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MASH TEST 3-10 OF GUARDRAIL SYSTEM ON 1H:1V SLOPE

by

Akram Y Abu-Odeh, Ph.D.
Research Scientist

Wanda L. Menges
Research Specialist

Glenn E. Schroeder
Research Specialist

and

Darrell L. Kuhn, P.E.
Research Specialist

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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 University System RELLIS Campus
Building 7091
1254 Avenue A
Bryan, TX 77807

ISO 17025 Laboratory
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Name of Contacting Representative: Joe Hall, P.E., P.S., West Virginia Department of Transportation

16. Abstract

The purpose of this research was to develop and evaluate a guardrail system to be placed with a 1H:1V slope. The structural capacity and the occupant risk factors of such proposed guardrail system were evaluated with respect to *MASH* TL-3 criteria. A W-beam guardrail system was tested under *MASH* TL 3-10 criteria, and based on the test result, more stiffness was desired.

The 1100C vehicle impacted the guardrail on 1H:1V slope 31.5 inches upstream of post 14 at an impact speed of 63.9 mi/h and an impact angle of 25.2 degrees. Due to rollover of the 1100C vehicle, the guardrail on 1H:1V slope did not perform acceptably for *MASH* Test 3-10 for longitudinal barriers.

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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 yards	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 1000L 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)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		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	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 (2000lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lb/in^2

*SI is the symbol for the International System of Units

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Roadside Safety Research Pooled Fund Committee
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ALABAMA

Stanley (Stan) C. Biddick, P.E.
Assistant State Design Engineer
Design Bureau, Final Design Division
Alabama Dept. of Transportation
1409 Coliseum Boulevard, T-205
Montgomery, AL 36110
(334) 242-6833
biddicks@dot.state.al.us

Steven E. Walker
Alabama Dept. of Transportation
(334) 242-6488
walkers@dot.state.al.us

ALASKA

Jeff C. Jeffers, P.E.
Statewide Standard Specifications
Alaska Depart. of Transportation & Public Facilities
3132 Channel Drive
P.O. Box 112500
Juneau, AK 99811-2500
(907) 465-8962
Jeff.Jeffers@alaska.gov

CALIFORNIA

Bob Meline, P.E.
Caltrans
Office of Materials and Infrastructure
Division of Research and Innovation
5900 Folsom Blvd
Sacramento, CA 95819
(916) 227-7031
Bob.Meline@dot.ca.gov

John Jewell, P.E.
Senior Crash Testing Engineer
Office of Safety Innovation & Cooperative Research
(916) 227-5824
John_Jewell@dot.ca.gov

COLORADO

Joshua Keith, P.E.
Standards & Specifications Engineer
Project Development Branch
Colorado Dept. of Transporation
4201 E Arkansas Ave, 4th Floor
Denver, CO 80222
(303) 757-9021
Josh.Keith@state.co.us

Joshua Palmer, P.E.
Guardrail Engineer
Colorado Dept. of Transportation
2829 W. Howard Pl
Denver, CO 80204
(303) 757-9229
Joshua.j.palmer@state.co.us

Chih Shawn Yu
(303) 757-9474
Shawn.yu@state.co.us

Andrew Pott, P.E. II
Staff Bridge
(303) 512-4020
Andrew.pott@state.co.us

CONNECTICUT

David Kilpatrick
State of Connecticut Depart. of Transportation
2800 Berlin Turnpike
Newington, CT 06131-7546
(806) 594-3288
David.Kilpatrick@ct.gov

DELAWARE

Mark Buckalew, P.E.
Safety Program Manager
Delaware Depart. of Transportation
169 Brick Store Landing Road
Smyrna, DE 19977
(302) 659-4073
Mark.Buckalew@state.de.us

FLORIDA

Derwood C. Sheppard, Jr., P.E.
Standard Plans Publication Engineer
Florida Depart. of Transportation
Roadway Design Office
605 Suwannee Street, MS-32
Tallahassee, FL 32399-0450
(850) 414-4334
Derwood.Sheppard@dot.state.fl.us

IDAHO

Kevin Sablan
Design and Traffic Engineer
Idaho Transportation Department
P. O. Box 7129
Boise, ID 83707-1129
(208) 334-8558
Kevin.Sablan@ITD.idaho.gov

Rick Jensen, P.E.
ITD Bridge Design
(208) 334-8589
Rick.jensen@itd.idaho.gov

Shanon M. Murgoitio, P.E.
Engineer Manager 1
ITD Bridge Division
(208) 334-8589
Shanon.murgoitio@ird.idaho.gov

Marc Danley, P.E.
Technical Engineer
(208) 334-8558
Marc.danley@itd.idaho.gov

ILLINOIS

Martha A. Brown, P.E.
Safety Design Bureau Chief
Bureau of Safety Programs and Engineering
Illinois Depart. of Transportation
2300 Dirksen Parkway, Room 005
Springfield, IL 62764
(217) 785-3034
Martha.A.Brown@illinois.gov

Tim Craven
Tim.craven@illinois.gov

Filberto (Fil) Sotelo
Safety Evaluation Engineer
(217) 785-5678
Filiberto.Sotelo@illinois.gov

Jon M. McCormick
Safety Policy & Initiatives Engineer
(217) 785-5678
Jon.M.McCormick@illinois.gov

LOUISIANA

Chris Guidry
Bridge Manager
Louisiana Transportation Center
Bridge & Structural Design Section
P.O. Box 94245
Baton Rouge, LA 79084-9245
(225) 379-1933
Chris.Guidry@la.gov

Kurt Brauner, P.E.
Bridge Engineer Manager
Louisiana Transportation Center
1201 Capital Road, Suite 605G
Baton Rouge, LA 70802
(225) 379-1933
Kurt.Brauner@la.gov

Brian Allen, P.E.
Bridge Design Engineer
(225) 379-1840
Brian.allen@la.gov

Steve Mazur
Bridge Design
(225) 379-1094
Steven.Mazur@la.gov

MARYLAND

Jeff Robert
Division Chief
Bridge Design Division
Office of Structures
707 N. Calvert Street, Mailstop C-203
Baltimore, MD 21202
(410) 545-8327
jrobert@sha.state.md.us

Sharon D. Hawkins
Project Manager
Office of Policy and Research, Research Division
707 N. Calvert Street, Mailstop C-412
Baltimore, MD 21202
(410) 545-2920
Shawkins2@sha.state.md.us

MASSACHUSETTS

Alex Bardow
Director of Bridges and Structure
Massachusetts Depart. of Transportation
10 Park Plaza, Room 6430
Boston, MA 02116
(517) 335-9430
Alexander.Bardow@state.ma.us

James Danila
Assistant State Traffic Engineer
(857) 368-9640
James. Danila@state.ma.us

MICHIGAN

Carlos Torres, P.E.
Crash Barrier Engineer
Geometric Design Unit, Design Division
Michigan Depart. of Transportation
P. O. Box 30050
Lansing, MI 48909
(517) 335-2852
TorresC@michigan.gov

MINNESOTA

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

Michelle Moser
Assistant Design Standards Engineer
(651) 366-4708
Michelle.Moser@state.mn.us

MISSOURI

Sarah Kleinschmit, P.E.
Policy and Innovations Engineer,
Missouri Department of Transportation
P.O. Box 270
Jefferson City, MO 65102
(573) 751-7412
sarah.kleinschmit@modot.mo.gov

MISSISSIPPI

Heath T. Patterson, P.E.
MDOT-State Maintenance Engineer
Emergency Coordinating Officer
401 N. West Street
Jackson, MS 39201
(601) 359-7113
hpatterson@mdot.ms.gov

NEW MEXICO

David Quintana, P.E.
Project Development Engineer
P.O. Box 1149, Room 203
Santa Fe, NM 87504-1149
(505) 827-1635
David quintana@state.nm.us

OHIO

Don P. Fisher, P.E.
Ohio Depart. of Transportation
1980 West Broad Street
Mail Stop 1230
Columbus, OH 43223
(614) 387-6214
Don.fisher@dot.ohio.gov

OKLAHOMA

Hebret Bokhru, P.E.
Engineering Manager
Traffic Engineering Division
Oklahoma Depart. of Transportation
200 NE 21st Street, 2-A7
Oklahoma City, OK 73105-3204
Office (direct): (405) 522-5373
Office (Traffic Div.): (405) 521-2861
Hebret.Bokhru@odot.org

OREGON

Christopher Henson
Senior Roadside Design Engineer
Oregon Depart. of Transportation
Technical Service Branch
4040 Fairview Industrial Drive, SE
Salem, OR 97302-1142
(503) 986-3561
Christopher.S.Henson@odot.state.or.us

PENNSYLVANIA

Guozhou Li
Pennsylvania DOT
GuLi@pa.gov

Hassan Raza
Standards & Criteria Engineer
Pennsylvania Depart. of Transportation
Bureau of Project Delivery
400 North Street, 7th Floor
Harrisburg, PA 17120
(717) 783-5110
HRaza@pa.gov

TENNESSEE

Ali Hangul, P.E., CPESC
Assistant Director
Tennessee Depart. of Transportation
Roadway Design & Office of Aerial Surveys
James K. Polk State Office Bldg.
505 Deaderick Street
Nashville, TN 37243
(615) 741-0840
Ali.Hangul@tn.gov

TEXAS

Chris Lindsey
Transportation Engineer
Design Division
Texas Department of Transportation
125 East 11th Street
Austin, TX 78701-2483
(512) 416-2750
Christopher.Lindsey@txdot.gov

Taya Retterer P.E.
TXDOT Bridge Standards Engineer
(512) 416-2719
Taya.Retterer@txdot.gov

Wade Odell
Transportation Engineer
Research & Technology Implementation
200 E. Riverside Drive
Austin, TX 78704
Wade.Odell@txdot.gov

UTAH

Shawn Debenham
Traffic and Safety Division
Utah Depart. of Transportation
4501 South 2700 West
PO Box 143200
Salt Lake City UT 84114-3200
(801) 965-4590
sdebenham@utah.gov

WASHINGTON

John Donahue
Design Policy and Analysis Manager
Washington State Dept. of Transportation
Development Division
P.O. Box 47329
Olympia, WA 98504-7246
(360) 704-6381
donahjo@wsdot.wa.gov

Mustafa Mohamedali
Assistant Research Project Manager
P.O. Box 47372
Olympia, WA 98504-7372
(360) 704-6307
mohamem@wsdot.wa.gov

WASHINGTON (continued)

Anne Freeman
Program Administrator
Research & Library Services
(306) 705-7945
Freeann@wsdot.gov

WEST VIRGINIA

Donna J. Hardy, P.E.
Safety Programs Engineer
West Virginia Depart. of
Transportation – Traffic Engineering
Building 5, Room A-550
1900 Kanawha Blvd E.
Charleston, WV 25305-0430
(304) 414-7338
Donna.J.Hardy@wv.gov

Ted Whitmore, P.E.
West Virginia Depart. Of Transportation -
Traffic Services Engineer
(304) 414-7373
Ted.J.Whitmore@wv.gov

Joe Hall, P.E., P.S.
West Virginia Depart. Of Transportation
Engineering Division
Technical Policy QA/QC Engineer
1334 Smith Street
Charleston, WV 25305-0430
(304) 414-6442
Joe.H.Hall@wv.gov

WISCONSIN

Erik Emerson, P.E.
Standards Development Engineer –
Roadside Design
Wisconsin Department of Transportation
Bureau of Project Development
4802 Sheboygan Avenue, Room 651
P. O. Box 7916
Madison, WI 53707-7916
(608) 266-2842
Erik.Emerson@wi.gov

