Texas A&M Transportation Institute
Proving Ground

Test Report No.: 510602-JJH9
Test Report Date: August 2012

MASH TEST 3-11 ON THE EASI-SET® INDUSTRIES J-J HOOKS/*MASH* PROPRIETARY BOLT-DOWN BARRIER SYSTEM

by

Roger P. Bligh, P.E.
Research Engineer

and

Wanda L. Menges
Research Specialist

Contract No.: P2012310
Test No.: 510602-JJH9
Test Date: 2012-06-05

Sponsored by
EASI-SET® Industries

TEXAS A&M TRANSPORTATION INSTITUTE PROVING GROUND

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

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

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

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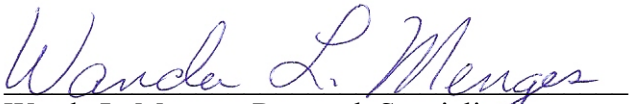
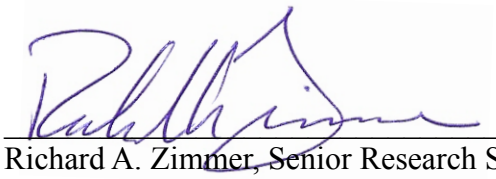


Wanda L. Menges, Research Specialist
Deputy Quality Manager



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

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16. Abstract

The purpose of the crash test reported herein was to assess the impact performance of the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system. The testing was performed in accordance with the safety-performance evaluation guidelines contained in the American Association of State Highway Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware (MASH)*. The crash test conditions conformed to *MASH* Test 3-11, which involves the 2270P vehicle (a 5000 lb (1/2-ton) Quad Cab Pickup) impacting the barrier at a speed of 62.2 mi/h and an angle of 25 degrees.

The EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system contained and redirected the 2270P. The vehicle did not penetrate, underride, or override the barrier. Maximum permanent deformation of the barrier was 4.0 inches. Maximum dynamic deflection during the test was 5.9 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment or to present hazard to others in the area. Maximum occupant compartment deformation was 0.5 inch along the left lateral area across the cab between the kickpanels on either side of the cab near the driver's feet. The 2270P vehicle remained upright during and after the collision period. Maximum roll and pitch angles were 36 degrees and 14 degrees, respectively. Occupant risk factors were within the preferred limits recommended in *MASH*. The 2270P vehicle exited within the exit box.

The EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system met all requirements for *MASH* test 3-11.

17. Key Words	18. Distribution Statement
Longitudinal barriers, portable concrete barriers, PCB, concrete median barriers, CMB, roadside safety, crash testing	

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Unclassified	Unclassified	58	

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

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

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

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1. INTRODUCTION

1.1 BACKGROUND

Portable concrete barriers (PCBs) are often used to provide positive protection for motorists and workers in a highway work zone. A buffer space is typically required behind a work zone barrier to accommodate barrier deflection and provide the needed separation between vehicles and workers or potential hazards in the work activity area.

Many highway work zones are restricted in terms of available lateral space for accommodating traffic and the work activity. When the work zone is so restrictive that lateral displacement of the work zone barrier cannot be tolerated, the movement of the barrier must be limited by pinning, staking, or otherwise tying the barrier to the deck, pavement or soil.

1.2 OBJECTIVES/SCOPE OF RESEARCH

The purpose of the crash test reported herein was to assess the impact performance of the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system. The testing was performed in accordance with the safety-performance evaluation guidelines contained in the American Association of State Highway Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware (MASH)*. The crash test conditions conformed to *MASH* Test 3-11, which involves the 2270P vehicle (a 5000 lb (1/2-ton) Quad Cab Pickup) impacting the barrier at a speed of 62.2 mi/h and an angle of 25 degrees.

2. SYSTEM DETAILS

2.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The precast segments used to construct the test installation were 12 ft-6 inches in length and had a standard F-shape profile. The barrier segments were 32 inches in height, 22½ inches wide at the base, and 8 inches wide at the top.

Longitudinal barrier reinforcement consisted of six #4 bars that were spaced symmetrically about the vertical axis of the barrier approximately 2¼ inches, 14⅜ inches, and 24⅜ inches from the top of the barrier. Vertical barrier reinforcement consisted of nine #4 bars. These vertical bars were closed stirrups bent to conform to the F-shape barrier profile.

Connector plates were cast into the ends of the concrete barrier segments. The ends of the 18 inch long, ⅜-inch thick steel connector plates were fabricated with a 180-degree hook with a 1½-inch return. A 2-inch × 2-inch × 3/16-inch steel angle was welded to the connector plate to form an internal pocket in the concrete barrier segment to accept the connector plate from the adjacent barrier segment. Four 30-inch long, #5 weldable steel rebars were welded to the connector plates to anchor them into the concrete.

A patented 3-inch × 3-inch × 3/8-inch steel deflection limiter plate was cast into each of the four corners of the barrier segments. An 18-inch long piece of #3 rebar was welded to the center of the plate to anchor it into the barrier segment.

Three vertical holes were cast into the toe of the barrier on each side of the barrier segment. The 2¼-inch diameter holes were located 24 inches from each end and in the center of the barrier segment. A 17-inch long, #4 U-bar was used to reinforce the barrier at each hole location. Additionally, a 4-inch wide × ½-inch thick steel strap (referred to as a bolt-down bar) provided additional reinforcement around the holes at the barrier ends. The strap was placed in a horizontal plane at the top of the holes and extended through the barrier cross section. A pocket or cutout was formed in the barrier concrete above each hole to provide a horizontal surface against which the anchor bolts could be tightened. The J-J Hooks/*MASH* barrier sections were fabricated by EASI-SET® Industries.

Nine barrier sections were connected to one another atop a reinforced concrete slab. Each barrier section was then anchored to the concrete slab using two 1-inch diameter, 10-inch long anchor bolts. The anchor bolts were installed at the hole locations nearest the barrier ends that were reinforced with the steel strap. They were threaded into 6-inch long anchor sleeves installed in the concrete slab using Hilti HIT-HY 200R adhesive. A 3-inch × 3-inch × ⅜-inch plate washer and 3-inch × 2½-inch × ⅛-inch retainer ring were placed under the head of the anchor bolt. A tab on the retainer ring was bent up against the head of the anchor bolt to prevent rotation. The Hilti Custom Inserts were installed by Hilti personnel. The holes for the inserts were cleaned following Hilti installation instructions. The cleaning procedure included blowing the holes out two times using compressed air, brushing the hole two times using a steel brush matched to the hole diameter, and blowing the hole out twice more using compressed air. A

piston plug was used to inject the Hilti HIT-HY-200R adhesive into the holes prior to installation of the inserts. After curing of the adhesive, the anchor bolts were tightened by TTI personnel and inspected by Hilti.

Additional details of the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system are shown in figure 2.1 and appendix A. Photographs of the completed test installation are shown in figure 2.2.

2.2 DESIGN MODIFICATIONS DURING TEST

There were no design modifications made during the test.

2.3 MATERIAL SPECIFICATIONS

The rebar used to anchor the connector plates inside the concrete barriers segments was A706 Grade 60 weldable rebar. All other reinforcing steel used in fabrication of the barrier was ASTM A615 grade 60. The unconfined compressive strength of the barrier concrete was specified to be a minimum of 4000 psi. The actual 28-day concrete compressive strength of the barrier segments in the impact region averaged 4767 psi. The compressive strength of the concrete deck to which the barrier was anchored was 5705 psi. The anchor bolts were ISO R898 Class 8.8, which has a minimum yield strength of 92,000 psi and a minimum tensile strength of 120,000 psi. This is equivalent to an SAE J429 Grade 5 or ASTM A325 bolt. The connector plate, angle, bolt-down bar strap, deflection limiter plate, plate washer, and retainer ring were all fabricated from A36 material. Material certification documents are provided in appendix B.

