Roadside Safety Pooled Fund

Texas A&M Transportation Institute Proving Ground

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Test Report Date: January 2022

MASH TL-4 EVALUATION OF CONCRETE MEDIAN BARRIER WITH FENCE MOUNTED ON TOP

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16. Abstract

Concrete median barriers (CMB) are used by Departments of Transportation (DOTs) as both permanent and temporary barriers for providing separation of traffic. Typically, the crashworthiness of these barriers is tested and evaluated through full-scale crash testing conducted per current roadside safety device standards. Occasionally, DOTs need to mount chain link fences on top of these barriers to serve different purposes. In other cases, due to space restrictions, signs or light poles are placed on top of such barriers. When DOTs mount these objects on top of barriers the crashworthiness of the modified system will need to be evaluated.

The purpose of this research was to investigate the crashworthiness of a 36-inch-tall concrete single slope median barrier with chain link fence mounted on top under *MASH* evaluation criteria. The structural capacity and the occupant risk factors of the proposed barrier system was evaluated with respect to *MASH* Test Level 4 (TL-4) criteria through full-scale crash testing.

The CMB with fence mounted on top met the performance criteria for *MASH* Test 4-11 for longitudinal barriers, but failed *MASH* Test 4-12.

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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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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

Chapter 1. INTRODUCTION

1.1 PROBLEM STATEMENT

Concrete median barriers are used by Departments of Transportation (DOTs) as permanent and temporary barriers for providing separation of traffic. Typically, the crashworthiness of these barriers is tested and evaluated through full-scale crash testing conducted per current roadside safety device standards. Occasionally, DOTs need to mount chain link fences on top of these barriers to serve different purposes. In other cases, due to space restrictions, signs or light poles are placed on top of such barriers. When DOTs mount these objects on top of barriers the crashworthiness of the modified system will need to be evaluated.

The purpose of this research was to investigate the crashworthiness of a 36-inch-tall concrete single slope median barrier with chain link fence mounted on top under *MASH* evaluation criteria. The structural capacity and the occupant risk factors of the proposed barrier system was evaluated with respect to *MASH* Test Level 4 (TL-4) criteria through full-scale crash testing.

1.2 BACKGROUND

The *MASH* 2016 edition is the latest in a series of documents that provides 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.

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 mph and 15 degrees with respect to the roadway (Test 4-12). The severity *MASH* 2016 tests 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.

In 1995, Buth and Menges conducted a research study which included the evaluation through full scale crash testing of a 31-inch-tall New Jersey safety shape concrete barrier with vandal protection fence mounted on top (4). Testing was conducted following the AASHTO performance level 2 impact conditions, which included a 5562-lb pickup truck impacting the test article at a nominal speed and angle of 60 mph and 20 degrees. The purpose of the full-scale crash testing was to evaluate the strength of the section in containing and redirecting the pickup and the interaction of the vehicle with the fence.

The New Jersey safety shape concrete barrier with vandal protection fence mounted on top consisted of concrete barrier segments that were 10-ft in length and 31 inches in height. The barrier was 6 inches wide at the top and 15 inches wide at the base. The vandal protection fence was mounted on 7.25-ft long × 2.875-inch OD (schedule 40 pipe) straight posts mounted to the back of the barrier. Attached to these posts were three 1.66 inches OD (schedule 40 pipe) horizontal line rails spaced 3 ft, with 1 inch by 1 inch wire fabric. Height to the top of the fence was 6 ft above the safety shape, for a total installation height of 8.7 ft above the road surface.

After the vehicle contacted the fence, the middle horizontal line rail pulled out of the connection at the upstream side of the post. The installation received minimal damage. As a result of the interaction with vehicle during the impact event, the lower edge of the wire fabric was pushed behind the lower horizontal line rail. The middle horizontal line rail was disconnected on the upstream side and the post anchor was pushed back 0.5 inches. Maximum dynamic deflection of the fence was 5.6 inches and maximum residual deformation was 3 inches. The vehicle remained upright during and after the impact event and occupant risk factors were within acceptable limits. The vehicle sustained moderate damage. The floor pan, frame and front axle were deformed, and the windshield was cracked. There was a small fold running diagonally in the floor pan of the occupant compartment and there was 2.8 inches deformation into the occupant compartment of the firewall on the passenger side of the vehicle. The impact performance of the vandal protection fence on New Jersey safety shape bridge railing was considered satisfactory according to the guideline set forth in AASHTO.

In 1972, Hirsch and Post conducted a research study which included the evaluation through full scale crash testing of a rigidly fixed 32-inch-tall Texas CMB barrier with chain link fabric fence and a luminaire mounted on top (*5*). The Texas CMB is similar to the New Jersey Median Barrier in dimensions and shape. A total of four tests were conducted with the purpose of a) evaluate the interaction between the impacting vehicle and the luminaire hardware posted on top of the concrete barrier (Test #1); b) determine if the 150-ft unanchored section of the CMB barrier would slide and/or rotate under vehicle impact; c) evaluate the barrier performance under representative in-service conditions of about 60 mph and 7 degrees; and d) evaluate the barrier performance under representative in-service conditions of about 60 mph and 15 degrees.

The Texas CMB concrete barrier with chain link fabric fence and luminaire hardware on top consisted of concrete barrier segments that were 50 ft in length and 32 inches in height. The barrier was 8 inches wide at the top and 27 inches wide at the base. The rigid 45’ luminaire pole was mounted on top of the Texas CMB barrier and anchored to it with use of four 1¼ inches diameter and 30 inches long AISI 1040 bolts. A 3-ft tall #9 gauge chain link fabric fence of 1-inch mesh was also mounted on top of the Texas CMB barrier.

The first test on the rigid concrete median barrier was conducted with the 4,000-lb large sedan impacting the test article at impact conditions of 62.4 mph and 25 degrees. The centerline of the vehicle was directed at the centerline of the luminaire support. The vehicle was contained and redirected, however the severely damaged impacting front quarter and wheel of the vehicle caused it to swerve back toward the barrier. The door on the driver’s side was also sprung open and the windshield was cracked.

The second test on the rigid concrete median barrier was conducted with the 4000-lb large sedan impacting the test article at impact conditions of 55.7 mph and 25 degrees. The vehicle was contained and redirected, and it was slightly less damaged than in the first test (door was not sprung open).

The third test on the rigid concrete median barrier was conducted with the 4000-lb large sedan impacting the test article at impact conditions of 60.9 mph and 7 degrees. The vehicle was contained and redirected, with a maximum climb of approximately 18 inches. The relatively minor damage consisted of bumper and sheet metal crushing.

The fourth test on the rigid concrete median barrier was conducted with the 4000-lb large sedan impacting the test article at impact conditions of 60.7 mph and 15 degrees. The vehicle

was contained and redirected. Sheet metal contact caused relatively minor damage to the fence. The damage to the vehicle in this test was somewhat less than the damaged vehicles in the previous CMB-1 and CMB-2 tests that were run at larger impact angles.

1.3 OBJECTIVE

The research objective was to investigate the crashworthiness of a 36-inch-tall concrete single slope median barrier with chain link fence mounted on top using *MASH* 2016 evaluation criteria. Engineering analysis aided in the selection of system details to be considered for testing. The structural capacity and the occupant risk factors of the proposed barrier system was evaluated with respect to *MASH* TL-4 criteria through full-scale crash testing.

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Chapter 2. TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 CRASH TEST PERFORMED/MATRIX

Table 2.1 shows the test conditions and evaluation criteria for *MASH* TL-4 for longitudinal barriers. The target critical impact point (CIP) for Test 4-12 was determined using the information provided in *MASH* Section 2.2.1 and Section 2.3.2. Figure 2.1 shows the target CIP for *MASH* Test 4-12 on the CMB with fence mounted on top.

The target CIP for Test 4-11 was determined after review of footage from existing conducted full-scale crash test involving a pickup truck vehicle impacting a 36-inch-tall single slope concrete barrier (6). Specifically, the interaction between the pickup truck and the single slope barrier was carefully reviewed considering vehicle maximum penetration beyond edge of the barrier in relation to the distance from the first impact location. Figure 2.2 shows the target CIP for *MASH* Test 4-11 on the CMB with fence mounted on top.

Table 2.1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-4 Longitudinal Barriers.

Test Article	Test Designation	Test Vehicle	Impact Conditions		Evaluation Criteria
			Speed	Angle	
Longitudinal Barrier	4-10	1100C	62 mi/h	25°	A, D, F, H, I
	4-11	2270P	62 mi/h	25°	A, D, F, H, I
	4-12	10000S	56 mi/h	15°	A, D, G

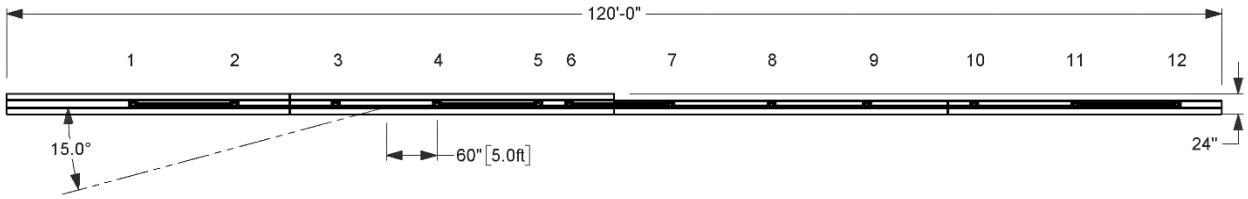


Figure 2.1. Target CIP for *MASH* Test 4-12 on CMB with Fence Mounted on Top.

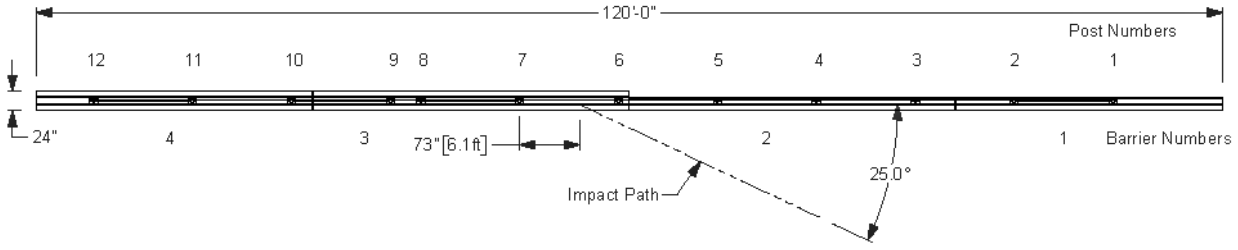


Figure 2.2 Target CIP for *MASH* Test 4-11 on CMB with Fence Mounted on Top.

TL-3 passenger car test (Test 3-10) had been conducted successfully by Caltrans on the Type 60 Median Barrier single slope concrete barrier with a barrier face slope of 9.1 degrees, which is considered to perform similarly to the Florida face slope of 10.8 degrees implemented under this project (7). The Type 60 Median Barrier perform successfully under MASH Test 3-10 conditions. During that test, very little to no interaction between the impacting passenger car and the top of the concrete barrier was observed. Therefore, it is expected that a passenger car would have no considerable interaction with the chain link fence system implemented in top of the 36-inch-tall single slope barrier investigate under this project. For this reason, MASH Test 3-10 was not performed.

The crash tests and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 3 presents brief descriptions of these procedures.

2.2 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 2.1 lists the test conditions and evaluation criteria required for *MASH* TL-4, and Table 2.2 provides detailed information on the evaluation criteria. An evaluation of the crash test results is presented in Chapter 7.

Table 2.2. Evaluation Criteria Required for *MASH* TL-4 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.*	*4-10, 4-11, and 4-12*
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.*	*4-10, 4-11, and 4-12*
	F.	*The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	*4-10 and 4-11*
	G.	*It is preferable, although not essential, that the vehicle remain upright during and after the collision.*	*4-12*
	H.	*Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.*	*4-10 and 4-11*
	I.	*The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.*	*4-10 and 4-11*

Chapter 3. TEST CONDITIONS

3.1 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 CMB with fence mounted on top 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.

3.2 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.

3.3 DATA ACQUISITION SYSTEMS

3.3.1 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 16-channel Tiny Data Acquisition System (TDAS) Pro 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 TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on

transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 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 TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each of the TDAS Pro units is returned to the factory annually for complete recalibration 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 data from the TDAS Pro 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 0.0001s 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).

3.3.2 Anthropomorphic Dummy Instrumentation

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 height of the CMB was 36 inches plus the 72-inch height of the fence, totaling 108 inches or 9 ft), a dummy was placed in the front seat of the 2270P vehicle on the impact side and restrained with lap and shoulder belts.

MASH does not recommend or require use of a dummy in the 10000S vehicle, and no dummy was placed in the vehicle.

3.3.3 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 CMB with fence mounted on top. 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 4. *MASH* TEST 4-11 (CRASH TEST NO. 613131-03-1)

4.1 SYSTEM DETAILS

4.1.1 Test Article and Installation Details

The installation consisted of a 72-inch tall, 2-inch mesh chain-link fence mounted on top of a series of 36-inch-tall concrete barriers: a traffic barrier system on the upstream end of the installation, and a median barrier system on the downstream end. The construction of the concrete single slope barrier system was utilized under two different projects, to minimize costs and expedite construction and testing. The impact side of such "combined" barrier system was the same and consistent throughout the installation, and therefore the barrier combination (bridge + median) did not have any influence on the impacts performance under this project. The slope of the barrier was 10.8 degrees.

The length of the barriers measured (from upstream traffic to downstream median): 27 ft; 32 ft-11¼ inches; 32 ft; and 27 ft-11¼ inches. A ¾-inch wide gap was cast between similar barrier segments, and a cold joint (no gap) transitioned the traffic to the median barriers. The total installation length was 120 ft.

The traffic barriers were 14½ inches wide at the base, sloped upwards on the traffic side, and had a vertical face on the field side, with the exception of a slight slope outward 22½ inches above grade for 1½ inches before continuing vertical, resulting in a top width of 9 inches.

The median barriers measured 24 inches at the base with constant slopes on both sides to a top width of 10 inches.

Post 12 (the farthest downstream) was set 70 inches from the most downstream end of the barriers. Post spacing was 10 ft center-to-center to post 1 (the farthest upstream) except for the 36¾-inch span between posts 8 and 9. The total length of the chain-link fence was 103 ft-¾ inches. Angled brace rails were attached between posts 1 and 2, 7 and 8, 9 and 10, and 11 and 12. The chain-link fabric was installed on the field side of the brace rails, and a tension wire along the top and bottom of the fence maintained the shape of the fence.

Figure 4.1 presents the overall information on the CMB with fence mounted on top, and Figure 4.2 provides photographs of the installation. Appendix A provides further details on the CMB with fence mounted on top. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

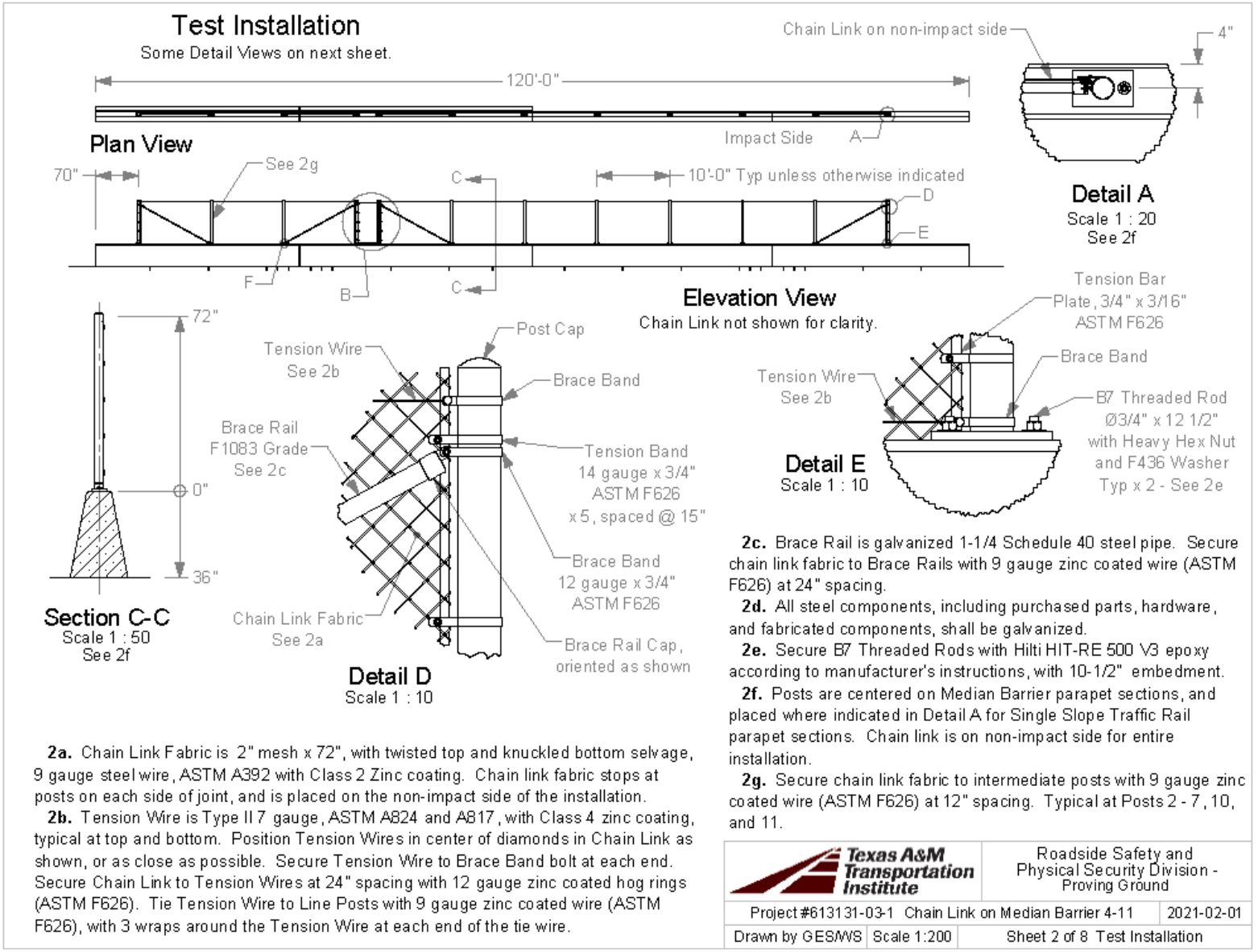
4.1.2 Design Modifications during Tests

No modification was made to the Test 4-11 installation during the testing phase.

4.1.3 Material Specifications

Concrete compressive strength was specified to be 3400 psi. The concrete was tested on April 3, 2020 for project 611971-02-1, barriers 2 and 4 had an average compressive strength of 4507 psi at 32 days of age, and barriers 1 and 3 had an average compressive strength of 5127 psi at 28 days of age.

Appendix B provides material certification documents for the materials used to install/construct the CMB with fence mounted on top.



2a. Chain Link Fabric is 2" mesh x 72", with twisted top and knuckled bottom selvage, 9 gauge steel wire, ASTM A392 with Class 2 Zinc coating. Chain link fabric stops at posts on each side of joint, and is placed on the non-impact side of the installation.

2b. Tension Wire is Type II 7 gauge, ASTM A824 and A817, with Class 4 zinc coating, typical at top and bottom. Position Tension Wires in center of diamonds in Chain Link as shown, or as close as possible. Secure Tension Wire to Brace Band bolt at each end. Secure Chain Link to Tension Wires at 24" spacing with 12 gauge zinc coated hog rings (ASTM F626). Tie Tension Wire to Line Posts with 9 gauge zinc coated wire (ASTM F626), with 3 wraps around the Tension Wire at each end of the tie wire.

2c. Brace Rail is galvanized 1-1/4 Schedule 40 steel pipe. Secure chain link fabric to Brace Rails with 9 gauge zinc coated wire (ASTM F626) at 24" spacing.

2d. All steel components, including purchased parts, hardware, and fabricated components, shall be galvanized.

2e. Secure B7 Threaded Rods with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 10-1/2" embedment.

2f. Posts are centered on Median Barrier parapet sections, and placed where indicated in Detail A for Single Slope Traffic Rail parapet sections. Chain link is on non-impact side for entire installation.

2g. Secure chain link fabric to intermediate posts with 9 gauge zinc coated wire (ASTM F626) at 12" spacing. Typical at Posts 2 - 7, 10, and 11.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-1 Chain Link on Median Barrier 4-11		2021-02-01
Drawn by GES/WS	Scale 1:200	Sheet 2 of 8 Test Installation

Q:\Accreditation-17025-2017\EIR-000 Project Files\613131-03 Fence on Median Barrier\-03-1&2\-03-1 (4-11)\Drafting, 613131-1\2021-01-15\613131-1 Drawing

Figure 4.1. Details of CMB with Fence Mounted on Top for Test No. 613131-03-1.

Figure 4.2. CMB with Fence Mounted on Top prior to Test No. 613131-01-1.

4.2 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 4-11 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 4-11 on the CMB with fence mounted on top was 6.1 ft (73 inches) ± 1 ft upstream of centerline of post 7 of the median barrier section. Figure 2.1 and Figure 4.3 depict the target impact setup.

Figure 4.3. CMB/Test Vehicle Geometrics for Test No. 613131-03-1.

The 2270P vehicle weighed 5042 lb, and the actual impact speed and angle were 63.2 mi/h and 25.0 degrees. The actual impact point was 6.1 ft upstream of the centerline of post 7. Minimum target IS was 106 kip-ft, and actual IS was 120 kip-ft.

4.3 WEATHER CONDITIONS

The test was performed on the morning of January 22, 2021. Weather conditions at the time of testing were as follows: wind speed: 1 mi/h; wind direction: 109 degrees (vehicle was traveling at a heading of 330 degrees); temperature: 64°F; relative humidity: 97 percent.

4.4 TEST VEHICLE

Figure 4.4 shows the 2015 RAM 1500 pickup truck used for the crash test. The vehicle's test inertia weight was 5042 lb, and its gross static weight was 5207 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 28.25 inches. Tables C.1 and C.2 in Appendix C.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.

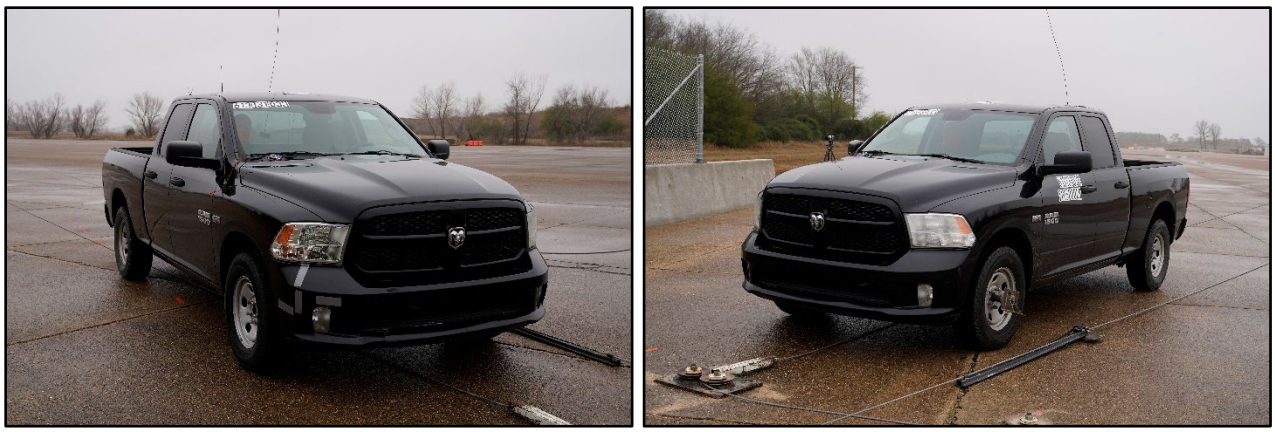


Figure 4.4. Test Vehicle before Test No. 613131-03-1.

4.5 TEST DESCRIPTION

Table 4.1 lists events that occurred during Test No. 613131-03-1. Figures C.1 and C.2 in Appendix C.2 present sequential photographs during the test.

Table 4.1. Events during Test No. 613131-03-1.

Time (s)	Events
0.0000	Vehicle impacts concrete median barrier
0.0140	Right front tire loses contact with pavement
0.0460	Vehicle begins to redirect
0.0830	Left front tire loses contact with pavement
0.2070	Vehicle traveling parallel with barrier
0.2450	Left rear tire loses contact with pavement
0.3670	Vehicle loses contact with barrier while traveling at 47.1 mi/h, at a trajectory of 2.1 degrees, and a heading of 2.8 degrees
0.5620	Right front tire contacts pavement

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 1.6 s after impact, and the vehicle subsequently came to rest 193 ft downstream of the point of impact and 3 ft toward traffic lanes.

4.6 DAMAGE TO TEST INSTALLATION

Figure 4.5 shows the damage to the CMB with fence mounted on top. There was some scuffing and gouging on the concrete barrier at the impact site. The chain-link was deformed towards the field side of the installation near post 7. On the field side of the installation, a debris field of very small vehicle pieces measured 24.5 ft wide and 9 ft towards the field side. Working

width* was 30.2 inches, and height of working width was 42.5 inches. Maximum dynamic deflection during the test was 16.4 inches at the bottom of the chain link fence.

Figure 4.5. CMB after Test No. 613131-03-1.

