Test Report No. 602191-1
Test Report Date: October 2013

MASH TEST 3-11 ON THE WASHINGTON CONCRETE TRAFFIC BARRIER WITH ACOUSTIC COATING

by

Roger P. Bligh, P.E.
Research Engineer

Wanda L. Menges
Research Specialist

and

Darrell L. Kuhn, P.E.
Research Specialist

Contract No.: P2005312.45 (T4541 M0600036)
Test No.: 602191-1
Test Date: 2013-08-26

Sponsored by
Roadside Safety Research Program Pooled Fund Study No. TPF-5(114)

TEXAS A&M TRANSPORTATION INSTITUTE PROVING GROUND

Mailing Address:
Roadside Safety & Physical Security
Texas A&M University System
3135 TAMU
College Station, TX 77843-3135

Located at:
Texas A&M Riverside Campus
Building 7091
3100 State Highway 47
Bryan, TX 77807

ISO 17025 Laboratory
Testing Certificate # 2821.01

DISCLAIMER

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the data, and the opinions, findings and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Roadside Safety Research Program Pooled Fund Study No. TPF-5(114), Washington State Department of Transportation, The Texas A&M University System, or Texas A&M Transportation Institute. This report does not constitute a standard, specification, or regulation. In addition, the above listed agencies assume no liability for its contents or use thereof. The names of specific products or manufacturers listed herein do not imply endorsement of those products or manufacturers. The results reported herein apply only to the article being tested. The full-scale crash test was performed according to TTI Proving Ground quality procedures and according to the *MASH* guidelines and standards.

Wanda L. Menges, Research Specialist
Deputy Quality Manager

Richard A. Zimmer, Senior Research Specialist
Test Facility Manager
Quality Manager
Technical Manager

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle MASH TEST 3-11 ON THE WASHINGTON CONCRETE TRAFFIC BARRIER WITH ACOUSTIC COATING		5. Report Date October 2013 6. Performing Organization Code
7. Author(s) Roger P. Bligh, Wanda L. Menges, and Darrell L. Kuhn		8. Performing Organization Report No. Test Report No. 602191-1
9. Performing Organization Name and Address Texas A&M Transportation Institute Proving Ground 3135 TAMU College Station, Texas 77843-3135		10. Work Unit No. (TRAIS) 11. Contract or Grant No. P2005312.45/T4541 M0600036
12. Sponsoring Agency Name and Address Washington State Department of Transportation Transportation Building, MS 47372 Olympia, Washington 98504-7372		13. Type of Report and Period Covered Test Report: June – October 2013 14. Sponsoring Agency Code

15. Supplementary Notes
Research Study Title: Evaluation of Concrete Traffic Barrier with Acoustic Coating
Name of Contacting Representative:

16. Abstract

The objective of this project was to evaluate the impact performance of a single slope concrete traffic barrier with an applied acoustic coating. Test 3-11 was performed following the guidelines of the AASHTO *Manual for Assessing Safety Hardware* (*MASH*). *MASH* test 3-11 involves a 5000-lb pickup truck impacting the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively.

The test installation consisted of 48-inch tall precast single slope concrete barrier segments connected together using grouted rebar connections and keyed into an adjacent concrete apron using a 3-inch asphalt overlay. This provided a 45-inch effective barrier height above grade. A thin layer of acoustical surfacing material (Pyrok Acoustement® 40) approximately ½-inch thick was field applied to the traffic face of the installed barrier.

The Washington concrete traffic barrier with Acoustement® 40 coating met all applicable *MASH* evaluation criteria for *MASH* test 3-11. The test vehicle was contained and redirected in a stable manner, and occupant risk factors were within the limits specified in *MASH*. Upon impact, the coating disintegrated into a powdery cloud, and there were no large fragments that would pose a hazard to other traffic, pedestrians, or work zone personnel. However, the coating cloud resulting from the impact could momentarily obstruct the vision of other motorists in the area.

The test results also verified that a 3-inch asphalt overlay/key is sufficient for anchorage of precast concrete median barrier with grouted rebar connections. The barrier used in the test had negligible movement and no structural damage.

17. Key Words Longitudinal barriers, median barriers, acoustic barrier coating, crash testing, roadside safety		18. Distribution Statement Copyrighted. Not to be copied or reprinted without consent from Roadside Safety Pooled Fund.	
19. Security Classif.(of this report) Unclassified	20. Security Classif.(of this page) Unclassified	21. No. of Pages 76	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

ACKNOWLEDGMENTS

This research project was performed under a pooled fund program between the State of Alaska Department of Transportation and Public Facilities, California Department of Transportation (Caltrans), Louisiana Department of Transportation and Development, Minnesota Department of Transportation, Pennsylvania Department of Transportation, Tennessee Department of Transportation, Texas Department of Transportation, Washington State Department of Transportation, West Virginia Department of Transportation, and the Federal Highway Administration. The authors acknowledge and appreciate their guidance and assistance.

Roadside Safety Research Pooled Fund Committee
CONTACTS

Revised October 2012

ALASKA
Jeff C. Jeffers, P.E.
Statewide Traffic & Safety Engineering
Alaska Department of Transportation and Public Facilities
3132 Channel Drive
P.O. Box 112500
Juneau, AK 99811-2500
(907) 465-8962
jeff.jeffers@alaska.gov

CALIFORNIA
John Jewell, P.E.
Caltrans
Office of Materials and Infrastructure
Division of Research and Innovation
5900 Folsom Blvd
Sacramento, CA 95819
(916) 227-5824
john_jewell@dot.ca.gov

LOUISIANA
Paul Fossier, P.E.
Assistant Bridge Design Administrator
Bridge and Structural Design Section
Louisiana Transportation Center
1201 Capitol Road
P.O. Box 94245
Baton Rouge, LA 79084-9245
(225) 379-1323
Paul.Fossier@la.gov

Louisiana (continued)

Kurt Brauner, P.E.
Bridge Engineer Manager
(225) 379-1933
Kurt.Brauner@la.gov

MINNESOTA
Michael Elle, P.E.
Design Standards Engineer
Minnesota Department of Transportation
395 John Ireland Blvd, MS 696
St. Paul, MN 55155-1899
(651) 366-4622
michael.elle@state.mn.us

PENNSYLVANIA
Mark R. Burkhead, P.E.
Standards & Criteria Engineer
Pennsylvania Department of Transportation
Bureau of Project Delivery
400 North Street
Harrisburg, PA 17105
(717) 783-5110
(717) 705-2379 (fax)
mburkhead@pa.gov

TENNESSEE

Ali Hangul, P.E.
Civil Engineering Manager
(615) 741-0840
(615) 532-7745 (fax)
Ali.Hangul@tn.gov

TEXAS

Aurora (Rory) Meza, P.E.
Roadway Design Section Director
Texas Department of Transportation
Design Division
125 East 11th Street
Austin, TX 78701-2483
(512) 416-2678
Rory.Meza@txdot.gov

WASHINGTON

John P. Donahue, P.E.
Design Policy & Strategic Analysis
Estimating Manager
Washington State Department of Transportation
310 Maple Park Avenue SE
Olympia, WA 98504-7329
(360)705-7952
DonahJo@wsdot.wa.gov

Jeffery K. Petterson, P.E.
Roadside Safety Engineer
(360) 705-7246
PetterJ@wsdot.wa.gov

Rhonda Brooks
Research Manager
(360) 705-7945
Brookrh@wsdot.wa.gov

WEST VIRGINIA

Donna J. Hardy, P.E.
Mobility and Safety Engineer
West Virginia Department of
Transportation – Traffic Engineering
Building 5, Room A-550
1900 Kanawha Blvd E.
Charleston, WV 25305-0430
(304) 558-9576
Donna.J.Hardy@wv.gov

FEDERAL HIGHWAY ADMINISTRATION

Richard B. (Dick) Albin, P.E.
Safety Engineer
FHWA Resource Center Safety & Design
Technical Services Team
711 South Capitol Blvd.
Olympia, WA 98504
(303) 550-8804
Dick.Albin@dot.gov

William Longstreet
Highway Engineer
FHWA Office of Safety Design
Room E71-107
1200 New Jersey Avenue, S.E.
Washington, DC 20590
(202) 366-0087
Will.Longstreet@dot.gov

TEXAS A&M TRANSPORTATION INSTITUTE

D. Lance Bullard, Jr., P.E.
Research Engineer
Roadside Safety & Physical Security Div.
Texas A&M Transportation Institute
Texas A&M University System
College Station, TX 77843-3135
(979) 845-6153
L-Bullard@tamu.edu

Roger P. Bligh, Ph.D., P.E.
Research Engineer
(979) 845-4377
RBligh@tamu.edu

TABLE OF CONTENTS

Section | Page

1 INTRODUCTION 1
1.1 PROBLEM 1
1.2 BACKGROUND 1
1.3 OBJECTIVES/SCOPE OF RESEARCH 2
2 SYSTEM DETAILS 3
2.1 TEST ARTICLE DESIGN AND CONSTRUCTION 3
2.2 MATERIAL SPECIFICATIONS 9
3 TEST REQUIREMENTS AND EVALUATION CRITERIA 11
3.1 CRASH TEST MATRIX 11
3.2 EVALUATION CRITERIA 11
4 TEST CONDITIONS 13
4.1 TEST FACILITY 13
4.2 VEHICLE TOW AND GUIDANCE SYSTEM 13
4.3 DATA ACQUISITION SYSTEMS 13
4.3.1 Vehicle Instrumentation and Data Processing 13
4.3.2 Anthropomorphic Dummy Instrumentation 14
4.3.3 Photographic Instrumentation and Data Processing 14
5 CRASH TEST 602191-1 (*MASH* TEST NO. 3-11) 17
5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS 17
5.2 TEST VEHICLE 17
5.3 WEATHER CONDITIONS 17
5.4 TEST DESCRIPTION 17
5.5 TEST ARTICLE AND COMPONENT DAMAGE 20
5.6 TEST VEHICLE DAMAGE 20
5.7 OCCUPANT RISK VALUES 20
5.8 ASSESSMENT OF TEST RESULTS 26
5.8.1 Structural Adequacy 26
5.8.2 Occupant Risk 26
5.8.3 Vehicle Trajectory 27
5.9 REPAIR OF BARRIER COATING 27
6 SUMMARY AND CONCLUSIONS 33
6.1 SUMMARY OF RESULTS 33
6.2 CONCLUSIONS 33
7 REFERENCES 35
APPENDIX A. DETAILS OF THE WASHINGTON CONCRETE TRAFFIC BARRIER WITH ACOUSTIC COATING 37
APPENDIX B . HY-FLEX 30-E BROCHURE 45
APPENDIX C . SUPPORTING CERTIFICATION DOCMENTS 49
APPENDIX D . CRASH TEST NO. 602191-1 53
D.1 VEHICLE PROPERTIES AND INFORMATION 53
D.2 SEQUENTIAL PHOTOGRAPHS 57
D.3. VEHICLE ANGULAR DISPLACEMENTS 60
D.4. VEHICLE ACCELERATIONS 61

LIST OF FIGURES

Page

Figure 2.1. Cross Section of the Installation for Washington Concrete Traffic Barrier with Acoustic Coating. 3
Figure 2.2. Compaction of 3-inch Asphalt Overlay/Key. 4
Figure 2.3. Application of Weld-Crete® Concrete Bonding Agent. 5
Figure 2.4. Mechanical Mixing of Acoustement® 40. 5
Figure 2.5. Application of First "Key" or "Flock" Coat of Acoustement® 40. 6
Figure 2.6. Coating Buildup of Acoustement® 40. 6
Figure 2.7. Application of Final Coat of Acoustement® 40. 7
Figure 2.8. Light Hand Finishing of Acoustement® 40 coating. 7
Figure 2.9. Finished Acoustement® 40 coating. 8
Figure 2.10. Completed test installation. 8
Figure 5.1. Vehicle/Installation Geometrics for Test No. 602191-1. 18
Figure 5.2. Vehicle before Test No. 602191-1. 19
Figure 5.3. Vehicle/Washington Concrete Traffic Barrier with Acoustic Coating Positions after Test No. 602191-1. 21
Figure 5.4. Installation after Test No. 602191-1. 22
Figure 5.5. Vehicle after Test No. 602191-1. 23
Figure 5.6. Interior of Vehicle for Test No. 602191-1. 24
Figure 5.7. Summary of Results for *MASH* Test 3-11 on the Washington Concrete Traffic Barrier with Acoustic Coating. 25
Figure 5.8. Damaged Coating after Test. 28
Figure 5.9. Preparing Edges of Damaged Coating for Repair. 28
Figure 5.10. Washing Down Damaged Coating Area. 29
Figure 5.11. Application of Repair Coat. 29
Figure 5.12. Calculated Area Requiring Coating Repair. 30
Figure 5.13. Repaired Coating. 30
Figure 5.14. Repaired coating after rain. 31
Figure A1. Sheet 1 Details of the Washington Acoustic Barrier. 37
Figure A2. Sheet 2 Details of the Washington Acoustic Barrier. 38
Figure A3. Sheet 3 Details of the Washington Acoustic Barrier. 39
Figure A4. Sheet 1 of the Washington WSDOT Standard Plan C-70.10-00. 40
Figure A5. Sheet 2 of the Washington WSDOT Standard Plan C-70.10-00. 41
Figure A6. Sheet 3 of the Washington WSDOT Standard Plan C-70.10-00. 42
Figure A7. Sheet 1 Oldcastle Precast Details. 43
Figure D.1. Sequential Photographs for Test No. 602191-1 (Overhead and Frontal Views). 57
Figure D.2. Sequential Photographs for Test No. 602191-1 (Rear View). 59
Figure D.3. Vehicle Angular Displacements for Test No. 602191-1. 60
Figure D.4. Vehicle Longitudinal Accelerometer Trace for Test No. 602191-1 (Accelerometer Rear of Center of Gravity). 61
Figure D.5. Vehicle Lateral Accelerometer Trace for Test No. 602191-1 (Accelerometer Located at Center of Gravity). 62
Figure D.6. Vehicle Vertical Accelerometer Trace for Test No. 602191-1 (Accelerometer Located at Center of Gravity). 63

LIST OF FIGURES (CONTINUED)

Page

Figure D.7. Vehicle Lateral Accelerometer Trace for Test No. 602191-1 (Accelerometer Located Rear of Center of Gravity). 64
Figure D.8. Vehicle Vertical Accelerometer Trace for Test No. 602191-1 (Accelerometer Located Rear of Center of Gravity). 65

LIST OF TABLES

Page

Table 6.1. Performance Evaluation Summary for *MASH* Test 3-11 on the Washington Concrete Traffic Barrier with Acoustic Coating. 34
Table D.1. Vehicle Properties for Test No. 602191-1. 53
Table D.2. Measurements of Vehicle Vertical CG for Test No. 602191-1. 54
Table D.3. Exterior Crush Measurements for Test No. 602191-1. 55
Table D.4. Occupant Compartment Measurements for Test No. 602191-1. 56

1 INTRODUCTION

1.1 PROBLEM

Vehicle noise is inherent in the highway environment. Increased traffic volumes on freeways have aggravated the issue of noise with surrounding businesses and residences. Departments of Transportation continue to seek cost-effective solutions for mitigating the transmission of this highway noise.

1.2 BACKGROUND

The single-slope concrete barrier (SSCB) was developed for use as both a permanent concrete median barrier and as a temporary barrier for use in construction zones (*1*). The advantage of the single-slope barrier over concrete safety shape barriers (e.g., New Jersey and F-shape profiles) is that the pavement adjacent to the single-slope barrier can be overlaid several times without changing its impact performance. This can significantly reduce maintenance costs associated with other barrier systems that do not provide this feature.

The connection involves a slot cast into both ends of the barrier segments. A temporary connection is achieved by inserting a welded reinforcing bar grid into the slots. A permanent connection is accomplished by filling the slots and any space between the barrier ends with grout with the rebar grid in place. The installation is completed by keying the barrier segments into place with an asphalt overlay adjacent to both sides of the barrier.

Four full-scale crash tests were performed to evaluate the impact performance of the SSCB in both permanent and temporary configurations. The tests were conducted following the guidelines of *National Cooperative Highway Research Program (NCHRP) Report 230* (*2*). The tests performed on the permanent configuration included a 4500-lb passenger sedan impacting the barrier at a nominal speed and angle of 60 mi/h and 25 degrees, respectively, and an 1800-1b passenger car impacting the barrier at a speed of 60 mi/h and an angle of 20 degrees. The tests met all applicable evaluation criteria, and the SSCB has seen widespread use in several states, including Texas and Washington.