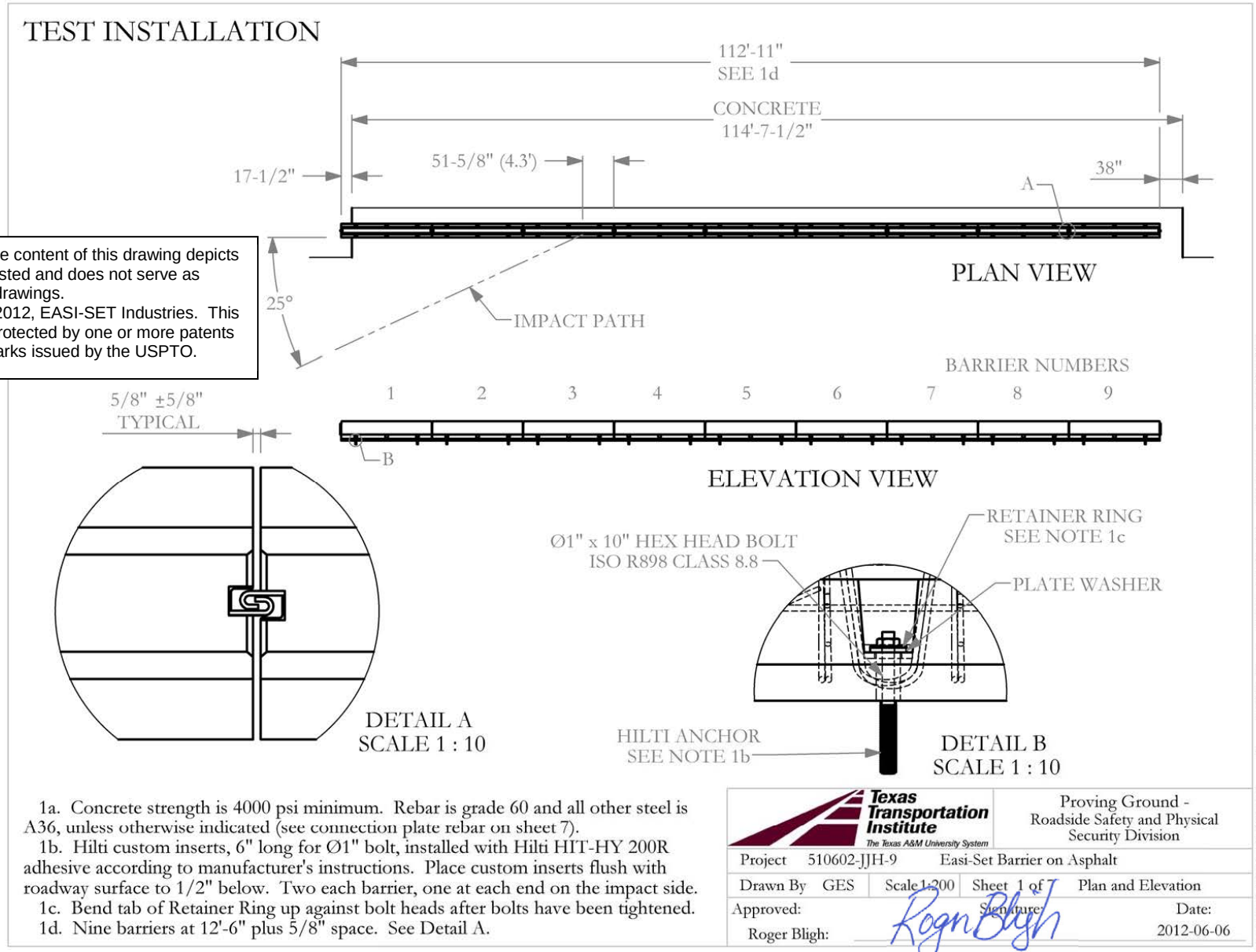


Figure 2.1. Details of the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system.

Figure 2.2. EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system prior to testing.

3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

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

Test 3-10 involves an 1100C (2425 lb/1100 kg) vehicle impacting the critical impact point (CIP) of the length of need (LON) of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This test investigates occupant risk.

Test 3-11 consists of a 2270P (5000 lb/2270 kg) vehicle impacting the CIP of the LON of the barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This is a strength evaluation for test level 3 to verify a barrier's performance for impacts involving light trucks and SUVs.

Test 3-11 was considered to be the most critical for evaluating the performance of the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system because the larger 2270P pickup truck imparts a higher impact load and is a less stable vehicle. Only *MASH* Test 3-11 was performed.

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

3.2 EVALUATION CRITERIA

The crash test was evaluated in accordance with the criteria presented in *MASH* for Test 3-11. The performance of the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system is judged on the basis of three factors: structural adequacy, occupant risk, and post impact vehicle trajectory. Structural adequacy is judged upon the ability of the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system to contain and redirect the vehicle. Occupant risk criteria evaluates the potential risk of hazard to occupants in the impacting vehicle, and to some extent other traffic, pedestrians, or workers in construction zones, if applicable. Post impact vehicle trajectory is assessed to determine potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles. The appropriate safety evaluation criteria from table 5.1 of *MASH* were used to evaluate the crash test reported herein. These criteria are listed in further detail under the assessment of the crash test.

4. TEST CONDITIONS

4.1 TEST FACILITY

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

The test facilities at the TTI Proving Ground consist of a 2000 acre (809-hectare) complex of research and training facilities situated 10 miles (16 km) northwest of the main campus of Texas A&M University. The site, formerly an Air Force Base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for the installation of the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system is along the surface of a wide out-of-service apron. The apron consists of an unreinforced jointed concrete pavement in 12.5 ft × 15 ft blocks nominally 6 inches deep. The aprons are over 50 years old and the joints have some displacement, but are otherwise flat and level.

4.2 VEHICLE TOW AND GUIDANCE SYSTEM

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

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, that 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 size, solid state units designs for crash test service. The TDAS Pro

hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once recorded, the data are backed up inside the unit by internal batteries should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiating the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The raw data are then processed by the Test Risk Assessment Program (TRAP) software to produce detailed reports of the test results. Each of the TDAS Pro units are returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology. Acceleration data is measured with an expanded uncertainty of ±1.7% at a confidence factor of 95% (k=2).

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

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals 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 of the vehicle-fixed coordinate systems being initial impact. Rate of rotation data is measured with an expanded uncertainty of ±0.7% at a confidence factor of 95% (k=2).

4.3.2 Anthropomorphic Dummy Instrumentation

Use of a dummy in the 2270P vehicle is optional according to *MASH*, and there was no dummy used in the test of the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier.

4.3.3 Photographic Instrumentation and Data Processing

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

5. CRASH TEST 510602-JJH9 (*MASH* TEST NO. 3-11)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

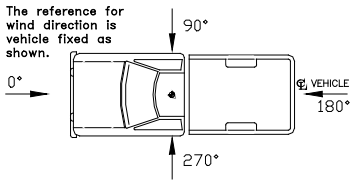
MASH test 3-11 involves a 2270P vehicle weighing 5000 lb ±100 lb and impacting the barrier at an impact speed of 62.2 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 4.3 ft upstream of the joint between segments 3 and 4 as determined from *MASH* guidelines. The 2006 Dodge Ram 1500 used in the test weighed 5009 lb and the actual impact speed and angle were 62.5 mi/h and 25.0 degrees, respectively. The actual impact point was 4.1 ft upstream of the joint between segments 3 and 4. Target Impact Severity (IS) was 115.1 kip*ft, and actual IS was calculated to be 116.8 kip*ft, which is 1.5 percent greater than target IS.

5.2 TEST VEHICLE

A 2006 Dodge Ram 1500 pickup truck, shown in figures 5.1 and 5.2, was used for the crash test. Test inertia weight of the vehicle was 5009 lb. The height to the lower edge of the vehicle front bumper was 13.75 inches, and the height to the upper edge of the front bumper was 25.38 inches. The height to the center of gravity was 28.00 inches. Additional dimensions and information on the vehicle are given in appendix C, tables C1 and C2. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

5.3 WEATHER CONDITIONS

The crash test was performed the morning of June 5, 2012. Weather conditions at the time of testing were: Wind speed: 3 mi/h; wind direction: 180 degrees with respect to the vehicle (vehicle was traveling in a northwesterly direction); temperature: 89 ºF; relative humidity: 55 percent.



5.4 TEST DESCRIPTION

The 2006 Dodge Ram 1500 pickup truck, traveling at an impact speed of 62.5 mi/h, impacted the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system 4.1 ft upstream of the joint between segments 3 and 4 at an impact angle of 25.0 degrees. At approximately 0.037 s, segments 3 and 4 began to deflect toward the field side, and at 0.038 s, the vehicle began to redirect. The vehicle began to travel parallel with the barrier at 0.177 s, and the rear of the vehicle contacted the barrier at 0.187 s. At 0.345 s, the vehicle lost contact with the barrier while traveling at an exit speed and angle of 55.2 mi/h and 7.2 degrees, respectively. Brakes on the vehicle were not applied, and the vehicle subsequently came to rest 229 ft downstream of impact and 13 ft forward of the traffic face of the barrier. Sequential photographs of the test period are shown in appendix C, figures C1 and C2.

Figure 5.1. Vehicle/installation geometrics for test 510602-JJH9.

Figure 5.2. Vehicle before test 510602-JJH9.

5.5 TEST ARTICLE AND COMPONENT DAMAGE

Damage to the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system is shown in figures 5.3 and 5.4. The concrete at the anchors at segments 3 and 4 were damaged and the anchor on the upstream end of segment 4 was pulled up 2 inches. Cracking of the concrete was also present around the upstream anchor on segment 5. Maximum dynamic deflection of the barrier during the test was 5.9 inches, and the working width was 27.5 inches. Maximum permanent deformation of the barrier was 4.0 inches at the joint between segments 3 and 4.