4.7 DAMAGE TO TEST VEHICLE

Figure 4.6 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 upper and lower control arms, right front floor pan, right front door and window glass, right rear door, right rear cab corner, right rear exterior bed, rear bumper, and rear tail gate were damaged. The windshield was shattered along the lower edge near the hood, and there was a small hole in the right lower edge due to shear in the liner, not by penetration by the test article. No fuel tank damage was observed. Maximum exterior crush to the vehicle was 10.0 inches in the side plane at the right front corner at bumper height. Maximum occupant compartment deformation was 6.5 inches in the right kick panel/floor pan area. Figure 4.7 shows the interior of the vehicle. Tables C.3 and C.4 in Appendix C.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 4.6. Test Vehicle after Test No. 613131-03-1.

Figure 4.7. Interior of Test Vehicle after Test No. 613131-03-1.

4.8 OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 4.2. Figure C.3 in Appendix C.3 shows the vehicle angular displacements, and Figures C.4 through C.6 in Appendix C.4 show acceleration versus time traces. Figure 4.8 summarizes pertinent information from the test.

Table 4.2. Occupant Risk Factors for Test No. 613131-03-1.

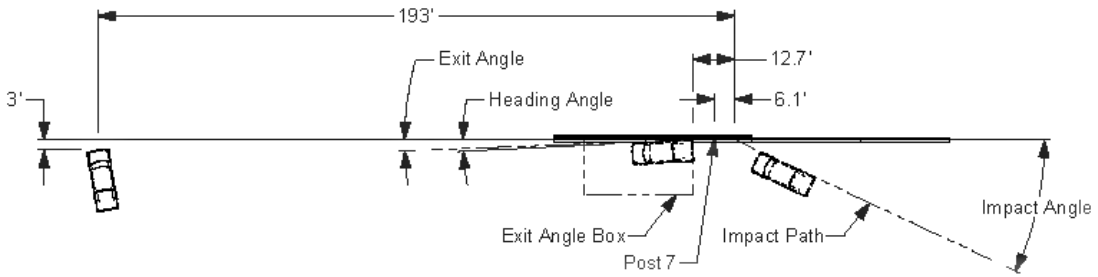
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		
Longitudinal	20.6 ft/s	at 0.0953 s on right side of interior
Lateral	27.3 ft/s	
Occupant Ridedown Accelerations		
Longitudinal	4.7 g	0.1989 - 0.2089 s
Lateral	7.9 g	0.2009 - 0.2109 s
Theoretical Head Impact Velocity (THIV)	10.5 m/s	at 0.0927 s on right side of interior
Acceleration Severity Index (ASI)	1.9	0.0630 - 0.1130 s
Maximum 50-ms Moving Average		
Longitudinal	−10.1 g	0.0244 - 0.0744 s
Lateral	−14.5 g	0.0350 - 0.0850 s
Vertical	−3.8 g	0.0343 - 0.0843 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	22°	0.6661 s
Pitch	6°	0.7442 s
Yaw	33°	0.7702 s

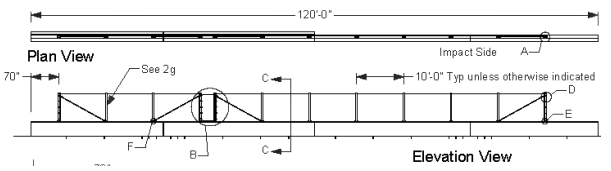
0.000 s

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 4-11
- TTI Test No. 613131-03-1
- Test Date 2021-01-22

Test Article
- Type ..... Longitudinal Barrier—Concrete Median Barrier
- Name ..... CMB with fence mounted on top
- Installation Length ..... 120 ft
- Material or Key Elements ... Single slope 36-inch concrete barrier with 72-inch chain link fence mounted on top of CMB

Soil Type and Condition ..... Concrete Surface, Damp

Test Vehicle
- Type/Designation 2270P
- Make and Model ..... 2015 RAM 1500 Pickup
- Curb ..... 4949 lb
- Test Inertial ..... 5042 lb
- Dummy ..... 165 lb
- Gross Static ..... 5207 lb

Impact Conditions
- Speed ..... 63.2 mi/h
- Angle ..... 25.0 degrees
- Location/Orientation ..... 6.1 ft upstream of post 7

Impact Severity ..... 120 kip-ft

Exit Conditions
- Speed ..... 47.1 mi/h
- Trajectory/Heading Angle ... 2.1°/2.8°

Occupant Risk Values
- Longitudinal OIV ..... 20.6 ft/s
- Lateral OIV ..... 27.3 ft/s
- Longitudinal Ridedown ..... 4.7 g
- Lateral Ridedown ..... 7.9 g
- THIV ..... 10.5 m/s
- ASI 1.9

Max. 0.050-s Average
- Longitudinal ..... −10.1 g
- Lateral ..... −14.5 g
- Vertical ..... −3.8 g

Post-Impact Trajectory
- Stopping Distance ..... 193 ft downstream 3 ft twd traffic lanes

Vehicle Stability
- Maximum Roll Angle ..... 22°
- Maximum Pitch Angle ..... 6°
- Maximum Yaw Angle ..... 33°
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 16.4 inches
- Permanent .....
- Working Width ..... 30.2 inches
- Height of Working Width ..... 42.5 inches

Vehicle Damage
- VDS 01RFQ4
- CDC 01FREW4
- Max. Exterior Deformation ..... 10.0 inches
- OCDI RF0020000
- Max. Occupant Compartment Deformation ..... 6.5 inches

Figure 4.8. Summary of Results for *MASH* Test 4-11 on Concrete Median Barrier with Fence Mounted on Top.

Chapter 5. *MASH* TEST 4-12 (CRASH TEST NO. 613131-03-2)

5.1 SYSTEM DETAILS

5.1.1 Test Article and Installation Details

The test installation for Test 4-12 was essentially the same as that for previous Test 4-11, except that the chain-link fence was relocated longitudinally, and the post and barrier references are from the opposite end due to the opposite vehicle impact direction.

The installation consisted of a 72-inch tall, 2-inch mesh chain-link fence mounted on top of a series of 36-inch-tall concrete barriers: two median barriers on the upstream end of the installation, and two traffic barriers on the downstream end.

The length of the barriers measured (from upstream median to downstream traffic): 27 ft-11¼ inches; 32 ft; 32 ft-11¼ inches; and 27 ft. A ¾-inch wide gap was cast between similar barrier segments, and a cold joint (no gap) transitioned the median to the traffic barriers. The barriers were anchored with epoxy.The total installation length was 120 ft.

The median barriers measured 24 inches at the base with constant slopes on both sides to a top width of 10 inches.

The traffic barriers were 14½ inches wide at the base, sloped upwards on the traffic side, and had a vertical face on the field side, with the exception of a slight slope outward 22½ inches above grade for 1½ inches before continuing vertical, resulting in a top width of 9 inches. The traffic side slope of the barrier was 10.8 degrees.

Post 1 (the farthest upstream) was located 12 ft-6 inches from the most upstream end of the barriers. Post spacing was 10 ft center-to-center to post 12 (the farthest downstream) except for: the 36¾-inch span between posts 5 and 6; the 9-ft 5-inch spacing between posts 8 and 9; and the 10-ft 7-inch spacing between posts 9 and 10 (the posts 8-9-10 spacing deviation was to avoid anchoring near the traffic barriers' gap). The total length of the chain-link fence was 103 ft-¾ inches. Angled brace rails were attached between posts 1 and 2, 4 and 5, 6 and 7, and 11 and 12. The chain-link fabric was installed on the field side of the brace rails, and a tension wire along the top and bottom of the fence maintained the shape of the fence.

Figure 5.1 presents the overall information on the CMB with fence mounted on top, and Figure 5.2 provides photographs of the installation. Appendix D provides further details on the CMB with fence mounted on top. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

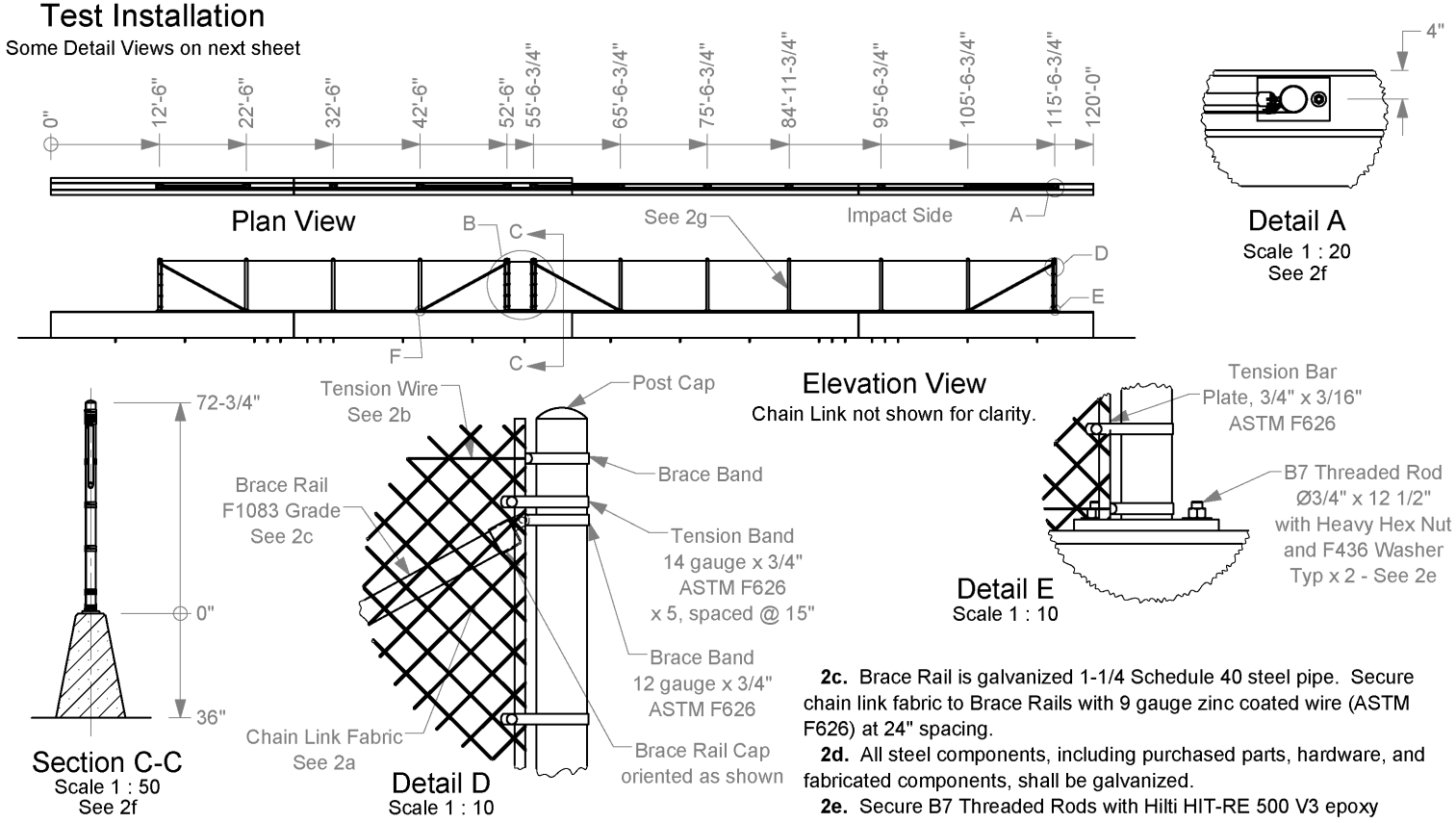
5.1.2 Design Modifications during Tests

No modification was made to the Test 4-12 installation during the testing phase.

5.1.3 Material Specifications

The compressive strength was identified in section 4.1.3.

Appendix B provides material certification documents for the materials used to install/construct the CMB with fence mounted on top.



2a. Chain Link Fabric is 2" mesh x 72", with twisted top and knuckled bottom selvage, 9 gauge steel wire, ASTM A392 with Class 2 Zinc coating. Chain link fabric stops at posts on each side of joint, and is placed on the impact side of the installation.

2b. Tension Wire is Type II 7 gauge, ASTM A824 and A817, with Class 4 zinc coating, typical at top and bottom. Position Tension Wires in center of diamonds in Chain Link as shown, or as close as possible. Secure Tension Wire to Brace Band bolt at each end. Secure Chain Link to Tension Wires at 24" spacing with 12 gauge zinc coated hog rings (ASTM F626). Secure Tension Wire to Line Posts with 9 gauge zinc coated wire (ASTM F626), with 3 wraps at each end of the wire.

2c. Brace Rail is galvanized 1-1/4 Schedule 40 steel pipe. Secure chain link fabric to Brace Rails with 9 gauge zinc coated wire (ASTM F626) at 24" spacing.

2d. All steel components, including purchased parts, hardware, and fabricated components, shall be galvanized.

2e. Secure B7 Threaded Rods with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 10-1/2" embedment.

2f. Posts are centered on Median Barrier parapet sections, and placed where indicated in Detail E for Single Slope Traffic Rail parapet sections. Chain link is on impact side for the entire installation.

2g. Secure chain link fabric to intermediate posts with 9 gauge zinc coated wire (ASTM F626) at 12" spacing. Typical at Posts 2 - 4 and 7 - 11.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-2 Chain Link on Median Barrier 4-12		2021-01-20
Drawn by GES/WS	Scale 1:200	Sheet 2 of 8 Test Installation

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Figure 5.1. Details of CMB with Fence Mounted on Top for Test No. 613131-03-2.

Figure 5.2. CMB with Fence Mounted on Top prior to Test No. 613131-01-2.

5.2 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 4-12 involves a 10000S vehicle weighing 22,000 lb ± 660 lb impacting the CIP of the longitudinal barrier at an impact speed of 56 mi/h ± 2.5 mi/h and an angle of 15 degrees ± 1.5 degrees. The CIP for *MASH* Test 4-12 on the CMB with fence mounted on top was 5 ft ± 1 ft upstream of the centerline of post 4 of the median barrier section. Figure 2.1 and Figure 5.3 depict the target impact setup.

Figure 5.3. CMB/Test Vehicle Geometrics for Test No. 613131-03-2.

The 10000S vehicle weighed 22,650 lb, and the actual impact speed and angle were 55.9 mi/h and 15.0 degrees. The actual impact point was 4.5 ft upstream of the centerline of post 4. Minimum target IS was 142 kip-ft, and actual IS was 159 kip-ft.

5.3 WEATHER CONDITIONS

The test was performed on the morning of March 3, 2021. Weather conditions at the time of testing were as follows: wind speed: 5 mi/h; wind direction: 200 degrees (vehicle was traveling at a heading of 110 degrees); temperature: 58°F; relative humidity: 42 percent.

5.4 TEST VEHICLE

Figure 5.4 shows the 2012 International 4300 single-unit truck used for the crash test. The vehicle's test inertia weight was 22,650 lb, and its gross static weight was 22,650 lb. The height to the lower edge of the vehicle bumper was 18.25 inches, and height to the upper edge of the bumper was 33.25 inches. The height to the center of gravity of the vehicle's ballast was 61.75 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 5.4. Test Vehicle before Test No. 613131-03-2.

5.5 TEST DESCRIPTION

Table 5.1 lists events that occurred during Test No. 613131-03-2. Figures E.1 and E.2 in Appendix E.2 present sequential photographs during the test.

Table 5.1. Events during Test No. 613131-03-2.

Time (s)	Events
0.0000	Vehicle impacts the barrier
0.0250	Vehicle begins to redirect
0.1070	Right front tire loses contact with the pavement
0.2410	Right rear tire loses contact with the pavement
0.2630	Vehicle traveling parallel with barrier
0.3380	Left side of the box begins to break and override the barrier
0.7650	Right front tire contacts the pavement

For longitudinal barriers, it is desirable for the vehicle to redirect and exit the barrier within the exit box criteria (not less than 65.6 ft for heavy vehicles). The test vehicle exited within the exit box criteria defined in *MASH*. Brakes on the vehicle were not applied. After loss of contact with the barrier, the vehicle came to rest 262 ft downstream of the point of impact and 34 ft toward the field side of the barrier.

5.6 DAMAGE TO TEST INSTALLATION

Figure 5.5 and Figure 5.6 show the damage to the CMB with fence mounted on top. There was some scuffing and gouging present on the concrete barriers. Post 4 was leaning 23 degrees towards the field side and slightly downstream. The post was also torn at the base plate. Posts 5, 6, 8, and 9 were completely sheared off at the base plate. Posts 7, 10, and 11 were torn at the base plate, but remained attached. Post 12 was leaning 58 degrees downstream and was deformed near its baseplate. Parts of the posts and fence landed 9 ft toward the field side of the barrier, and the remainder of the fence beyond post 4 was dragged by the vehicle until the

vehicle came to rest. Working width* was 76.6 inches, and height of working width was 143.5 inches. There. was no permanent deformation in the barrier Maximum dynamic deflection during the test was unobtainable due to camera view concealment.

Figure 5.5. CMB after Test No. 613131-03-2.

* 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 5.6. Damage to Posts 4 through 11 after Test No. 613131-03-2.

Figure 5.7. Post 12 and Separated Chain Link Fence after Test No. 613131-03-2.

5.7 DAMAGE TO TEST VEHICLE

Figure 5.8 shows the damage sustained by the vehicle. The front bumper, hood, left front tire and rim, left front A-pillar, roof, left door and window glass, left front floor pan, left battery box, left side of the cargo box, and left rear outer tire and rim were damaged. No damage to the fuel tank was observed. Maximum exterior crush to the vehicle was 10.0 inches in the left front corner at bumper height. Maximum occupant compartment deformation was 10.0 inches at the midpoint of the collapsed left A-pillar. The windshield sustained heavy damage, with cracks and tears, and was pulled from its mounting. Figure 5.9 shows the interior of the vehicle.

Figure 5.8. Test Vehicle after Test No. 613131-03-2.

Figure 5.9. Interior of Test Vehicle after Test No. 613131-03-2.

5.8 VEHICLE INSTRUMENTATION

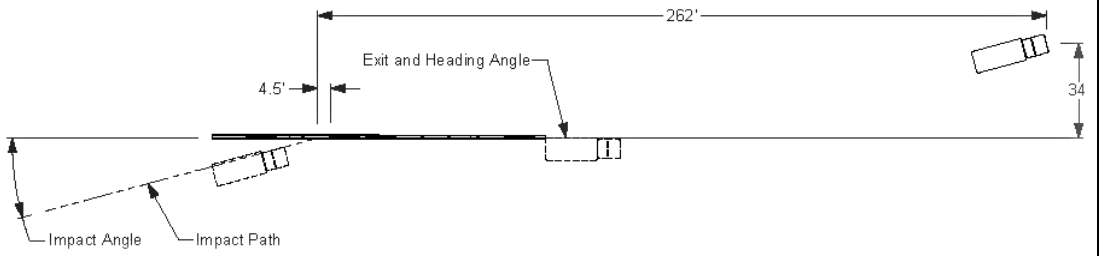
Data from the accelerometers were digitized for informational purposes only and are reported in Figure 5.10. Figure E.3 in Appendix E.3 shows the vehicle angular displacements, and Figures E.4 through E.9 in Appendix C.4 show acceleration versus time traces. Figure 5.10 summarizes pertinent information from the test.

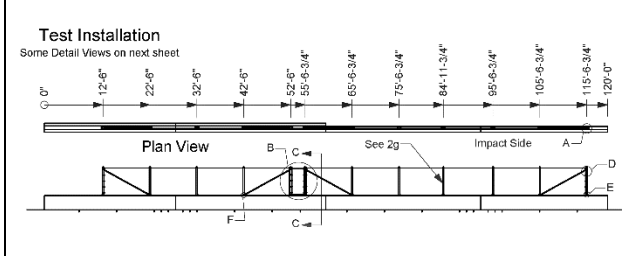
0.000 s

0.200 s

0.400 s

0.600 s





General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... *MASH* Test 4-12
- TTI Test No. 613131-03-2
- Test Date 2021-03-03

Test Article
- Type ..... Longitudinal Barrier—Concrete Median Barrier
- Name ..... CMB with fence mounted on top
- Installation Length ..... 120 ft
- Material or Key Elements ... Single slope 36-inch concrete barrier with 72-inch chain link fence mounted on top of CMB

Soil Type and Condition ..... Concrete Surface, Damp

Test Vehicle
- Type/Designation 10000S
- Make and Model ..... 2012 International 4300 SUT
- Curb ..... 14,310 lb
- Test Inertial ..... 22,650 lb
- Dummy ..... No Dummy
- Gross Static ..... 22,650 lb

Impact Conditions
- Speed ..... 55.9 mi/h
- Angle ..... 15.0°
- Location/Orientation ..... 4.5 ft upstream of post 4

Impact Severity .....

Exit Conditions
- Speed ..... Off end of barrier
- Trajectory/Heading Angle ... Off end of barrier

Occupant Risk Values
- Longitudinal OIV ..... 6.5 ft/s
- Lateral OIV ..... 11.3 ft/s
- Longitudinal Ridedown ..... 4.4 g
- Lateral Ridedown ..... 9.9 g
- THIV ..... 4.1 m/s
- ASI 0.6

Max. 0.050-s Average
- Longitudinal ..... −1.9 g
- Lateral ..... 4.8 g
- Vertical ..... −3.3 g

Post-Impact Trajectory
- Stopping Distance ..... 262 ft downstream 34 ft twd field side

Vehicle Stability
- Maximum Roll Angle ..... 33°
- Maximum Pitch Angle ..... 8°
- Maximum Yaw Angle ..... 20°
- Vehicle Snagging ..... Yes, carried fence
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... Obscured, not obtainable
- Permanent ..... No Deformation
- Working Width ..... 76.6 inches
- Height of Working Width ..... 143.5 inches

Vehicle Damage
- VDS 11FLEW4
- CDC ..... NA
- Max. Exterior Deformation ..... 10.00 inches
- OCDI ..... NA
- Max. Occupant Compartment Deformation ..... 10.00 inches

Figure 5.10. Summary of Results for *MASH* Test 4-12 on CMB with Fence Mounted on Top.

Chapter 6. SUMMARY AND CONCLUSIONS

6.1 ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* Tests 4-11 and 4-12. Table 6.1 and Table 6.2 provide an assessment of each test based on the applicable safety evaluation criteria for *MASH* TL-4 longitudinal barriers.

6.2 CONCLUSIONS

Table 6.3 shows that the CMB with fence mounted on top failed to meet the performance criteria for *MASH* TL-4 longitudinal barriers.

MASH Test 4-10 (Passenger car, 62 mph, 25-deg orientation angle impact conditions) was not conducted under this research/testing effort.

In 2016, Caltrans had conducted a MASH Test 3-10 on their Type 60 single slope concrete median barrier *(7)*. The 36-inch-tall Type 60 barrier has a barrier face slope of 9.1 degrees, and is considered to perform similarly to the 10.8-degree sloped barrier under this project. The Type 60 barrier successfully redirected an 1100-kg small car impacting at nominal 62 mph and 25 degrees impact conditions, meeting the MASH criteria for Test 3-10 for longitudinal barriers.

During the impact against the Type 60 barrier, the passenger car did not show protrusion on the top of the 36-inch-tall barrier.

The single slope barrier investigated in this research project has the same height of the Type 60 barrier and is considered to perform similarly to the 9.1-degree sloped Type 60 barrier. No interaction is anticipated between the impacting passenger car and the chain link fence and posts implemented on top of the 36-inch-tall barrier. Therefore, the implementation of the chain link fence on top of the 36-inch-tall sloped concrete barrier would not interfere with the crashworthiness of the overall system per MASH Test 4-10 impact and evaluation criteria.

The system investigated in this project meets the crashworthiness evaluation per MASH TL3 criteria.

**The opinions/interpretations identified/expressed in this section of the report are outside the scope of the TTI Proving Ground A2LA Accreditation*

Table 6.1. Performance Evaluation Summary for *MASH* Test 4-11 on CMB with Fence Mounted on Top.

Test Agency: Texas A&M Transportation Institute Test No.: 613131-03-1 Test Date: 2021-01-22

MASH Test 4-11 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 CMB with fence on mounted on top contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 16.4 inches near the bottom of the chain link fence	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 test article were present to penetrate or show potential for penetrating the occupant compartment, or to 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 6.5 inches in the right kick panel/floor pan 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. Maximum roll and pitch angles were 22 degrees and 6 degrees.	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 20.6 ft/s, and lateral OIV was 27.3 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.	Longitudinal occupant ridedown acceleration was 4.7 g, and lateral occupant ridedown acceleration was 7.9 g.	Pass

Table 6.2. Performance Evaluation Summary for *MASH* Test 4-12 on CMB with Fence Mounted on Top.

Test Agency: Texas A&M Transportation Institute Test No.: 613131-03-2 Test Date: 2021-03-03

MASH Test 4-12 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 CMB with fence mounted on top contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection of the fence and barrier during the test were not obtainable (overhead camera obscured by vehicle).	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.	Post 8 and 9 penetrated the front windshield as the vehicle passed.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	Maximum occupant compartment deformation was 10.0 inches at the midpoint of the left front A-pillar, and 8 inches at the left front corner of the roof.	
G. It is preferable, although not essential, that the vehicle remain upright during and after collision.	The 10000S vehicle remained upright during and after the collision event.	Pass

Table 6.3. Assessment Summary for *MASH* Tests 4-11 and 4-12 on CMB with Fence Mounted on Top.

Evaluation Factors	Evaluation Criteria	Test No. 613131-03-1	Test No. 613131-03-2
Structural Adequacy	A	S	S
Occupant Risk	D	S	F
	F	S	N/A
	G	N/A	S
	H	S	N/A
	I	S	N/A
	Test No.	***MASH* Test 4-11**	***MASH* Test 4-12**
	Pass/Fail	Pass	Fail

Note: S = Satisfactory; N/A = Not Applicable.