A 32-inch tall SSCB was subsequently evaluated as a Test Leve1 Four (TL-4) bridge rail in accordance with guidelines set forth in *NCHRP Report 350* (*3,4*). The first test involved a 4405-lb pickup truck impacting the bridge rail at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. The second crash test involved an 18,000-lb single unit truck (SUT) impacting the bridge rail at a nominal impact speed of 50 mi/h and angle of 15 degrees. The bridge rail was found to comply with *NCHRP Report 350* TL-4 criteria.

More recently, a 36-inch single slope bridge rail was successfully tested to American Association of State Highway Officials (AASHTO) *Manual for Assessing Safety Hardware (MASH)* TL-4 impact conditions (*5,6*). The test involved a 24,200-lb SUT impacting the bridge rail at a nominal speed of 56 mi/h and an angle of 15 degrees. In addition to evaluating the single slope barrier, this test more generally established minimum rail height and design impact loads for *MASH* TL-4 impacts.

1.3 OBJECTIVES/SCOPE OF RESEARCH

The objective of this project is to evaluate the impact performance of a single slope concrete traffic barrier with an applied acoustic coating. Test 3-11 will be performed following the guidelines of the AASHTO *MASH*.

The research will provide data pertaining to the crashworthiness of concrete traffic barrier with an acoustic material applied to the traffic face. Compliance with *MASH* guidelines will permit the proposed acoustic coating to be used on the face of concrete barriers when noise abatement is needed. The research will have application to bridge rails, median barriers, and roadside barriers.

2 SYSTEM DETAILS

2.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The test installation consisted of four WSDOT Standard 48-inch tall single slope precast concrete barriers, each 20 feet in length, coated with "Acoustement® 40" material of approximately ½-inch thick. The total length of the barriers was 80 ft- 0¾ inch on an asphalt pad 82 ft-0 inch long by 14 ft-4¼ inches wide. The test site installation abutted the edge of an existing concrete apron.

The four precast concrete barrier segments were fabricated by Oldcastle Precast in Auburn, Washington and shipped to the TTI Proving Ground site. Each 20-ft long barrier was 48 inches tall and had a 4H:21V slope on both faces. The segments were 2 ft- 2¼ inch wide at the base, and tapered to 8 inches wide at the top. The top longitudinal edges were chamfered ¾-inch at a 45 degree angle, and the bottom surface contained a longitudinal 4-inch high by 20¼-inch wide triangular relief channel. Transverse reliefs (5 ft long × 3 in high) were precast and centered at 5 ft-10 inches from the ends of each barrier segment.

The steel reinforcement was comprised of ten #5 longitudinal bars spaced on 9¾-inch vertical centers, and thirty-three #4 vertical bars on varying centers that were bent to match the slope of the barrier: The centermost thirteen bars were evenly spaced on 12-inch centers; then towards each end, there was one bar at 8 inches, four at 6-inches, and finally three at 4-inch spacing. Thus, reinforcement was concentrated at the ends of the barrier segments, especially surrounding the connection slots for the rebar grid connectors (see Figure A4 – A6 WSDOT Standard Plan C-70.10-00 and Figure A7 Oldcastle Precast Dwg No. 010-0390260-001 rev C for more barrier details).

The barrier segments were placed along the centerline of a 14 ft- 4¼ inch wide × 82-ft long × 2-inch thick pad of HMAC Type D hotmix asphalt that was rolled and compacted on top of 6 inches of Type A, Grade 1 road base compacted to 95 percent of Standard Proctor Density. Once set, the barriers were secured in place with a 6-ft wide × 3-inch thick overlay of HMAC Type D hotmix asphalt on each side of the barrier (see Figure 2.1 and 2.2). No other methods were used to secure the barrier in place.

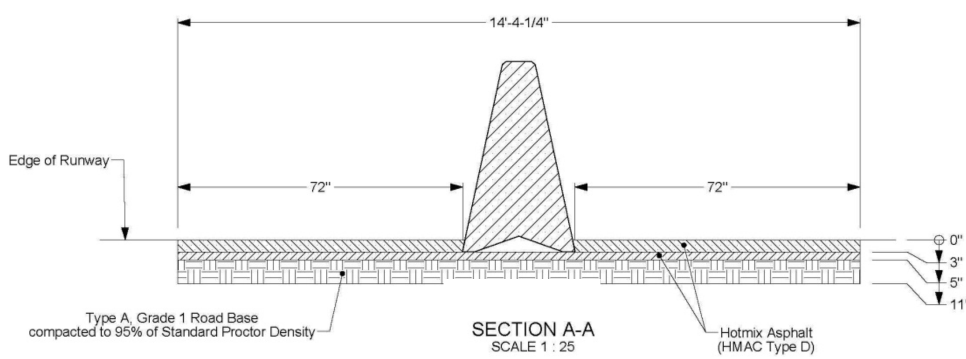


Figure 2.1. Cross Section of the Installation for Washington Concrete Traffic Barrier with Acoustic Coating.

Figure 2.2. Compaction of 3-inch Asphalt Overlay/Key.

At each barrier joint, a rebar grid was placed in the 3-inch wide × 24-inch deep × 10½-inch long connection leav-outs precast into each end of each of barrier segment. The 18-inch × 18-inch rebar grids were made of five bars: two evenly spaced vertical #6 bars and three evenly spaced horizontal #8 bars, tack welded at all six overlap locations (see Figure A3). The rebar grids were centered in the connection blockouts and void was filled with Shepler's SHEP 1107 premium non-shrinking grout.

Once the barrier construction was complete, the sloped traffic surface of the barrier was coated with Acoustement® 40 manufactured by Pyrok, Inc. The manufacturer's literature represents that "Acoustement® 40 is a 40 lb per cubic foot Portland cement formulation suitable for exterior applications to unpainted concrete and other substrates containing Portland cement." Preparation of the barrier surface consisted of a rolled on application of Weld-Crete® Concrete Bonding Agent (Larsen Products, Jessup, MD) to enhance surface bonding by providing control of irregular moisture 'suction' into the concrete surface (see Figure 2.3). The Weld-Crete® application dried for at least one hour per the manufacturer's instructions.

The Acoustement® 40 was applied via a Hy-Flex (New Castle, IN; http://hyflexcorp.com) HZ-30E fireproofing-stucco pumping and mixing rig that incorporated a 2L6 Rotor/Stator pump and a supplied Nathan Kimmel 1-inch mixing nozzle and hose with a ½-inch diameter orifice and rubber over cap (see Appendix B). Compressed air was supplied at 50 psi at approximately 6 cfm via a ⅜-inch diameter hose. The dry Acoustement® 40 base material, supplied in 35 lb bags, was wetted at a mix ratio of 5 gallons of water to each 35 lb bag of dry material and mechanically mixed for approximately 2 minutes to form a pumpable slurry (see Figure 2.4). A "key" or "flock" coat (see-through sputter coat) was applied to establish an adhesion "tooth" on which to apply subsequent layers (see Figure 2.5). Plastic tarp and roofing felt were used to shield the pavement from the spray, and a plywood shield was moved along the barrier to prevent overspray. The next day, three additional coats of approximately ⅛-inch thick per pass were applied to a final built-up nominal thickness of ½ inch. The coating buildup is shown in Figure 2.6, and the application of the final coat is shown in Figure 2.7. After the final coat, the surface was lightly troweled by hand to knock down the peaks to the specified semi-smooth surface finish and thickness (see Figure 2.8). Photos of the finished coating surface are shown in Figure 2.9, and the completed test installation is shown in Figure 2.10 The Acoustement® 40 product sets overnight as a low density coating, and like most cementitious concrete, is considered fully cured in 28 days. Fifteen bags (525 lb) of Acoustement® 40 material were used to coat one side of the four barrier segments for the entire 80 foot length.

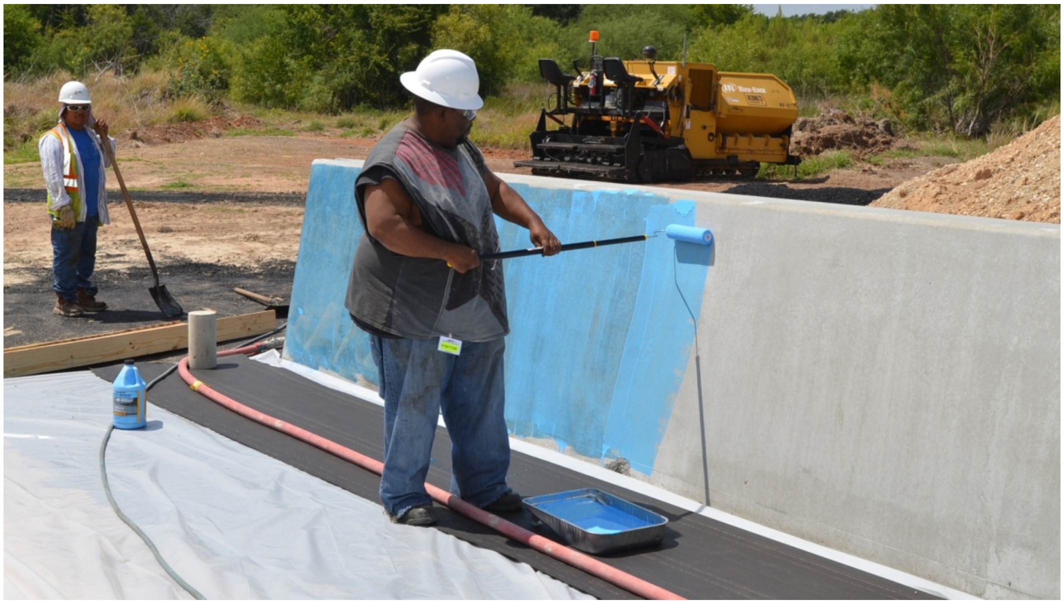


Figure 2.3. Application of Weld-Crete® Concrete Bonding Agent.

Figure 2.4. Mechanical Mixing of Acoustement® 40.

Figure 2.5. Application of First "Key" or "Flock" Coat of Acoustement® 40.

Figure 2.6. Coating Buildup of Acoustement® 40.

Figure 2.7. Application of Final Coat of Acoustement® 40.

Figure 2.8. Light Hand Finishing of Acoustement® 40 coating.

Figure 2.9. Finished Acoustement® 40 coating.

Photographs of the completed test installation are shown in Figure 2.10.

Figure 2.10. Completed test installation.

2.2 MATERIAL SPECIFICATIONS

The soil base prepared for placement and compaction of the asphalt pad was 6 inches of Type A, Grade 1 road base compacted to 95% of Standard Proctor Density. See Appendix C for field density test measurements. HMAC Type D hotmix asphalt was used for both the 2-inch pad upon which the barriers were placed and the 3-inch overlay that “keyed” the barriers in place.

The precast concrete barrier segments were fabricated by Oldcastle Precast in Auburn, Washington. The manufacture dates were February 20, 2013 and February 21, 2013. The mix design and test data are shown at the end of Appendix C. The 28-day unconfined compressive strength averaged 8,900 psi and 9950 psi for the two manufacture dates. Steel reinforcement used in the barriers and for fabrication of the rebar connection grids was Grade 60 with a specified minimum yield strength of 60 ksi. The grout used to fill the void in connection blockout in which the rebar grids were centered was Shepler’s SHEP 1107 premium non-shrinking grout.

A ½-inch thick coat of Acoustement® 40 was applied to the traffic surface of the barrier by the manufacturer (Pyrok, Inc.). Product data and physical performance properties are provided in Appendix C.

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

According to *MASH*, two tests are recommended to evaluate longitudinal barriers to Test Level Three (TL-3).

> ***MASH* Test 3-10:** A 2420-lb vehicle impacting the critical impact point (CIP) of the length of need (LON) of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This test investigates a barrier's ability to successfully contain and redirect a small passenger vehicle.
>
> ***MASH* Test 3-11:** A 5000-lb pickup truck impacting the CIP of the LON of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This test investigates a barrier's ability to successfully contain and redirect light trucks and sport utility vehicles.

The test reported herein corresponds to *MASH* Test 3-11. It was not certain what affect the coating would have on the barrier's surface friction or how it would influence the vehicle-barrier interaction. The pickup truck experiences more climb and vehicle instability than the passenger car and was, therefore, identified as the critical test for evaluation of the effects of the applied acoustical coating on the impact performance of the single slope barrier. After reviewing the test results, it was concluded that the coating had little influence on vehicle dynamics and the small car test was not necessary.

The crash test and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 4 presents brief descriptions of these procedures.

3.2 EVALUATION CRITERIA

The crash test was evaluated in accordance with the criteria presented in *MASH*. The performance of the Washington concrete traffic barrier with acoustic coating was judged on the basis of three factors: structural adequacy, occupant risk, and post-impact vehicle trajectory. Structural adequacy was judged on the ability of the Washington concrete traffic barrier with acoustic coating to contain and redirect the vehicle. Occupant risk criteria evaluated the potential risk of hazard to occupants in the impacting vehicle, and, to some extent, other traffic and pedestrians or workers in construction zones, if applicable. Post impact vehicle trajectory was 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 reported herein. These criteria are listed in further detail under the assessment of the crash test.

4 TEST CONDITIONS

4.1 TEST FACILITY

The full-scale crash test reported herein was performed at Texas A&M Transportation Institute (TTI) Proving Ground. TTI Proving Ground is an International Standards Organization (ISO) 17025 accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing certificate 2821.01. The full-scale crash test was performed according to TTI Proving Ground quality procedures and according to the *MASH* guidelines and standards.

The test facilities at the TTI Proving Ground consist of a 2000 acre (809-hectare) complex of research and training facilities situated 10 miles (16 km) northwest of the main campus of Texas A&M University. The site, formerly an Air Force Base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and evaluation of roadside safety hardware. The site selected for the installation of the Washington concrete traffic barrier with acoustic coating was along the edge of a wide out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The apron is over 60 years old, and the joints have some displacement, but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE SYSTEM

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A two-to-one speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained freewheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time brakes on the vehicle were activated to bring it to a safe and controlled stop.

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro that Diversified Technical Systems, Inc. produced. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results. Each of the TDAS Pro units is returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology. Acceleration data is measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k=2).

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals, then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact. Rate of rotation data is measured with an expanded uncertainty of ±0.7 percent at a confidence factor of 95 percent (k=2).

4.3.2 Anthropomorphic Dummy Instrumentation

Use of a dummy in the 2270P vehicle is optional according to *MASH*, and there was no dummy used in the test.

4.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of the test included three high-speed cameras: one overhead with a field of view perpendicular to the ground and directly over the impact point; one placed behind the installation at an angle; and a third placed to have a field of view parallel to and aligned with the installation at the downstream end. A flashbulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked motion analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A mini-DV camera and still cameras recorded and documented conditions of the test vehicle and installation before and after the test.

5 CRASH TEST 602191-1 (*MASH* TEST NO. 3-11)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

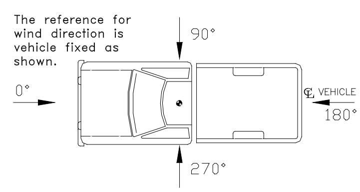
MASH test 3-11 involves a 2270P vehicle weighing 5000 lb ±110 lb and impacting the longitudinal barrier at an impact speed of 62.2 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 54 inches upstream of the joint between barrier segments 2 and 3. The 2007 Dodge Ram 1500 pickup truck used in the test weighed 5031 lb and the actual impact speed and angle were 63.2 mi/h and 24.8 degrees, respectively. The actual impact point was 44 inches upstream of the joint between segments 2 and 3. Target impact severity (IS) was 115.5 kip-ft, and actual IS was 118.2 kip-ft.

5.2 TEST VEHICLE

Figure 5.1 and Figure 5.2 show the 2007 Dodge Ram 1500 pickup truck used in the crash test. Test inertia weight of the vehicle was 5031 lb, and its gross static weight was 5031 lb. The height to the lower edge of the vehicle front bumper was 15.25 inches, and the height to the upper edge of the front bumper was 27.00 inches. The height to the center of gravity was 28.25 inches. Additional dimensions and information on the vehicle are given in Appendix D.1, Table D.1 and Table D.2. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

5.3 WEATHER CONDITIONS

The crash test was performed the morning of August 26, 2013. Weather conditions at the time of testing were: wind speed: 9 mi/h; wind direction: 48 degrees with respect to the vehicle (vehicle was traveling in a northwesterly direction); temperature: 83 ºF; relative humidity: 72 percent.