5.6 TEST VEHICLE DAMAGE

Figure 5.5 shows the damage to the vehicle after test 510602-JJH9. The left frame rail and left upper and lower A-arms were deformed. Also damaged were the front bumper, hood, grill, left front fender, left front tire and wheel rim, left front and rear door, left rear exterior bed, left rear wheel rim, rear bumper and tailgate. Maximum exterior crush of the vehicle was 12.0 inches in the side plane at the left front corner at bumper height. Maximum occupant compartment deformation was 0.5 inch along the left lateral area across the cab between the kickpanels on either side of the cab near the driver's feet. Photographs of the interior of the vehicle before and after the test are shown in figure 5.6. Exterior vehicle crush and occupant compartment measurements are shown in appendix C, tables C3 and C4.

5.7 OCCUPANT RISK VALUES

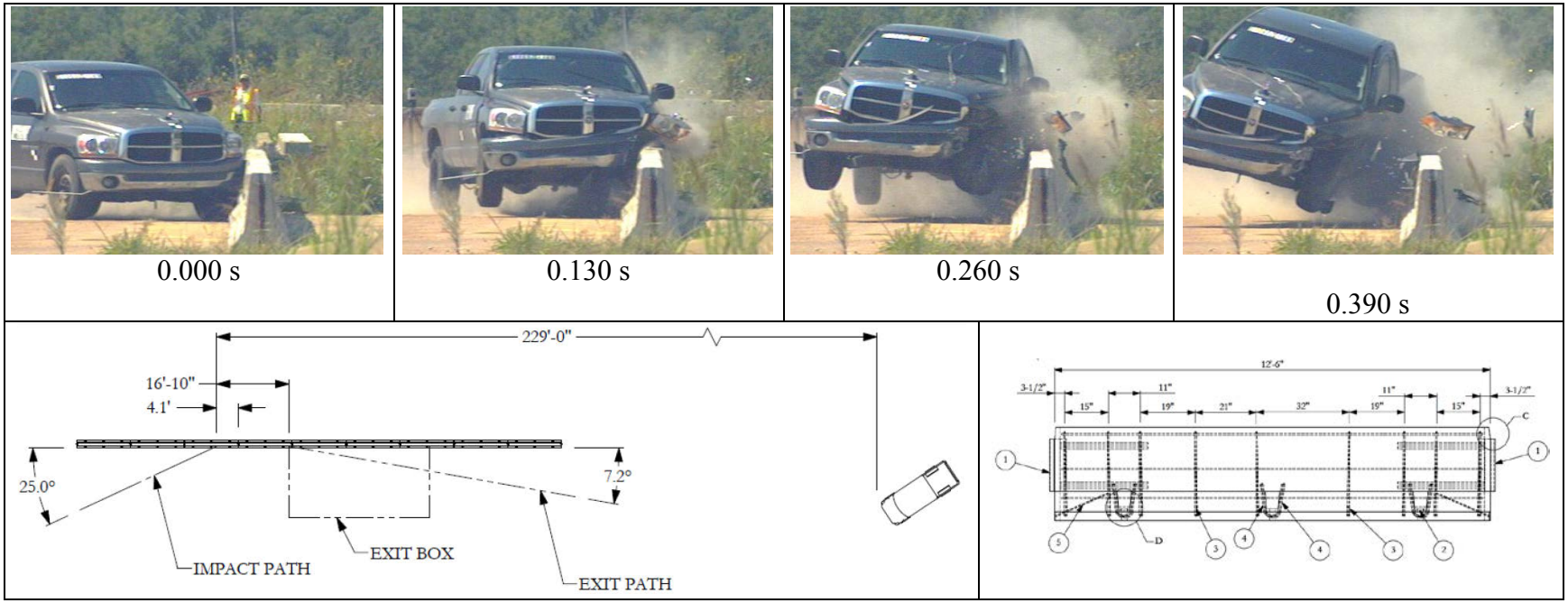
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity was 16.1 ft/s at 0.096 s, the highest 0.010-s occupant ridedown acceleration was 5.5 Gs from 0.096 to 0.106 s, and the maximum 0.050-s average acceleration was -7.8 Gs between 0.018 and 0.068 s. In the lateral direction, the occupant impact velocity was 25.6 ft/s at 0.096 s, the highest 0.010-s occupant ridedown acceleration was 9.9 Gs from 0.210 to 0.220 s, and the maximum 0.050-s average was 12.9 Gs between 0.037 and 0.087 s. Theoretical Head Impact Velocity (THIV) was 33.2 km/h or 9.2 m/s at 0.093 s; Post-Impact Head Decelerations (PHD) was 10.1 Gs between 0.210 and 0.220 s; and Acceleration Severity Index (ASI) was 1.54 between 0.037 and 0.087 s. These data and other pertinent information from the test are summarized in figure 5.7. Vehicle angular displacements and accelerations versus time traces are presented in appendix C, figures C3 through C9.

Figure 5.3. Vehicle/installation after test 510602-JJH9.

Figure 5.4. Installation after test 510602-JJH9.

Figure 5.5. Vehicle after test 510602-JJH9.

Figure 5.6. Interior of vehicle for test 510602-JJH9.



General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... MASH Test 3-11
- TTI Test No. 510602-JJH9
- Date 2012-06-05

Test Article
- Type ..... Concrete median barrier
- Name ..... EASI-SET® Industries J-J Hooks/MASH proprietary bolt-down barrier system
- Installation Length ..... 112.9 ft
- Material or Key Elements .... F-shape 12.5 ft concrete barrier segments bolted to concrete surface with HILTI custom insert and HILTI HIT-HY 200R adhesive

Soil Type and Condition..... Placed on concrete surface, dry

Test Vehicle
- Type/Designation 2270P
- Make and Model..... 2006 Dodge Ram 1500 Pickup
- Curb ..... 4792 lb
- Test Inertial ..... 5009 lb
- Dummy..... No dummy
- Gross Static..... 5009 lb

Impact Conditions
- Speed.....62.5 mi/h
- Angle.....25.0 degrees
- Location/Orientation .....4.1 upstrm of joint 3-4

Impact Severity.....114.5 kip*ft

Exit Conditions
- Speed.....55.2 mi/h
- Angle.....7.2 degrees

Occupant Risk Values
- Impact Velocity
  - Longitudinal.....16.1 ft/s
  - Lateral.....25.6 ft/s
- Ridedown Accelerations
  - Longitudinal.....5.5 G
  - Lateral.....9.9 G
- THIV.....33.2 km/h
- PHD .....10.1 G
- ASI 1.54

Max. 0.050-s Average
- Longitudinal.....-7.8 G
- Lateral.....12.9 G
- Vertical.....-3.6 G

Post-Impact Trajectory
- Stopping Distance ..... 229 ft dwnstrm
  13 ft twd traffic

Vehicle Stability
- Maximum Yaw Angle..... 39 degrees
- Maximum Pitch Angle..... 14 degrees
- Maximum Roll Angle..... 36 degrees
- Vehicle Snagging..... No
- Vehicle Pocketing..... No

Test Article Deflections
- Dynamic ..... 5.9 inches
- Permanent..... 4.0 inches
- Working Width..... 27.5 inches

Vehicle Damage
- VDS..... 11LFQ5
- CDC 11FLEW3
- Max. Exterior Deformation ..... 12.0 inches
- OCDI LF0000000
- Max. Occupant Compartment Deformation..... 0.5 inch

Figure 5.7. Summary of results for *MASH* test 3-11 on EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system.

5.8 ASSESSMENT OF TEST RESULTS

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

5.8.1 Structural Adequacy

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

Results: The EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system contained and redirected the 2270P. The vehicle did not penetrate, underride, or override the barrier. Maximum dynamic deflection during the test was 5.9 inches. (PASS)

5.8.2 Occupant Risk

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

Results: No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment or to present hazard to others in the area. (PASS)
Maximum occupant compartment deformation was 0.5 inch along the left lateral area across the cab between the kickpanels on either side of the cab near the driver's feet. (PASS)

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

Results: The 2270P vehicle remained upright during and after the collision period. Maximum roll and pitch angles were 36 degrees and 14 degrees, respectively. (PASS)

H. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

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

Results: Longitudinal occupant impact velocity was 16.1 ft/s, and lateral occupant impact velocity was 25.6 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 Gs	*20.49 Gs*

Results: Longitudinal ridedown acceleration was 5.5 G, and lateral ridedown acceleration was 9.9 G. (PASS)

5.8.3 Vehicle Trajectory

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

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

6. SUMMARY AND CONCLUSIONS

6.1 SUMMARY OF RESULTS

The EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system successfully contained and redirected the 2270P. The vehicle did not penetrate, underride, or override the barrier. Maximum dynamic deflection during the test was 5.9 inches. No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment or to present hazard to others in the area. Maximum occupant compartment deformation was 0.5 inch along the left lateral area across the cab between the kickpanels on either side of the cab near the driver's feet. The 2270P vehicle remained upright during and after the collision period. Maximum roll and pitch angles were 36 degrees and 14 degrees, respectively. Occupant risk factors were within the preferred limits recommended in *MASH*. The 2270P vehicle exited within the exit box.

