MASH Evaluation of Roadside Hardware

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What is MASH?

- AASHTO’s Manual for Assessing Safety Hardware (MASH)
- Standardized criteria for crash testing and evaluation of roadside safety hardware
  - Test vehicles and impact conditions
  - Documentation and data analysis
  - Hardware evaluation criteria
- Focus on repeatability and occupant safety/survivability
Roadside Hardware Test Matrices

- **Purpose**
  - Establish minimum level of performance
  - Establish basis for comparison of alternatives

- **Philosophy of “worst practical conditions”**
  - Evaluate devices over range of both potential and critical impact conditions with limited crash tests
  - Consider the general class and function of the safety feature

- **Test levels defined to accommodate speeds and vehicle types for various applications**
  - TL-1 ➔ low speed, passenger vehicles
  - TL-2 ➔ intermediate speed, passenger vehicles
  - TL-3 ➔ high speed, passenger vehicles
  - TL-4 ➔ high speed, single unit truck
  - TL-5 ➔ high speed, tractor van-trailer
  - TL-6 ➔ high speed, tractor tank-trailer
MASH Vehicles and Impact Conditions

- **Vehicles**
  - Practical representation of passenger vehicle fleet with limited no. of test vehicles
    - $\approx 5^{th}$ percentile small passenger vehicle
    - $\approx 95^{th}$ percentile passenger vehicle
  - Heavy commercial vehicles

- **Impact Conditions**
  - Speed and angle based on reconstruction of crashes
  - $85^{th}$ percentile speed
    - 62 mph (TL-3)
  - $85^{th}$ percentile impact angle
    - 25 degrees (TL-3)
MASH Test Vehicles

- 1100C
- 1500A
- 2270P
- 10000S
- 36000V
- 36000T
Full-Scale Crash Testing

TL-3 Single Slope Concrete Barrier
(62 mph, 25 deg.)

TL-2 Bridge Rail for Low-Volume Roads
(44 mph, 25 deg.)

TL-6 Concrete Barrier
(50 mph, 15 deg.)
MASH Hardware Evaluation Methods

- Current roadside hardware evaluation
  - FHWA eligibility letter
  - States may self certify through their own process
- Full-scale crash testing
  - Run the complete matrix of tests
    - Currently only way to obtain FHWA eligibility letter
  - Run only critical tests
    - Provide justification for tests deemed non-critical
- Other methods
  - Engineering analysis
    - Structural calculations and comparison to existing tested hardware
  - Dynamic component testing of modifications
  - Computer simulation analysis
Full-Scale Crash Testing – Complete Matrix

- Midwest Guardrail System (MGS)
- MASH TL-3 longitudinal barrier test matrix
  - Test 3-10
    - 1100C, 62 mph, 25 deg.
  - Test 3-11
Partial Crash Test Matrix

- **F-shape PCB**
  - 2270P critical for structural loading and deflection
  - Previous safety shape parapet testing indicated acceptable small car occupant risk and vehicle stability

- Test 3-10 deemed non-critical

- Only test 3-11 conducted to evaluate safety performance
System Modification During Testing

- Thrie beam bullnose
  - Slotted thrie beam rail
    - Control forces and improve capture
  - Breakaway posts
    - Energy dissipation
  - Nose retention cables
    - Vehicle capture
# MASH TL-3 Test Matrix