5.4 TEST DESCRIPTION

The 2007 Dodge Ram 1500 pickup truck, traveling at an impact speed of 63.2 mi/h, contacted the barrier 44 inches upstream of the joint between segments 2 and 3 at an impact angle of 24.8 degrees. At approximately 0.042 s, the 2270P vehicle began to redirect, and the vehicle yawed to be parallel with the barrier at 0.216 s. As the vehicle traveled forward, a dust cloud from the acoustic coating blocked much of the high-speed camera views. It is estimated that the vehicle lost contact with the barrier at 0.312 s, traveling at an exit speed and angle of 46.5 mi/h and 1.6 degrees, respectively. Brakes on the vehicle were applied 1.3 s after impact, and the vehicle came to rest 150.7 ft downstream of impact, with the centerline of the vehicle aligned with the centerline of the barrier. Appendix D.2, Figure D.1 and Figure D.2 present sequential photographs of the test.

Figure 5.1. Vehicle/Installation Geometrics for Test No. 602191-1.

Figure 5.2. Vehicle before Test No. 602191-1.

5.5 TEST ARTICLE AND COMPONENT DAMAGE

Figure 5.3 and Figure 5.4 show damage to the Washington concrete traffic barrier with acoustic coating. The acoustic coating material was scraped off the surface of the barrier exposing the blue undercoat, and the barrier sustained scuff marks. There was no discernible movement of the barrier and no structural cracking noted. Length of contact of the vehicle with the barrier was 13.7 ft. No measurable dynamic deflection or permanent deformation was noted. Working width was 9.2 inches, and vehicle penetration was 10.3 inches.

5.6 TEST VEHICLE DAMAGE

Figure 5.5 shows damage to the vehicle after the test. The left frame rail, left front upper and lower A-arm, rear axle, and drive shaft were deformed. Also damaged were the front bumper, hood, grill, radiator and support, left front tire and wheel rim, left front fender, left front door, left rear door, left rear exterior bed, left rear tire and wheel rim, left rear tail gate, and left rear bumper. Maximum exterior crush to the vehicle was 24.0 inches in the side plane at the left front corner at bumper height. Maximum occupant compartment deformation was 2.25 inches in the left kick panel. Figure 5.6 shows the interior of the vehicle. Exterior vehicle crush and occupant compartment measurements are shown in Appendix D.2, Table D.3 and Table D.4.

5.7 OCCUPANT RISK VALUES

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. The wire for the longitudinal accelerometer was cut during the test, therefore, the longitudinal accelerometer just to the rear of center of gravity was used for analysis. In the longitudinal direction, the occupant impact velocity was 20.3 ft/s at 0.101 s, the highest 0.010-s occupant ridedown acceleration was 6.4 Gs from 0.790 to 0.800 s, and the maximum 0.050-s average acceleration was -13.4 Gs between 0.018 and 0.068 s. In the lateral direction, the occupant impact velocity was 25.3 ft/s at 0.101 s, the highest 0.010-s occupant ridedown acceleration was 7.8 Gs from 0.208 to 0.218 s, and the maximum 0.050-s average was 13.7 Gs between 0.045 and 0.095 s. Theoretical Head Impact Velocity (THIV) was 37.2 km/h or 10.3 m/s at 0.098 s; Post-Impact Head Decelerations (PHD) was 8.8 Gs between 0.208 and 0.218 s; and Acceleration Severity Index (ASI) was 1.98 between 0.059 and 0.109 s. Figure 5.7 summarize these data and other pertinent information from the test. Vehicle angular displacements are presented in Appendix D3, Figure D.3, and accelerations versus time traces are presented in Appendix D4, Figure D.4 through Figure D.8.

Figure 5.3. Vehicle/Washington Concrete Traffic Barrier with Acoustic Coating Positions after Test No. 602191-1.

Figure 5.4. Installation after Test No. 602191-1.

Figure 5.5. Vehicle after Test No. 602191-1.

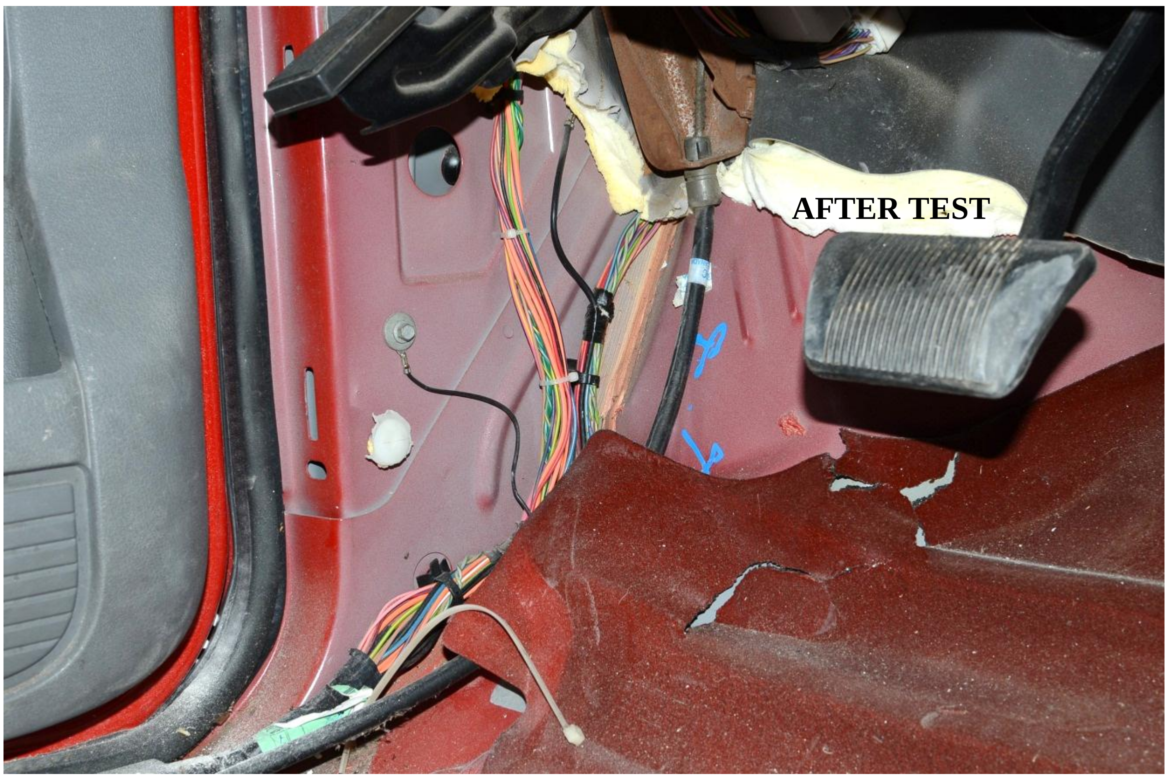
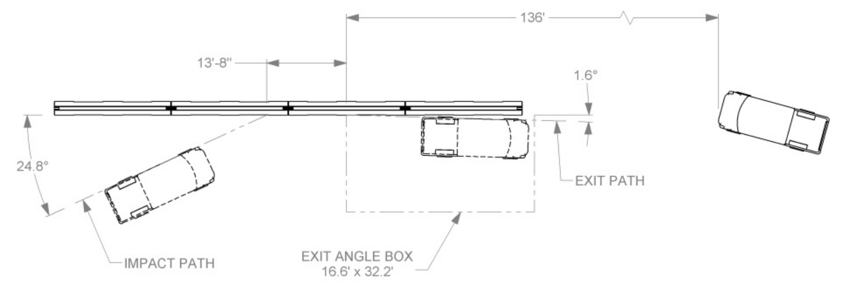
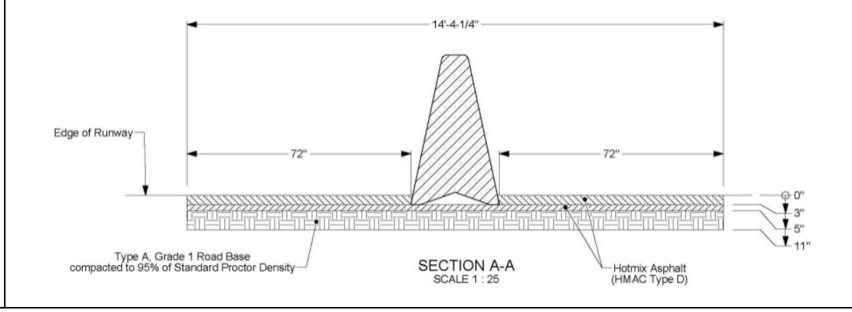


Figure 5.6. Interior of Vehicle for Test No. 602191-1.

0.000 s | 0.140 s | 0.280 s | 0.490 s





General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-11
TTI Test No.	602191-1
Date	2013-08-26

Test Article

Type	Median Barrier
Name	Washington Concrete Traffic Barrier
Installation Length	80 ft
Material or Key Elements	Precast single slope concrete barrier segments (48 inches tall, 20-ft long), grouted rebar connections and 3-inch asphalt key; ½-inch thick acoustic coating applied to barrier surface
Soil Type and Condition	Hot-Mix asphalt on crushed limestone base

Test Vehicle

Type/Designation	2270P
Make and Model	2007 Dodge Ram 1500 Pickup
Curb	4985 lb
Test Inertial	5031 lb
Dummy	No dummy
Gross Static	5031 lb

Impact Conditions

Speed	63.2 mi/h
Angle	24.8 degrees
Location/Orientation	36.3 ft dwnstrm end
Impact Severity	

Exit Conditions

Speed	46.5 mi/h
Angle	1.6 degrees

Occupant Risk Values

Impact Velocity	
Longitudinal	20.3 ft/s
Lateral	25.3 ft/s
Ridedown Accelerations	
Longitudinal	6.4 G
Lateral	7.8 G
THIV	37.2 km/h (10.3m/s)
PHD	8.8 G
ASI	1.98
Max. 0.050-s Average	
Longitudinal	-13.4 G
Lateral	13.7 G
Vertical	-5.6 G

Post-Impact Trajectory

Stopping Distance	150.7 ft

Vehicle Stability

Maximum Yaw Angle	27 degrees
Maximum Pitch Angle	7 degrees
Maximum Roll Angle	10 degrees
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	None
Permanent	None
Working Width	9.2 inches
Vehicle Intrusion	10.3 inches

Vehicle Damage

VDS	11LFQ5
CDC	11FLEW4
Max. Exterior Deformation	24.0 inches
OCDI	LF0210000
Max. Occupant Compartment Deformation	2.25 inches

Figure 5.7. Summary of Results for *MASH* Test 3-11 on the Washington Concrete Traffic Barrier with Acoustic Coating.

5.8 ASSESSMENT OF TEST RESULTS

An assessment of the test based on applicable *MASH* safety evaluation criteria is presented below.

5.8.1 Structural Adequacy

A. *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*

Results: The Washington concrete traffic barrier with acoustic coating contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. No measurable deflection occurred. (PASS)

5.8.2 Occupant Risk

D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤102 mm (4.0 inches); windshield = ≤76 mm (3.0 inches); side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤229 mm (9.0 inches); forward of A-pillar ≤305 mm (12.0 inches); front side door area above seat ≤229 mm (9.0 inches); front side door below seat ≤305 mm (12.0 inches); floor pan/transmission tunnel area ≤305 mm (12.0 inches))*

Results: No detached elements, fragments, or other debris was present to penetrate the occupant compartment or show potential for penetrating the occupant compartment, or to present a hazard to others in the area. (PASS)
Maximum occupant compartment deformation was 2.25 inches. (PASS)

F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*

Results: The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 10 degrees and 7 degrees, respectively. (PASS)

H. *Occupant impact velocities should satisfy the following:*

Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
30 ft/s	*40 ft/s*

Results: Longitudinal occupant impact velocity was 20.3 ft/s, and lateral occupant impact velocity was 25.3 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*

<u>Longitudinal and Lateral Occupant Ridedown Accelerations</u>

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 6.4 G, and lateral ridedown acceleration was 7.8 G. (PASS)

5.8.3 Vehicle Trajectory

For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).

Result: The 2270P vehicle exited within the exit box criteria. (PASS)

5.9 REPAIR OF BARRIER COATING

One week after the crash test, repairs were made to the Acoustement® 40 coating in the areas affected by the vehicle impact (see Figure 5.8). The edges of the damaged coating were first smoothed with a trowel (see Figure 5.9). The affected area was then washed down with water to remove any loose material (see Figure 5.10). The same equipment and similar procedures to those described for the initial coating installation were then used for the repair, with the exception of the Weld-Crete® concrete bonding agent that was already in place (see Figure 5.11). The repair process, including all four coats, was completed in one day. The area requiring repair was approximately 39 sq ft (see Figure 5.12), and required approximately three bags (105 lbs) of Acoustement® 40 material. The repairs took approximately 2 hours to complete, including setup, application, and cleanup. The coating immediately after repair (before site cleanup) is shown in Figure 5.13. The coating after a subsequent rain storm is shown in Figure 5.14.

Figure 5.8. Damaged Coating after Test.

Figure 5.9. Preparing Edges of Damaged Coating for Repair.

Figure 5.10. Washing Down Damaged Coating Area.

Figure 5.11. Application of Repair Coat.

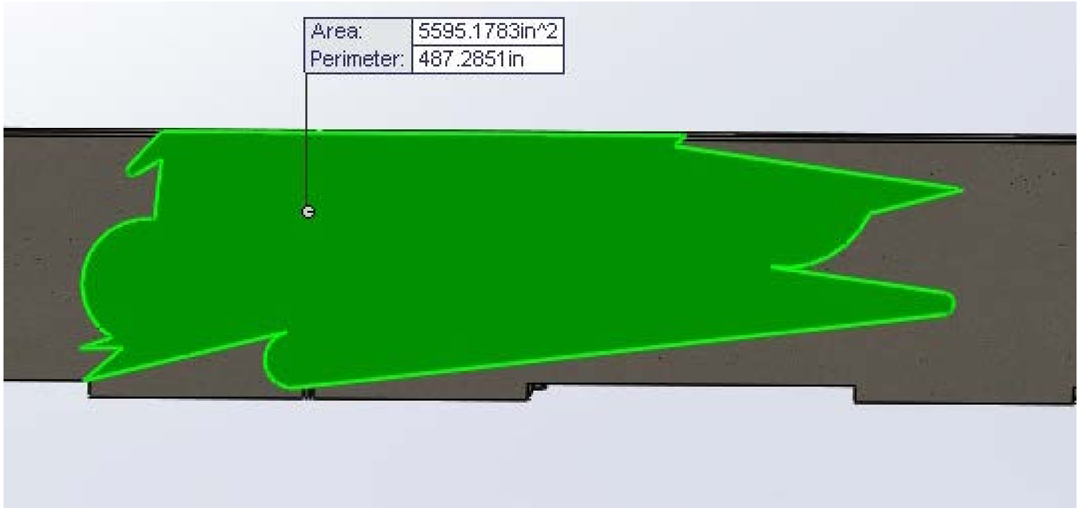


Figure 5.12. Calculated Area Requiring Coating Repair.

Figure 5.13. Repaired Coating.

Figure 5.14. Repaired coating after rain.

6 SUMMARY AND CONCLUSIONS

6.1 SUMMARY OF RESULTS

The Washington concrete traffic barrier with acoustic coating contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. No measurable deflection occurred. No detached elements, fragments, or other debris was present to penetrate the occupant compartment or show potential for penetrating the occupant compartment, or to present a hazard to others in the area. Maximum occupant compartment deformation was 2.25 inches. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 10 degrees and 7 degrees, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 2270P vehicle exited within the exit box criteria.

6.2 CONCLUSIONS

As summarized in Table 6.1, the single slope concrete barrier with Acoustement® 40 coating met all applicable *MASH* evaluation criteria. The presence of the coating did not adversely influence the dynamic behavior of the test vehicle. Upon impact, the coating disintegrated into a powdery cloud, and there were no large fragments that would pose a hazard to other traffic, pedestrians, or work zone personnel. The coating cloud resulting from the impact could momentarily obstruct the vision of other motorists in the area depending on factors such as coating thickness, impact conditions, impact vehicle, wind conditions, etc.

It should be noted that the test results verify that a 3-inch asphalt overlay/key is sufficient for anchorage of precast concrete median barrier with grouted rebar connections. The barrier used in the test had negligible movement and no structural damage.

Table 6.1. Performance Evaluation Summary for *MASH* Test 3-11 on the Washington Concrete Traffic Barrier with Acoustic Coating.