CANADA – ONTARIO

Kenneth Shannon, P. Eng.
Senior Engineer, Highway Design (A)
Ontario Ministry of Transportation
301 St. Paul Street
St. Catharines, ON L2R 7R4
CANADA
(904) 704-3106
Kenneth.Shannon@ontario.ca

FEDERAL HIGHWAY ADMINISTRATION (FHWA)

WebSite: safety.fhwa.dot.gov

Richard B. (Dick) Albin, P.E.
Safety Engineer
FHWA Resource Center Safety & Design
Technical Services Team
711 S. Capital
Olympia, WA 98501
(303) 550-8804
Dick.Albin@dot.gov

Eduardo Arispe
Research Highway Safety Specialist
U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank Highway Research Center
Mail Code: HRDS-10
6300 Georgetown Pike
McLean, VA 22101
(202) 493-3291
Eduardo.arispe@dot.gov

Greg Schertz, P.E.
FHWA – Federal Lands Highway Division
Safety Discipline Champion
12300 West Dakota Ave. Ste. 210
Lakewood, CO 80228
(720)-963-3764
Greg.Schertz@dot.gov

Christine Black
Highway Safety Engineer
Central Federal Lands Highway Division
12300 West Dakota Ave.
Lakewood, CO 80228
(720) 963-3662
Christine.black@dot.gov

TEXAS A&M TRANSPORTATION INSTITUTE (TTI)

WebSite: tti.tamu.edu
www.roadsidepooledfund.org

D. Lance Bullard, Jr., P.E.
Senior Research Engineer
Roadside Safety & Physical Security Div.
Texas A&M Transportation Institute
3135 TAMU
College Station, TX 77843-3135
(979) 317-2855
L-Bullard@tti.tamu.edu

Roger P. Bligh, Ph.D., P.E.
Senior Research Engineer
(979) 317-2703
R-Bligh@tti.tamu.edu

Chiara Silvestri Dobrovolny, Ph.D.
Associate Research Scientist
(979) 317-2687
C-Silvestri@tti.tamu.edu

REPORT AUTHORIZATION

REPORT REVIEWED BY:

DocuSigned by: Glenn Schroeder E692F9CB5047487...	DocuSigned by: Ken Reeves 60D556935596468...
Glenn Schroeder, Research Specialist Drafting & Reporting	Ken Reeves, Research Specialist Electronics Instrumentation
DocuSigned by: Gary Gerke FBA2101E9F6B4B7...	DocuSigned by: Richard Badillo 0F51DA60AB144F9...
Gary Gerke, Research Specialist Construction	Richard Badillo, Research Specialist Photographic Instrumentation
DocuSigned by: Scott Dobrovolny 1C613885787C44C...	DocuSigned by: Wanda L. Menges B92179622AF24FE...
Scott Dobrovolny, Research Specialist Mechanical Instrumentation	Wanda L. Menges, Research Specialist Research Evaluation and Reporting

DocuSigned by: Bill Griffith 44A122CB271845B...	DocuSigned by: Darrell L. Kuhn D4CC23E85D5B4E7...
Bill L. Griffith, Research Specialist Deputy Quality Manager	Darrell L. Kuhn, P.E., Research Specialist Quality Manager
DocuSigned by: Matt Robinson EAA22BFA5BFD417...	DocuSigned by: Akram 6066AE1BB17D407...
Matthew N. Robinson, Research Specialist Test Facility Manager & Technical Manager	Akram Abu-Odeh Ph.D. Associate Research Scientist

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CHAPTER 1. INTRODUCTION

1.1. PROBLEM STATEMENT

The American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide recommends that guardrail be installed with the back edges of the guardrail post being 2 ft from a slope break (*1*). In many areas with tight environmental controls, this width is difficult to provide. As a result, designers often have to make a trade-off between reduced shoulder width and a less than optimal guardrail placement. The Washington State Department of Transportation (WSDOT) Design Manual provides for the placement of the guardrail post closer to or on slopes as steep as 1H:1V slope (*2*).

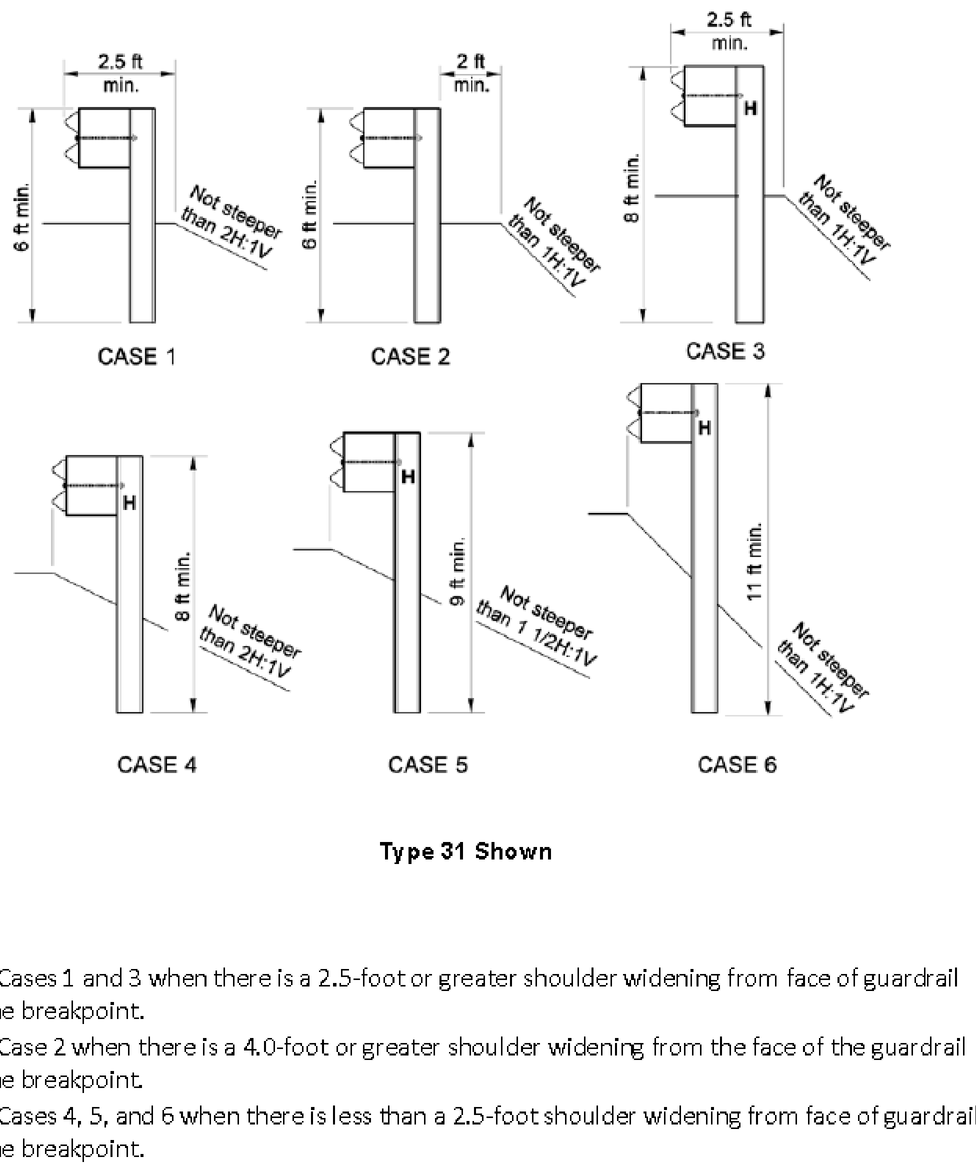

Figure 1.1. Allowable Post on Slope Installation Cases from WSDOT Design Manual; Beam Guardrail Post Installation — Exhibit 1610-11 (*2*)

1.2. BACKGROUND

Texas A&M Transportation Institute (TTI) researchers conducted in March 2018 a full-scale crash tests of a 31-inch high guardrail system placed on 2H:1V slope in accordance with AASHTO *MASH* (*3*, *4*). The posts were placed 1 ft from the slope break such that the face of the guardrail was aligned with the slope break, as shown in Figure 1.2.

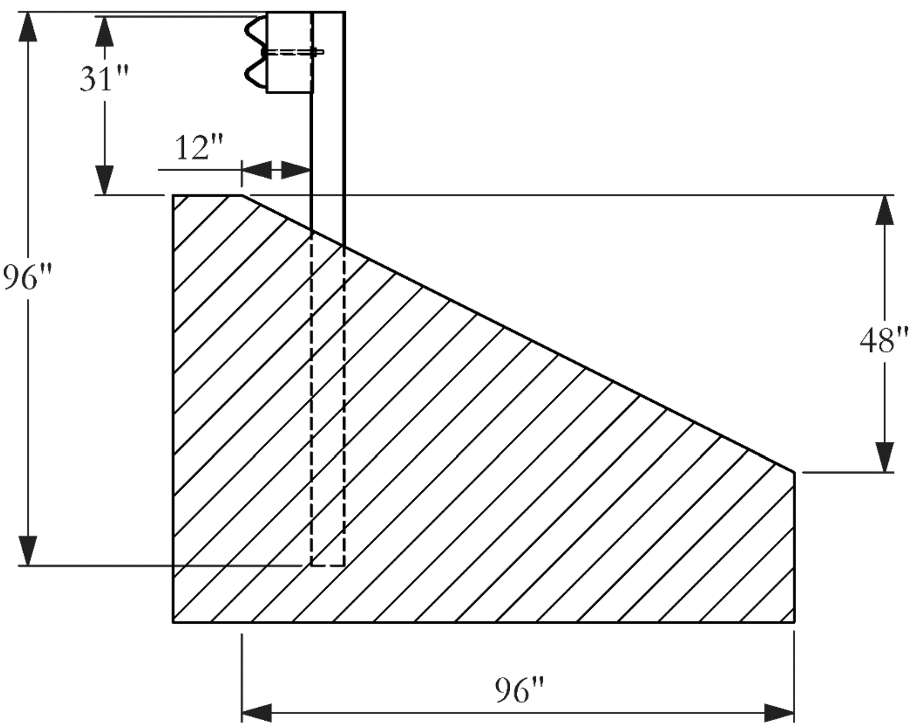

Figure 1.2. Cross Section of the Guardrail on Slope System Tested by TTI.

The guardrail on slope system was comprised of a 106.25-ft length of need section and a 37.5-ft long ET PLUS terminal on each end. The 12-gauge W-beam was mounted on W6×8.5 steel posts. The guardrail height was 31 inches above the flat terrain. A 2H:1V sloped ditch was excavated behind the rail to represent the slope terrain. An overview of this system installation is shown in Figure 1.3. Standard size 6-inch × 8-inch × 14-inch wood blockouts were used in the length of needed section.

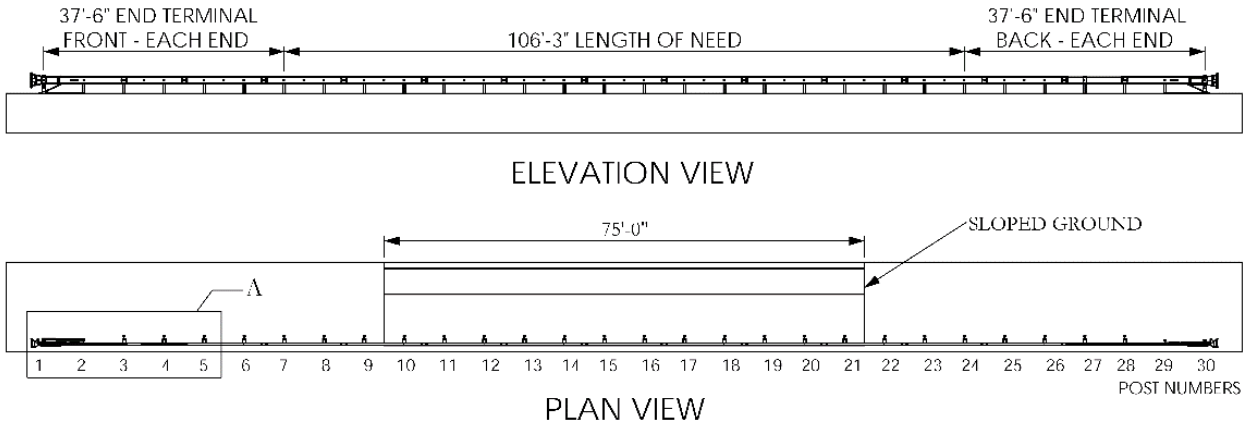

Figure 1.3. Guardrail on Slope System as Tested by TTI.

