U.S. Department of Transportation
Federal Highway Administration

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

November 17, 2011

In Reply Refer To:
HSST/ B-225

David K. Olson
Design Policy Standards & Research Manager
Washington State Department of Transportation
310 Maple Park Avenue S.E.
Olympia, WA. 98504

Dear Mr. Olson:

This letter is in response to your request 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:	Single Slope Concrete Barrier placed in front of steep slope
Type of system:	Permanent Single Slope Reinforced Concrete Barrier
Test Level:	AASHTO Manual for Assessing Safety Hardware (MASH) Test Level 3 (TL-3)
Testing conducted by:	Texas Transportation Institute (TTI)
Date of Request:	April 20, 2011
Drawing Designator:	SGR42

You certify that the device described herein meets the crashworthiness criteria of the American Association of State Highway and Transportation Association's (AASHTO) Manual on Assessing Safety Hardware (MASH). Based on your testing you asked that we find the device 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 the FHWA for any particular purpose or use.

Requirements
Roadside safety devices should meet the guidelines contained in the Manual for Accessing Safety Hardware. The FHWA Memorandum "ACTION: Identifying Acceptable Highway Safety Features" of July 24, 1997, provides further guidance on crash testing requirements of longitudinal barriers.

Decision
The following device is eligible, with details provided below:

• Permanent Single Slope Concrete Barrier placed in front of steep slope

FHWA: HSSI: WLongstreet: ms: x60087:10/5/11
File: h: //directory folder/HSST/ B-225_Perm Single Slope Concrete Barrier in front of steep slope.docx

Description

The test article was comprised of a 100 foot long installation of single-slope concrete barrier embedded 10 inches in soil. Five 20-foot long barrier segments were connected using the grouted rebar-grid slot connections to achieve the 100 foot installation length.

The single-slope barrier segments were 42 inches tall, 24 inches wide at the base and 8 inches wide at the top. At each end of the barrier segments, a 3-inch wide, 2-inch deep, and 10.5-inch long slot was cast into the barrier to accommodate the grouted rebar-grid connection. The concrete reinforcement of the barrier segments was comprised of #4 vertical bars that were bent to approximately match the profile of the barrier faces and were spaced 12 inches apart along the length of the barrier. The spacing of the vertical bars was reduced around the slot cast at each end for the grouted rebar-grid connection. The vertical bars, ten #5 longitudinal bars were located along the height of the barrier. A 4-inch wide, 2-inch high slot was cast at the bottom of the segments along their centerline.

The barrier was embedded in crushed limestone road base material that conforms to MASH standard soil. To embed the barrier to a depth of 2 feet, the native soil adjacent to the testing facility's concrete pavement was excavated. The excavated area was then backfilled with standard MASH soil and compacted in approximately 6-inch lifts. Once the backfill soil reached a level of 10 inches below the concrete pavement surface, the barrier was set in place and further soil was added and compacted in front and back of the barrier. As the soil was backfilled, a 1.5H:1V slope was built into the embankment with the breakpoint located 2 feet from the field side of the barrier.

A rebar-grid was then dropped into the slot at each barrier connection location. It was comprised of two vertical No. 6 bars that were spaced 10 inches apart, and three longitudinal #8 bars that were spaced eight inches apart. With the rebar-grid in place, the connection was grouted using a non-shrink grout.

The barrier concrete was specified to have a minimum 28-day compressive strength of 4000 psi. The reinforcing steel was specified to be grade 60. The steel material used for manufacturing the rebar-grid was also specified to be grade 60. The grout used for making the connection was a non-shrink grout which had a minimum compressive strength of 4000 psi. The soil used for embedding the barriers was a crushed limestone road base material that conforms to standard MASH soil. The moisture content of the soil on the day of the test was 8.5%.

Test article details are included in this correspondence as an enclosure.

Crash Testing

The crash test was evaluated in accordance with the criteria presented in MASH. The performance of the barrier is judged on the basis of three factors: structural adequacy, occupant risk, and post impact vehicle trajectory. Structural adequacy is judged upon the barrier's ability to contain and redirect the vehicle, or bring the vehicle to a controlled stop in a predictable manner. Occupant risk criteria evaluate the potential risk of hazard to occupants in the impacting vehicle, and to some extent other traffic, pedestrians, or workers in construction zones, if applicable.