Test Agency: Texas A&M Transportation Institute Test No.: 602191-1 Test Date: 2013-08-26

***MASH* Test 3-11 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> A. *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable*	The Washington concrete traffic barrier with acoustic coating contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. No measurable deflection occurred.	Pass
<u>Occupant Risk</u> D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris was present to penetrate the occupant compartment or show potential for penetrating the occupant compartment, or to present a hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 2.25 inches.	Pass
F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 10 degrees and 7 degrees, respectively.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.*	Longitudinal occupant impact velocity was 20.3 ft/s, and lateral occupant impact velocity was 25.3 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.*	Longitudinal ridedown acceleration was 6.4 G, and lateral ridedown acceleration was 7.8 G.	Pass
<u>Vehicle Trajectory</u> *For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).*	The 2270P vehicle exited within the exit box criteria.	Pass

7 REFERENCES

1. Beason, W. L., Ross, H. E., Jr., Perera, H. S., Campise, W. L., and Bullard, D. L., Jr., “Development of a Single-Slope Concrete Median Barrier,” Report No. 9429CDK-1, Texas Transportation Institute, College Station, TX, June 1989.
2. Michie, J. D., “Recommended Practices for the Safety Performance Evaluation of Highway Appurtenances,” *NCHRP Report 230*, March 1981.
3. Mak, K. K. and Menges, W. L., “Testing of State Roadside Safety Systems, Volume VIII: Appendix G - Crash Testing and Evaluation of the Single Slope Bridge Rail,” Report No. FHWA-RD-98-043, February 1998.
4. Ross, Jr., H. E., Sicking, D. L., Zimmer, R. A, and Michie, 1. D., “Recommended Procedures for the Safety Performance Evaluation of Highway Features,” *NCHRP Report 350*, Transportation Research Board, Washington, D. C., 1993.
5. Sheikh, N. M., Bligh, R. P., and Menges, W. L., “Determination of Minimum Height and Lateral Design Load for *MASH* Test Level 4 Bridge Rails,” Research Report No. FHWAlTX-12/9-1002-5, Texas Transportation Institute, College Station, TX, December 2011.
6. AASHTO, *Manual for Assessing Safety Hardware*, American Association of State Highway and Transportation Officials, Washington D.C., 2002.

APPENDIX A. DETAILS OF THE WASHINGTON CONCRETE TRAFFIC BARRIER WITH ACOUSTIC COATING

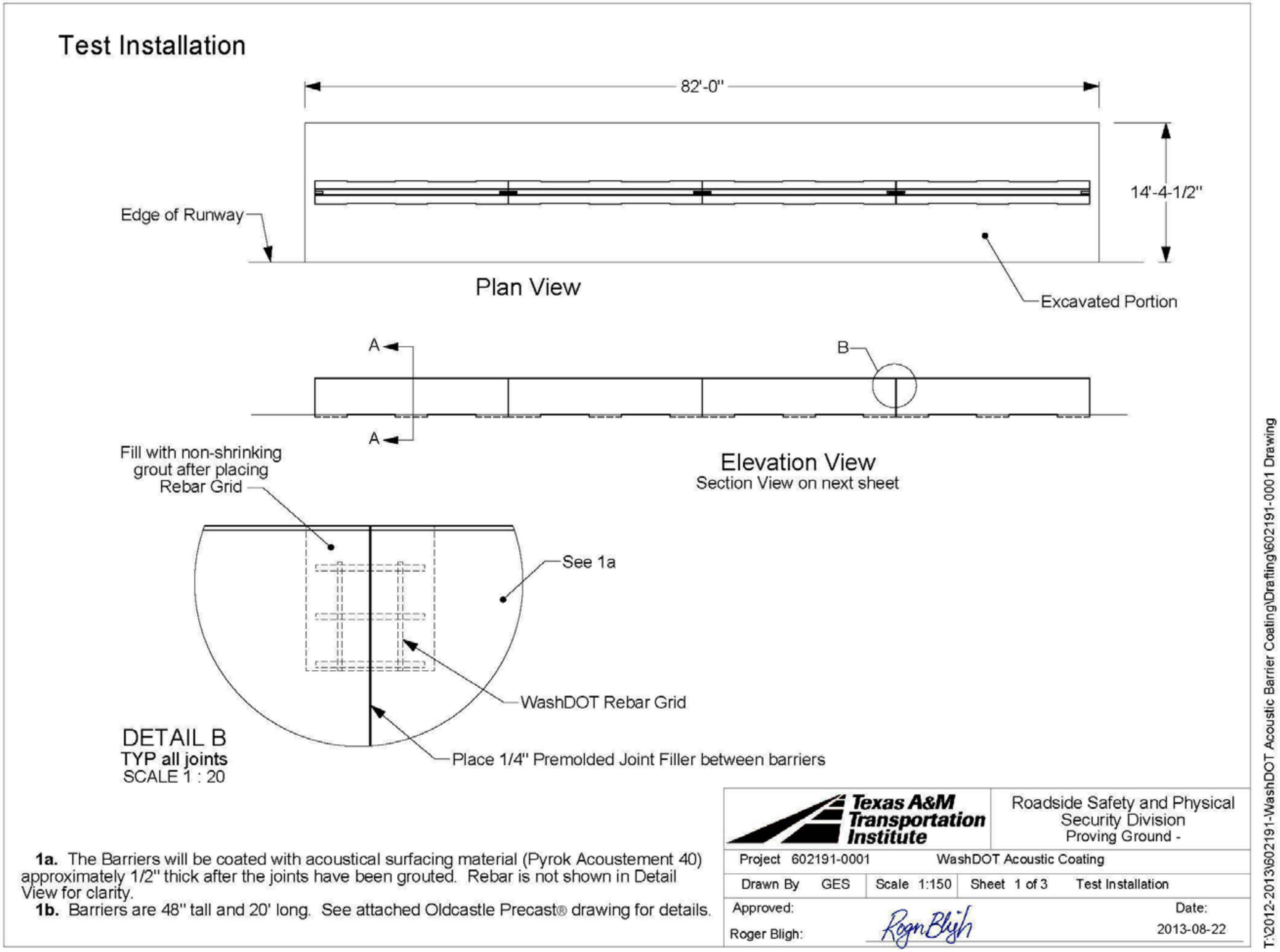


Figure A1. Sheet 1 Details of the Washington Acoustic Barrier.

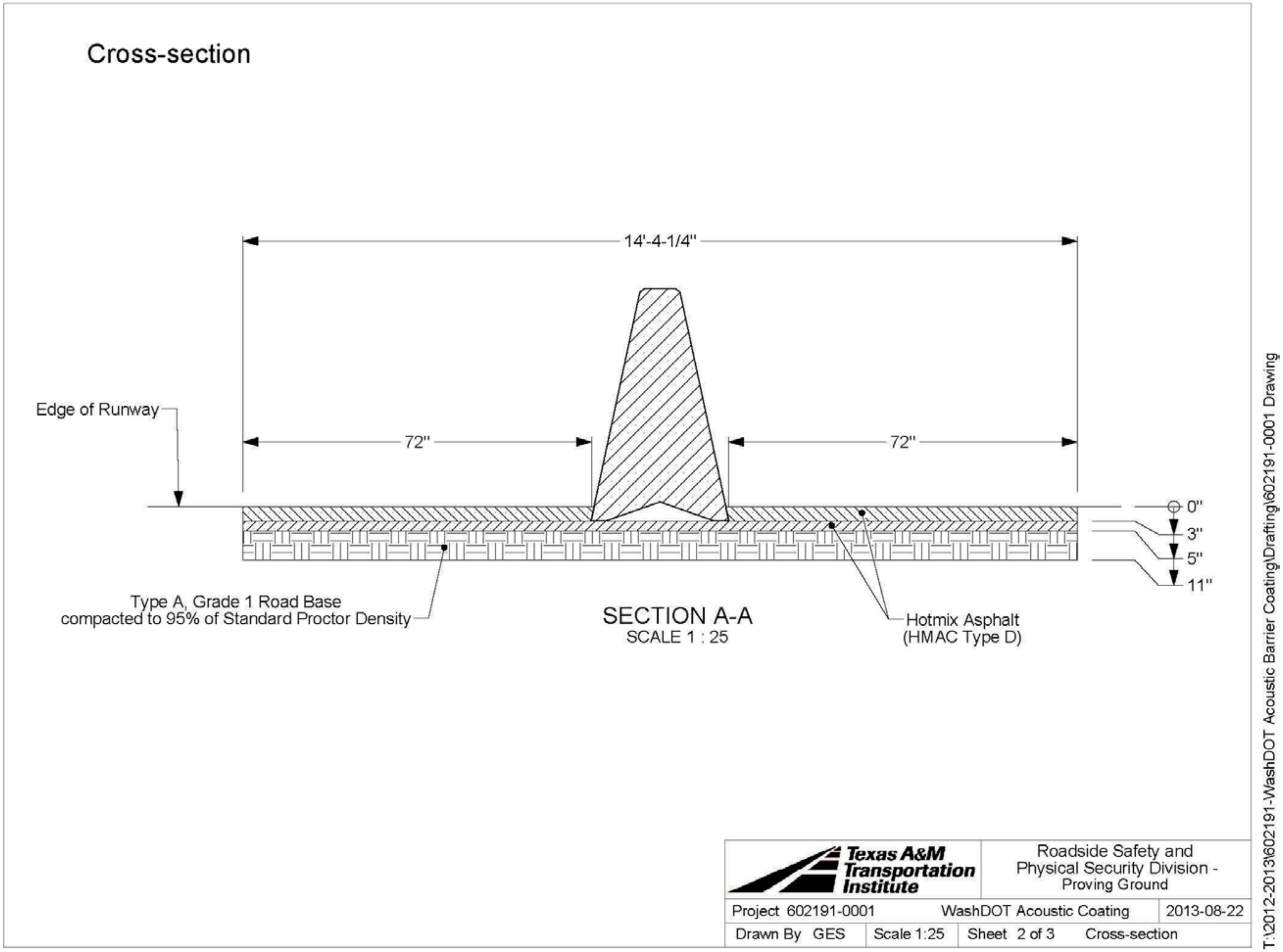


Figure A2. Sheet 2 Details of the Washington Acoustic Barrier.

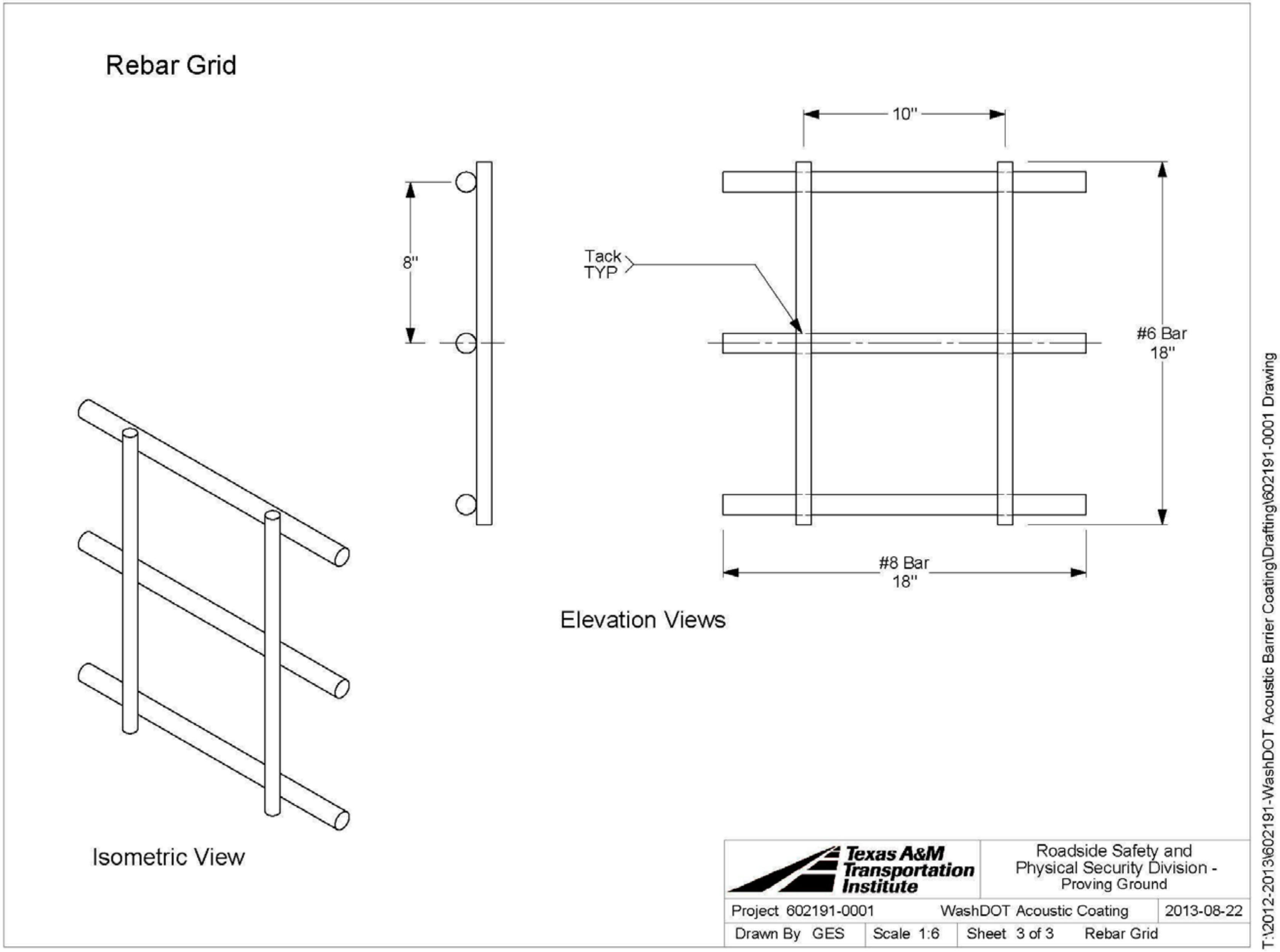
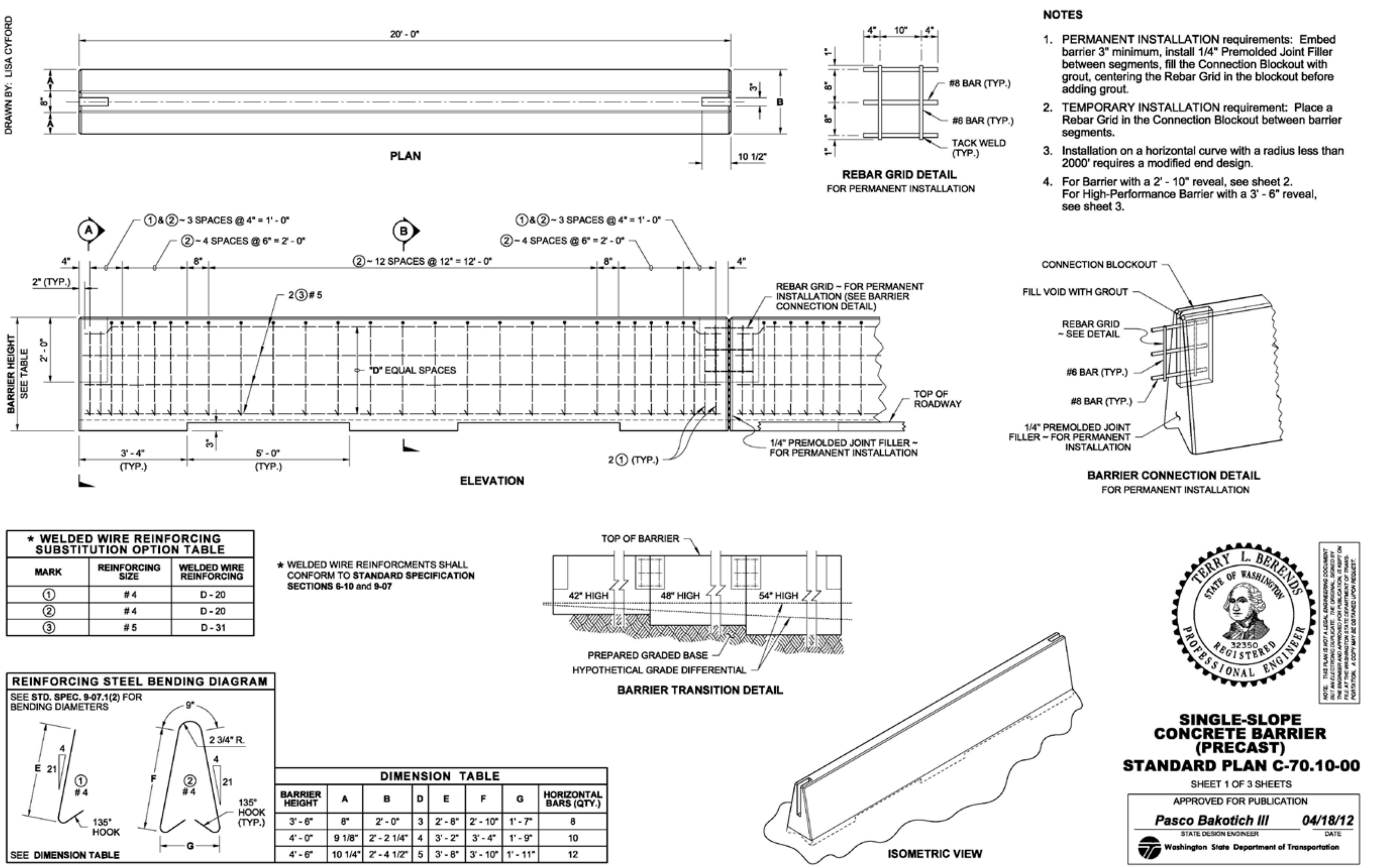


Figure A3. Sheet 3 Details of the Washington Acoustic Barrier.



