Barriers for Moveable Bridges: Options & Design Considerations

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Current Practice for Roadside Safety Barriers

- Strength Requirements & Design Test Level from Section 13, LRFD Specifications
- Performance Requirements as per MASH (Manual for Assessing Safety Hardware)
### Table A13.2-1 - Design Forces for Traffic Railings

<table>
<thead>
<tr>
<th>Design Forces and Designations</th>
<th>TL-1</th>
<th>TL-2</th>
<th>TL-3</th>
<th>TL-4</th>
<th>TL-5A</th>
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<th>TL-6</th>
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<tbody>
<tr>
<td>$F_t$ Transverse (KIP)</td>
<td>13.5</td>
<td>27</td>
<td>54</td>
<td>54</td>
<td>116</td>
<td>124</td>
<td>175</td>
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<tr>
<td>$F_L$ Longitudinal (KIP)</td>
<td>4.5</td>
<td>9.0</td>
<td>18.0</td>
<td>18</td>
<td>39</td>
<td>41</td>
<td>58</td>
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<tr>
<td>$F_v$ Vertical (KIP) Down</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
<td>18</td>
<td>50</td>
<td>80</td>
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<td>$L_v$ and $L_L$ (FT)</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>3.5</td>
<td>8.0</td>
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<tr>
<td>$L_v$ (FT)</td>
<td>18.0</td>
<td>18.0</td>
<td>18.0</td>
<td>18.0</td>
<td>40.0</td>
<td>40.0</td>
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<tr>
<td>$H_v$ (min) (IN)</td>
<td>18</td>
<td>20</td>
<td>24</td>
<td>32</td>
<td>40</td>
<td>42</td>
<td>56</td>
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<tr>
<td>Minimum H Height of Rail (IN)</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>32</td>
<td>40</td>
<td>54</td>
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![Figure A13.2-1 - Metal Bridge Railing Design Forces, Vertical Location, and Horizontal Distribution Length](image.png)
MASH Performance Evaluation Criteria – Structural Adequacy

• A. Structural Adequacy - Barrier should contain and redirect the vehicle or bring the vehicle to a controlled stop. The vehicle should not penetrate, underride, or override the installation

• B. Structural Adequacy – The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding

• C. Structural Adequacy – Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle
MASH Test Designation 3-40 to 45 – Non-Redirective Crash Cushions
MASH Performance Evaluation Criteria – Occupant Risk

• D. Occupant Risk – Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone.

• F. Occupant Risk – The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.
MASH Performance Evaluation Criteria – Occupant Risk

• H. Occupant Impact Velocity (OIV):
  – Longitudinal & Lateral
    • Preferred – 30 ft/sec (9.1 m/s)
    • Maximum – 40 ft/sec (12.2 m/s)

• I. Occupant Ridedown Acceleration (G’s):
  – Longitudinal & lateral
    • Preferred – 15 G’s
    • Maximum – 20.49 G’s
Question?

- Rigid or MASH?
- Lethal barriers .... Any impact condition above MASH occupant risk thresholds
- Nonlethal barriers .... Well below the MASH occupant risk thresholds
- Examples of Barrier Types
Certification Crash Testing

• SD-STD-02.01 Revision A “Specification For Vehicle Crash Test Of Perimeter Barriers and Gates” (2003)

• 15,000 lb single unit truck

• 3 impact severities (i.e., energy levels)
  • 50 mph (K12); 40 mph (K8); 30 mph (K4)

• DOS oversight of all testing

• Adopted by other agencies
New Test Standard for Crash Testing Perimeter Devices

- ASTM F2656-07
  - Committee Chaired by TTI
- Incorporated SD-STD-02.01 Revision A
- Incorporated DOE Standard Test Vehicle
- Incorporated NCHRP Report 350 Vehicles
- Adopted the reporting of NCHRP Report 350 Occupant Risk
- Maybe PU40 Test Conditions (4000 Pickup @ 40 MPH)
Devices to be Tested

- Bollards
- Walls
- Fences
- Gates

- Berms
- Soil Filled
- Drop Arms
- Wedges
USR GRAB Net System
Ideal Manufacturing, Inc. Drop Arm Gate
Drop Arm for Dept. Of State
Pop-Up Bollards
Fixed Bollards
Flush Mounted Wedge Barriers
Vehicle Testing with 90-degree Impacts
TxDOT Type T223 Bridge Rail

