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Texas A&M Transportation Institute Proving Ground

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Development of Thrie-Beam Retrofit for Upgrading Obsolete Bridge Rails

by

William F. Williams, P.E.
Associate Research Engineer

Sana Moran
Assistant Transportation Researcher

Wanda L. Menges
Research Specialist

William J. L. Schroeder
Engineering Research Associate

Bill L. Griffith
Research Specialist

Sarah W. Wegenast
Research Associate

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

A2LA ACCREDITED
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Name of Contacting Representative: Carlos Torres, P.E., Michigan Department of Transportation

16. Abstract

The purpose of this research was to investigate the crashworthiness of a thrie-beam retrofit bridge rail with respect to *MASH* Test Level 3 (TL-3) performance criteria. This new bridge rail can be anchored to a concrete curb without removing the existing obsolete or historical bridge rail that is already in place. The research team designed and tested this new retrofit bridge rail for this project. The research team evaluated the structural capacity and the occupant risk factors of this new thrie-beam retrofit bridge rail design with respect to *MASH* TL-3 criteria through full-scale crash testing.

The crash tests reported herein were performed in accordance with *MASH* TL-3 longitudinal barriers, which involves two tests on the Thrie Beam Bridge Rail Retrofit. The Thrie Beam Bridge Rail Retrofit met the performance criteria for *MASH* TL-3 longitudinal barriers.

17. Key Words	18. Distribution Statement
Longitudinal barrier, guardrail, bridge rail, bridge railing, thrie beam, retrofit, crash testing, roadside safety, *MASH*	

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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 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 for MASH Implementation Pooled Fund Committee
Revised January 2021

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 Transportation
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

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

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) 558-9576
Donna.J.Hardy@wv.gov

WEST VIRGINIA (continued)

Ted Whitmore
Traffic Services Engineer
(304) 558-9468
Ted.J.Whitmore@wv.gov

Joe Hall, P.E., P.S.
Division of Highways & Engineering
Technical Policy QA/QC Engineer
Value Engineering Coordinator
1334 Smith Street
Charleston, WV 25305-0430
(304) 558-9733
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.
Research Scientist
(979) 317-2687
C-Silvestri@tti.tamu.edu

REPORT AUTHORIZATION

REPORT REVIEWED BY:

DocuSigned by:
Glenn Schroeder
E632F9CB5047487...

Glenn Schroeder, Research Specialist
Drafting & Reporting

DocuSigned by:
Ken Reeves
60D556935596468...

Ken Reeves, Research Specialist
Electronics Instrumentation

DocuSigned by:
Gary Gerke
EBA2101E9E6B4B7...

Gary Gerke, Research Specialist
Construction

DocuSigned by:
Richard Badillo
9F51DA60AD144F9...

Richard Badillo, Research Specialist
Photographic Instrumentation

DocuSigned by:
Scott Dobrovolny
1G613885787C44C...

Scott Dobrovolny, Research Specialist
Mechanical Instrumentation

DocuSigned by:
Wanda L. Menges
B92179622AF24FE...

Wanda L. Menges, Research Specialist
Research Evaluation and Reporting

DocuSigned by:
Bill Griffith
44A122CB271845B...

Bill L. Griffith, Research Specialist
Deputy Quality Manager

DocuSigned by:
Darrell L. Kuhn
D4CC23E85D5B4E7...

Darrell L. Kuhn, P.E., Research Specialist
Quality Manager

DocuSigned by:
Matt Robinson
EAA22BFA8BFD417...

Matthew N. Robinson, Research Specialist
Test Facility Manager & Technical Manager

DocuSigned by:
William F. Williams
2B8AC4D2B3784AE...

William F. Williams, P.E.
Associate Research Engineer

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Chapter 1. INTRODUCTION

1.1. PROBLEM STATEMENT

The American Association of State Highway and Transportation Officials (AASHTO) recently published an updated 2016 edition of the Manual for Assessing Safety Hardware (*MASH*) document (*1*). Along with this, the Federal Highway Administration (FHWA) and AASHTO developed a revised joint implementation agreement which establishes dates for discontinuing the use of safety hardware that has met earlier crash testing criteria for new installations and full replacements on the National Highway System (NHS). Although some barrier testing was performed during the development of the updated criteria, many barrier systems and other roadside safety features have yet to be evaluated under the proposed guidelines. As we approach *MASH* implementation agreement sunset dates for National Cooperative Highway Research Program (NCHRP) *Report 350* devices, evaluation of the remaining widely used roadside safety features using the safety-performance evaluation guidelines included in *MASH* 2016 is needed (*2*).

There are over 600,000 bridges in the United States. Many of these bridges are obsolete with respect to the American Associations of State Highways and Transportation Officials (AASHTO) strength requirements as well as the safety performance criteria stated in *MASH*. Many of these bridges utilize a wide concrete curb with a concrete post and bridge rail system. More often than not, it is not economically feasible to replace the bridge rails for a newer *MASH* compliant design. Oftentimes, state transportation agencies may need to resort to a thrie-beam retrofit design when an obsolete bridge railing needs to be brought up to acceptable performance levels. Furthermore, it is often desirable for the existing bridge railing to remain in place for historical purposes and/or safety reasons.

The purpose of this research was to investigate the crashworthiness of a thrie-beam retrofit bridge rail with respect to *MASH* Test Level 3 (TL-3) performance criteria. This new bridge rail can be anchored to a concrete curb without removing the existing obsolete or historical bridge rail that is already in place. The research team designed and tested this new retrofit bridge rail for this project. The research team evaluated the structural capacity and the occupant risk factors of this new thrie-beam retrofit bridge rail design with respect to *MASH* TL-3 criteria through full-scale crash testing.

The information compiled from this research will provide the FHWA and State Departments of Transportation with an acceptable thrie-beam bridge rail system evaluated under *MASH* 2016 TL-3 conditions. A successfully crash-tested system will provide a good crashworthy retrofit design that all the states can use.

1.2. BACKGROUND

The 2016 *MASH* edition is the latest in a series of documents that provided guidance on testing and evaluation of roadside safety features. The original *MASH* document was published in 2009 and represents a comprehensive update to crash test and evaluation procedures to reflect changes in the vehicle fleet, operating conditions, and roadside safety knowledge and technology (*3*). The *MASH* documents supersede the *NCHRP Report 350*, "Recommended Procedures for the Safety Performance Evaluation of Highway Features" standards (*2*).

The FHWA issued a January 7, 2016 memo mandating the AASHTO/FHWA Joint Implementation Agreement for *MASH* with compliance dates for installing *MASH* hardware that differ by hardware category. After December 31, 2019, all roadside safety devices must have been successfully tested and evaluated according to the 2016 *MASH* standard edition. FHWA will no longer issue eligibility letters for highway safety hardware that has not been successfully crash tested according to the 2016 *MASH* edition evaluation criteria. At a minimum, all barriers on high-speed roadways on the NHS are required to meet TL-3 requirements.

The structural adequacy *MASH* 2016 test for TL-4 conditions consists of a 22,000-lb single unit truck (SUT) (denoted 10000S) impacting the barrier at 56 mi/h and 15 degrees with respect to the roadway (Test 4-12). The severity *MASH* 2016 test consists of a 5000-lb pickup truck (denoted 2270P) (Test 4-11) and a 2420-lb passenger car (denoted 1100C) (Test 4-10) impacting the barrier at 62 mph and 25 degrees with respect to the roadway.

MASH was developed to incorporate significant changes and additions to procedures for safety-performance evaluation, and updates reflecting the changing character of the highway network and the vehicles using it. For example, *MASH* increased the weight of the pickup truck design test vehicle from 4409 lb to 5000 lb, changed the body style from a ¾-ton, standard cab to a ½-ton, 4-door, and imposed a minimum height for the vertical center of gravity (cg) of 28 inches. The increase in vehicle mass represents an increase in impact severity of approximately 13 percent for Test 4-11 with the pickup truck design test vehicle with respect to the impact conditions of *NCHRP Report 350*. The increased impact severity may, therefore, result in increased impact forces and taller/higher barriers to contain and redirect vehicles compared to *NCHRP Report 350*.

The impact conditions for the small car test have also changed. The weight of the small passenger design test vehicle increased from 1800 lb to 2420 lb, and impact angle increased from 20 degrees to 25 degrees with respect to the roadway. These changes represent an increase in impact severity of 188 percent for Test 4-10 with the small car design test vehicle with respect to the impact conditions of *NCHRP Report 350*. This increase in impact severity might result in increased vehicle deformation and aggravate vehicle stability.

MASH also adopted more quantitative and stringent evaluation criteria for occupant compartment deformation than *NCHRP Report 350*. An increase in impact severity might result in increased vehicle deformation and could possibly result in failure to meet the latest *MASH* evaluation criteria. For example, *NCHRP Report 350* established a 6-inch threshold for occupant compartment deformation or intrusion. *MASH*, by comparison, limited the extent of roof crush to no more than 3.9 inches. In addition, *MASH* requires that the vehicle windshield not sustain a deformation greater than 3 inches, and not have holes or tears in the safety lining as a result of the test impact. Although these evaluation criteria are applicable to all roadside safety devices tested, they are most relevant for sign supports design and testing. In addition, little evaluation of sign supports has been performed with larger vehicles such as the pickup.

In addition, *MASH* Performance criteria requires bridge rails to meet the minimum height requirements of 36 inches for TL-4 and 29 inches TL-3. The design force for *MASH* TL-4 consists of 80 kips distributed over 4.0 ft at a loading height of 30 inches. The design force for *MASH* TL-3 consists of 71 kips distributed over 4.0 feet at a loading height of 19 inches. Many of these older/obsolete bridge rail systems do not meet the strength and height requirements for *MASH*.

Numerous states have existing bridge rails that do not meet the strength and performance requirements of *MASH*. Many of these old/obsolete bridge rail systems use wide curbs that can be used for limited pedestrian use. For example, Louisiana utilizes concrete barriers with walkways. One such design is used on the Lake Pontchartrain bridges in New Orleans over Lake Pontchartrain. There are numerous miles of bridges in Louisiana that use a similar design.

1.3. OBJECTIVE

The research objective was to design and test a thrie beam bridge rail retrofit that can be installed on bridges with old/obsolete bridge rail systems with a concrete curb that do not meet the crash performance requirements of *MASH* 2016. This new retrofit design should meet the crash performance requirements of *MASH* TL-3.

1.4. SCOPE OF WORK

1.4.1. Task 1 – Literature Review

The researchers performed a literature review of similar barrier retrofits systems that have been investigated and/or tested with thrie beam rail elements anchored to the curb or existing bridge rails. Details from several states department of transportation were review and evaluated. Information from this review was used to developed the concrete deck and curb details used for this project. The researchers used information gathered from this task to develop the proposed retrofit design for this project.

1.4.2. Task 2 – Engineering Design and Detailing

Based on the information gathered in Task 1, TTI researchers developed engineering details from information gathered from the member states involved with this project, along with the information gathered from Task 1. TTI researchers developed engineering details from the information received and circulated these details to the project team for review and approval. TTI researchers performed engineering strength calculations as necessary on the selected design in accordance with the design impact loading conditions for *MASH* TL-3. Within this task TTI researchers finalized the retrofit details of the installation characteristics of the system to be constructed. As part of this task, full scale test installation drawings were developed for construction of the test installation planned for Task 3.

1.4.3. Task 3 – Construction of Full-Scale Test Installation

For this task, TTI researchers constructed a full-scale test installation from the drawings and details developed in Task 2. The installation was constructed so that two full-scale crash tests could be performed. *MASH* Tests 3-11 and 3-10 were performed for this project.

1.4.4. Task 4 – Full-Scale Crash Testing – *MASH* Tests 3-11 and 3-10

TTI researchers performed two full-scale crash tests according to *MASH* 2016 TL-3 for longitudinal barriers. One full-scale test involves a 5000-lb pickup truck impacting the barrier system at 62 mi/h nominal speed with a nominal orientation of 25 degrees relative to the

roadway. A second full-scale crash test involves a 2425-lb small car impacting the rail at 62 mi/h nominal speed and at nominal orientation of 25 degrees relative to the roadway. Both tests were assessed according to the evaluation criteria set in *MASH* 2016 standards for *MASH* TL-3 requirements. These tests investigate the occupant risk of the retrofit bridge rail, as well as the passenger vehicles' stability during the impact events. These tests were assessed according to the evaluation criteria set in *MASH* 2016 standards. The results from these tests are reported herein.

Chapter 2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

The installation consisted of a 10-gauge thrie beam guardrail system mounted to 33 posts, spaced on 37½ inch centers, that were anchored to a concrete curb on a bridge deck. The bridge deck measured 42 inches wide, 103 ft-1½ inches long, and included a 12-inch-thick wall, so the deck was cantilevered 30". The 18-inch wide, 6-inch tall curb was installed 1½ inches from the field side edge of the bridge deck, and extended for the length of the deck. The top of the thrie beam rail was located 34 inches above the roadway and supported by W6×15 posts with timber blockouts. The traffic side faces of the posts were located 6½ inches back from the traffic side face of the curb. Each bridge deck post was welded to a ¾-inch thick anchor plate, which was bolted to the curb with four ⅞-inch diameter B7 threaded rods secured with Hilti HIT-RE 500 V3 epoxy. On both the upstream and downstream ends, the thrie beam transitioned to a Texas Department of Transportation (TxDOT) Downstream Anchor Terminal (DAT). The length-of-need for this installation was 100 ft.

Figure 2.1 presents the overall information on the Thrie Beam Bridge Rail Retrofit, and Figure 2.2 provides photographs of the installation. Appendix A provides further details on the Thrie Beam Bridge Rail Retrofit. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by MBC Management supervised by TTI Proving Ground personnel.

Instrumentation On Anchor Bolts

Load washers were placed on the traffic side anchors bolts for Post Numbers 14 through 18 (10 total). These load washers were manufactured by Transducer Techniques Model No. LWO-80. These load washers were used to record the tension forces in the traffic side anchor bolts for the post in the impact area for Test 3-11. This information from these load washers is not provided in this report and has been shared separately with the pooled fund team members associated with this project. Please refer to the test installation drawings and the photographs provided in this report for additional information.

2.2. DESIGN MODIFICATIONS DURING TESTS

No modification was made to the installation during the testing phase.

2.3. MATERIAL SPECIFICATIONS

Table 2.1 shows the average compressive strengths of the concrete used in the installation:

Table 2.1 Concrete Strength.

Location	Design Strength (psi)	Average Strength (psi)	Age (days)	Detailed Location
Wall and Deck	3300	4587	22	Right of expansion joint
Wall and Deck	3300	4870	18	Section left of expansion joint
Curb	3300	4427	18	Section right of expansion joint
Curb	3300	4173	13	Section left of expansion joint

Appendix B provides material certification documents for the materials used to install/construct the Thrie Beam Bridge Rail Retrofit.

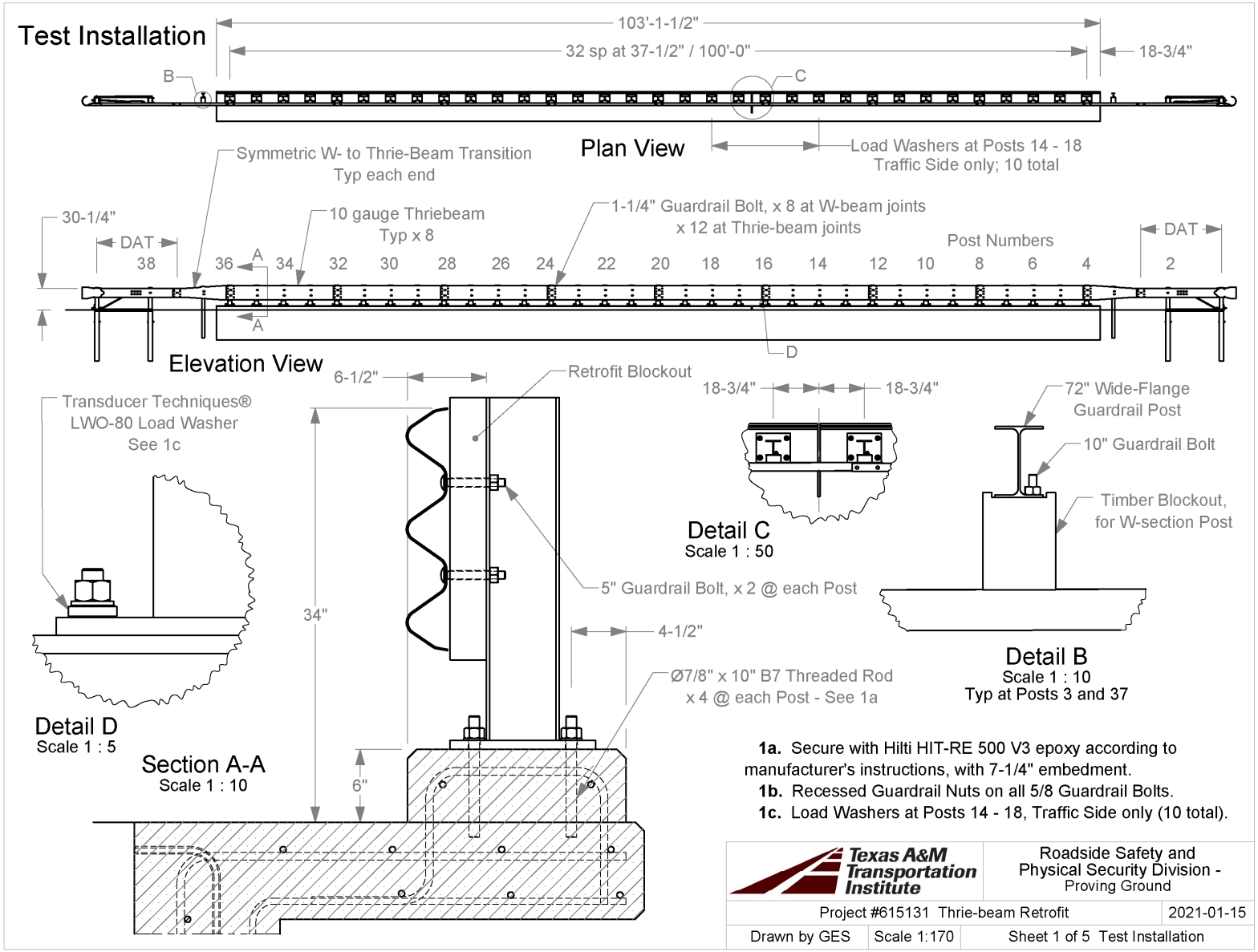


Figure 2.1. Details of Thrie Beam Bridge Rail Retrofit.

Figure 2.2. Thrie Beam Bridge Rail Retrofit prior to Testing.

2.4 SOIL CONDITIONS

Three posts on each end were installed in standard soil with crushed concrete backfill meeting grading D of AASHTO standard specification M147-2017 "Materials for Aggregate and Soil Aggregate Subbase, Base and Surface Courses."

In accordance with Appendix B of *MASH*, soil strength was measured the day of the crash test. During installation of the Thrie Beam Bridge Rail Retrofit for full-scale crash testing, two 6-ft long W6×16 posts were installed in the immediate vicinity of the Thrie Beam Bridge

Rail Retrofit using the same fill materials and installation procedures used in the test installation and the standard dynamic test. Table C.1 in Appendix C presents minimum soil strength properties established through the dynamic testing performed in accordance with *MASH* Appendix B.

As determined by the tests summarized in Appendix C, Table C.1, the minimum post loads required for deflections at 5 inches, 10 inches, and 15 inches, measured at a height of 25 inches, are 4420 lbf, 4981 lbf, and 5282 lbf (90 percent of static load for the initial standard installation).

On the day of Test No. 615131-01-2, June 23, 2021, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 5808 lbf, 7272 lbf, and 8333 lbf. Table C.2 in Appendix C shows the strength of the backfill material in which the Thrie Beam Bridge Rail Retrofit was installed met minimum *MASH* requirements for soil strength.

On the day of Test No. 615131-01-1, July 21, 2021, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 7818 lbf, 7819 lbf, and 7606 lbf. Table C.3 in Appendix C shows the strength of the backfill material in which the Thrie Beam Bridge Rail Retrofit was installed met minimum *MASH* requirements for soil strength.

Chapter 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1. CRASH TEST PERFORMED/MATRIX

Table 3.1. shows the test conditions and evaluation criteria for *MASH* TL-3 for longitudinal barriers. The target critical impact points (CIPs) for each test were determined using the information provided in *MASH* Section 2.2.1 and Section 2.3.2. Figure 3.1 and Figure 3.2 show the target CIPs for *MASH* Tests 3-10 and 3-11 on the Thrie Beam Bridge Rail Retrofit.

Table 3.1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Longitudinal Barriers.

Test Article	Test Designation	Test Vehicle	Impact Conditions		Evaluation Criteria
			Speed	Angle	
Longitudinal Barrier	3-10	1100C	62 mi/h	25°	A, D, F, H, I
	3-11	2270P	62 mi/h	25°	A, D, F, H, I

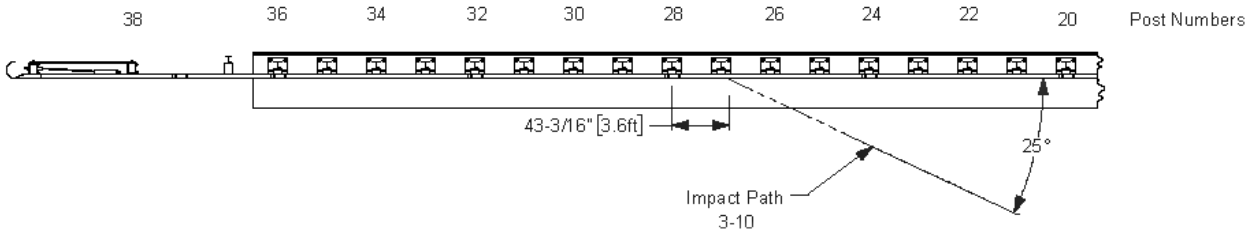


Figure 3.1. Target CIP for *MASH* Test 3-10 on Thrie Beam Bridge Rail Retrofit.

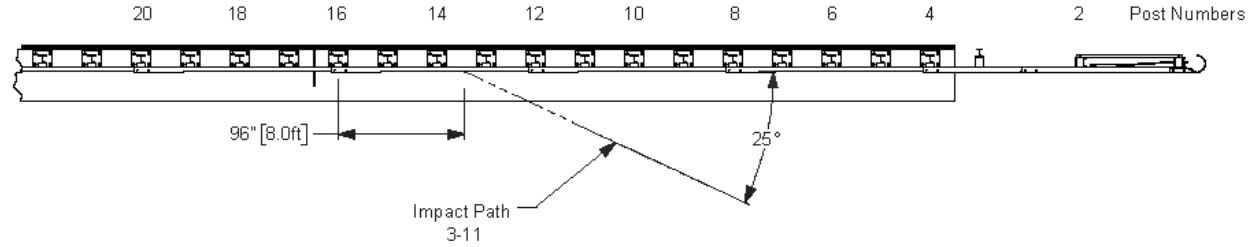


Figure 3.2. Target CIP for *MASH* Test 3-11 on Thrie Beam Bridge Rail Retrofit.

The crash tests 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 appropriate safety evaluation criteria from Tables 2-2 and 5-1 of *MASH* were used to evaluate the crash tests reported herein. Table 3.1. lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 3.2 provides detailed information on the evaluation criteria. An evaluation of the crash test results is presented in Chapter 7.

Table 3.2. Evaluation Criteria Required for *MASH* TL-3 Longitudinal Barriers.

Evaluation Factors	Evaluation Criteria	*MASH* Test
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.*	*3-10 and 3-11*
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 undue hazard to other traffic, pedestrians, or personnel in a work zone.* *Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.*	*3-10 and 3-11*
	F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	*3-10 and 3-11*
	H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.	*3-10 and 3-11*
	I. The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	*3-10 and 3-11*

Chapter 4. TEST CONDITIONS

4.1. TEST FACILITY

The full-scale crash tests reported herein were performed at the TTI Proving Ground, an International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing Certificate 2821.01. The full-scale crash tests were performed according to TTI Proving Ground quality procedures, as well as *MASH* guidelines and standards.

The test facilities of the TTI Proving Ground are located on The Texas A&M University System RELLIS Campus, which consists of a 2000-acre complex of research and training facilities situated 10 mi northwest of the flagship campus of Texas A&M University. The site, formerly a United States Army Air Corps 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, highway pavement durability and efficacy, and roadside safety hardware and perimeter protective device evaluation. The site selected for construction and testing of the Thrie Beam Bridge Rail Retrofit was along the edge of an 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 aprons were built in 1942, and the joints have some displacement but are otherwise flat and level.

4.2. VEHICLE TOW AND GUIDANCE SYSTEM

Each 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 and 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 2:1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released and ran unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site.

4.3. DATA ACQUISITION SYSTEMS

4.3.1. Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a multi-channel data acquisition system (DAS) produced by Diversified Technical Systems Inc. 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 data acquisition hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 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 samples per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit in case the primary battery cable is severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the DAS 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 DAS is returned to the factory annually for complete recalibration and to ensure that all instrumentation used in the vehicle conforms to the specifications outlined by SAE J211. All accelerometers are calibrated annually by means of an ENDEVCO® 2901 precision primary vibration standard. This standard and its support instruments are checked annually and receive a National Institute of Standards Technology (NIST) traceable calibration. The rate transducers used in the data acquisition system receive calibration via a Genisco Rate-of-Turn table. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel per SAE J211. Calibrations and evaluations are also made anytime data are suspect. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k = 2).

TRAP uses the DAS-captured data to compute the occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and 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 an SAE Class 180-Hz low-pass 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, and 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 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

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the front seat on the impact side of the 1100C vehicle. The dummy was not instrumented.

According to *MASH*, use of a dummy in the 2270P vehicle is optional. However, *MASH* recommends that a dummy be used when testing "any longitudinal barrier with a height greater than or equal to 33 inches." More specifically, use of the dummy in the 2270P vehicle is recommended for tall rails to evaluate the "potential for an occupant to extend out of the vehicle and come into direct contact with the test article." Although this information is reported, it is not part of the impact performance evaluation. Since the rail height of the Thrie Beam Bridge Rail Retrofit was 34 inches, a dummy was placed in the front seat of the 2270P vehicle on the impact side and restrained with lap and shoulder belts.

4.3.3. Photographic Instrumentation Data Processing

Photographic coverage of each test included three digital high-speed cameras:

- One overhead with a field of view perpendicular to the ground and directly over the impact point.
- One placed upstream from the installation at an angle to have a field of view of the interaction of the rear of the vehicle with the installation.
- A third placed with a field of view parallel to and aligned with the installation at the downstream end.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Thrie Beam Bridge Rail Retrofit. The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

Chapter 5. *MASH* TEST 3-11 (CRASH TEST NO. 615131-01-2)

5.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb ± 110 lb impacting the CIP of the longitudinal barrier 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 3-11 on the Thrie Beam Bridge Rail Retrofit was 8.0 ft ± 1 ft upstream of centerline of post 16. Figure 3.1 and Figure 5.1 depict the target impact setup.

