U.S. Department
of Transportation
**Federal Highway
Administration**

1200 New Jersey Ave., SE
Washington, D.C. 20590

July 10, 2014

In Reply Refer To:
HSST/B-236 Revised

Mr. Scott Rosenbaugh
Midwest Roadside Safety Facility
130 Whittier Research Center
P. O. Box 830853
Lincoln, NE 68583-0853

Dear Mr. Rosenbaugh:

This letter is in response to your request for revisions to the existing eligibility letter B-236 dated May 30, 2012, and for the Federal Highway Administration (FHWA) to review a roadside safety system for eligibility for reimbursement under the Federal-aid highway program.

Name of system:	Wood-Post 31-inch (787-millimeter) Midwest Guardrail System (MGS) to Thrie Beam Approach Guardrail Transition
Type of system:	W-Beam Guardrail Transition
Test Level:	AASHTO Manual for Assessing Safety Hardware, TL-3
Testing conducted by:	Midwest Roadside Safety Facility
Date of Original request:	January 19, 2012
Date of Revision Request:	April 10, 2014
Task Force 13 Designator:	STG03b

Based on a review of submitted revisions to existing eligibility letter dated May 30, 2012 and crash test results submitted by the manufacturer certifying the device described herein meets the crash test and evaluation criteria of the American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH), the device is eligible for reimbursement under the Federal-aid highway program. Eligibility for reimbursement under the Federal-aid highway program does not establish approval or endorsement by FHWA for any particular purpose or use.

The FHWA, the Department of Transportation, and the United States Government do not endorse products or services and the issuance of a reimbursement eligibility letter is not an endorsement of any product or service

Decision

The following device is eligible, with details provided below:

- Wood-Post 31-inch (787-millimeter) Midwest Guardrail System (MGS) to Thrie Beam Approach Guardrail Transition

Requirements
To be found eligible for Federal-aid funding, roadside safety devices should meet the crash test and evaluation criteria contained in the American Association of State Highway and Transportation Officials' Manual for Assessing Safety Hardware (MASH).

Description
For many years the roadside safety community has considered 6-in. x 8-in. (152 millimeters x 203 millimeters) wood posts and W6x9 (W152x13.4) steel posts as interchangeable options for 6 feet (1.8 meters) long guardrail posts. However, the posts in these older systems were embedded 43 inches (1,092 millimeters) to 44 inches (1,118 millimeters) in the soil, while MGS posts are embedded only 40 inches (1,016 millimeters). Blockout depth and splice location differences make the behavior of the MGS different from older W-beam systems. Therefore a review of previous testing (post-in-soil component testing and full-scale crash testing) was conducted to compare the performance of 6 inches x 8 inches (152 millimeters x 203 millimeters) wood posts and W6x9 (W152x13.4) steel posts when used in the MGS. However, no such tests have been conducted on either W6x15 (W152x22.3) steel posts or large cross section wood posts. Therefore, a series of dynamic component tests were conducted to determine the post-soil interaction force characteristics for these large post sizes in an effort to find an equivalent wood post for the W6x15 (W152x22.3) steel posts utilized in the steel-post MGS stiffness transition to thrie beam.

This research objective was met through a combination of historical data review, dynamic component testing, and computer simulation and analysis as follows.

I. Historical Data Review:
   A. W6x9 (W152x13.4) steel posts:
      A literature review was conducted on post-soil resistance for both W6x9 (W152x13.4) steel posts and 6 inches x 8 inches (152 millimeters x 203 millimeters) wood posts and conclusions were made regarding these standard post sizes. In a recent dynamic testing study, two 6 inches x 8 inches (152 millimeters x 203 millimeters) wood posts and two W6x16 (W152x23.8) steel posts were embedded 40 inches (1,016 millimeters) in a highly compacted soil and impacted at 20 mph (32 km/h). The W6x16 (W152x23.8) posts have the same flange width and overall depth as a W6x9 (W152x13.4) so the soil resistances for the two posts are considered the same. This testing showed these particular wood and steel posts provided very similar soil resistances throughout the impact event.
   B. W6x15 (W152x22.3) steel posts:
      A literature review conducted on post-soil resistance for W6x15 (W152x22.3) steel posts found no past research was conducted.
   C. MASH Crash Testing:
      Two full-scale MASH 3-11 crash tests were selected to compare the W6x9 (W152x13.4) steel-post and the 6 inches x 8 inches (152 millimeters x 203 millimeters) wood-post performance when installed in the MGS. Test no. 1 (2214MG-2) utilized steel posts, while test no. 2 (MGSWP-1) utilized the wood posts. Both test installations were 181 feet 3 inches (55.2 meters) long