★ WELDED WIRE REINFORCING SUBSTITUTION OPTION TABLE		
MARK	REINFORCING SIZE	WELDED WIRE REINFORCING
①	# 4	D - 20
②	# 4	D - 20
③	# 5	D - 31

DIMENSION TABLE							
BARRIER HEIGHT	A	B	D	E	F	G	HORIZONTAL BARS (QTY.)
3' - 6"	8"	2' - 0"	3	2' - 8"	2' - 10"	1' - 7"	8
4' - 0"	9 1/8"	2' - 2 1/4"	4	3' - 2"	3' - 4"	1' - 9"	10
4' - 6"	10 1/4"	2' - 4 1/2"	5	3' - 8"	3' - 10"	1' - 11"	12

Figure A4. Sheet 1 of the Washington WSDOT Standard Plan C-70.10-00.

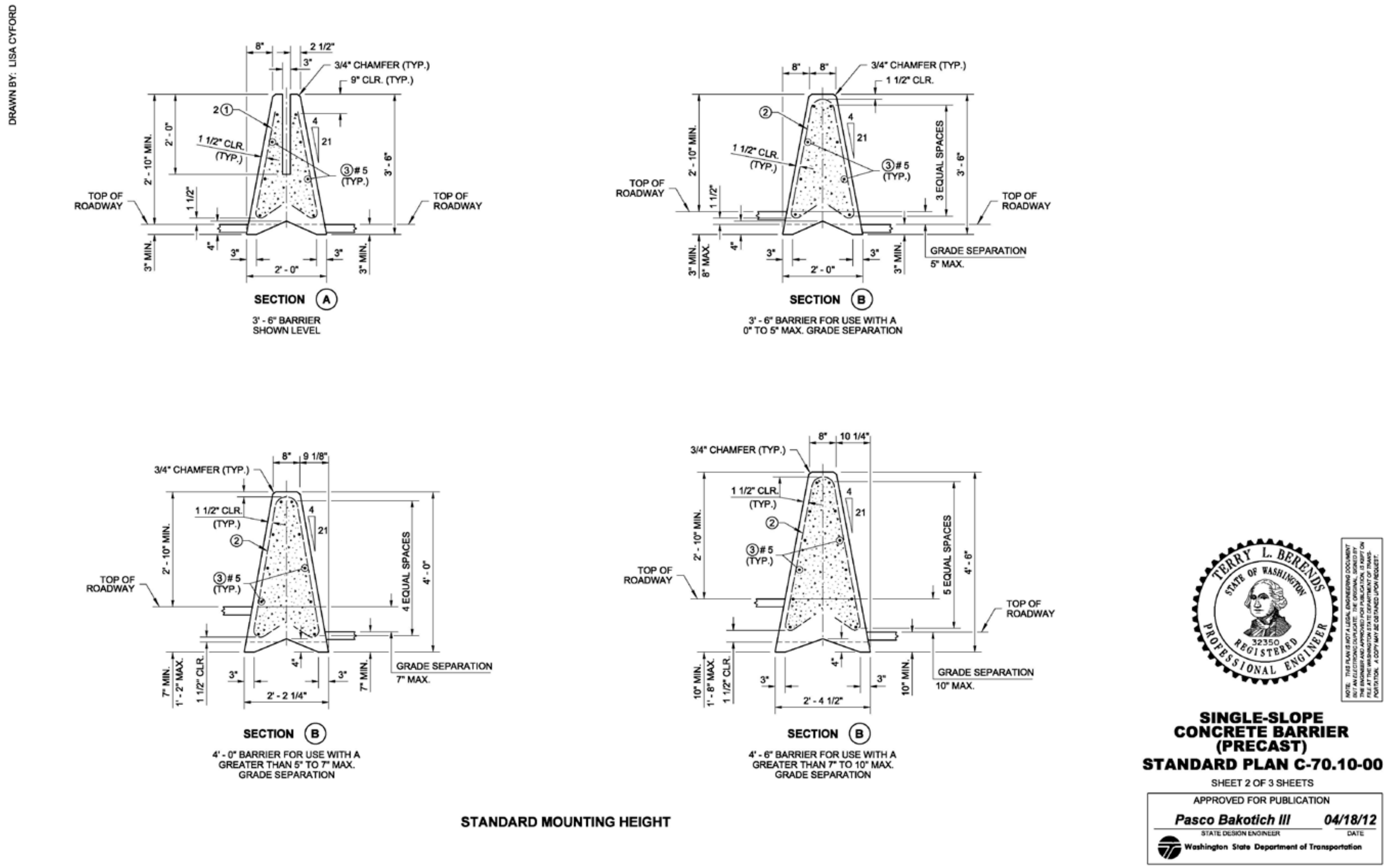


Figure A5. Sheet 2 of the Washington WSDOT Standard Plan C-70.10-00.

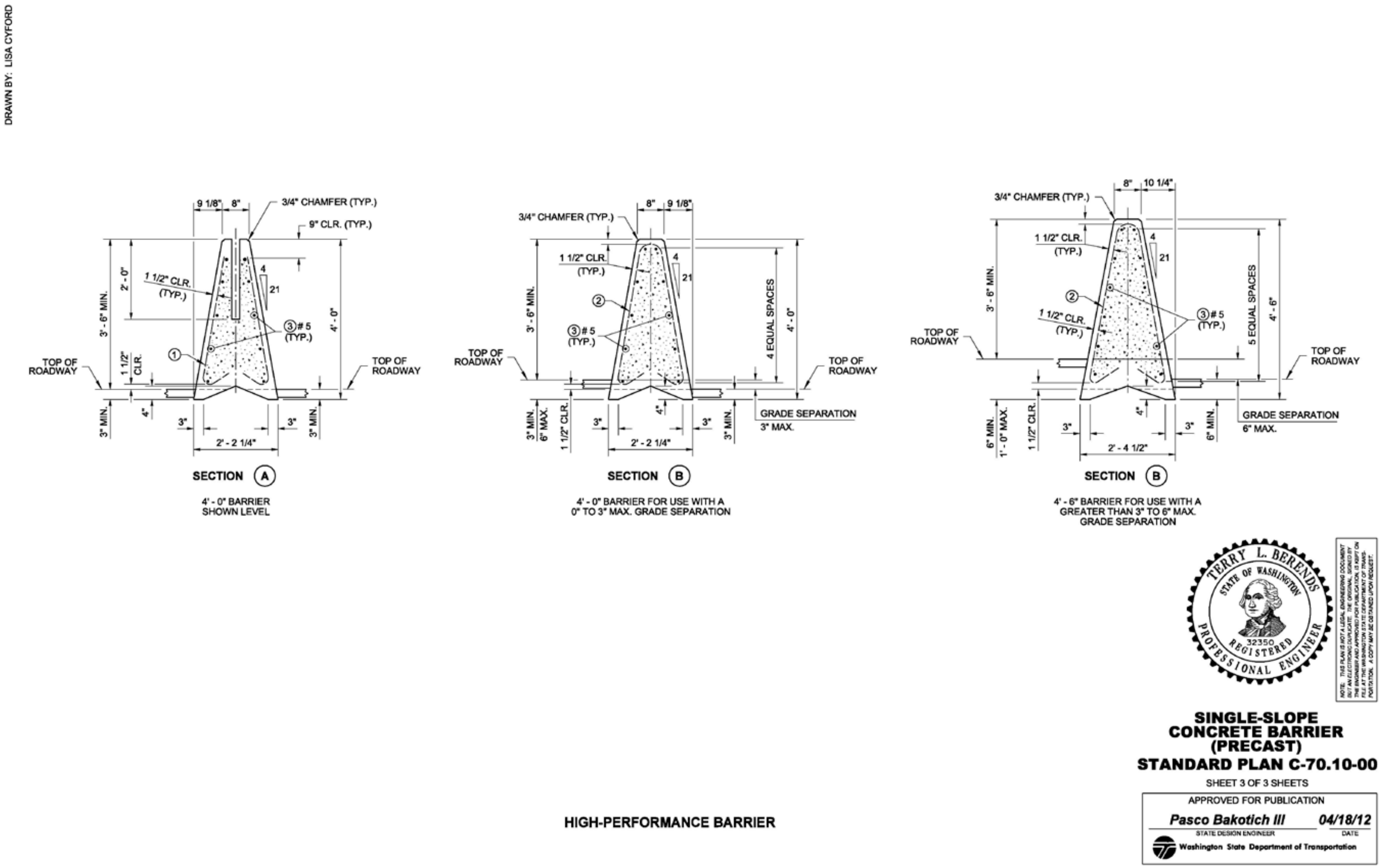


Figure A6. Sheet 3 of the Washington WSDOT Standard Plan C-70.10-00.

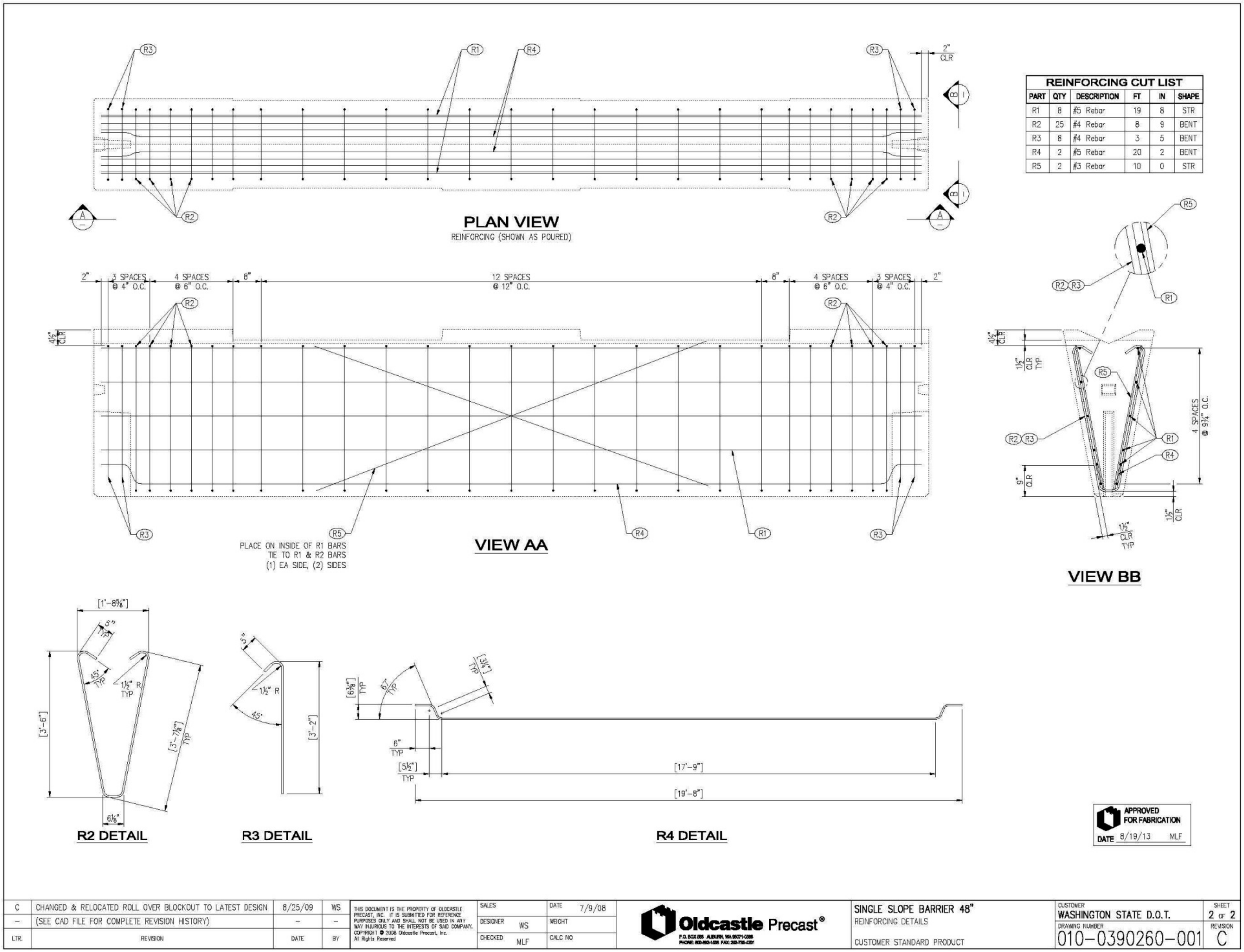


Figure A7. Sheet 1 Oldcastle Precast Details.

APPENDIX B. HY-FLEX 30-E BROCHURE

SPECIFICATIONS & CAPACITIES

Power	5 HP Variable Speed
Power Requirement	208/240 V 30A
	1 or 3 Phase
Air Output (optional)	12 cfm
Pump Size	Optimized 2L6
Hopper Capacity	60 Gal
Hopper Height	32"/ 81 cm
Volume Control	Variable 0-10 gpm
Pressure Outout	500 PSI Maximum
Directional Control	Forward and Reverse
Controls	Manual/Remote
Machine Width	33"/ 839 cm
Machine Length	72"/ 1829 cm
Machine Height	43"/ 1092 cm
Machine Weight	585 lbs / 266 kg
Wheels - Rear	15"/38cm OD Pneumatic
Wheels - Front	10"/25cm OD Pneumatic Casters
Max Aggregate Size	.125"/3 mm
Max Pumping Distance	200' (Note: It can be greater or less)
Optional Equipment	Air Compressor

HZ-30E

321E

321E Specifications and Capacities

Power	15 HP Electric	Controls	Manual/Remote
Power Requirement	208/230 volt 50A 3 PH	Directional Control	Forward and Reverse
Pump Type	3" Dual Piston	Machine Width	28" / 71 cm
Air Output	12 cfm	Machine Length	62" / 157 cm
Pump Size	2" Ball Valve	Machine Height	34" / 86 cm
Pump Output	70 Bags Per Hour	Machine Weight	1350 lbs / 615 kg
Hopper Height	23" /58 cm	Wheels	8" Rigid and Swivel Casters
Volume Control	Variable Hydraulic	Max Aggregate Size	.187 in/ 5 mm
Pressure Outout	1000 psi / adjustable	Max Pumping Distance	550' maximum

CM71

CM71 Specifications and Capacities

Power	3 HP	Machine Width	28"/71cm - 30"/76cm (with Platform)
Power Requirement	230 V Single Phase 20A	Machine Length	92.5"/235 cm (with 40" mix tube)
Mixer Output	70 Bags Per Hour	Machine Height	70.5"/179 cm
Hopper Capacity	3 Bags	Machine Weight	693 lbs/314 kg
Charge Height	54"/ 137 cm	Wheels	8" Rigid and Swivel Casters
Volume Control	Single Speed	Optional Equipment	Water System
Max Aggregate Size	Fireproofing		Work Platform

HF-15
SPRAY BUDDY

Spray Buddy Specifications and Capacities

Power	1 HP Electric	Controls	Manual/Remote
Power Requirement	110 Volt 15A	Machine Width	26"/66cm
Pump Type	Optimized 2L3 Stator	Machine Length	54"/137cm
Hopper Capacity	15 Gallon	Machine Height	41"/104cm
Hopper Height	32"/81cm	Machine Weight	190 lbs/86kg
Volume Control	Variable 0-2 gpm	Wheels	12" OD Semi-Solid
Pressure Outout	200 PSI	Max Aggregate Size	.125"/3 mm
Directional Control	Forward/Reverse	Max Pumping Distance	150' (Note: It can be greater or less)

HZ-30G

30G Specifications and Capacities

Power	13 HP Honda Gas Engine	Controls	Manual/Remote
Fuel Tank	1.7 Gal / 6.9 qts	Machine Width	33"/84cm (48"/122cm w/Tow Package)
Pump Output	0-10 gpm	Machine Length	84"/213cm
Pump Size	Optimized 2L6	Machine Height	42"/107cm
Air Output	12 cfm @ 90 psi	Machine Weight	675 lbs/ 306 kg
Hopper Capacity	60 Gal	Wheels - Rear	20" OD Pneumatic
Hopper Height	30 in / 76 cm	Wheels - Front	10" OD Pneumatic Casters
Volume Control	Variable 0-10 gpm	Max Aggregate Size	.125 in / 3 mm
Pressure Output	500 PSI Maximum	Max Pumping Distance	200' (Note: It can be greater or less)
Directional Control	Forward and Reverse	Optional Equipment	Tow Package

PYROK ACOUSTEMENT
ACOUSTEMENT 40
DECORATIVE/ACOUSTICAL SURFACING MATERIAL
PRODUCT DATA

1. **DESCRIPTION**
Pyrok Acoustement 40 is a nominal 41 PCF (air-dried density) Portland cement/exfoliated vermiculite spray-applied formulation 100% free from asbestos and mineral fibers, polystyrene, and cellulose. Pyrok Acoustement 40 is highly abuse resistant (impact, abrasion, moisture, hostile industrial environments), has excellent adhesion to a variety of substrates, allows substrates to breath and be cleaned by a variety o methods.