The researchers conducted two AASHTO *Manual for Assessing Safety Hardware* (*MASH*) crash tests (*3*, *4*).

***MASH* Test 3-11**, which involves a 2000 kg (4409-lb) pickup truck impacting the critical impact point (CIP) of the length of need section at a nominal impact speed of 100 km/h (62 mi/h) and a nominal impact angle of 25 degrees.

***MASH* Test 3-10**, which involves an 1100 kg (2420-lb) passenger car impacting the CIP of the length of need section at a nominal impact speed of 100 km/h (62 mi/h) and nominal impact angle of 25 degrees.

The test vehicle was successfully redirected by the guardrail system in each test. The test evaluation metrics were all within the limit of *MASH* test evaluation metrics. Hence, both tests passed *MASH* test evaluation criteria. Sequential images of both tests are shown in Figure 1.4.

(a) Test No. 405160-20-1

(b) Test No. 405160-20-2

Figure 1.4. Sequential Photos of *MASH* 3-11 and *MASH* 3-10.

1.3. OBJECTIVE

The objective of this study is to crash test a guardrail system with the face of the rail aligned with the break point of a 1H:1V slope. The system is to be tested and evaluated per MASH TL-3 impact conditions and criteria.

1.4. BENEFITS

A guardrail system in which the face of the rail is aligned with the slope break will provide significant savings in terms of reduced shoulder width in mountainous areas as well as other locations that have very restrictive space.

CHAPTER 2. *MASH* TEST 3-10 (CRASH TEST 609301-01-1)

2.1. TEST ARTICLE DESIGN AND CONSTRUCTION

The test installation consisted of a flexible W-beam guardrail system, with the top edge of the rail 31 inches above the roadway. The length of need portion (W-beam guardrail, supported by 9-ft long, W6×8.5 posts on 75-inch spacings, and offset from the posts with routered timber blockouts, with the rail splices midspan between the posts) was 162.5 ft long. It was anchored on each end with a TxDOT DAT terminal, for a total installation length of 181.25 ft. The ground sloped down and toward the field side at 45 degrees (1:1 slope) in the impact area, beginning approximately at the traffic side face of the guardrail, and extending for 8 ft to the field side and 8 ft deep. Figure 2.1 provides photographs of the installation. Appendix A.1 and A.2 provide further details of the guardrail on 1H:1V slope.

Figure 2.1. Guardrail on 1H:1V Slope prior to Test No. 609301-01-1.

In accordance with Appendix B of *MASH*, soil strength was measured the day of the crash test. During installation of the guardrail on 1H:1V slope for full-scale crash testing, two W6×16 posts were installed in the immediate vicinity of the guardrail on 1H:1V slope utilizing the same fill materials and installation procedures used in the test installation and the standard dynamic test. The minimum post loads required for deflections at 5 inches, 10 inches, and 15 inches, measured at a height of 25 inches, are 3940 lb, 5500 lb, and 6540 lb, respectively (90% of static load for the initial standard installation). On the day of the test, March 9, 2018, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 8030 lbf, 8030 lbf, and 7272 lbf, respectively. Table A.1 in Appendix A.3 shows the strength of the backfill material in which the guardrail on 1H:1V slope was installed met minimum *MASH* requirements.

2.2. TEST DESIGNATION AND ACTUAL TEST CONDITIONS

MASH Test 3-10 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the CIP of the guardrail at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The CIP for *MASH* Test 3-10 on the guardrail on 1H:1V slope was 31 inches ±1 ft upstream of post 14.

The 2009 Kia Rio used in the test weighed 2437 lb, and the actual impact speed and angle were 63.9 mi/h and 25.2 degrees, respectively. The actual impact point was 31.5 inches upstream of post 14. Minimum target impact severity (IS) was 51 kip-ft, and actual IS was 60 kip-ft.

2.3. TEST VEHICLE

Figure 2.2 shows the 2009 Kia Rio used for the crash test. The vehicle's test inertia weight was 2437 lb, and its gross static weight was 2602 lb. The height to the lower edge of the vehicle bumper was 7.75 inches, and height to the upper edge of the bumper was 21.5 inches. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact. Table A.2 in Appendix A.4 provides measurements of the vehicle.

Figure 2.2. Guardrail on 1H:1V Slope/Test Vehicle Geometrics for Test No. 609301-01-1.

2.4. WEATHER CONDITIONS

MASH Test 3-10 on the guardrail on 1H:1V slope was performed on the morning of March 9, 2018. Weather conditions at the time of testing were as follows: wind speed: 13 mi/h; wind direction: 163 degrees (vehicle was traveling at a heading of 325 degrees); temperature: 68°F; relative humidity: 63 percent.

2.5. TEST DESCRIPTION

Table 2.1 lists times and significant events that occurred during Test No. 609301-01-1. Figures A.1 and A.2 in Appendix A.4 provides sequential photos from the test.

Table 2.1. Events during Test No. 609301-01-1.

TIME (s)	EVENTS
0.000	Vehicle impacts guardrail
0.010	Post 14 begins to move
0.016	Post 13 begins to move
0.025	Post 15 begins to move
0.044	Vehicle begins to redirect
0.056	Post 16 begins to move
0.087	Rail element begins to tear at joint between posts 14 and 15
0.096	Rail element disconnects from post 15
0.099	Rail element completely disconnected between posts 14 and 15
0.106	Vehicle loses contact with the guardrail while traveling at 57.4 mi/h and 20.8°
0.156	Vehicle hits post 16, to right of middle of front bumper
0.207	Vehicle begins to roll into ditch
0.254	Vehicle hits post 17, right of middle of front bumper
0.689	Vehicle lands on side in ditch (continues rolling)
1.555	Vehicle in ditch facing upstream, slightly to the left (from original direction)

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft downstream from impact for cars and pickups). The rail element ruptured at the splice between posts 14 and 15, and the vehicle penetrated the guardrail. After loss of contact with the guardrail, the vehicle came to rest 40 ft downstream of the impact and 10 ft toward the field side.

2.6. TEST ARTICLE/COMPONENT DAMAGE

Figure 2.3 shows the damage to the guardrail on 1H:1V slope. The soil around post 1 and 12 was disturbed. Post 13 deflected 0.4 inch toward the field side, and post 14 deflected 4.0 inches toward the field side. The rail element tore at the splice between posts 14 and 15. The rail element released from posts 15-18, and the blockouts released from the posts 15 and 16. Posts 15-17 were leaning downstream at 35 degrees from vertical, and post 18 was leaning downstream at 68 degrees from vertical and deflected toward the field side 1.0 inch. No movement was noted at other posts.

Figure 2.3. Guardrail on 1H:1V Slope after Test No. 609301-01-1.

2.7. TEST VEHICLE DAMAGE

Due to vehicle rollover, the vehicle sustained damage to all exterior components as shown in Figure 2.4. Figure 2.5 shows the interior of the vehicle.

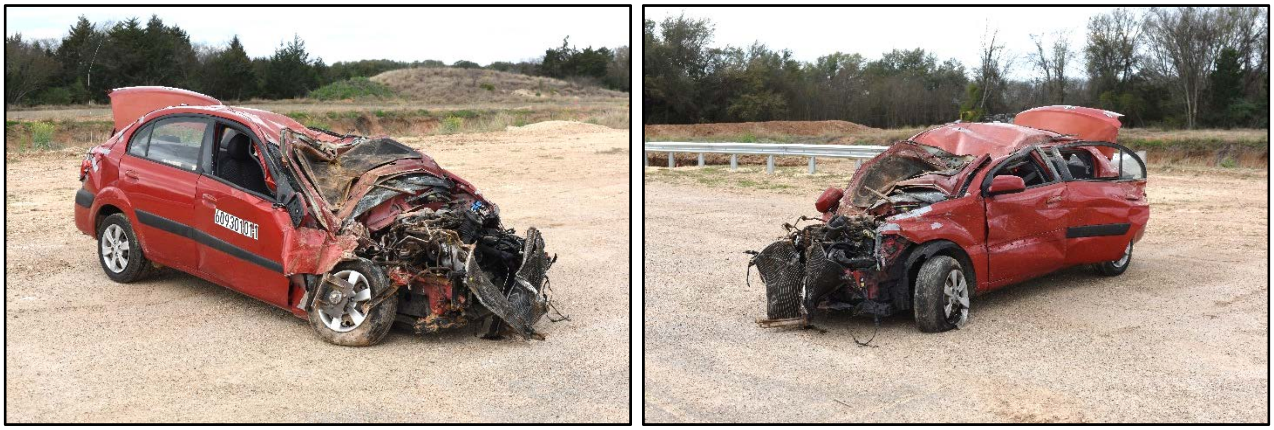

Figure 2.4. Test Vehicle after Test No. 609301-01-1.

Figure 2.5. Interior of Test Vehicle after Test No. 609301-01-1.

2.8. OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 2.2. Figure A.3 in Appendix A.5 shows the vehicle angular displacements, and Figures A.4 through A.6 in Appendix A.6 show accelerations versus time traces.

Table 2.2. Occupant Risk Factors for Test No. 609301-01-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV) Longitudinal Lateral	 14.4 ft/s 13.8 ft/s	at 0.1286 s on left side of interior
Occupant Ridedown Accelerations Longitudinal Lateral	 12.3 g 12.0 g	 0.1785 - 0.1885 s 0.8958 - 0.9058 s
Theoretical Head Impact Velocity (THIV)	21.6 km/h 6.0 m/s	at 0.1230 s on left side of interior
Post Head Deceleration (PHD)	15.1 g	0.9028 - 0.9128 s
Acceleration Severity Index (ASI)	1.3	0.8995 - 0.9495 s
Maximum 50-ms Moving Average Longitudinal Lateral Vertical	 −7.7 g −9.3 g 7.7 g	 0.8639 - 0.9139 s 0.8740 - 0.9240 s 0.8305 - 0.8805 s
Maximum Roll, Pitch, and Yaw Angles Roll Pitch Yaw	 156° 83° 138°	 0.9062 s 1.2362 s 2.2724 s

CHAPTER 3. SUMMARY AND CONCLUSIONS

The crash test reported herein was performed in accordance with *MASH* Test 3-10, which involves an 1100C vehicle impacting the guardrail at a target impact speed and impact angle of 62 mi/h and 25 degrees, respectively. Figure 2.6 summarizes the data and other pertinent information from the test. An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-10 for longitudinal barriers is provided in Table 2.3.

The 1100C vehicle impacted the guardrail on 1H:1V slope 31.5 inches upstream of post 14 at an impact speed of 63.9 mi/h and an impact angle of 25.2 degrees. Due to rollover of the 1100C vehicle, the guardrail on 1H:1V slope did not perform acceptably for *MASH* Test 3-10 for longitudinal barriers.

A finite element analysis was performed to determine feasible enhancements to be made for the guardrail to perform acceptably. The analysis and results are reported in a separate report (5).