6.2 CONCLUSIONS

The EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system met all specifications for *MASH* test 3-11, as shown in table 6.1.

Table 6.1. Performance evaluation summary for *MASH* test 3-11 on the EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system.

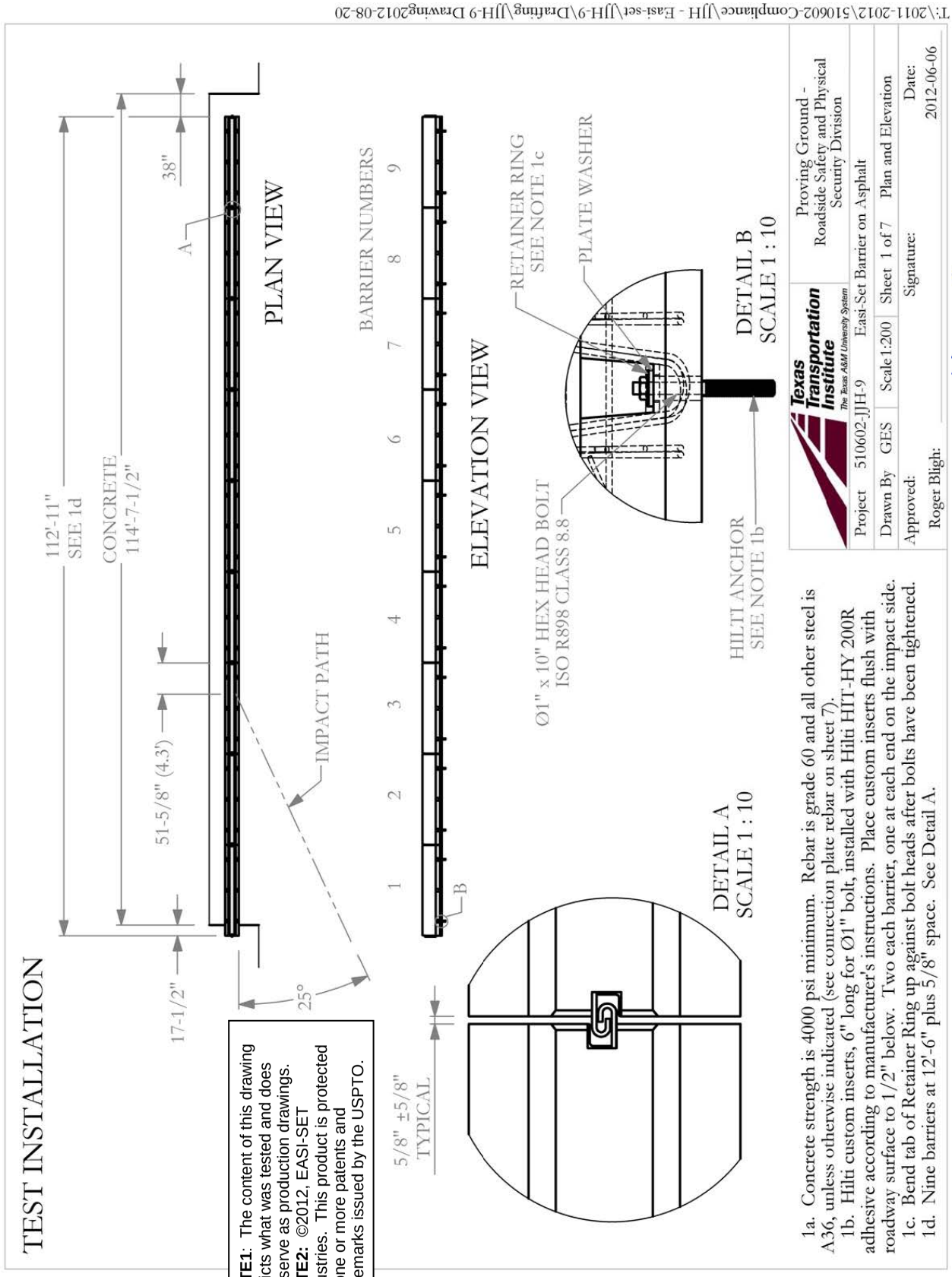
Test Agency: Texas Transportation Institute Test No.: 510602-JJH9 Test Date: 2012-06-05

***MASH* Test 3-11 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable*	The EASI-SET® Industries J-J Hooks/*MASH* proprietary bolt-down barrier system contained and redirected the 2270P. The vehicle did not penetrate, underride, or override the barrier. Maximum dynamic deflection during the test was 5.9 inches.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 0.5 inch along the left lateral area across the cab between the kickpanels on either side of the cab near the driver's feet.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision period. Maximum roll and pitch angles were 36 degrees and 14 degrees, respectively.	Pass
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.	Longitudinal occupant impact velocity was 16.1 ft/s, and lateral occupant impact velocity was 25.6 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.	Longitudinal ridedown acceleration was 5.5 G, and lateral ridedown acceleration was 9.9 G.	Pass
Vehicle Trajectory *For redirective devices, the vehicle shall exit the barrier within the exit box (not less than 32.8 ft).*	The 2270P vehicle exited within the exit box.	Pass

REFERENCES

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

APPENDIX A. DETAILS OF EASI-SET® INDUSTRIES J-J HOOKS/*MASH* PROPRIETARY BOLT-DOWN BARRIER SYSTEM



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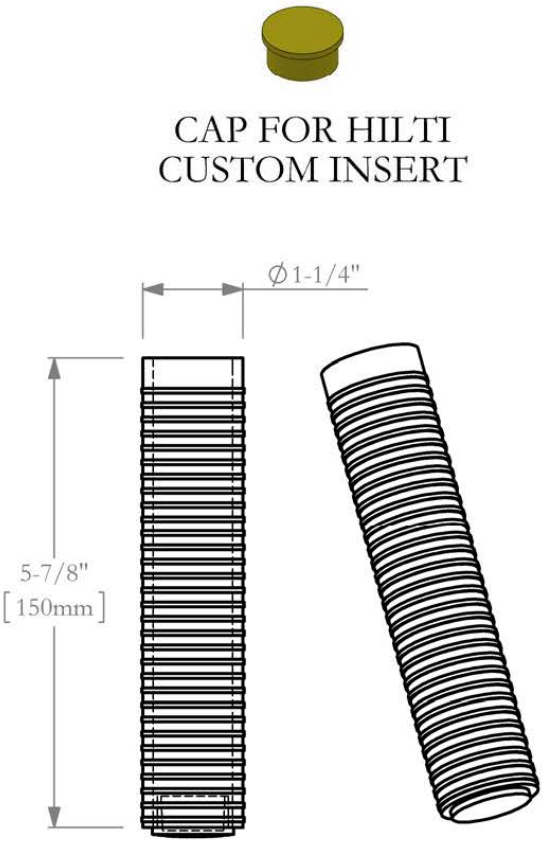
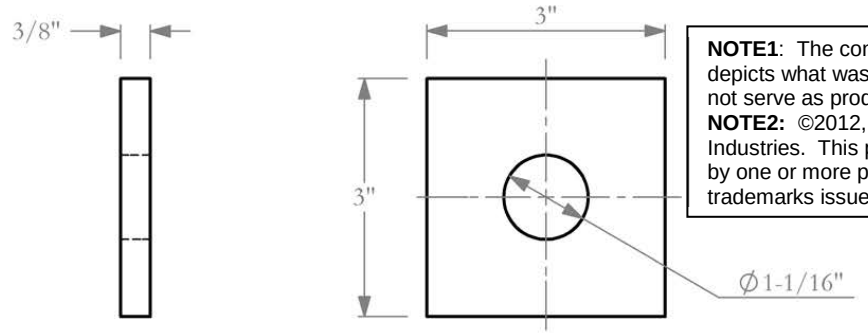
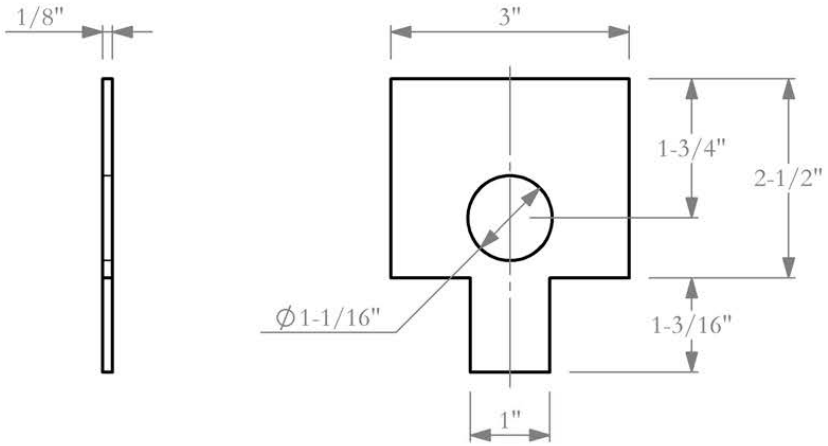
NOTE2: ©2012, EASI-SET Industries. This product is protected by one or more patents and trademarks issued by the USPTO.