2. **USES**
Pyrok Acoustement 40 can be used as a decorative surfacing material or as a combination of these qualities even in conjunction as a fireproofing material.

This material is recommended for exterior exposures where resistance to environmental pollution, rain, corrosion, and spalling is required. It may be used in interior exposures where superior abuse resistance is required.

Typically Pyrok Acoustement 40 is specified for transportation facilities, correctional projects, lobbies, atriums, tunnels, natatoriums, gymnasiums, manufacturing facilities, contact wall areas, and any other area requiring high abuse resistance and sound absorption qualities.

It can also be used on interior surfaces of walkways, hallways, and rooms where a purely decorative finish is desired.

Pyrok Acoustement 40 may also be used on ceilings as a combination acoustical finish and fireproofing material.

Custom integral coloration is available within the limits of iron oxide pigmentation.

3. **PACKAGING**
35 lb. Kraft paper/polyethylene lined bags
55 bags shrink wrapped pallet (minimum)
1100 bags per truckload

4. **YIELD**
17 Bd. ft./bag (ideal)

5. **APPLICATIONS**
Pyrok, Inc. recommends application of Pyrok Acoustement 40 be performed only by approved Pyrok Applicators. An approved applicator list is available from Pyrok, Inc.

6. **APPLICATION PROCEDURES SUMMARY**
Pyrok Acoustement 40 may be applied directly to clean, bare steel, clean galvanized steel or a wide variety of unpainted concrete, cement board and other clean, sound substrates. Some substrates will require metal lath. Contact Pyrok, Inc. for verification of compatibility with substrate, suitability of primer and potential requirement of expanded metal lath. Mix in mechanical type mixer with paddle or ribbon type blades. Use 4-5 gallons of clean, potable water per each 35-pound bag of Pyrok Acoustement 40. Mix 1 to 3 minutes. Spray-apply using equipment recommended by Pyrok, Inc. Air supply at the spray nozzle shall be a minimum of 40 pounds per square inch. Wet density at the nozzle shall be 70-85 pounds per cubic foot.

APPLICATION
Brush or roll-apply a liberal coat of Weldcrete to substrate immediately prior to application of Acoustement 40. Apply a splatter coat covering 60% to 80% of the substrate surface. Allow splatter coat to cure overnight. Successive coats of Pyrok Acoustement 40 shall not exceed ¼ inch thick per application. Thicknesses that exceed 2 ⅛ inches may require metal lath. Contact Pyrok, Inc. to determine if metal lath is required. Pyrok, Inc may vary these procedures based upon review of site and project conditions.

TOPCOATING/CURING
Pyrok Acoustement 40 may be supplied in several integral colors or may be topcoated for more pleasing aesthetic finish or for curing. Consult Pyrok, Inc. for further information regarding suitable topcoating and curing compounds.

PATCHING OR REPAIR
Contact Pyrok, Inc. or your construction representative for patching or repair procedures.

6. **APPLICATION PROCEDURES SUMMARY (CONT.)**

CLEANING

Wet Pyrok Acoustement 40 may be removed by brushing or with water. Dry Pyrok Acoustement 40 may require scraping or chipping to remove.

Pyrok Acoustement 40 may be steam cleaned or pressure washed after full cure (minimum 28 days).

STORAGE AND SHELF LIFE

Store Pyrok Acoustement 40 off the ground in unopened, original packages and keep dry. Pyrok Acoustement 40, kept dry, has a five (5) year shelf life.

WARRANTY

Manufacturer warrants the material to be supplied, agreeing to replace that which has cracked, flaked, dusted excessively, peeled or fallen from substrate, or otherwise deteriorated to a condition where it would not perform effectively as intended for fire protection and sound absorbent purposes; due to defective materials and not due to abuse, or improper maintenance, unforeseeable ambient exposures or other causes beyond anticipate conditions by manufacturer. The warranty period will be 10-years from date of installation. Manufacturer's liability under any expressed or implied warranty is limited solely to replacement of Pyrok products proved defective and does not include labor or other consequential damages. The suitability of the product for any intended use shall be solely up to the user.

THE EXPRESS WARRANTIES SET FORTH HERIN ARE IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCUDING WITHOUT LIMITATION, ANY WARRANTIES OR MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL MANUFACTURER BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, OR CONSEQUENTIAL DAMAGES RESULTING FROM ANY DEFECT IN THE MATERIAL EVEN IF MANUFACTURER HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

PHYSICAL PERFORMANCE PROPERTIES

PROPERTY	TEST METHOD	VALUE
Asbestos Content	EPA 400/4M-82-020	No Asbestos No Mineral Fiber
Bond Strength	ASTM E 736	5000 – 6800 PSF
Compressive Strength	ASTM E 761	300 – 800 PSI
Density	ASTM E 605	41 PCF (Avg)
Sound Absorption	ASTM C 423	0.60 NRC @1″
Surface Burning	ASTM E 84	0 Flame Spread 0 Smoke Developed
Toxicity	University of Pittsburgh Toxicity Test	LC(50)>300 Grams
Combustibility	ASTM E 136	Non-combustible

SOUND ABSORPTION COEFFICIENT ON SOLID BACKING WITH NO AIR GAP
ASTM C 423

FREQUENTY (HZ)	125	250	500	1000	2000	4000	NRC
Absorption Coefficient @ ⅜″	0.17	0.20	0.29	0.34	0.56	1.00	0.35
Absorption Coefficient @ ½ ″	0.01	0.20	0.43	0.68	0.75	0.80	0.50
Absorption Coefficient @ 1″	0.18	0.35	0.64	0.73	0.73	0.77	0.60
Absorption Coefficient @ 1 ½ ″	0.36	0.51	0.64	0.74	0.84	0.91	0.70
Absorption Coefficient @ 1 ⅝″	0.24	0.59	0.74	0.81	0.91	0.97	0.75

Distributed by:
Pyrok, Inc.
914-777-7071 / Fax 914-777-7103

APPENDIX C. SUPPORTING CERTIFICATION DOCMENTS

FIELD DENSITY TEST REPORT

Report Number: A1131064.0001
Service Date: 08/16/13
Report Date: 08/20/13
Task: PO #602191, Brazos Paving Inc

Terracon
6198 Imperial Loop
College Station, TX 77845
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1131064

Material Information

				Lab Test Data		Project Requirements	
Mat. No.	Proctor Ref. No.	Classification and Description	Laboratory Test Method	Optimum Water Content (%)	Max. Lab Density (pcf)	Water Content (%)	Minimum Compaction (%)
1	A1111007.0045B	Light tan crushed rock	ASTM D698	7.3	133.6	7.3 - 11.3	95%

Field Test Data

Test No.	Test Location	Lift / Elev.	Mat. No.	Probe Depth (in)	Wet Density (pcf)	Water Content (pcf)	Water Content (%)	Dry Density (pcf)	Percent Compaction (%)
	PO #602191								
1	South end	Grade	1	6	129.2	8.8	7.3	120.4	90.1 *
2	RECHECK Test #1 of this report	Grade	1	6	127.0	8.3	7.0 *	118.7	88.8 *
3	RECHECK Test #2 of this report	Grade	1	6	133.1	9.5	7.7	123.6	92.5 *

Datum: **Serial No:** 30483 **Std. Cnt. M:** 682 **Std. Cnt. D:** 2160

Comments: **Test and/or retest results on this report meet project requirements as noted above.**
*Test rechecked and shown on Report No. A1131064.0002.

Services: Perform in-place density and moisture content tests with a Troxler type gauge to determine degree of compaction and material moisture condition.

Terracon Rep.: Mohammed Mobeen
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Mark Dornak

Started: 1030
Finished: 1200

Reviewed By: [signature]
Mark E.Dornak, P.E.
Project Manager

Test Methods: ASTM D6938-07 Method A

The tests were performed in general accordance with applicable ASTM, AASHTO, or DOT test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

CR0007, 4-17-12, Rev.5

Page 1 of 1

FIELD DENSITY TEST REPORT

Report Number: A1131064.0002
Service Date: 08/17/13
Report Date: 08/20/13
Task: PO #602191, Brazos Paving Inc

Terracon
6198 Imperial Loop
College Station, TX 77845
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1131064

Material Information

				Lab Test Data		Project Requirements	
Mat. No.	Proctor Ref. No.	Classification and Description	Laboratory Test Method	Optimum Water Content (%)	Max. Lab Density (pcf)	Water Content (%)	Minimum Compaction (%)
1	A1111007.0045B	Light tan crushed rock	ASTM D698	7.3	133.6	7.3 - 11.3	95%

Field Test Data

Test No.	Test Location	Lift / Elev.	Mat. No.	Probe Depth (in)	Wet Density (pcf)	Water Content (pcf)	Water Content (%)	Dry Density (pcf)	Percent Compaction (%)
	PO #602191								
1	RECHECK Test #3 of Report No. 0001	Grade	1	6	140.4	11.6	9.0	128.8	96.4
2	Center	Grade	1	6	137.3	10.4	8.2	126.9	95.0
3	North end	Grade	1	6	137.3	10.4	8.2	126.9	95.0

Datum: **Serial No:** 30483 **Std. Cnt. M:** 685 **Std. Cnt. D:** 2153

Comments: **Test and/or retest results on this report meet project requirements as noted above.**

Services: Perform in-place density and moisture content tests with a Troxler type gauge to determine degree of compaction and material moisture condition.

Terracon Rep.: Mohammed Mobeen
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Mark Dornak

Started: 0900
Finished: 1000

Reviewed By:
Mark E.Dornak, P.E.
Project Manager

Test Methods: ASTM D6938-07 Method A

The tests were performed in general accordance with applicable ASTM, AASHTO, or DOT test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

CR0007, 4-17-12, Rev.5

Page 1 of 1

TODAY'S DATE: 8/19/2013

OLDCASTLE PRECAST CONCRETE TESTING DATA

Mix #50

Test Date	Initials	Batch Time	Air Temp	Overnigh Low Tem	Concrete Temp	Unit weight	W/C Ratio	VSI	Slump Flow	% Air	1 Day (Stripping	1 Day Stripping)	3 Day	7 Day Field	7 Day Field	28 Day	28 Day	28 Day Average
02/01/13	CW	9:18	44	42	90	35.55	0.327	0	26	5.2			6240	7440	7500	9290	8870	9080
02/04/13	MD	10:14	49	46	90	35.75	0.310	1	27	5.0	4960	4660		5910	5830	8990	8680	8840
02/05/13	CW	10:03	47	43	88	35.4	0.311	0	26	7.3	4460	4920		6170	6310	8890	8590	8740
02/06/13	CW	10:19	47	42	84	35.4	0.314	0	25	5.0	4360	4550		7170	6720	8330	9330	8830
02/07/13	MD	10:03	40	42	85	35.25	0.325	0	26	5.5	4000	4340		6350	6450	8960	8490	8730
02/08/13	MD	9:40	36	32	83	35.25	0.323	0	25	5.9			6490	7940	7950	10060	9940	10000
02/11/13	MD	9:56	43	44	88	35.5	0.340	0	26.5	5.0	4160	4150		6060	6170	7890	7960	7930
02/12/13	MD	10:29	46	44	90	35.6	0.339	0	26	4.8	5300	5350		7440	7440	10090	10180	10140
02/13/13	MD	10:24	47	43	89	35.6	0.319	0	25	5.1	4330	4620		6210	7000	8880	9230	9060
02/14/13	MD	10:23	47	43	89	35.45	0.312	0	25	5.2	4940	5780		6100	6300	9400	9400	9400
02/15/13	MD	10:19	43	40	88	35.5	0.317	0	26	5.5			6430	7080	7050	9520	9290	9410
02/18/13	MD	10:09	43	38	90	35.9	0.331	0	25	4.8	5050	5260		6660	6520	9130	9360	9250
02/19/13	MD	10:15	43	36	90	35.4	0.337	0	25	5.5	4270	4250		6510	6440	8760	8650	8710
02/20/13	MD	9:58	38	34	89	35.4	0.339	0	26	5.9	4220	4240		6090	6230	8910	8880	8900
02/21/13	MD	9:34	40	34	90	35.65	0.340	0	26.5	4.5	4300	4860		6480	6520	9910	9980	9950
02/22/13	JM	10:32	42	41	83	34.5	0.335	1	27	6.1			4520	5820	5670	7920	7520	7720
02/25/13	JM	9:55	43	42	90	35.15	0.329	0	25	5.8	4610	4730		6970	6980	8670	8860	8770
02/26/13	JM	9:49	46	40	83	34.8	0.336	0	25	6.0	3750	3750		6300	6360	8230	8060	8150
02/27/13	JM	9:50:00	44	40	88	35.25	0.338	0	26	6.2	4010	4290		6270	6130	8460	8430	8450
02/28/13	JM	10:13	45	42	86	35.35	0.347	0	26	5.5	4080	4110		5970	5830	8610	8840	8730

MIX DESIGN #50		
MATERIALS:	**WEIGHT:**	
CEMENT	507	lbs
COARSE AGGREGATE-PEA GRAVEL	1490	lbs
FINE AGGREGATE-SAND	1464	lbs
SLAG	218	lbs
ADMIXTURES:	**DOSAGE:**	
Grace Daravair	24+/- fl/oz	
Grace ADVA Cast 575	48 +/- fl/oz	

AVE SPREAD (IN). 25.72	1 DAY	7 DAY	28 DAY
TOTAL BREAKS	28	36	36
AVERAGE STRENGTH	4521	6615	8940
STANDARD DEVEATION	485	591	662
1 CU-FT WEIGHT AVERAGE (lb)	**141.53**		

APPENDIX D. CRASH TEST NO. 602191-1

D.1 VEHICLE PROPERTIES AND INFORMATION

Table D.1. Vehicle Properties for Test No. 602191-1.

Date: 2013-08-26 Test No.: 602191-1 VIN No.: 1D7HA18PS75101997

Year: 2007 Make: Dodge Model: Ram 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 322959

Note any damage to the vehicle prior to test: ______

● Denotes accelerometer location.

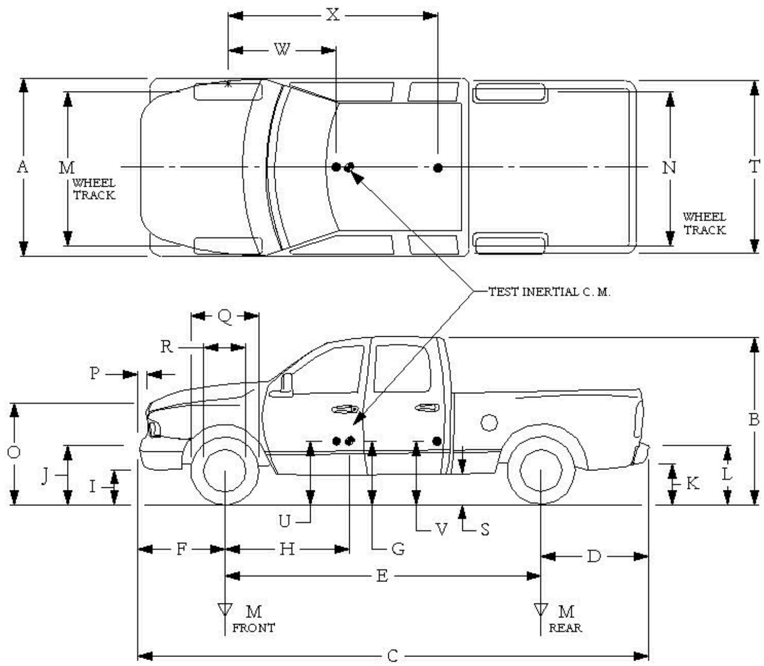
NOTES: ______

Engine Type: V-8
Engine CID: 4.7 liter

Transmission Type:
x Auto or ____ Manual
____ FWD x RWD ____ 4WD

Optional Equipment:

Dummy Data:
Type: No dummy
Mass: NA
Seat Position: NA



Geometry: inches

A	78.25	F	36.00	K	20.75	P	2.88	U	28.50
B	75.75	G	28.25	L	29.25	Q	30.50	V	30.50
C	223.75	H	62.42	M	68.50	R	18.38	W	62.00
D	47.25	I	15.25	N	68.00	S	16.00	X	75.00
E	140.50	J	27.00	O	46.50	T	77.50		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	18.75
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	11.25	Bottom Frame Height - Rear	26.00

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2862	2796	
Back	3900	M_{rear}	2123	2235	
Total	6700	M_{Total}	4985	5031	

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1404 RF: 1392 LR: 1121 RR: 1114

Table D.2. Measurements of Vehicle Vertical CG for Test No. 602191-1.