Figure 5.1. Bridge Rail Retrofit/Test Vehicle Geometrics for Test No. 612131-01-2.

The 2270P vehicle weighed 5021 lb, and the actual impact speed and angle were 62.0 mi/h and 25.1 degrees. The actual impact point was 8.2 ft upstream of centerline of post 16. Minimum target impact severity (IS) was 106 kip-ft, and actual IS was 116 kip-ft.

5.2. WEATHER CONDITIONS

The test was performed on the afternoon of June 23, 2021. Weather conditions at the time of testing were as follows: wind speed: 7 mi/h; wind direction: 171 degrees (vehicle was traveling at a heading of 135 degrees); temperature: 89°F; relative humidity: 78 percent.

6.3. TEST VEHICLE

Figure 5.2 shows the 2018 RAM 1500 pickup truck used for the crash test. The vehicle's test inertia weight was 5021 lb, and its gross static weight was 5186 lb. The height to the lower edge of the vehicle bumper was 11.75 inches, and height to the upper edge of the bumper was 27.0 inches. The height to the vehicle's center of gravity was 28.5 inches. Tables D.1 and D.2 in Appendix D.1 give additional dimensions and information on the vehicle. 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.

Figure 5.2. Test Vehicle before Test No. 612131-01-2.

6.4. TEST DESCRIPTION

Table 5.1 lists events that occurred during Test No. 612131-01-2. Figures D.1 and D.2 in Appendix D.2 present sequential photographs during the test.

Table 5.1. Events during Test No. 612131-01-2.

Time (s)	Events
0.0000	Vehicle impacts bridge rail
0.0188	Post 14 begins to deflect towards field side
0.0400	Vehicle begins to redirect
0.1350	Left rear tire lifts off of the pavement
0.1480	Left front tire lifts off of the pavement
0.2450	Vehicle travelling parallel to bridge rail
0.2450	Right rear bumper contacts rail
0.4420	Vehicle loses contact with bridge rail while traveling at 46.7 mi/h, exit trajectory of 7.2°, and exit heading of 10.9°

For longitudinal barriers, it is desirable for the vehicle to redirect and exit the barrier within the exit box criteria (not less than 32.8 ft downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in *MASH*. Brakes on the vehicle were applied at 3.0 s after impact, and the vehicle subsequently came to rest 206 ft downstream of the point of impact and 35 ft toward field side.

6.5. DAMAGE TO TEST INSTALLATION

Figure 5.3 shows the damage to the Thrie Beam Bridge Rail Retrofit. There was scuffing and gouging of the rail and curb at impact and for the duration of contact. The rail tore at post 15 and a piece of the vehicle's tire rim was embedded in the rail. There were cracks in the curb extending from the upstream edge of post 15 to the midspan between posts 14 and 15, and from the upstream edge of post 14 to the midspan between posts 13 and 14. There was also a crack at post 13, and the deck was cracked from the field joint extending upstream to post 14. The lower

portion of the rail was deformed more than the upper portion, and the deformation measured 4¾ inches at 15 inches upstream from post 15. Posts 13, 14, and 16 were all leaning 1.0 degree toward the field side from vertical, and post 15 was leaning 1.5 degrees toward the field side. Working width* was 22.1 inches, and height of working width was 52.1 inches. Maximum dynamic deflection during the test was 2.2 inches, and maximum permanent deformation was 2.0 inches.

6.6. DAMAGE TO TEST VEHICLE

Figure 5.4 shows the damage sustained by the vehicle. The front bumper, hood, grill, right front fender, right upper and lower control arms, right frame rail, right front tire and rim, right front floor pan, right front door, right rear door, right rear cab corner, right rear exterior bed, and rear bumper were damaged. The windshield sustained cracks radiating upward and inward from the right lower corner. No fuel tank damage was observed. Maximum exterior crush to the vehicle was 15.0 inches in the side plane at the right front corner at bumper height. Maximum occupant compartment deformation was 3.5 inches in the right kick panel area. Figure 5.5 shows the interior of the vehicle. Tables D.3 and D.4 in Appendix D.1 provide exterior crush and occupant compartment measurements.

6.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 5.2. Figure D.3 in Appendix D.3 shows the vehicle angular displacements, and Figures D.4 through D.6 in Appendix D.4 show acceleration versus time traces. Figure 5.6 summarizes pertinent information from the test.

* Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 5.3. Bridge Rail Retrofit after Test No. 612131-01-2.

Figure 5.4. Test Vehicle after Test No. 612131-01-2.

Figure 5.5. Interior of Test Vehicle after Test No. 612131-01-2.

Table 5.2. Occupant Risk Factors for Test No. 612131-01-2.

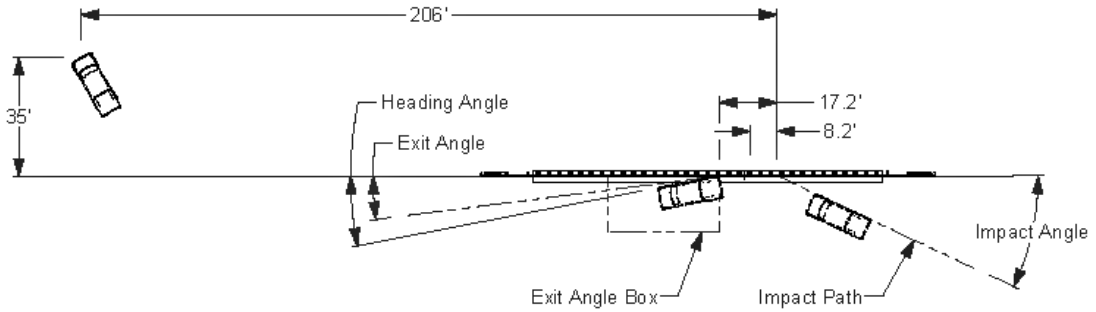
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		
Longitudinal	26.3 ft/s	at 0.1025 s on right side of interior
Lateral	25.3 ft/s	
Occupant Ridedown Accelerations		
Longitudinal	8.2 g	0.1066 - 0.1166 s
Lateral	7.6 g	0.3101 - 0.3201 s
Theoretical Head Impact Velocity (THIV)	11.1 m/s	at 0.1000 s on right side of interior
Acceleration Severity Index (ASI)	1.7	0.0535 - 0.1035 s
Maximum 50-ms Moving Average		
Longitudinal	−12.0 g	0.0419 - 0.0919 s
Lateral	−12.1 g	0.0374 - 0.0874 s
Vertical	5.2 g	0.1045 - 0.1545 s
Maximum Yaw, Pitch, and Roll Angles		
Roll	20°	0.6517 s
Pitch	9°	0.4752 s
Yaw	41°	0.7531 s

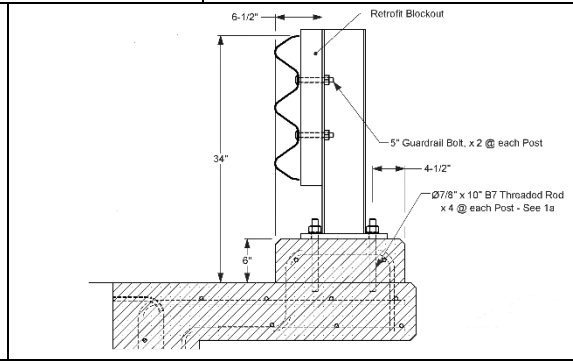

0.000 s


0.100 s


0.200 s


0.400 s





General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... *MASH* Test 3-11
- TTI Test No. 615131-01-2
- Test Date 2021-06-23

Test Article
- Type ..... Longitudinal Barrier—Bridge Rail
- Name ..... Thrie Beam Bridge Rail Retrofit
- Installation Length ..... 100 ft of 34-inch tall rail
- Material or Key Elements ... Thrie-Beam with blockouts mounted to steel posts retrofit anchored to existing concrete bridge deck curb

Soil Type and Condition ..... Concrete bridge deck, damp

Test Vehicle
- Type/Designation 2270P
- Make and Model ..... 2018 RAM 1500 Pickup
- Curb ..... 4955 lb
- Test Inertial ..... 5021 lb
- Dummy ..... 165 lb
- Gross Static ..... 5186 lb

Impact Conditions
- Speed ..... 62.0 mi/h
- Angle ..... 25.1°
- Location/Orientation ..... 8.2 ft upstream of post 16

Impact Severity ..... 116 kip-ft

Exit Conditions
- Speed ..... 46.7 mi/h
- Trajectory/Heading Angle ... 7.2°/10.9°

Occupant Risk Values
- Longitudinal OIV ..... 26.3 ft/s
- Lateral OIV ..... 25.3 ft/s
- Longitudinal Ridedown ..... 8.2 g
- Lateral Ridedown ..... 7.6 g
- THIV ..... 11.1 m/s
- ASI 1.7

Max. 0.050-s Average
- Longitudinal ..... −12.0 g
- Lateral ..... −12.1 g
- Vertical ..... 5.2 g

Post-Impact Trajectory
- Stopping Distance ..... 206 ft downstream 35 ft twd field side

Vehicle Stability
- Maximum Roll Angle ..... 20°
- Maximum Pitch Angle ..... 9°
- Maximum Yaw Angle ..... 41°
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 2.2 inches
- Permanent ..... 2.0 inches
- Working Width ..... 22.1 inches
- Height of Working Width ..... 52.1 inches

Vehicle Damage
- VDS 01RFQ5
- CDC 01FREW4
- Max. Exterior Deformation ..... 15.0 inches
- OCDI RF0010000
- Max. Occupant Compartment Deformation ..... 3.5 inches

Figure 5.6. Summary of Results for *MASH* Test 3-11 on Thrie Beam Bridge Rail Retrofit.

Chapter 6. *MASH* TEST 3-10 (CRASH TEST NO. 615131-01-1)

5.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-10 involves a 1100C vehicle weighing 2420 lb ± 55 lb impacting the CIP of the longitudinal barrier 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 Thrie Beam Bridge Rail Retrofit was 3.6 ft ± 1 ft upstream of the centerline of post 28. Figure 3.1 and Figure 6.1 depict the target impact setup.

Figure 6.1. Bridge Rail Retrofit/Test Vehicle Geometrics for Test No. 615131-01-1.

The 1100C vehicle weighed 2451 lb, and the actual impact speed and angle were 62.1 mi/h and 24.3 degrees. The actual impact point was 3.2 ft upstream of the centerline of post 28. Minimum target IS was 51 kip-ft, and actual IS was 54 kip-ft.

5.2. WEATHER CONDITIONS

The test was performed on the morning of July 21, 2021. Weather conditions at the time of testing were as follows: wind speed: 5 mi/h; wind direction: 5 degrees (vehicle was traveling at a heading of 135 degrees); temperature: 84°F; relative humidity: 79 percent.

5.3. TEST VEHICLE

Figure 6.2 shows the 2015 Nissan Versa used for the crash test. The vehicle's test inertia weight was 2451 lb, and its gross static weight was 2616 lb. The height to the lower edge of the vehicle bumper was 7.0 inches, and the height to the upper edge of the bumper was 22.25 inches. Table E.1 in Appendix E.1 gives additional dimensions and information on the vehicle. 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.

Figure 6.2. Test Vehicle before Test No. 615131-01-1.

5.4. TEST DESCRIPTION

Table 6.1 lists events that occurred during Test No. 615131-01-1. Figures E.1 and E.2 in Appendix E.2 present sequential photographs during the test.

Table 6.1. Events during Test No. 615131-01-1.

Time (s)	Events
0.0000	Vehicle impacts bridge rail
0.0263	Post 28 begins to deflect towards the field side
0.0290	Vehicle begins to redirect
0.1580	Vehicle travelling parallel to bridge rail
0.1690	Right rear bumper contacts rail
0.3010	Vehicle exits the installation at 49.7 mi/h, exit trajectory of 7.0 degrees, and exit heading of 10.6 degrees

For longitudinal barriers, it is desirable for the vehicle to redirect and exit the barrier within the exit box criteria (not less than 32.8 ft downstream from loss of contact for cars and pickups). The test vehicle exited within the exit box criteria defined in *MASH*. Brakes on the vehicle were applied at 2.1 s after impact, and the vehicle subsequently came to rest 202 ft downstream of the point of impact and 52 ft toward traffic lanes.

5.5. DAMAGE TO TEST INSTALLATION

Figure 6.3 shows the damage to the bridge rail retrofit. There was scuffing and gouging of the rail and curb at impact and for the duration of contact. The lower rib of the thrie-beam was deformed, and the blockout at post 27 was damaged. The curb had some spalling, and there were cracks at posts 27 and 28. Cracks in the curb pre-impact were outlined in blue, and cracks that

occurred post-impact were outlined in red. Working width* was 19.5 inches, and height of working width was 34.0 inches. Maximum dynamic deflection during the test was 2.2 inches, and maximum permanent deformation was 0.9 inch.

Figure 6.3. Bridge Rail Retrofit after Test No. 615131-01-1.

5.6. DAMAGE TO TEST VEHICLE

Figure 6.4 shows the damage sustained by the vehicle. The front bumper, hood, grill, radiator and support, right front fender, right front tire and rim, right front strut and tower, right inner CV joint, right front floor pan, right front door and window glass, right rear door, right rear rim, right rear quarter panel, and rear bumper were damaged. The windshield sustained cracks radiating upward and inward from the right lower corner. No fuel tank damage was observed. Maximum exterior crush to the vehicle was 10.0 inches in the front plane at the right front corner at bumper height. Maximum occupant compartment deformation was 1.5 inches in the right front floor pan. Figure 6.5 shows the interior of the vehicle. Tables E.2 and E.3 in Appendix E.1 provide exterior crush and occupant compartment measurements.

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* Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 6.4. Test Vehicle after Test No. 615131-01-1.

Figure 6.5. Interior of Test Vehicle after Test No. 615131-01-1.

5.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.2. Figure E.3 in Appendix E.3 shows the vehicle angular displacements, and Figures E.4 through E.6 in Appendix E.4 show acceleration versus time traces. Figure 6.6 summarizes pertinent information from the test.

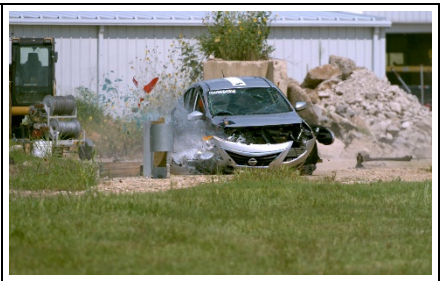
Table 6.2. Occupant Risk Factors for Test No. 615131-01-1.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	21.2 ft/s	at 0.0796 s on right side of interior
Lateral	31.4 ft/s	
Occupant Ridedown Accelerations		
Longitudinal	3.0 g	0.1803 - 0.1903 s
Lateral	10.9 g	0.1823 - 0.1923 s
THIV	11.5 m/s	at 0.0779 s on right side of interior
ASI	2.7	0.0507 - 0.1007 s
Maximum 50-ms Moving Average		
Longitudinal	−12.1 g	0.0256 - 0.0756 s
Lateral	−18.9 g	0.0226 - 0.0726 s
Vertical	3.6 g	0.0062 - 0.0562 s
Maximum Yaw, Pitch, and Roll Angles		
Roll	18°	1.9682 s
Pitch	11°	1.6759 s
Yaw	53°	2.0000 s

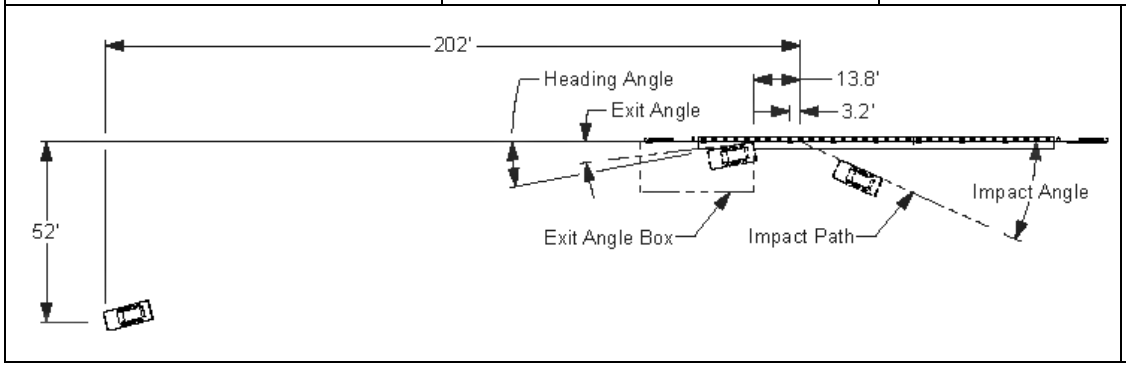
0.000 s

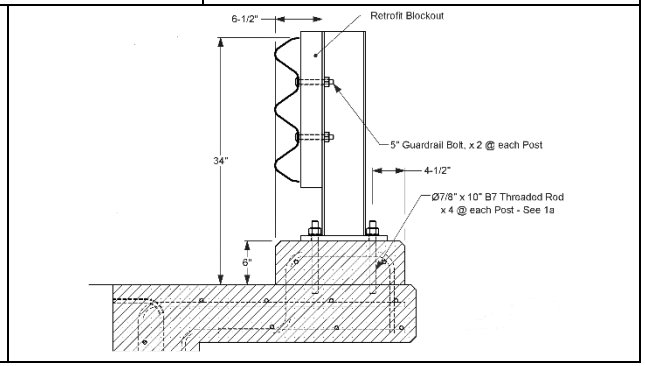
0.100 s

0.200 s



0.300 s





General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... *MASH* Test 3-10
- TTI Test No. 615131-01-1
- Test Date 2021-07-21

Test Article
- Type ..... Longitudinal Barrier—Bridge Rail
- Name ..... Thrie Beam Bridge Rail Retrofit
- Installation Length ..... 100 ft of 34-inch tall rail
- Material or Key Elements ... Thrie-Beam with blockouts mounted to steel posts retrofit anchored to existing concrete bridge deck curb

Soil Type and Condition ..... Concrete bridge deck, damp

Test Vehicle
- Type/Designation ..... 2015 Nissan Versa
- Make and Model 1100C
- Curb ..... 2419 lb
- Test Inertial ..... 2451 lb
- Dummy ..... 165 lb
- Gross Static ..... 2616 lb

Impact Conditions
- Speed ..... 62.1 mi/h
- Angle ..... 24.3°
- Location/Orientation ..... 3.2 ft upstream of post 28

Impact Severity ..... 54 kip-ft

Exit Conditions
- Speed ..... 49.7 mi/h
- Trajectory/Heading Angle ... 7.0°/10.6°

Occupant Risk Values
- Longitudinal OIV ..... 21.2 ft/s
- Lateral OIV ..... 31.4 ft/s
- Longitudinal Ridedown ..... 3.0 g
- Lateral Ridedown ..... 10.9 g
- THIV ..... 11.5 m/s
- ASI 2.7

Max. 0.050-s Average
- Longitudinal ..... −12.1 g
- Lateral ..... −18.9 g
- Vertical ..... 3.6 g

Post-Impact Trajectory
- Stopping Distance ..... 202 ft downstream 52 ft twd traffic

Vehicle Stability
- Maximum Roll Angle ..... 18°
- Maximum Pitch Angle ..... 11°
- Maximum Yaw Angle ..... 53°
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 2.2 inches
- Permanent ..... 0.9 inch
- Working Width ..... 19.5 inches
- Height of Working Width ..... 34.0 inches

Vehicle Damage
- VDS 01RFQ5
- CDC 01FREW4
- Max. Exterior Deformation ..... 10.0 inches
- OCDI RF0121000
- Max. Occupant Compartment Deformation ..... 1.5 inches

Figure 6.6. Summary of Results for *MASH* Test 3-10 on Thrie Beam Bridge Rail Retrofit.

Chapter 7. SUMMARY AND CONCLUSIONS

7.1. ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* TL-3 longitudinal barriers, which involves two tests, on the Thrie Beam Bridge Rail Retrofit. Table 8.1 through Table 8.3 provide an assessment of each test based on the applicable safety evaluation criteria for *MASH* TL-3 longitudinal barriers.

7.2. CONCLUSIONS

Table 8.4 shows that the Thrie Beam Bridge Rail Retrofit as shown and reported herein, met all the performance criteria for *MASH* TL-3 longitudinal barriers.

Table 8.1. Performance Evaluation Summary for *MASH* Test 3-11 on Thrie Beam Bridge Rail Retrofit.

Test Agency: Texas A&M Transportation Institute Test No.: 615131-01-2 Test Date: 2021-06-23

MASH Test 3-11 Evaluation Criteria	Test Results	Assessment
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.	The Thrie Beam Bridge Rail Retrofit contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.2 inches.	Pass
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.	No detached elements, fragments, or other debris from the installation were present to penetrate or show potential for penetrating the occupant compartment or present undue hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	Maximum occupant compartment deformation was 3.5 inches in the right kick panel area.	
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 20° and 9°.	Pass
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 26.3 ft/s, and lateral OIV was 25.3 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 occupant ridedown acceleration was 8.2 g, and maximum lateral occupant ridedown acceleration was 7.6 g.	Pass

Table 8.2. Performance Evaluation Summary for *MASH* Test 3-10 on Thrie Beam Bridge Rail Retrofit.

Test Agency: Texas A&M Transportation Institute Test No.: 615131-01-1 Test Date: 2021-07-21

MASH Test 3-10 Evaluation Criteria	Test Results	Assessment
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.	The Thrie Beam Bridge Rail Retrofit contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.2 inches.	Pass
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.	No detached elements, fragments, or other debris from the installation were present to penetrate or show potential for penetrating the occupant compartment or present undue hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	Maximum occupant compartment deformation was 1.5 inches in the right front floor pan.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 18° and 11°.	Pass
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 21.2 ft/s, and lateral OIV was 31.4 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 occupant ridedown acceleration was 3.0 g, and maximum lateral occupant ridedown acceleration was 10.9 g.	Pass

Table 8.3. Assessment Summary for *MASH* TL-3 Tests on Thrie Beam Bridge Rail Retrofit.

Evaluation Factors	Evaluation Criteria	Test No. 615131-01-1	Test No. 615131-01-2
Structural Adequacy	A	S	S
Occupant Risk	D	S	S
	F	S	S
	H	S	S
	I	S	S
	Test No.	***MASH* Test 3-10**	***MASH* Test 3-11**
	Pass/Fail	Pass	Pass

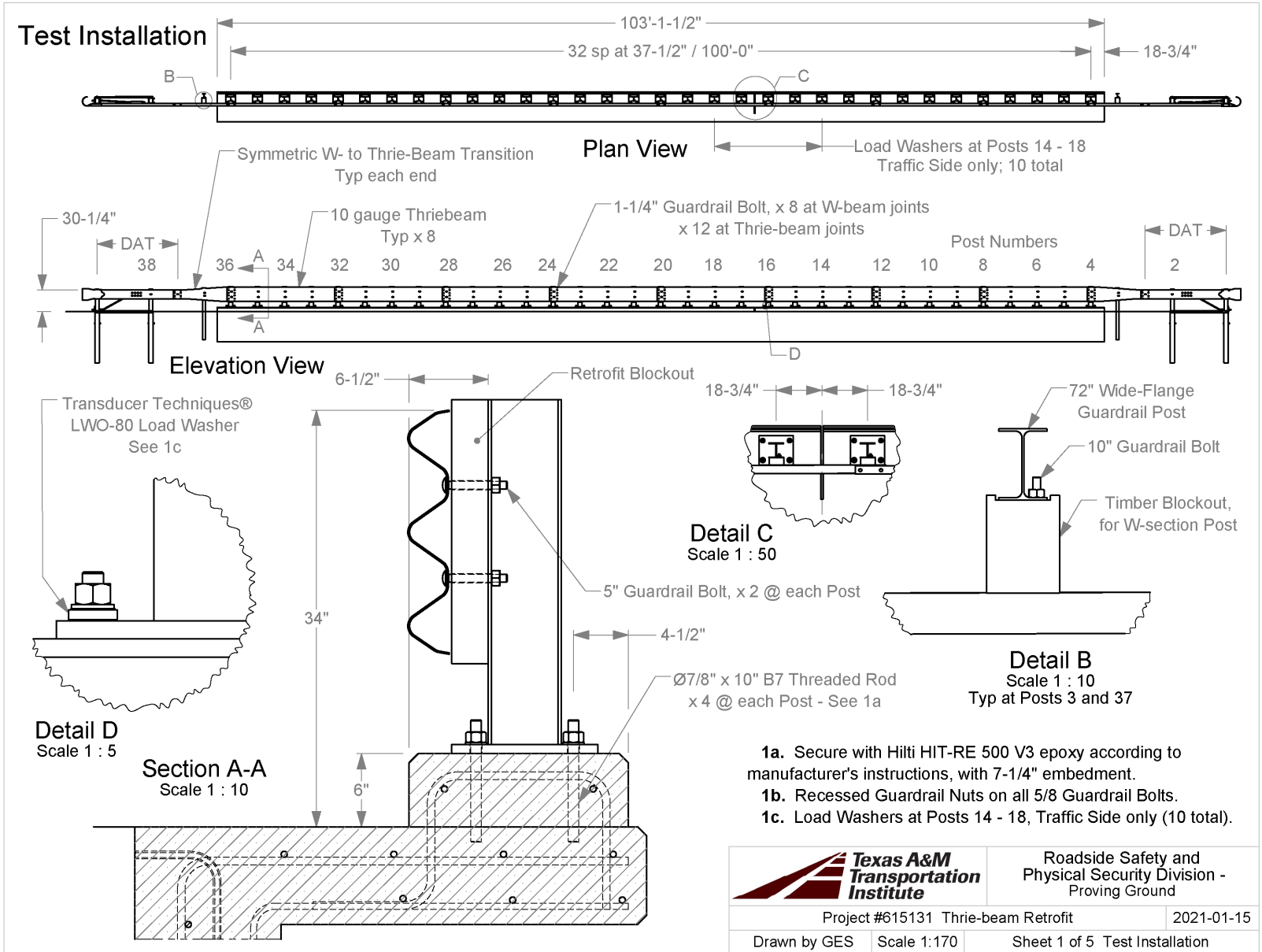
Note: S = Satisfactory.

REFERENCES

1. AASHTO. *Manual for Assessing Roadside Safety Hardware, Second Edition.* American Association of State Highway and Transportation Officials: Washington, DC, 2016.

2. Ross, Jr., H.E., Sicking, D.L., Zimmer, R.A. and Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Features," National Cooperative Highway Research Program *Report 350*, Transportation Research Board, National Research Council, Washington, D.C., 1993.