REFERENCES

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

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

3. American Association of State Highway and Transportation Officials, *Manual for Assessing Safety Hardware*, AASHTO Subcommittee on Bridges and Structures, Washington, DC, 2009.

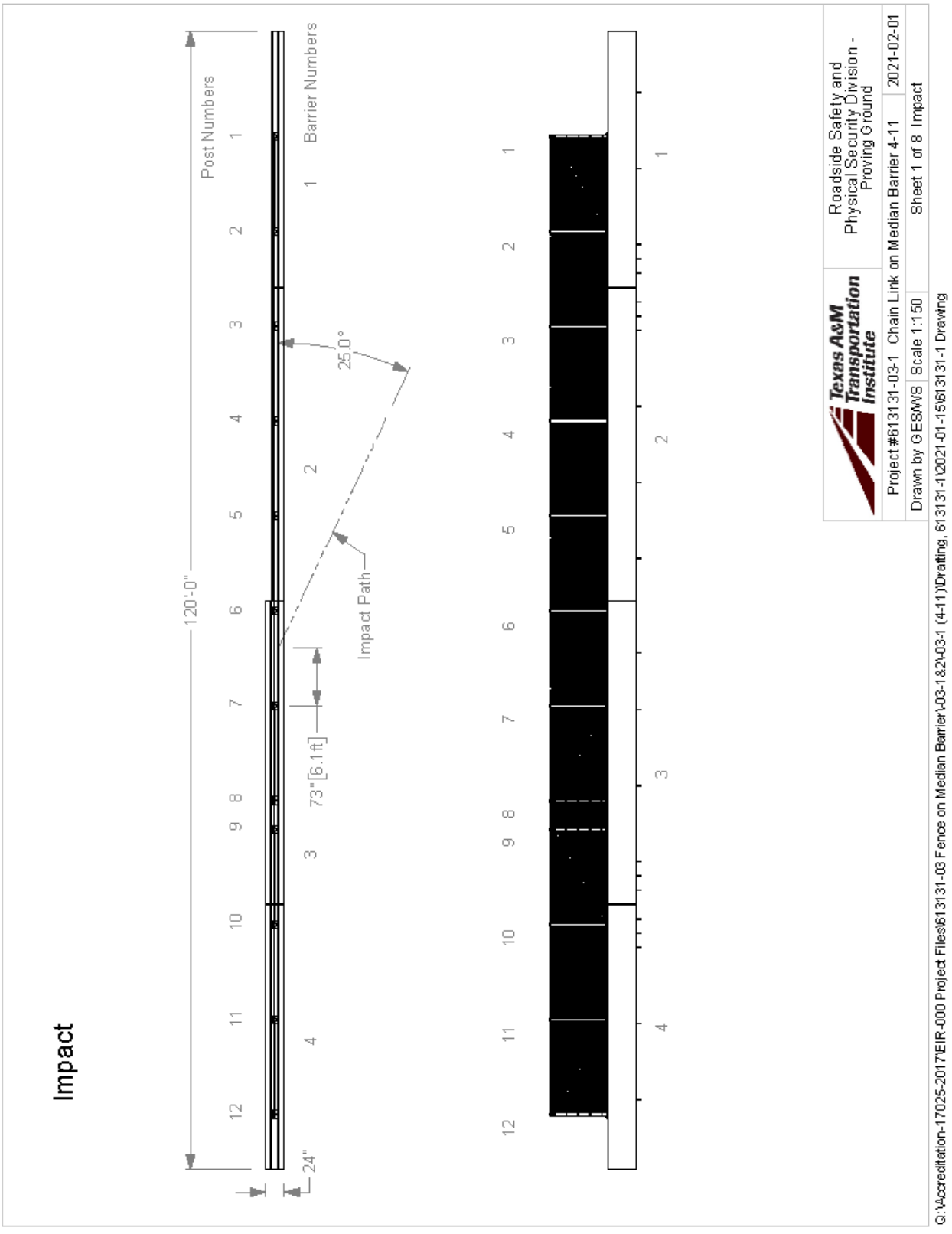
4. C. E. Buth and W. L. Menges. Crash Testing and Evaluation of Retrofit Bridge Railings and Transitions. FHWA-RD-96-032. Texas A&M Transportation Institute, College Station, TX, March 1996.

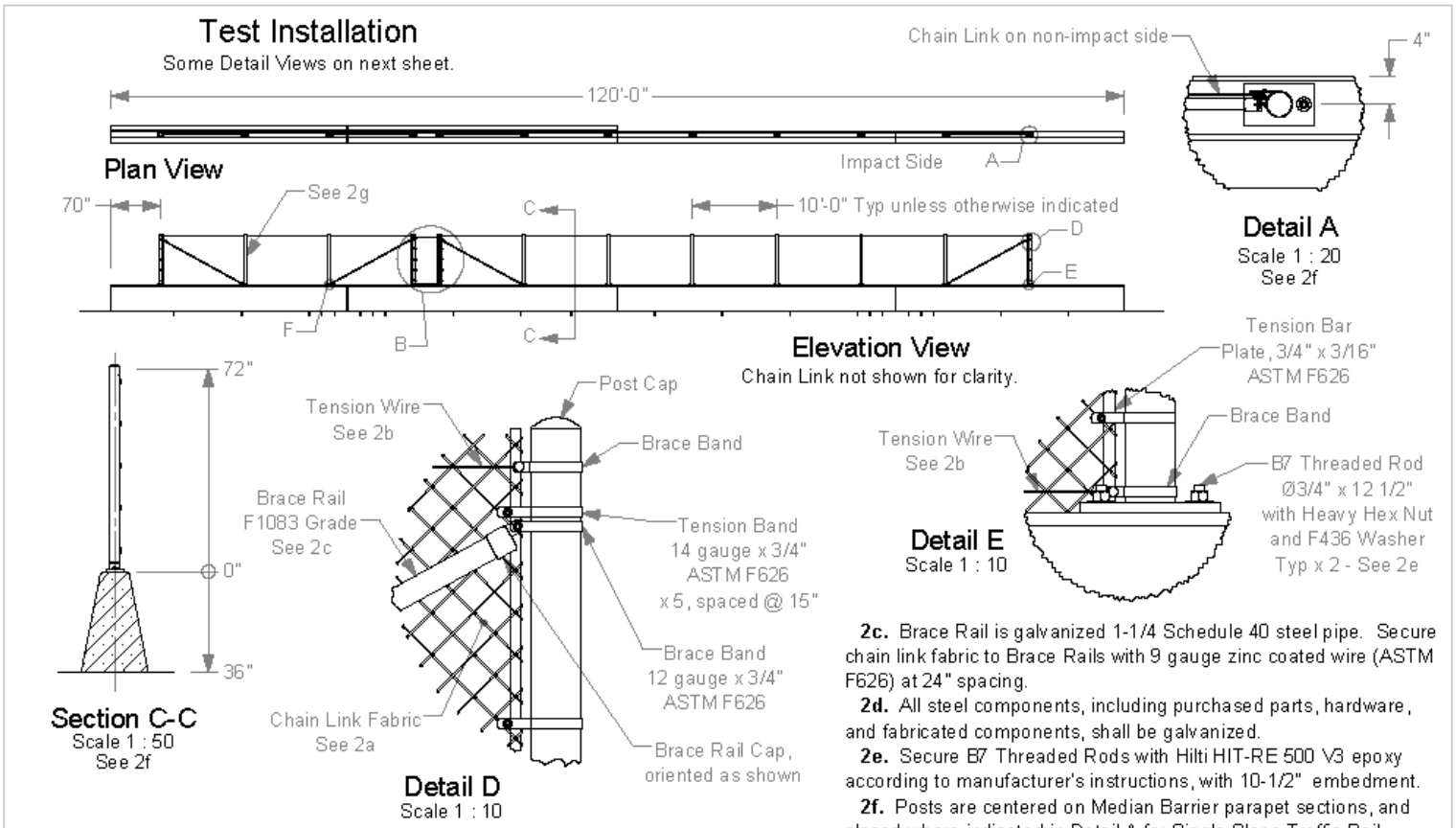
5. T. J. Hirsch and E. R. Post. Truck Tests on Texas Concrete Median Barrier. TxDOT Research Report 146-7. Texas A&M Transportation Institute, College Station, TX, August 1972.

6. W.F. Williams, R.P. Bligh, and W.L. Menges. MASH Test 3-11 of the TxDOT Single Slope Bridge Rail (Type SSTR) on Pan-Formed Bridge Deck. TxDOT Research Report 9-1002-3. Texas Transportation Institute, College Station, TX, November 2010.

7. D. Whitesel, J. Jewell, and R. Meline. Compliance Crash Testing of the Type 60 Median Barrier, Test 140MASH3C16-04 - Type 60 Median Barrier. Research Report FHWA/CA17-2654. Roadside Safety Research Group, California Department of Transportation, Sacramento, CA, May 2018.

APPENDIX A. DETAILS OF CMB WITH FENCE MOUNTED ON TOP FOR TEST NO. 613131-03-1





2a. Chain Link Fabric is 2" mesh x 72", with twisted top and knuckled bottom selvage, 9 gauge steel wire, ASTM A392 with Class 2 Zinc coating. Chain link fabric stops at posts on each side of joint, and is placed on the non-impact side of the installation.

2b. Tension Wire is Type II 7 gauge, ASTM A824 and A817, with Class 4 zinc coating, typical at top and bottom. Position Tension Wires in center of diamonds in Chain Link as shown, or as close as possible. Secure Tension Wire to Brace Band bolt at each end. Secure Chain Link to Tension Wires at 24" spacing with 12 gauge zinc coated hog rings (ASTM F626). Tie Tension Wire to Line Posts with 9 gauge zinc coated wire (ASTM F626), with 3 wraps around the Tension Wire at each end of the tie wire.

2c. Brace Rail is galvanized 1-1/4 Schedule 40 steel pipe. Secure chain link fabric to Brace Rails with 9 gauge zinc coated wire (ASTM F626) at 24" spacing.

2d. All steel components, including purchased parts, hardware, and fabricated components, shall be galvanized.

2e. Secure B7 Threaded Rods with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 10-1/2" embedment.

2f. Posts are centered on Median Barrier parapet sections, and placed where indicated in Detail A for Single Slope Traffic Rail parapet sections. Chain link is on non-impact side for entire installation.

2g. Secure chain link fabric to intermediate posts with 9 gauge zinc coated wire (ASTM F626) at 12" spacing. Typical at Posts 2 - 7, 10, and 11.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-1 Chain Link on Median Barrier 4-11		2021-02-01
Drawn by GES/WS	Scale 1:200	Sheet 2 of 8 Test Installation

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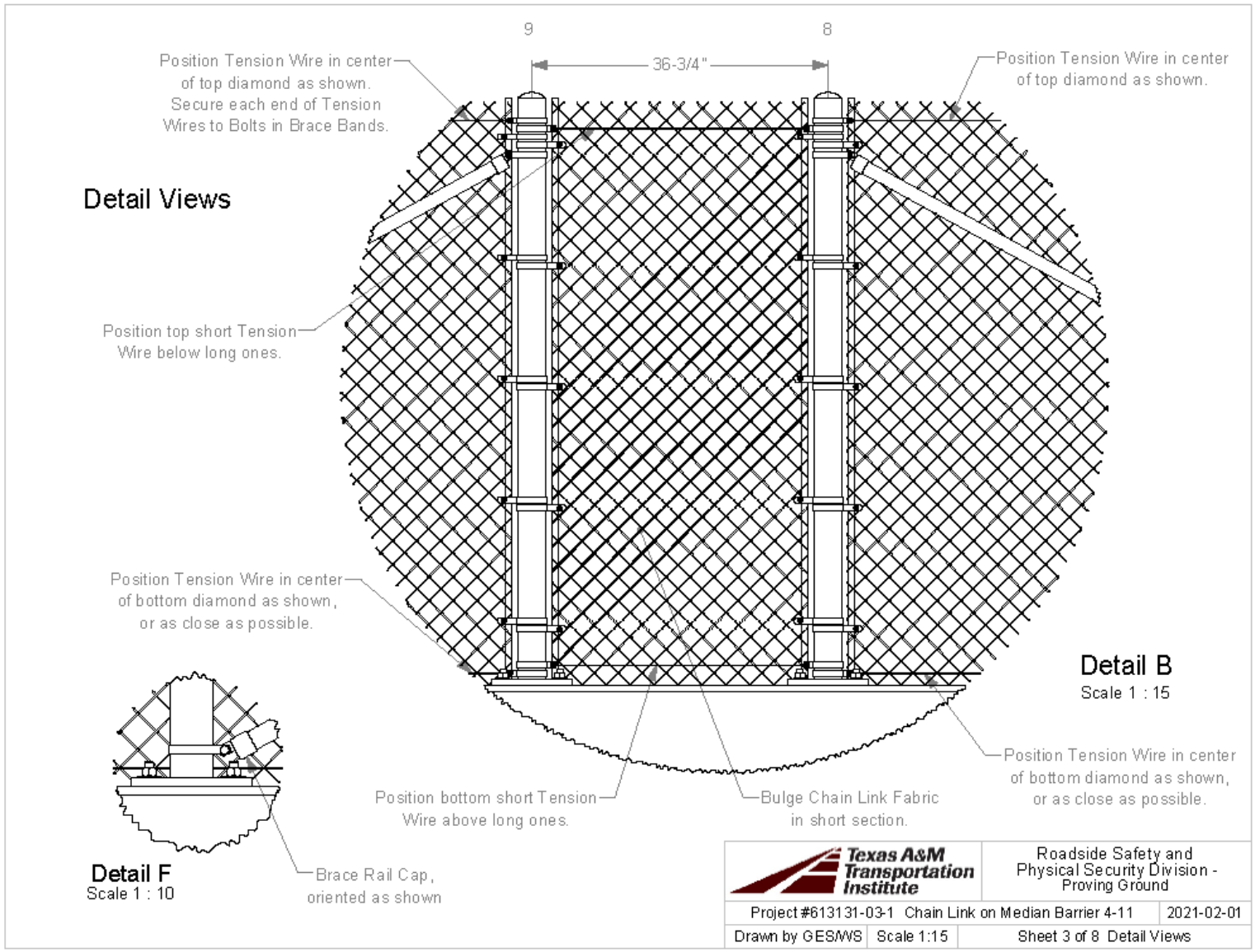
9
8
36-3/4"
Position Tension Wire in center of top diamond as shown. Secure each end of Tension Wires to Bolts in Brace Bands.
Position Tension Wire in center of top diamond as shown.
Detail Views
Position top short Tension Wire below long ones.
Position Tension Wire in center of bottom diamond as shown, or as close as possible.
Detail B
Scale 1 : 15
Position Tension Wire in center of bottom diamond as shown, or as close as possible.
Position bottom short Tension Wire above long ones.
Bulge Chain Link Fabric in short section.
Detail F
Scale 1 : 10
Brace Rail Cap, oriented as shown
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Roadside Safety and Physical Security Division - Proving Ground
Project #613131-03-1 Chain Link on Median Barrier 4-11
2021-02-01
Drawn by GES/WS
Scale 1:15
Sheet 3 of 8 Detail Views
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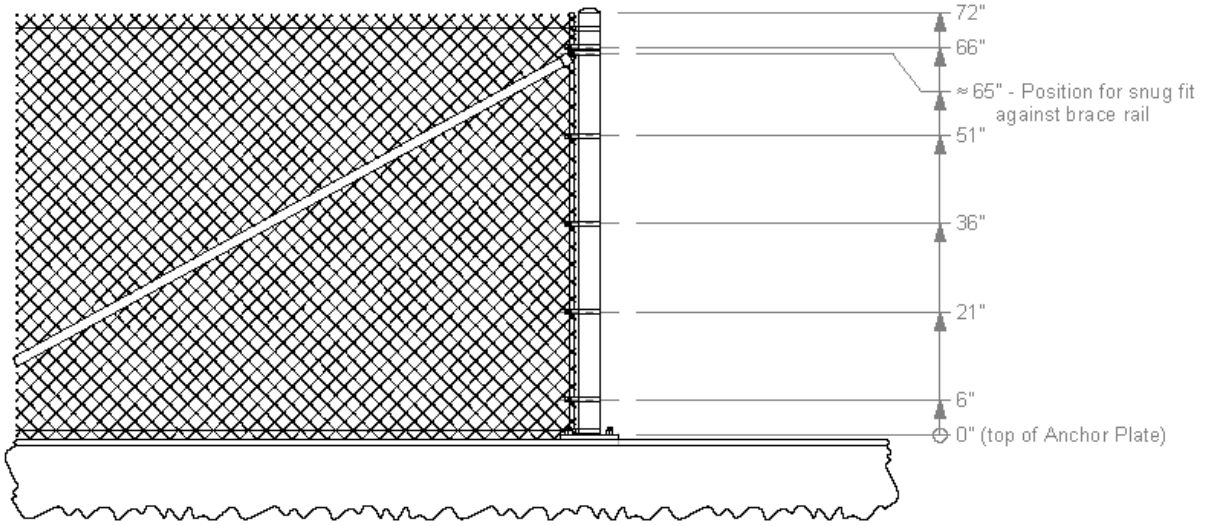
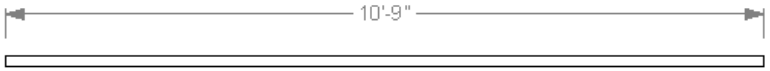
Anchor Post Details



Elevation View



Brace Rail

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-1 Chain Link on Median Barrier 4-11		2021-02-01
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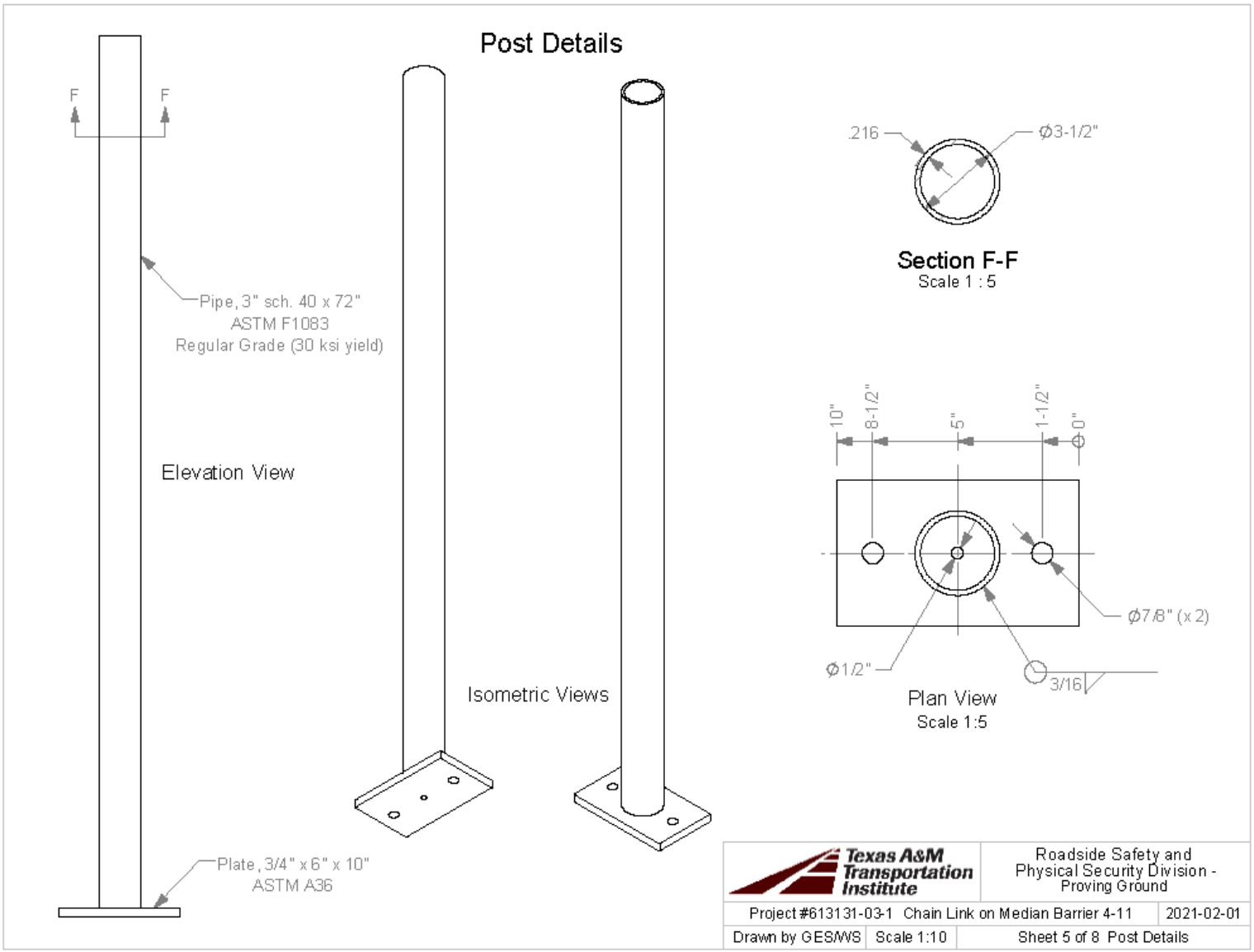

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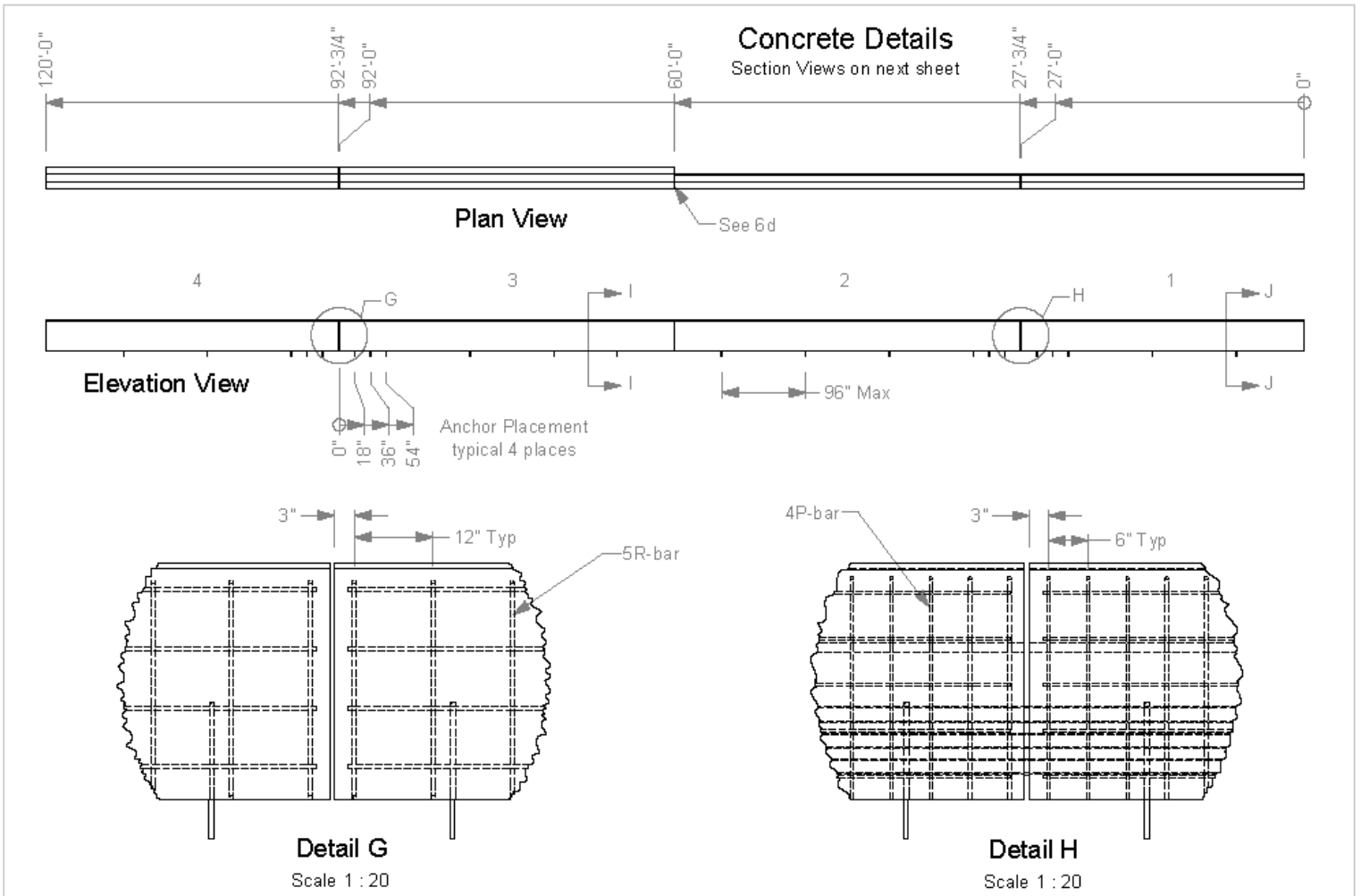

6a. Concrete shall be 3400 psi. Chamfer top edges of Parapets 3/4".
6b. Rebar dimensions are to the centerline unless otherwise indicated by cvr (cover).
6c. Minimum rebar lap is 17" for #4 bars and 21" for #5 bars. All rebar is grade 60.
6d. Cold joint between profiles, with no space.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground
Project #613131-03-1 Chain Link on Median Barrier 4-11		2021-02-01
Drawn by GES/WS	Scale 1:150	Sheet 6 of 8 Concrete Details