General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-10
TTI Test No.	609301-01-1
Test Date	2018-03-09

Test Article

Type	Longitudinal Barrier – Guardrail
Name	Guardrail on 1H:1V Slope
Installation Length	181 ft 3 inches
Material or Key Elements	31-inch W-Beam Guardrail on 9 ft W6x8.5 steel posts with wood blockouts spaced at 75 inches on 1H:1V slope

Soil Type and Condition	Embedded in AASHTO M147-65(2004), grading B Soil (crushed limestone)

Test Vehicle

Type/Designation	1100C
Make and Model	2009 Kia Rio
Curb	2338 lb
Test Inertial	2437 lb
Dummy	165 lb
Gross Static	2602 lb

Impact Conditions

Speed	63.9 mi/h
Angle	25.2°
Location/Orientation	31.5 inches upstream of post 14

Impact Severity	60 kip-ft

Exit Conditions

Speed	57.4 mi/h
Angle	20.8°

Occupant Risk Values

Longitudinal OIV	14.4 ft/s
Lateral OIV	13.8 ft/s
Longitudinal Ridedown	12.3 g
Lateral Ridedown	12.0 g
THIV	21.6 km/h
PHD	15.1 g
ASI	1.3
Max. 0.050-s Average	
Longitudinal	−7.7 g
Lateral	−9.3 g
Vertical	7.7 g

Post-Impact Trajectory

Stopping Distance	40 ft downstream 10 ft twd field side

Vehicle Stability

Maximum Yaw Angle	138°
Maximum Pitch Angle	83°
Maximum Roll Angle	156°
Vehicle Snagging	Yes
Vehicle Pocketing	No

Test Article Deflections

Dynamic	Rail Ruptured
Permanent	Rail Ruptured
Working Width	15 ft
Height of Working Width	NA

Vehicle Damage

VDS	Rollover
CDC	Rollover
Max. Exterior Deformation	NA
OCDI	NA
Max. Occupant Compartment Deformation	NA

Figure 2.1. Summary of Results for *MASH* Test 3-10 on Guardrail on 1H:1V Slope.

Table 2.1. Performance Evaluation Summary for *MASH* Test 3-10 on Guardrail on 1H:1V Slope.

Test Agency: Texas A&M Transportation Institute | Test No.: 609301-01-1 | Test Date: 2018-03-09

***MASH* Test 3-10 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 guardrail on 1H:1V slope did not contain or redirect the 1100C vehicle. The 1100C vehicle penetrated guardrail.	Fail
<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.*	Some of the wood blockouts separated from the rail element and posts, and the rail element ruptured. These elements did not penetrate or show potential to penetrate the occupant compartment, or present hazard to others.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	Due to vehicle rollover, the occupant compartment deformation could not be adequately measured.	
F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	Vehicle roll was 156 degrees, and pitch was 83 degrees.	Fail
H. *Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.*	Longitudinal OIV was 14.4 ft/s, and lateral OIV was 13.8 ft/s.	Pass
I. *The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.*	Maximum longitudinal 10-ms occupant ridedown acceleration was 12.3 g, and maximum lateral occupant ridedown acceleration was 12.0 g.	Pass

REFERENCES

1. AASHTO Roadside Design Guide. American Association of State Highway and Transportation Officials, Washington, DC.
2. Washington State Department of Transportation (WSDOT) Design Manual, https://wsdot.wa.gov/Publications/Manuals/M22-01.htm, last accessed 2020-09-27.
3. AASHTO *Manual for Assessing Safety Hardware; Second Edition*. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
4. Akram Y. Abu-Odeh, Kelly Ha, Ivan Liu, and Wanda L. Menges. *MASH TL-3 Testing and Evaluation of the W-Beam Guardrail on Slope*, Test Report No. 405160-20, Texas A&M Transportation Institute, College Station, Tx, March 2013.
5. Sun Hee Park and Akram Y Abu-Odeh. *Finite Element Analysis of Placement of Guardrail System on 1H:1V Slope*. Test Report No. 609301-01-FEA, Texas A&M Transportation Institute, College Station, Tx, October 2020.

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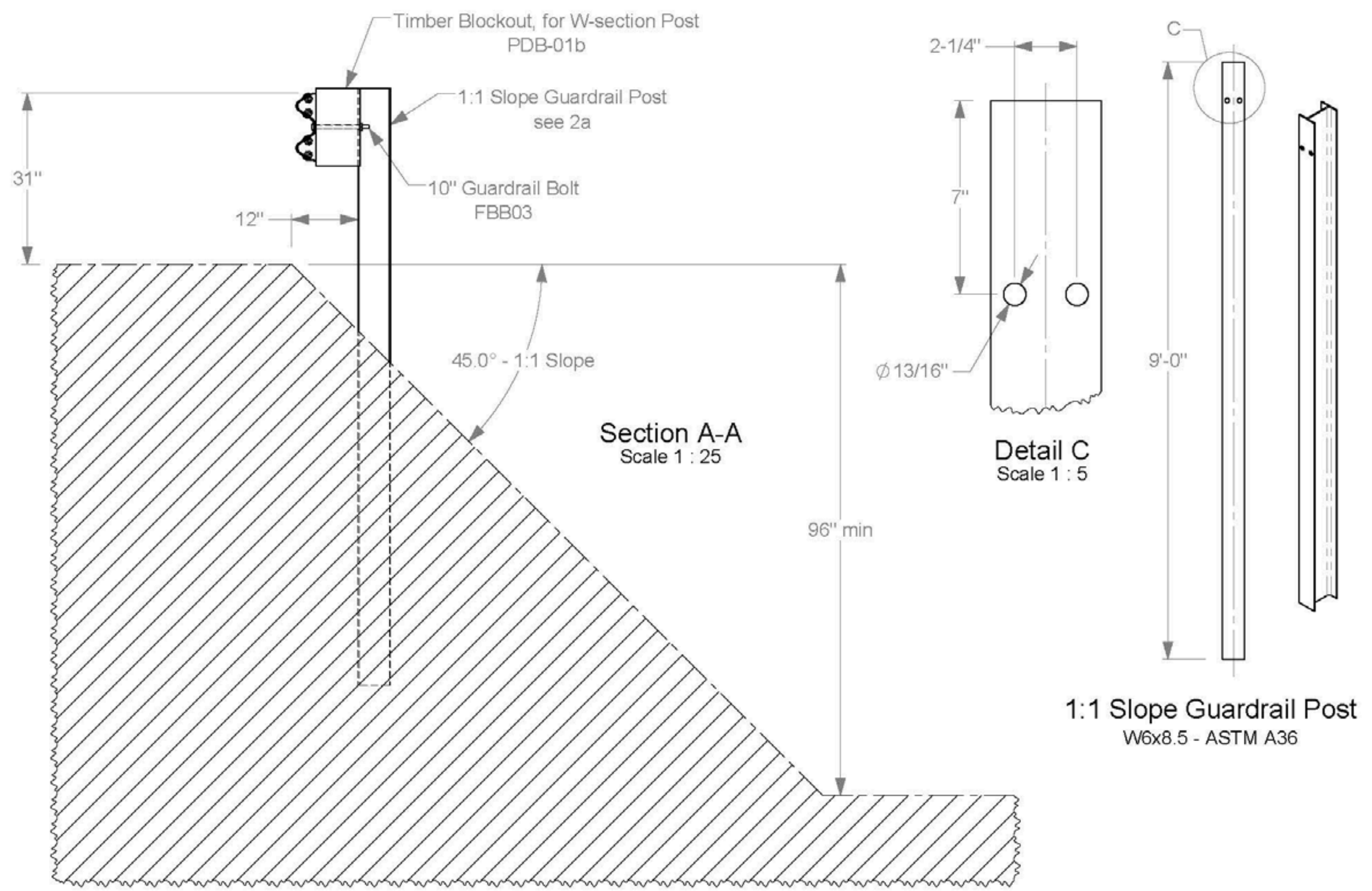
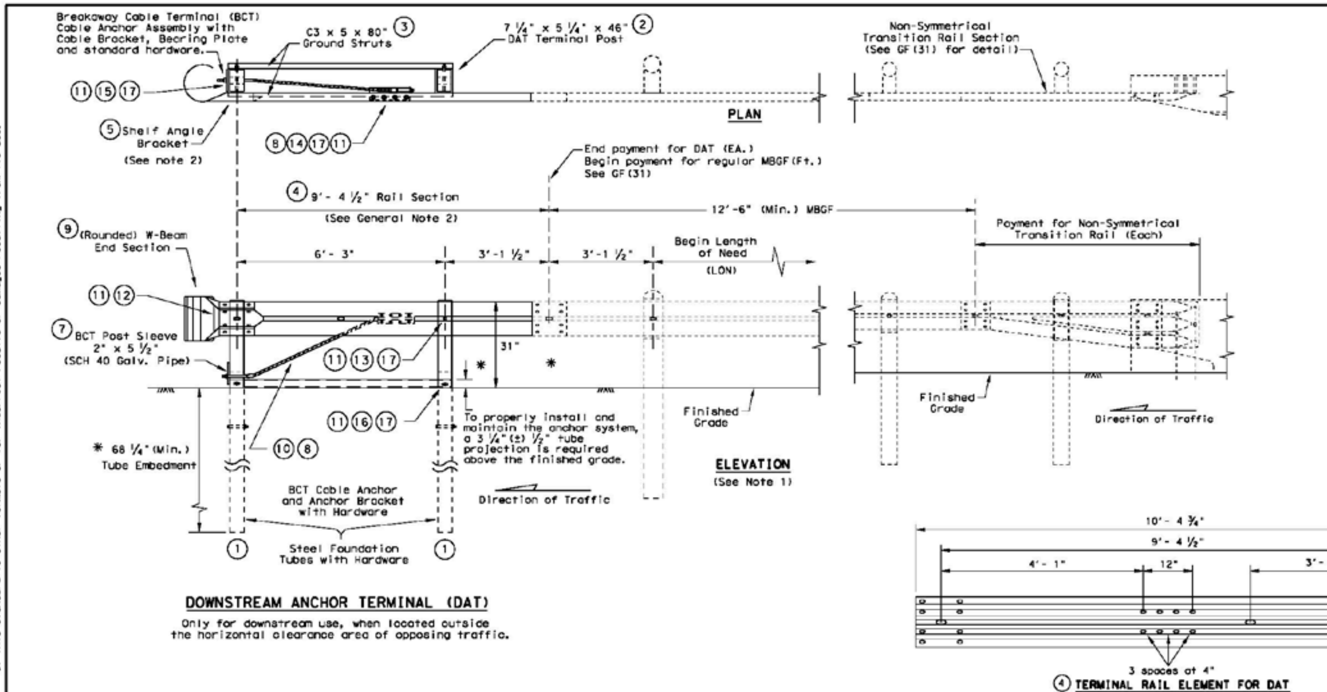
APPENDIX A.