3. AASHTO. *Manual for Assessing Roadside Safety Hardware.* American Association of State Highway and Transportation Officials: Washington, DC, 2009.



1a. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 7-1/4" embedment.
1b. Recessed Guardrail Nuts on all 5/8 Guardrail Bolts.
1c. Load Washers at Posts 14 - 18, Traffic Side only (10 total).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project #615131 Thrie-beam Retrofit			2021-01-15
Drawn by GES	Scale 1:170	Sheet 1 of 5 Test Installation	

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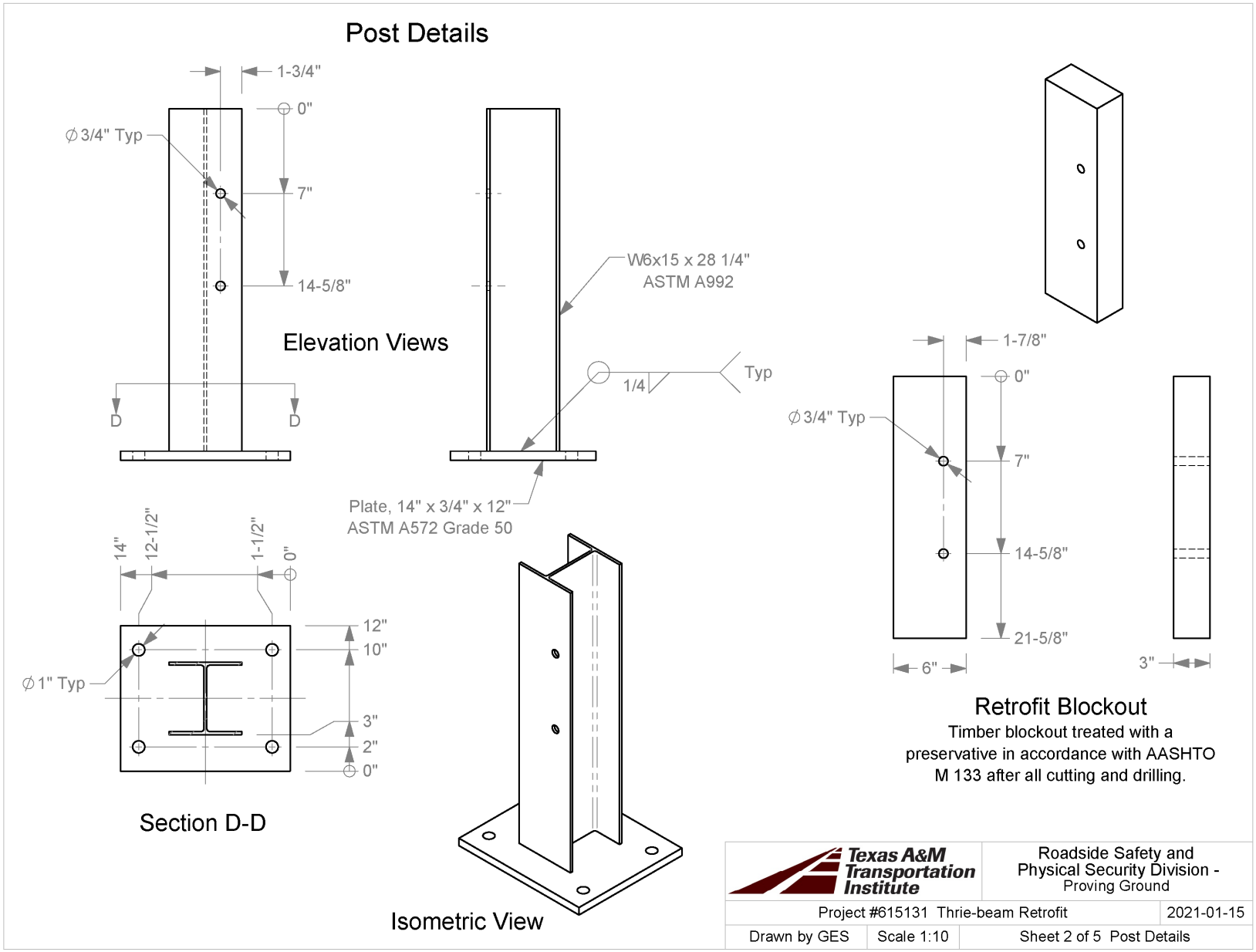

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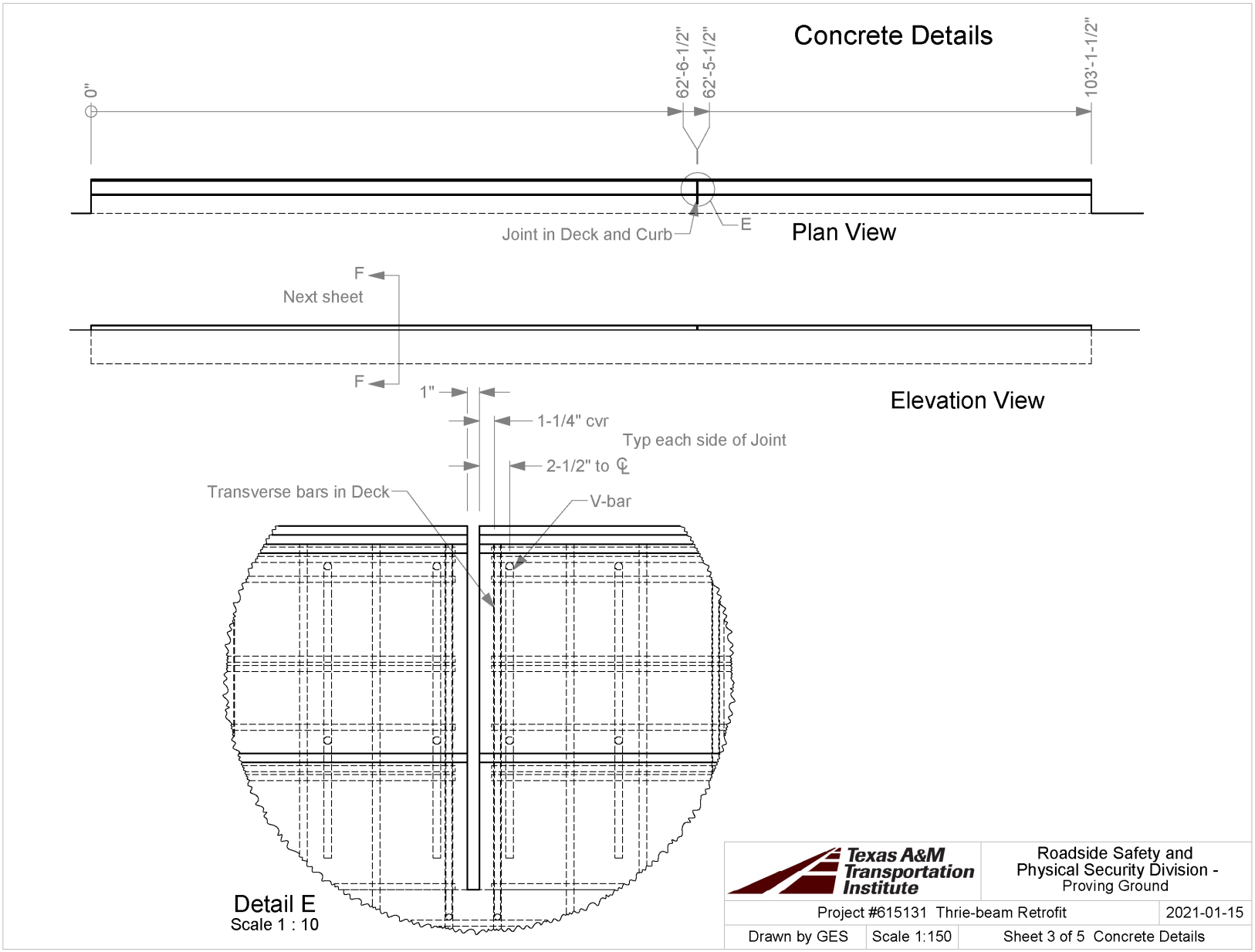

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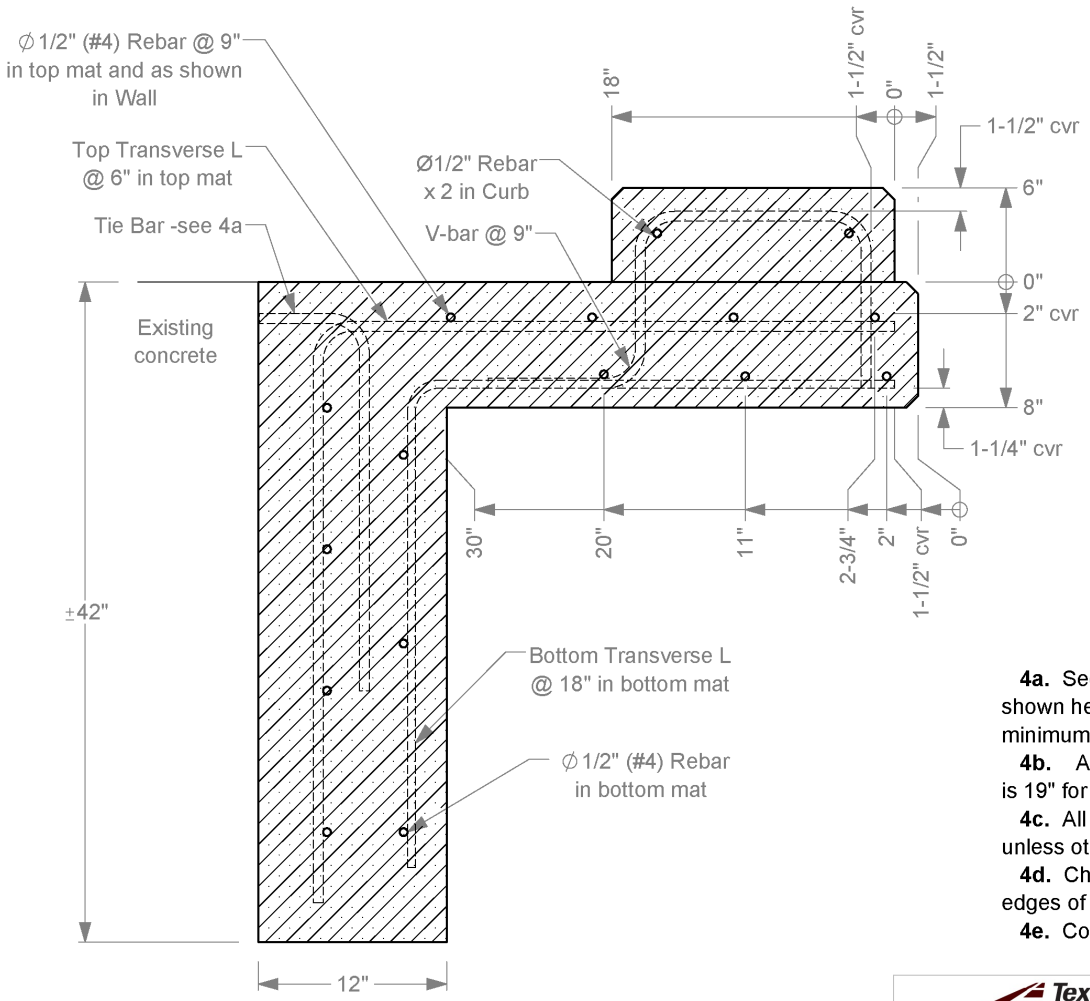
Section F-F



4a. Secure each Tie Bar to existing rebar (not shown here) protruding from the runway with a minimum 3" weld. Maximum spacing is 18".

4b. All rebar is grade 40. Minimum rebar lap is 19" for #4 bars and 24" for #5 bars.

4c. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

4d. Chamfer top edges of Curb and field side edges of Deck 3/4" each way as shown.

4e. Concrete shall be 3,300 psi.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #615131 Thrie-beam Retrofit			2021-01-15
Drawn by GES	Scale 1:10	Sheet 4 of 5 Concrete Section	

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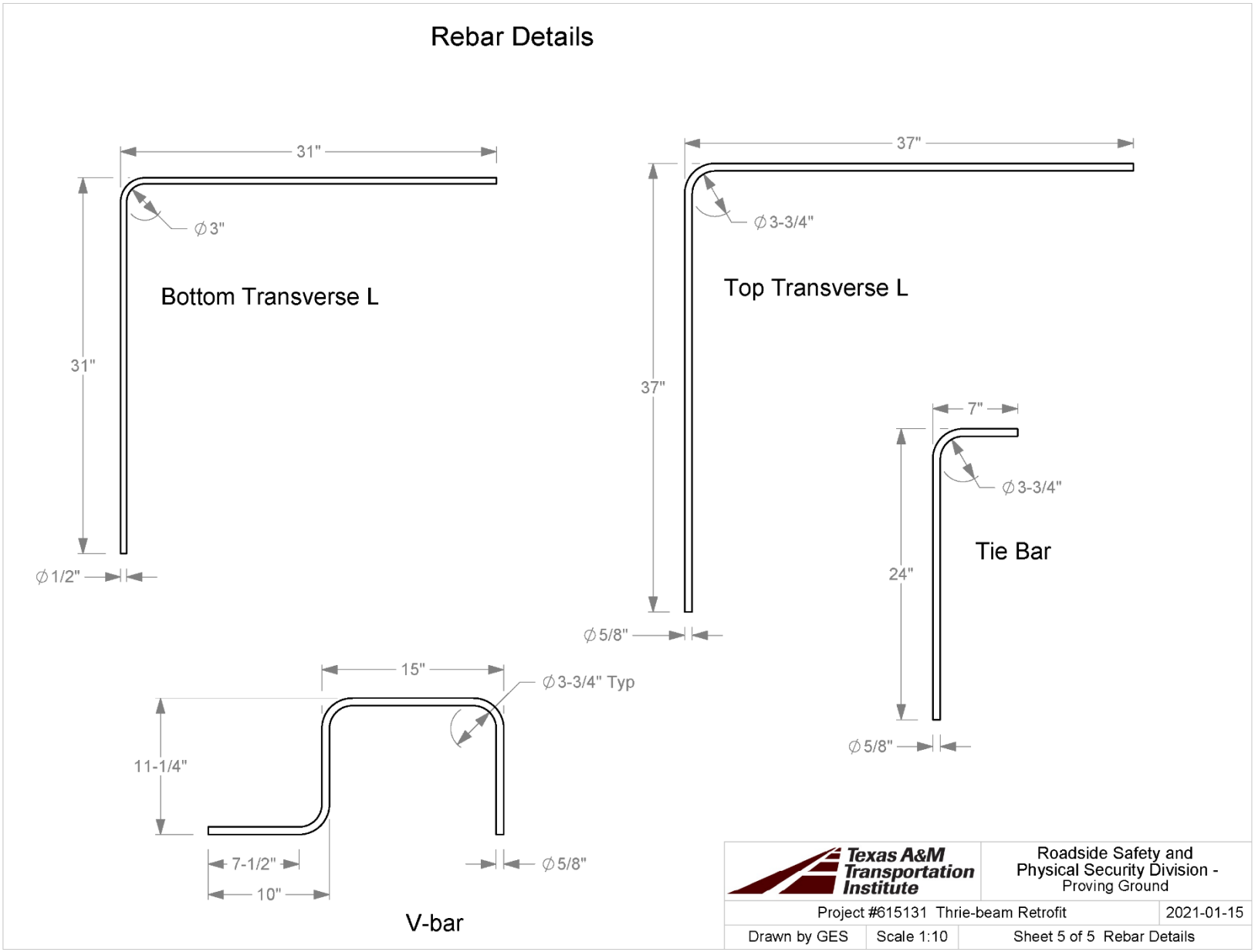
Rebar Details
31"
∅3"
Bottom Transverse L
31"
∅1/2"
37"
∅3-3/4"
Top Transverse L
37"
∅5/8"
7"
∅3-3/4"
Tie Bar
24"
∅5/8"
15"
∅3-3/4" Typ
11-1/4"
7-1/2"
10"
∅5/8"
V-bar
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #615131 Thrie-beam Retrofit
2021-01-15
Drawn by GES
Scale 1:10
Sheet 5 of 5 Rebar Details
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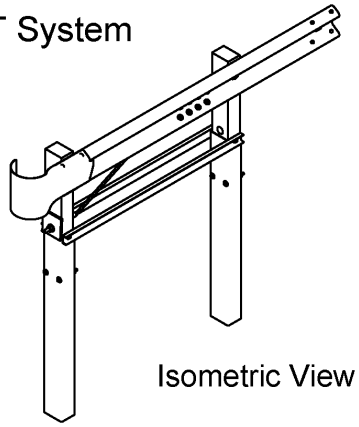
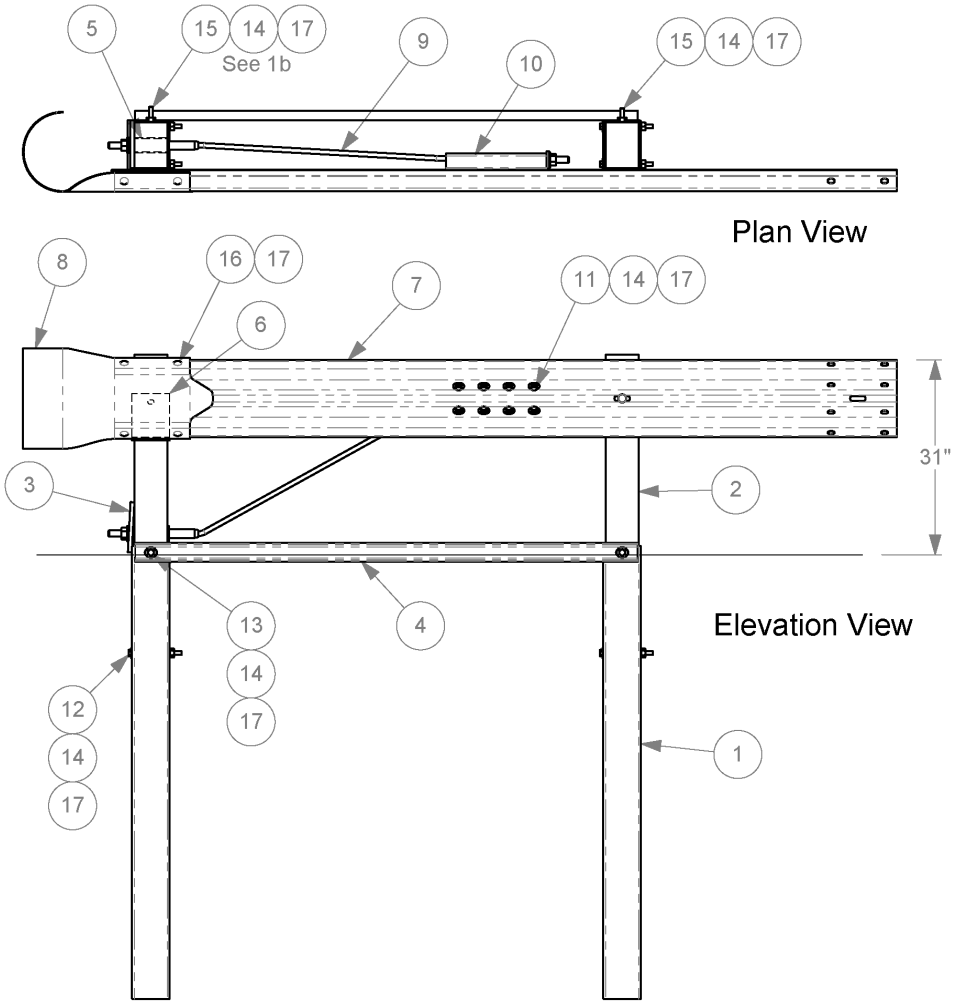
DAT System



Isometric View



#	Part Name	Qty.
1	Foundation Tube	2
2	Terminal Timber Post	2
3	BCT Bearing Plate	1
4	DAT Strut	2
5	BCT Post Sleeve	1
6	Shelf Angle Bracket	1
7	DAT Terminal Rail	1
8	W-beam End Section	1
9	Anchor Cable Assembly	1
10	Guardrail Anchor Bracket	1
11	Bolt, 5/8 x 2" hex	8
12	Bolt, 5/8 x 8" hex	4
13	Bolt, 5/8 x 10" hex	2
14	Washer, 5/8 F844	16
15	10" Guardrail Bolt	2
16	1-1/4" Guardrail Bolt	4
17	Recessed Guardrail Nut	20

1a. All bolts are ASTM A307.

1b. Hardware secures Shelf Angle Bracket to Post. Rail is supported by Shelf Angle Bracket and does not attach directly to Post.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
DAT (Downstream Anchor Terminal)		2019-07-26
Drawn by GES	Scale 1:25	Sheet 1 of 3

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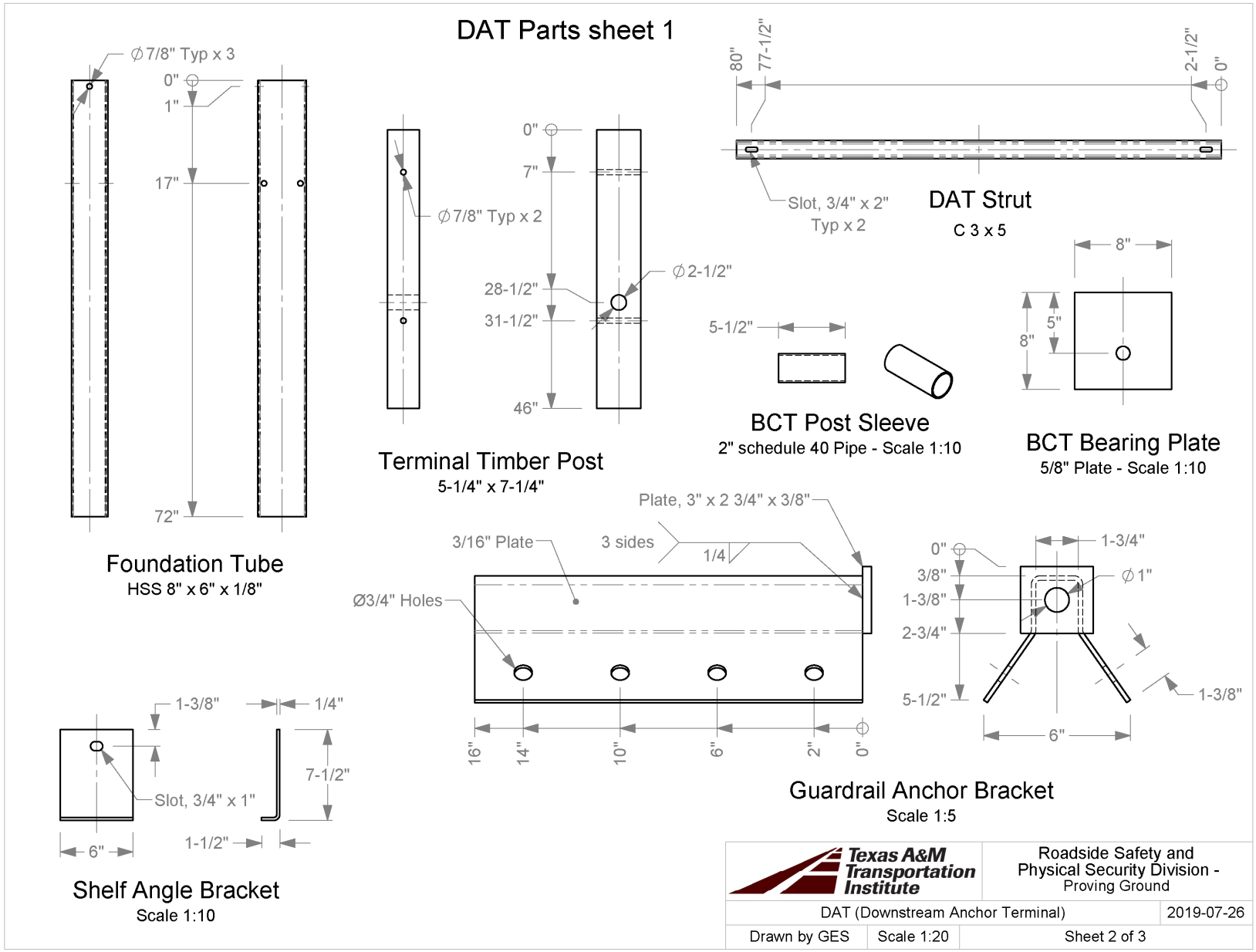

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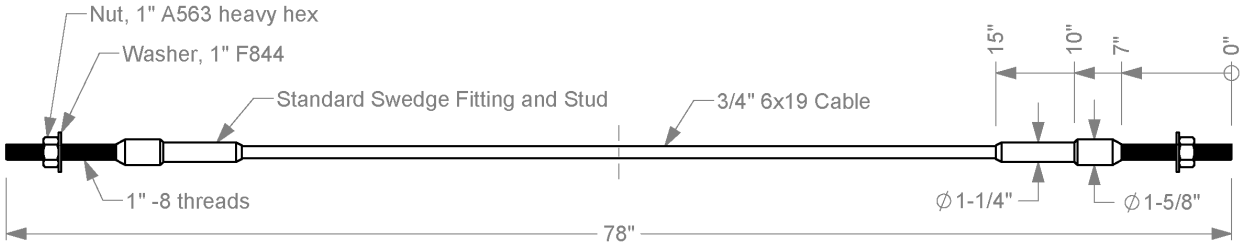
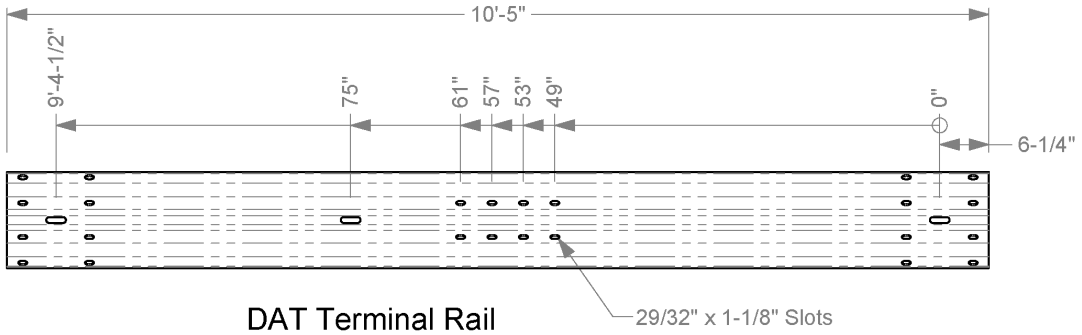
DAT Parts sheet 2

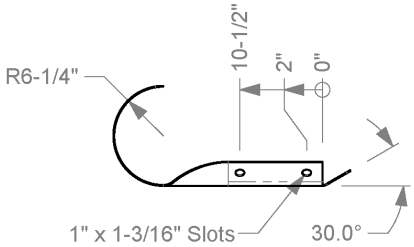


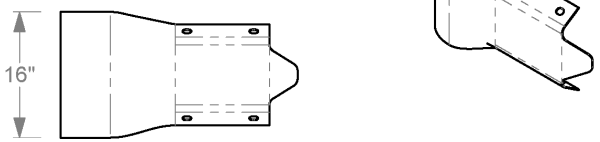
Anchor Cable Assembly



DAT Terminal Rail

Scale 1:20 - See 4-space W-beam Guardrail drawing for cross-section and other dimensions.