Date: 2013-08-26 Test No.: 602191-1 VIN: 1D7HA18PS75101997

Year: 2007 Make: Dodge Model: Ram 1500

Body Style: Quad Cab Mileage: 322959

Engine: V-8 4.7 liter Transmission: Automatic

Fuel Level: Empty Ballast: 176 lb (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)						
LF:	1404	RF:	1392	Front Axle:	2796	
LR:	1121	RR:	1114	Rear Axle:	2235	
Left:	2525	Right:	2506	Total:	5031	
				5000 ±110 lb allowed		
Wheel Base:	140.5 inches	Track: F:	68.5 inches	R:	68	inches
	148 ±12 inches allowed		Track = (F+R)/2 = 67 ±1.5 inches allowed			
Center of Gravity, SAE J874 Suspension Method						
X:	62.42 in	Rear of Front Axle	(63 ±4 inches allowed)			
Y:	-0.13 in	Left - Right +	of Vehicle Centerline			
Z:	28.25 in	Above Ground	(minumum 28.0 inches allowed)			

Hood Height: 46.50 inches
43 ±4 inches allowed

Front Bumper Height: 27.00 inches

Front Overhang: 36.00 inches
39 ±3 inches allowed

Rear Bumper Height: 29.25 inches

Overall Length: 223.75 inches

Table D.3. Exterior Crush Measurements for Test No. 602191-1.

Date: 2013-08-26 Test No.: 602191-1 VIN No.: 1D7HA18PS75101997

Year: 2007 Make: Dodge Model: Ram 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = ______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger side in Front or Rear impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Side plane at bumper ht	20	17	29	17	14	9	3	1.5	0	-12
2	Front plane at bumper ht	20	24	55	1.5	5.25	----	----	18	24	+76
	Measurements recorded										
	in inches										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

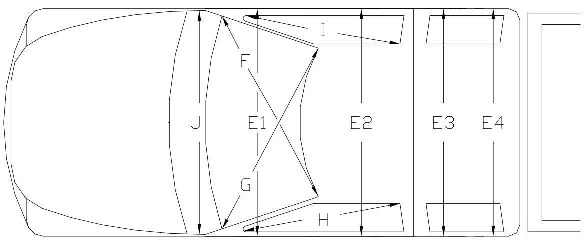
***Measure and document on the vehicle diagram the location of the maximum crush.

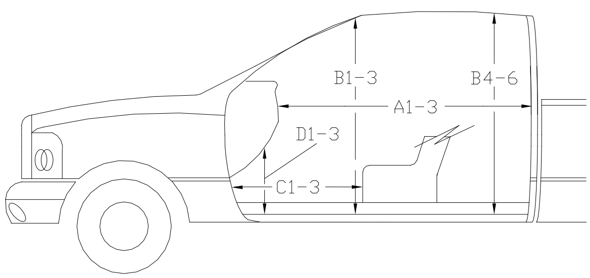
Note: Use as many lines/columns as necessary to describe each damage profile.

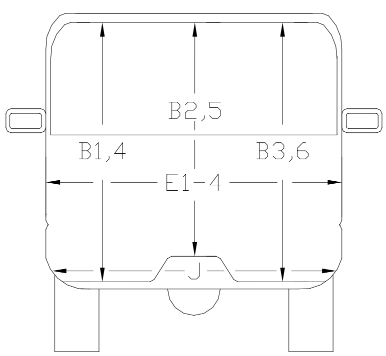
Table D.4. Occupant Compartment Measurements for Test No. 602191-1.

Date: 2013-08-26 Test No.: 602191-1 VIN No.: 1D7HA18PS75101997

Year: 2007 Make: Dodge Model: Ram 1500







*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	64.75	64.25
A2	64.75	64.75
A3	65.00	65.00
B1	45.25	45.25
B2	39.00	37.00
B3	45.25	45.25
B4	42.25	42.25
B5	44.75	44.75
B6	42.25	42.25
C1	29.75	28.75
C2	----	----
C3	27.00	27.00
D1	12.75	13.00
D2	----	----
D3	12.00	12.00
E1	62.75	62.75
E2	64.75	65.75
E3	64.25	64.25
E4	64.25	64.25
F	60.00	60.00
G	60.00	60.00
H	39.00	39.00
I	39.00	39.00
J*	62.25	60.00

D.2 SEQUENTIAL PHOTOGRAPHS

0.000 s

0.070 s

0.140 s

0.210 s

Figure D.1. Sequential Photographs for Test No. 602191-1 (Overhead and Frontal Views).

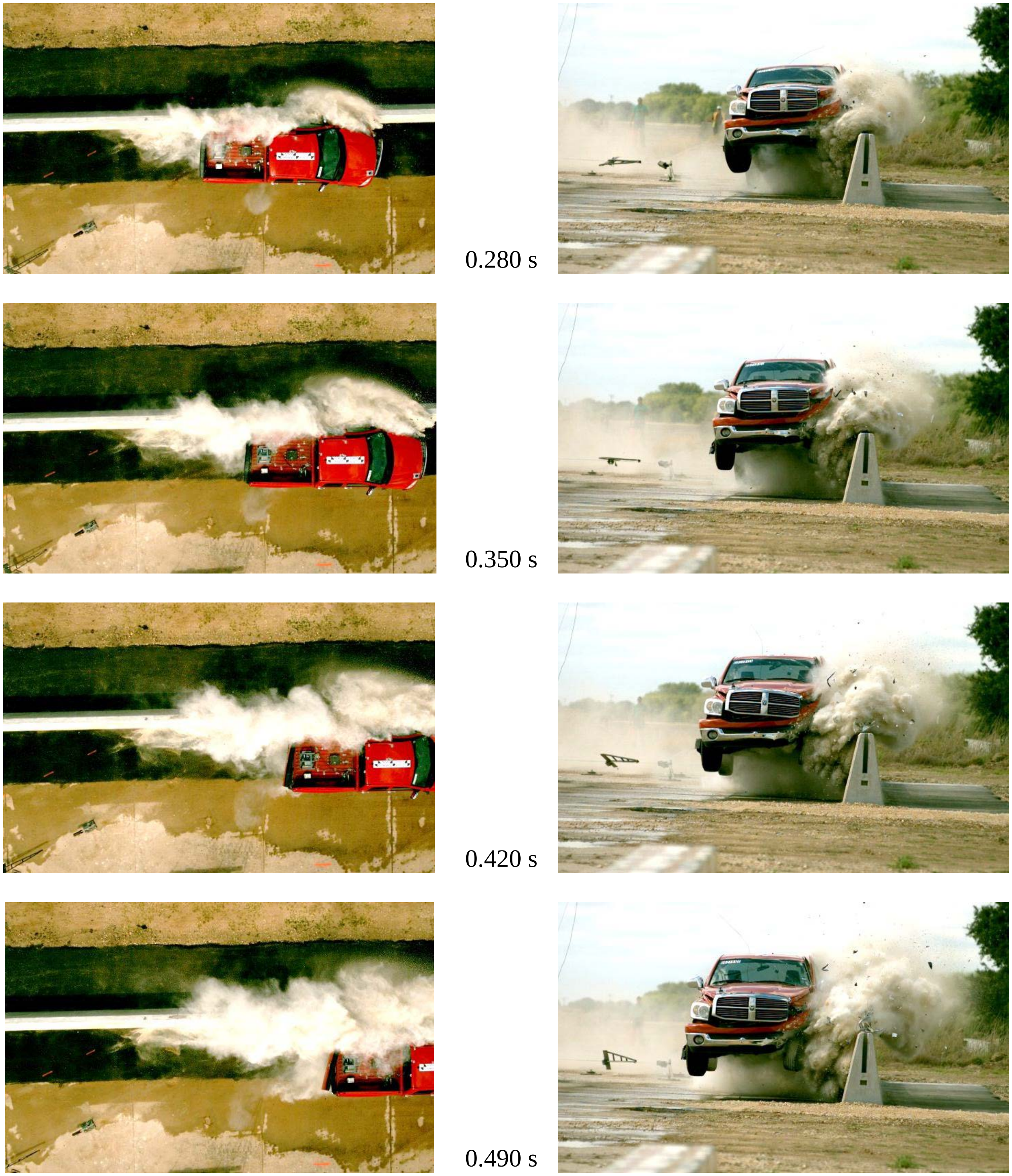


Figure D.1. Sequential Photographs for Test No. 602191-1 (Overhead and Frontal Views) (Continued).

0.000 s

0.070 s

0.140 s

0.210 s

0.280 s

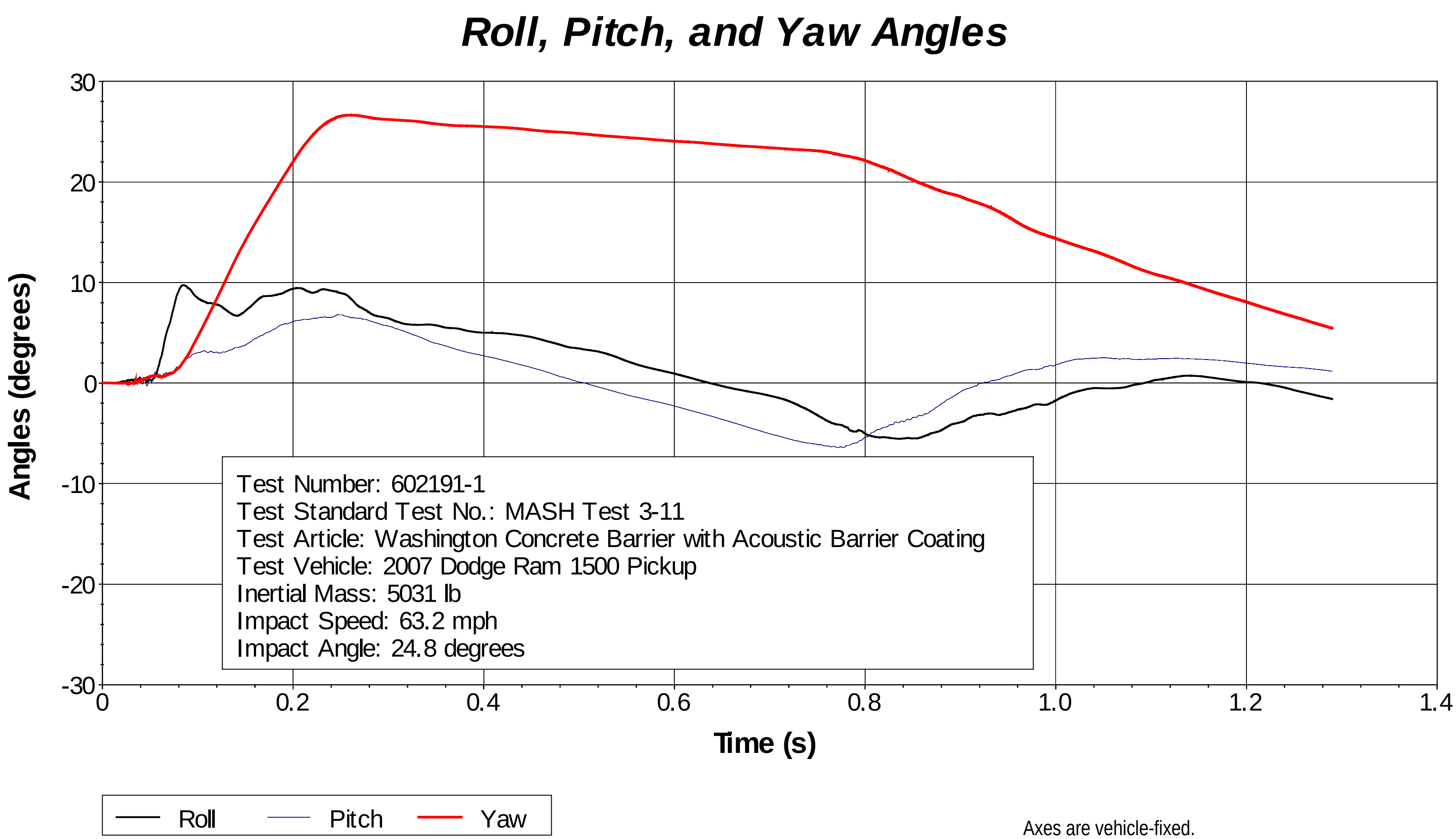
0.350 s

0.420 s

0.490 s

Figure D.2. Sequential Photographs for Test No. 602191-1 (Rear View).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

1. Yaw.
2. Pitch.
3. Roll.

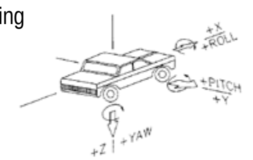


Figure D.3. Vehicle Angular Displacements for Test No. 602191-1.

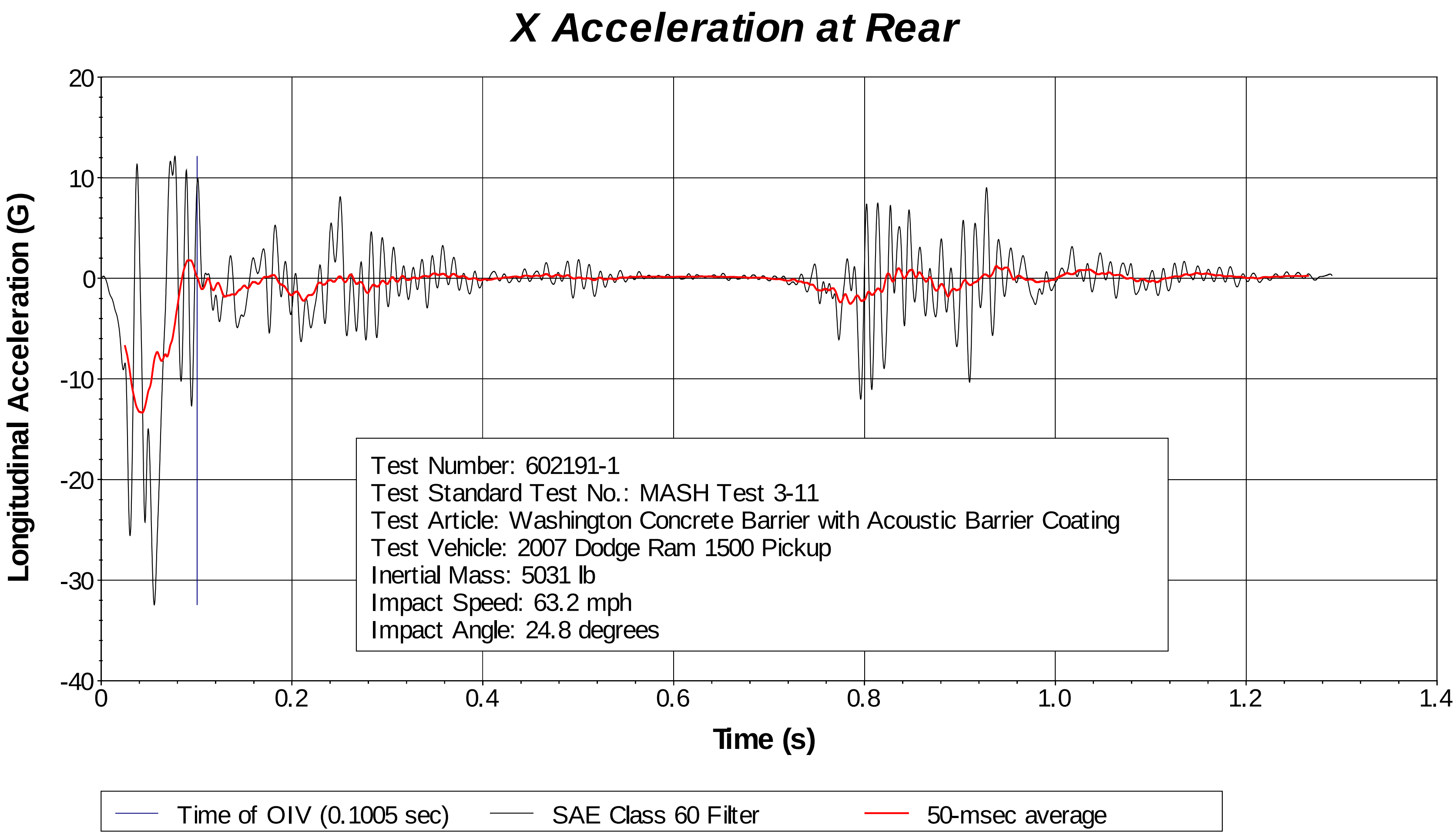


Figure D.4. Vehicle Longitudinal Accelerometer Trace for Test No. 602191-1 (Accelerometer Rear of Center of Gravity).