II. Physical Testing:

A. Dynamic Component Testing:

Dynamic component testing was conducted to determine the post-soil resistance characteristics of W6x15 (W152x22.3) steel transition posts embedded 54 inches (1,372 millimeters) in soil as well as wood posts of multiple cross-sections and embedment depths. Twenty dynamic component tests were conducted on W6x15 (W152x22.3) steel posts and various wood-post sizes in soil. The target impact conditions for all tests were 20 mph (32 km/h) at an angle of 0 degrees, creating a classical "head-on" or full-frontal impact and strong axis bending. The posts were impacted 24⅞ inches (632 millimeters) above the ground line. Four of these dynamic component tests specified AASHTO Grade B Moderate Compaction Soil (NCHRP350), and the remainder of the tests specified AASHTO Grade B Heavy Compaction (AASHTO MASH).

III. Computer Simulation and Analysis:

After determining equivalent wood posts for both steel post sizes used in the MGS approach transition, BARRIER VII computer simulations were conducted to compare the performance of the wood and steel post systems. The steel-post BARRIER VII model was validated against the full-scale crash testing of the steel-post transition system under MASH safety standards (Test no. MWTSP-2) and served as the basis for comparison and evaluation of the wood-post transition system.

After the wood-post transition system was determined to be an adequate alternative via physical component testing and computer simulation and analysis, the final design drawings were created.

Details of this system are included in this correspondence as an enclosure.

Crash Testing

All physical testing was conducted at the test facilities at the Midwest Roadside Safety Facility. This research uses both existing physical cash test results, bogie testing results and BARRIERVII analysis.

A. Dynamic Component Testing:

Bogie testing program was conducted to identify a wood post that provided similar force vs. deflection, or energy absorption, characteristics to the 7 feet (2.1 meters) W6x15 (W152x22.3) steel posts utilized in the original MGS approach transition system. Although Grade 1 Southern Yellow Pine posts (SYP) were utilized during all of the tests, wood defects are inevitable in timber posts, especially with the larger cross sectional dimensions. Therefore, posts utilized in actual installations would be expected to have some natural defects that may lead to premature post fracture. Posts that fracture absorb far less energy and do not provide any resistance after fracture, typically within the first few inches of deflection. From a guardrail transition design perspective, this lack of resistance can have negative effects on the safety performance of the system in this sensitive region of the barrier. Similar performance results are expected for a transition system in which a post fractured prematurely. Therefore, posts that showed a propensity for fracture before rotating were removed from consideration as equivalent posts to the W6x15 (W152x22.3) steel posts. Post fracture was prevalent in tests conducted on 7 feet (2.1 meters) long versions of 8 inches x 8 inches (203 millimeters x 203 millimeters) and 6 inches x 10 inches (152 millimeters x 254 millimeters) wood posts. As a result, these posts were not recommended for use in the MGS approach transition.

The individual test results for each post size were averaged together in order to compare the various posts. The 6.5 feet (2.0 meters) long 8 inches x 10 inches (203 millimeters x 254 millimeters) wood posts provide average force characteristics that best match those of W6x15 (W152x22.3) steel posts when the soil was heavily compacted. At 15 inches (381 millimeters) of deflection, the 8 inches x 10 inches (203 millimeters x 254 millimeters) wood posts averaged 17.7 kips (78.8 kN), only 1.1 percent higher than the steel posts. Although the average force of 8 inches x 10 inches (203 millimeters x 254 millimeters) wood posts showed an increase of 15.5 percent over the steel post at 10 inches (254 millimeters) of deflection, the average forces were relatively close.