- Concrete post and beam bridge rail Common in Texas
- Needed more strength for new 32-inch high design
- Increase in Rail strength due to larger rail and posts
- T223 has a smaller post width (4-ft) and larger clear opening (6-ft.) for drainage
- Evaluate the strength of the T223 rail with different reinforcing steel details in the rail and deck
• Increase the rail height from 27 inches to 32 inches
• Increase overall strength of the rail (at mid-span & joint) using optimum reinforcing steel orientation, placement, and frequency in post & rail
• Review deck strength and consider new deck
  • reinforcement to increase deck strength
Typical T223 Details Cont’d

T223 FRONT VIEW
Construct Full-Scale Test Installation with 4 different Rail & Deck Reinforcing Configurations
T223 Mid-Span Failure
Test @ End/Joint
T223 Failure @ End/Joint
Recommended Details @ T223 Post/Joint (w/o "J" Bars)

TEST 1 REBAR LAYOUT
ELEVATION VIEW

NOTE: 
- #4 REBAR LAPSPlice=17"
- #5 REBAR LAPSPlice=21"

The Texas A&M University System
Recommended Details @ T223 Post/Joint (w/o "J" Bars)

TEST 1 SECTION A-A

The Texas A&M University System
Recommended Details @ Mid-Span Post (w/o “J” Bars)

TEST 3
REBAR LAYOUT
POSTS 2-4

NOTE: -#4 REBAR LAP SPlice=17”
-#5 REBAR LAP SPlice=21”
Summary of T223 Design & Testing

- Mid-Span strength varied from approx. 75 kips to 85 kips
- Joint strength approximately 54 kips
- New T223 Bridge Rail Reduced the severity of deck damage for severe impact loads from the previous T203 Design (27 inches high)
Tests on Portable Concrete Barriers
PCB Barrier with Signs Attached
Mounting Design Option #3

BARRIER MOUNTED SIGN SUPPORT ON CTB IN CONSTRUCTION WORK ZONE

48"x4"x3/16" CONNECTOR PLATE
3/4" HILTI ANCHOR

DETIAL A
SCALE 1 : 5

2-7/8" PIPE
Φ 7/8"
3-1/8" x 6" COLLAR PIPE
HS 6" x 2" x 3/16"

3/4" GALV. HAS-E ROD EMBED. 7 IN. ANCHORED W/HILTI HIT HY 150 ADHESIVE SYSTEM (TYP)

The Texas A&M University System
Texas Transportation Institute
College Station, Texas 77843

Revisions:
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MASH Crash Test Conditions

- Full Scale Crash Test Performed on May 24, 2010
- MASH Test 3-11, Test Conditions, Speed 62 mph, Impact Angle 25 degrees
- 2270P (5000lb +/- 110 lb)
- CIP : 9 ft. Upstream of centerline of joint between barriers 4 & 5
Computational Mechanics

• Crash Testing Expensive
  – >$30,000/test

• Advanced Finite Element Technology
  – Predictive Impact Simulations Lead Design Efforts
  – Reduces Development Cost
    • Minimizes number of crash tests needed to achieve successful design

• Computer Simulation Approach
  – Explicit Modeling of Hardware and Vehicle
  – Cost Effective Evaluation of Design Alternatives
  – Design Optimization
  – Verification Crash Tests
Component Testing

- Investigate dynamic impact response of key system components
  - Reusable surrogate impact vehicles
- Used for design & validation of computer models
Model Validation

Vehicle CG Acceleration History Comparison

- **Experimental Test Data**
- **Simulation Data**

Axes:
- **Time (s)**
- **Acceleration (G's)**
• **Vehicle Model**
• Vehicle Model
Vehicle Model
• Vehicle Model
• **Vehicle Model**
• Vehicle Model
• Vehicle Model
• Vehicle Model
• **Vehicle Model**
• Chevrolet C2500 Pickup Truck
Full-Scale Guardrail Model

- 107,839 Elements
- 111,361 Nodes
- 207 CPU hours / 0.500 s (Compaq Alpha Server)
• **W-Beam Guardrail**
• *Pin-and-Loop PCB*