2a. 9'-0" Post is typical at Slope (Posts 10 - 21). 72" W6x8.5 Wide Flange Guardrail Posts at other LON locations.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 609301	Guardrail on 1:1 Slope		2017-11-08
Drawn By GES	Scale 1:25	Sheet 2 of 2	Cross Section



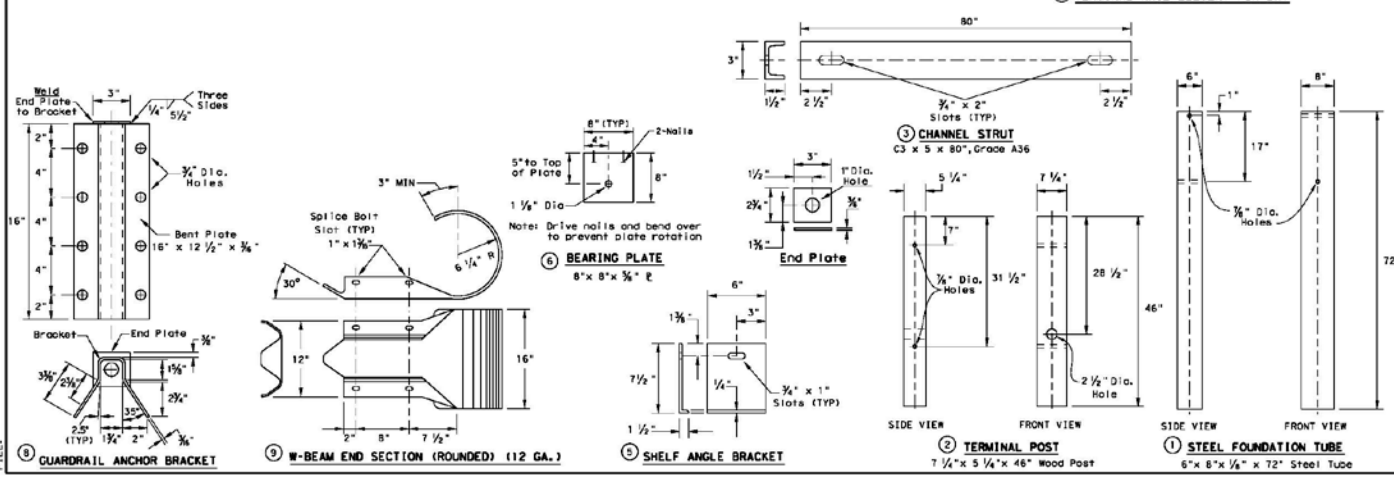
GENERAL NOTES

1. The detail shown is the minimum Length of Need (LON) for a DAT connected to a concrete rail.
2. The rail section at the end post is supported by the Shelf Angle Bracket. The rail element is not attached to the end post.
3. The foundation tubes shall not project more than 3 3/4" above the finished grade.
4. All hardware for DAT shall be ASTM A307 unless otherwise shown.
5. Refer to GF(31) sheet for terminal connection details.

MOW STRIP INSTALLATION

If a mow strip is required with the DAT installation the leave-out area around the steel foundation tubes and the two channel struts may be omitted. This will require a full pour of the foundation tubes.

#	(DAT) PARTS LIST	QTY
1	Steel Foundation Tube	2
2	DAT Terminal Post	2
3	Channel Strut	2
4	Terminal Rail Element	1
5	Shelf Angle Bracket	1
6	BCT Bearing Plate	1
7	BCT Post Sleeve	1
8	Guardrail Anchor Bracket	1
9	(Rounded) W-Beam End Section	1
10	BCT Cable Anchor	1
11	Recessed Nut, Guardrail	20
12	1 1/4" Button Head Bolt	4
13	10" Button Head Bolt	2
14	5/8" x 2" Hex Head Bolt	8
15	5/8" x 8" Hex Head Bolt	4
16	5/8" x 10" Hex Head Bolt	2
17	5/8" Flat Washer	18



Texas Department of Transportation | Design Division Standard

METAL BEAM GUARD FENCE
(Downstream Anchor Terminal)

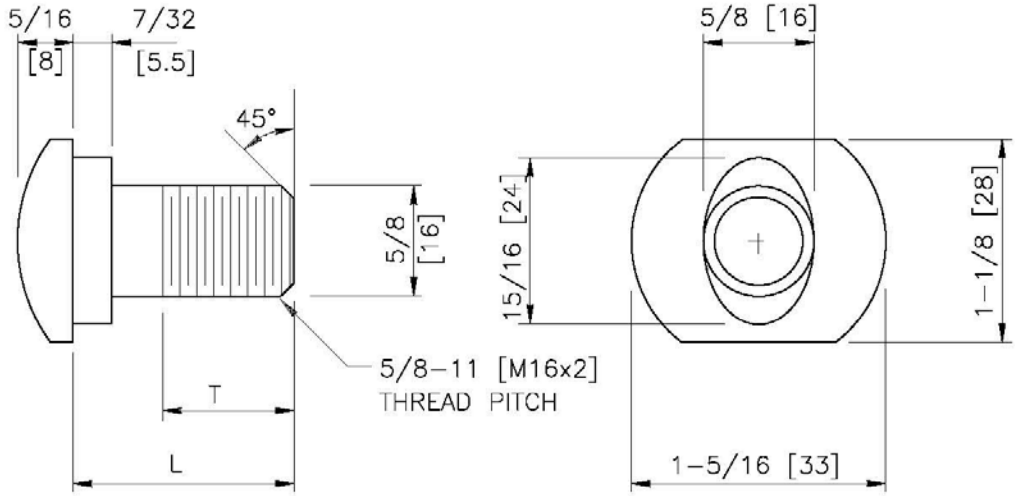
GF(31)DAT-14

FILE: gf31dt14.dgn	DN: TxDOT	CK: AM	DW: VP	CK: DOL
© TxDOT: December 2011	CONT	SECT	JOB	HIGHWAY
REVISIONS	DIST	COUNTY		SHEET NO.

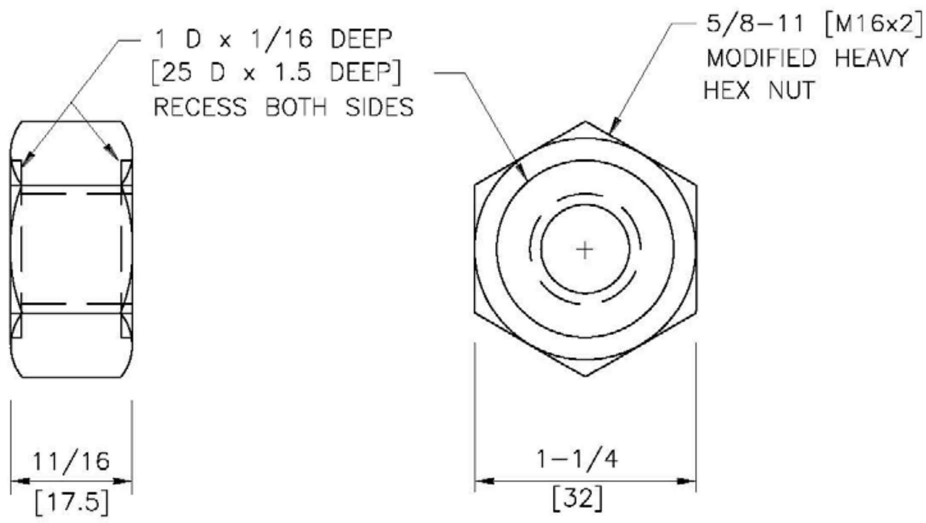
DATE:
FILE:

2020-11-19

NOTES: 1. ALL FILLETS SHALL HAVE A MINIMUM RADIUS OF 1/16 [2].
2. IF THE BOLT EXTENDS MORE THAN 1/4 [6] FROM THE NUT THE BOLT SHOULD BE TRIMMED BACK.



DESIGNATOR	L	T (MIN)
FBB01	1–1/4 [35]	1–1/8 [30]
FBB02	2 [50]	1–3/4 [45]
FBB03	10 [255]	4 [100]
FBB04	18 [460]	4 [100]
FBB05	25 [640]	4 [100]



1976

GUARDRAIL BOLT AND RECESSED NUT

FBB01–05	
SHEET NO.	DATE:
1 of 2	6/30/2005

SPECIFICATIONS

The geometry and material specifications for this oval shoulder button-headed bolt and hex nut are found in AASHTO M 180. The bolt shall have 5/8-11 [M16x2] threads as defined in ANSI B1.1 [ANSI B1.13M] for Class 2A [6g] tolerances. Bolt material shall conform to ASTM A307 Grade A [ASTM F 568M Class 4.6], with a tensile strength of 60 ksi [400 MPa] and yield strength of 36 ksi [240 MPa]. Material for corrosion-resistant bolts shall conform to ASTM A325 Type 3 [ASTM F 568M Class 8.8.3], with tensile strength of 120 ksi [830 MPa] and yield strength of 92 ksi [660 MPa]. This bolt material has corrosion resistance comparable to ASTM A588 steels. Metric zinc-coated bolt heads shall be marked as specified in ASTM F 568 Section 9 with the symbol "4.6."

Nuts shall have ANSI B1.1 Class 2B [ANSI B1.13M Class 6h] 5/8-11 [M16x2] threads. The geometry of the nuts, with the exception of the recess shown in the drawing, shall conform to ANSI B18.2.2 [ANSI B18.2.4.1M Style 1] for zinc-coated hex nuts (shown in drawing) and ANSI B18.2.2 [ANSI B18.2.4.6M] for heavy hex corrosion-resistant nuts (not shown in drawing). Material for zinc-coated nuts shall conform to the requirements of AASHTO M 291 (ASTM A 563) Grade A [AASHTO M 291M (ASTM A 563M) Class 5], and material for corrosion-resistant nuts shall conform to the requirements of AASHTO M 291 (ASTM A 563) Grade C3 [AASHTO M 291M (ASTM A 563M) Class 8S3].

When zinc-coated bolts and nuts are required, the coating shall conform to either AASHTO M 232 (ASTM A 153/A 153M) for Class C or AASHTO M 298 (ASTM B 695) for Class 50. Zinc-coated nuts shall be tapped over-size as specified in AASHTO M 291 (ASTM A 563) [AASHTO M 291M (ASTM A 563M)], except that a diametrical allowance of 0.020 inch [0.510 mm] shall be used instead of 0.016 inches [0.420 mm].

Designator	Stress Area of Threaded Bolt Shank (in^2 [mm^2])	Min. Bolt Tensile Strength (kips [kN])
FBB01-05	0.226 [157.0]	13.6 [62.8]

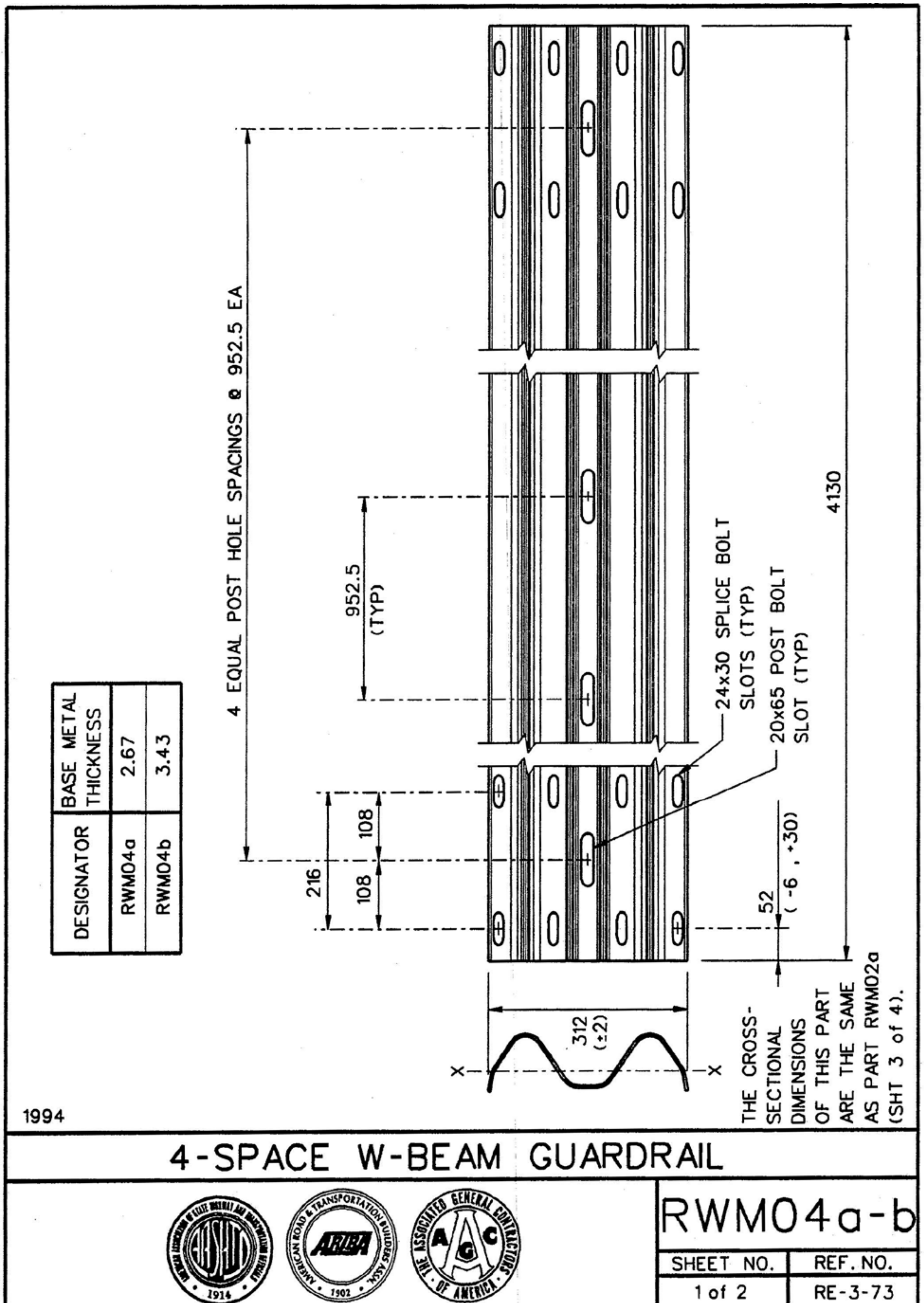
Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