Post impact vehicle trajectory is assessed to determine potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles. The appropriate safety evaluation criteria from table 5.1 of MASH were used to evaluate the crash test report.

According to MASH, two tests are recommended to evaluate longitudinal barriers to test level three (TL-3) as described below.

MASH Test Designation 3-10: A 2425 lb vehicle impacting the critical impact point (CIP) of the length of need section at a speed of 62 mi/h and an angle of 25 degrees.

MASH Test Designation 3-11: A 5000 lb pickup truck impacting the CIP of the length of need section at a speed of 62 mi/h and an angle of 25 degrees.

MASH test 3-11 involves a 2270P vehicle weighing 5000 lb ±100 lb and impacting the barrier at an impact speed of 62.2 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 4 ft upstream of the centerline of the joint located between segments 2 and 3. The 2002 Dodge pickup used in the test weighed 4953 lb and the actual impact speed and angle were 63.1 mi/h and 24.2 degrees, respectively. The actual impact point was 62.0 inches upstream of the joint between segments 2 and 3.

The 2270P vehicle, traveling at an impact speed of 63.1 mi/h, impacted the single-slope barrier 62 inches upstream of the joint between segments 2 and 3, at an impact angle of 24.2 degrees. At approximately 0.042 s, the right front tire began to climb the face of the barrier and the vehicle began to redirect. At 0.169 s, the vehicle was parallel to the barrier and was traveling at a speed of 58.7 mi/h. At 0.173 s, the right rear of the vehicle contacted the barrier, and at 0.176 s, the vehicle began to roll clockwise. The right rear corner of the bed of the vehicle contacted the top of the barrier at 0.616 s, and after that, dust obscured the view in all camera views. Brakes on the vehicle were applied 1.5 s after impact, and the vehicle came to rest 247 ft downstream of impact and 10 ft toward traffic lanes.

Based on the results of MASH test 3-11 with the 5000 lb pickup truck, the embedded single slope barrier system is expected to behave as a rigid barrier when impacted under MASH test 3-10 conditions with the smaller 2425 lb passenger car. MASH test 3-10 was successfully performed on a rigid F-shape concrete barrier. Previous analysis and testing indicates that F-shape and single-slope barriers have similar impact performance. Therefore, it was concluded that test 3-10 on the embedded single-slope barrier system was unnecessary.

Test summary details are included in this correspondence as an enclosure.

Findings
The embedded single-slope barrier successfully contained and redirected the 2270P vehicle. The vehicle did not penetrate, under ride, or override the installation. Maximum dynamic and static deflections of the barrier during the test were 5.6 inches and 5.5 inches, respectively. No detached elements, fragments, or other debris were present to penetrate or show potential to penetrate the occupant compartment, or to present undue hazard to others in the area. Maximum occupant compartment deformation was 5.5 inches. The 2270P vehicle remained upright during and after the collision event. Maximum roll was 44 degrees. Occupant risk factors were within the limits specified in MASH. The vehicle remained within the exit box.

Therefore, the system described and detailed in the enclosed drawings 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 FHWA eligibility letters:

- This letter provides a AASHTO/ARTBA/AGC Task Force 13 designator that should be used for the purpose of the creation of a new and/or the update of existing Task Force 13 drawing for posting on the on-line 'Guide to Standardized Highway Barrier Hardware' currently referenced in AASHTO Roadside Design Guide.
- This finding of eligibility is limited to the crashworthiness characteristics of the systems and does not cover their structural features, nor conformity with the Manual on Uniform Traffic Control Devices.
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- Should the FHWA discover that the qualification testing was flawed, that in-service performance reveals unacceptable safety problems, or that the system being marketed is significantly different from the version that was crash tested, we reserve the right to modify or revoke this letter.
- You will be expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.
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- To prevent misunderstanding by others, this letter of eligibility is designated as number B-225 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.