HILTI CUSTOM INSERT
FOR 1" BOLT, WITH CAP
INTERIOR THREADS NOT SHOWN FOR CLARITY



J-J HOOKS PLATE WASHER



J-J HOOKS RETAINER RING

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7a. Plate Washer and Retainer Ring are made from A36 material.

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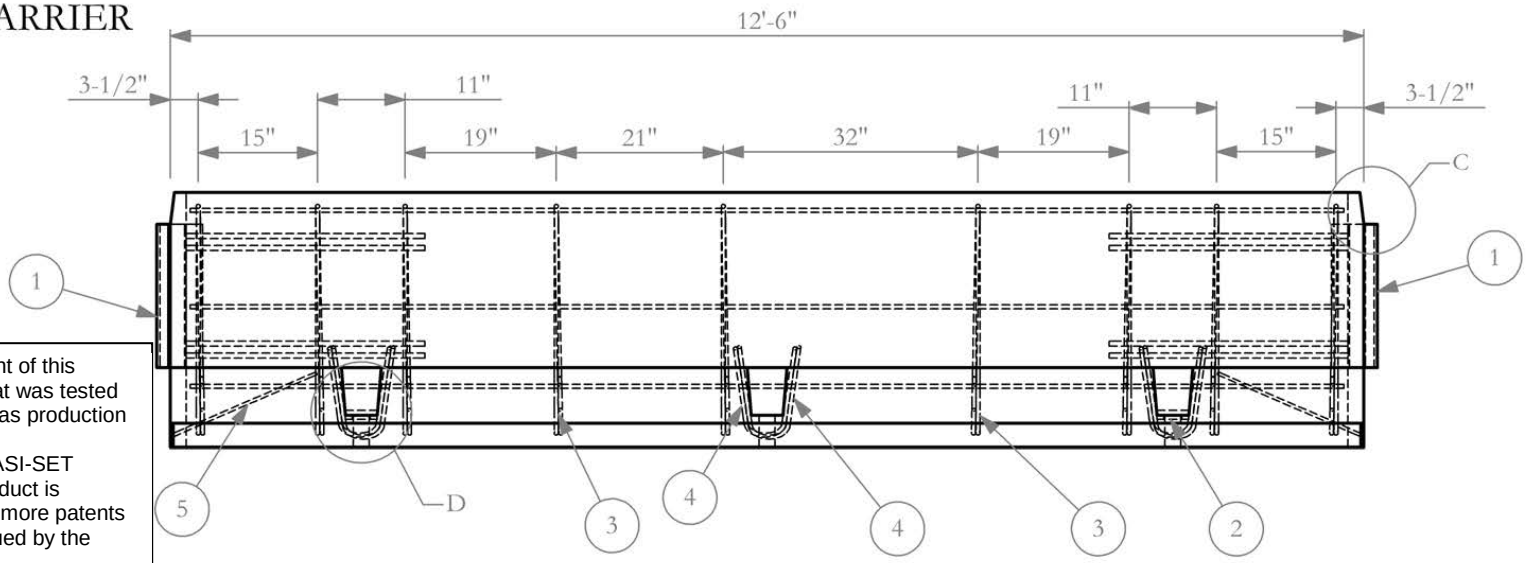
Project 510602-JJH-9	Easi-Set Barrier on Asphalt		2012-06-06
Drawn By GES	Scale 1:2	Sheet 2 of 7	Anchoring System Parts

T:\2011-2012\510602-Compliance\JJH - Easi-set\JJH-9\Drafting\JJH-9 Drawing2012-08-20

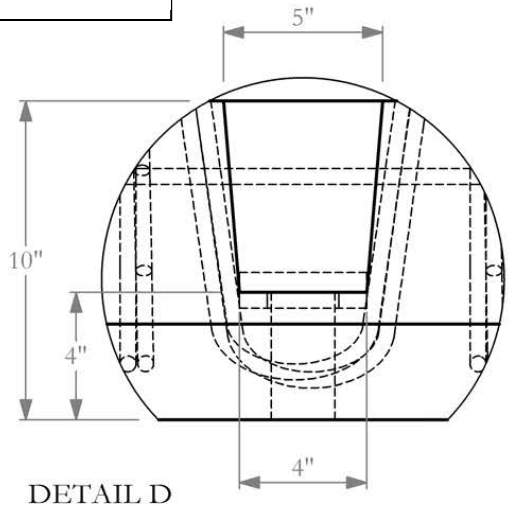
BARRIER



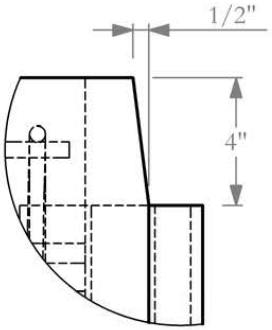
ELEVATION VIEW

NOTE1: The content of this drawing depicts what was tested and does not serve as production drawings.

NOTE2: ©2012, EASI-SET Industries. This product is protected by one or more patents and trademarks issued by the USPTO.



DETAIL D
SCALE 1 : 5



DETAIL C
SCALE 1 : 5

BARRIER PARTS		
#	PART NAME	QTY.
1	Connector Plate	2
2	Bolt-down Bar	2
3	Stirrup	9
4	Pocket U Bar	6
5	Deflection Limiter	4
6	Rebar, #4 x 145"	6

3a. Detail C is typical each end. Detail D is typical x 6 (3 each side).

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Proving Ground - Roadside Safety and Physical Security Division

Project 510602-JJH-9	Easi-Set Barrier on Asphalt	2012-06-06
Drawn By GES	Scale 1:20	Sheet 3 of 7 Barrier Details1