INTENDED USE

These bolts and nuts are used in numerous guardrail and median barrier designs.

GUARDRAIL BOLT AND RECESSED NUT

FBB01-05	
SHEET NO.	DATE
2 of 2	6/30/2005


DESIGNATOR
BASE METAL THICKNESS
RWM04a
2.67
RWM04b
3.43
4 EQUAL POST HOLE SPACINGS @ 952.5 EA
952.5 (TYP)
216
108
108
24x30 SPLICE BOLT SLOTS (TYP)
20x65 POST BOLT SLOT (TYP)
4130
52 (-6 , +30)
312 (±2)
X
X
THE CROSS-SECTIONAL DIMENSIONS OF THIS PART ARE THE SAME AS PART RWM02a (SHT 3 of 4).
1994
4-SPACE W-BEAM GUARDRAIL
RWM04a-b
SHEET NO.
1 of 2
REF. NO.
RE-3-73

SPECIFICATIONS

Corrugated sheet steel beams shall conform to the current requirements of AASHTO M180. The section shall be manufactured from sheets with a nominal width of 483 mm. Guardrail RWM04a shall conform to AASHTO M180 Class A and RWM04b shall conform to Class B. Corrosion protection may be either Type II (zinc-coated) or Type IV (corrosion resistant steel). Corrosion resistant steel should conform to ASTM A606 for Type IV material and shall not be zinc-coated, painted or otherwise treated. Inertial properties are calculated for the whole cross-section without a reduction for the splice bolt holes.

Designator	Area (10^3 mm^2)	I_x (10^6 mm^4)	I_y (10^6 mm^4)	S_x (10^3 mm^3)	S_y (10^3 mm^3)
RWM04a-b	1.3	1.0	--	23	--

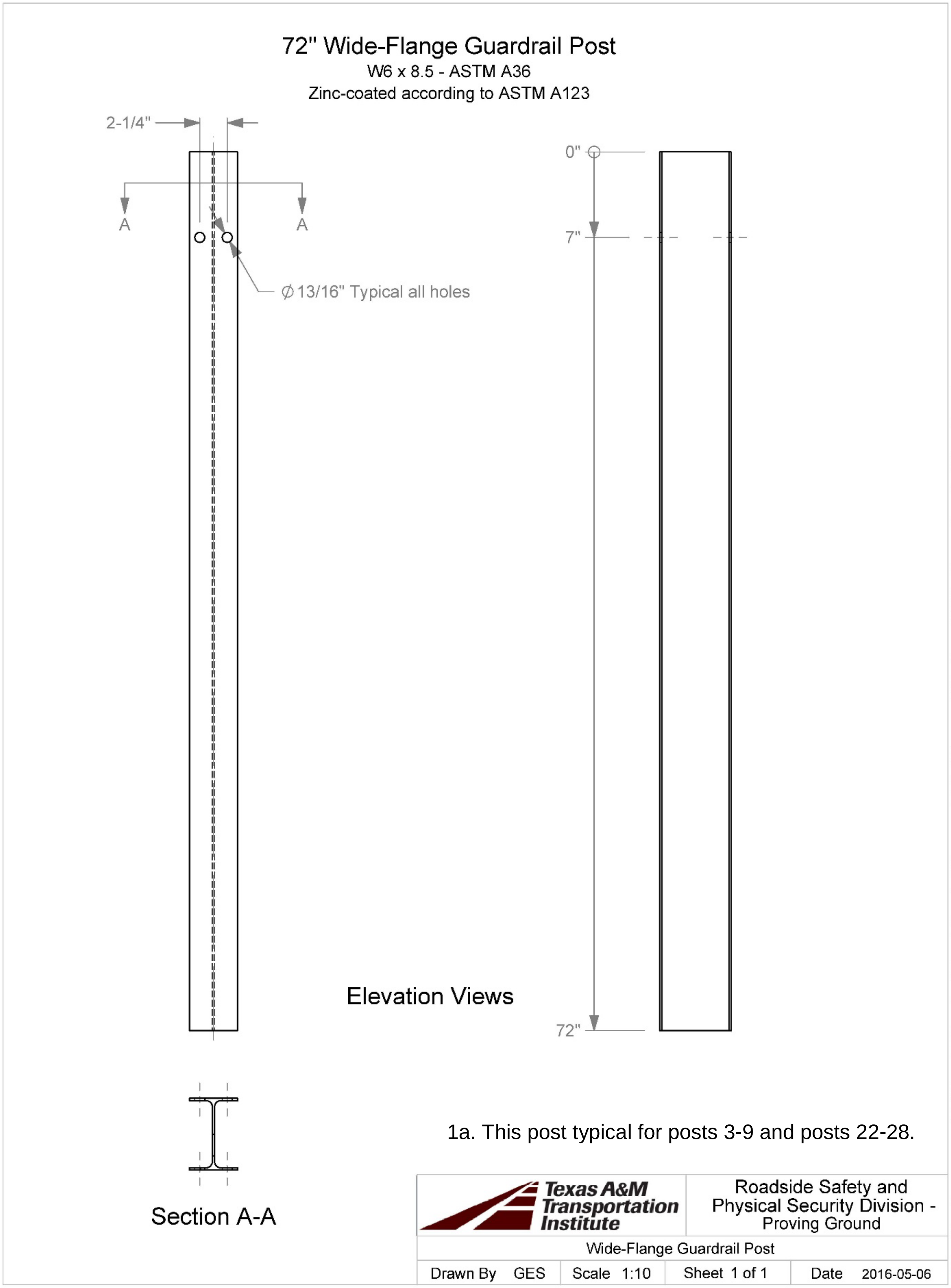
Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

INTENDED USE

This corrugated sheet steel beam is used as a rail element in transition systems STB02 and STB03 or when a reduced post spacing is desired in the SGR02, SGR04a-b, SGM02, and SGM04a-b.

4-SPACE W-BEAM GUARDRAIL

RWM04a-b	
SHEET NO.	DATE
2 of 2	04-01-95



T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Posts and Blockouts\Wide-Flange Guardrail Post Drawing

Certified Analysis

Trinity Highway Products , LLC
600 Prosperity Road
Orangeburg, SC 29115 Phn:(803) 533-1608

Customer: TEXAS A&M TRANSPORTATION INSTI
ROADSIDE SAFETY & PHYSICA
BUSINESS OFFICE
3135 TAMU
COLLEGE STATION, TX 77843-3135

Order Number: 1289023 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: POOL FUND
BOL Number: 59074 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 2/9/18

Project: POOL FUND GR ON SLOPE TESTING

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
13	24938G	9'0 POST/8.5#/DR	A-36			1800846	57,600	70,500	26.2	0.070	0.840	0.011	0.016	0.220	0.100	0.015	0.040	0.003	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

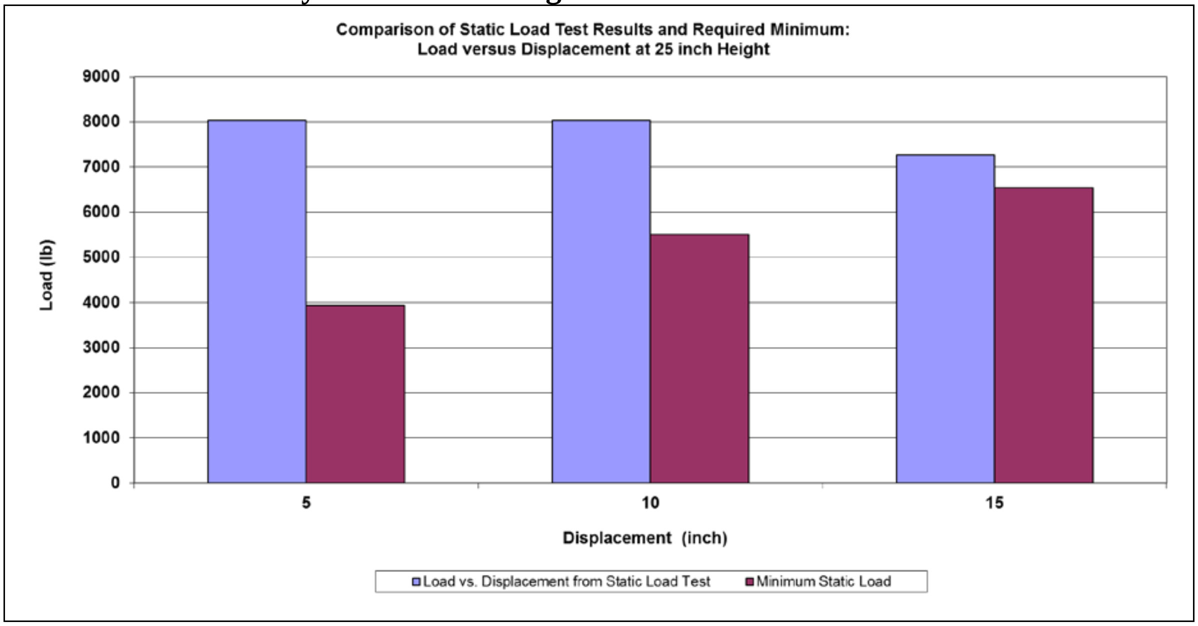
State of South Carolina, County of Orangeburg. Sworn and subscribed before me this 9th day of February, 2018 .

Notary Public: Jill A. Welch
Commission Expires 6/30/2027

Trinity Highway Products , LLC
Certified By:
Quality Assurance

A.3. SOIL PROPERTIES

Table A.1. Test Day Static Soil Strength Documentation for Test No. 609301-01-1.



Date	2018-03-09
Test Facility and Site Location..................	TTI Proving Ground – 3100 SH 47, Bryan, Tx
In Situ Soil Description (ASTM D2487).....	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis)
Description of Fill Placement Procedure...	6-inch lifts tamped with a pneumatic compactor

A.4. VEHICLE PROPERTIES

Table A.2. Vehicle Properties for Test No. 609301-01-1.