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Sincerely yours,

Michael S. Griffith
Office of Safety Technologies
Office of Safety

Enclosures

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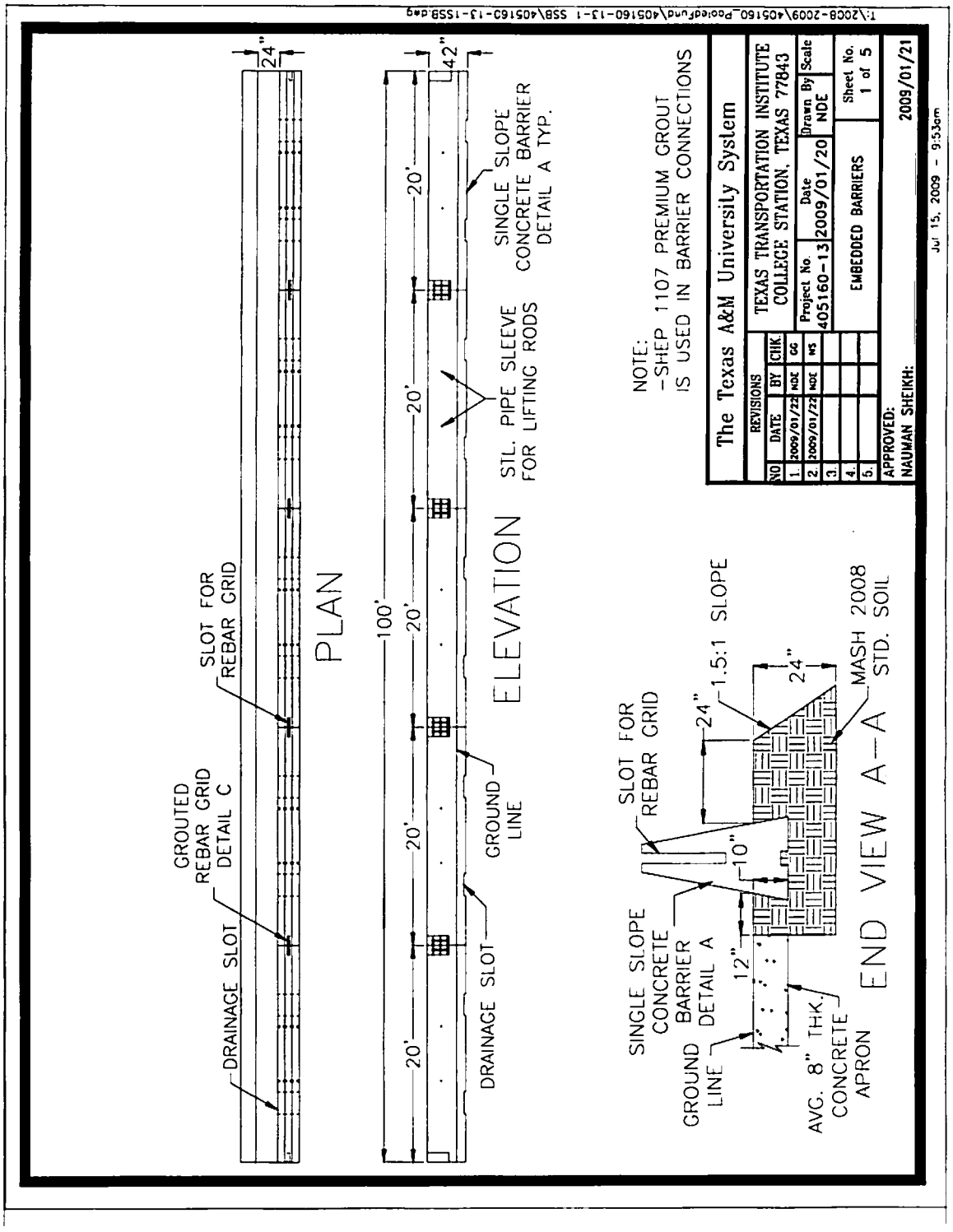
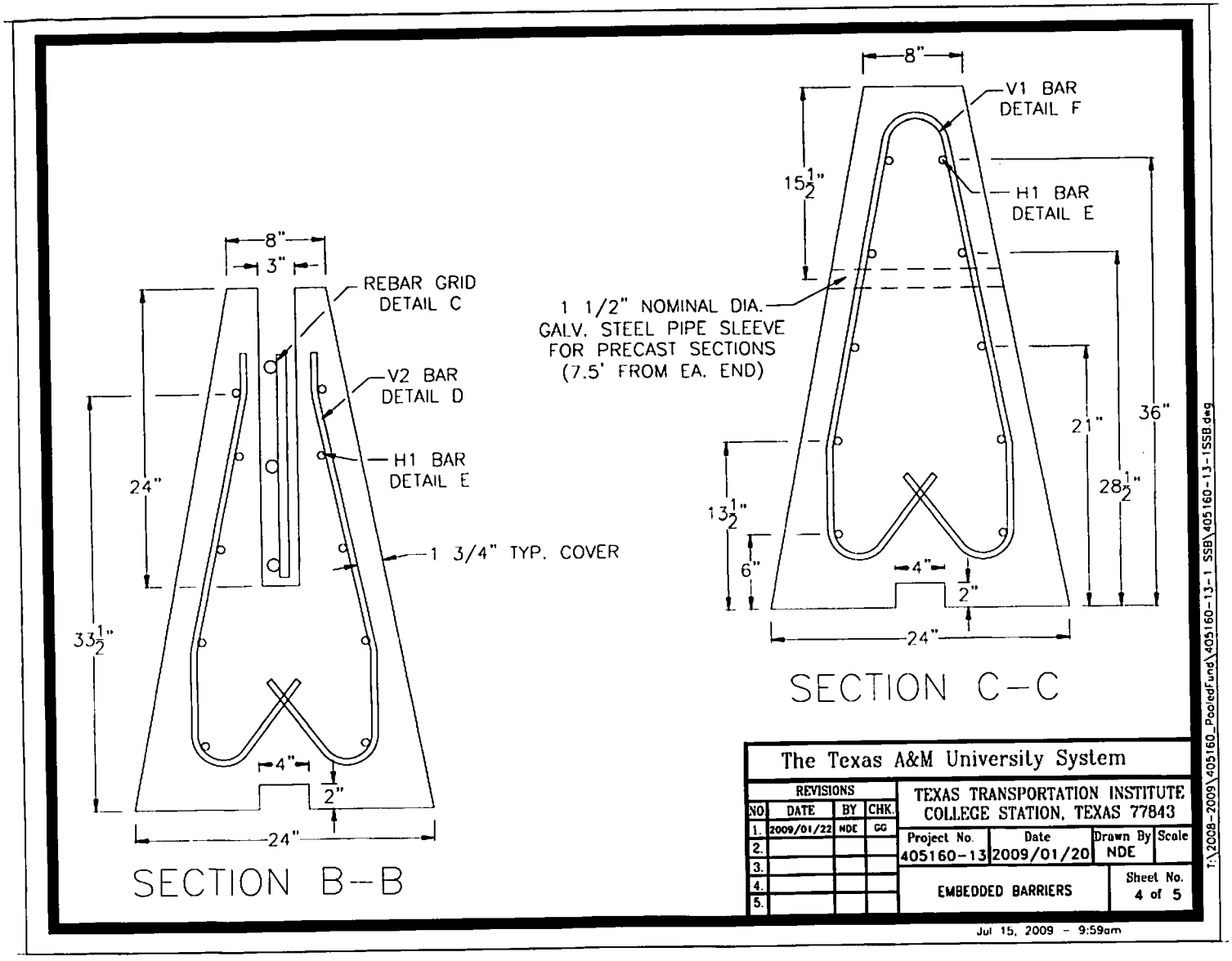
Sincerely yours,