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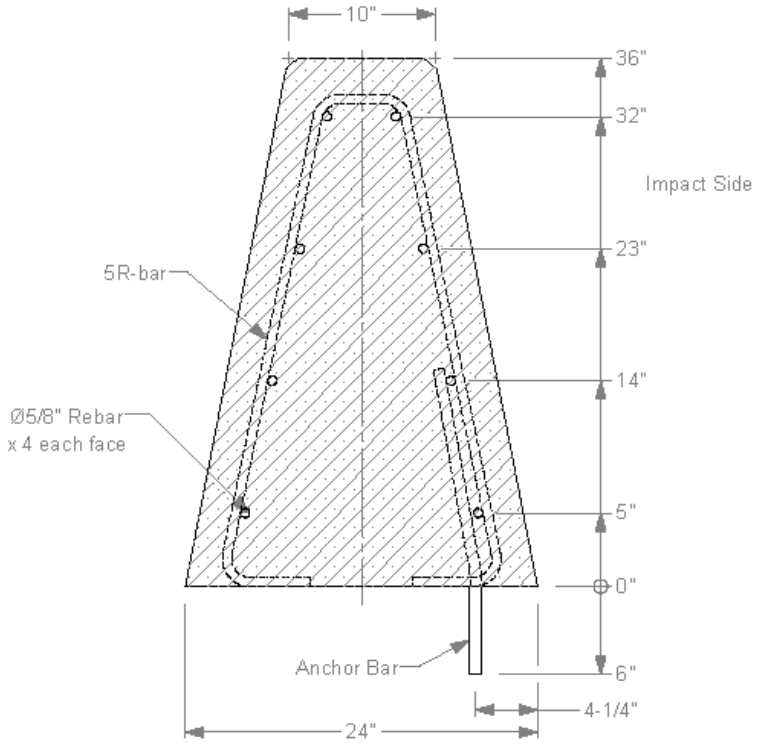
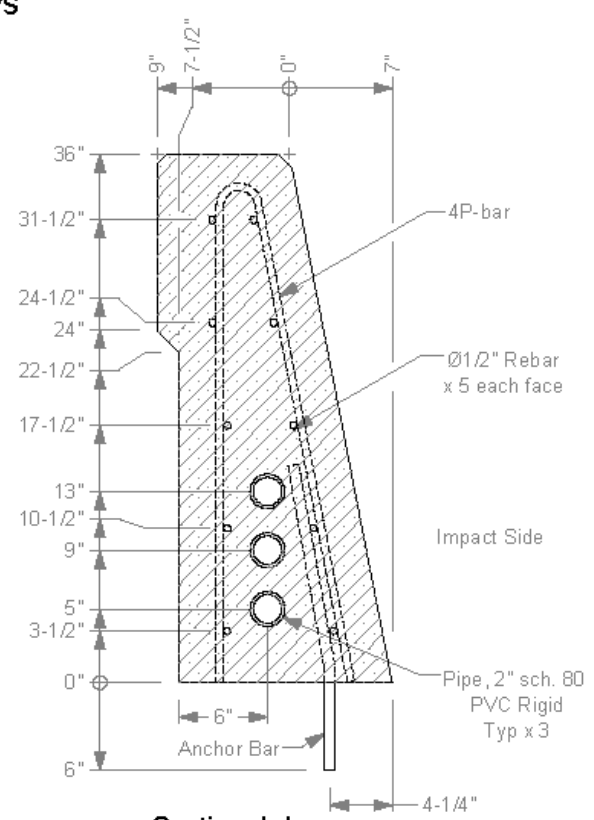
Parapet Section Views



Section I-I
Typ in Parapet Sections 3 and 4



Section J-J
Typ in Parapet Sections 1 and 2

7a. Concrete shall be 3400 psi. Chamfer top edges of Parapets 3/4".
7b. Rebar dimensions are to the centerline unless otherwise indicated by cvr (cover).
7c. Minimum rebar lap is 17" for #4 bars and 21" for #5 bars. All rebar is grade 60.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-1 Chain Link on Median Barrier 4-11		2021-02-01
Drawn by GES/WS	Scale 1:10	Sheet 7 of 8 Parapet Section Views

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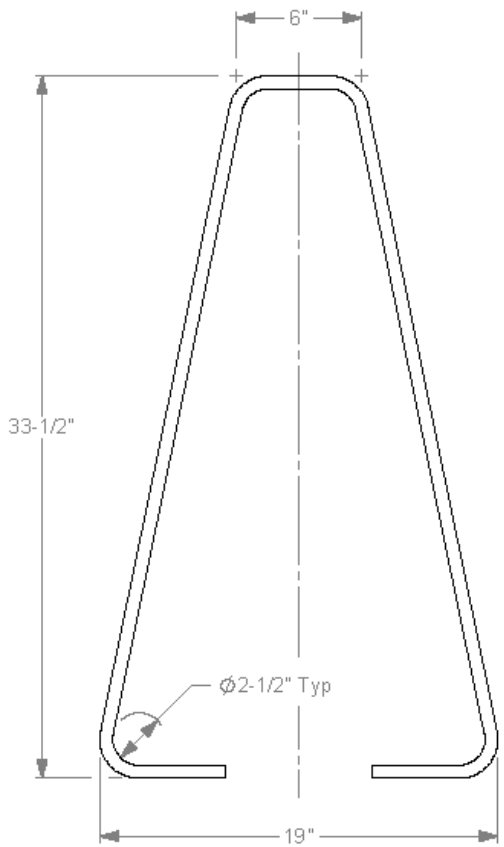
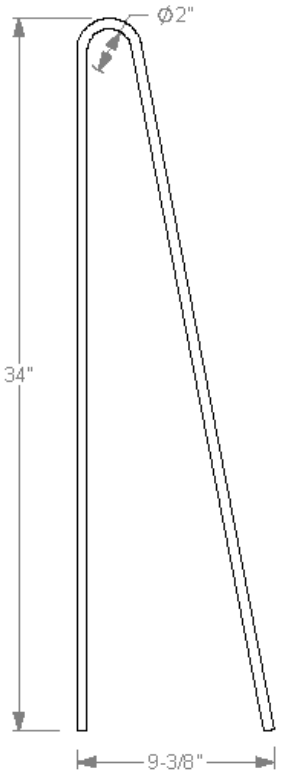
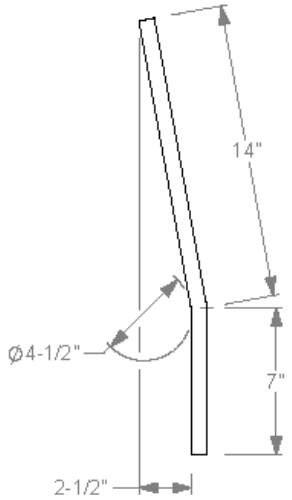
Rebar Details



5R-bar
Ø5/8" Grade 60 Rebar



4P-bar
Ø1/2" Grade 60 Rebar



Anchor Bar
Ø3/4" Grade 60 Rebar

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-1 Chain Link on Median Barrier 4-11		2021-02-01
Drawn by GES/WS	Scale 1:7	Sheet 8 of 8 Rebar Details

Q:\Accreditation-17025-2017\EIR-000 Project Files\613131-03 Fence on Median Barrier\-03-1&2\-03-1 (4-11)\Drafting, 613131-1\2021-01-15\613131-1 Drawing

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

10-14-2020 07:02 **Load - 3681177** **BL - 3891094** **blr466**

Mack Bolt & Steel **Heat - 1100012769**

Cust. PO - 36446 **Order - 19093844**

NUCOR®

Mill Certification

08/07/2020

MTR#:468772-7
Lot #:110001276961
8812 HWY 79 W
Jewett, TX 75846 US
903 626-4461
Fax: 903 626-6290

Sold To: KLOECKNER METALS CORP
500 COLONIAL CENTER PKWY
STE 500
ROSWELL, GA 30076 US

Ship To: KLOECKNER METALS
2560 S LOOP 4
BUDA, TX 78610 US

Customer PO	7533209	Sales Order #	11020379 - 16.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	2138582
Grade	Nucor Multigrade	Lot #	110001276961
Size	0.75" x 6"	Heat #	1100012769
BOL #	BOL-550925	Load #	468772
Description	Hot Roll - Merchant Bar Quality Flat 3/4" x 6" Nucor Multigrade 20' 0" [240"] 2001-6000 lbs	Customer Part #	MB346FLTMA360240
Production Date	06/12/2020	Qty Shipped LBS	4900
Product Country Of Origin	United States	Qty Shipped EA	16
Original Item Description	Hot Roll - Merchant Bar Quality Flat 3/4" x 6" Nucor Multigrade 20' 0" [240"]	Original Item Number	1037263

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 06/09/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Sn (%)
0.12	0.86	0.022	0.020	0.239	0.13	0.28	0.04	0.34	0.000	0.052	0.011

ASTM A529 S78.2 CE (%) : 0.41

Other Test Results

Yield (PSI) : 56500	Yield (PSI) : 57800	Tensile (PSI) : 72900
Tensile (PSI) : 74800	Elongation in 8" (%) : 20.0	Elongation in 8" (%) : 21.0

Comments:

NUCOR MULTIGRADE MEETS THE REQUIREMENTS OF: ASTM A36/A36M-14; A529/529M-05(2009) GR50(345); A572/572M-07 GR50(345); A709/709M-10 GR36(250) & GR50(345); CSA G40.21-04 GR44W(300W)& GR50W(350W); AASHTO M270/M270M-10 GR36(270) & GR50(345); ASME SA36/SA36M-07; MEETS REPORTING REQUIREMENTS OF EN10204 SEC 3.1

1. All manufacturing processes of the steel, including melting, casting & hot rolling, have been performed in U.S.A
2. Mercury in any form has not been used in the production or testing of this product.
3. Welding or weld repair was not performed on this material.
4. This material conforms to the specifications described on this document and may not be reproduced, except in full, without written approval of Nucor Corporation.
5. Results reported ASTM E45 (Inclusion content) and ASTM E381 (Macro-etch) are provided as interpretation of ASTM procedures.

Reddy Vantari, Chief Metallurgist

Page **1** of **1**

Certified Material Test Report to ISO16228 F3.1 (EN 10204-2004 3.1)

FOR ASME SA194/ ASTM A194-16 GRADE 2H HVY HEX NUTS

FACTORY: NINGBO HAIXIN HARDWARE CO.,LTD.
ADDRESS: XUJINGTANG,LUOTUO NINGBO ZHEJIANG 315205 CHINA
CUSTOMER: BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC
QNTY SHIPPED: 9.000MPCS
SAMPLE SIZE : ACC. TO ASME B18 . 18 . 1 - 11
SIZE & DESCRIPTION: 3/4-10(BLK)

DATE: NOV.01.2018
COUNTRY OF ORIGIN: CHINA
MFG LOT NUMBER: 5143520014
PO NUMBER: MILL
PART NO: 314958
MANUFACTURER DATE: 2018/10/29

STEEL PROPERTIES: TEST FACILITY: S
STEEL GRADE: SWRCH45K SIZE: 30mm HEAT NO: J21805862
CHEMISTRY COMPOSITION:

CHEMIST	C %	Mn %	P %	S %	Si %	Cr %	Ni %	Cu %	Mo %	OTHERS
SPE:	MIN 0.40	MAX 1.00	MAX 0.04	MAX 0.05	MAX 0.40					
TEST:	0.44	0.69	0.01	0.005	0.19					

DIMENSIONAL INSPECTIONS SPECIFICATION: ASME /ANSI B18.2.2-2015 TEST FACILITY: M

CHARACTERISTICS	TEST METHOI	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********	**********	**********	**********	******	*******
APPEARANCE	ASTM F812-12		PASSED	100	0
WIDTH A/F	1.212"-1.250"		1.229"-1.241"	32	0
WIDTH A/C	1.382"-1.443"		1.398"-1.408"	32	0
THREAD	ASME B1.1-03		PASSED	8	0
HEIGHT	0.710"-0.758"		0.726"-0.742"	32	0
MARK	2H LM		PASSED	100	0

MECHANICAL PROPERTIES: TO 1-1/2" in SPECIFICATION:ASTM/ASME A194/SA194-16 TEST FACILITY: M

CHARACTERISTICS	TEST METHOI	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
**********	**********	**********	**********	*******	*******
HARDNESS	ASTM E18-12	24-35HRC	HRC29-30	5	0
PROOF LOAD	ASTM F606-11	MIN58450LBF	58450LBF	5	0
HARDNESS AFTER 24H AT 540°C ASTM A194		MIN 89 HRB	HRB 97-99	5	0
TEMPERING TEMPERATURE Min455°C			PASSED(520°C)		
MACROETCH	ASTM E381-12	S1/R1/C1~S4/R4/C4	S2/R2/C2	5	0

PARTS ARE MANUFACTURED AND TESTED IN ACCORDANCE WITH ASTM/ASME A194/SA194-16
PARTS MEET ASME SECTION Ⅱ PART A
ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

All parts meet the requirements of FQA and records of compliance are on file.

Maker's ISO#00109Q211593R0M/3302

(SIGNATURE OF Q.A. OR LAB MGR.)
(NAME OF MANUFACTURER)

TIANJIN PINGYUAN HARDWARE CO., LTD.

NO.8 CONSTRUCTION FIVE BRANCH,BALITAI TOWN, JINNAN DISTRICT, TIANJIN
TEL: 0086-22-23792163 FAX : 0086-22-23790387 e-mail: lxm@tjpyco.com

CERTIFICATE OF INSPECTION

PURCHASER :	BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC.		
ADDRESS :	NO. 122 YILIN ROAD, RENDE DIST., TAINAN CITY 71752, TAIWAN		
DESCRIPTION :	ASTM F436M -18 TYPE 1 WASHERS LIGHT PROTECTIVE OIL		
INSP. DATE :	10/12/2019	ISSUED DATE:	10/12/2019
PO # :	U69524	LOT NO . :	54219030014
INVOICE NO :	FPB19090059-2	CERT. NO . :	201410060000056
MATERIAL TYPE :	45#/3.5mm	MANU. DATE :	09/30/2019
SAMPLE SIZ E :	50400 PCS	SIZE :	ASTM F436M -18 3/4"
HEAT NO :	1441000609	LOT SIZE :	252000 PCS
MANUFACTURER: TIANJIN PINGYUAN HARDWARE CO., LTD.		PART NO .:	355080

DIMENSIONAL INSP. SPEC.:ASTM F436M -18 TEST FACILITY:M

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACCE.	REJE.
VISUAL APPEARANCE	LIGHT PROTECTIVE OIL	PASSED	29	0
INSIDE:	20.64-21.43	21.15-21.24	8	0
OUTSIDE:	36.52-38.10	36.66-36.78	8	0
THICKNESS:	3.10-4.50	3.45-3.50	8	0
HEAD MARKING	F436 PY	F436 PY	8	0

MECHANICAL INSP. SPEC.: ASTM F436M -18 TEST FACILITY:M

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACCE.	REJE.
HARDNESS	ASTM F436M -18	38-45 HRC	39-42	4	0

CHEMICAL COMPOSITION % TEST FACILITY:S

C	Si	Mn	P	S	Cu	Ni	Cr	B	V
0.47	**0.21**	**0.55**	**0.0159**	**0.024**	**0.03**	**0.03**	**0.05**	**0.0000**	**0.00**

INSP. RESULT:SAMPLES TESTED CONFORM TO ALL OF THE SPECIFICATION AS ABOVE.

LAB. CHIEF/CERT. SIGNATORY: (XIANYIN) PAGE: 1 OF 1

REMARKS: Xianjing Country of Origin: CHINA

DIMENSION=mm, TENSILE=Mpa

THE REPORT MUST NOT BE REPRODUCED EXCEPT IN FULL AND RELATE ONLY TO THE ITEM TESTED.

THE REPORT IS ISSUED ACCORDING TO ISO16228 F3.1(EN10204 3.1).

THE QMS IS APPROVED TO ISO9001-2015, VALID TO JUN.24.21

TEMPERING TEMPERATURE CONFORM TO THE REQUIREMENT OFASTM F436-11

天津市平源五金制品有限公司
TIANJIN PINGYUAN HARDWARE CO., LTD.

INSPECTION CERTIFICATE

KPF FACTORY : 50, CHUNGJUSANDAN 5-RO, CHUNGJU-SI
CHUNGCHEONGBUK-DO, KOREA 380-250
TEL : (043)849 - 1114 FAX : (043)849 - 1234

FIELD OF TESTING : MECHANICAL TESTING
LAB. ID. : 111983
CERT. NO. : 0382.01

STANDARD OF CERTIFIED : IATF 16949, ISO 9001, ISO 14001
CERTIFICATE NO. : TS-01899, AC-01899, EAC-01899

STANDARD OF CERTIFIED : EN 14399-1,2,3,4,5,6,10
CERTIFICATE NO. : 1020 - CPR - 070038467

STANDARD OF CERTIFIED : EN 15048-1
CERTIFICATE NO. : 1020 - CPR - 070048404

Certificate No. : J420200710113
P/O No. : U73082
L/C No. : BBI(HOUSTON)FOB
Date Issued : 2020.07.10
Date Shipped : 2020.07.16
Date Tested : 2020.06.07
Date Manufactured : 2020.06.04
Specifications : BBI ASTM A193/A193M - 19

Customer : HOUSTON
Description : THREAD ROD GR.B7
Grade : GR.B7
Size : 3/4-10UNCx6'
Marking : B7,KPF LOGO
Surface Condition : PLAIN
Lot No. : 2030331900
Q'ty Shipped : 375 PCS

1. Chemical Composition (%)

Heat No.		C x100	Si x100	Mn x100	P x1000	S x1000	Cr x100	Mo x100	Ni x100	B x10000	Cu x100	Ti x100	V x100	Al x1000
Spec.	Min.	38	15	75			80	15						
	Max.	48	35	100	35	40	110	25						
S40718		41	19	81	15	10	94	19	14		7			

2. Macroetch Meet

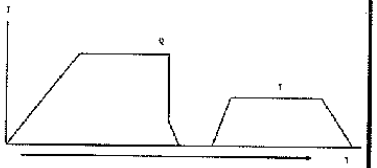
Division	Surface Condition	Random Condition	Center Segregation	Spec. of Test Method
Spec.	S2	R2	C3	ASTM E381 - 2017
Results	S1	R1	C1	
Tested By	C.I.LEE			

3. Mechanical Properties

Division		Hardness		Specimen Tensile				Proof Load		Wedge Tensile Load	Impact Test		Bolt Retempering Hardness
		Surface	Core	Yield Strength	Tensile Strength	Elongation	Reduction of Area	Load	Elongation		Individual	Average	
			n = 3	n = 2									
Unit	Min.			ksi	ksi	%	%						
	Max.		HRC										
Spec.	Min.			105	125	16	50						
	Max.		35										
Results	1		HRC 30	119	134	23	60						
	2		29	120	136	24	60						
	3		30										
	4												
	5												
	6												
	7												
	8												
	9												
	10												
	Avg.		30	120	135	24	60						
Tested By			B.S.KANG	B.S.KANG									
Spec. of Test Method			ASTM A370-19	ASTM A370-19									

4. Heat Treatment

Quenching	Min. Temp.	
	Max. Temp.	
	Working Temp.	
	Holding Time	
Tempering	Min.Temp.	
	Working Temp.	
	Holding Time	



Reference : 1. PART NO:778073
2. MADE IN KOREA
3. MATERIAL TYPE : 4140
4. THE REPORT IS ISSUED ACCORDING TO ISO16228 F3.1(EN10204 3.1).
5. TEST FACILITY : M
6. HEAT TREATMENT : Q'T:1,672°F / T'T:1,166°F

This is to certify that the above results are true and correct in every details.

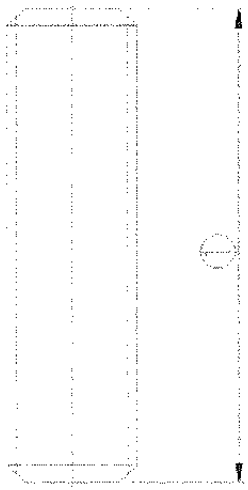
jai man Park
JAI - MAN PARK
Chef of Quality Management Dept

KPF

TR No. 613131-03-1&2

INSPECTION CERTIFICATE

Description	THREAD ROD GR.B7	Size	3/4-10UNCx6'	Date of Issue	Jul. 10. 2020
P/O No.	U73082	Heat No.	S40718	Quantity	375 EA
Sampling Method	-	Marking	B7,KPF LOGO	LOT NO.	2030331900
Quality Character	ASME B18.31.3-2014			Customer	HOUSTON



Characteristic	Sample Quantity	SPEC MIN	SPEC MAX	Measurement 1	2	3	4	5	Result
1	5	71.500	72.500	72.024	72.110	71.972	72.063	72.228	Good
Thread Major Diameter (1A)	5	0.729	0.748	0.745	0.746	0.745	0.746	0.746	"
Thread Acceptability	5	GO Thread Ring Gage(1A)		Answered					"
		NOT Thread Ring Gage(1A)		Not Answered					"
Visual Inspection	5	ISO 6157-1		passed					"

Reference :

Witnessed by :

This is to certify that the above results are true and correct in every details.

jai man Park

Chef of Quality Management Dept.

KPF

2022-04-11

华凌

凌源钢铁股份有限公司
产品质量证明书

LINGYUAN IRON&STEEL CO., LTD.

CERTIFICATE OF QUALITY AND QUANTITY

LG-JL-KJ-33

收货用户 凌源钢源工贸有限公司

到站地址

订货用户 CUSTOMER	凌源钢源工贸有限公司	标准 STANDARD	GB/T711-2008	交货状态 CONDITION OF DELIVERY	热轧	证明书号 CERTIFICATE NO.	20141208000042
产品名称 PRODUCT	中宽热带	牌号 STEEL GRADE	45	发货日期 DATE OF DELIVERY	20141208	合同号 CONTRACT NO.	[illegible]

炉号 HEAT NO.	材料号 COIL NO.	规格 DIMENSIONS mm * mm	数量 QUANTITY 件(卷) PIECES	重量 WEIGHT 吨(T)	化学成分(%) CHEMICAL COMPOSITION C ×10⁻²	Si ×10⁻²	Mn ×10⁻²	P ×10⁻³	S ×10⁻³	Cr ×10⁻²	Ni ×10⁻²	Cu ×10⁻²	×10	×10	×10	×10	力学工艺性能 MECHANICAL PROPERTIES ReH MPa	Rm MPa	A %	A11.3	AkV J	冷弯 BEND TEST	脱碳层 (mm)	晶粒度 (级)	车号 VEHICLE NO.
1441207209	H14C0185036	3.4 * 690	1	6.505	43	22	53	13	13	4	2	2						645	20.0						蒙D70090
1441207210	H14C0185037	3.25 * 710	1	7.83	43	22	53	13	13	4	2	2						640	20.5						蒙D70590
1441207212	H14C0185039	3.25 * 710	1	7.905	43	22	53	13	13	4	2	2						640	20.5						蒙D70590
1441207304	H14C0185045	3.25 * 710	1	7.915	43	23	53	16	17	5	2	2						649	19.0						蒙D70590
1441207305	H14C0185046	3.25 * 710	1	7.915	43	23	53	16	17	5	2	2						649	19.0						蒙D70590
1441207307	H14C0185048	3.25 * 710	1	7.92	43	23	53	16	17	5	2	2						649	19.0						蒙D70590
1441207403	H14C0185056	5 * 710	1	7.905	44	24	57	19	14	5	2	2						680	25.5						蒙D70590
1441207615	H14C0186034	4.9 * 710	1	7.93	45	24	57	10	14	5	2	2						676	18.0						蒙D70590
																		以下空白							
合计 TOTAL			8	61.825	备注 REMARK	1.本证明书加盖产品质量专用章后方可生效; 2.销售部门(现代铺仓)出具本证明书复印件时必须如实填写销售单位名称、日期、品名、规格、件数、重量,并加盖其红色印章后方可生效。 用途 结构件																			质量证明章 QUALITY PROVE SEAL

地址:中国辽宁省凌源市钢铁路3号 ADDRESS:NO.3 GANGTIE ROAD, LINGYUAN CITY, LIAONING PROVINCE, CHINA

电话:[illegible] TEL:[illegible]

开证员 OPERATOR 陈兰

日期 DATE [illegible]

凌源钢铁股份有限公司 质量专用章

APPENDIX C. *MASH* TEST 4-11 (CRASH TEST NO. 613131-03-1)

C.1. VEHICLE PROPERTIES AND INFORMATION

Table C.1. Vehicle Properties for Test No. 613131-03-1.

Date: 2021-1-22 Test No.: 613131-03-1 VIN No.: 1C6RR6FT7FS530567

Year: 2015 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 228852

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

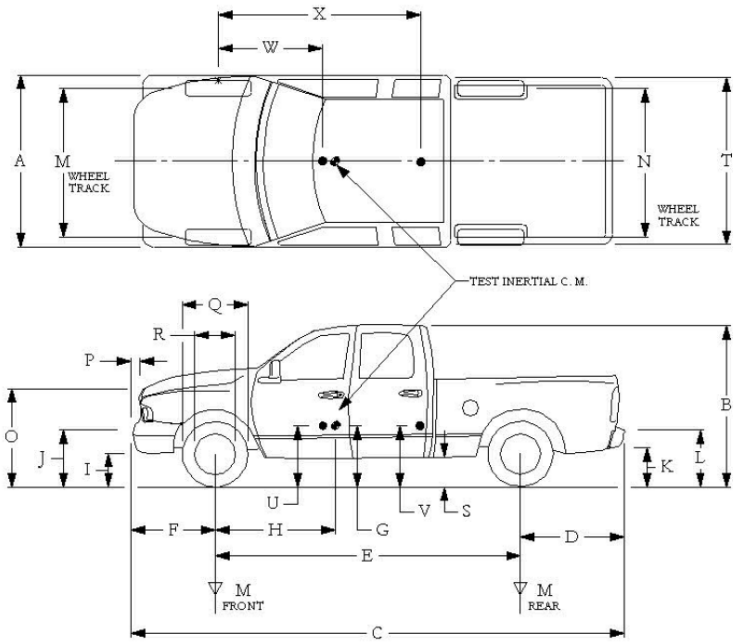
NOTES: None

Engine Type: V-8
Engine CID: 5.7L

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	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.25	L	30.00	Q	30.50	V	30.25
C	227.50	H	62.69	M	68.50	R	18.00	W	62.70
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}	2877	2792	2877
Back	3900	M_{rear}	2072	2250	2330
Total	6700	M_{Total}	4949	5042	5207

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

Mass Distribution:
lb LF: 1397 RF: 1395 LR: 1155 RR: 1095

Table C.2. Measurements of Vehicle Vertical Center of Gravity for Test No. 613131-03-1.