Date:	2018-03-09	Test No.:	609301-01-1	VIN No.:	KNADE223696461040
Year:	2009	Make:	KIA	Model:	RIO
Tire Inflation Pressure:	32 PSI	Odometer:	146457	Tire Size:	185/65R14

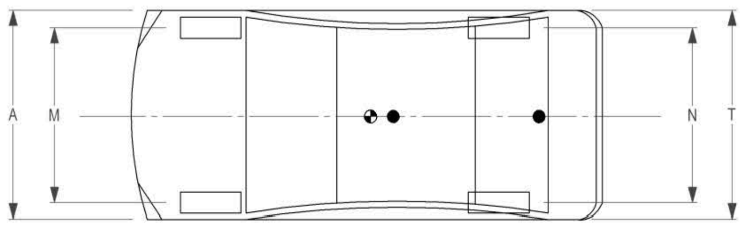
Describe any damage to the vehicle prior to test: None

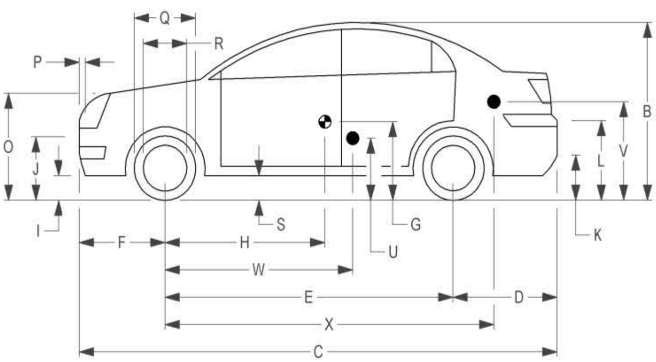
● Denotes accelerometer location.

NOTES: None

Engine Type: 4 CYL
Engine CID: 1.6 L
Transmission Type:
☑ Auto or ☐ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:
None

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Driver Side





Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	15.25
B	51.50	G		L	25.25	Q	22.50	V	20.50
C	165.75	H	35.80	M	57.75	R	15.50	W	35.80
D	34.00	I	7.75	N	57.70	S	8.25	X	107.00
E	98.75	J	21.50	O	28.25	T	66.20		
		Wheel Center Ht Front	11.00			Wheel Center Ht Rear	11.00	W-H	0.00

RANGE LIMIT: A = 65 ±3 inches; C = 168 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; G = 39 ±4 inches; O = TOP OF RADIATOR SUPPORT ~~(24 ±4 inches)~~; M+N/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1552	1554	1639
Back	1874	M_{rear}	786	883	963
Total	3638	M_{Total}	2338	2437	2602

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 761 RF: 793 LR: 438 RR: 445

A.4. SEQUENTIAL PHOTOGRAPHS

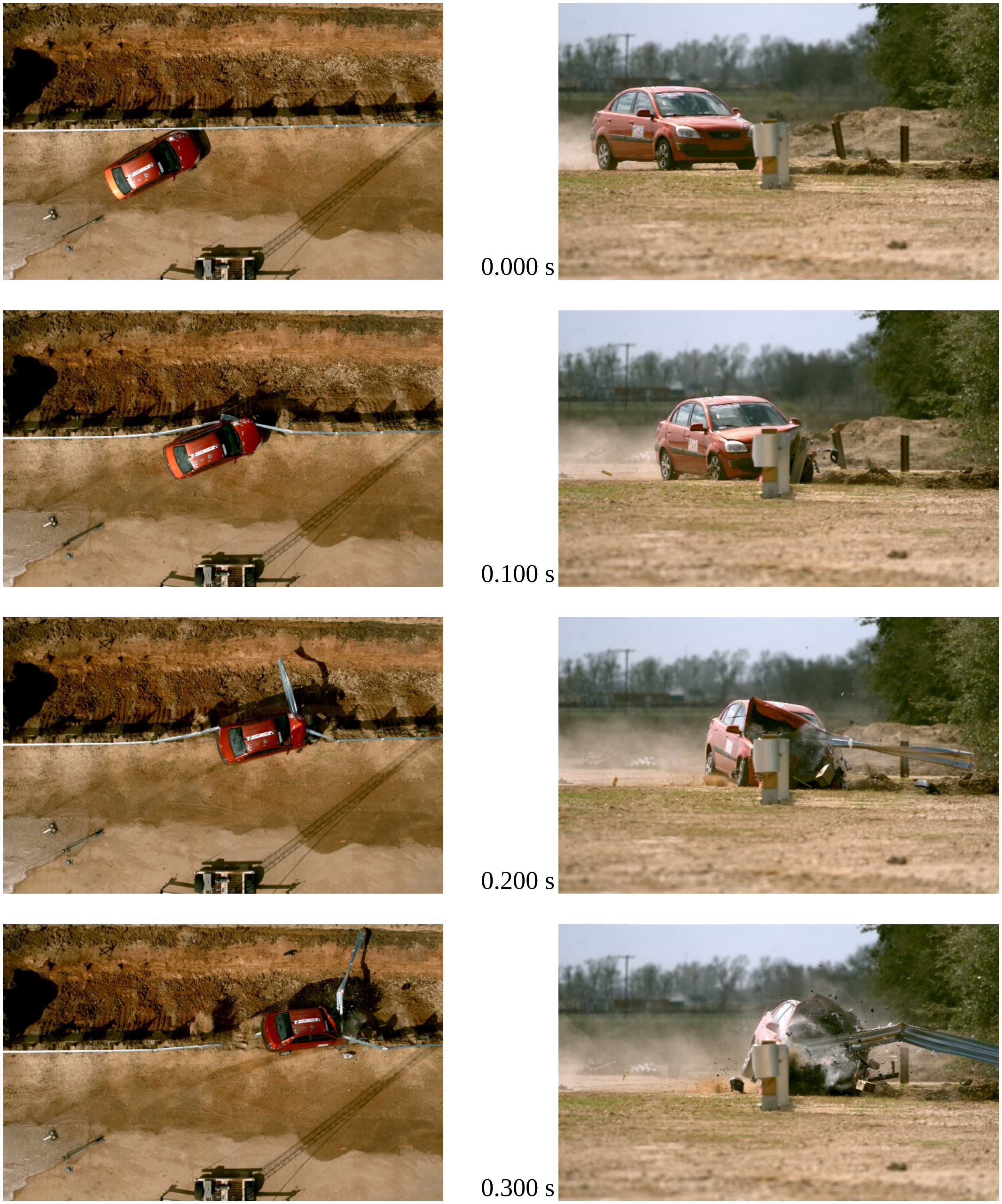


Figure A.1. Sequential Photographs for Test No. 609301-01-1 (Overhead and Frontal Views).

0.400 s

0.500 s

0.600 s

0.700 s

Figure A.1. Sequential Photographs for Test No. 609301-01-1 (Overhead and Frontal Views) (Continued).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

0.500 s

0.600 s

0.700 s

Figure A.2. Sequential Photographs for Test No. 609301-01-1 (Rear View).