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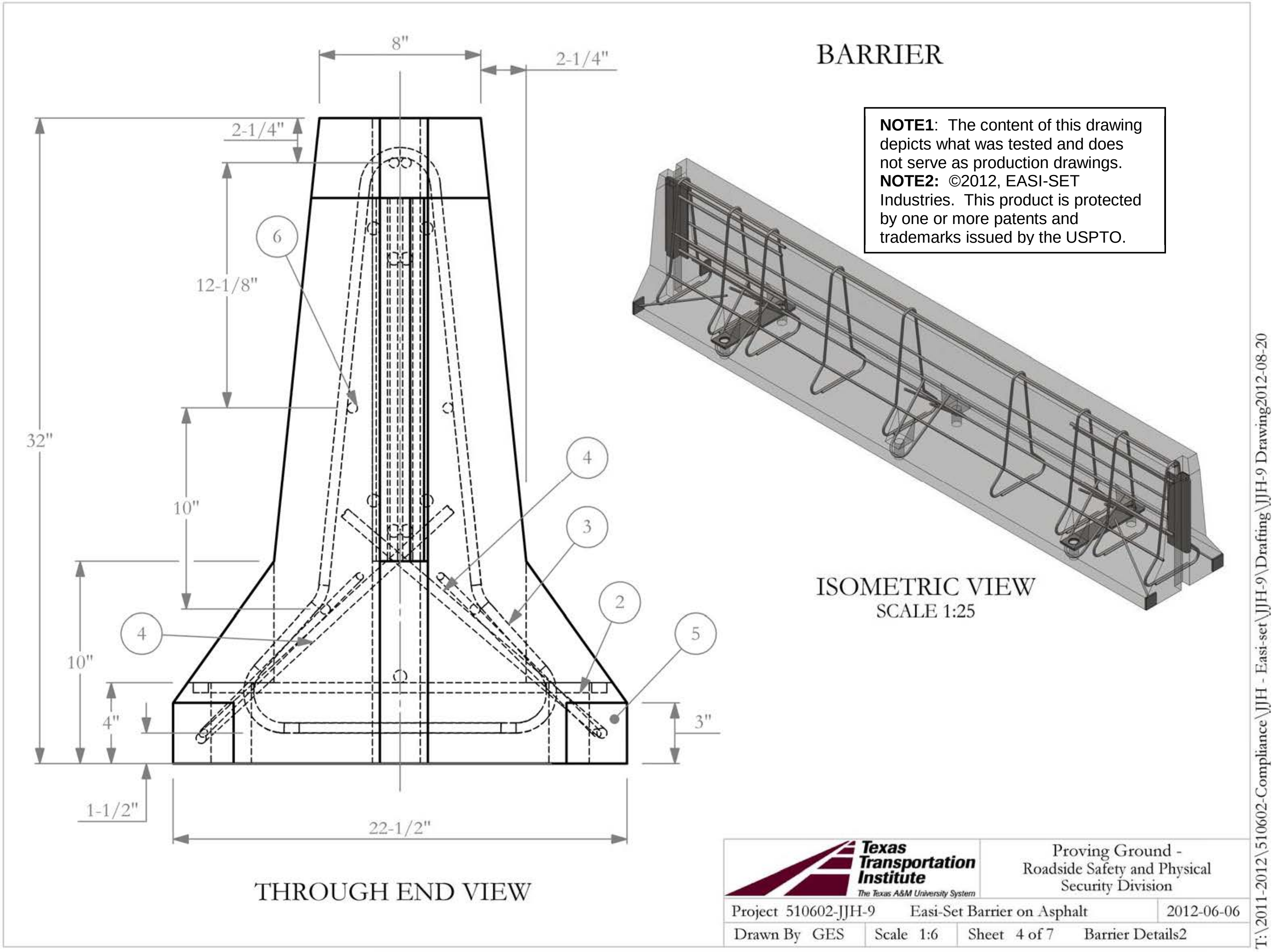
BARRIER
NOTE1: The content of this drawing depicts what was tested and does not serve as production drawings.
NOTE2: ©2012, EASI-SET Industries. This product is protected by one or more patents and trademarks issued by the USPTO.
8"
2-1/4"
2-1/4"
12-1/8"
32"
10"
10"
4"
1-1/2"
3"
22-1/2"
6
4
3
2
5
4
THROUGH END VIEW
ISOMETRIC VIEW
SCALE 1:25
Texas Transportation Institute
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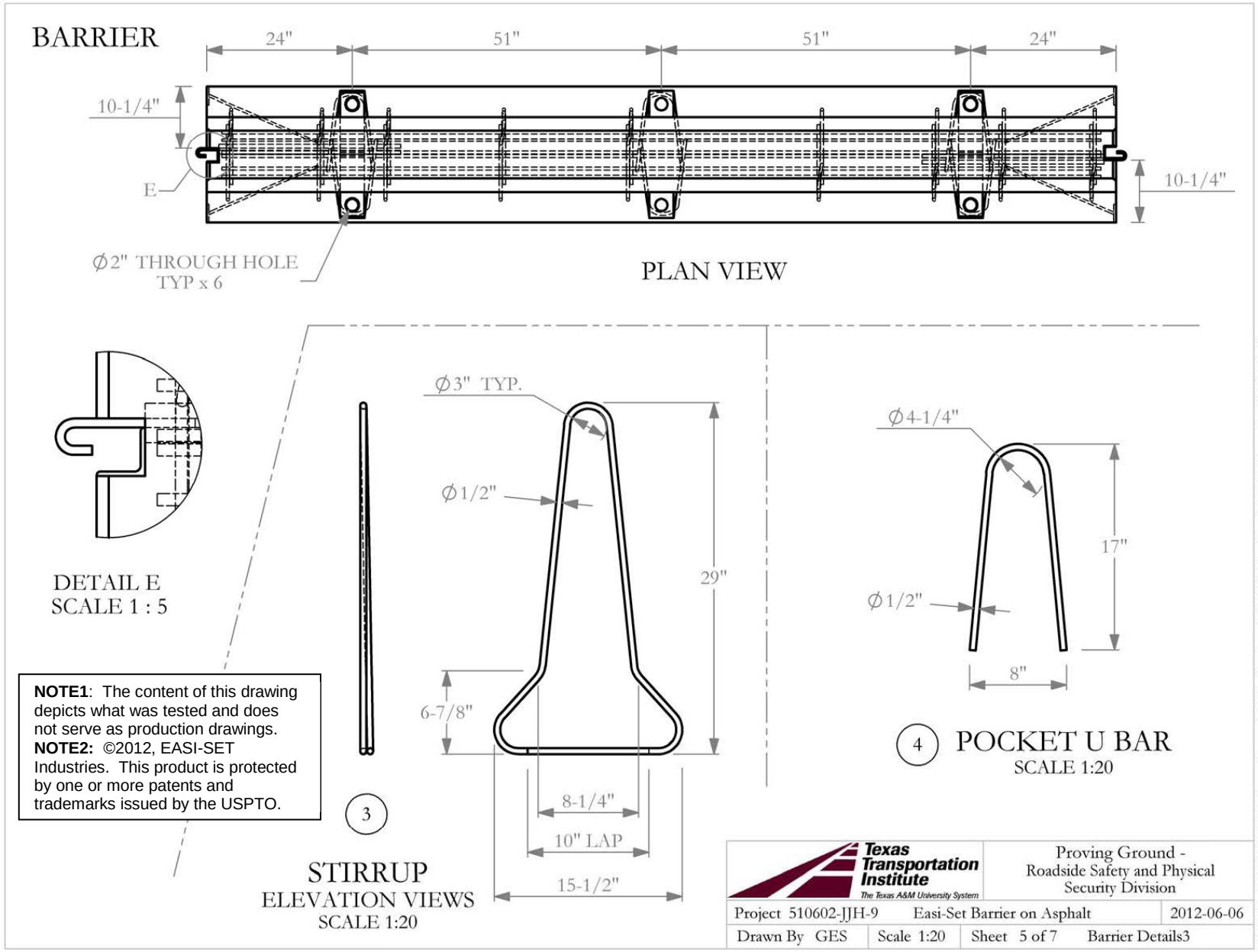
Roadside Safety and Physical Security Division
Project 510602-JJH-9
Easi-Set Barrier on Asphalt
2012-06-06
Drawn By GES
Scale 1:6
Sheet 4 of 7
Barrier Details2
T:\2011-2012\510602-Compliance\JJH - Easi-set\JJH-9\Drafting\JJH-9 Drawing2012-08-20


BARRIER
24"
51"
51"
24"
10-1/4"
E
10-1/4"
Ø2" THROUGH HOLE
TYP x 6
PLAN VIEW
DETAIL E
SCALE 1 : 5
Ø3" TYP.
Ø1/2"
29"
6-7/8"
8-1/4"
10" LAP
15-1/2"
3
STIRRUP
ELEVATION VIEWS
SCALE 1:20
Ø4-1/4"
17"
Ø1/2"
8"
4
POCKET U BAR
SCALE 1:20
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Project 510602-JJH-9
Easi-Set Barrier on Asphalt
2012-06-06
Drawn By GES
Scale 1:20
Sheet 5 of 7
Barrier Details3
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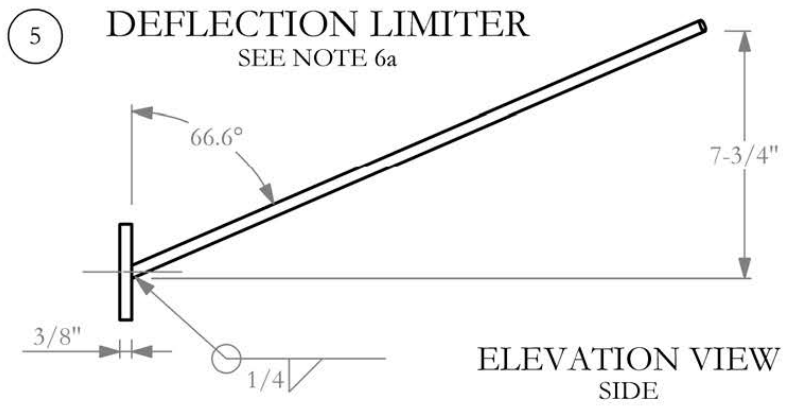