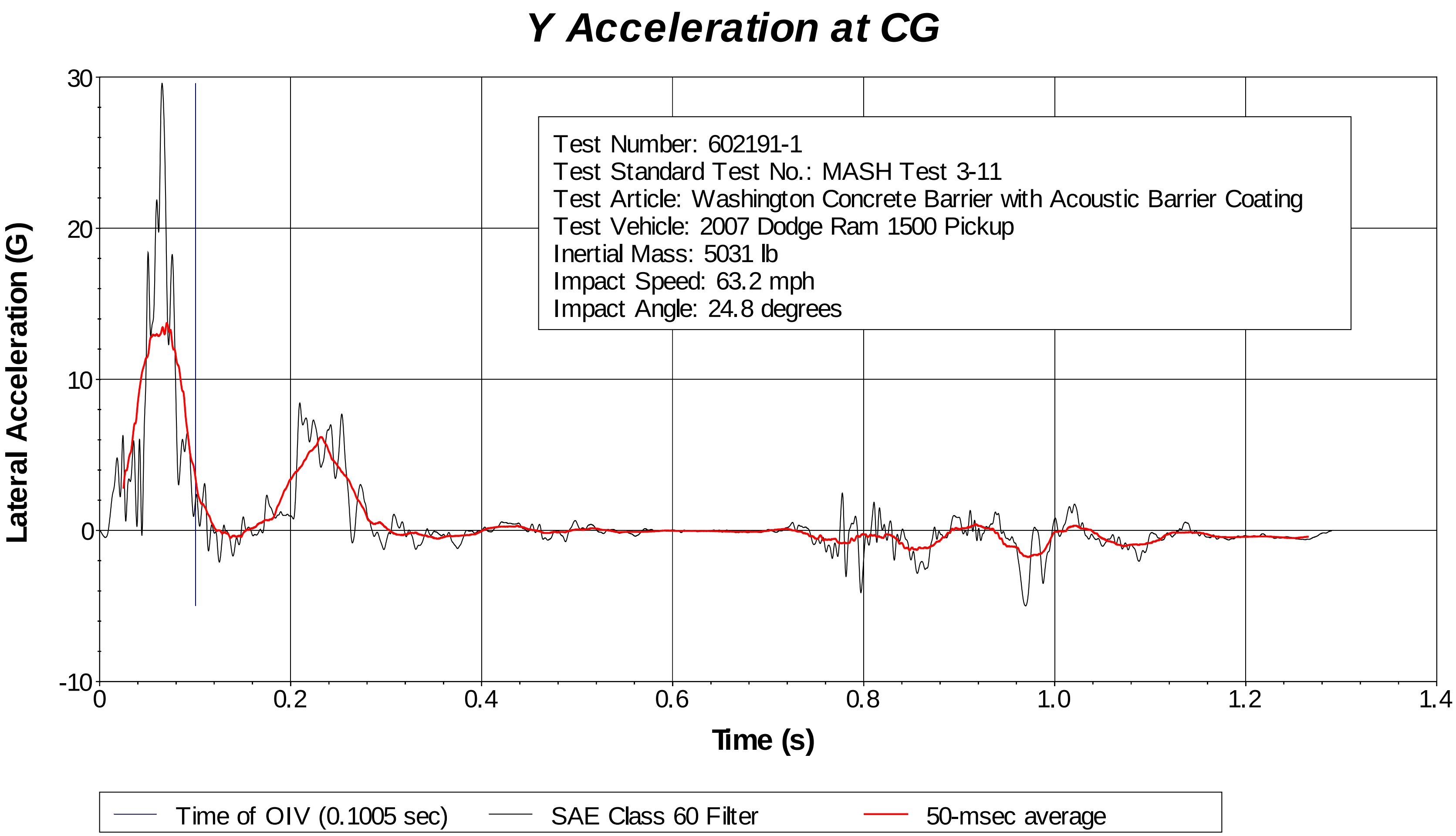


Figure D.5. Vehicle Lateral Accelerometer Trace for Test No. 602191-1 (Accelerometer Located at Center of Gravity).

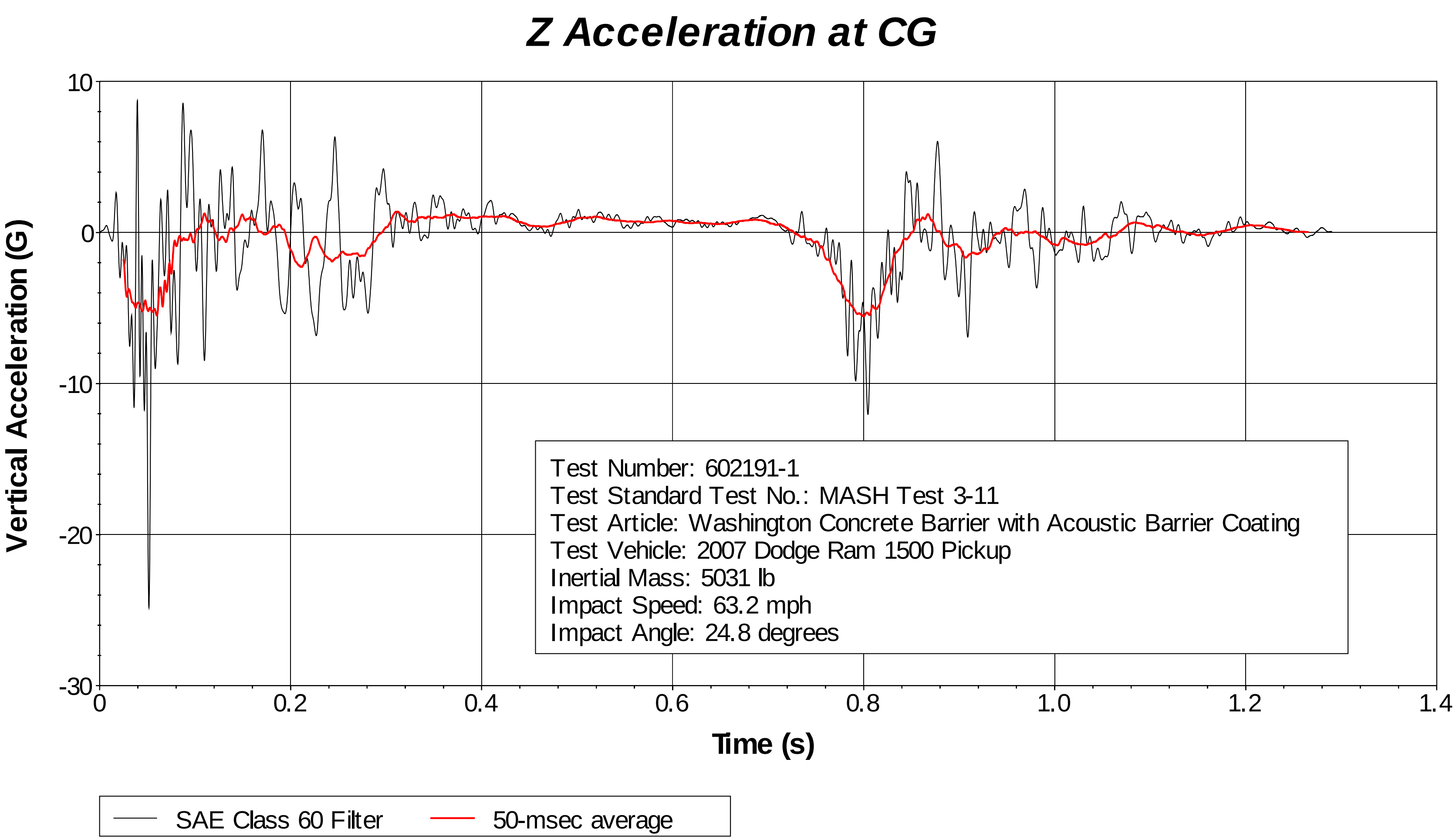


Figure D.6. Vehicle Vertical Accelerometer Trace for Test No. 602191-1 (Accelerometer Located at Center of Gravity).

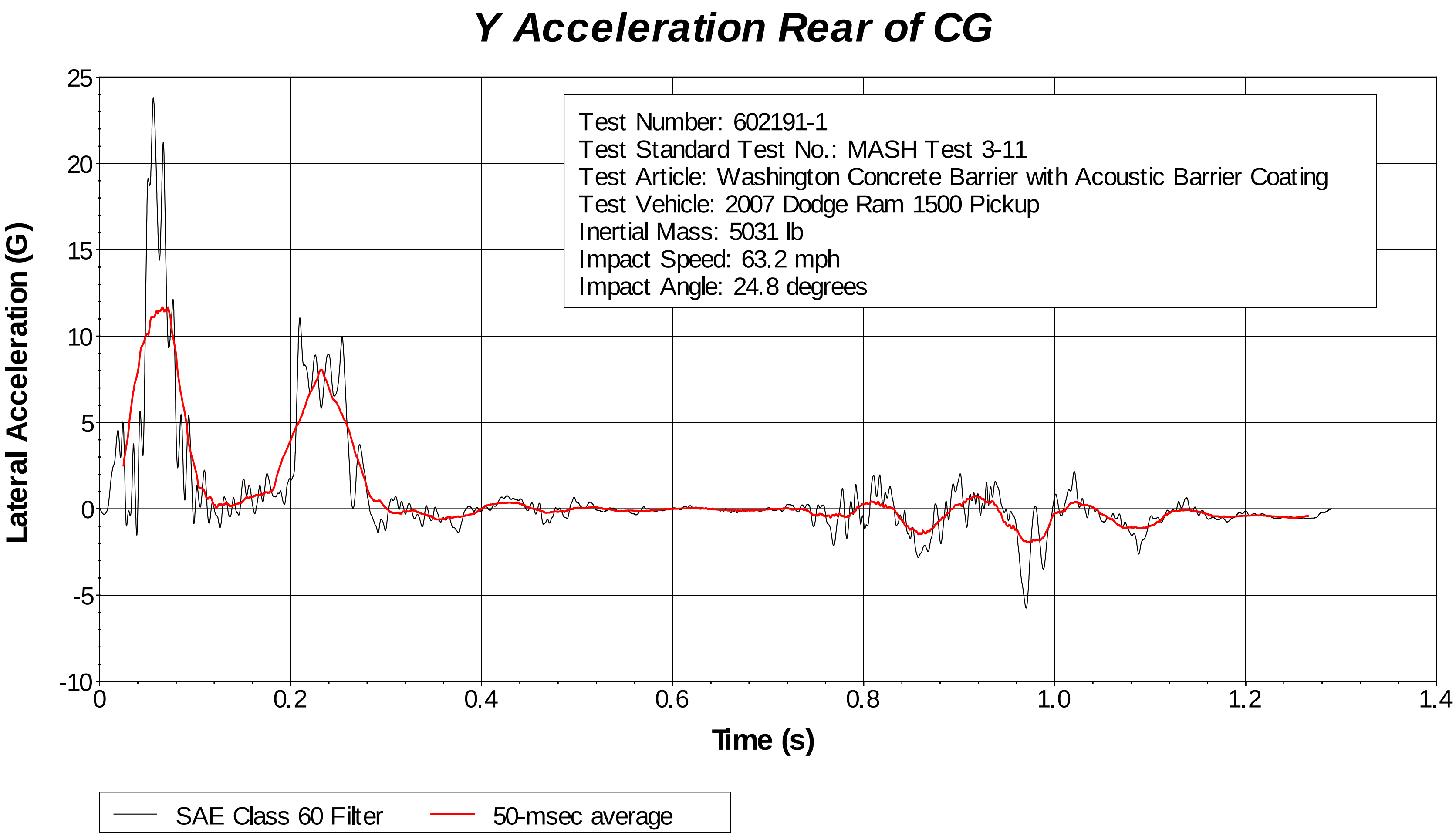


Figure D.7. Vehicle Lateral Accelerometer Trace for Test No. 602191-1 (Accelerometer Located Rear of Center of Gravity).

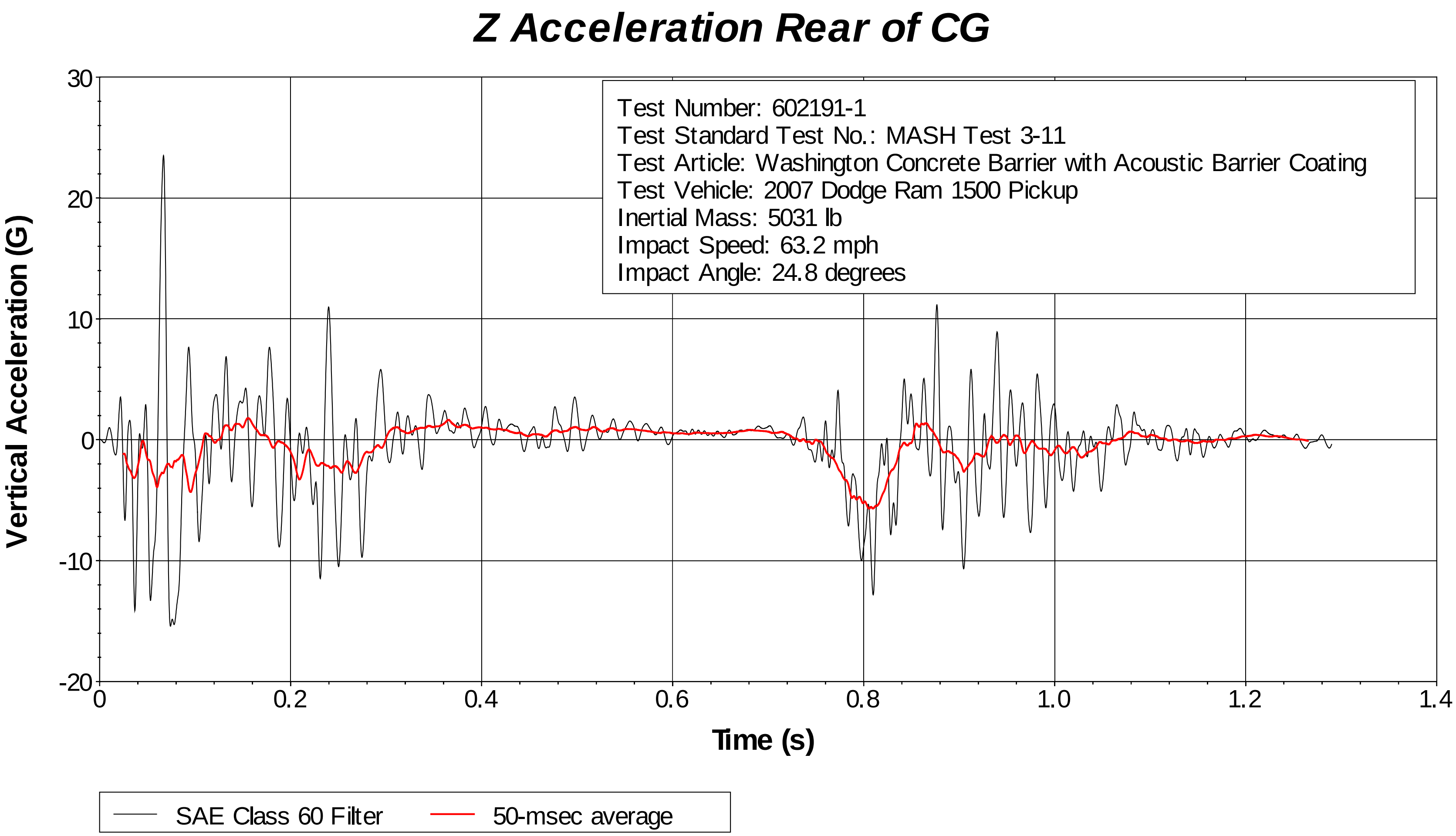


Figure D.8. Vehicle Vertical Accelerometer Trace for Test No. 602191-1 (Accelerometer Located Rear of Center of Gravity).