rail for Rural Roads (NE)

- MASH TL-2 crashworthy, low-cost bridge rail option for low-volume roads
  - Available for both CIP and precast decks
  - No deck damage
  - Easily repaired
- Welded socket version developed as well
- Future Work
  - Analyze connection to MGS
  - Guidelines for MGS lengths adjacent to bridge
  - Summary report
TL-4 Steel Tube Bridge Rail (OH/IL)

- Objectives:
  - Development of a MASH TL-4, side-mounted, steel tube bridge rail
  - Development of an adjacent approach guardrail transition to MASH TL-3

- Recent Developments:
  - Railing design and optimization
  - Post-to-deck attachment design
Existing Steel Tube Bridge Rail

• Twin-Tube Bridge Rail
  ▪ NCHRP Report 350 TL-4
  ▪ Post offset 4” from deck
  ▪ 31.5” total height
  ▪ W6x25 posts
  ▪ Shear stud anchorage
Design Criteria

- MASH TL-4
- Three tube rails
- Future 3” overlay
- Optimize system (weight/cost)
- Side-mounted posts
- Face of barrier flush with edge of deck
- Minimize potential for deck damage
- Compatible with CIP slab decks and pre-stressed box beams
Rail Design

- NCHRP Report 22-20(2) design loads
- Variables
  - Post spacing
  - Tube sections
  - Tube spacing
- W6x15 Posts
  - Limit loading to deck
  - More efficient rail system
- Selected Rail Configuration
  - Post Spacing = 8 ft
  - Weight: 90.7 lb/ft
  - Lateral Capacity: 80.1 kips
Deck Configurations

• Configuration #1
  - Slab deck
  - Anchor to slab edge
  - Limited deck depth
  - Critical for anchorage loads

• Configuration #2
  - Pre-stressed box
  - Wearing surface
  - Anchor to box
  - Critical post/system strength
Post-To-Deck Attachment

- Prototype design
  - Coupling nut and threaded rod attachment
  - Welded post and plate assembly
  - HSS5x4x3/8 spacer
  - A325 bolts

- Design benefits
  - Limit deck damage
  - Compatible with multiple decks
  - Bolted attachment
  - No external hardware from deck
Future Work

• Post-to-deck component testing
   Optimize attachment hardware
    ▪ Anchor diameter and embedment
    ▪ Plate thickness
    ▪ Tube thickness

• Full-scale testing of bridge rail
   MASH 4-12
   MASH 4-11
   MASH 4-10

• Design of approach transition

• Full-scale testing of transition
   MASH 3-20 & 3-21
Objective

- Develop a MASH TL-2 crashworthy, low-height, vertical-face traffic barrier with an attached crashworthy bicycle railing
- Determine a minimum TL-2 vertical parapet height
- Combination railing
  - 42” above sidewalk
  - Prefer top mounted
  - Maximize visibility
TL-2 Parapet Height Selection

- LS-DYNA simulation of low-height parapet
  - Investigate minimum height
  - Study ZOI
    - Help with placement of rail
    - Determine probability of vehicle/rail interaction
- Review previous testing
  - Vehicle/barrier geometry comparisons
- 24 in. barrier height selected
Bicycle Rail Design Parameters

- Top-mounted posts, offset to reduce vehicle interaction
- 48-in. total height for all installations
  - 24-in. tall parapet and 24-in. tall bicycle rail
- Welded, pre-fabricated rail and post sections
  - 20-ft long
- Single horizontal rail
- AASHTO pass through opening requirements not applied
  - Iowa defines system as traffic separator
Proposed Bicycle Rail Design

- Full-scale crash testing
  - MASH test no. 2-11
Standardized Concrete Parapet for AGTs

• Objective
  ▪ Develop a concrete end buttress compatible with all NCHRP 350 and MASH approved thrie-beam AGTs (with or without curbs)

• Recent developments
  ▪ Preliminary buttress geometry failed MASH 3-21
  ▪ Revised geometry has been successfully tested at 31” and 34” AGT heights
## Buttress Details – 31-in. AGT

<p>| | |</p>
<table>
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<th></th>
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<tbody>
<tr>
<td>Height</td>
<td>36”</td>
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<tr>
<td>Width</td>
<td>12”</td>
</tr>
<tr>
<td>Length</td>
<td>7 ft</td>
</tr>
<tr>
<td>Vertical Taper</td>
<td>4”x24”</td>
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<td>1:6 Slope</td>
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<tr>
<td>Top Chamfer</td>
<td>3”x4”</td>
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<td>Bottom Chamfer</td>
<td>4.5”x18”</td>
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<td></td>
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<td>Height of Bottom Chamfer</td>
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<td>(blockouts)</td>
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![Diagram of Buttress Details]
Test No. AGTB-2 (31-in. AGT)
Full-Scale Testing - 34-in. AGT

- Same geometry as 31-in. buttress with 3-in. height increase

Test No. 3-21

Test No. 3-20
Standardized AGT Buttress Testing

• 31-in. standardized buttress
  ▪ MASH 3-21: Pass
  ▪ MASH 3-20: Non-Critical
    - 1100C small car test was successfully tested on standardized buttress connected to a 34” tall thrie beam AGT
    - 31” rail height has reduced exposure and less likely to snag

• 34-in. standardized buttress
  ▪ MASH 3-20: Pass
  ▪ MASH 3-21: Pass
31-in. Standardized AGT Buttress

- System crashworthy to MASH TL-3
- For use with all crashworthy thrie beam AGTs of similar or greater stiffness
  - With or without curbs
- Standardized buttress can be transitioned to various parapet geometries and heights
- Upstream stiffness transition required
34” AGT - Design

First Installation

After 3” Overlay
Other Bridge Related Research

- **WisDOT Strong Post, Culvert Mounted MGS**
  - Two full-scale crash tests
    - Test no. 3-10 - Passed
    - Test no. 3-11 – Passed

- **NCHRP 22-34**
  - Determination of ZOI Under MASH Impact Conditions
Acknowledgements

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