Date: 2021-1-22 Test No.: 613131-03-1 VIN: 1C6RR6FT7FS530567

Year: 2015 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 228852

Engine: 5.7L V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 170 (440 lb max)

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

Measured Vehicle Weights: (lb)									
LF:	1397		RF:	1395		Front Axle:	2792		
LR:	1155		RR:	1095		Rear Axle:	2250		
Left:	2552		Right:	2490		Total:	5042		
							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:	62.70	inches	Rear of Front Axle	(63 ±4 inches allowed)					
Y:	-0.42	inches	Left -	Right +	of Vehicle Centerline				
Z:	28.25	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 C.3. Exterior Crush Measurements for Test No. 613131-03-1.

Date:	2021-1-22	Test No.:	613131-03-1	VIN No.:	1C6RR6FT7FS530567
Year:	2015	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	15	9	36							-18
2	Side plane at bmp ht	15	10	56							80
	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.

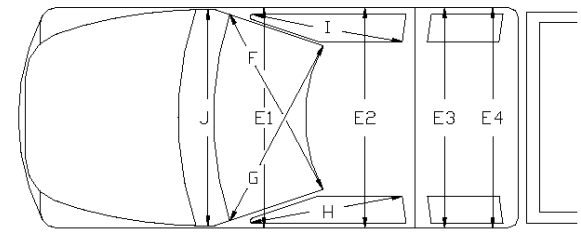
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

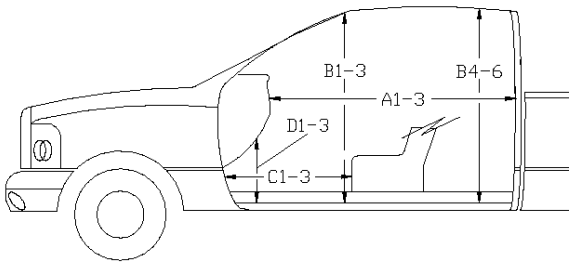
***Measure and document on the vehicle diagram the location of the maximum crush.

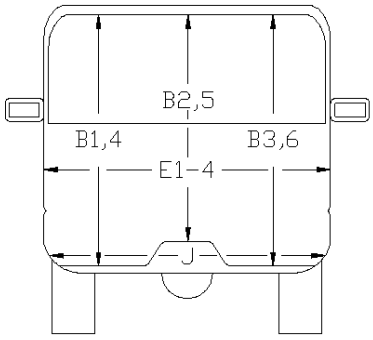
Note: Use as many lines/columns as necessary to describe each damage profile.

Table C.4. Occupant Compartment Measurements for Test No. 613131-03-1.

Date:	2021-1-22	Test No.:	613131-03-1	VIN No.:	1C6RR6FT7FS530567
Year:	2015	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	19.50	-6.50
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	59.50	61.50	2.00
E2	63.50	66.55	3.05
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	21.00	-4.00

C.2. SEQUENTIAL PHOTOGRAPHS

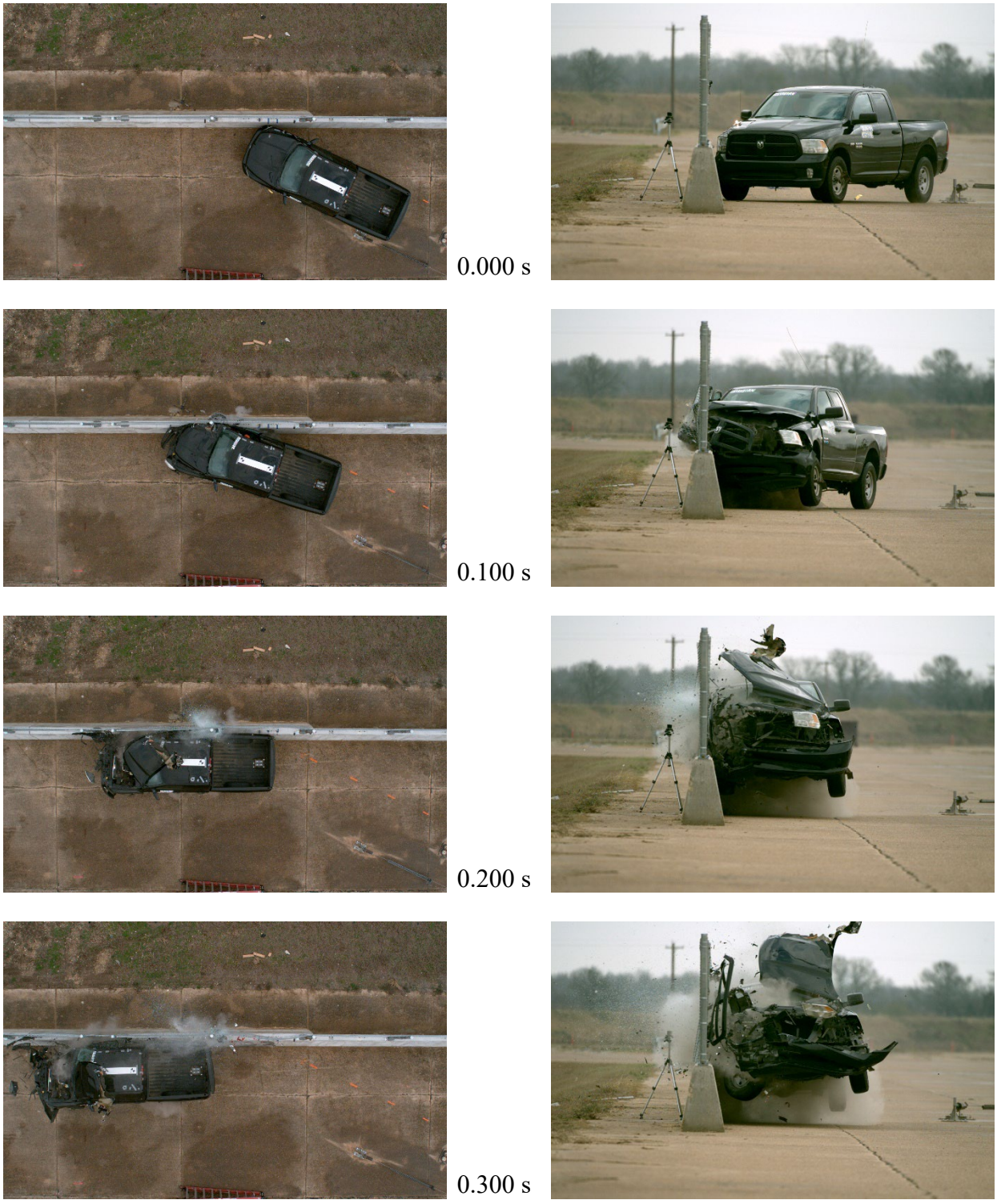
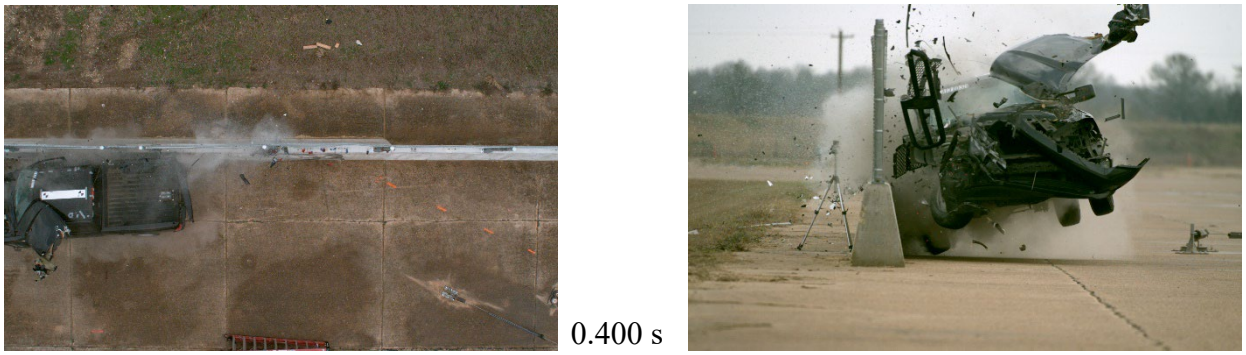
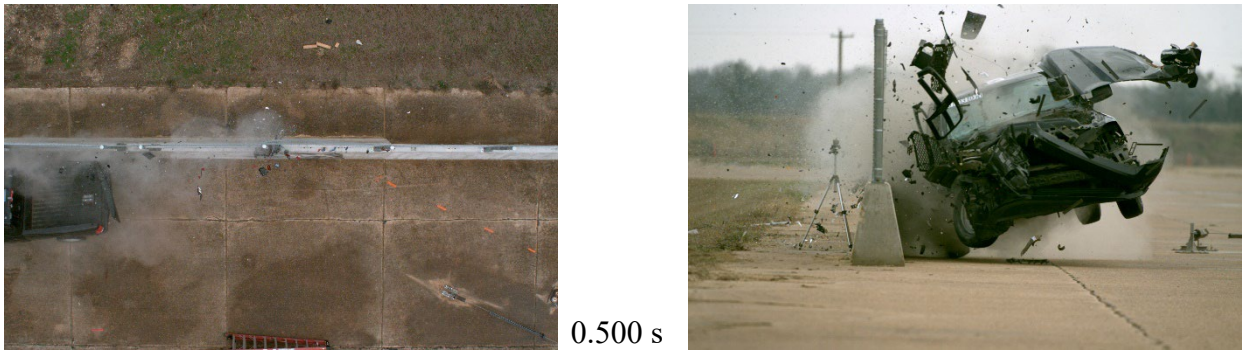
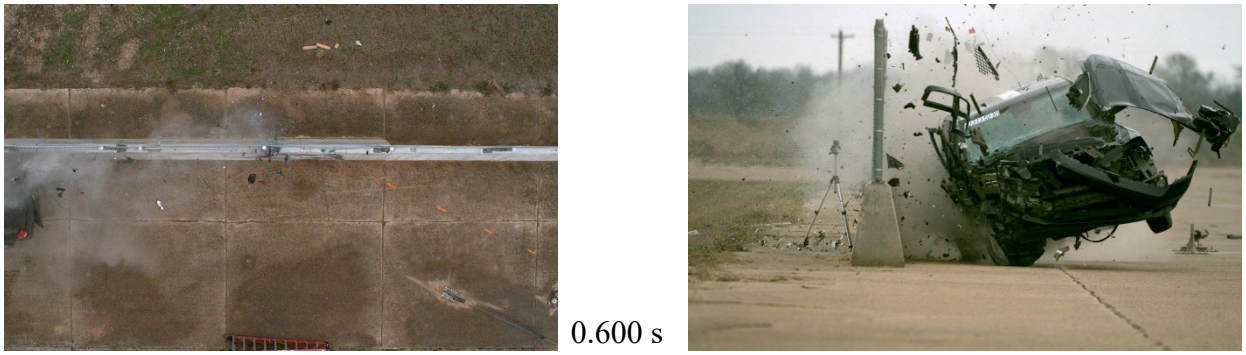


Figure C.1. Sequential Photographs for Test No. 613131-03-1 (Overhead and Frontal Views).


0.400 s


0.500 s


0.600 s

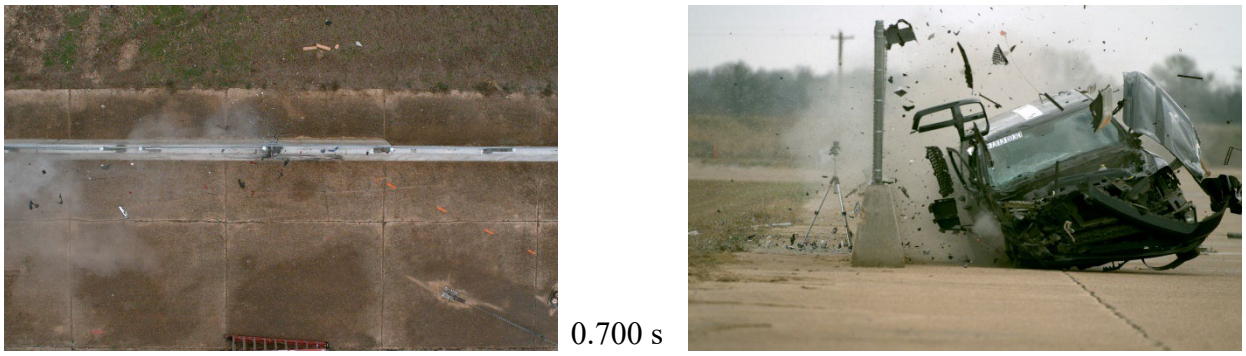

0.700 s

Figure C.1. Sequential Photographs for Test No. 613131-03-1 (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 C.2. Sequential Photographs for Test No. 613131-03-1 (Rear View).

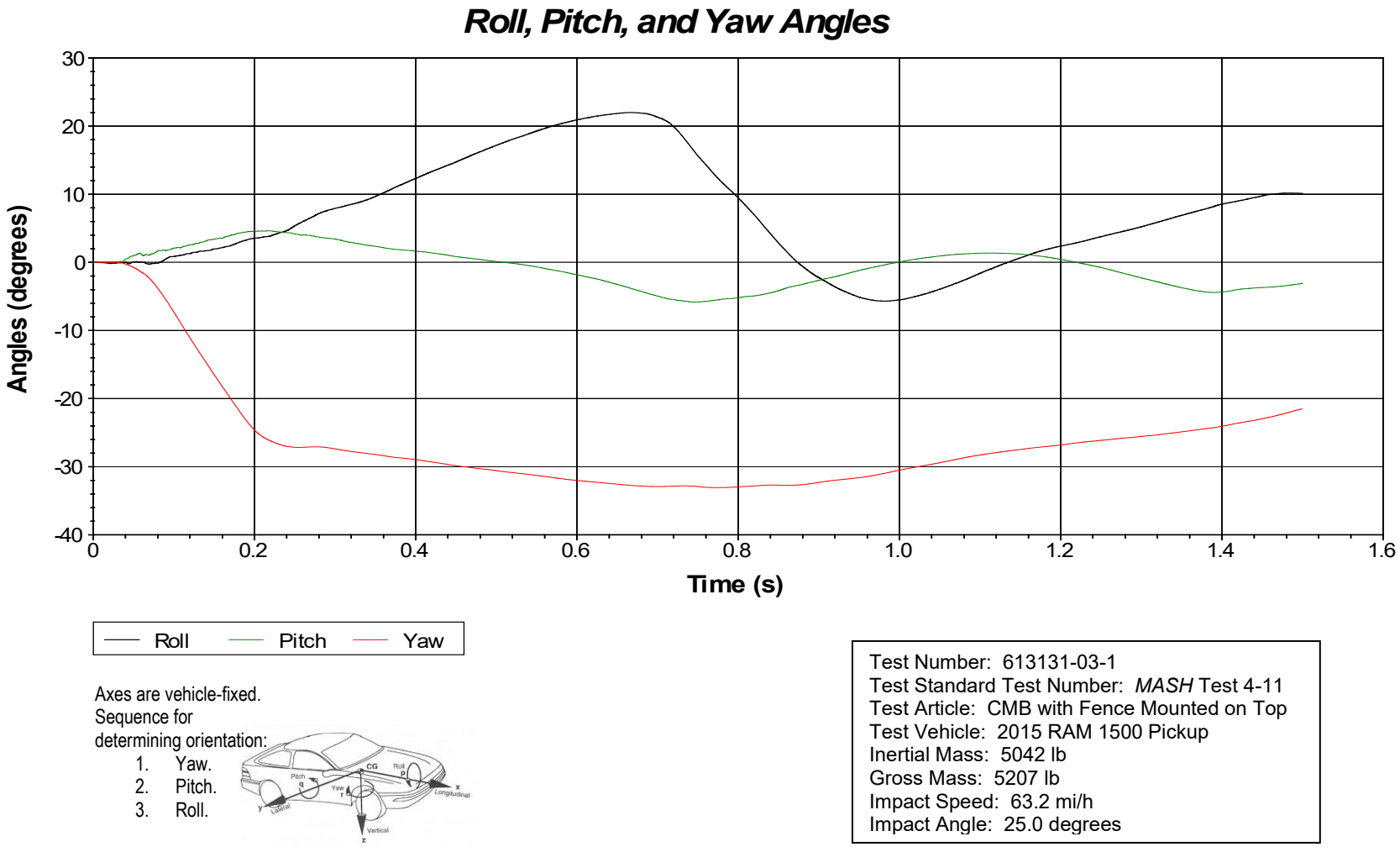


Figure C.3. Vehicle Angular Displacements for Test No. 613131-03-1.

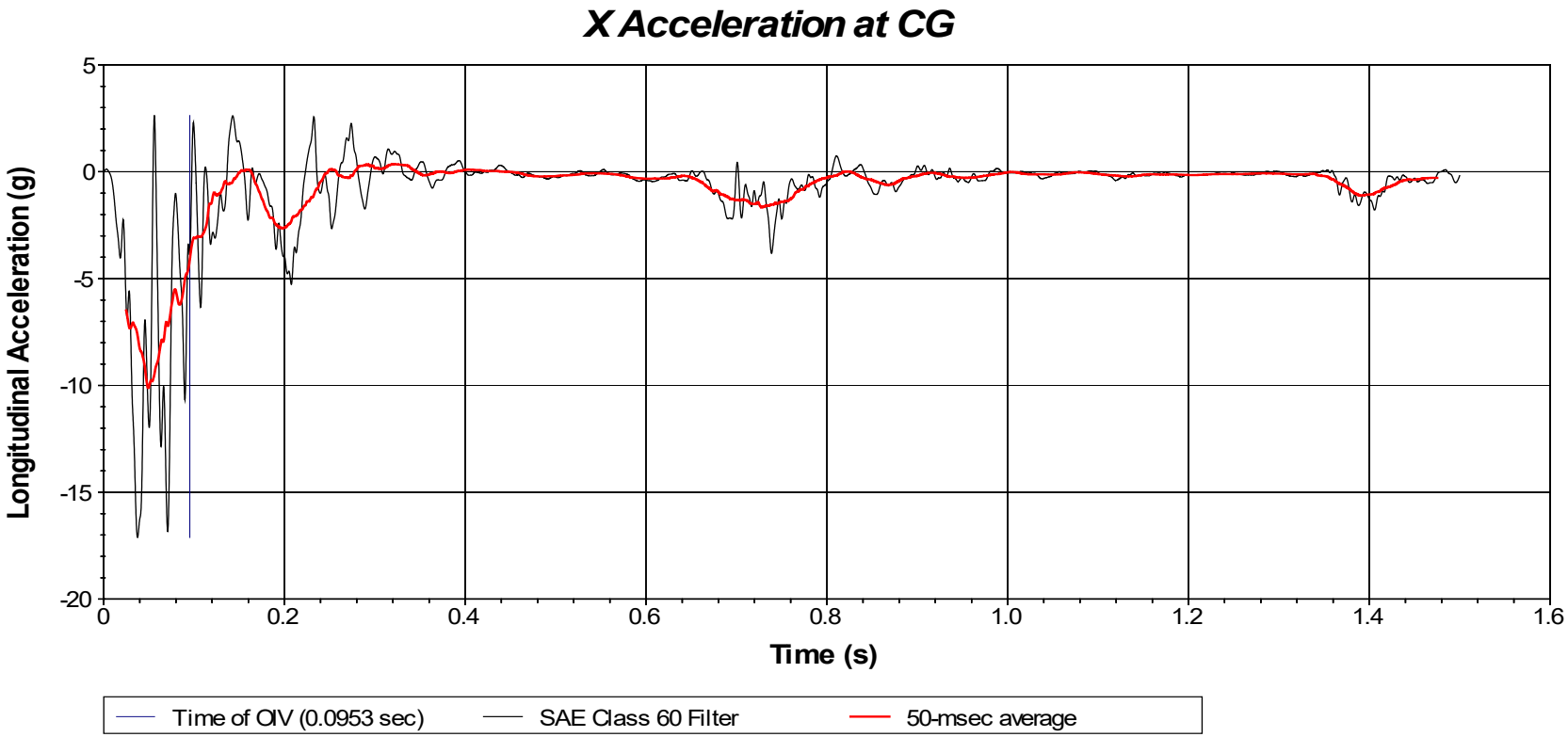


Figure C.4. Vehicle Longitudinal Accelerometer Trace for Test No. 613131-03-1 (Accelerometer Located at Center of Gravity).

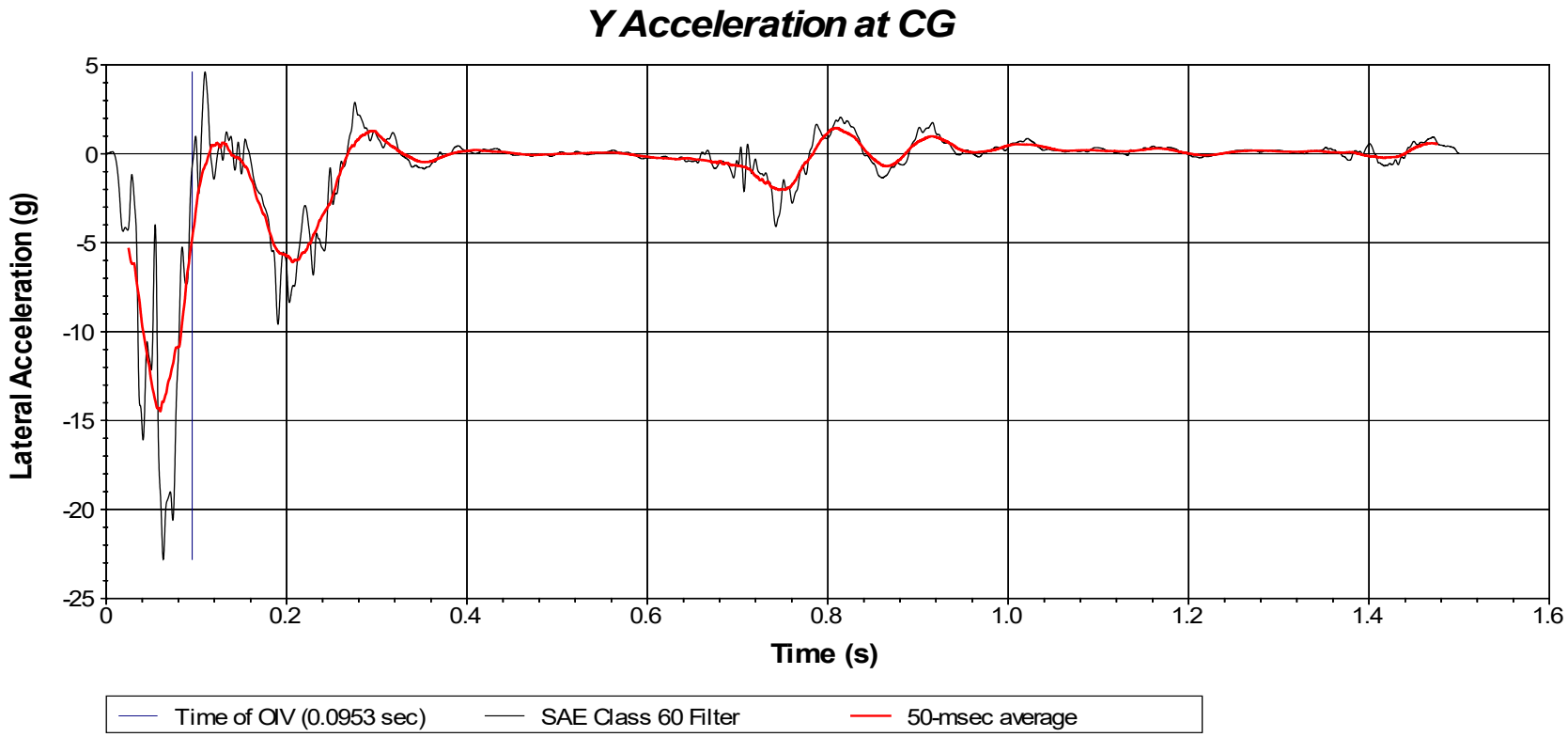


Figure C.5. Vehicle Lateral Accelerometer Trace for Test No. 613131-03-1 (Accelerometer Located at Center of Gravity).