W-beam End Section

12 gauge steel - Scale 1:20

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
DAT (Downstream Anchor Terminal)		2019-07-26
Drawn by GES	Scale 1:10	Sheet 3 of 3

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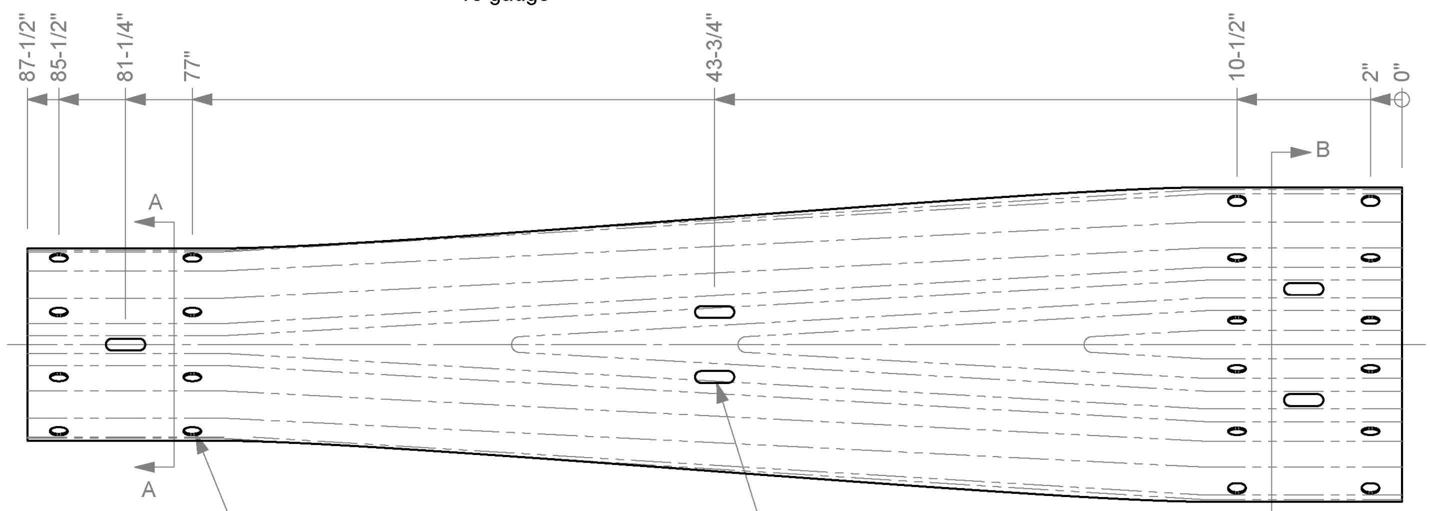
W- to Thrie-Beam, symmetric

10 gauge



Elevation View

Section A-A

See W-beam Drawing

Section B-B

See Thrie-beam Drawing

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Symmetric W- to Thre-beam Transition		2020-10-13
Drawn by GES	Scale 1:10	Sheet 1 of 1

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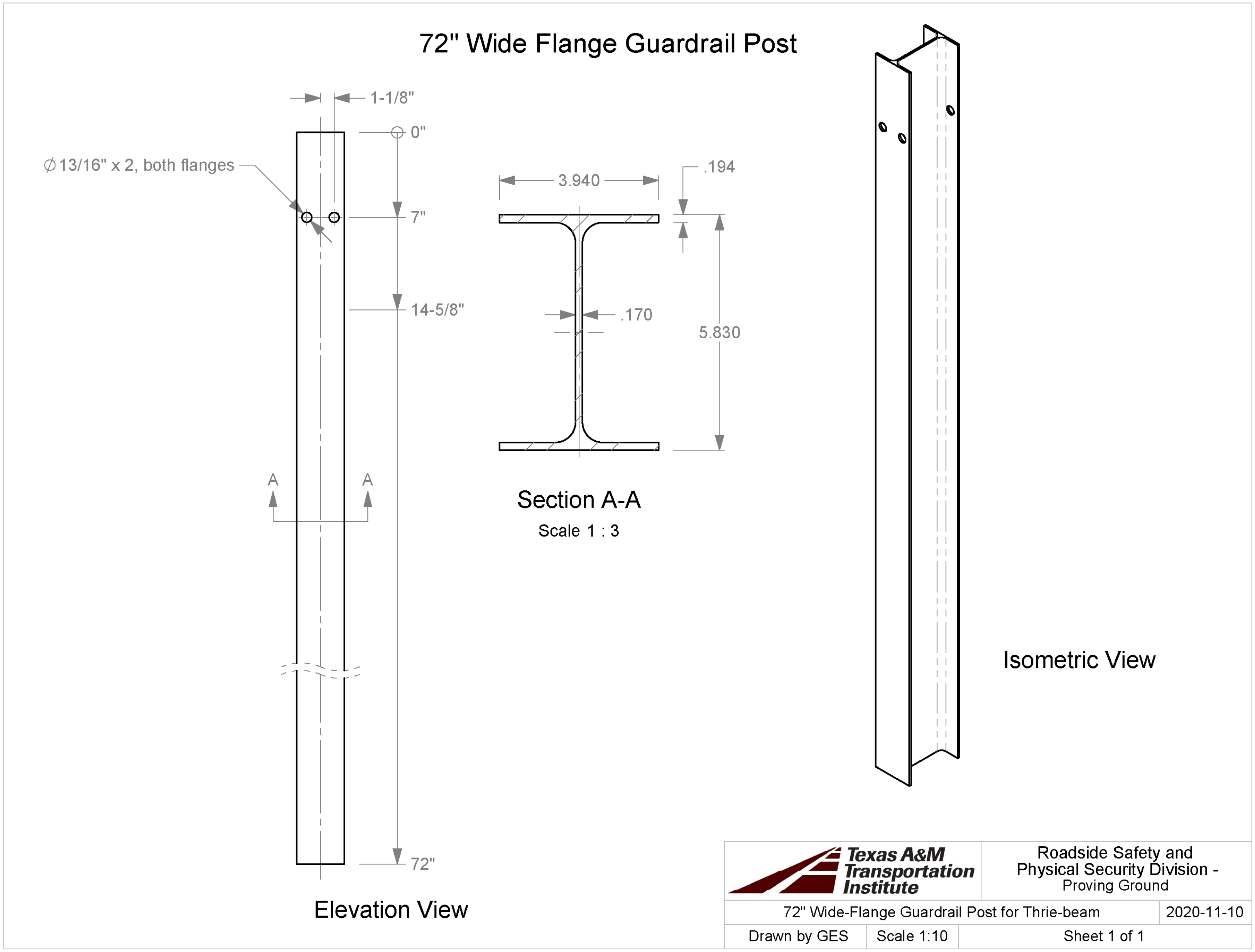
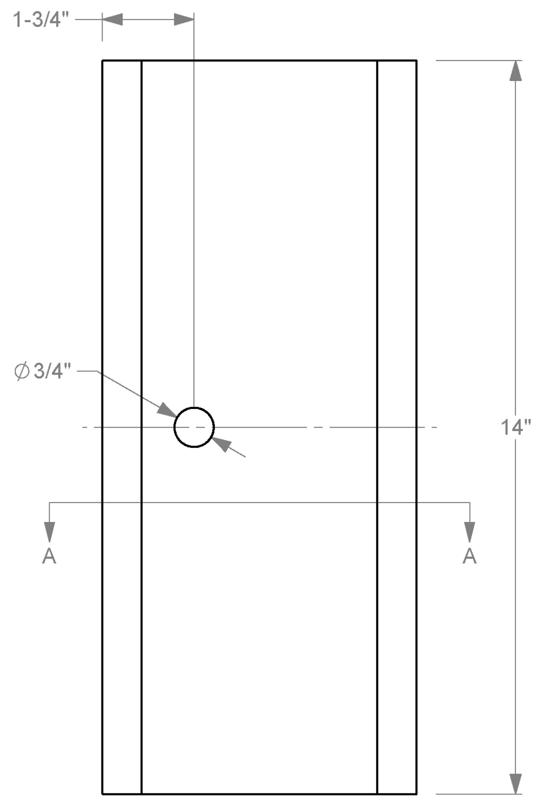
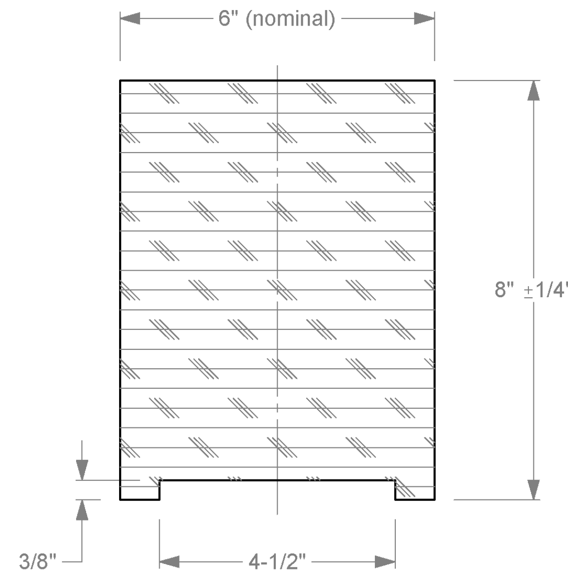


Timber Blockout for W-section Post



Elevation View



Section A-A

1a. Timber blockouts are treated with a preservative in accordance with AASHTO M 133 after all cutting and drilling.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Timber Blockout, for W-section Post		2019-07-03
Drawn by GES	Scale 1:3	Sheet 1 of 1

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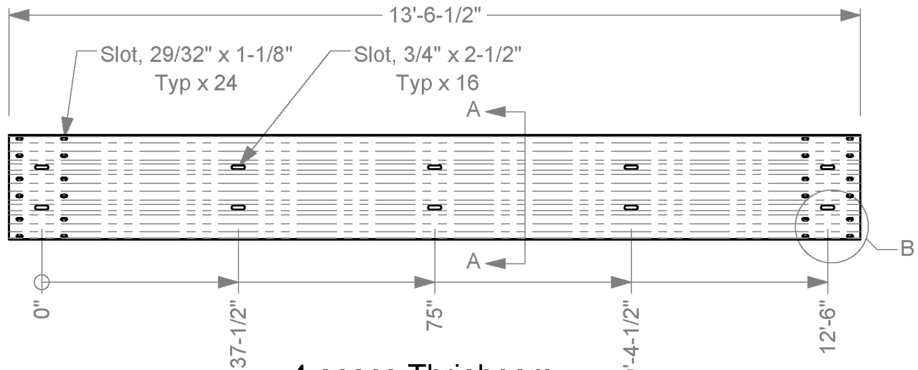
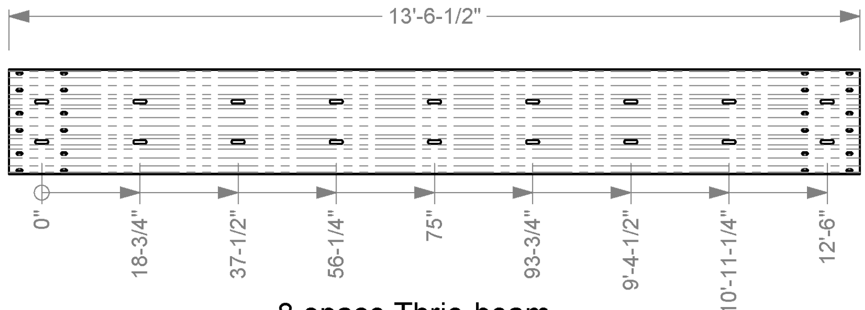
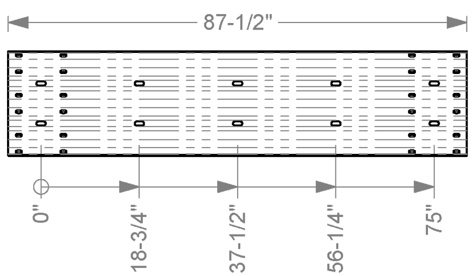


4-space Thriebeam



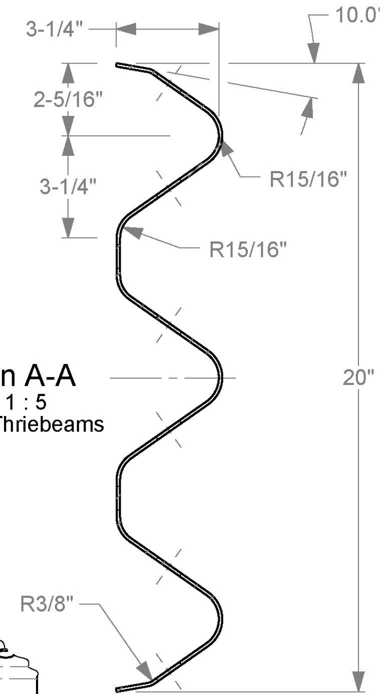
8-space Thrie-beam

Dimensions not shown here same as 4-space Thriebeam

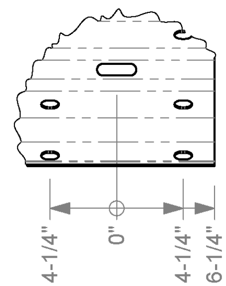


Thriebeam, 12 gauge 75" span

Dimensions not shown here same as 4-space Thriebeam



Section A-A
Scale 1 : 5
Typical all Thriebeams

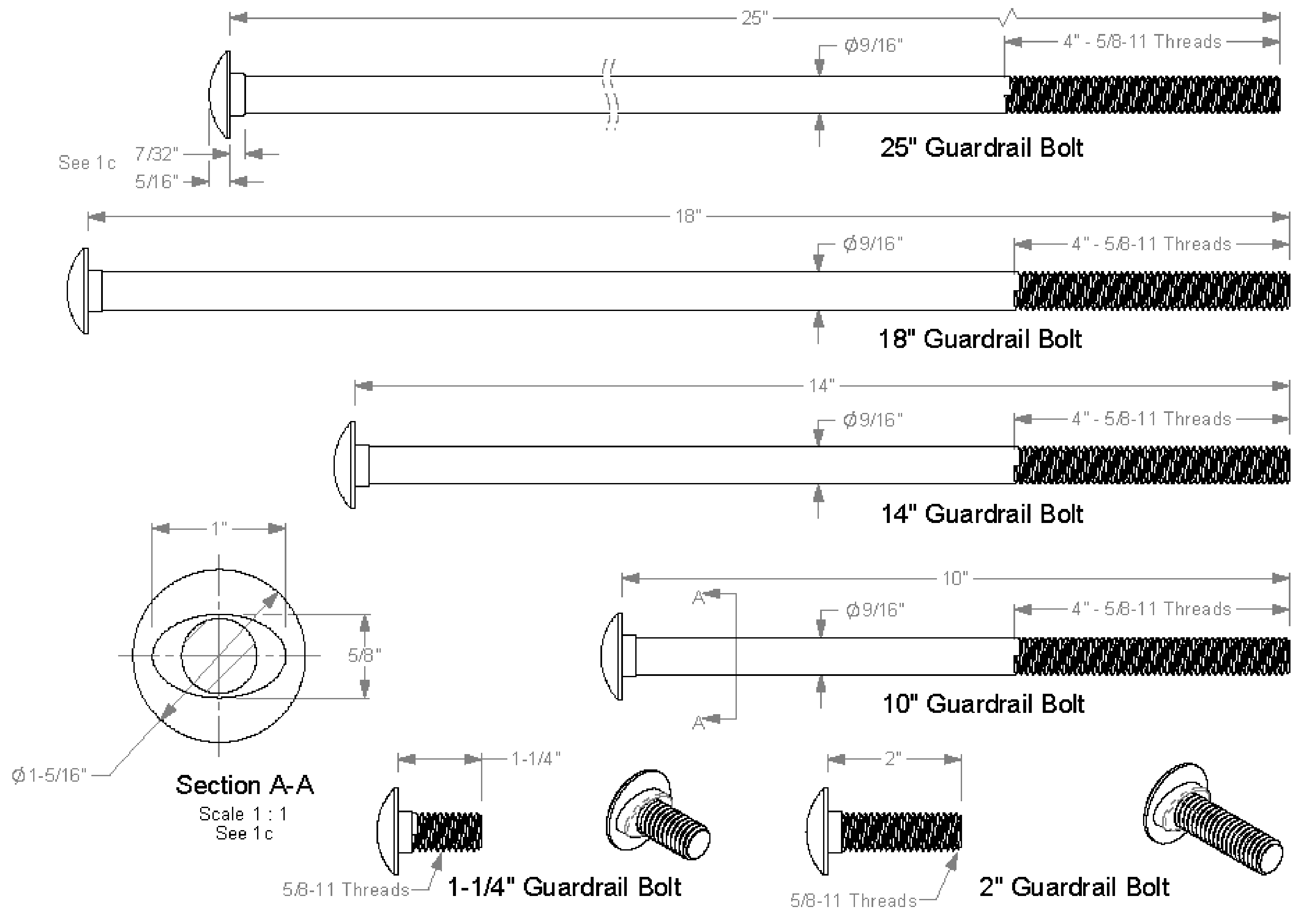


Detail B
Scale 1 : 10
Typical all Thriebeams, both ends

1a. 12 gauge is 0.1046" before galvanizing and 0.1084" after, and 10 gauge is 0.1345" before galvanizing and 0.1382" after.
1b. Not all versions shown here used in all installations.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Thrie-beam		2020-03-31
Drawn by GES	Scale 1:30	Sheet 1 of 1

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Thrie-Beam

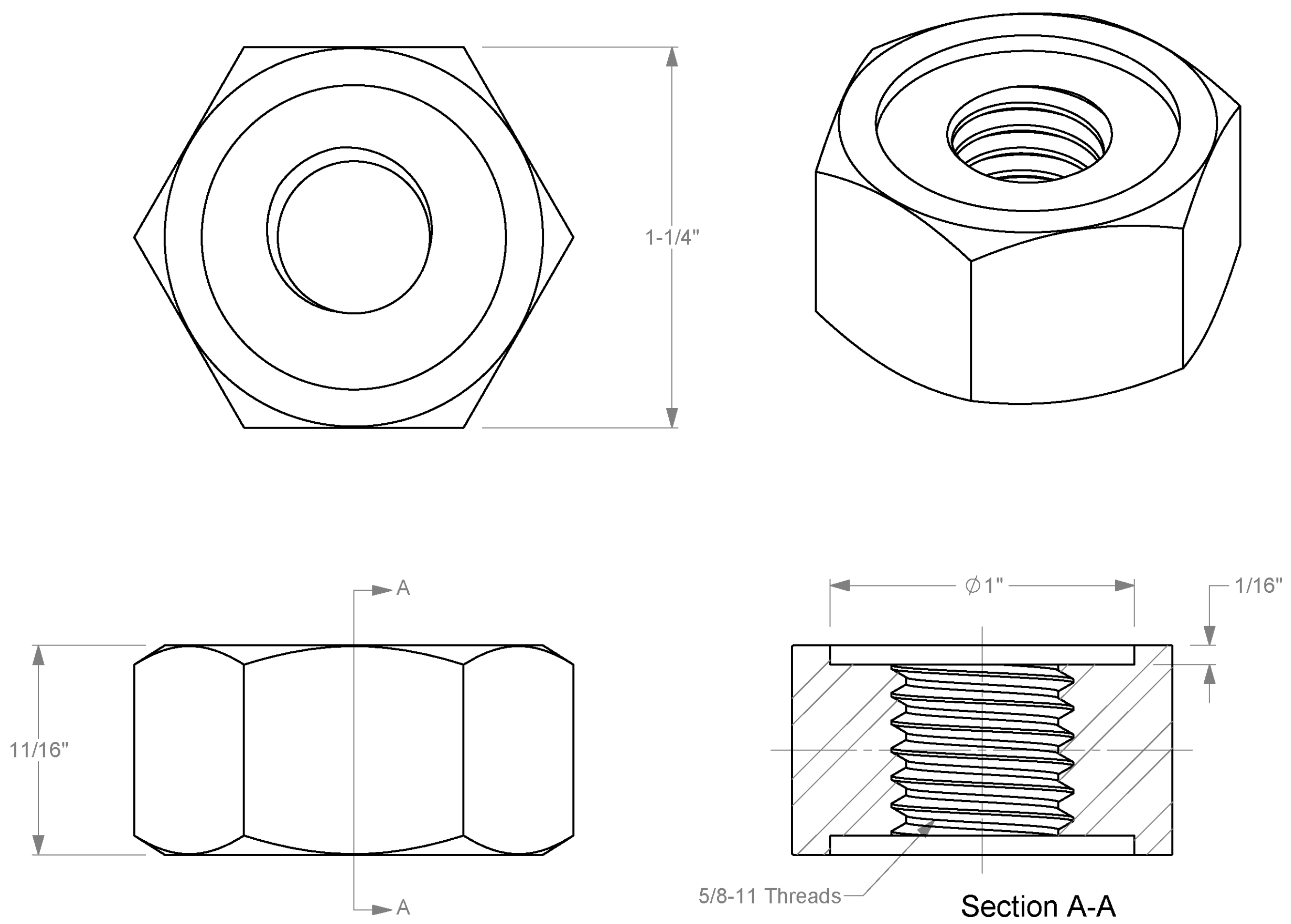


1a. Material is ASTM A307.
1b. All bolt sizes not used in all projects. See system drawing.
1c. Head and shoulder dimensions typical all sizes.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Guardrail Bolt		2020-04-22
Drawn by GES/WS	Scale 1:2	Sheet 1 of 1

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Guardrail Bolt

Recessed Guardrail Nut

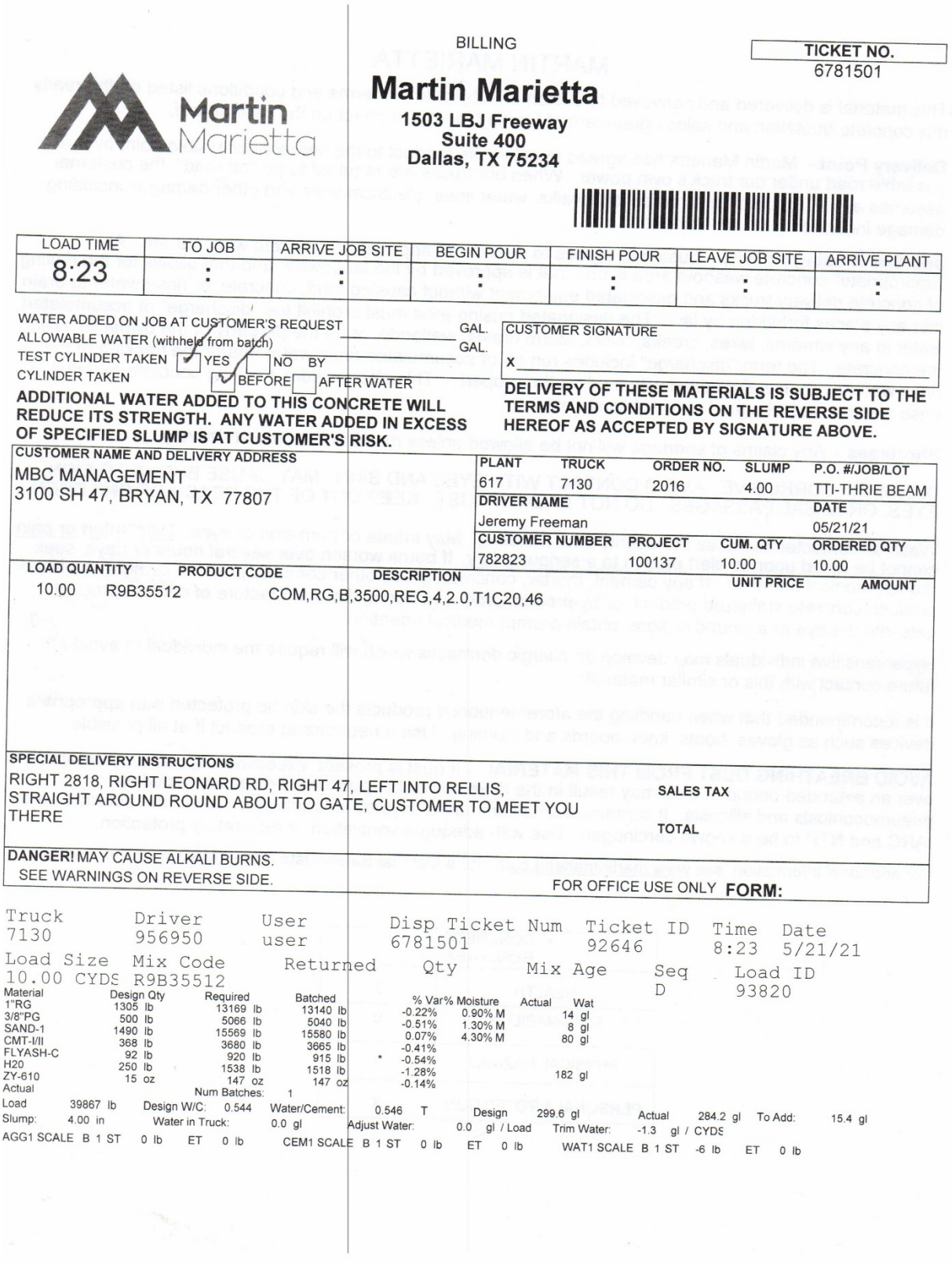


1a. Material is ASTM A 563 Grade A.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Recessed Guardrail Nut			2019-06-27
Drawn by GES	Scale 2:1	Sheet 1 of 1	

T:\Drafting Department\Solidworks\Standard Parts\Guardrail Parts and Subs\Guardrail Drawings\Nut, Recessed Guardrail

APPENDIX B. SUPPORTING



BILLING

Martin Marietta
1503 LBJ Freeway
Suite 400
Dallas, TX 75234

TICKET NO. 6781501

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
8:23	:	:	:	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST _____ GAL.
ALLOWABLE WATER (withheld from batch) _____ GAL.
TEST CYLINDER TAKEN [✓] YES [ ] NO BY
CYLINDER TAKEN [✓] BEFORE [ ] AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X _____

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
MBC MANAGEMENT
3100 SH 47, BRYAN, TX 77807

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT
617	7130	2016	4.00	TTI-THRIE BEAM

DRIVER NAME Jeremy Freeman
DATE 05/21/21

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
782823	100137	10.00	10.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
10.00	R9B35512	COM,RG,B,3500,REG,4,2.0,T1C20,46		