B. Physical Crash Testing:
Two full-scale crash tests were selected to compare the W6x9 (W152x13.4) steel-post and the 6 inches x 8 inches (152 millimeters x 203 millimeters) wood-post performance when installed in the MGS. Test no. 2214MG-2 utilized steel posts, while test no. MGSWP-1 utilized the wood posts. Both 181 feet 3 inches (55.2 meters) long test installations satisfied all MASH safety performance criteria of test designation no. 3-11. The two systems behaved similarly during the test in terms of maximum dynamic deflection, contact length, and exit conditions, as shown in Table 2. Further, the Occupant Impact Velocities (OIV) and Occupant Ridedown Accelerations (ORA) were very similar, thus suggesting the forces imparted to the vehicle were very similar. Similar performance between W6x9 (W152x13.4) steel and 6 inches x 8 inches (152 millimeters x 203 millimeters) wood guardrail posts has been documented in both dynamic component testing and full scale testing. Therefore, the 6 inches x 8 inches (152 millimeters x 203 millimeters) wood posts was selected as the alternative for the W6x9 (W152x13.4) steel posts found in the MGS to thrie beam stiffness transition.

C. The BARRIER VII analysis simulations used in this research verified that the wood posts did not adversely affect the safety performance of the stiffness transition.

Summary and Standard Provisions

A. At the conclusion of the bogie testing program, the 8 inches x 10 inches (203 millimeters x 254 millimeters) wood post with an embedment depth of 48 inches (1,219 millimeters) best resembled the performance of the W6x15 (W152x22.3) steel transition post and was recommended for further analysis in the MGS approach transition.

B. The existing MASH crash testing included both systems that behaved similarly during the test in terms of maximum dynamic deflection, contact length, and exit conditions, as described below.
   - Test no. 2214MG-2 featured a 5,174-lb (2,347-kg) 4-door pickup truck that impacted the MGS W6x9 (W152x13.4) Steel post barrier at a speed of 62.8 mph (99.6 km/h) and at an angle of 25.5 degrees. The MGS rail successfully redirected the vehicle while meeting all required safety criteria and sustaining a maximum deflection of 31⅝ in. (803 mm).

- Test no. MGSWP-1, featured a 5,174-lb (2,347-kg) 4-door pickup truck that impacted the MGS Wood 6 in. x 8 in. (152 mm x 203 mm) post barrier at a speed of 63.8 mph (99.6 km/h) and at an angle of 25.6 degrees. The MGS rail successfully redirected the vehicle while meeting all required safety criteria and sustaining a maximum deflection of 31⅝ in. (803 mm).

Crash Test Summary details of this system are provided as enclosures to this correspondence.

C. At the conclusion of BARRIERVII analysis, the wood-post MGS stiffness transition outperformed the original steel-post transition system in all three of the evaluation criteria. The maximum deflections for the wood-post system were consistently 15 to 30 percent lower than the original steel-post system. This deflection reduction was the result of the wood posts having a higher stiffness and resistance to rotation than their steel counterparts. The wood-post system also consistently showed a 5 to 25 percent reduction in the maximum pocketing angle. Thus, the wood post system is expected to reduce the risk of vehicle instability. Finally, the propensity for wheel snag was found to be lower for the wood-post system. The reduction in system deflection significantly reduced the estimated wheel snag for the 6-in. x 8-in. (152-mm x 203-mm) wood post. However, the wheel snag estimations for the larger 8-in. x 10-in. (203-mm x 254-mm) wood transition posts were found to be closer to (or slightly higher) the estimations for the steel W6x15 (W152x22.3) steel posts. Thus, the potential benefits (as far wheel snag are concerned) of deflection reduction were offset by the reduction in embedment depth.

Therefore, this system as described is eligible for reimbursement and should be installed under the range of conditions tested, when such use is acceptable to a highway agency. Please note the following standard provisions that apply to the FHWA eligibility letters:

- This letter includes an AASHTO/ARTBA/AGC Task Force 13 designator that should be used to identify any new or updated Task Force 13 drawings.
- This finding of eligibility does not cover other structural features of the systems, nor conformity with the Manual on Uniform Traffic Control Devices.
- Any changes that may influence system conformance with MASH will require a new reimbursement eligibility letter.
- Should the FHWA discover that the qualification testing was flawed, that in-service performance reveals safety problems, or that the system is significantly different from the version that was crash tested, we reserve the right to modify or revoke this letter.
- You are expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.
- You are expected to certify to potential users that the hardware furnished has the same chemistry, mechanical properties, and geometry as that submitted for review, and that it will meet the test and evaluation criteria of the MASH.
- To prevent misunderstanding by others, this letter is designated as number B-236, and shall not be reproduced except in full. This letter and the test documentation upon which it is based are public information. All such letters and documentation may be reviewed at our office upon request.