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Vehicle</th>
<th>Speed (km/h)</th>
<th>Angle (deg)</th>
<th>Impact Point</th>
<th>Other Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-30</td>
<td>1100C</td>
<td>100</td>
<td>0</td>
<td>Center of nose @ ¼ offset</td>
<td>-</td>
</tr>
<tr>
<td>3-31</td>
<td>2270P</td>
<td>100</td>
<td>0</td>
<td>Center of nose</td>
<td>-</td>
</tr>
<tr>
<td>3-32</td>
<td>1100C</td>
<td>100</td>
<td>5/15</td>
<td>Center of nose</td>
<td>15-degree impact angle</td>
</tr>
<tr>
<td>3-33</td>
<td>2270P</td>
<td>100</td>
<td>5/15</td>
<td>Center of nose</td>
<td>15-degree impact angle</td>
</tr>
<tr>
<td>3-34</td>
<td>1100C</td>
<td>100</td>
<td>15</td>
<td>CIP for capture/redirection</td>
<td>CIP selected at post no. 2 of the system</td>
</tr>
<tr>
<td>3-35</td>
<td>2270P</td>
<td>100</td>
<td>25</td>
<td>CIP for capture/redirection</td>
<td>CIP selected at post no. 3 of the system</td>
</tr>
<tr>
<td>3-36</td>
<td>2270P</td>
<td>100</td>
<td>25</td>
<td>CIP @ transition to rigid structure</td>
<td>Deemed non-critical if using MASH TL-3 AGT</td>
</tr>
<tr>
<td>3-37a</td>
<td>2270P</td>
<td>100</td>
<td>25</td>
<td>CIP for reverse direction</td>
<td>Deemed non-critical</td>
</tr>
<tr>
<td>3-37b</td>
<td>1100C</td>
<td>100</td>
<td>25</td>
<td>CIP for reverse direction</td>
<td>CIP selected 2,876 mm upstream from the end post in the system</td>
</tr>
<tr>
<td>3-38</td>
<td>1500A</td>
<td>100</td>
<td>0</td>
<td>Center of nose @ ¼ offset</td>
<td>Deemed non-critical based on 1500A estimation procedure</td>
</tr>
</tbody>
</table>
System Modification During Testing

Test 3-35

Test 3-32

Test 3-34
System Modification During Testing

- Test 3-30 ➔ Vehicle penetration
System Modification During Testing

- Additional nose cable behind lowest thrie beam corrugation
  - Test nos. 3-34 and 3-35 on side of system and unaffected by additional cable
  - Test no. 3-32 – angled impact on nose captured without additional cable

- Additional cable does not affect previous testing
- Remaining tests run successfully
  - System deemed MASH TL-3 compliant
Engineering Analysis

- NCHRP 20-7 Task 395 - MASH Equivalency of NCHRP Report 350 Approved Bridge Railings
  - Review and evaluation of existing bridge railings
    - Stability – Height and shape
    - Strength – Structural analysis
    - Geometry – Snag potential
  - 22 bridge rails analyzed
    - 12 satisfactory
    - Non-satisfactory still may meet full-scale crash testing
Dynamic Component Testing

- Iowa BR27C Bridge Rail
  - Cast-in-place anchorage
- Designed epoxy anchorage options and compared to original design through dynamic component testing
Anchorage Options

Original Cast-in-Place

Iowa US 20 Bridge
Hardin, IA

Four Anchor Spread Concept

Two Anchor Offset Concept
Anchorage Options

- Original Cast-in-Place
- Iowa US 20 Bridge Hardin, IA
- Four Anchor Spread Concept
- Two Anchor Offset Concept
Comparison – Anchor Forces

- All alternatives developed higher peak loads than cast-in-place BR27C
- Damage levels much greater than full-scale test
  - Indicates lower loading during actual vehicle impacts
- All three designs viable alternatives

<table>
<thead>
<tr>
<th>Design Configuration</th>
<th>Peak Force (kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR27C Cast-In-Place</td>
<td>22.9</td>
</tr>
<tr>
<td>Spread, Four-Anchor</td>
<td>24.9</td>
</tr>
<tr>
<td>Offset, Two-Anchor</td>
<td>28.3</td>
</tr>
<tr>
<td>US-20 Bridge</td>
<td>23.2</td>
</tr>
</tbody>
</table>
Computer Simulation

- Finite element analysis
  - Powerful tool for design and analysis
- Evaluation of hardware
  - Must validate models against existing test data to ensure accuracy
  - Still may not capture all possible failure modes
- Currently limited to evaluating limited changes to existing hardware
  - Not for evaluation of new hardware
Summary

- MASH provides guidance on evaluation of roadside hardware
  - Crash testing based on current vehicle fleet and worst practical impact conditions
  - Full-scale crash testing of entire matrix required for FHWA eligibility
  - States self certification

- Alternative evaluation methods exist
  - Reduced test matrices
  - Engineering analysis
  - Dynamic component testing
  - Computer simulation
Acknowledgements

- Midwest Pooled Fund Program
- Iowa DOT