SAFETY PERFORMANCE OF WORK-ZONE DEVICES UNDER MASH TESTING

Schmidt, Faller, Lechtenberg, Sicking, Holloway
Midwest Roadside Safety Facility
Nebraska Transportation Center
University of Nebraska-Lincoln

Smart Work Zone Deployment Initiative
July 26, 2010
Background

- NCHRP Report No. 350
- Crash test conditions at Test-Level 3 (TL-3)
  - 1,808-lb small car (820C)
    - 22 mph
    - 62 mph
  - Normally tested at 0° and 90° orientations
  - 4,409-lb pickup truck (2000P) not used
Problem Statement

- Work zone signs only tested with small car
- Systems tuned for small car
- Simulated pickup truck tests indicated failure
- MASH requires pickup truck testing
- Current WZ sign systems may not meet MASH
Pickup Truck Bogie Testing

Potential for sign to penetrate windshield
Research Objectives

- Determine if current WZ sign systems meet MASH
- Identify WZ hardware parameters that increase propensity for failure
- Provide guidelines and recommendations
Research Plan

- Analytical study
  - Evaluate all full-scale tests
  - Study individual hardware parameters
  - Select work zone sign systems with a propensity for failure

- Conduct 4 full-scale tests
  - 2 small car and 2 pickup truck
  - 2 systems per test

- Provide guidelines and recommendations
Previous Testing

- Small Car Crash Tests
  - 157 full scale
- Pickup Truck Tests
  - 157 full scale
  - 18 bogie tests
System Parameters

- Flag Holder
- Sign Panel
- Rigid Bracket
- Springs
- Legs
- Flags
- Mast
- Base
Methods of Failure

- Severe Windshield Cracking and Failure
- Windshield Indentation \( \geq 3 \) inches
- Windshield Penetration
- Other Occupant Compartment Penetration
- Roof Deformation \( \geq 4 \) inches
# Vehicle Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>820C</th>
<th>1100C</th>
<th>2000P</th>
<th>2270P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hood Length [in.]</td>
<td>31.5</td>
<td>34.7</td>
<td>45.1</td>
<td>41</td>
</tr>
<tr>
<td>Height to bumper [in.]</td>
<td>18</td>
<td>18</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>Height to roof [in.]</td>
<td>58</td>
<td>55.5</td>
<td>73.3</td>
<td>75.8</td>
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<tr>
<td>Windshield Angle</td>
<td>39</td>
<td>32</td>
<td>42</td>
<td>34</td>
</tr>
<tr>
<td>Windshield Length [in.]</td>
<td>30.2</td>
<td>28.1</td>
<td>26.8</td>
<td>31.5</td>
</tr>
</tbody>
</table>
Predicted Performance

- Sign trajectory
- Vehicle geometry
- Classified by risk of failure
  - 1: 75-100%
  - 2: 50-75%
  - 3: 25-50%
  - 4: 0-25%
Important Parameters for Failure

- ≥50% of systems with a parameter were predicted to fail for either vehicle

Both Vehicles
- Height to top of mast
- Sign panel material
- Mast stages
- Mast material
- Flag staff material
- Orientation

Car Only
- Height to top of flags
- Sign-locking mechanism

Truck Only
- Base layout
System Analysis

- Systems that were predicted to fail MASH by:
  - Windshield penetration
  - Other occupant compartment penetration
  - Roof deformation

- Analyzed systems based on combinations of important parameters
Critical Parameters for 2270P Test Failure

Low-Mounting Height
- X-footprint base
  - Spring base
  - Aluminum and vinyl panel
  - 0 and 90 degree orientations
  - With flags
- Parallel Dual Uprights
  - Aluminum panel
  - 0 degree orientation
  - Without flags

High-Mounting Height
- X-footprint base
  - Spring base or slipbase
  - Aluminum panel
  - 90 degree orientation
  - With flags
- Parallel Dual Uprights
  - Aluminum panel
  - 90 degree orientation
  - Without flags
Critical Parameters for 1100C Test Failure

Low-Mounting Height
- X-footprint base
  - Spring base
  - Flags
  - Aluminum panel @ 0 degree orientation
  - Vinyl panel @ 90 degree orientation

Low-Mounting Height
- Parallel Dual Uprights
  - Aluminum Panel
  - 0 and 90 degree orientations
  - No flags
Crash Testing Requirements

- MASH Test Level 3 Criteria
  - 5,000 lb pickup truck, 62 mph
  - 2,425 lb small passenger car, 62 mph

- Evaluation Criteria
  - Structural Adequacy
  - Occupant Risk
  - Vehicle Trajectory
Full-Scale Crash Testing

- 4 small car tests at 62 mph (Test Designation No. 3-71)
- 4 pickup truck tests at 62 mph (Test Designation No. 3-72)
WZ09-1A

- FAILURE
WZ09-1B
WZ09-1B

- FAILURE
WZ09-2A
WZ09-2A

- PASS
WZ09-2B

- FAILURE
WZ09-3A
WZ09-3A

- FAILURE
WZ09-3B
WZ09-3B

PASS
WZ09-4A
WZ09-4A

FAILURE
WZ09-4B

PASS
Test Summary

- 3 of the 8 systems passed MASH evaluation criteria
  - 3 of the 4 systems failed with the pickup truck
  - 2 of the 4 systems failed with the small car

- Comparing systems with similar parameters can be difficult
## Important for MASH Failure

- Designers cautioned against using important parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pickup Truck</th>
<th>Small Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sign Panel Material</td>
<td>Aluminum*</td>
<td>Aluminum*</td>
</tr>
<tr>
<td>Height to Top of Mast</td>
<td>75-135 in.</td>
<td>59-110 in.</td>
</tr>
<tr>
<td>Presence of Flags</td>
<td>Without Flags</td>
<td>With and Without Flags</td>
</tr>
<tr>
<td>Orientation</td>
<td>Both 0 and 90 degrees</td>
<td>Both 0 and 90 degrees</td>
</tr>
<tr>
<td>Sign Locking Mechanism</td>
<td>NA</td>
<td>Rigid Brackets</td>
</tr>
<tr>
<td>Base Layout</td>
<td>X-footprint</td>
<td>NA</td>
</tr>
</tbody>
</table>

*Aluminum sign panels should be tested with reflective sheeting
Design Aides

1Breakaway Mechanism Height: Low ≤ 24”, High > 24” or no breakaway mechanism
2Chance of Failing MASH: 1 - 75 to 100%, 2 – 50 to 75%, 3 – 25 to 50%, 4 – 0 to 25%, 5 – Unknown
Acknowledgements

- Center for Transportation Research Education at Iowa State
- Mid-America Transportation Center
- Private Industry