- This letter shall not be construed as authorization or consent by the FHWA to use, manufacture, or sell any patented device for which the applicant is not the patent holder. The finding of eligibility is limited to the crashworthiness characteristics of the candidate device, and the FHWA does not become involved in issues concerning patent law. Patent issues, if any, are to be resolved by the applicant.

Sincerely yours,

Michael S. Griffith

Michael S. Griffith
Director, Office of Safety Technologies
Office of Safety

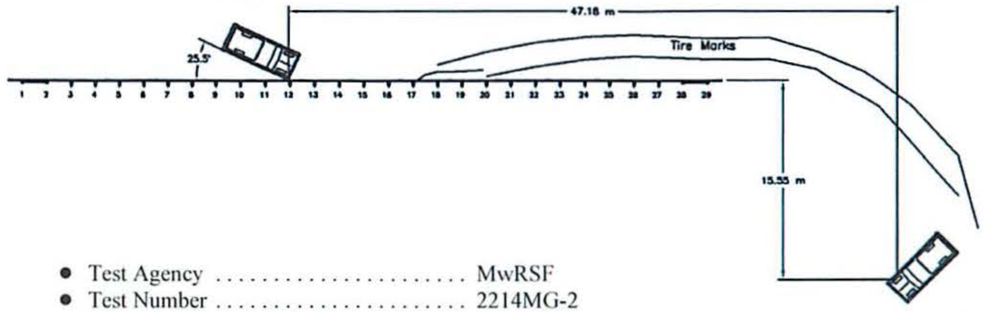
Enclosures

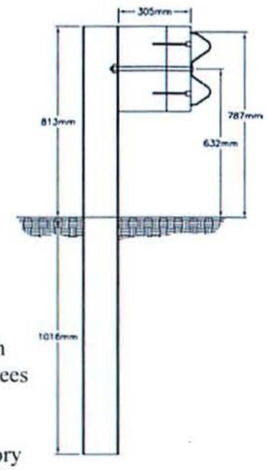
Table 2. Comparison of Wood and Steel Post from Full-Scale Crash Testing

	Test No. 2214MG-2 [1]	**Test No. MGSWP-1 [10]**
System	181-ft 3-in. (55.2-m) long MGS	181-ft 3-in. (55.2-m) long MGS
Posts	W6x9 (W152x13.4) Steel	Wood 6 in. x 8 in. (152 mm x 203 mm)
Vehicle	2002 Dodge Ram 1500 Quad Cab	2003 Dodge Ram 1500 Quad Cab
Impact Speed	62.8 mph (101.1 km/h)	63.8 mph (102.7 km/h)
Impact Angle	25.5°	25.6°
Exit Speed	39.6 mph (63.7 km/h)	39.6 mph (63.7 km/h)
Exit Angle	13.5°	16.6°
Contact Length	33 ft – 8 in. (10.3 m)	30 ft – 6 in. (9.3 m)
Maximum Dynamic Deflection	43.9 in. (1,115 mm)	46.3 in. (1,176 mm)
System Permanent Set	31⅝ in. (803 mm)	33¾ in. (857 mm)
Longitudinal OIV	15.32 ft/s (4.67 m/s)	15.27 ft/s (4.65 m/s)
Lateral OIV	15.62 ft/s (4.76 m/s)	16.14 ft/s (4.92 m/s)
Longitudinal ORA	8.23 g's	8.25 g's
Lateral ORA	6.93 g's	10.13 g's