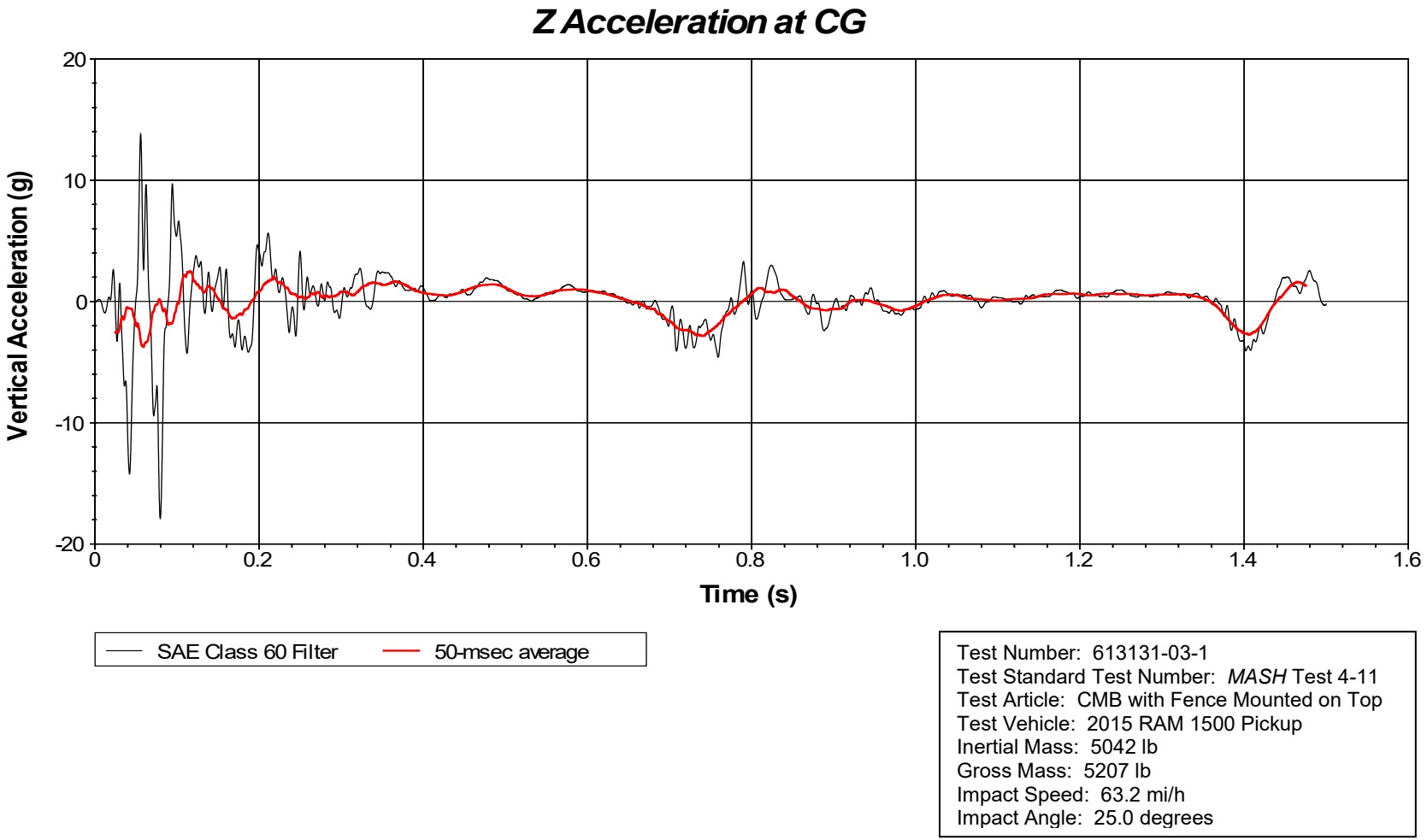
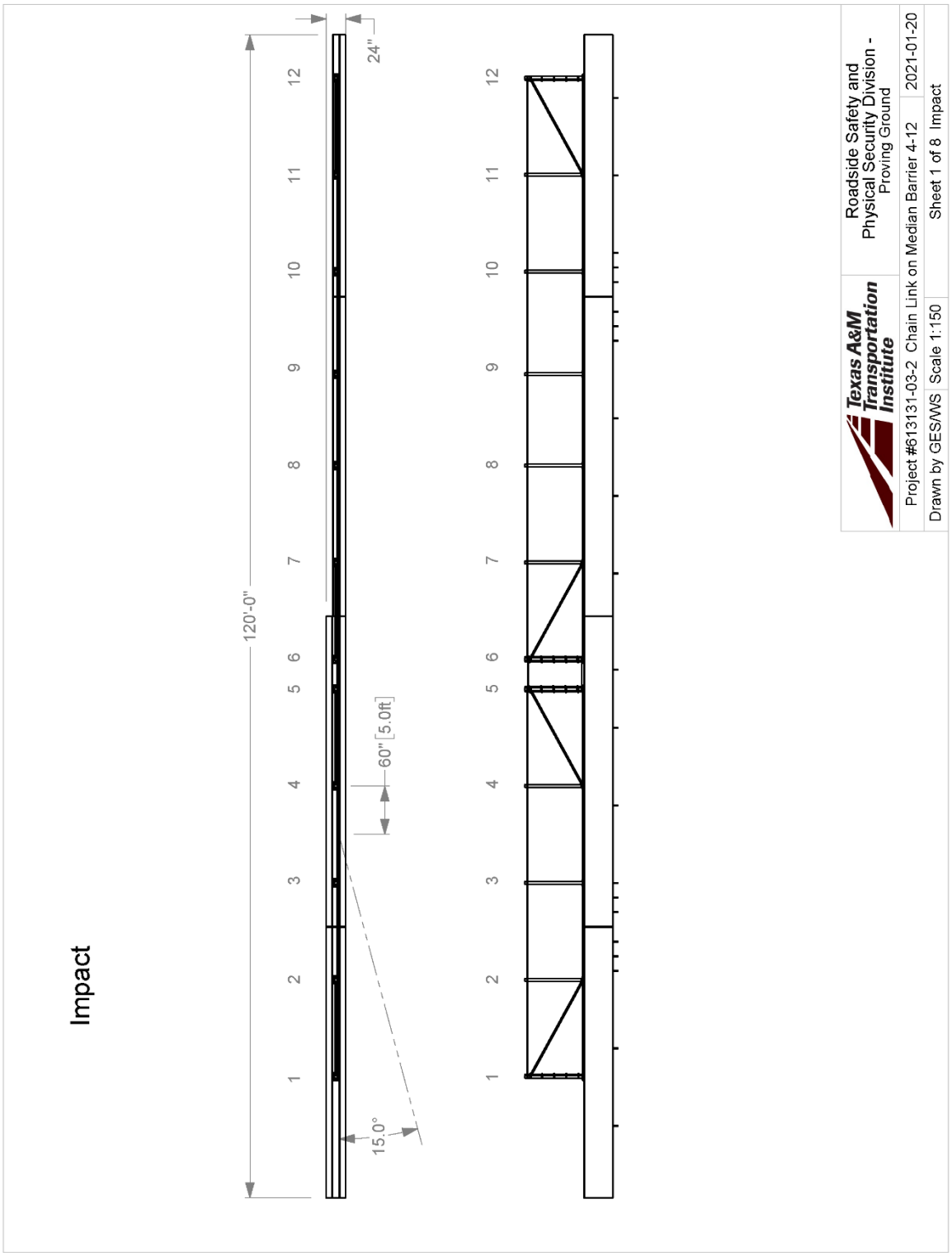


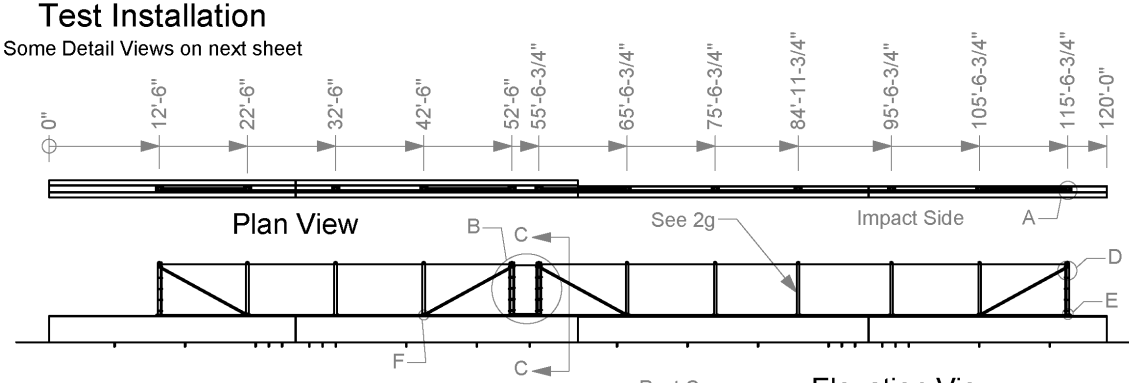
Figure C.6. Vehicle Vertical Accelerometer Trace for Test No. 613131-03-1 (Accelerometer Located at Center of Gravity).

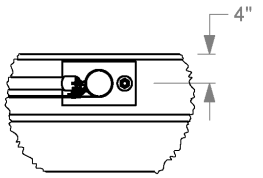
APPENDIX D. DETAILS OF CMB WITH FENCE MOUNTED ON TOP FOR TEST NO. 613131-03-2



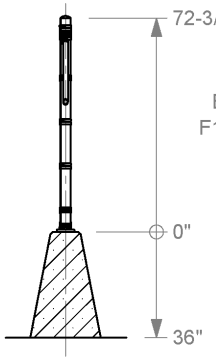
Test Installation

Some Detail Views on next sheet

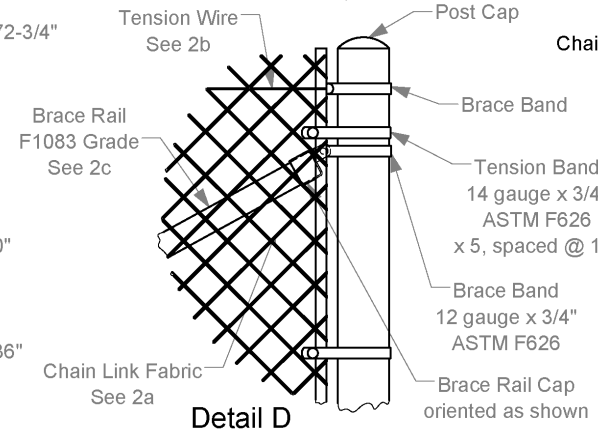




Detail A
Scale 1 : 20
See 2f

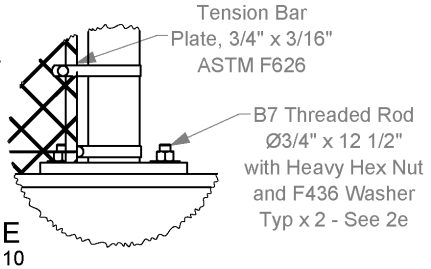


Section C-C
Scale 1 : 50
See 2f



Detail D
Scale 1 : 10

Elevation View
Chain Link not shown for clarity.



Detail E
Scale 1 : 10

2a. Chain Link Fabric is 2" mesh x 72", with twisted top and knuckled bottom selvage, 9 gauge steel wire, ASTM A392 with Class 2 Zinc coating. Chain link fabric stops at posts on each side of joint, and is placed on the impact side of the installation.

2b. Tension Wire is Type II 7 gauge, ASTM A824 and A817, with Class 4 zinc coating, typical at top and bottom. Position Tension Wires in center of diamonds in Chain Link as shown, or as close as possible. Secure Tension Wire to Brace Band bolt at each end. Secure Chain Link to Tension Wires at 24" spacing with 12 gauge zinc coated hog rings (ASTM F626). Secure Tension Wire to Line Posts with 9 gauge zinc coated wire (ASTM F626), with 3 wraps at each end of the wire.

2c. Brace Rail is galvanized 1-1/4 Schedule 40 steel pipe. Secure chain link fabric to Brace Rails with 9 gauge zinc coated wire (ASTM F626) at 24" spacing.

2d. All steel components, including purchased parts, hardware, and fabricated components, shall be galvanized.

2e. Secure B7 Threaded Rods with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 10-1/2" embedment.

2f. Posts are centered on Median Barrier parapet sections, and placed where indicated in Detail E for Single Slope Traffic Rail parapet sections. Chain link is on impact side for the entire installation.

2g. Secure chain link fabric to intermediate posts with 9 gauge zinc coated wire (ASTM F626) at 12" spacing. Typical at Posts 2 - 4 and 7 - 11.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-2 Chain Link on Median Barrier 4-12		2021-01-20
Drawn by GES/WS	Scale 1:200	Sheet 2 of 8 Test Installation

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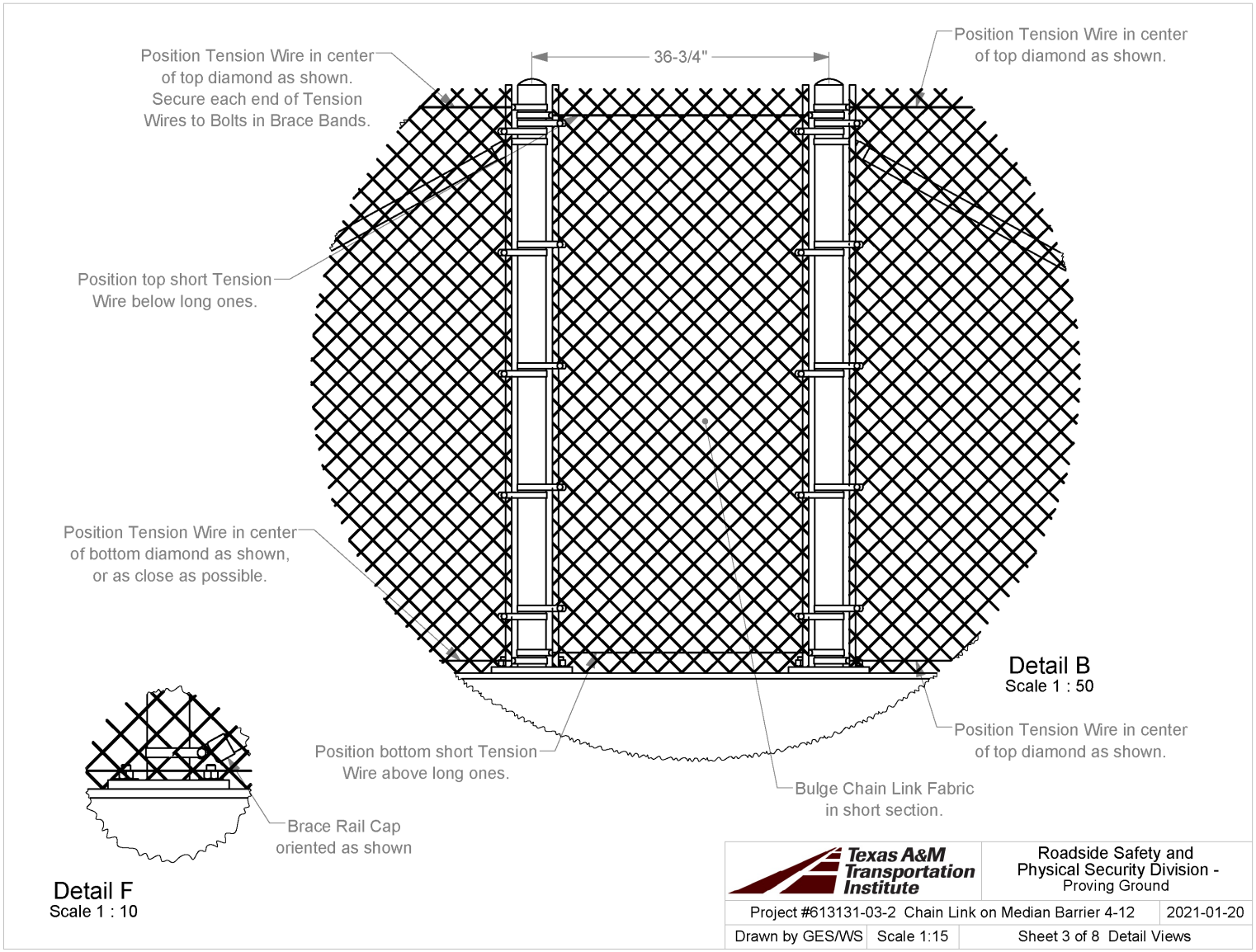

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-2 Chain Link on Median Barrier 4-12		2021-01-20
Drawn by GES/WS	Scale 1:15	Sheet 3 of 8 Detail Views

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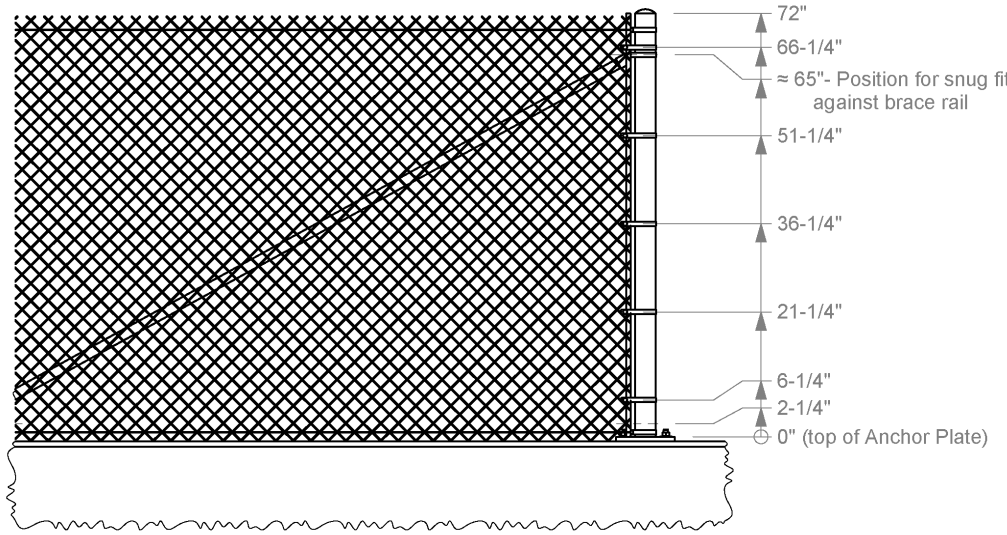
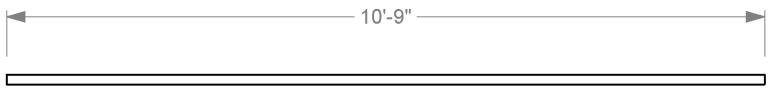
Anchor Post Details



Elevation View



Brace Rail

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-2 Chain Link on Median Barrier 4-12			2021-01-20
Drawn by GES/WS	Scale 1:25	Sheet 4 of 8 Anchor Post Details	

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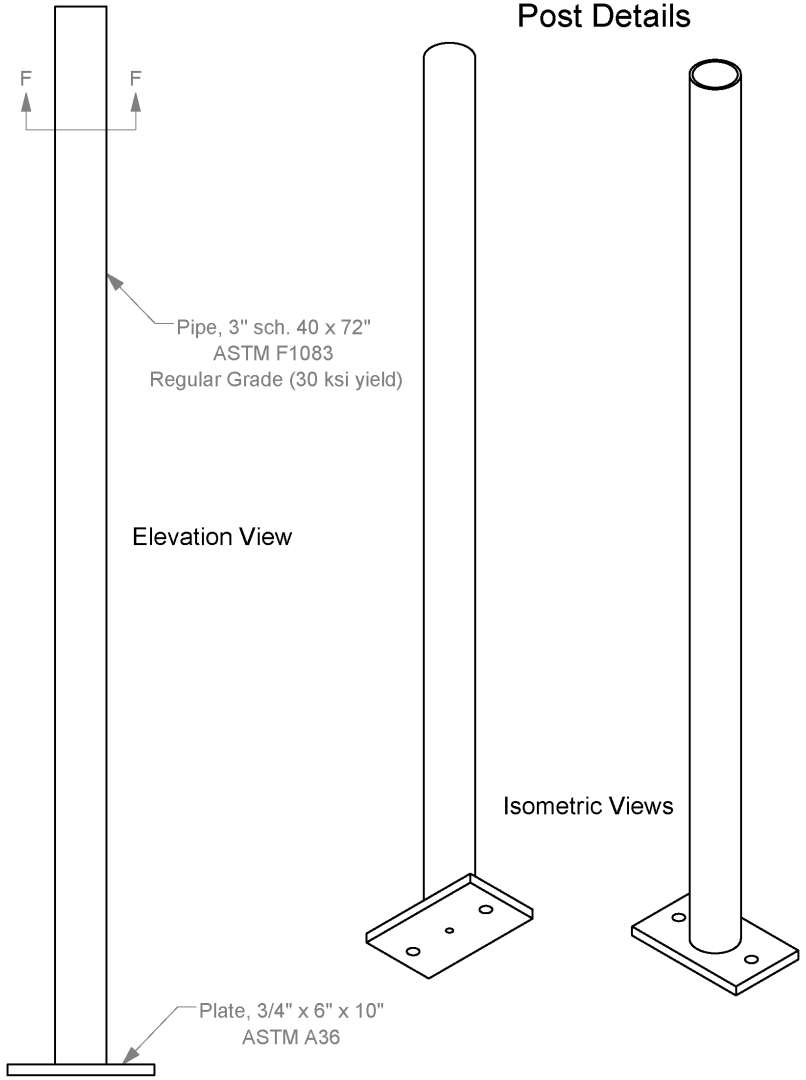
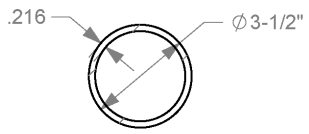
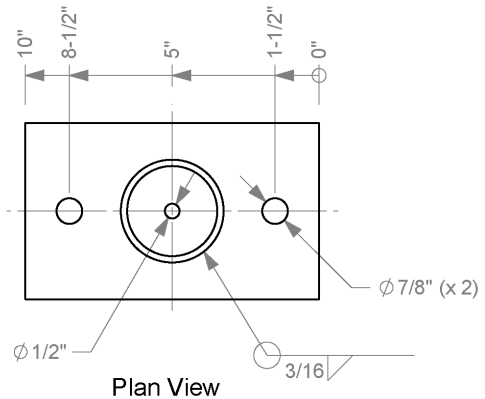
Post Details





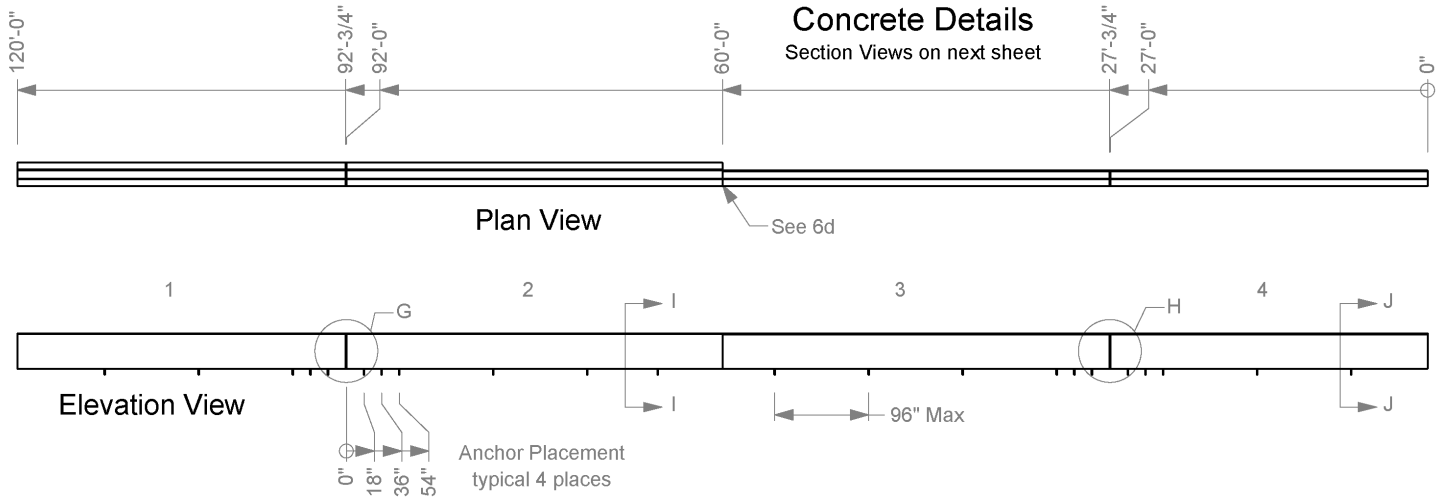
Section F-F
Scale 1 : 5

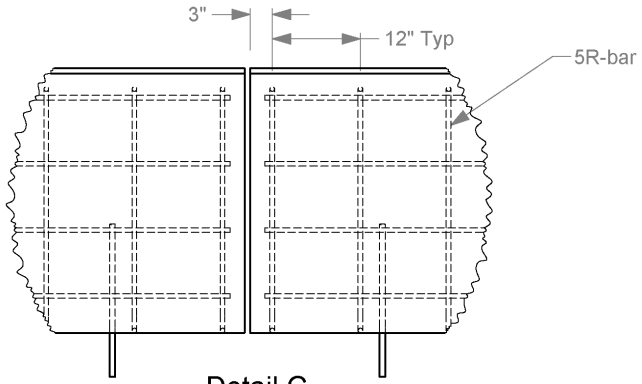


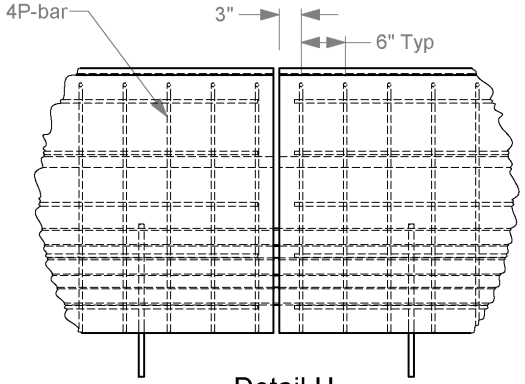
Plan View
Scale 1:5

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-2 Chain Link on Median Barrier 4-12		2021-01-20
Drawn by GES/WS	Scale 1:10	Sheet 5 of 8 Post Details