Michael S. Griffith
Office of Safety Technologies
Office of Safety

Enclosures

APPENDIX A. DETAILS OF TEST ARTICLE




8"
3"
REBAR GRID
DETAIL C
V2 BAR
DETAIL D
H1 BAR
DETAIL E
1 3/4" TYP. COVER
24"
33 1/2"
4"
2"
24"
SECTION B--B
8"
V1 BAR
DETAIL F
15 1/2"
H1 BAR
DETAIL E
1 1/2" NOMINAL DIA.
GALV. STEEL PIPE SLEEVE
FOR PRECAST SECTIONS
(7.5' FROM EA. END)
21"
36"
28 1/2"
13 1/2"
6"
4"
2"
24"
SECTION C-C
The Texas A&M University System
REVISIONS
NO | DATE | BY | CHK.
1. | 2009/01/22 | NDE | GG
2.
3.
4.
5.
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843
Project No. 405160-13
Date 2009/01/20
Drawn By NDE
Scale
EMBEDDED BARRIERS
Sheet No. 4 of 5
Jul 15, 2009 - 9:59am
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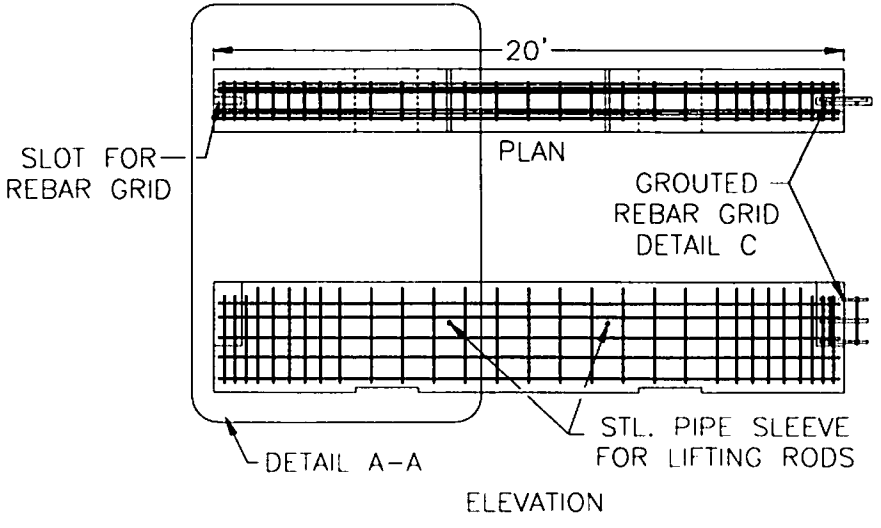

DETAIL A
SINGLE SLOPE
CONCRETE BARRIER

The Texas A&M University System				
REVISIONS				TEXAS TRANSPORTATION INSTITUTE COLLEGE STATION, TEXAS 77843
NO	DATE	BY	CHK.	
1	2009/01/22	NDE	GG	
2.				Project No. 405160-13 | Date 2009/01/20 | Drawn By NDE | Scale
3.				
4.				EMBEDDED BARRIERS | Sheet No. 2 of 5
5.				