2.3 Conclusions

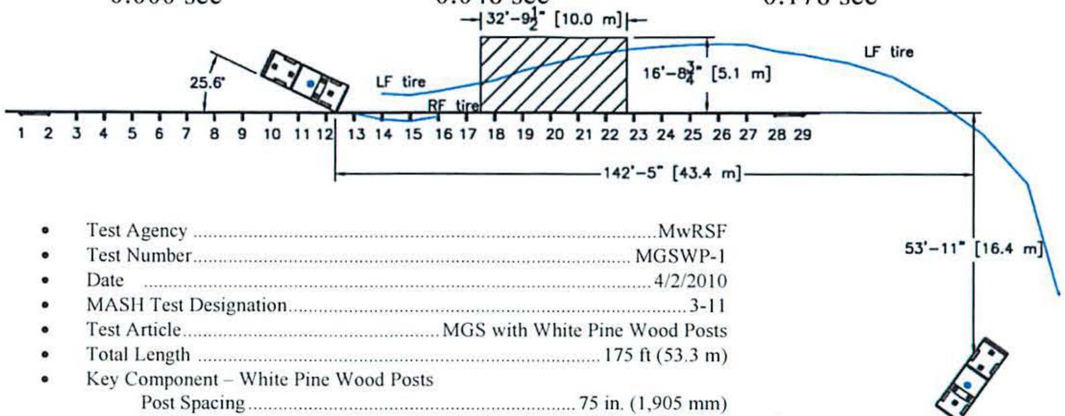
Similar performance between W6x9 (W152x13.4) steel and 6-in. x 8-in. (152-mm x 203-mm) wood guardrail posts has been documented in both dynamic component testing and full-scale testing. Therefore, 6-in. x 8-in. (152-mm x 203-mm) wood posts were selected as the alternative for the W6x9 (W152x13.4) steel posts found in the MGS to thrie beam stiffness transition. BARRIER VII simulations were used to verify the wood posts did not adversely affect the safety performance of the stiffness transition, as described in Chapter 5.

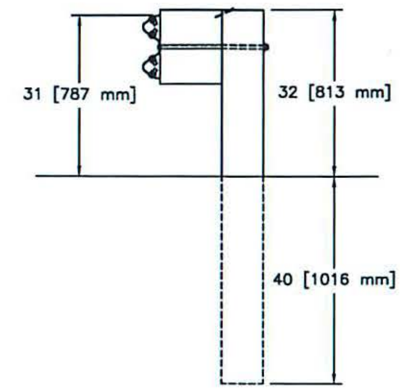




- Test Agency .... MwRSF
- Test Number 2214MG-2
- Date 10/6/04
- NCHRP 350 Update Test Designation .. 3-11
- Appurtenance .... Midwest Guardrail System
- Total Length .... 55.25 m
- Key Elements - Steel W-Beam
  - Thickness .... 2.66 mm
  - Top Mounting Height .... 787 mm
- Key Elements - Steel Posts
  - Post Nos. 3 - 27 .... W152x13.4 by 1,829 mm long
  - Spacing .... 1,905 mm
- Key Elements - Wood Posts
  - Post Nos. 1 - 2, 28 - 29 (BCT) .... 140 mm x 190 mm by 1,080 mm long
- Key Elements - Steel Foundation Tube . 1,829 mm long
- Key Elements - Wood Spacer Blocks
  - Post Nos. 3 - 27 .... 152 mm x 305 mm by 362 mm long
- Type of Soil .... Grading B - AASHTO M 147-65 (1990)
- Test Vehicle
  - Type/Designation 2270P
  - Make and Model .... 2002 Dodge Ram 1500 Quad Cab Pickup
  - Curb .... 2,292 kg
  - Test Inertial .... 2,268 kg
  - Gross Static .... 2,268 kg
- Impact Conditions
  - Speed .... 101.1 km/h
  - Angle .... 25.5 degrees
  - Impact Location .... 5.25 m upstream splice between posts 14 & 15
- Exit Conditions
  - Speed .... 63.7 km/h
  - Angle .... 13.5 degrees
  - Exit Box Criterion .... Pass
- Post-Impact Trajectory
  - Vehicle Stability .... Satisfactory
  - Stopping Distance .... 47.18 m downstream
    15.56 m laterally behind
- Occupant Impact Velocity (350 Update)
  - Longitudinal .... 4.67 m/s < 12 m/s
  - Lateral .... 4.76 m/s < 12 m/s
- Occupant Ridedown Deceleration (350 Update)
  - Longitudinal .... 8.23 Gs < 20 Gs
  - Lateral .... 6.93 Gs < 20 Gs
- THIV (not required) .... 6.91 m/s
- PHD (not required) .... 10.76 Gs
- Test Article Damage .... Moderate
- Test Article Deflections
  - Permanent Set .... 803 mm
  - Dynamic .... 1,114 mm
  - Working Width .... 1,234 mm
- Vehicle Damage .... Moderate
  - VDS[5] 1-RFQ-4
  - CDC[6] 1-RYEN2
  - Maximum Deformation .... 19 mm at right-center floorpan