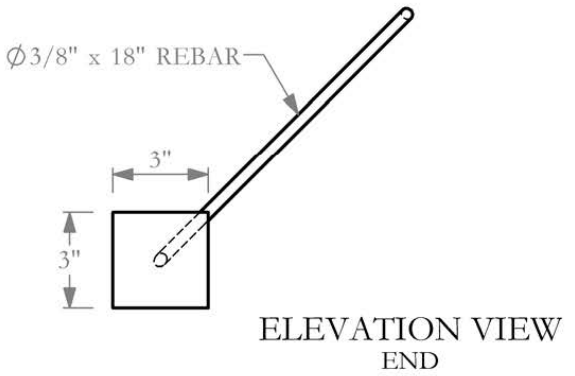

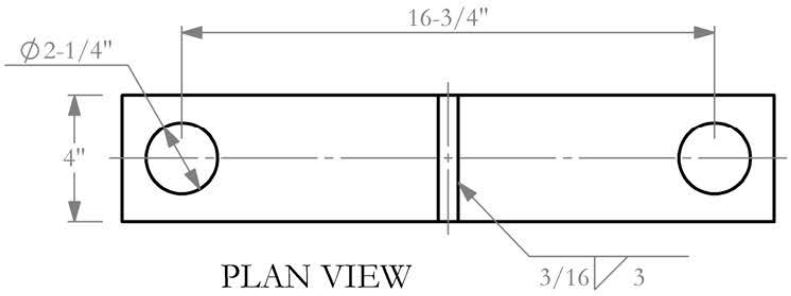

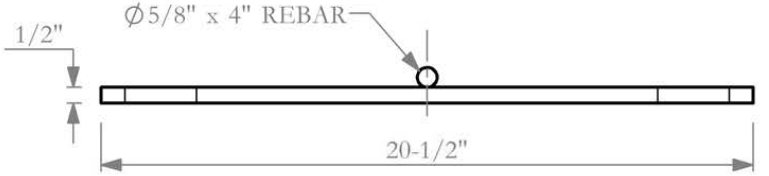

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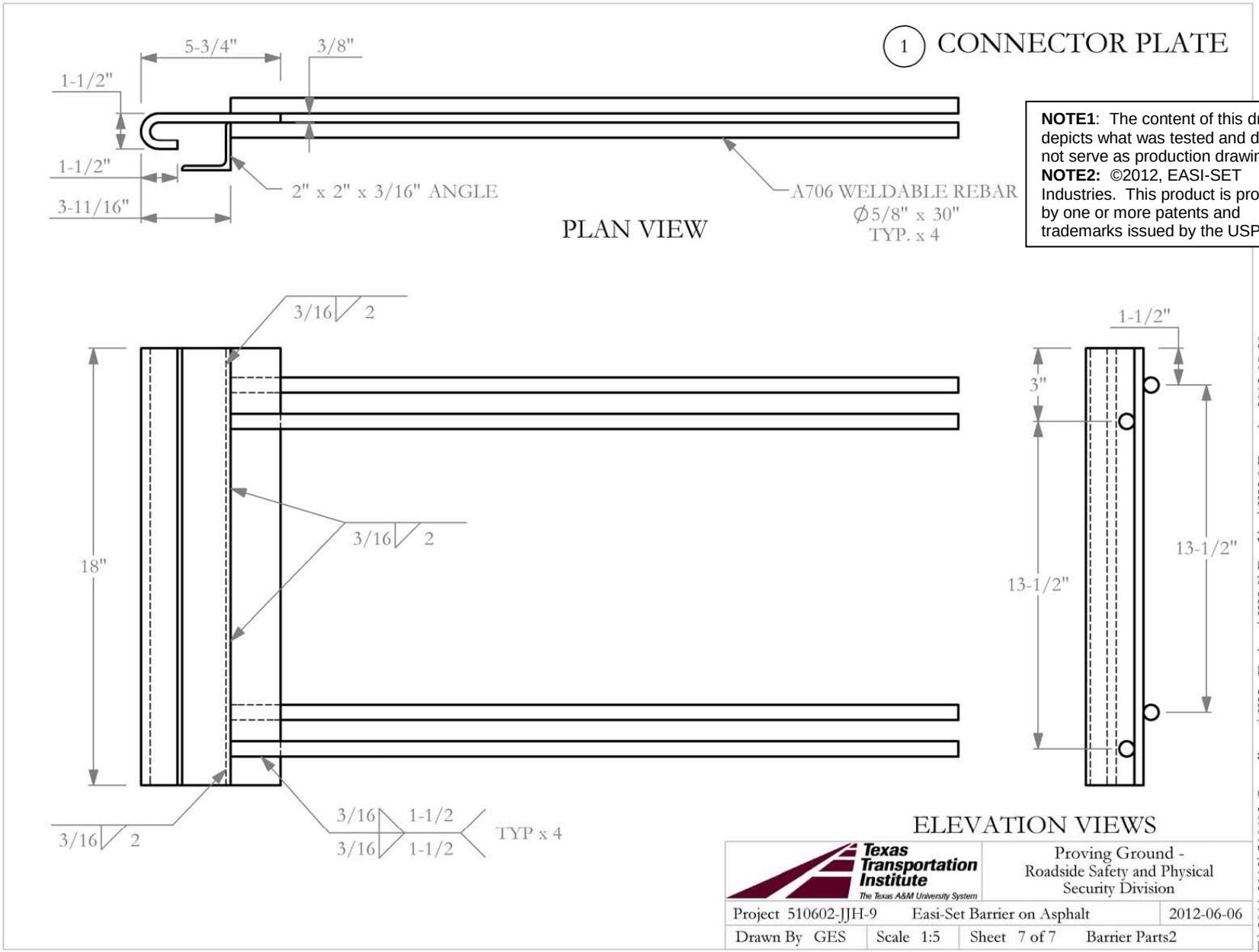
6a. Rebar is welded to plate at a compound angle. Dimensions for Plan View are identical to Elevation View. 3" x 3" plate may be trimmed up to 1/4" on each side to allow for forming issues such as chamfers.

Texas Transportation Institute, The Texas A&M University System		Proving Ground - Roadside Safety and Physical Security Division	
Project 510602-JJH-9	Easi-Set Barrier on Asphalt		2012-06-06
Drawn By GES	Scale 1:5	Sheet 6 of 7	Barrier Parts1

T:\2011-2012\510602-Compliance\JJH - Easi-set\JJH-9\Drafting\JJH-9 Drawing2012-08-20


1 CONNECTOR PLATE
5-3/4"
3/8"
1-1/2"
1-1/2"
3-11/16"
2" x 2" x 3/16" ANGLE
A706 WELDABLE REBAR
∅5/8" x 30"
TYP. x 4
PLAN VIEW
NOTE1: The content of this drawing depicts what was tested and does not serve as production drawings.
NOTE2: ©2012, EASI-SET Industries. This product is protected by one or more patents and trademarks issued by the USPTO.
3/16 2
3/16 2
18"
3/16 2
3/16 1-1/2
3/16 1-1/2
TYP x 4
1-1/2"
3"
13-1/2"
13-1/2"
ELEVATION VIEWS
Texas Transportation Institute
The Texas A&M University System
Proving Ground - Roadside Safety and Physical Security Division
Project 510602-JJH-9
Easi-Set Barrier on Asphalt
2012-06-06
Drawn By GES
Scale 1:5
Sheet 7 of 7
Barrier Parts2
T:\2011-2012\510602-Compliance\JJH - Easi-set\JJH-9\Drafting\JJH-9 Drawing2012-08-20

APPENDIX B. SUPPORTING CERTIFICATION DOCMENTS

MATERIAL USED

TEST NUMBER	510602-JJH9
TEST NAME	JJH Hooks Bolt-down Barrier
DATE	2012-06-05

All material used for this test were supplied by the client. No cert papers were provided.

May 29, 2012

Compression Test Results

J-J Hooks Mash Crash Test
with Kansas/Iowa Shape

Job Number 18821

Barrier #	Casting Date	28 Days (1)	28 Days (2)	28 Days (3)
1	04/03/12	5069 psi	4783 psi	4694 psi
2	04/05/12	4066 psi	4123 psi	4226 psi
3	04/09/12	4769 psi	4805 psi	4810 psi
4	04/10/12	4131 psi	4367 psi	4152 psi
5	04/11/12	5267 psi	5123 psi	5230 psi
6	04/12/12	4378 psi	4230 psi	3895 psi
7	04/23/12	4733 psi	5130 psi	4954 psi
8	04/25/12	4494 psi	4325 psi	4349 psi

APPENDIX C. CRASH TEST NO. 510602-JJH9

C1. VEHICLE PROPERTIES AND INFORMATION

Table C1. Vehicle properties for test 510602-JJH9.

Date: 2012-06-05 Test No.: 510602-JJH9 VIN No.: 1D7HA18N36J185644

Year: 2006 Make: Dodge Model: Ram 1500

Tire Size: P265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 137385

Note any damage to the vehicle prior to test:

• Denotes accelerometer location.

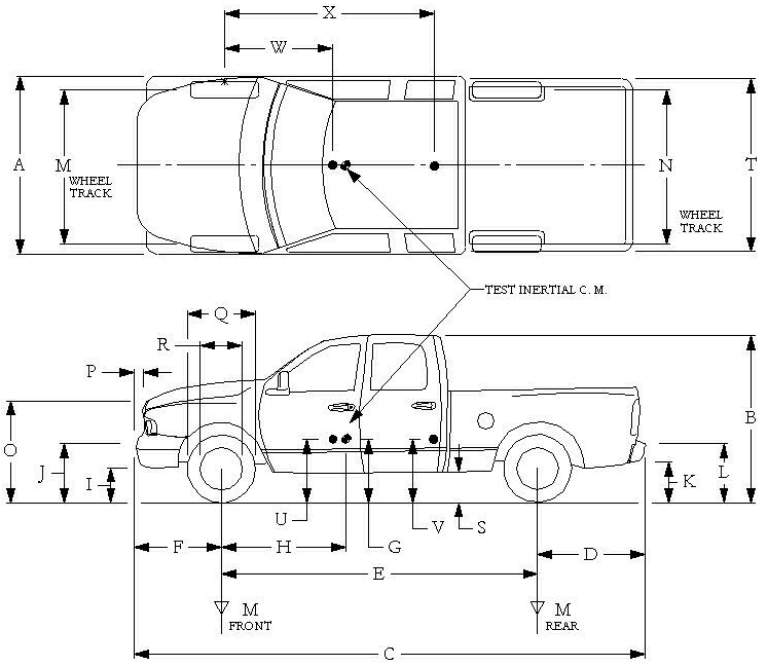
NOTES:

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment:

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



Geometry: inches

A	78.25	F	36.00	K	20.50	P	2.88	U	28.50
B	75.00	G	28.00	L	29.12	Q	31.25	V	29.50
C	223.75	H	61.57	M	68.50	R	18.38	W	59.50
D	47.25	I	13.75	N	68.00	S	12.00	X	78.00
E	140.50	J	25.38	O	44.50	T	77.50		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	5.00	Bottom Frame Height - Front	17.125
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	10.25	Bottom Frame Height - Rear	24.75

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}	2790	2814	
Back	3900	M_{rear}	2002	2195	
Total	6700	M_{Total}	4792	5009	

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

Mass Distribution:
lb LF: 1456 RF: 1358 LR: 1059 RR: 1136

Table C2. Measurements of vehicle vertical CG for test 510602-JJH9.