SPECIAL DELIVERY INSTRUCTIONS
RIGHT 2818, RIGHT LEONARD RD, RIGHT 47, LEFT INTO RELLIS, STRAIGHT AROUND ROUND ABOUT TO GATE, CUSTOMER TO MEET YOU THERE

SALES TAX
TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:**

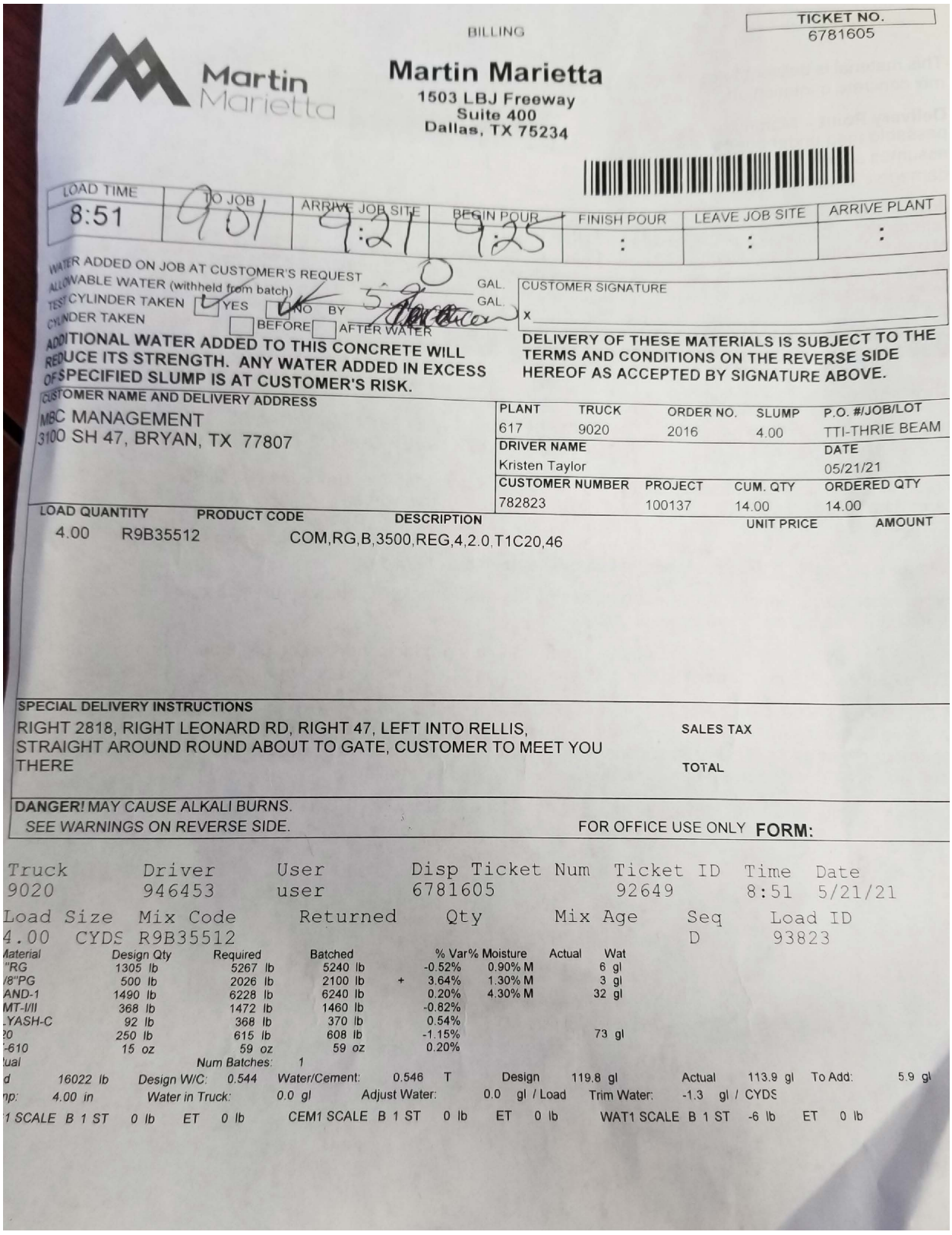
Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
7130	956950	user	6781501	92646	8:23	5/21/21

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
10.00 CYDS	R9B35512				D	93820

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual	Wat
1"RG	1305 lb	13169 lb	13140 lb	-0.22%	0.90% M	14 gl	
3/8"PG	500 lb	5066 lb	5040 lb	-0.51%	1.30% M	8 gl	
SAND-1	1490 lb	15569 lb	15580 lb	0.07%	4.30% M	80 gl	
CMT-I/II	368 lb	3680 lb	3665 lb	-0.41%			
FLYASH-C	92 lb	920 lb	915 lb	* -0.54%			
H20	250 lb	1538 lb	1518 lb	-1.28%		182 gl	
ZY-610	15 oz	147 oz	147 oz	-0.14%			
Actual		Num Batches: 1					

Load 39867 lb Design W/C: 0.544 Water/Cement: 0.546 T Design 299.6 gl Actual 284.2 gl To Add: 15.4 gl
Slump: 4.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.3 gl / CYDS

AGG1 SCALE B 1 ST 0 lb ET 0 lb CEM1 SCALE B 1 ST 0 lb ET 0 lb WAT1 SCALE B 1 ST -6 lb ET 0 lb



BILLING

TICKET NO. 6781605

Martin Marietta

Martin Marietta
1503 LBJ Freeway
Suite 400
Dallas, TX 75234

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
8:51	901	9:21	9:25	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST 0 GAL.
ALLOWABLE WATER (withheld from batch) 5.2 GAL.
TEST CYLINDER TAKEN [X] YES [ ] NO BY
CYLINDER TAKEN [ ] BEFORE [ ] AFTER WATER

CUSTOMER SIGNATURE
X

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
MBC MANAGEMENT
3100 SH 47, BRYAN, TX 77807

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT
617	9020	2016	4.00	TTI-THRIE BEAM

DRIVER NAME Kristen Taylor
DATE 05/21/21

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
782823	100137	14.00	14.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
4.00	R9B35512	COM,RG,B,3500,REG,4,2.0,T1C20,46		

SPECIAL DELIVERY INSTRUCTIONS
RIGHT 2818, RIGHT LEONARD RD, RIGHT 47, LEFT INTO RELLIS, STRAIGHT AROUND ROUND ABOUT TO GATE, CUSTOMER TO MEET YOU THERE

SALES TAX
TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:**

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
9020	946453	user	6781605	92649	8:51	5/21/21

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
4.00 CYDS	R9B35512				D	93823

Material	Design Qty	Required	Batched		% Var	% Moisture	Actual	Wat
"RG	1305 lb	5267 lb	5240 lb		-0.52%	0.90% M		6 gl
/8"PG	500 lb	2026 lb	2100 lb	+	3.64%	1.30% M		3 gl
AND-1	1490 lb	6228 lb	6240 lb		0.20%	4.30% M		32 gl
MT-I/II	368 lb	1472 lb	1460 lb		-0.82%			
YASH-C	92 lb	368 lb	370 lb		0.54%			
0	250 lb	615 lb	608 lb		-1.15%			73 gl
-610	15 oz	59 oz	59 oz		0.20%			
ual		Num Batches:	1					

d 16022 lb Design W/C: 0.544 Water/Cement: 0.546 T Design 119.8 gl Actual 113.9 gl To Add: 5.9 gl
np: 4.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.3 gl / CYDS

1 SCALE B 1 ST 0 lb ET 0 lb CEM1 SCALE B 1 ST 0 lb ET 0 lb WAT1 SCALE B 1 ST -6 lb ET 0 lb

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0193
Service Date: 05/21/21
Report Date: 06/08/21
Task: PO# 615131-01

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
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: A1171057

Material Information

Specified Strength: 4,000 psi @ 28 days

Mix ID: R9B35512
Supplier: Martin Marietta
Batch Time: 0823 **Plant:** 617
Truck No.: 7130 **Ticket No.:** 6781501

Sample Information

Sample Date: 05/21/21 **Sample Time:** 0920
Sampled By: Matcek, James
Weather Conditions: Partly Cloudy
Accumulative Yards: 10 **Batch Size (cy):** 10
Placement Method:
Water Added Before (gal): 5
Water Added After (gal): 0
Sample Location: Beam
Placement Location: Trye beam

Field Test Data

Test	Result	Specification
Slump (in):	4	
Air Content (%):	2.3	
Concrete Temp. (F):	78	
Ambient Temp. (F):	73	
Plastic Unit Wt. (pcf):	149.6	
Yield (Cu. Yds.):	10.0	

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
1	A	6.01	28.37		06/08/21	18 F	150,170	5,290	4	SLS
1	B	6.01	28.37		06/08/21	18 F	138,930	4,900	1	SLS
1	C	6.01	28.37		06/08/21	18 F	125,500	4,420	3	SLS
1	D					Hold				

Initial Cure: Outside **Final Cure:**

Comments: **F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).
Na

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Matcek, James **Start/Stop:** 0815-1100
Reported To: Billy with TTI
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke
(1) Terracon Consultants, Inc., Alex Dunigan, P.E.
(1) Texas Transportation Institute, Bill Griffith

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0193
Service Date: 05/21/21
Report Date: 06/08/21
Task: PO# 615131-01

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
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: A1171057

Material Information

Specified Strength: 4,000 psi @ 28 days

Mix ID: R9B35512
Supplier: Martin Marietta
Batch Time: 0851 **Plant:** 617
Truck No.: 9020 **Ticket No.:** 6781605

Sample Information

Sample Date: 05/21/21 **Sample Time:** 0950
Sampled By: Matcek, James
Weather Conditions: Partly cloudy
Accumulative Yards: 4 **Batch Size (cy):** 4
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Trye beam
Placement Location: Trye beam

Field Test Data

Test	Result	Specification
Slump (in):	4 3/4	
Air Content (%):	2.5	
Concrete Temp. (F):	78	
Ambient Temp. (F):	73	
Plastic Unit Wt. (pcf):	148.2	
Yield (Cu. Yds.):	4.0	

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
2	A	6.01	28.37		06/08/21	18 F	126,200	4,450	3	SLS
2	B	6.01	28.37		06/08/21	18 F	124,790	4,400	3	SLS
2	C	6.01	28.37		06/08/21	18 F	125,630	4,430	3	SLS
2	D					Hold				

Initial Cure: Outside **Final Cure:**

Comments: **F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).
N/a

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Matcek, James **Start/Stop:** 0815-1100
Reported To: Billy with TTI
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Alex Dunigan, P.E.
(1) Texas Transportation Institute, Bill Griffith

Reviewed By: Alexander Dunigan
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Texas A&M Transportation Institute	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Revision Date: 2020-07-29
Quality Form	Revised by: B.L. Griffith Approved by: D. L. Kuhn	Revision: 7	Page: 1 of 1

Project No: 615131 **Casting Date:** 5/26/2021 **Mix Design (psi):** 3300

Name of Technician Taking Sample: Terracon

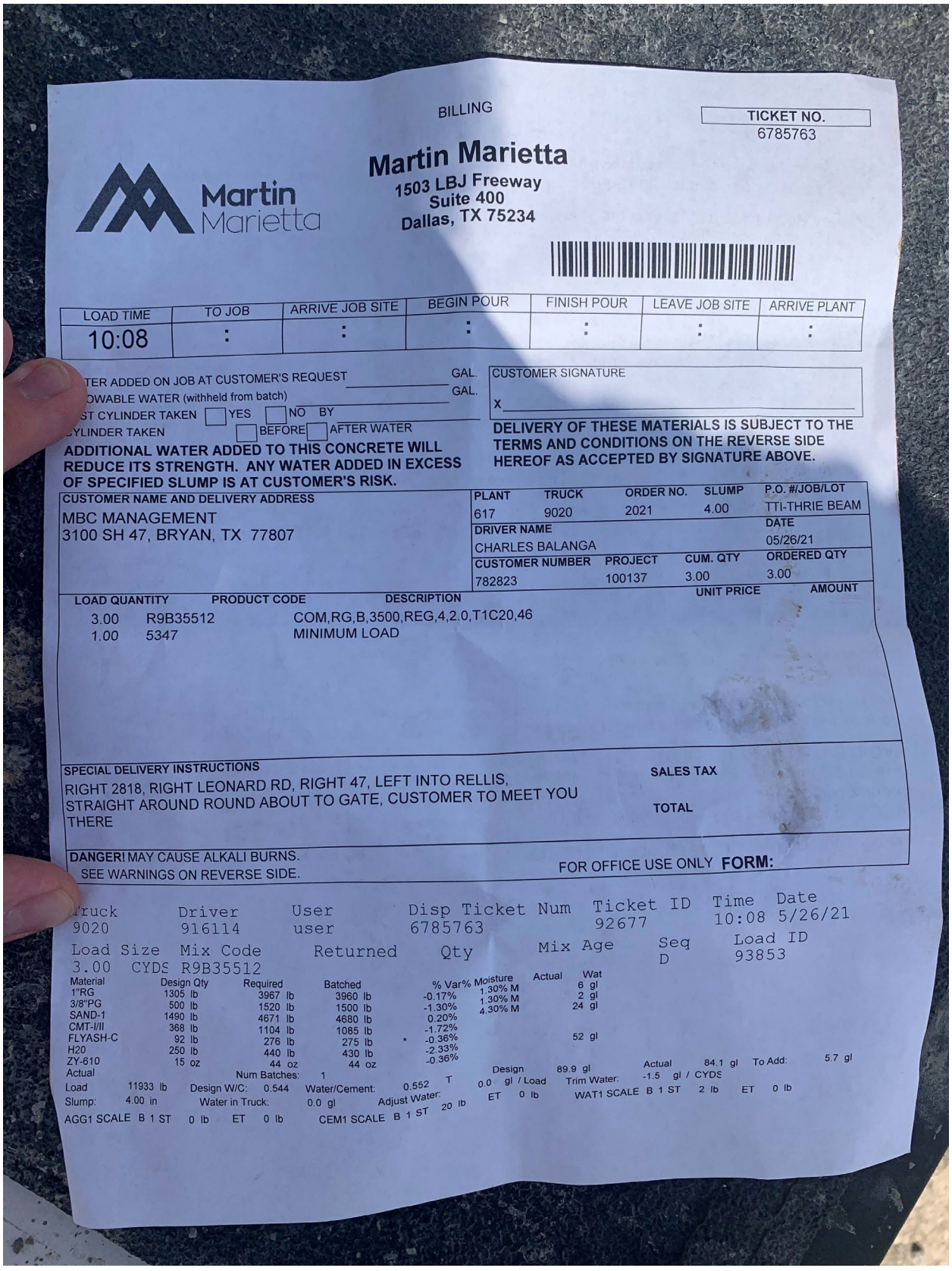
Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	9020	6785763	South Section of curb

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average



BILLING

TICKET NO. 6785763

Martin Marietta
1503 LBJ Freeway
Suite 400
Dallas, TX 75234

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
10:08	:	:	:	:	:	:

TER ADDED ON JOB AT CUSTOMER'S REQUEST _____ GAL.
OWABLE WATER (withheld from batch) _____ GAL.
ST CYLINDER TAKEN ☐ YES ☐ NO BY _____
YLINDER TAKEN ☐ BEFORE ☐ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X _____

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
MBC MANAGEMENT
3100 SH 47, BRYAN, TX 77807

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT
617	9020	2021	4.00	TTI-THRIE BEAM

DRIVER NAME: CHARLES BALANGA
DATE: 05/26/21

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
782823	100137	3.00	3.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
3.00	R9B35512	COM,RG,B,3500,REG,4,2.0,T1C20,46		
1.00	5347	MINIMUM LOAD		

SPECIAL DELIVERY INSTRUCTIONS
RIGHT 2818, RIGHT LEONARD RD, RIGHT 47, LEFT INTO RELLIS, STRAIGHT AROUND ROUND ABOUT TO GATE, CUSTOMER TO MEET YOU THERE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:**

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
9020	916114	user	6785763	92677	10:08	5/26/21

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
3.00 CYDS	R9B35512				D	93853

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual	Wat
1"RG	1305 lb	3967 lb	3960 lb	-0.17%	1.30% M	6 gl	
3/8"PG	500 lb	1520 lb	1500 lb	-1.30%	1.30% M	2 gl	
SAND-1	1490 lb	4671 lb	4680 lb	0.20%	4.30% M	24 gl	
CMT-I/II	368 lb	1104 lb	1085 lb	-1.72%			
FLYASH-C	92 lb	276 lb	275 lb	* -0.36%		52 gl	
H20	250 lb	440 lb	430 lb	-2.33%			
ZY-610	15 oz	44 oz	44 oz	-0.36%			

Actual Num Batches: 1 Design 89.9 gl Actual 84.1 gl To Add: 5.7 gl
Load 11933 lb Design W/C: 0.544 Water/Cement: 0.552 T 0.0 gl / Load Trim Water: -1.5 gl / CYDS
Slump: 4.00 in Water in Truck: 0.0 gl Adjust Water: 20 lb ET 0 lb WAT1 SCALE B 1 ST 2 lb ET 0 lb
AGG1 SCALE B 1 ST 0 lb ET 0 lb CEM1 SCALE B 1 ST

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0194
Service Date: 05/26/21
Report Date: 06/08/21
Task: PO# 615131-01

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
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: A1171057

Material Information

Specified Strength:

Mix ID: R9B35512
Supplier: Martin Marietta
Batch Time: 1008 **Plant:** 617
Truck No.: 9020 **Ticket No.:** 6785763

Sample Information

Sample Date: 05/26/21 **Sample Time:** 1130
Sampled By: Mohammed Mobeen
Weather Conditions: Partly Cloudy Light Wind
Accumulative Yards: 3/3 **Batch Size (cy):** 3
Placement Method: Direct Discharge
Water Added Before (gal):
Water Added After (gal):
Sample Location: PO #615131-01
Placement Location: PO #615131-01

Field Test Data

Test	Result	Specification
Slump (in):	5	
Air Content (%):	1.8	
Concrete Temp. (F):	85	
Ambient Temp. (F):	74	
Plastic Unit Wt. (pcf):	146.2	
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
1	A	6.01	28.37		06/08/21	13 F	116,670	4,110	4	SLS
1	B	6.01	28.37		06/08/21	13 F	120,970	4,260	1	SLS
1	C	6.01	28.37		06/08/21	13 F	117,830	4,150	3	SLS
1	D					Hold				

Initial Cure: Outside **Final Cure:** Field Cured

Comments: **F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Mohammed Mobeen
Start/Stop:
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke
(1) Texas Transportation Institute, Bill Griffith
(1) Terracon Consultants, Inc., Alex Dunigan, P.E.

Reviewed By:
Alexander Dunigan
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Texas A&M Transportation Institute	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Revision Date: 2020-07-29
Quality Form	Revised by: B.L. Griffith Approved by: D. L. Kuhn	Revision: 7	Page: 1 of 1

Project No: 615131 **Casting Date:** 5/17/2021 **Mix Design (psi):** 3300

Name of Technician Taking Sample: Terracon

Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	7130	6777320	North section to expansion joint of wall and deck

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average

BILLING

TICKET NO.
6777320

Martin Marietta

Martin Marietta
1503 LBJ Freeway
Suite 400
Dallas, TX 75234

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
12:53	:	:	:	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST 10 GAL.
ALLOWABLE WATER (withheld from batch) GAL.
TEST CYLINDER TAKEN ☑ YES ☐ NO BY
CYLINDER TAKEN ☐ BEFORE ☑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
IBC MANAGEMENT
100 SH 47, BRYAN, TX 77807

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT
617	7130	2013	4.00	TTI-THRIE BEA

DRIVER NAME: Jeremy Freeman
DATE: 05/17/21

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
782823	100137	8.00	8.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
8.00	R9B35512	COM,RG,B,3500,REG,4,2.0,T1C20,46		

SPECIAL DELIVERY INSTRUCTIONS
RIGHT 2818, RIGHT LEONARD RD, RIGHT 47, LEFT INTO RELLIS, STRAIGHT AROUND ROUND ABOUT TO GATE, CUSTOMER TO MEET YOU THERE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:**

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
30	956950	user	6777320	92566	12:53	5/17/21

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
00 CYDS	R9B35512				D	93740

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual	Wat
	1305 lb	10524 lb	10500 lb	-0.23%	0.80% M	10 gl	
PG	500 lb	4053 lb	4060 lb	0.18%	1.30% M	6 gl	
D-1	1490 lb	12391 lb	12400 lb	0.07%	3.80% M	56 gl	
I/II	368 lb	2944 lb	2925 lb	-0.65%			
ASH-C	92 lb	736 lb	735 lb	* -0.14%			
	250 lb	1299 lb	1288 lb	-0.83%		154 gl	
610	15 oz	118 oz	118 oz	0.20%			
ial		Num Batches: 1					

d	31915 lb	Design W/C:	0.544	Water/Cement:	0.546 T	Design	239.7 gl	Actual	227.2 gl	To Add:	12.5 gl
np:	4.00 in	Water in Truck:		0.0 gl	Adjust Water:	0.0 gl / Load		Trim Water:	-1.4 gl / CYDS		

G1 SCALE B 1 ST 20 lb ET 0 lb CEM1 SCALE B 1 ST 5 lb ET 0 lb WAT1 SCALE B 1 ST 4 lb ET 0 lb

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0192
Service Date: 05/17/21
Report Date: 06/08/21
Task: PO# 615131-01

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
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: A1171057

Material Information

Specified Strength:

Mix ID: R9B35512
Supplier: Martin Marietta
Batch Time: 1253 **Plant:** 617
Truck No.: 7130 **Ticket No.:** 6777320

Sample Information

Sample Date: 05/17/21 **Sample Time:** 1404
Sampled By: Adam Hill
Weather Conditions: Partly cloudy low wind
Accumulative Yards: 8/8 **Batch Size (cy):** 8
Placement Method: Direct Discharge
Water Added Before (gal): 10
Water Added After (gal): 0
Sample Location: South edge of west rail foundation
Placement Location: PO# 615131-01

Field Test Data

Test	Result	Specification
Slump (in):	5 3/4	
Air Content (%):	2.4	
Concrete Temp. (F):	83	
Ambient Temp. (F):	86	
Plastic Unit Wt. (pcf):	148.6	
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
1	A	6.01	28.37		06/08/21	22 F	132,820	4,680	4	SLS
1	B	6.01	28.37		06/08/21	22 F	125,360	4,420	3	SLS
1	C	6.01	28.37		06/08/21	22 F	132,320	4,660	3	SLS
1	D					Hold				

Initial Cure: Outside **Final Cure:**

Comments: **F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Adam Hill **Start/Stop:** 1230-1430
Reported To: Bill with TTI
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Alex Dunigan, P.E.
(1) Texas Transportation Institute, Bill Griffith

Reviewed By: Alexander Dunigan
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Texas A&M Transportation Institute	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Revision Date: 2020-07-29
Quality Form	Revised by: B.L. Griffith Approved by: D. L. Kuhn	Revision: 7	Page: 1 of 1

Project No: 615131 **Casting Date:** 5/21/2021 **Mix Design (psi):** 3300

Name of Technician Taking Sample	Terracon	Name of Technician Breaking Sample	Terracon
Signature of Technician Taking Sample	Terracon	Signature of Technician Breaking Sample	Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	7130	6781501	South section to expansion joint of wall and deck, missing southern 6 feet
T2	9020	6781605	6 ft of south end of deck and wall and North section of curb to expansion joint

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average

CERTIFICATION DOCUMENTS

ArcelorMittal Burns Harbor Plate

QUALITY ASSURANCE
REPORT OF TEST AND ANAYLSES

SHIPMENT NO	DATE SHIPPED	CAR OR VEHICLE NO.	
803-64202	09-22-20	TTPX 080892	PAGE

SOLD TO

SHIP TO

NOTE	SERIAL NUMBER	PAT NO.	HEAT NUMBER	NO. PCS.	SIZE AND QUANTITY: THICKNESS	WIDTH OR DIA.	LENGTH	WEIGHT	YIELD POINT	TENSILE STRENGTH	ELONG.	RED
					INCHES	INCHES	INCHES	POUNDS	PSI	PSI	IN	% %

QUALITY STEEL MELTED & MANUFACTURED IN THE U. S. A.
PLATES - ASTM A709-18 GR 50 MOD SI.15/.25
KLD FINE GRAIN PRAC TYPE 2 CE=.43X
PER IIW FORMULA, ASTM A572-13A GR
50, CH-V A673 FREQ (H) L 20 FTLB AT
-22F --- PLT CONTROLLED FINISH ---
IN ACCORDANCE WITH EN 10204:2004
TYPE 3.1 10204:2004 TYPE 3.1
MFST - MFST MILL SERIAL# & PATTERN# MFST PPI 0086025-
0001 MFST IN ACCORDANCE WITH EN 10204:2004 TYPE
3.1 MFST 10204:2004 TYPE 3.1
- LIFT MAX 20
TON UNLDG FORK LIFT-SIDE
CO# 24.559 GH 405-2371C

⇨	812N38470	7	3/4	96	240	34307	56700	78500	8	25
							58200	80900	8	23
(M55)MFST REF#:HR PLATE A572										
	822N38470	8	3/4	96	240	39208	56700	78500	8	25
							58200	80900	8	23
(M55)MFST REF#:HR PLATE A572										

3 / 25 / 2021

SFI-GRAY STEEL

Customer Name:
Customer PO #:
Thickness: 3/4"
SFI PO #: 703425
Heat & Slab: 812N38470
Plate #: 60607,60608

Q-QUENCH TEMPERATURE

N-NORMALIZE TEMPERATURE

SERIAL NUMBER	PAT NO.	HEAT NUMBER	HARD BHN	BEND	CHARPY IMPACT: THICKNESS INCHES	TYPE	SIZE	DIR	TEST TEMP F	ENERGY FT LBS 1	2	3	SHEAR(%) 1	2	3	LAT. EXP MILS 1	2	3
		812N38470			1.000	V	FULL	L	-22	61	87	94						
		822N38470			.625	V	FULL	L	-22	90	102	100						

HEAT NUMBER	CHEMICAL ANALYSIS: C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Ti	Al	B	Co	N	Sn	MOD AID GRAIN SIZE
812N38470	.18	1.21	.008	.004	.179	.017	.01	.03	.004	.058	.002	.035	.0002		.002	.006	.002
	CE .40																
822N38470	.18	1.21	.008	.004	.179	.017	.01	.03	.004	.058	.002	.035	.0002		.002	.006	.002
	CE .40																

I certify that the above results are a true and correct copy of actual results contained in records maintained by ArcelorMittal Burns Harbor and are in full compliance with the requirements of the specification cited above. This test report cannot be altered and must be transmitted intact with any subsequent third party test reports, if required.