Figure 14. Summary of Test Results and Sequential Photographs, Test 2214MG-2





- Test Agency .... MwRSF
- Test Number MGSWP-1
- Date 4/2/2010
- MASH Test Designation 3-11
- Test Article .... MGS with White Pine Wood Posts
- Total Length .... 175 ft (53.3 m)
- Key Component – White Pine Wood Posts
  - Post Spacing .... 75 in. (1,905 mm)
  - Post Dimensions .... 6 x 8 x 72 in. (152 x 203 x 1,829 mm)
- Key Component – Wood Spacer Blocks
  - Blockout Dimensions .... 6 x 12 x 14¼ in. (152 x 305 x 362 mm)
- Key Component – Steel MGS Rail
  - Thickness .... 12 gauge (2.66 mm)
  - Top Mounting Height .... 31 in. (787 mm)
- Soil Type .... Grading B of AASHTO M147-65 (1990)
- Vehicle Make /Model .... 2003 Dodge Ram 1500 Quad Cab
  - Curb .... 4,979 lb (2,258 kg)
  - Test Inertial .... 4,999 lb (2,268 kg)
  - Gross Static .... 5,169 lb (2,345 kg)
- Impact Conditions
  - Speed .... 63.8 mph (102.7 km/h)
  - Angle .... 25.6 deg
  - Location ..... 13 ft – 4½ in. (4.1 m) US of splice between posts 14 and 15
- Exit Conditions
  - Speed .... 39.6 mph (63.7 km/h)
  - Angle .... 16.6 deg
- Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 142 ft – 5 in. (43.4 m) downstream 53 ft – 11 in. (16.4 m) laterally behind
- Vehicle Damage .... Moderate
  - VDS[17] 01-RFQ-4
  - CDC[18] 01-RYEN-3
  - Maximum Interior Deformation .... 1 in. (25 mm), door below seat
- Test Article Damage .... Moderate
- Test Article Deflections
  - Permanent Set .... 33¾ in. (857 mm)
  - Dynamic .... 46.3 in. (1,176 mm)
  - Working Width .... 58.4 in. (1,483 mm)
- Maximum Angular Displacements
  - Roll .... 7 ° < 75°
  - Pitch .... -3 ° < 75°
  - Yaw .... 78 °
- Impact Severity (IS) .... 131.5 kip-ft (178.3 kJ) > 106 kip-ft (144 kJ)
- Transducer Data

Evaluation Criteria		Transducer			MASH Limit
		EDR-3	DTS Set 1	DTS Set 2	
OIV ft/s (m/s)	Longitudinal	-15.38 (-4.69)	-15.27 (-4.65)	-15.75 (-4.80)	≤ 40 (12.2)
	Lateral	-14.95 (-4.56)	-16.14 (-4.92)	-15.91 (-4.85)	≤ 40 (12.2)
ORA g's	Longitudinal	-8.08	-8.25	-8.25	≤ 20.49
	Lateral	-9.32	-10.13	-9.86	≤ 20.49
THIV – ft/s (m/s)		NA	21.23 (6.47)	NA	not required
PHD – g's		NA	12.36	NA	not required
ASI		0.69	0.77	NA	not required