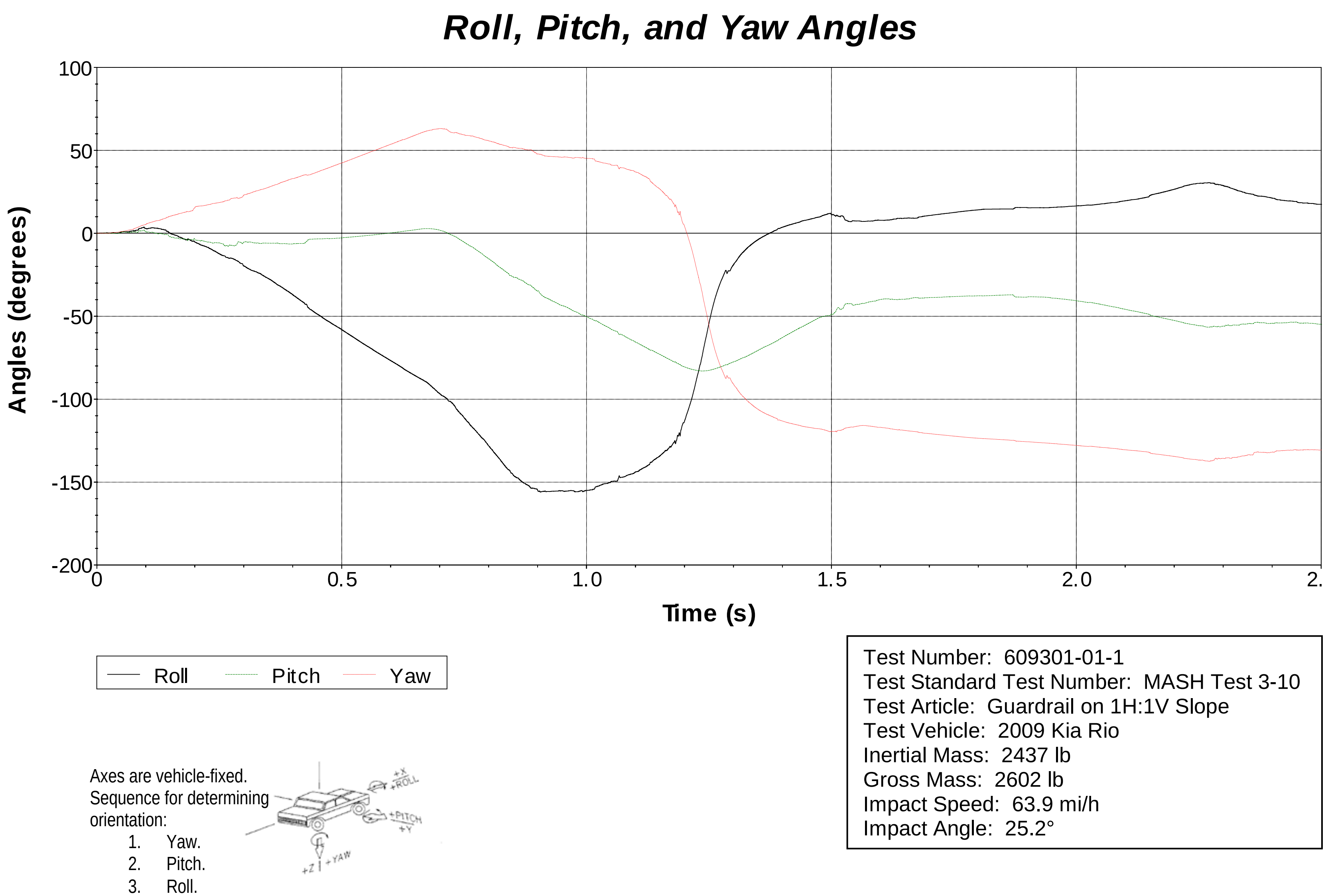
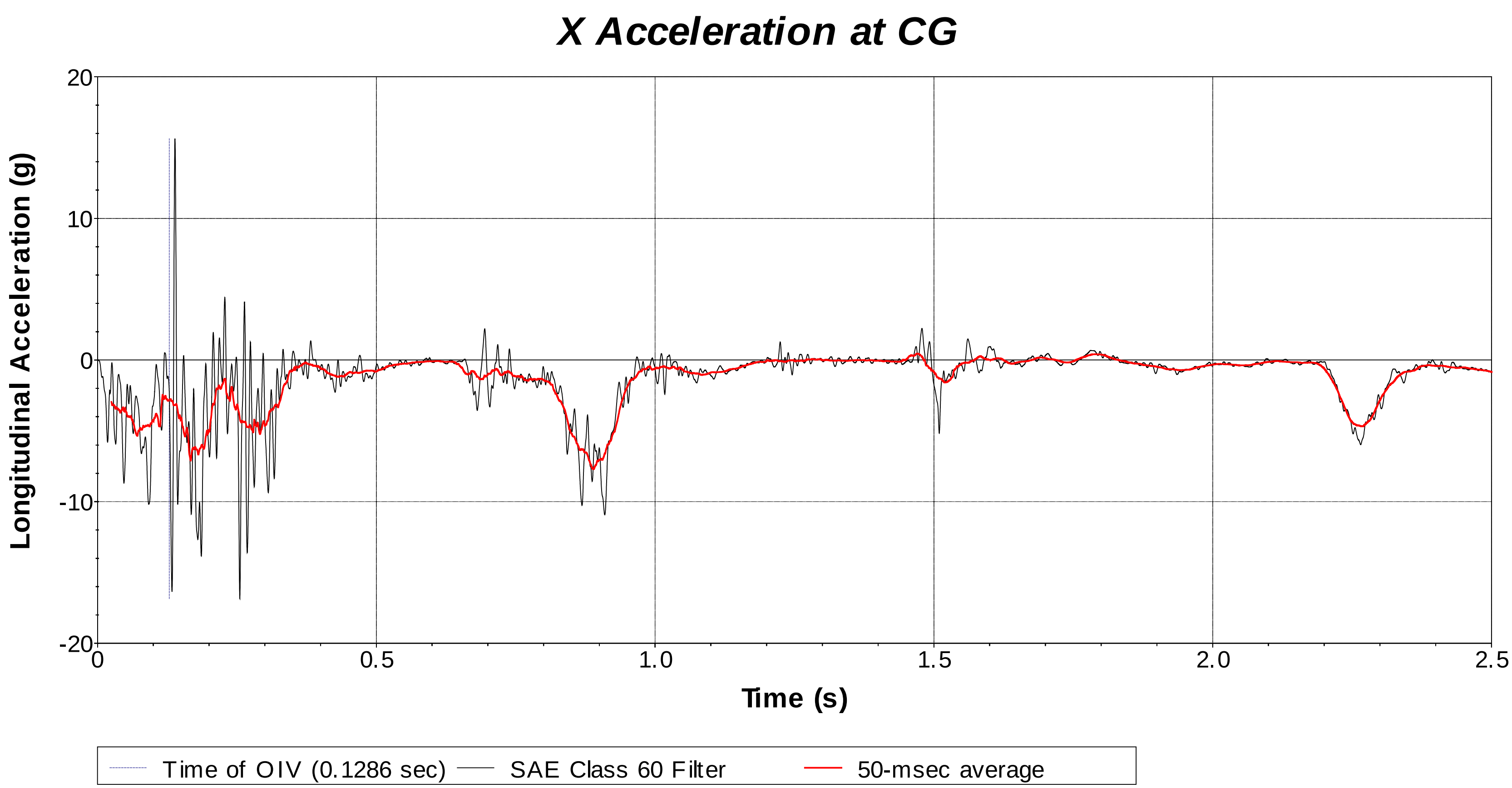
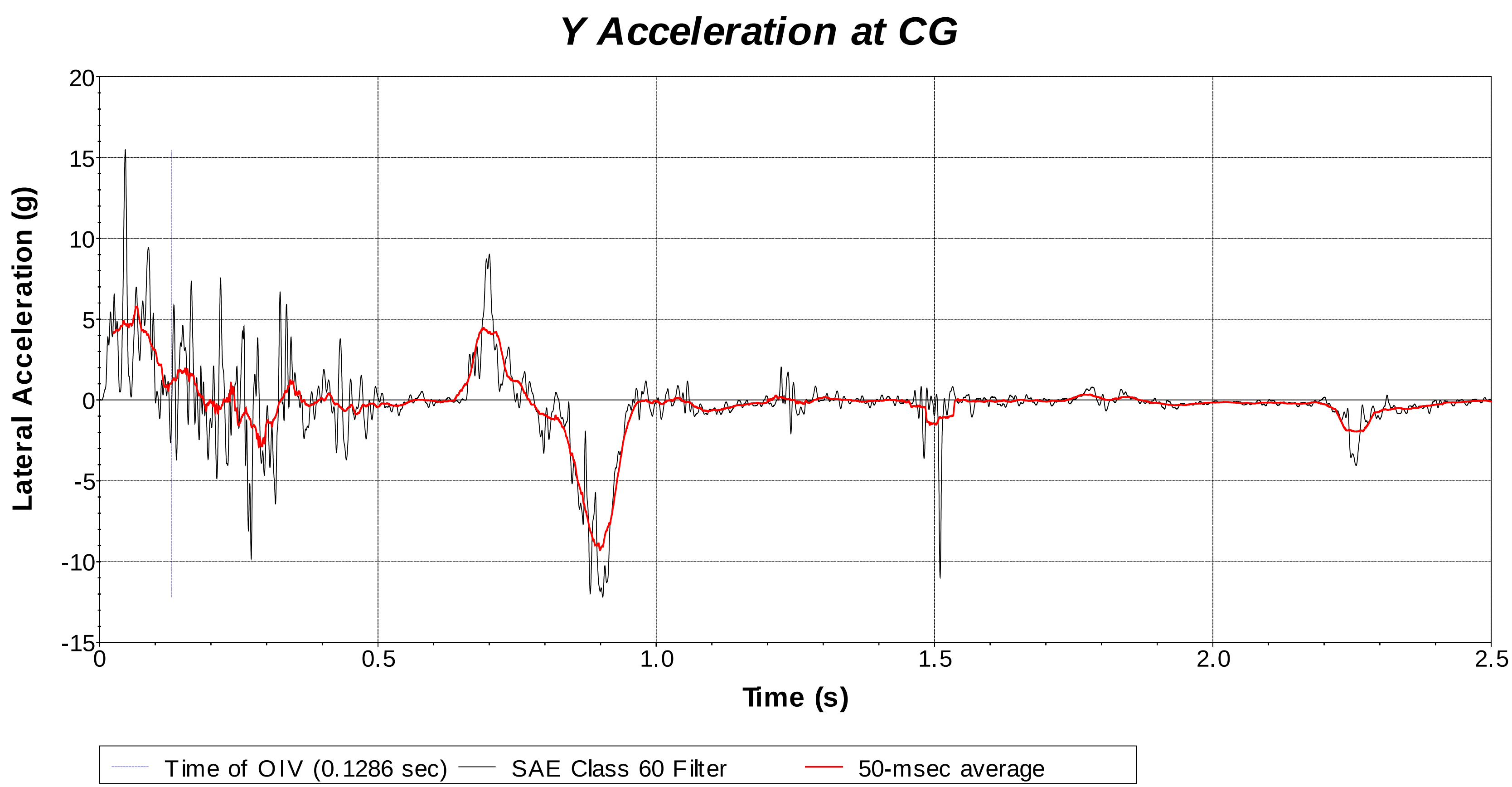


Figure A.3. Vehicle Angular Displacements for Test No. 609301-01-1.



Test Number: 609301-01-1
Test Standard Test Number: MASH Test 3-10
Test Article: Guardrail on 1H:1V Slope
Test Vehicle: 2009 Kia Rio
Inertial Mass: 2437 lb
Gross Mass: 2602 lb
Impact Speed: 63.9 mi/h
Impact Angle: 25.2°

Figure A.4. Vehicle Longitudinal Accelerometer Trace for Test No. 609301-01-1 (Accelerometer Located at Center of Gravity).



Test Number: 609301-01-1
Test Standard Test Number: MASH Test 3-10
Test Article: Guardrail on 1H:1V Slope
Test Vehicle: 2009 Kia Rio
Inertial Mass: 2437 lb
Gross Mass: 2602 lb
Impact Speed: 63.9 mi/h
Impact Angle: 25.2°

Figure A.5. Vehicle Lateral Accelerometer Trace for Test No. 609301-01-1 (Accelerometer Located at Center of Gravity).

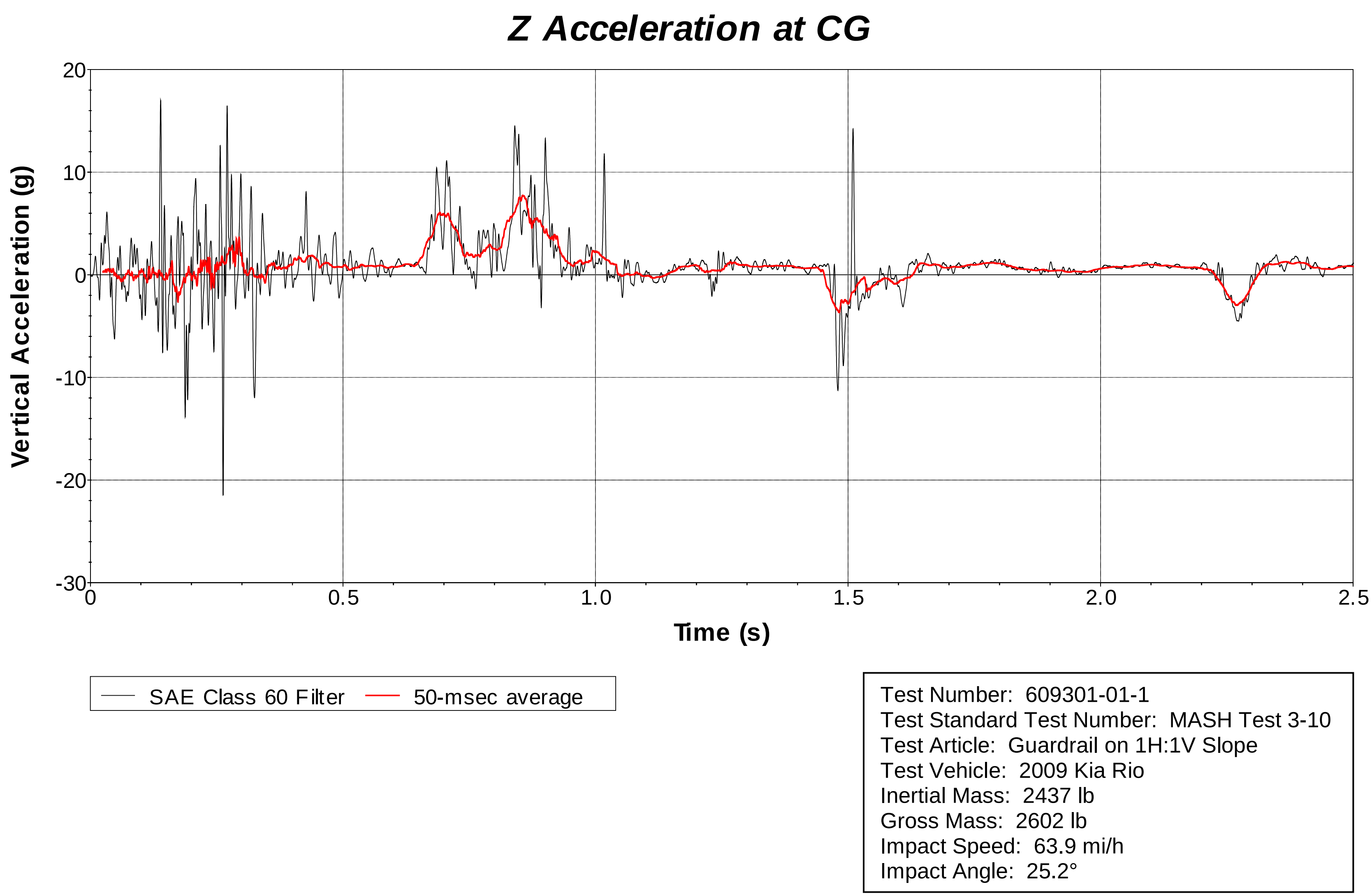


Figure A.6. Vehicle Vertical Accelerometer Trace for Test No. 609301-01-1 (Accelerometer Located at Center of Gravity).