Q:\Accreditation-17025-2017\EIR-000 Project Files\613131-03 Fence on Median Barrier\-03-1&2\-03-2 (4-12)\Drafting, 613131-2\2021-01-19\613131-2 Drawing







6a. Concrete shall be 3400 psi. Chamfer top edges of Parapets 3/4".
6b. Rebar dimensions are to the centerline unless otherwise indicated by cvr (cover).
6c. Minimum rebar lap is 17" for **#4** bars and 21" for **#5** bars. All rebar is grade 60.
6d. Cold joint between profiles, with no space.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-2 Chain Link on Median Barrier 4-12		2021-01-20
Drawn by GES/WS	Scale 1:150	Sheet 6 of 8 Concrete Details

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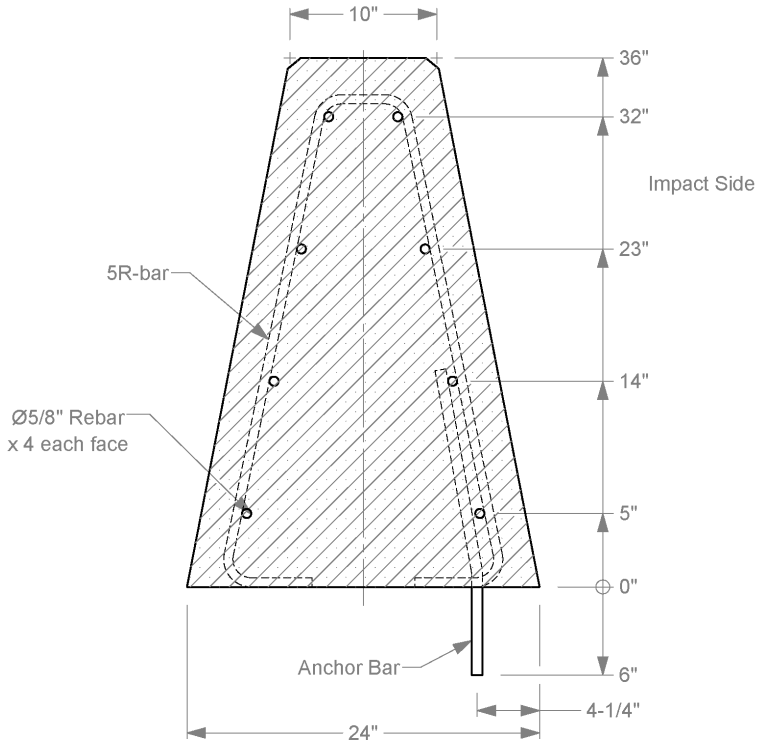
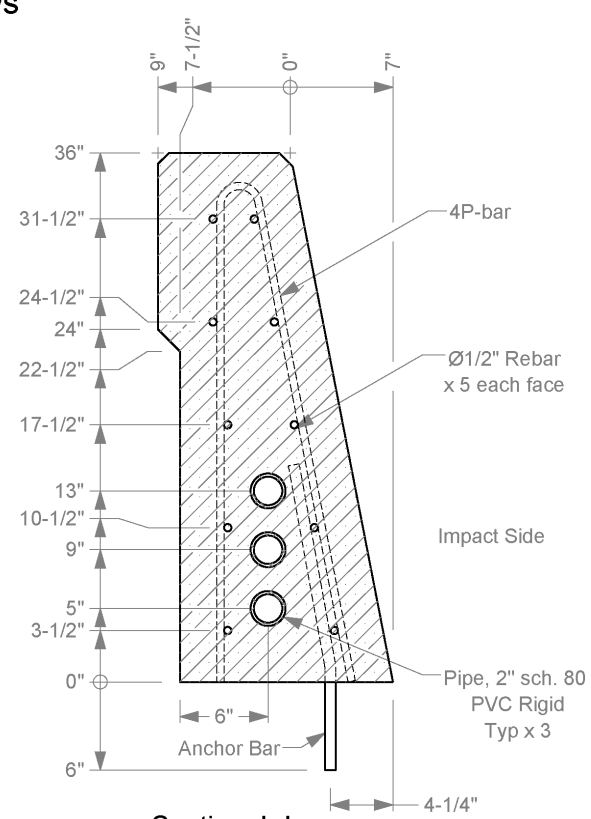
Parapet Section Views



Section I-I
Typ in Parapet Sections 1 and 2



Section J-J
Typ in Parapet Sections 3 and 4

7a. Concrete shall be 3400 psi. Chamfer top edges of Parapets 3/4".
7b. Rebar dimensions are to the centerline unless otherwise indicated by cvr (cover).
7c. Minimum rebar lap is 17" for **#4** bars and 21" for **#5** bars. All rebar is grade 60.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #613131-03-2 Chain Link on Median Barrier 4-12		2021-01-20
Drawn by GES/WS	Scale 1:10	Sheet 7 of 8 Parapet Section Views

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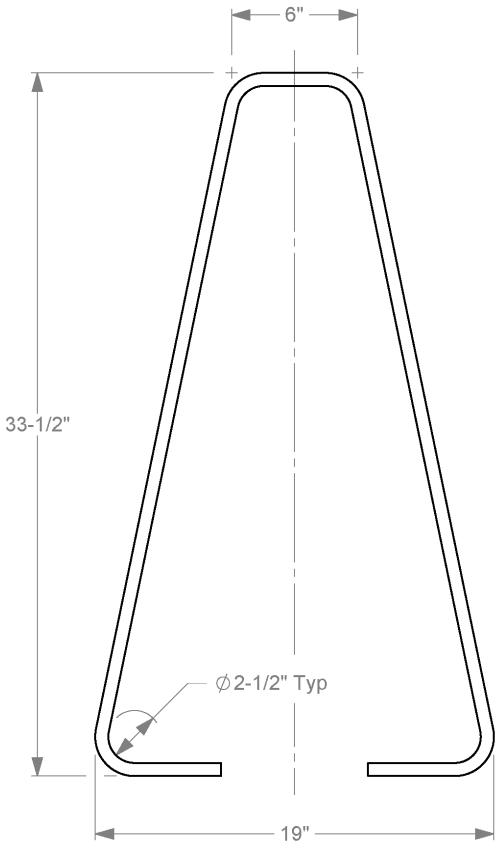
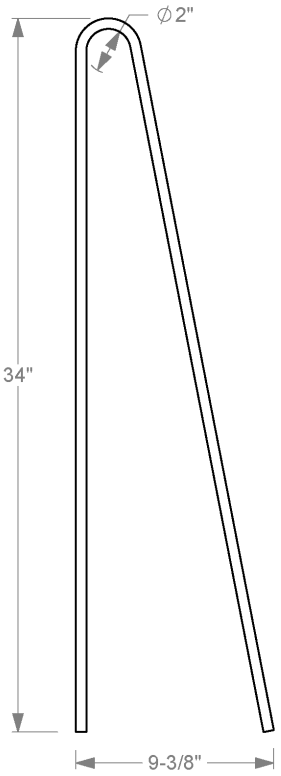
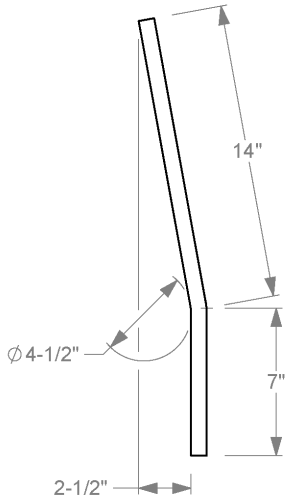
Rebar Details



5R-bar
Ø5/8" Grade 60 Rebar



4P-bar
Ø1/2" Grade 60 Rebar



Anchor Bar
Ø3/4" Grade 60 Rebar

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground
Project #613131-03-2 Chain Link on Median Barrier 4-12		2021-01-20
Drawn by GES/WS	Scale 1:7	Sheet 8 of 8 Rebar Details

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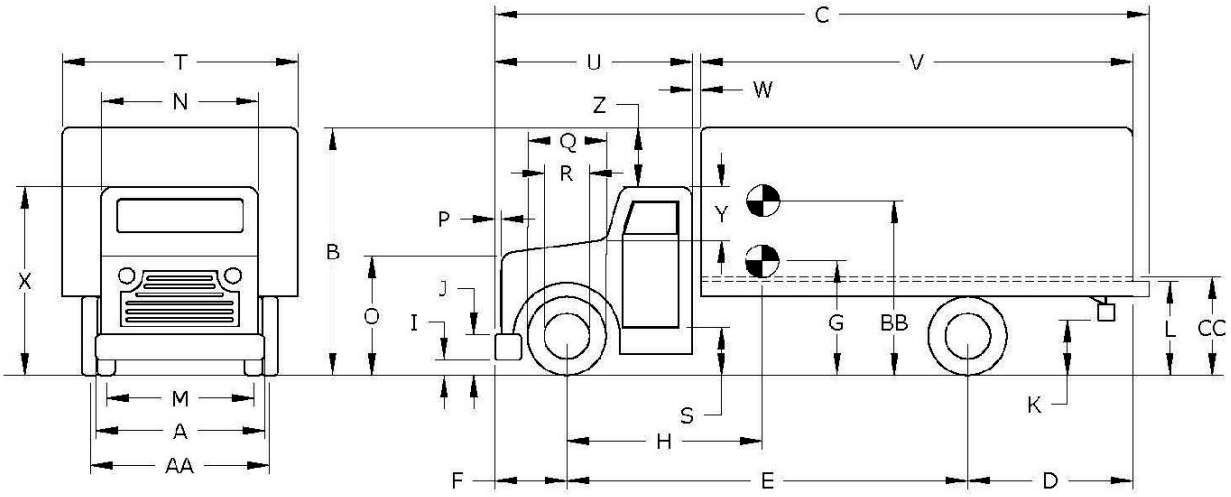
APPENDIX E. *MASH* TEST 4-12 (CRASH TEST NO. 613131-03-2)

E.1. VEHICLE PROPERTIES AND INFORMATION

Table E.1. Vehicle Properties for Test No. 613131-03-2.

Date:	2021-3-3	Test No.:	613131-3-2	VIN No.:	1HTMMAAN6CJ562234
Year:	2012	Make:	INTERNATIONAL	Model:	4300
Odometer:	193125	Tire Size Front:	275/80R22.5	Tire Size Rear:	275/80R22.5



Vehicle Geometry: ☐ inches or ☐ mm

A	Front Bumper Width:	92.50	K	Rear Bumper Bottom:		U	Cab Length:	106.00
B	Overall Height:	146.00	L	Rear Frame Top:	38.00	V	Trailer/Box Length:	222.00
C	Overall Length:	330.75	M	Front Track Width:	80.00	W	Gap Width:	2.00
D	Rear Overhang:	84.00	N	Roof Width:	71.00	X	Overall Front Height:	98.50
E	Wheel Base:	206.75	O	Hood Height:	59.00	Y	Roof-Hood Distance:	30.00
F	Front Overhang:	40.00	P	Bumper Extension:		Z	Roof-Box Height Difference:	47.50
G	C.G. Height:		Q	Front Tire Width:	39.00	AA	Rear Track Width:	73.00
H	C.G. Horizontal Dist. w/Ballast:	127.97	R	Front Wheel Width:	23.50	BB	Ballast Center of Mass:	61.75
I	Front Bumper Bottom:	18.25	S	Bottom Door Height:	37.00	CC	Cargo Bed Height:	49.00
J	Front Bumper Top:	33.25	T	Overall Width:	96.00			

Allowable Range: C = 394 inches max.; E = 240 inches max.; CC = 49 ±2 inches; BB = 63 ±2 inches above ground;

Wheel Center Height Front	19.00	Wheel Well Clearance (Front)	9.00	Bottom Frame Height (Front)	25.50
Wheel Center Height Rear	19.00	Wheel Well Clearance (Rear)	3.50	Bottom Frame Height (Rear)	27.50

More information needed on next page →

Table E.1. Vehicle Properties for Test No. 613131-03-2 (Continued).

Date: 2021-3-3 Test No.: 613131-3-2 VIN No.: 1HTMMAAN6CJ562234

Year: 2012 Make: INTERNATIONAL Model: 4300

WEIGHTS (☑ lb or ☐ kg)	CURB	TEST INERTIAL
$W_{front\ axle}$	7370	8630
$W_{rear\ axle}$	6940	14020
W_{TOTAL}	14310	22650

Allowable Range for CURB = 13,200 ±2200 lb | Allowable Range for TIM = 22,046 ±660 lb

Ballast: 8341 (☑ lb or ☐ kg) **(as-needed)**
(See *MASH* Section 4.2.1.2 for recommended ballasting)

Mass Distribution (☑ lb or ☐ kg): **LF:** 4280 **RF:** 4350 **LR:** 7100 **RR:** 6920

Engine Type: DT

Engine Size: 466

Transmission Type:

☐ Auto or ☑ Manual

☐ FWD ☑ RWD ☐ 4WD

Accelerometer Locations (☑ inches or ☐ mm)

	x[1]	y	z[2]
Front:			
Center:	128.00	0.00	48.50
Rear:	228.00	0.00	48.50

Describe any damage to the vehicle prior to test: NONE

Other notes to include ballast type, dimensions, mass, location, center of mass, and method of attachment:

Two blocks: 30 inches high x 60 inches wide x 30 inches long

Centered in middle of bed

61.75 inches from ground to center of block

Tied down with four 3/8-inch diameter cables per block

Performed by: SCD **Date:** 2021-3-3

[1] Referenced to the front axle
[2] Above ground

E.2. SEQUENTIAL PHOTOGRAPHS

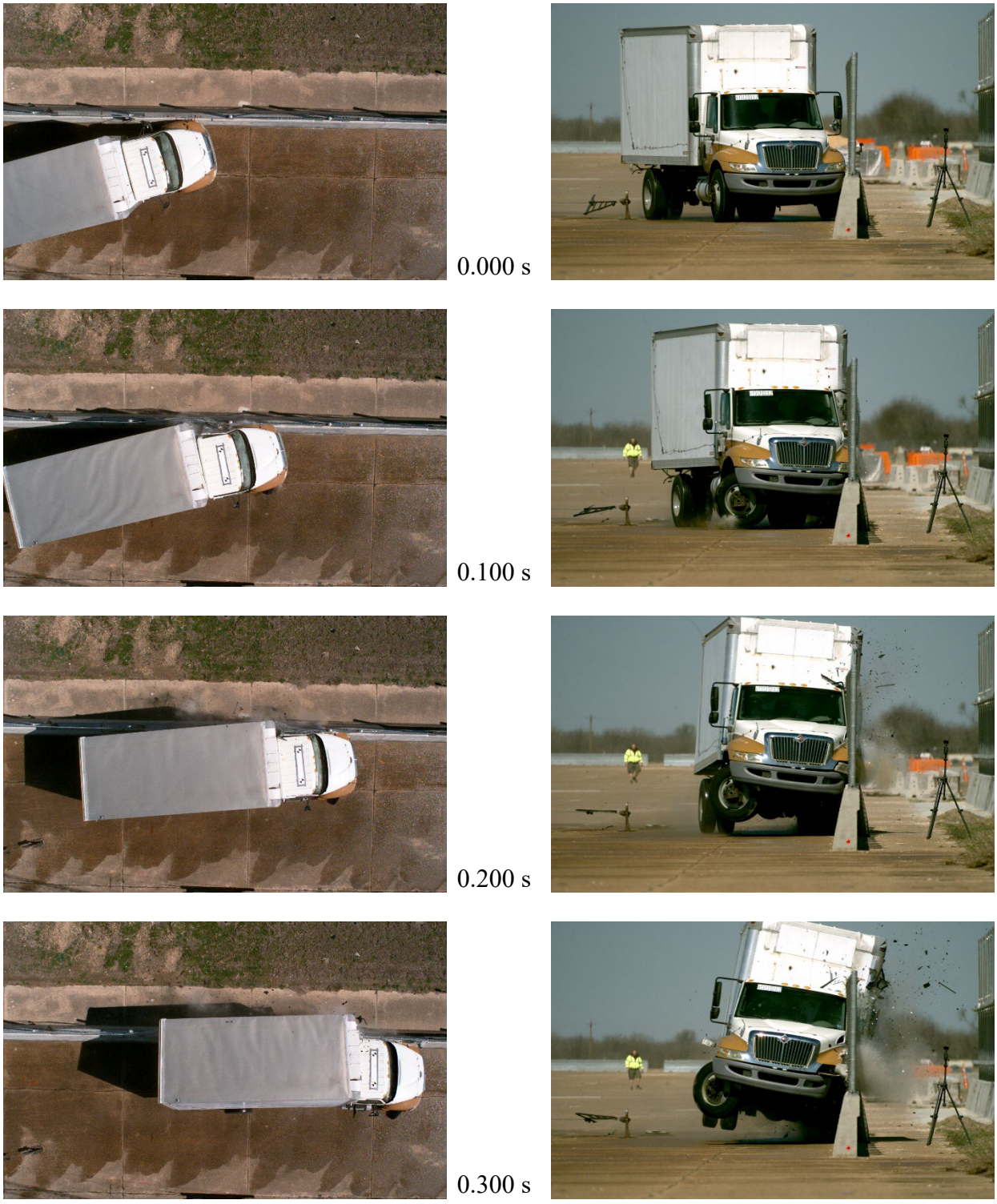
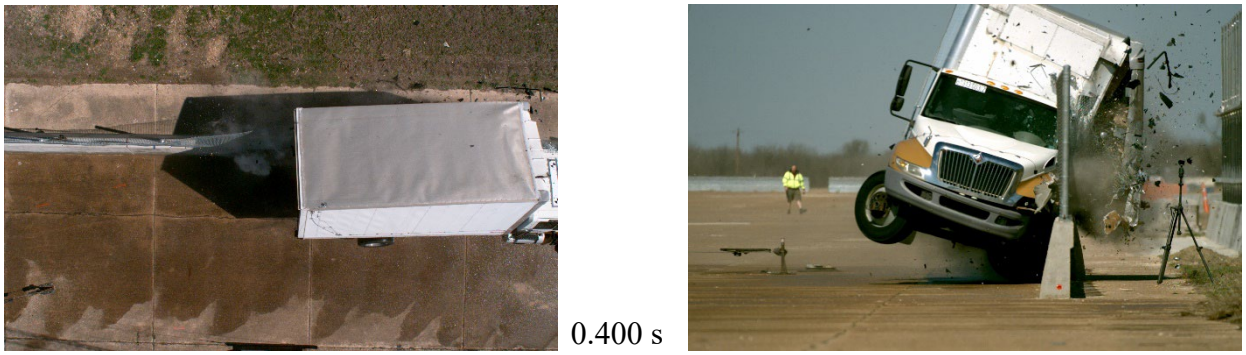
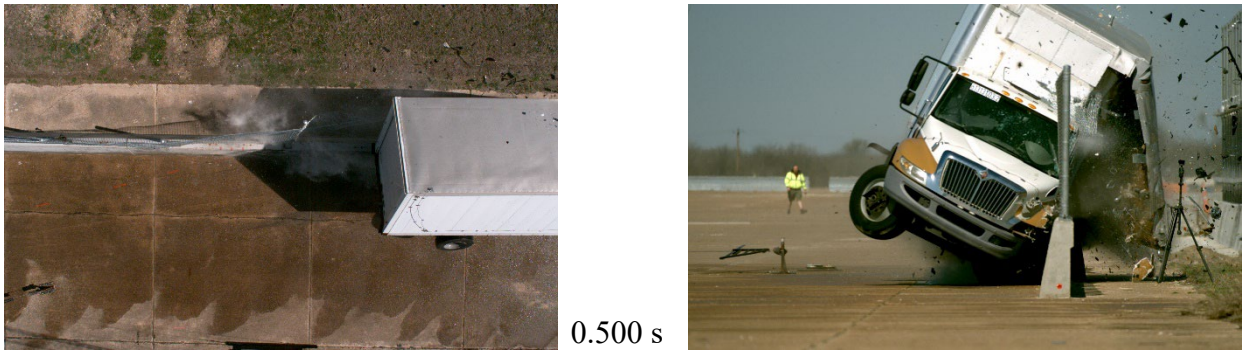
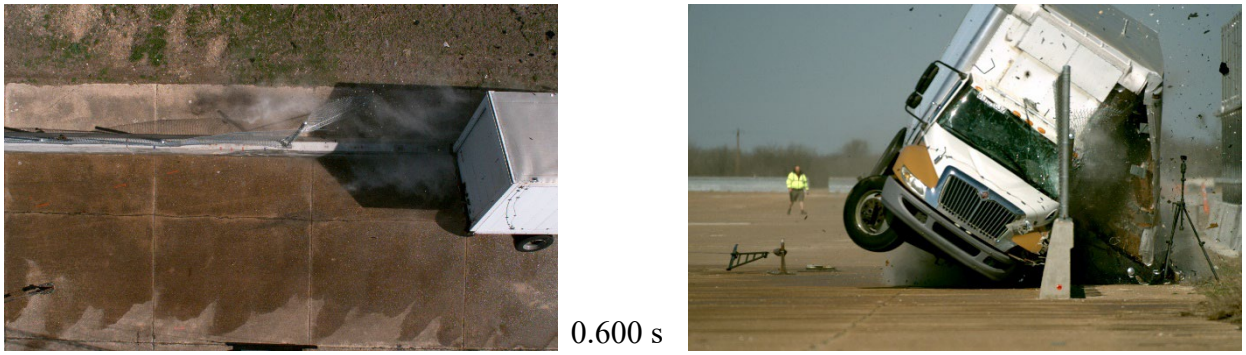


Figure E.1. Sequential Photographs for Test No. 613131-03-2 (Overhead and Frontal Views).


0.400 s


0.500 s


0.600 s

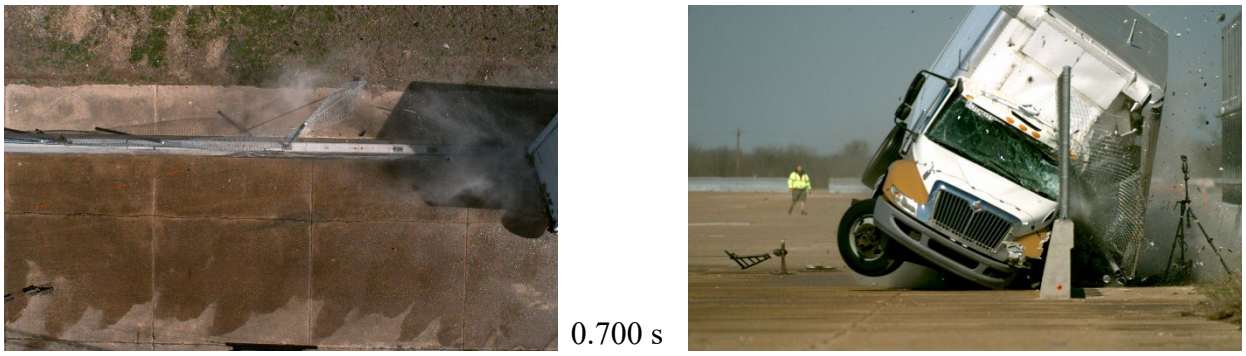

0.700 s

Figure E.1. Sequential Photographs for Test No. 613131-03-2 (Overhead and Frontal Views) (Continued).


0.000 s


0.400 s


0.100 s


0.500 s

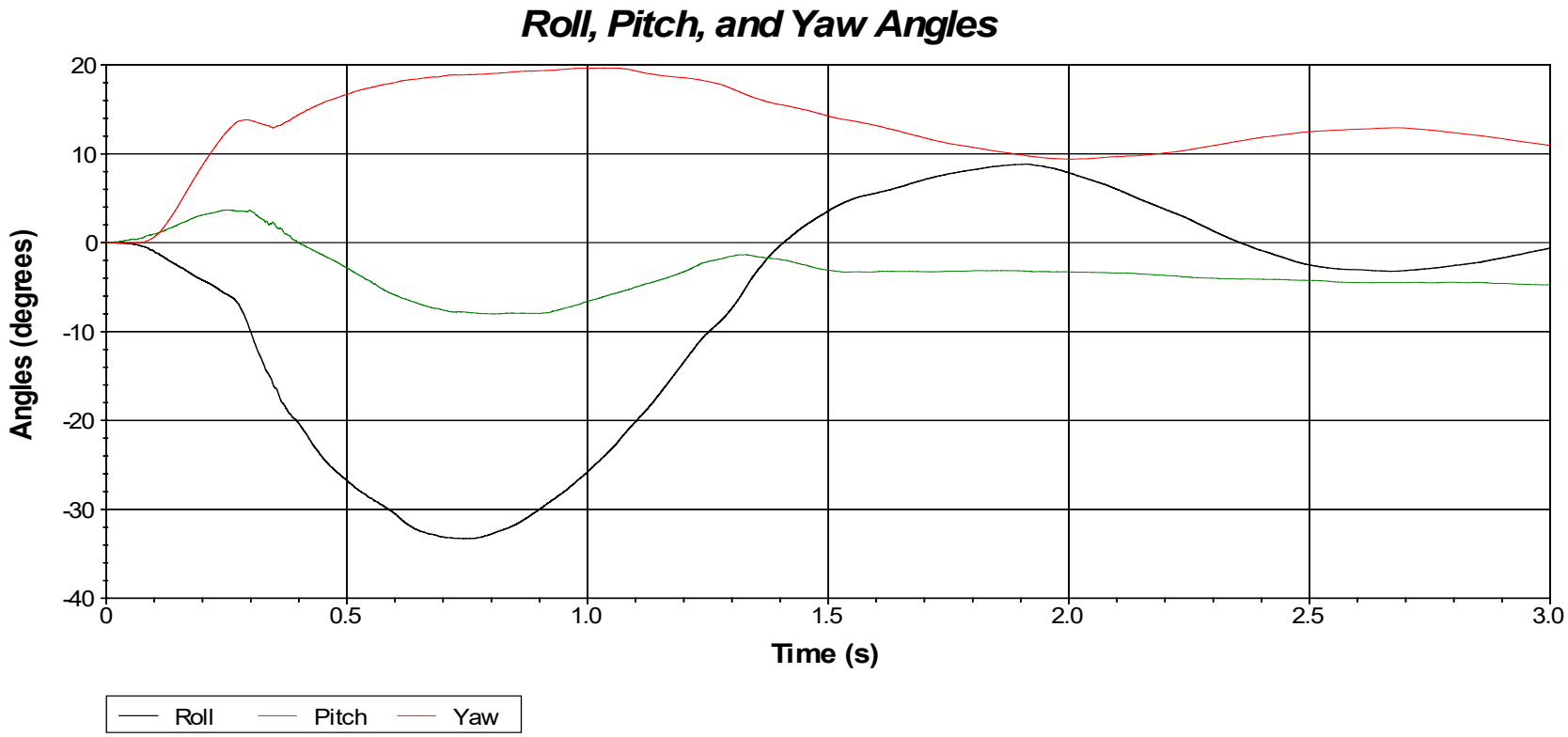

0.200 s


0.600 s


0.300 s

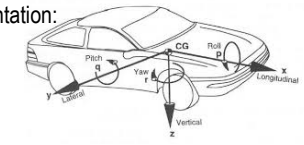

0.700 s

Figure E.2. Sequential Photographs for Test No. 613131-03-2 (Rear View).