Figure 19. Summary of Test Results and Sequential Photographs, Test No. MGSWP-1

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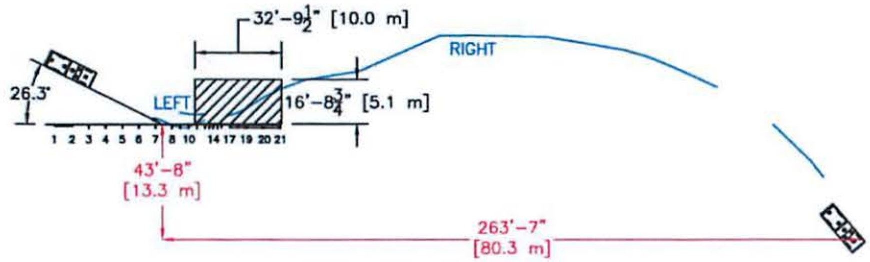
- Test Agency .... MwRSF
- Test Number MWTSP-2
- Date 7/7/08
- MASH Test Designation 3-21
- Test Article .... Stiffness Transition between MGS and Thrie Beam Transition
- Total Length .... 87 ft – 6 in. (26.7 m)
- Height to Top of Rail .... 31 in. (787 mm)
- Key Components – Steel W-Beam Guardrail
  - Thickness .... 12 gauge (2.66 mm)
- Key Components – Steel W-Beam to Thrie Beam Transition
  - Thickness .... 10 gauge (3.42 mm)
  - Segment Length .... 75 in. (1,905 mm)
- Key Components – Steel Thrie Beam
  - Thickness .... 12 gauge (2.66 mm)
- Key Components – Steel Posts
  - Post Nos. 3 - 15 .... 72 in. (1,829 mm) long, W6x9 (W152x13.4)
  - Post Nos. 16 - 18 .... 84 in. (2,134 mm) long, W6x15 (W152x22.3)
  - Post Nos. 19 - 21 .... 29⅝ in. (752 mm) long, W6x20 (W152x29.8)
- Post Spacing
  - Post Nos. 1 - 8, 19 - 21 .... 75 in. (1,905 mm)
  - Post Nos. 8 - 12, 16 - 19 .... 37½ in. (953 mm)
  - Post Nos. 12 - 16 .... 18¾ in. (476 mm)
- Type of Soil .... Grading B – AASHTO M 147-65
- Vehicle
  - Make and Model .... 2002 Dodge Ram 1500 Quad Cab
  - Curb .... 5,138 lb (2,331 kg)
  - Test Inertial .... 4,993 lb (2,265 kg)
  - Gross Static .... 5,158 lb (2,340 kg)
- Impact Conditions
  - Speed .... 61.2 mph (98.5 km/h)
  - Angle .... 26.3 deg
  - Impact Location .... 75 in. (1,905 mm) US of Post No. 9
- Exit Conditions
  - Speed .... 37.3 mph (60.0 km/h)
  - Angle .... 22.0 deg
- Vehicle Stability .... Satisfactory
- Exit Box Criteria .... Passed
- Vehicle Damage .... Moderate
  - VDS[28] 1-RFQ-5
  - CDC[29] 01-RFEW2



- Vehicle Stopping Distance .... 263 ft (80.2 m) DS of Impact
  43.7 ft (13.3 m) Laterally Behind the System
- Test Article Damage .... Moderate
- Test Article Deflections
  - Permanent Set .... 25¾ in. (654 mm)
  - Dynamic .... 32.8 in. (833 mm)
  - Working Width .... 51.6 in. (1,310 mm)
- Maximum Angular Displacements
  - Roll .... 13° < 75°
  - Pitch .... 10° < 75°
  - Yaw .... 51°
- Impact Severity .... 126.8 kip-ft (171.9 kJ) > 106 kip-ft (144 kJ)
- Transducer Data

Evaluation Criteria		Transducer			MASH Limit
		EDR-3	EDR-4	DTS	
OIV ft/s (m/s)	Longitudinal	-21.21 (-6.46)	NA	NA	≤ 40 (12.2)
	Lateral	-16.91 (-5.15)	NA	NA	≤ 40 (12.2)
ORA g's	Longitudinal	-12.03	NA	NA	≤ 20.49
	Lateral	-9.87	NA	NA	≤ 20.49
THIV – ft/s (m/s)		-	NA	NA	not required
PHD – g's		-	NA	NA	not required
ASI		0.91	NA	NA	not required

Figure 64. Summary of Test Results and Sequential Photographs, Test No. MWTSP-2