8HPLTRPT.TIF

FARID HASSANI PER MWT

SUPV. QUALITY ASSURANCE

SF | AY STEEL - Date:3/30/2021 - Customer:TEXAS CORRUGATORS- | JTIN DIV. (EMAIL INV) - PO#:G-0340 - P/N:

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499

Customer: TEXAS CORRUGATORS INC
P.O.BOX 938

ROUNDROCK, TX 78680

Project: STOCK

Order Number: 1335969 Prod Ln Grp: 0-OE2.0
Customer PO: M-2462
BOL Number: 83315 Ship Date:
Document #: 1
Shipped To:
Use State: TX

As of: 4/5/21

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
650	533G	6'0 POST/8.5/DDR	A-36			1801947	55,000	68,200	25.6	0.070	0.830	0.007	0.028	0.250	0.090	0.014	0.040	0.003	4
	533G		A-36			2817878	59,800	71,100	25.0	0.070	0.860	0.007	0.030	0.160	0.260	0.014	0.050	0.004	4
	533G		A-36			58046122	59,584	70,959	24.4	0.070	0.900	0.015	0.038	0.200	0.330	0.020	0.210	0.001	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, UNLESS OTHERWISE STATED.
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 Texas, County of Tarrant. Sworn and subscribed before me this 5th day of April, 2021 .

Notary Public:
Commission Expires: / /

MELISSA GUTIERREZ
Notary Public, State of Texas
Comm. Expires 01-14-2023
Notary ID 130076934

Trinity Highway Products LLC
Certified By:
Quality Assurance

TR No. 615131-01

Certifie_ Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: TEXAS CORRUGATORS INC
P.O.BOX 938

ROUNDROCK, TX 78680
Project: STOCK

Order Number: 1335969 Prod Ln Grp: 0-OE2.0
Customer PO: M-2462
BOL Number: 83315 Ship Date:
Document #: 1
Shipped To:
Use State: TX

As of: 4/5/21

62

2021-10-20

TR No. 615131-01

63

2021-10-20

**LAND 15
NUCOR STEEL - BERKELEY
1455 Hagan Avenue
Huger, SC 29450
Phone: (843) 336-6000

CERTIFIED MILL TEST REPORT

1/30/21 14:09:38
100% EAF MELTED AND MANUFACTURED IN THE USA
Structural sections produced by Nucor-Berkeley are cast
and hot rolled to a fully killed and fine grain practice.
Mercury not intentionally added at any point during manufacturing.

Sold To: TEXAS CORRUGATORS INC
PO BOX 938

ROUND ROCK, TX 78680

Ship To: TEXAS CORRUGATORS INC
105 TRADESMAN PARK DRIVE

HUTTO, TX 78634

Customer #.: 1948 - 3
Customer PO: M-2367
B.o.L. #...: 1532227

MOS: T

SPECIFICATIONS: Tested in accordance with ASTM specification A6/A6M-19 and A370. Tested in accordance with EN10204-2004-3.1.
Quality Manual Rev #14 (9-23-20).
AASHTO : m270-345M270-50-19
ASME : SA-36 13
ASTM : A992-11(15:/A36-19/A529-19-50/A5725018T1/A7093618/A7095018
CSA : G40.21-44w/G40.21-50w/G40.2150WM

Description / Part #	Heat# / Grade(s) / Test/Heat JW	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C / Cr / ******	Mn / Mo / Ti	P / Sn / ******	S / B / ******	Si / V / N	Cu / Nb / ******	Ni / ****** / CI	CE1 / CE2 / Pcm
S3X5.7	2013857	.82	57400	70000	22.00	.07	.84	.016	.018	.24	.08	.03	.23
040' 00.00"	A992-11(15		396	483		.07	.01	.0036	.0002	.002	.014		.2725
S75X8.5		.83	59300	71800	25.00		.001			.0048		2.71	.1268
012.1920m			409	495	35 Pc(s)	7,980 lbs	Customer PO: M-2367			BoL#: 1532227			
W6X12	1018161	.81	56900	70100	26.00	.07	.85	.006	.020	.20	.13	.05	.23
040' 00.00"	A992-11(15		392	483		.05	.01	.0053	.0002	.002	.028		.2722
W150X18.0		.82	57300	70200	25.00		.001			.0047		3.39	.1293
012.1920m			395	484	12 Pc(s)	5,760 lbs	Customer PO: M-2367			BoL#: 1532227			
W6X15	1101481	.85	59000	69600	26.00	.07	.89	.009	.014	.18	.16	.05	.24
040' 00.00"	A992-11(15		407	480		.04	.01	.0080	.0002	.002	.032		.2759
W150X22.5		.83	59100	71300	26.00		.001			.0061		3.88	.1310
012.1920m			407	492	9 Pc(s)	5,400 lbs	Customer PO: M-2367			BoL#: 1532227			

Elongation based on 8" (20.32cm) gauge length. 'No Weld Repair' was performed. "All mechanical testing is performed by the Quality testing lab, which is independent of the production departments"

CI = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29Cu*Ni)-(9.10Ni*P)-33.39(Cu*Cu)

Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B

CE1= C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)

CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

Nucor certifies that the contents of this report are accurate and correct. All test results and operations performed by the material manufacturer are in compliance with material specifications, and when designated by the Purchaser, meet applicable specifications.

Dmitri Nassyrov
Metallurgist/
Quality Control

TR No. 615131-01

64

2021-10-20

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT
For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3103939 SECTION: REBAR 16MM (#5) 20'0" 300/40 GRADE: ASTM A615-20 Grade 300/40 ROLL DATE: 03/17/2021 MELT DATE: 03/01/2021 Cert. No.: 83418902 / 103939A138	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83418902 BOL#: 74080272 CUST PO#: 877496 CUST P/N: DLVRY LBS / HEAT: 4006.000 LB DLVRY PCS / HEAT: 192 EA

Characteristic	Value
C	0.15%
Mn	0.82%
P	0.013%
S	0.039%
Si	0.18%
Cu	0.32%
Cr	0.13%
Ni	0.14%
Mo	0.047%
V	0.031%
Cb	0.005%
Sn	0.013%
Al	0.006%
Yield Strength test 1	53.0ksi
Tensile Strength test 1	70.2ksi
Elongation test 1	26%
Elongation Gage Lgth test 1	8IN
Bend Test 1	Passed
Bend Test Diameter	2.188IN

Characteristic	Value

Characteristic	Value

The Following is true of the material represented by this MTR:

**Material is fully killed*
**100% melted and rolled in the USA*
**EN10204:2004 3.1 compliant*
**Contains no weld repair*
**Contains no Mercury contamination*
**Manufactured in accordance with the latest version of the plant quality manual*
**Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661*
**Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov*

REMARKS :

TR No. 615131-01

65

2021-10-20

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3104702 SECTION: REBAR 13MM (#4) 20'0" 300/40 GRADE: ASTM A615-20 Grade 300/40 ROLL DATE: 04/05/2021 MELT DATE: 03/30/2021 Cert. No.: 83418902 / 104702A293	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83418902 BOL#: 74080272 CUST PO#: 877496 CUST P/N: DLVRY LBS / HEAT: 2191.000 LB DLVRY PCS / HEAT: 164 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.09%				
Mn	0.82%				
P	0.013%				
S	0.039%				
Si	0.17%				
Cu	0.35%				
Cr	0.11%				
Ni	0.18%				
Mo	0.052%				
V	0.000%				
Cb	0.001%				
Sn	0.018%				
Al	0.001%				
Yield Strength test 1	42.5ksi				
Tensile Strength test 1	60.8ksi				
Elongation test 1	29%				
Elongation Gage Lgth test 1	8IN				
Bend Test 1	Passed				
Bend Test Diameter	1.750IN				

The Following is true of the material represented by this MTR:

**Material is fully killed*
**100% melted and rolled in the USA*
**EN10204:2004 3.1 compliant*
**Contains no weld repair*
**Contains no Mercury contamination*
**Manufactured in accordance with the latest version of the plant quality manual*
**Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661*
**Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov*

REMARKS :

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: SAMPLES, TESTING MATERIALS
15601 Dallas Pkwy
Suite 525
ADDISON, TX 75001
Project: POOLED FUND 615131

Order Number: 1335837 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO:
BOL Number: 83078 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 3/19/21

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
12	111G	10/12'6/3'1.5/S			2	F10521													4
			M-180	A	2	2107037	63,900	85,600	22.0	0.210	0.780	0.009	0.001	0.030	0.090	0.001	0.040	0.004	4
			M-180	A	2	2107660	59,400	82,900	24.0	0.200	0.770	0.012	0.001	0.030	0.080	0.002	0.060	0.003	4
			M-180	A	2	2208099	55,700	81,100	24.0	0.240	0.970	0.009	0.002	0.020	0.080	0.001	0.050	0.004	4
			M-180	A	2	2210348	53,600	76,300	28.0	0.190	0.780	0.009	0.002	0.030	0.080	0.002	0.050	0.003	4
			M-180	A	2	2210350	57,100	76,900	29.0	0.190	0.800	0.009	0.002	0.030	0.090	0.002	0.050	0.003	4
			M-180	B	2	2110285	57,300	79,200	27.0	0.220	0.770	0.009	0.002	0.020	0.080	0.001	0.050	0.002	4
2	850G	12/BUFFER/ROLLED	M-180	A	2	256002	63,096	80,968	21.9	0.190	0.730	0.009	0.004	0.010	0.110	0.000	0.050	0.002	4
	850G		M-180	A	2	256002	63,096	80,968	21.9	0.190	0.730	0.009	0.004	0.010	0.110	0.000	0.050	0.002	4
	850G		M-180	A	2	31847970	48,400	62,300	35.0	0.060	0.450	0.015	0.001	0.030	0.090	0.000	0.070	0.002	4
2	977G	T10/TRANS RAIL/6'3"/3'1.5	RHC		2	L32420													4
			M-180	A	2	251386	62,920	81,060	24.4	0.200	0.720	0.010	0.002	0.020	0.100	0.000	0.070	0.002	4
			M-180	B	2	248862	64,080	82,460	25.1	0.180	0.730	0.011	0.001	0.020	0.100	0.000	0.060	0.001	4
			M-180	B	2	249478	61,020	80,630	27.0	0.190	0.720	0.010	0.001	0.020	0.090	0.000	0.060	0.000	4
	977G		M-180	A	2	211727	62,980	82,080	24.0	0.190	0.730	0.013	0.005	0.010	0.130	0.000	0.060	0.001	4
2	3000G	CBL 3/4X6'6/DBL	WIRE			S394298													4
230	3340G	5/8" GR HEX NUT	FAST			21-54-006													4
150	3360G	5/8"X1.25" GR BOLT	A307-3360			922031-13													4
80	4441G	5/8"X5" GR BOLT A307	A307-4441			33536													4

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: SAMPLES, TESTING MATERIALS
15601 Dallas Pkwy
Suite 525
ADDISON, TX 75001
Project: POOLED FUND 615131

Order Number: 1335837 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO:
BOL Number: 83078 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 3/19/21

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
4	19481G	C3X5#X6'-8" RUBRAIL	A-36			3077310	55,400	77,200	32.0	0.170	0.560	0.013	0.039	0.210	0.330	0.002	0.090	0.017	4
	19481G		A-36			3086787	56,100	76,000	29.0	0.150	0.630	0.013	0.035	0.210	0.320	0.000	0.130	0.000	4
2	20207G	12/9'4.5/8-HOLE ANCH/S			2	F10121													
			M-180	A	2	2106683	65,400	86,900	21.0	0.230	0.990	0.011	0.008	0.030	0.160	0.001	0.060	0.004	4
			M-180	A	2	2107036	61,900	85,900	24.0	0.220	0.800	0.010	0.017	0.030	0.100	0.001	0.050	0.004	4
			M-180	A	2	2107037	63,900	85,600	22.0	0.210	0.780	0.009	0.001	0.030	0.090	0.001	0.040	0.004	4
			M-180	A	2	2207254	63,700	87,700	21.0	0.240	1.030	0.011	0.001	0.020	0.110	0.001	0.050	0.004	4
			M-180	A	2	2207255	60,100	84,200	27.0	0.230	0.990	0.011	0.001	0.020	0.110	0.002	0.060	0.004	4
			M-180	A	2	2207619	63,800	85,300	19.0	0.210	0.790	0.009	0.001	0.030	0.080	0.001	0.030	0.004	4
2	36120A	DAT-31-TX-HDW-CAN	A-36			4110390	47,000	66,600	34.0	0.180	0.400	0.015	0.002	0.030	0.040	0.001	0.060	1.000	4
	36120A		WIRE			16652240													4
	36120A		A-36			1100008623	58,600	60,100	21.0	0.130	0.820	0.022	0.020	0.212	0.310	0.000	0.190	0.057	4
	36120A		HW			025689													
	36120A		A-36			1053561	60,000	77,100	23.0	0.160	0.750	0.018	0.024	0.180	0.330	0.001	0.200	0.032	4
	36120A		F844-3300			64249													4
	36120A		FAST			21-54-006													4
	36120A		A307-3360			922031-13													4
	36120A		A307-3403			848773-8													4

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: SAMPLES, TESTING MATERIALS
15601 Dallas Pkwy
Suite 525
ADDISON, TX 75001
Project: POOLED FUND 615131

Order Number: 1335837 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO:
BOL Number: 83078 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 3/19/21

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
	36120A		A307-3500			931506-1													4
	36120A		HW			025689													
	36120A		A-36			99592D	45,000	68,000	31.0	0.180	0.780	0.015	0.011	0.009	0.020	0.000	0.040	0.000	4
	36120A		F844-3900			P39692 R74946-02													4
	36120A		A563-3910			P39341 R73497													4
	36120A		A307-4470			893006-7													4
	36120A		A307-4500			940249-4													4
	36120A		A-500			X6030	61,500	65,000	29.8	0.110	0.350	0.014	0.004	0.030	0.150	0.001	0.080	0.001	4
4	130896G	6'0 TUBE SL/.125X8X6	A-500			PL0724	56,815	76,042	31.0	0.190	0.370	0.007	0.001	0.027	0.120	0.006	0.050	0.004	4
4	626079B	WD 3'10 POST	WOOD			3660													

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.

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: SAMPLES, TESTING MATERIALS
15601 Dallas Pkwy
Suite 525
ADDISON, TX 75001
Project: POOLED FUND 615131

Order Number: 1335837 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO:
BOL Number: 83078 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 3/19/21

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, UNLESS OTHERWISE STATED.
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 Texas, County of Tarrant. Sworn and subscribed before me this 19th day of March, 2021 .

Notary Public:
Commission Expires: /

MELISSA GUTIERREZ
Notary Public, State of Texas
Comm. Expires 01-14-2023
Notary ID 130076834

Melissa M. Gutierrez

Trinity Highway Products, LLC
Certified By:
Quality Assurance

APPENDIX C. SOIL PROPERTIES

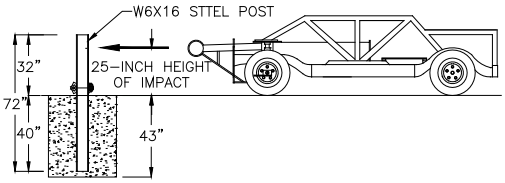
Table C.1. Summary of Strong Soil Test Results for Establishing Installation Procedure.

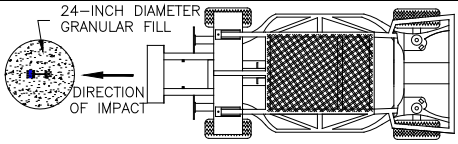
Dynamic Test Setup

Post-Test Photo of post

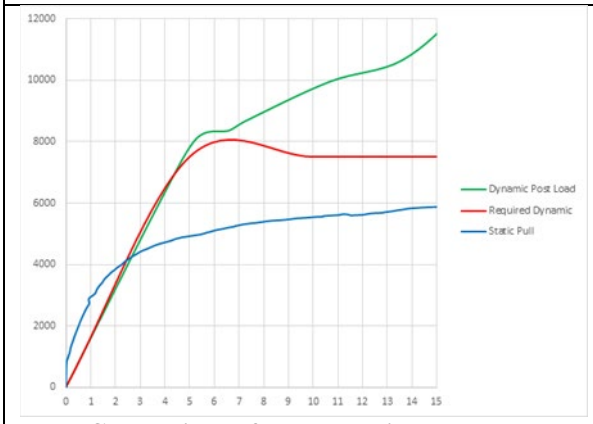
Static Load Test

Post-Test Photo

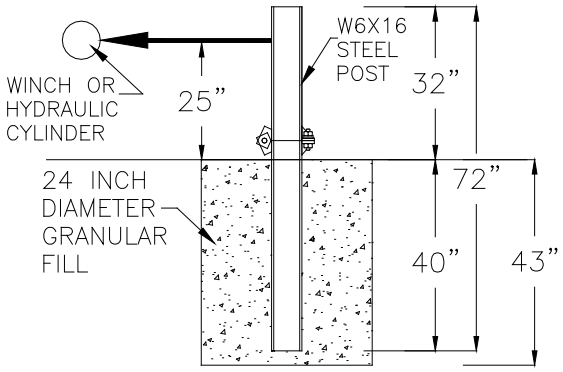




Dynamic Test Installation Details



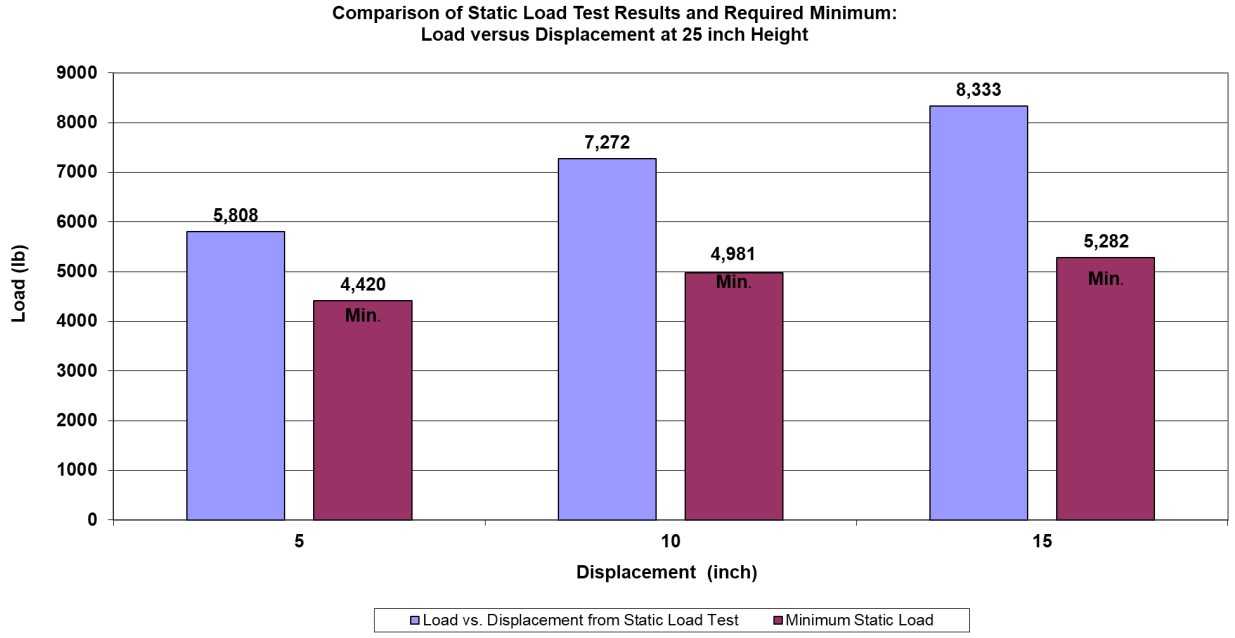
Comparison of Load vs. Displacement



Static Load Test Installation Details

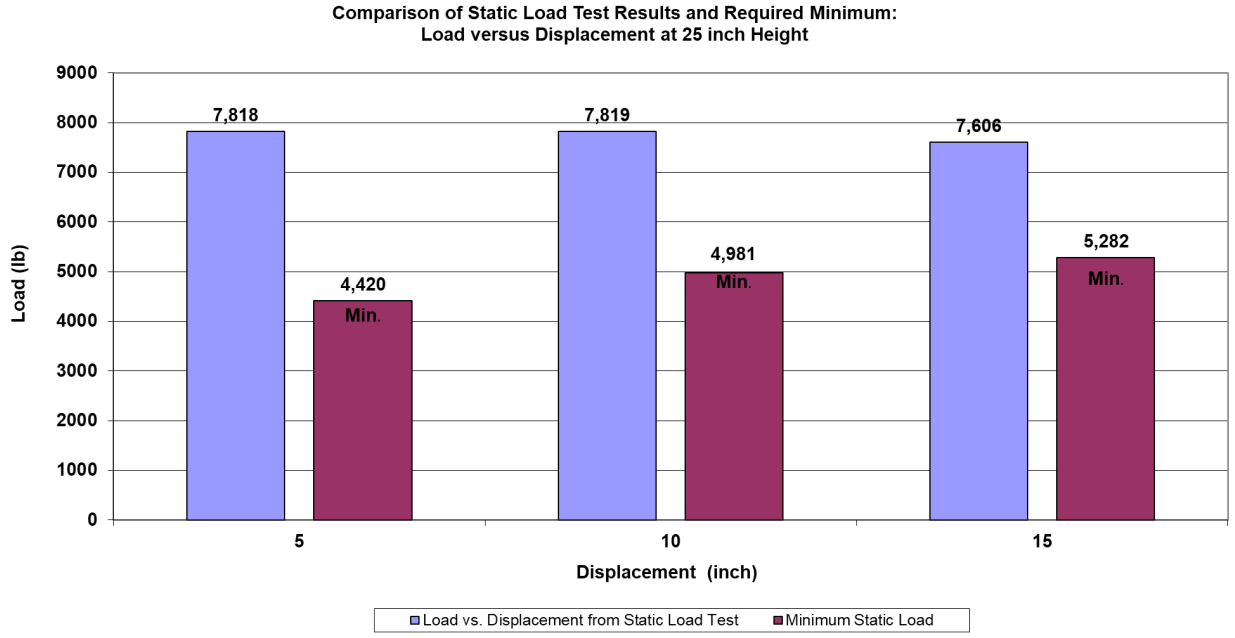
Date	2020-02-02
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO M147 Grade D or Type D Crushed Concrete Road Base
Description of Fill Placement Procedure	12-inch lifts tamped with a pneumatic compactor for 20 sec
Bogie Weight	2020 lb
Impact Velocity	19.2 mph

Table C.2. Test Day Static Soil Strength Documentation for Test No. 615131-01-2.



Date	2021-06-23 Test No. 615131-01-2
Test Facility and Site Location	TTI Proving Ground – 3100 SH 47, Bryan, Tx
In Situ Soil Description (ASTM D2487)	Crushed concrete
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO M147 Grade B Soil-Aggregate
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

Table C.2. Test Day Static Soil Strength Documentation for Test No. 615131-01-1.



Date	2021-07-21 Test No. 615131-01-1
Test Facility and Site Location	TTI Proving Ground – 3100 SH 47, Bryan, Tx
In Situ Soil Description (ASTM D2487)	Crushed concrete
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO M147 Grade B Soil-Aggregate
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

APPENDIX D. *MASH* TEST 3-11 (CRASH TEST NO. 615131-01-2)

D.1. VEHICLE PROPERTIES AND INFORMATION

Table D.1. Vehicle Properties for Test No. 615131-01-1.

Date: 2021-7-23 Test No.: 615131-01-2 VIN No.: 1C6RR6FTOJS317985

Year: 2018 Make: RAM Model: 1500

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 177496

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

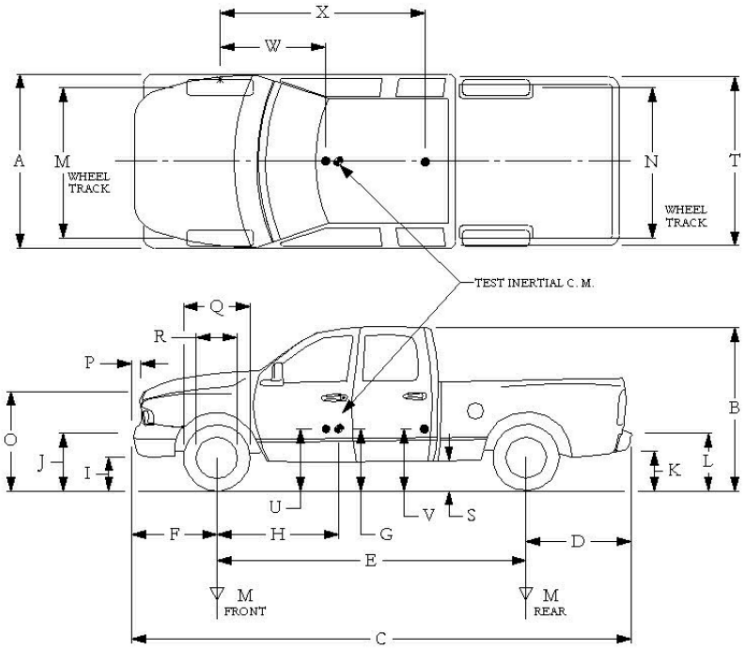
NOTES: None

Engine Type: V-8
Engine CID: 5.7 L

Transmission Type:
☑ Auto ☐ FWD or ☐ Manual ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: IMPACT SIDE



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.50	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.36	M	68.50	R	18.00	W	61.30
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2907	2828	2913
Back	3900	M_{rear}	2048	2193	2273
Total	6700	M_{Total}	4955	5021	5186

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

Mass Distribution:
lb LF: 1432 RF: 1396 LR: 1105 RR: 1088

Table D.2. Measurements of Vehicle Vertical Center of Gravity for Test No. 615131-01-1.

Date: 2021-7-23 Test No.: 615131-01-2 VIN: 1C6RR6FTOJS317985

Year: 2018 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 177496

Engine: 5.7 L V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 160 (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)								
LF:	1432	RF:	1396	Front Axle:	2828			
LR:	1105	RR:	1088	Rear Axle:	2193			
Left:	2537	Right:	2484	Total:	5021			
				5000 ±110 lb allowed				
Wheel Base:	140.50 inches	Track: F:	68.50 inches	R:	68.00 inches			
148 ±12 inches allowed		Track = (F+R)/2 = 67 ±1.5 inches allowed						
Center of Gravity, SAE J874 Suspension Method								
X:	61.37 inches	Rear of Front Axle	(63 ±4 inches allowed)					
Y:	-0.36 inches	Left -	Right +	of Vehicle Centerline				
Z:	28.50 inches	Above Ground	(minumum 28.0 inches allowed)					

Hood Height: 46.00 inches
43 ±4 inches allowed

Front Bumper Height: 27.00 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

Rear Bumper Height: 30.00 inches

Overall Length: 227.50 inches
237 ±13 inches allowed

Table D.3. Exterior Crush Measurements for Test No. 615131-01-1.