Jul 15, 2009 - 9:56am

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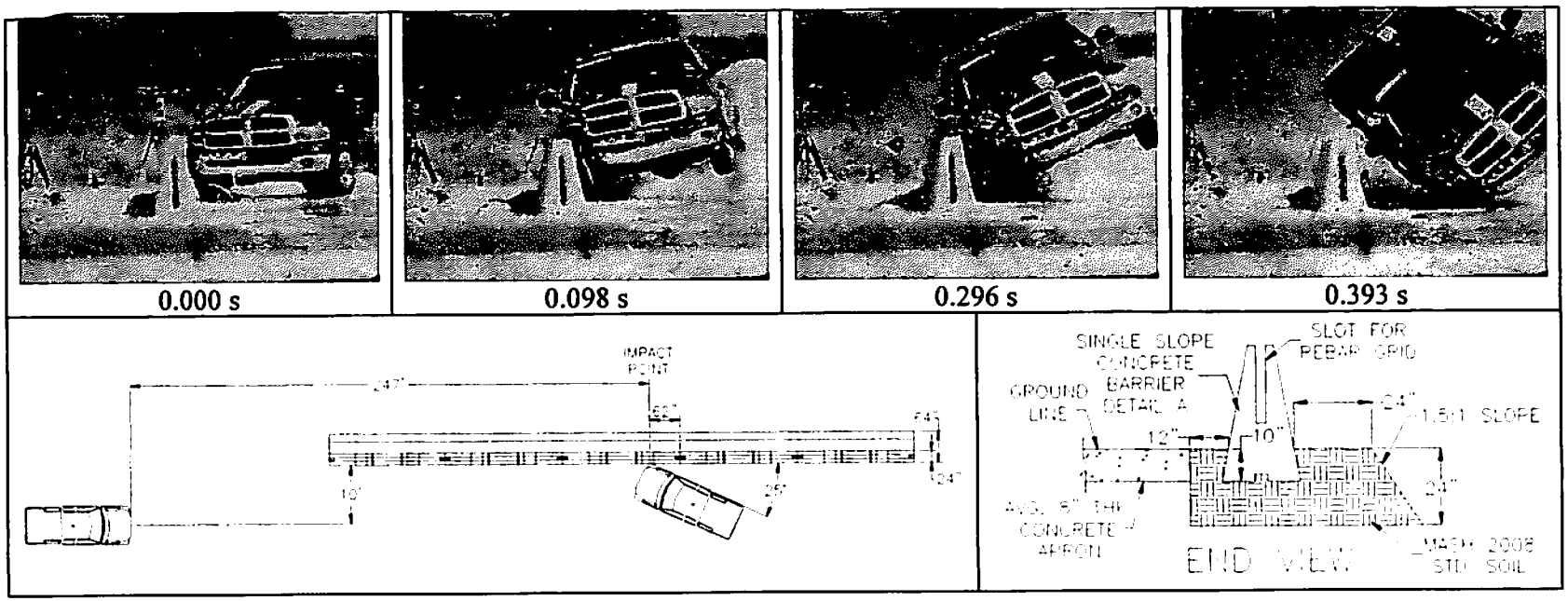

General Information
- Test Agency ..... Texas Transportation Institute
- Test No. 405160-13-1
- Date ..... April 16, 2009

Test Article
- Type ..... Concrete Barrier
- Name ..... Single-Slope Barrier offset 2 ft from 1.5:1 Slope
- Installation Length ..... 100 ft
- Material or Key Elements ..... 42-inch tall x 20 ft long single-slope concrete barrier embedded 10 inches in soil in front of 1.5H:1V slope
- Soil Type and Condition ..... Standard Soil, Dry

Test Vehicle
- Type/Designation 2270P
- Make and Model ..... 2002 Dodge Ram 1500 Pickup
- Curb ..... 4630 lb
- Test Inertial ..... 4953 lb
- Dummy ..... No Dummy
- Gross Static ..... 4953 lb

Impact Conditions
- Speed ..... 63.1 mi/h
- Angle ..... 24.2 degrees
- Location/Orientation ..... 62 inch upstrm Joint 2-3

Exit Conditions
- Speed ..... Out of view
- Angle ..... Out of view

Occupant Risk Values
- Impact Velocity
  - Longitudinal ..... 12.1 ft/s
  - Lateral ..... 24.6 ft/s
- Ridedown Accelerations
  - Longitudinal ..... -2.4 G
  - Lateral ..... -11.3 G
- THIV ..... 29.6 km/h
- PHD ..... 11.3 G
- Max. 0.050-s Average
  - Longitudinal ..... -6.5 G
  - Lateral ..... -13.0 G
  - Vertical ..... -4.2 G

Post-Impact Trajectory
- Stopping Distance ..... 247 ft dwnstrm 10 ft fwd

Vehicle Stability
- Maximum Yaw Angle ..... -42 degrees
- Maximum Pitch Angle ..... -11 degrees
- Maximum Roll Angle ..... 44 degrees
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 5.6 inches
- Permanent ..... 5.5 inches
- Working Width ..... 19.6 inches

Vehicle Damage
- VDS 01RFQ5
- CDC 01RFEW4
- Max. Exterior Deformation ..... 14.0 inches
- Max. Occupant Compartment Deformation ..... 0.56 inch

Figure 6.7. Summary of results for *MASH* test 3-11 on the single-slope barrier on 1.5:1 slope.