Axes are vehicle-fixed.
Sequence for
determining orientation:

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



Test Number: 613131-03-2
Test Standard Test Number: *MASH* Test 4-12
Test Article: CMB with fence mounted on top
Test Vehicle: 2012 International 4300 SUT
Inertial Mass: 22,650 lb
Gross Mass: 22,650 lb
Impact Speed: 55.9 mi/h
Impact Angle: 15.0°

Figure E.3. Vehicle Angular Displacements for Test No. 613131-03-2.

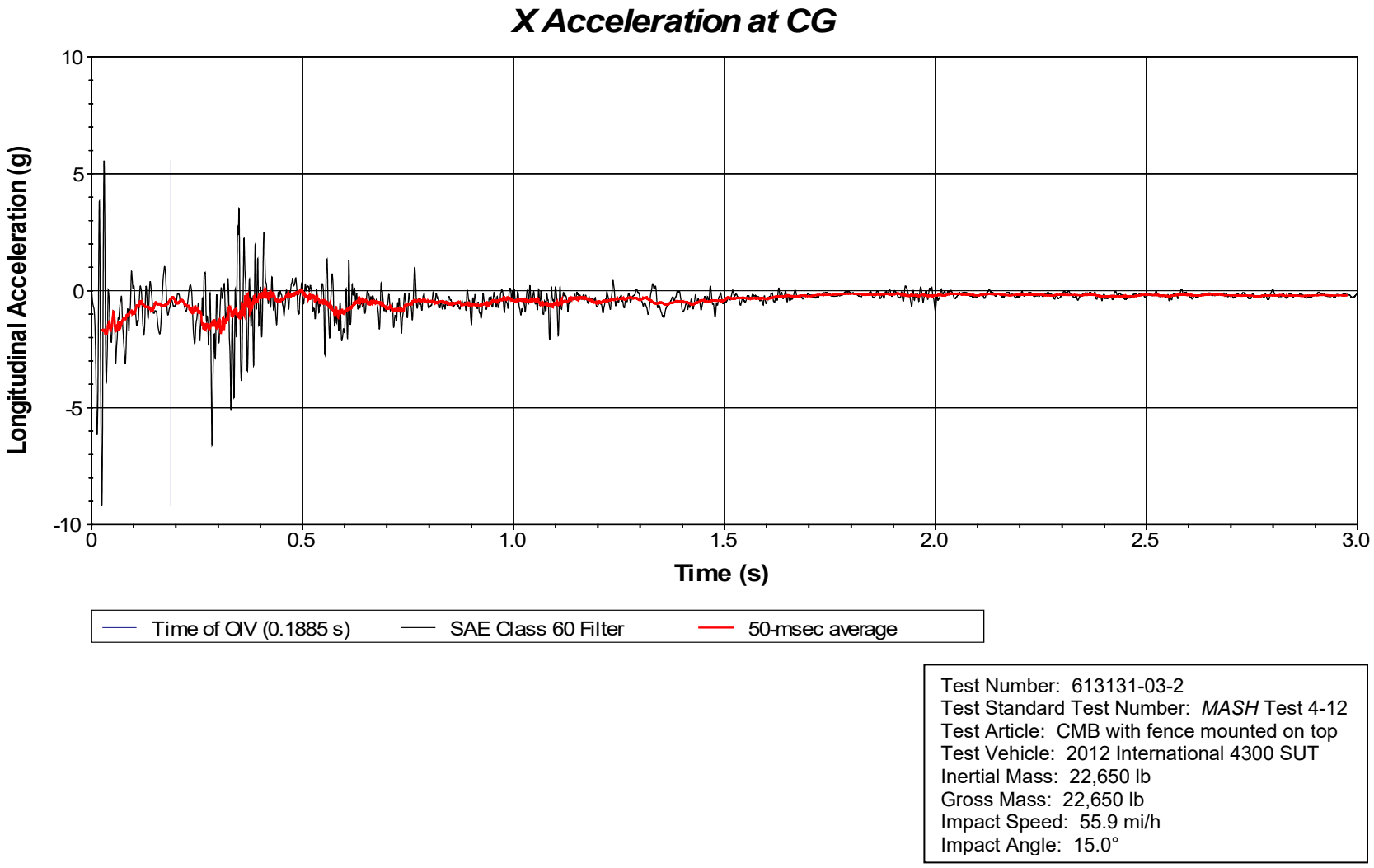


Figure E.4. Vehicle Longitudinal Accelerometer Trace for Test No. 613131-03-2 (Accelerometer Located at Center of Gravity).

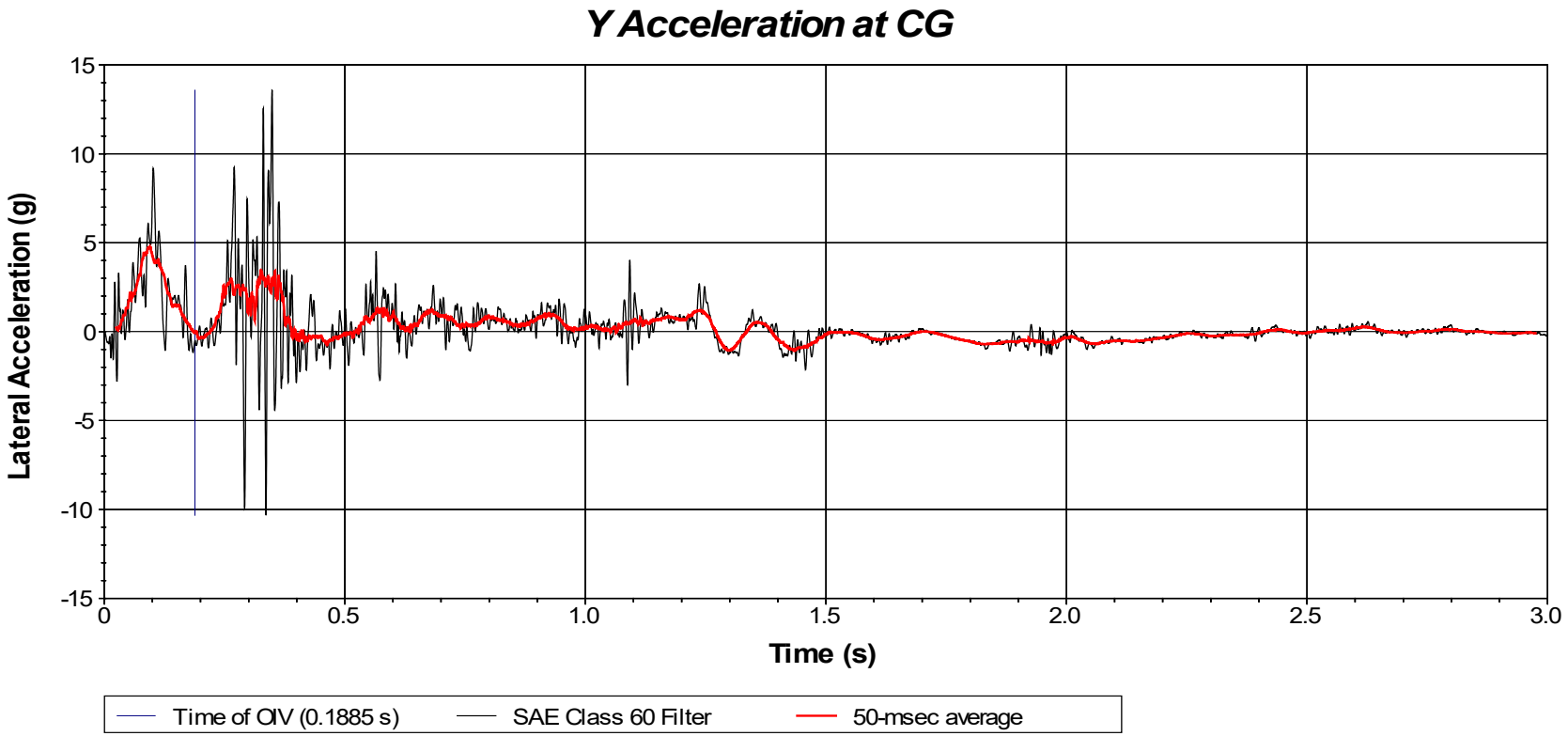


Figure E.5. Vehicle Lateral Accelerometer Trace for Test No. 613131-03-2 (Accelerometer Located at Center of Gravity).

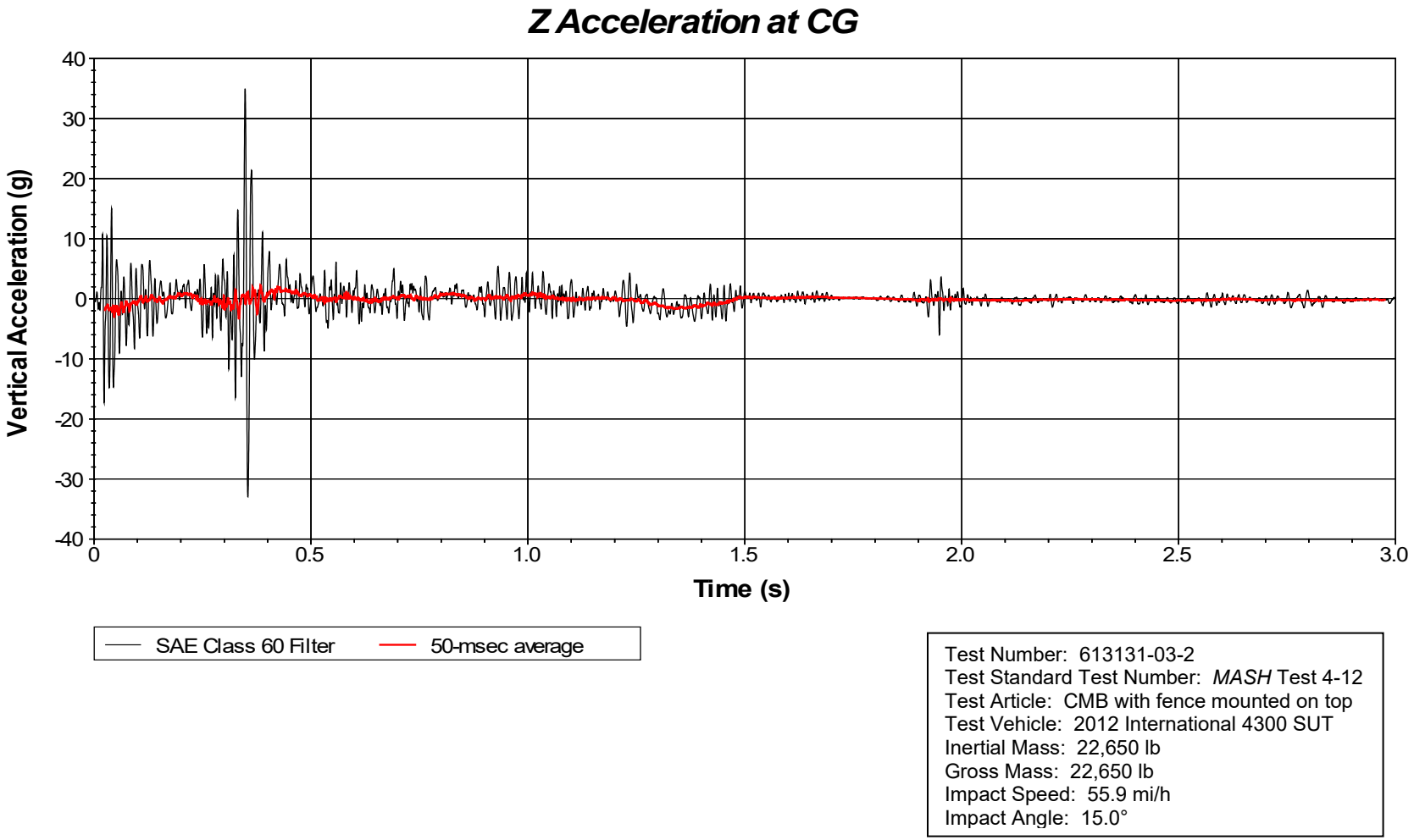


Figure E.6. Vehicle Vertical Accelerometer Trace for Test No. 613131-03-2 (Accelerometer Located at Center of Gravity).

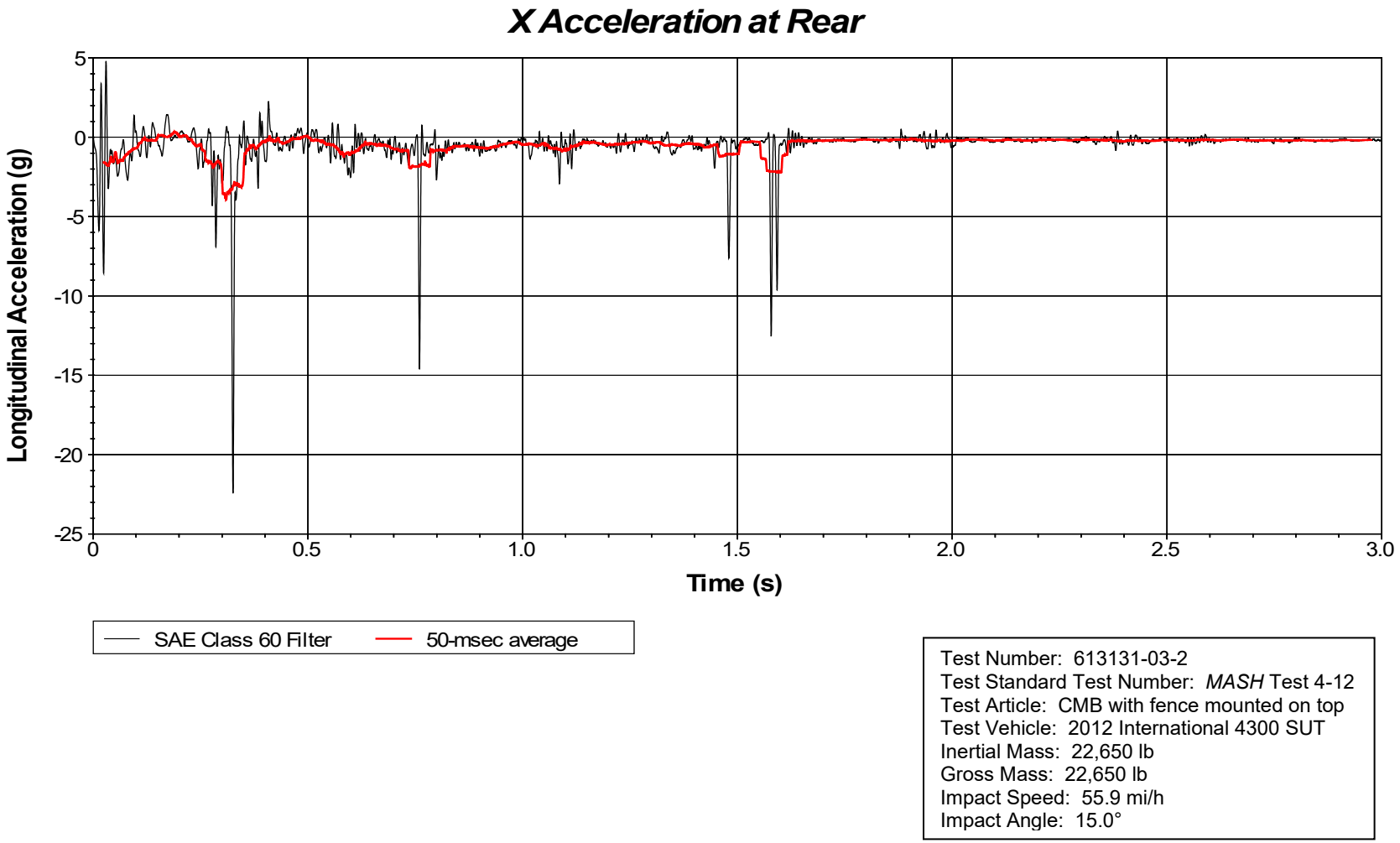


Figure E.7. Vehicle Longitudinal Accelerometer Trace for Test No. 613131-03-2 (Accelerometer Located at Rear of Vehicle).

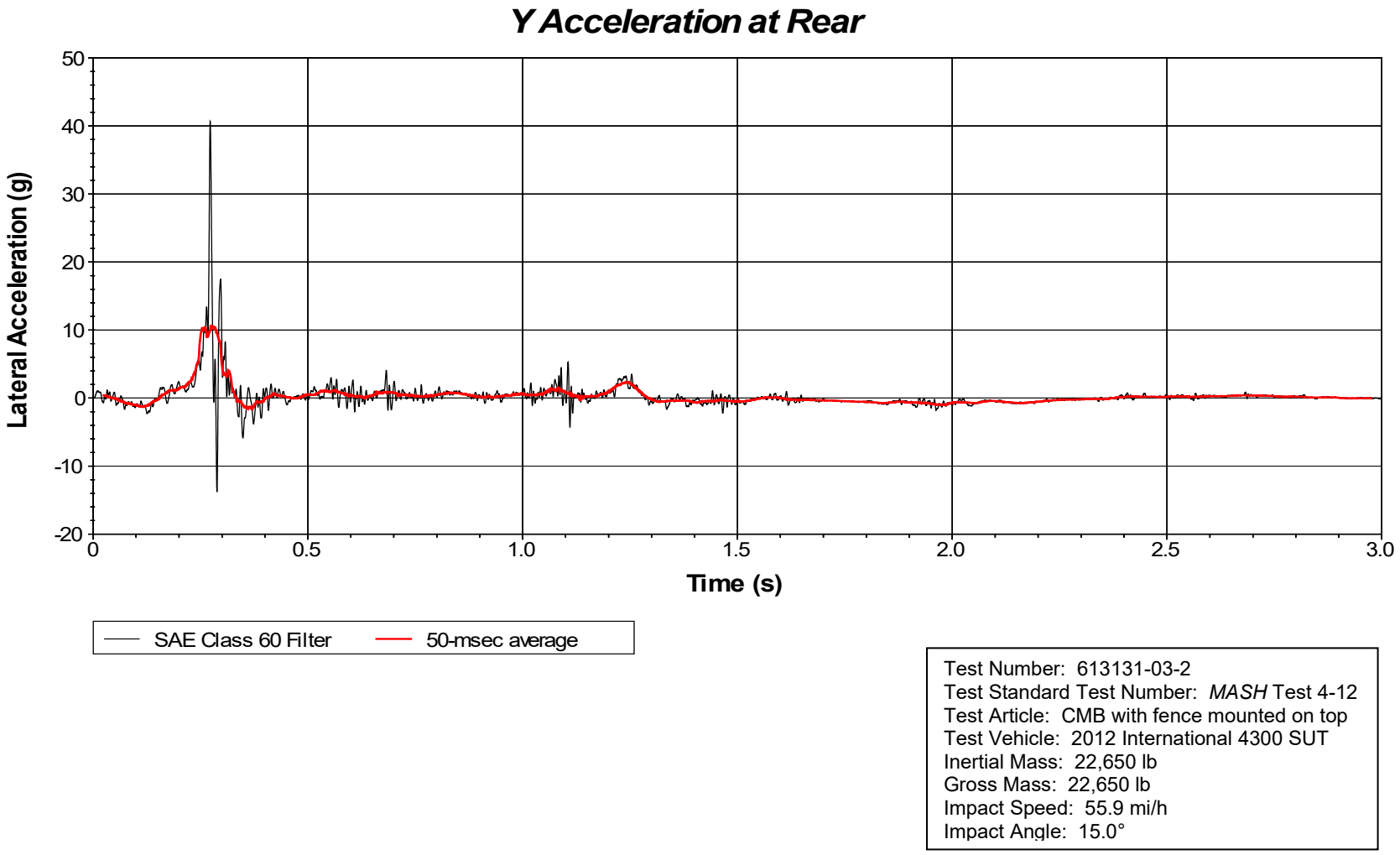


Figure E.8. Vehicle Lateral Accelerometer Trace for Test No. 613131-03-2 (Accelerometer Located at Rear of Vehicle).

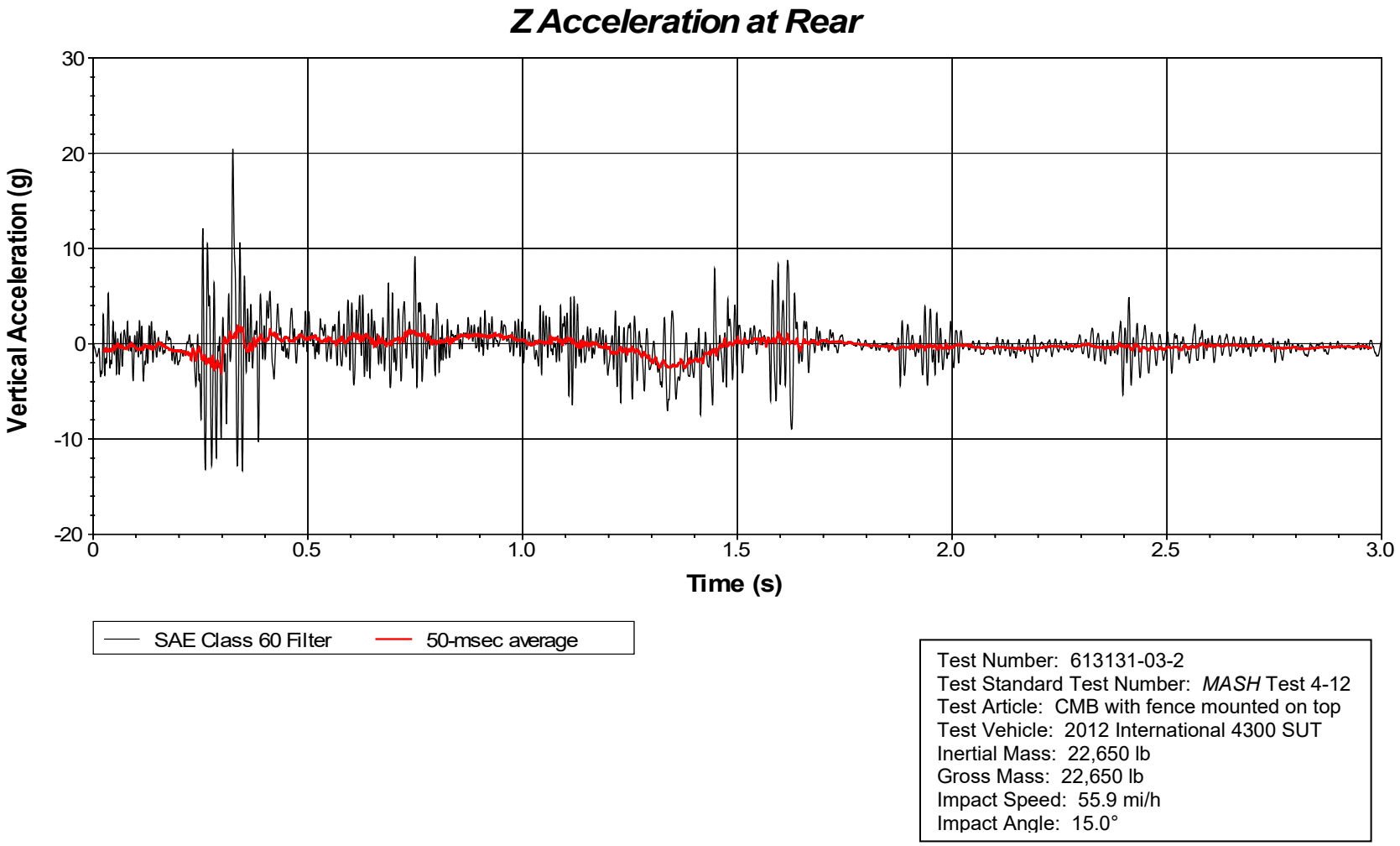


Figure E.9. Vehicle Vertical Accelerometer Trace for Test No. 613131-03-2 (Accelerometer Located at Rear of Vehicle).