Date:	2021-7-23	Test No.:	615131-01-2	VIN No.:	1C6RR6FTOJS317985
Year:	2018	Make:	RAM	Model:	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		Field L***	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max**** Crush								
1	Front plane at bmp ht	18	12	36	-	-	-	-	-	-	-18
2	Side plane at bmp ht	18	15	60	-	-	-	-	-	-	75
	Measurements recorded										
	☑ **inches or** ☐ **mm**										

[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.

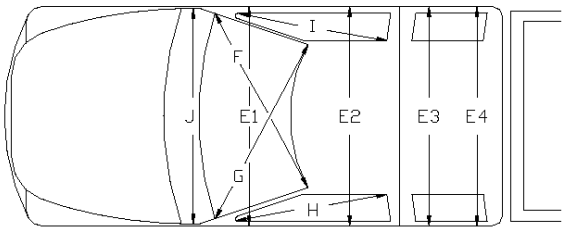
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

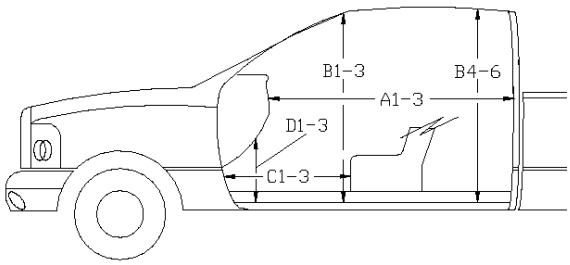
***Measure and document on the vehicle diagram the location of the maximum crush.

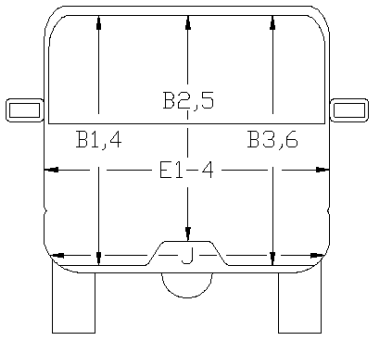
Note: Use as many lines/columns as necessary to describe each damage profile.

Table D.4. Occupant Compartment Measurements for Test No. 615131-01-1.

Date:	2021-7-23	Test No.:	615131-01-2	VIN No.:	1C6RR6FTOJS317985
Year:	2018	Make:	RAM	Model:	1500







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	23.00	-3.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	57.00	-1.50
E2	63.50	66.50	3.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	21.50	-3.50

D.2. SEQUENTIAL PHOTOGRAPHS

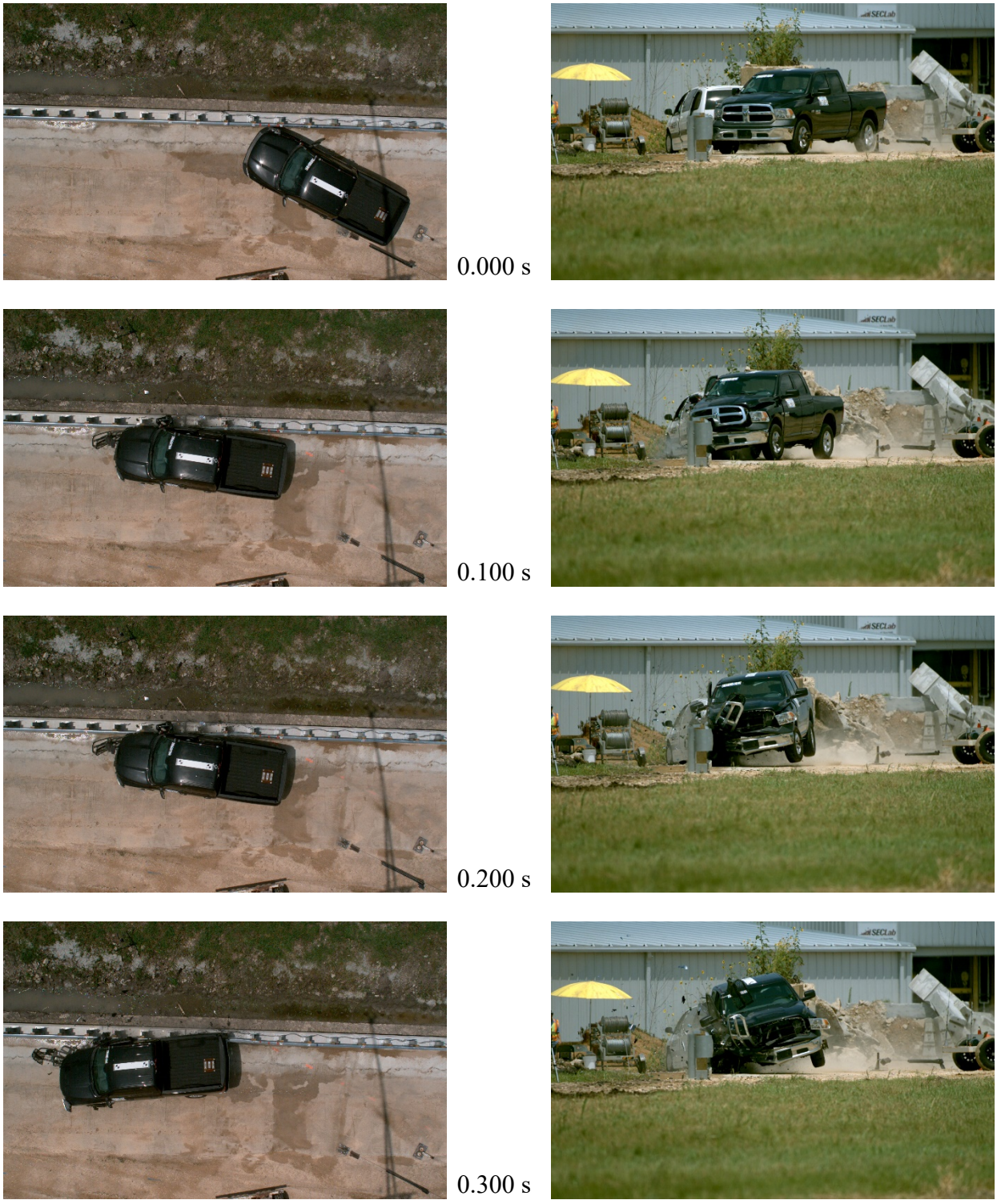


Figure D.1. Sequential Photographs for Test No. 615131-01-2 (Overhead and Frontal Views).

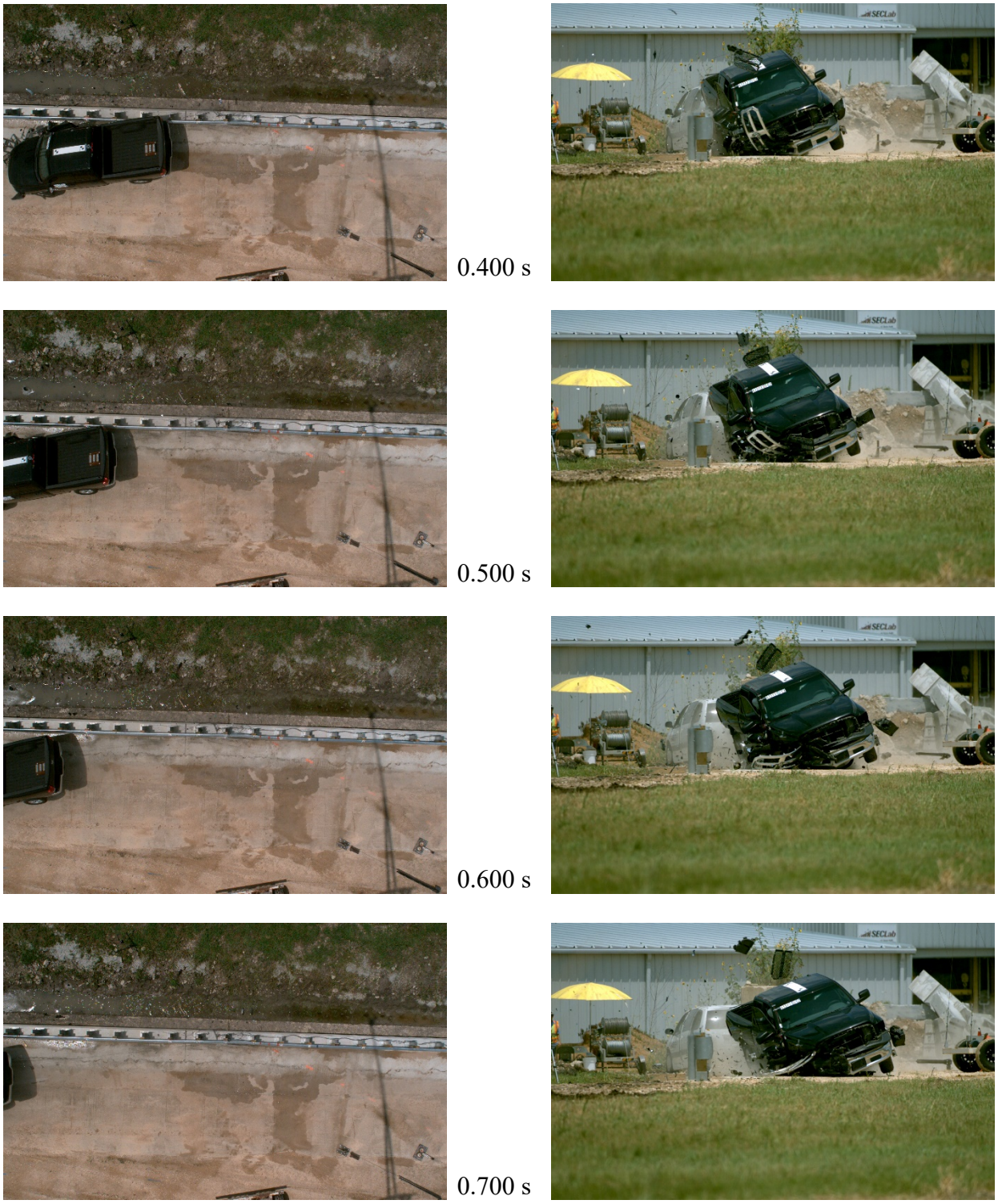


Figure D.1. Sequential Photographs for Test No. 615131-01-2 (Overhead and Frontal Views) (Continued).


0.000 s


0.400 s


0.100 s


0.500 s


0.200 s


0.600 s


0.300 s


0.700 s

Figure D.2. Sequential Photographs for Test No. 615131-01-2 (Rear View).

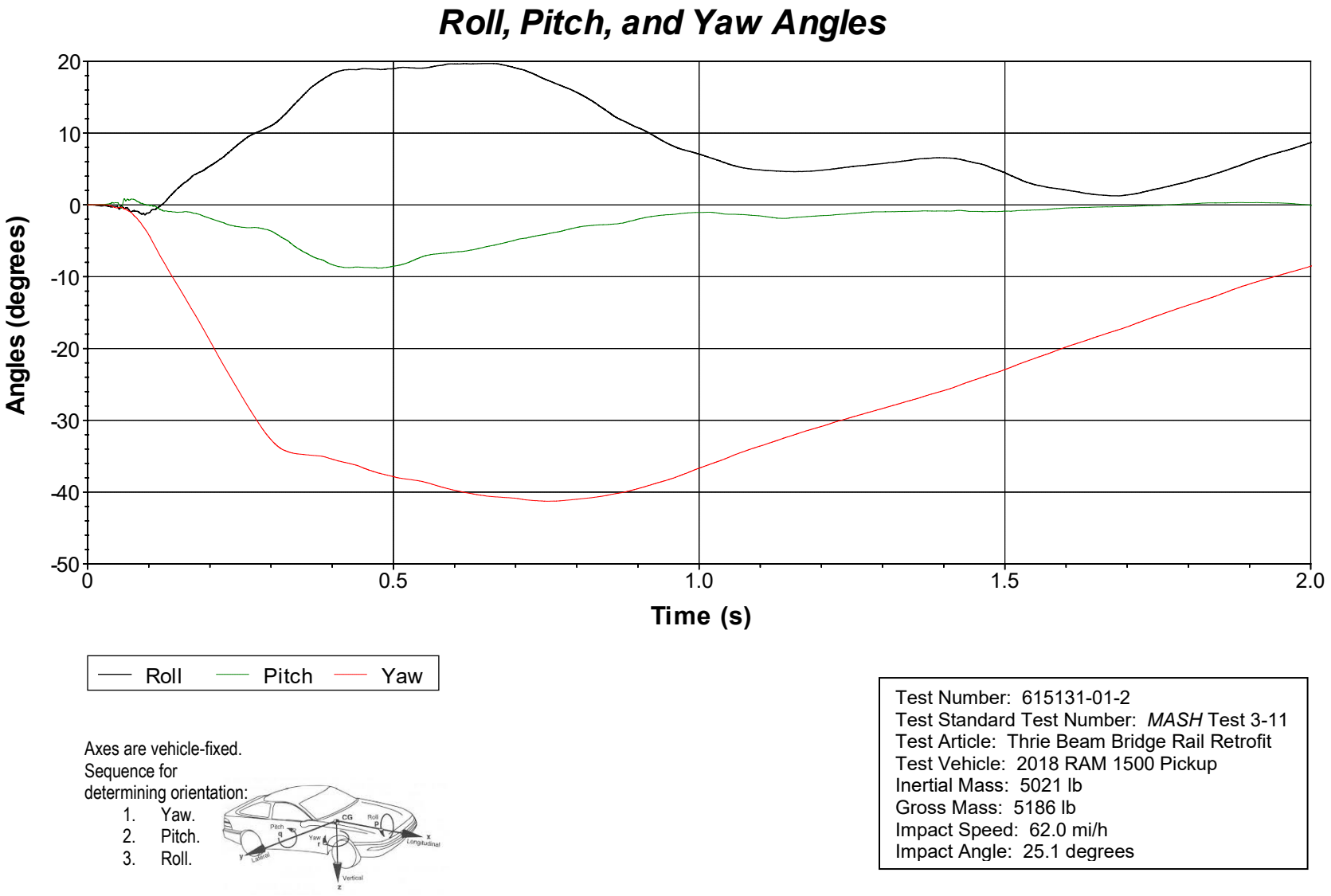


Figure D.3. Vehicle Angular Displacements for Test No. 615131-01-2.

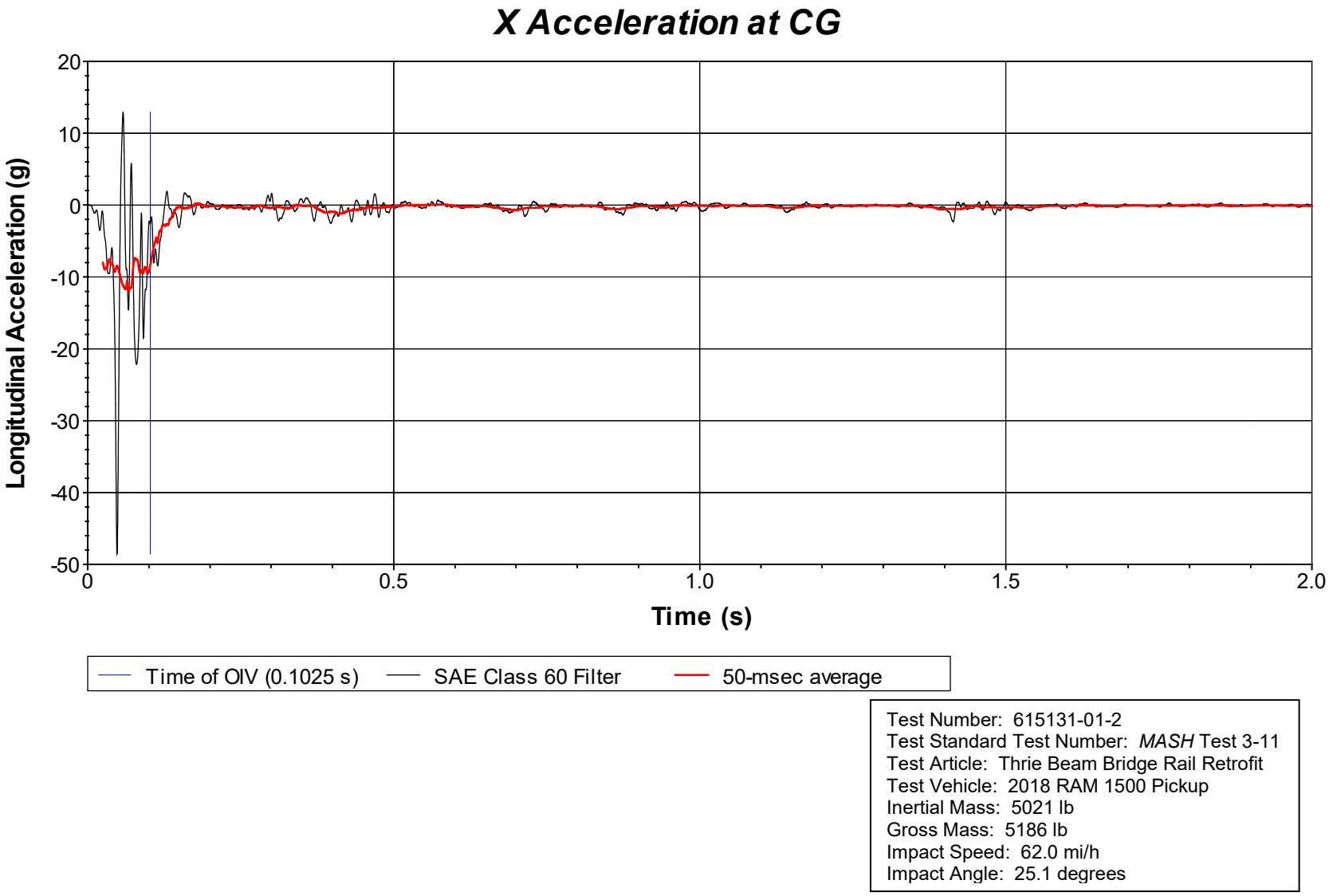


Figure D.4. Vehicle Longitudinal Accelerometer Trace for Test No. 615131-01-2 (Accelerometer Located at Center of Gravity).

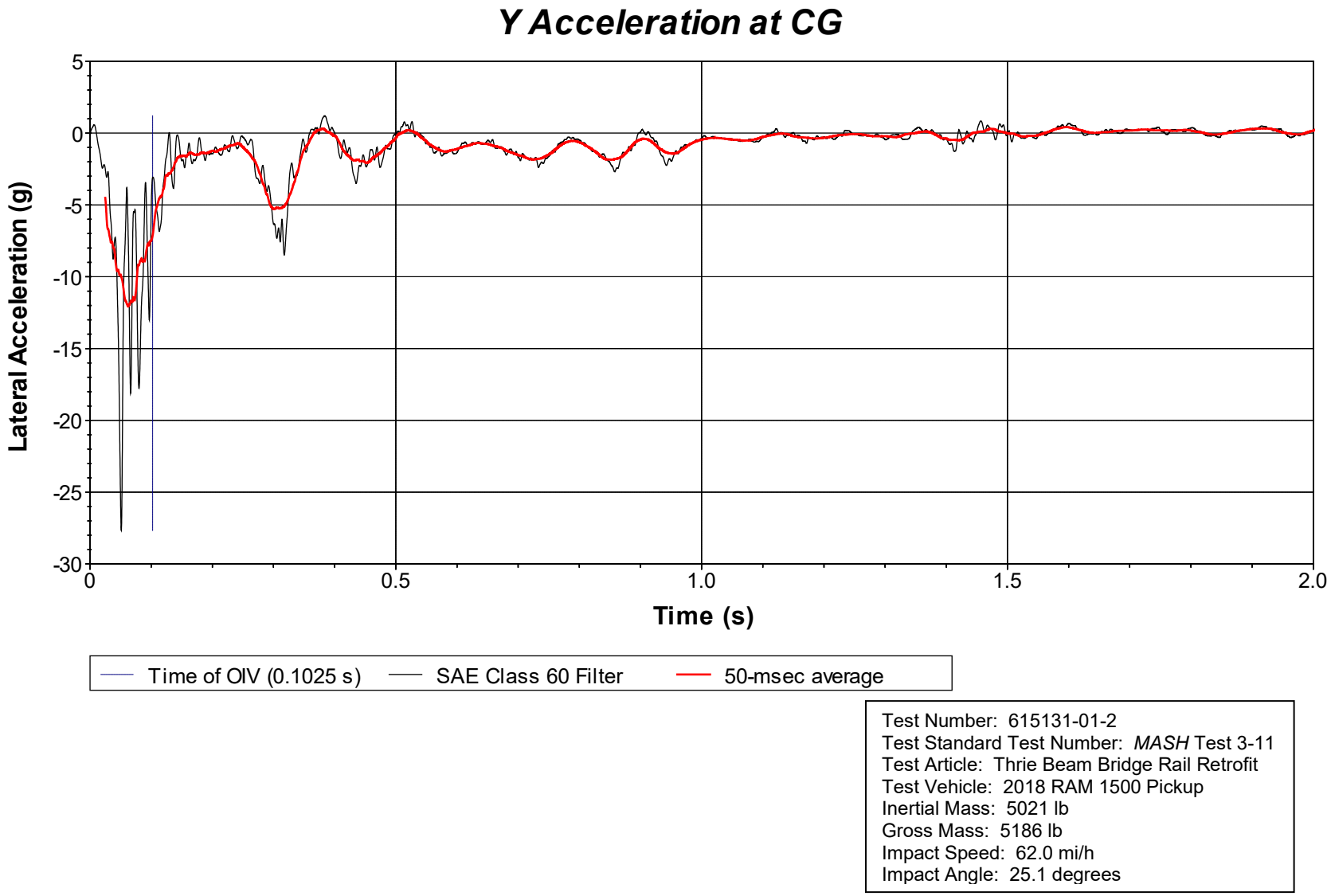


Figure D.5. Vehicle Lateral Accelerometer Trace for Test No. 615131-01-2 (Accelerometer Located at Center of Gravity).

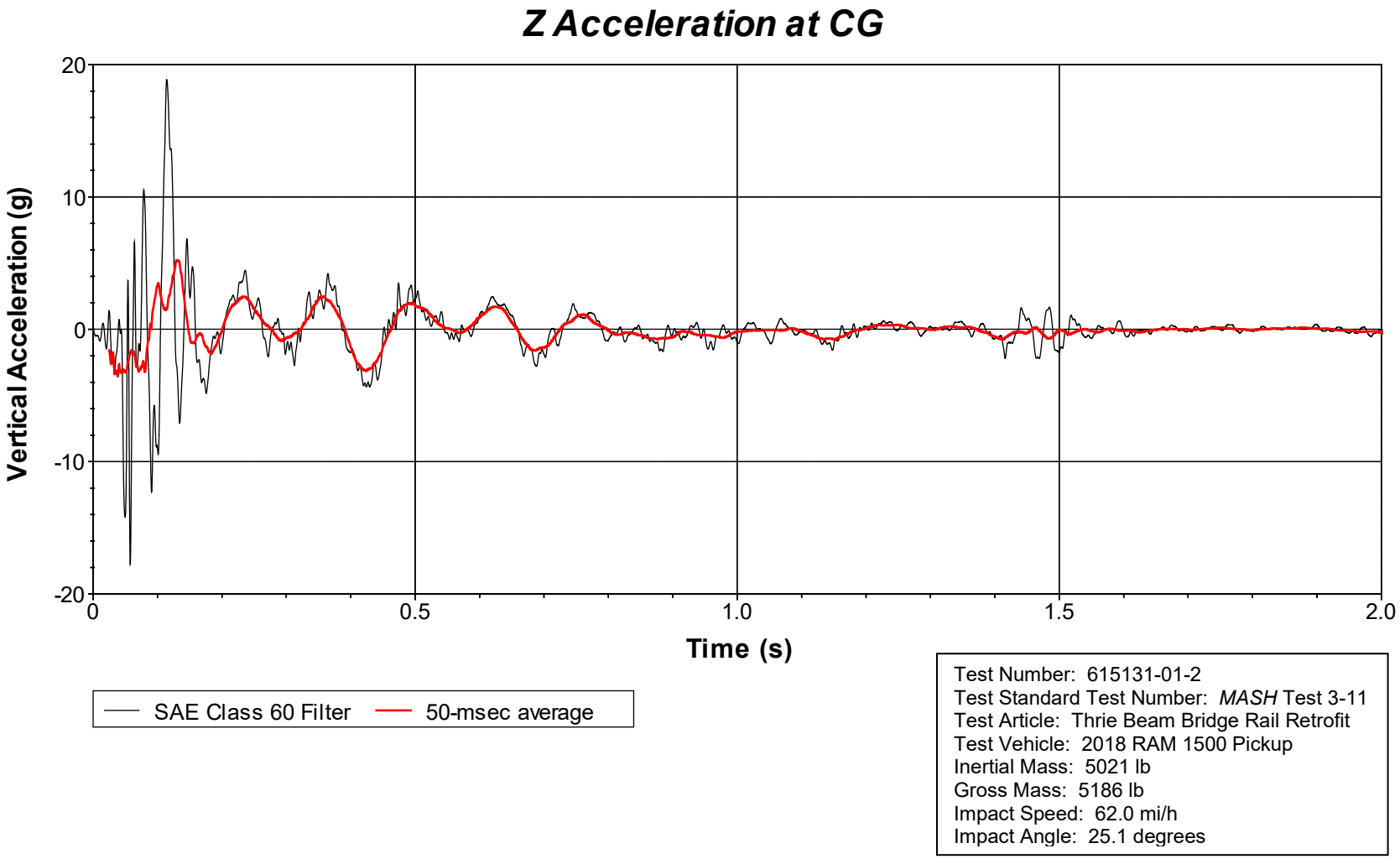


Figure D.6. Vehicle Vertical Accelerometer Trace for Test No. 615131-01-2 (Accelerometer Located at Center of Gravity).

APPENDIX E. *MASH* TEST 3-10 (CRASH TEST NO. 615131-01-1)

E.1. VEHICLE PROPERTIES AND INFORMATION

Table E.1. Vehicle Properties for Test No. 615131-01-1.

Date: 2021-07-21 Test No.: 615131-01-1 VIN No.: 3N1CN7APXFL811662

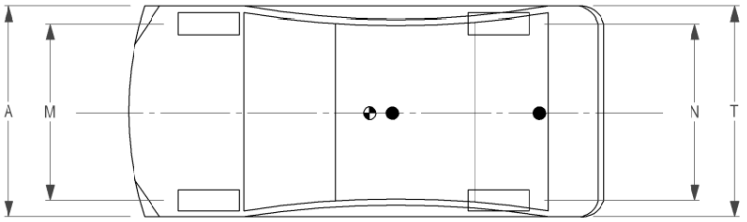
Year: 2015 Make: NISSAN Model: VERSA

Tire Inflation Pressure: 36 PSI Odometer: 208418 Tire Size: P185/65R15

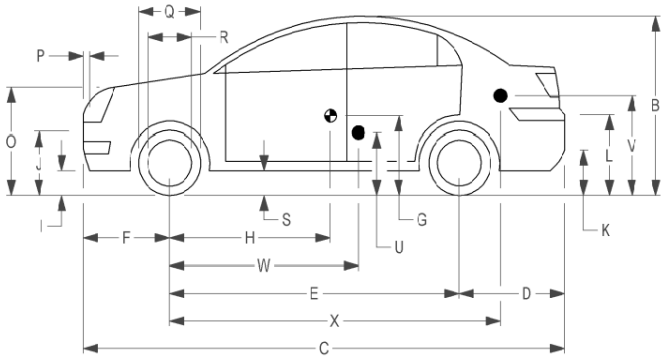
Describe any damage to the vehicle prior to test: None

● 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: IMPACT SIDE

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G		L	26.00	Q	24.00	V	21.25
C	175.40	H	40.81	M	58.30	R	16.25	W	40.80
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.25	O	30.50	T	64.50		
	Wheel Center Ht Front	11.50		Wheel Center Ht Rear	11.50		W-H	-0.01	

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Top of Radiator Support) = 28 ±4 inches
(M+N)/2 = 59 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1462	1474	1559
Back	1687	M_{rear}	957	977	1057
Total	3389	M_{Total}	2419	2451	2616

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

Mass Distribution:
lb LF: 724 RF: 750 LR: 527 RR: 450

Table E.2. Exterior Crush Measurements for Test No. 615131-01-1.

Date: 2021-7-21 Test No.: 615131-01-1 VIN No.: 3N1CN7APXFL811662

Year: 2015 Make: NISSAN Model: VERSA

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		Field L***	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max**** Crush								
1	Front plane at bumper ht	14	10	28	-	-	-	-	-	-	14
2	Side plane above bmp ht	14	8	40	-	-	-	-	-	-	60
	Measurements recorded										
	☑ **inches or** ☐ **mm**										

[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.

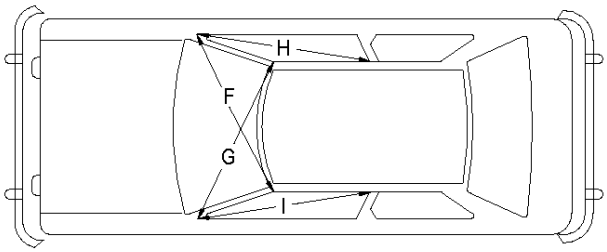
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

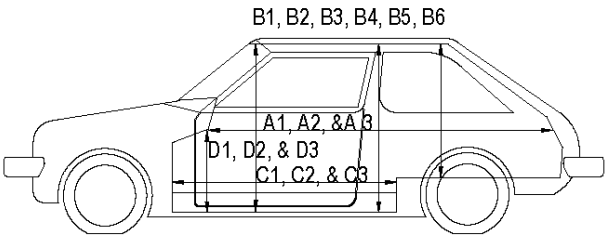
***Measure and document on the vehicle diagram the location of the maximum crush.

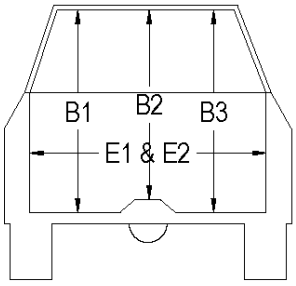
Note: Use as many lines/columns as necessary to describe each damage profile.

Table E.3. Occupant Compartment Measurements for Test No. 615131-01-1.

Date:	2021-7-21	Test No.:	615131-01-1	VIN No.:	3N1CN7APXFL811662
Year:	2015	Make:	NISSAN	Model:	VERSA







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	75.00	75.00	0.00
A2	74.00	74.00	0.00
A3	74.00	74.00	0.00
B1	43.00	43.00	0.00
B2	37.00	37.00	0.00
B3	43.00	42.00	-1.00
B4	46.50	46.50	0.00
B5	42.50	42.50	0.00
B6	46.50	46.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	25.00	-1.00
D1	12.50	12.50	0.00
D2	0.00	0.00	0.00
D3	10.00	8.50	-1.50
E1	45.00	47.00	2.00
E2	48.75	50.75	2.00
F	47.50	47.50	0.00
G	47.50	47.50	0.00
H	39.00	39.00	0.00
I	39.00	39.00	0.00
J*	48.50	47.50	-1.00

E.2. SEQUENTIAL PHOTOGRAPHS

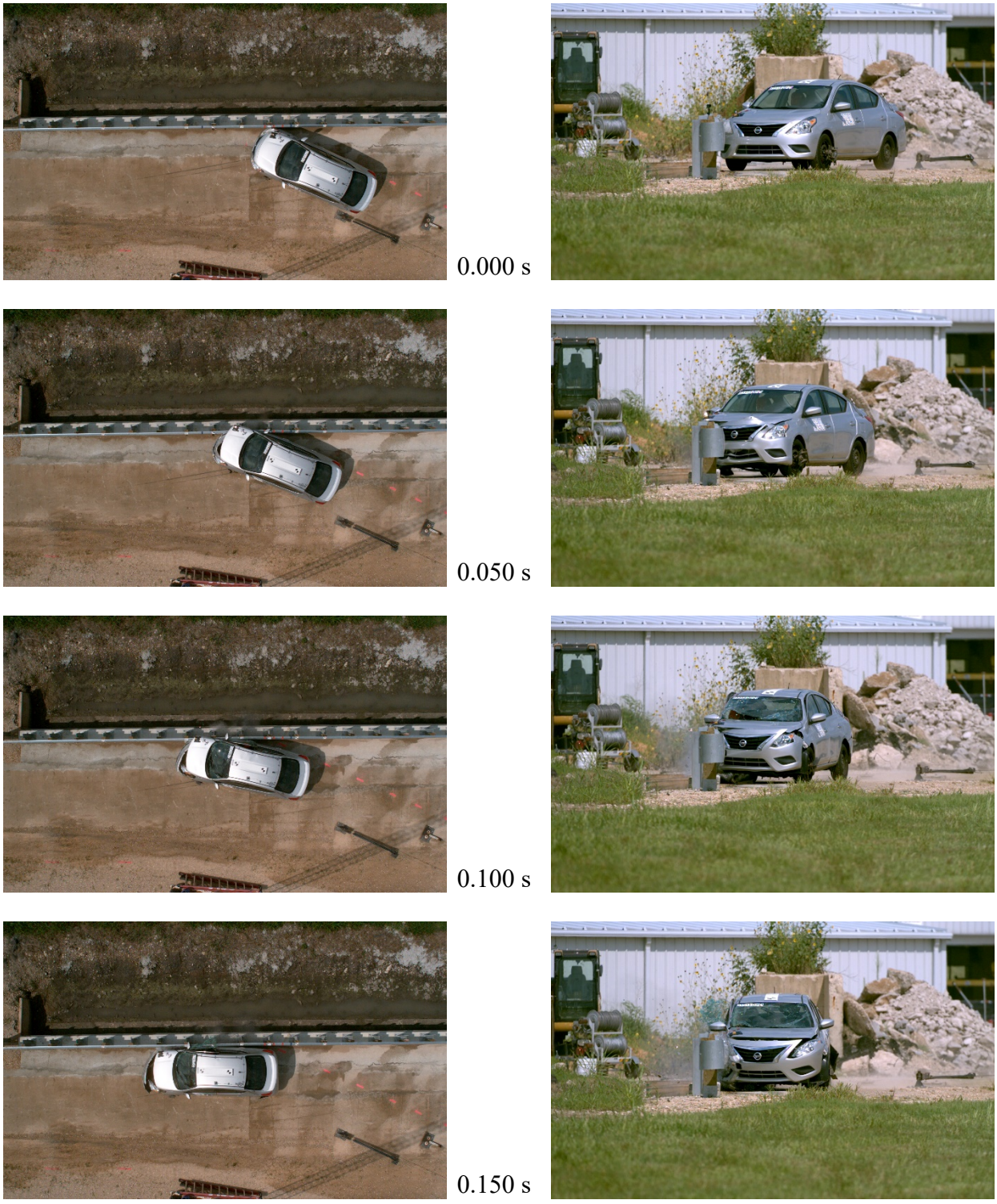
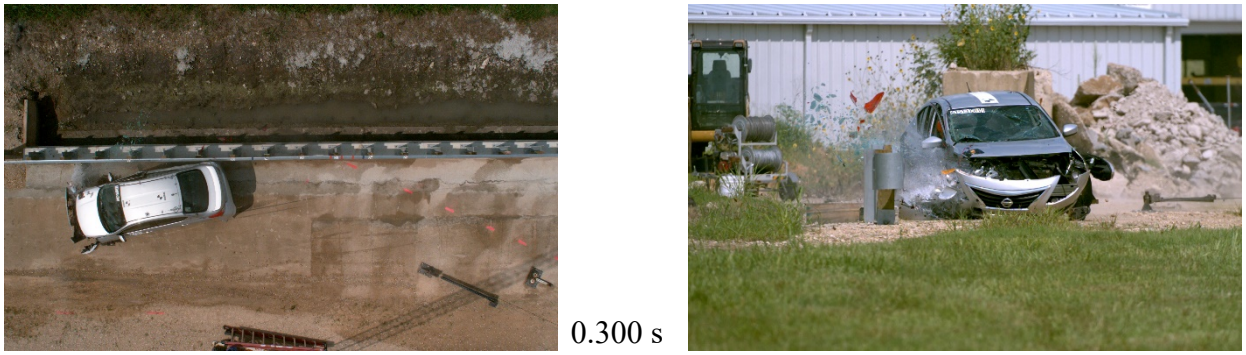


Figure E.1. Sequential Photographs for Test No. 615131-01-1 (Overhead and Frontal Views).


0.200 s


0.250 s


0.300 s

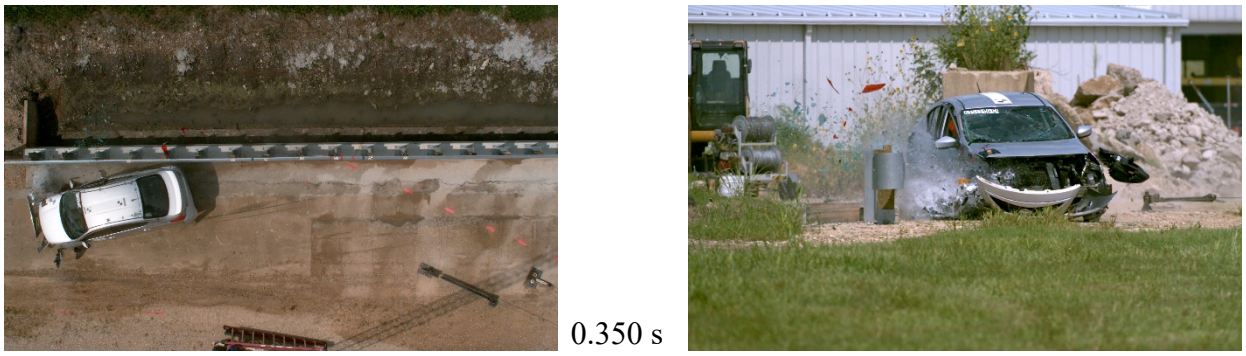

0.350 s

Figure E.1. Sequential Photographs for Test No. 615131-01-1 (Overhead and Frontal Views) (Continued).

0.000 s

0.200 s

0.050 s

0.250 s

0.100 s

0.300 s

0.150 s

0.350 s

Figure E.2. Sequential Photographs for Test No. 615131-01-1 (Rear View).

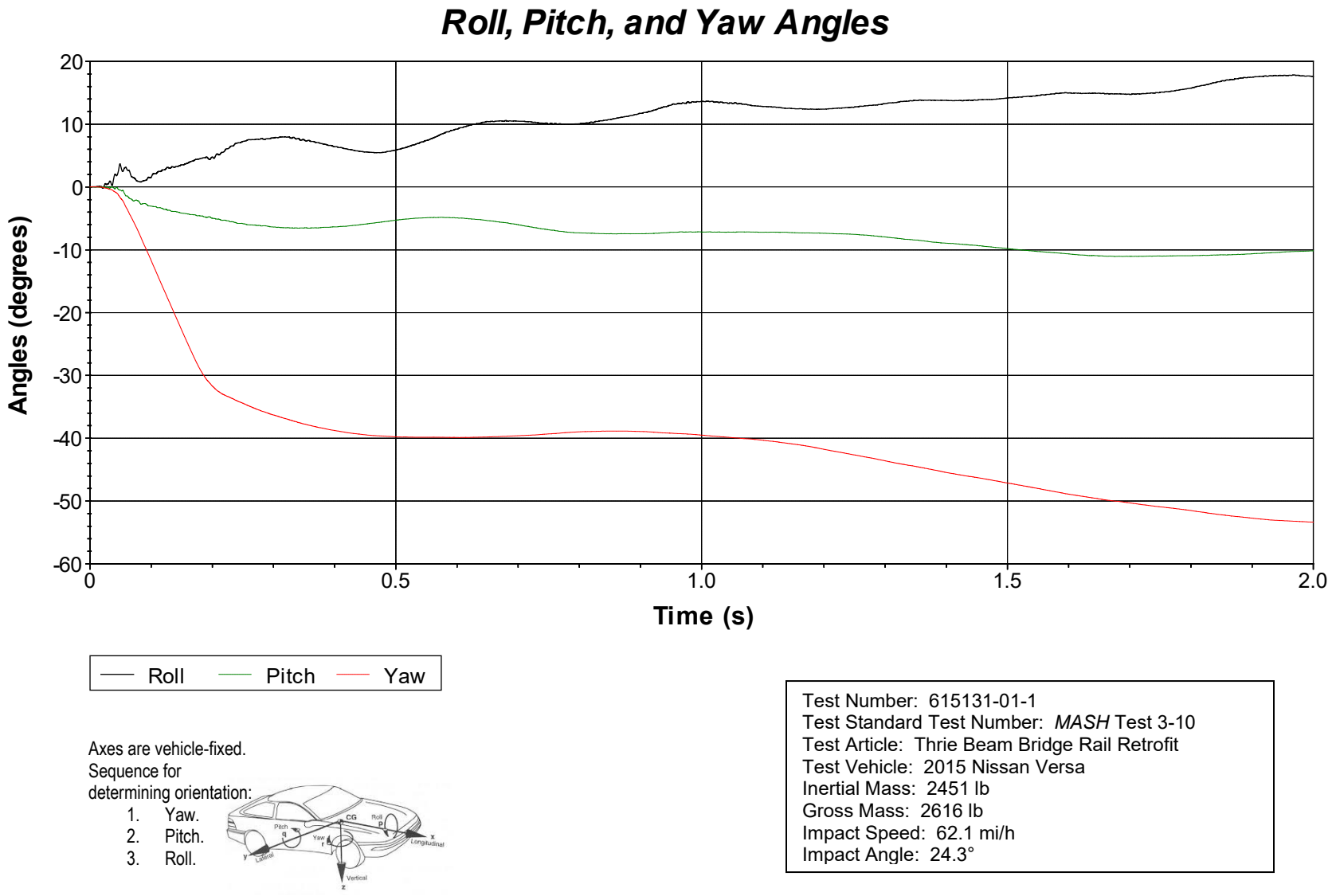


Figure E.3. Vehicle Angular Displacements for Test No. 615131-01-1.

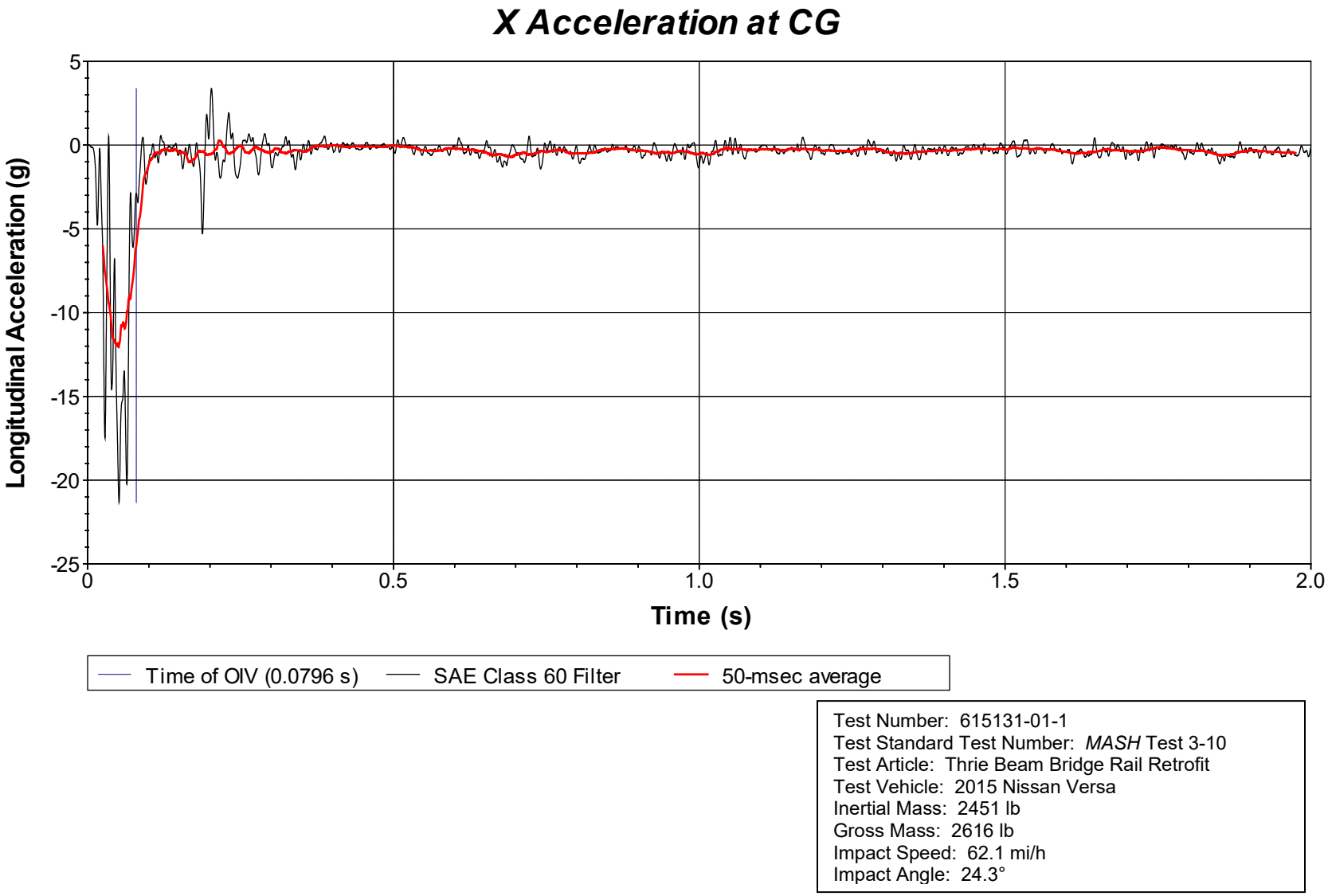


Figure E.4. Vehicle Longitudinal Accelerometer Trace for Test No. 615131-01-1 (Accelerometer Located at Center of Gravity).

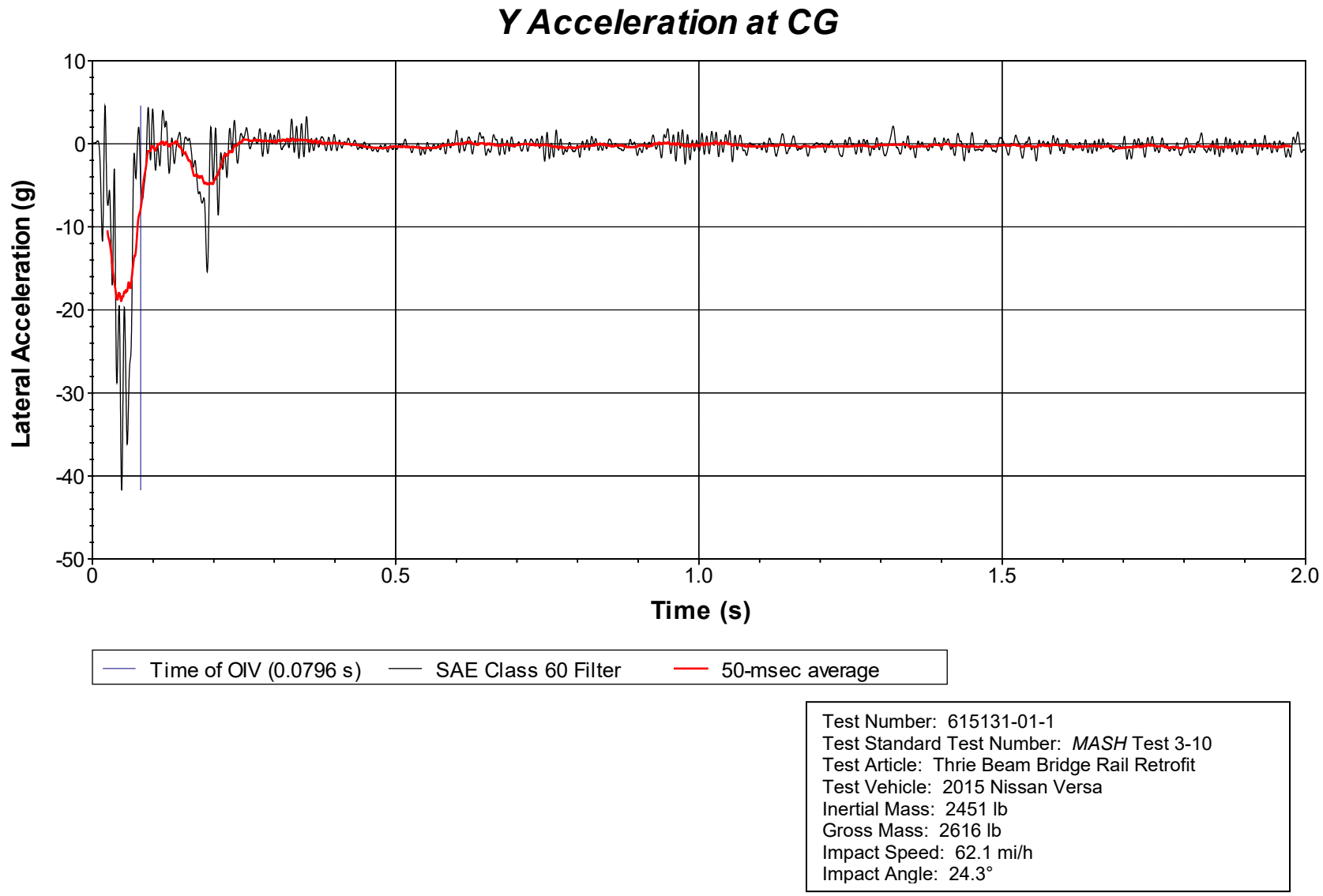


Figure E.5. Vehicle Lateral Accelerometer Trace for Test No. 615131-01-1 (Accelerometer Located at Center of Gravity).

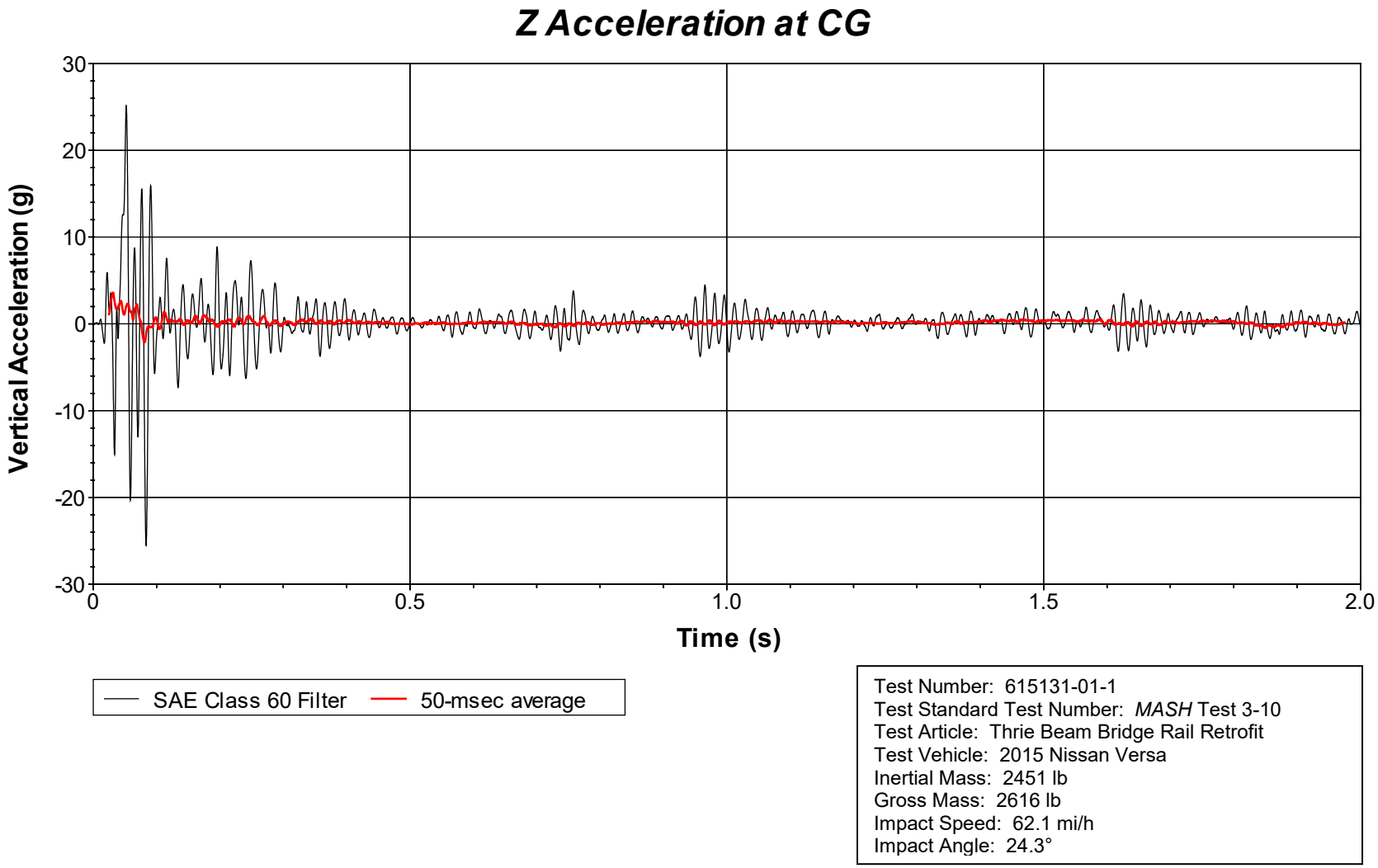


Figure E.6. Vehicle Vertical Accelerometer Trace for Test No. 615131-01-1 (Accelerometer Located at Center of Gravity).