Date: 2012-06-05 Test No.: 510602-JJH9 VIN: 1D7HA18N36J185644

Year: 2006 Make: Dodge Model: Ram 1500

Body Style: Quad-cab Mileage: 137385

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 200 lbs in front of bed (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: P265/70R17

Measured Vehicle Weights: (lb)

LF:	1456	RF:	1358	Front Axle:	2814
LR:	1059	RR:	1136	Rear Axle:	2195
Left:	2515	Right:	2494	Total:	5009

5000 ±110 lb allowed

Wheel Base: 140.5 inches (148 ±12 inches allowed)

Track: F: 68.5 inches R: 68 inches (Track = (F+R)/2 = 67 ±1.5 inches allowed)

Center of Gravity, SAE J874 Suspension Method

X: 61.57 in Rear of Front Axle (63 ±4 inches allowed)

Y: -0.14 in Left - Right + of Vehicle Centerline

Z: 28.00 in Above Ground (minumum 28.0 inches allowed)

Hood Height: 44.50 inches (43 ±4 inches allowed)

Front Bumper Height: 25.375 inches

Front Overhang: 36.00 inches (39 ±3 inches allowed)

Rear Bumper Height: 29.125 inches

Overall Length: 223.75 inches (237 ±13 inches allowed)

Table C3. Exterior crush measurements for test 510602-JJH9.

Date: 2012-06-05 Test No.: 510602-JJH9 VIN No.: 1D7HA18N36J185644

Year: 2006 Make: Dodge Model: Ram 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane at bumper ht	15	10	30	10	7	6	3	1.75	0	-15
2	Side plane at bumper ht	15	12	48	0	1.25	3.5	6	8	12	+74
	Measurements recorded										
	in inches										

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

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

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

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

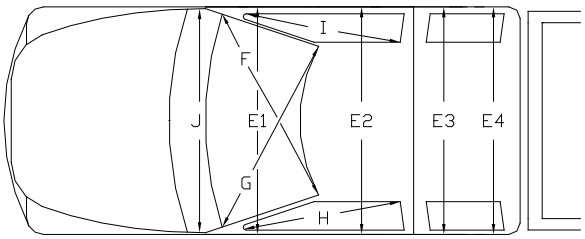
***Measure and document on the vehicle diagram the location of the maximum crush.

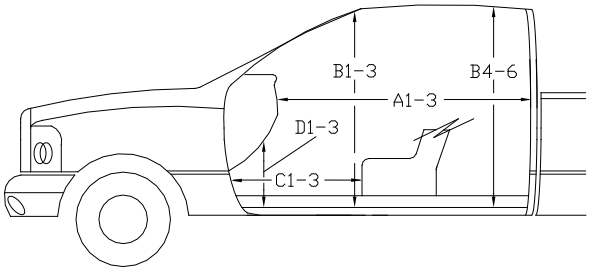
Note: Use as many lines/columns as necessary to describe each damage profile.

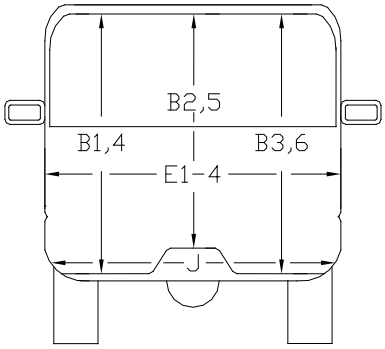
Table C4. Occupant compartment measurements for test 510602-JJH9.

Date: 2012-06-05 Test No.: 510602-JJH9 VIN No.: 1D7HA18N36J185644

Year: 2006 Make: Dodge Model: Ram 1500







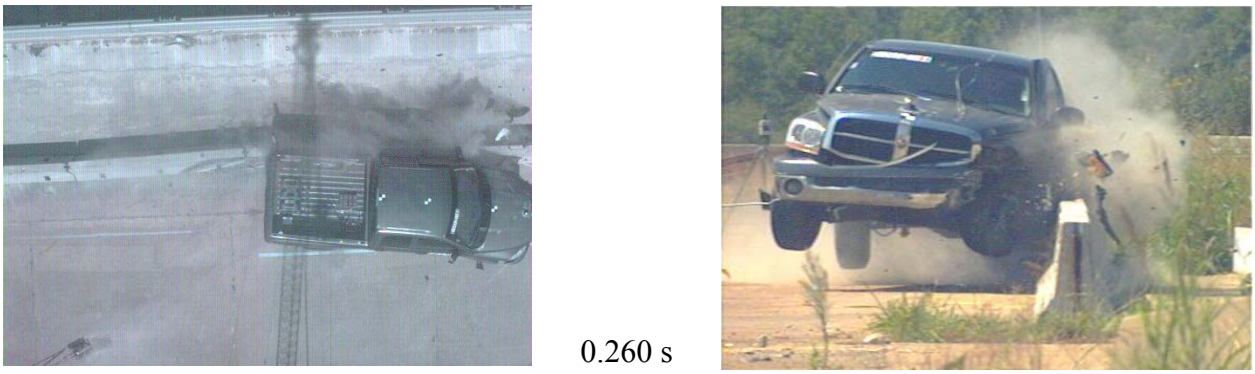
*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	64.50	64.50
A2	64.50	64.50
A3	65.00	65.00
B1	45.25	45.25
B2	39.00	39.00
B3	45.25	45.25
B4	42.12	42.12
B5	42.50	42.50
B6	42.12	42.12
C1	247.00	247.00
C2	----	----
C3	26.50	26.50
D1	12.75	12.75
D2	----	----
D3	11.62	11.62
E1	62.75	63.50
E2	64.50	65.75
E3	64.00	64.25
E4	64.38	64.50
F	59.50	59.50
G	59.50	59.50
H	39.00	39.00
I	39.00	39.00
J*	62.00	61.50

C2. SEQUENTIAL PHOTOGRAPHS

Figure C1. Sequential photographs for test 510602-JJH9
(overhead and frontal views).



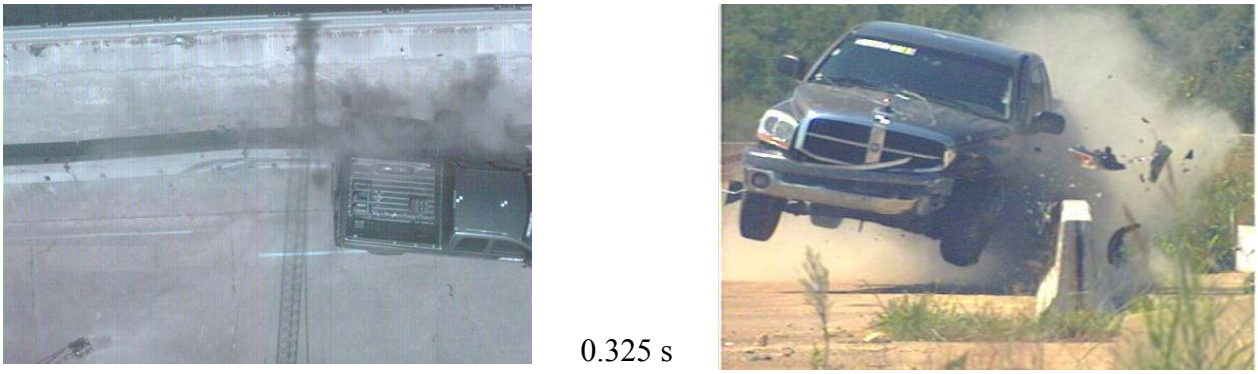


Figure C1. Sequential photographs for test 510602-JJH9
(overhead and frontal views) (continued).

0.000 s

0.260 s

0.065 s

0.325 s

0.130 s

0.390 s

0.195 s

0.455 s

Figure C2. Sequential photographs for test 510602-JJH9 (rear view).

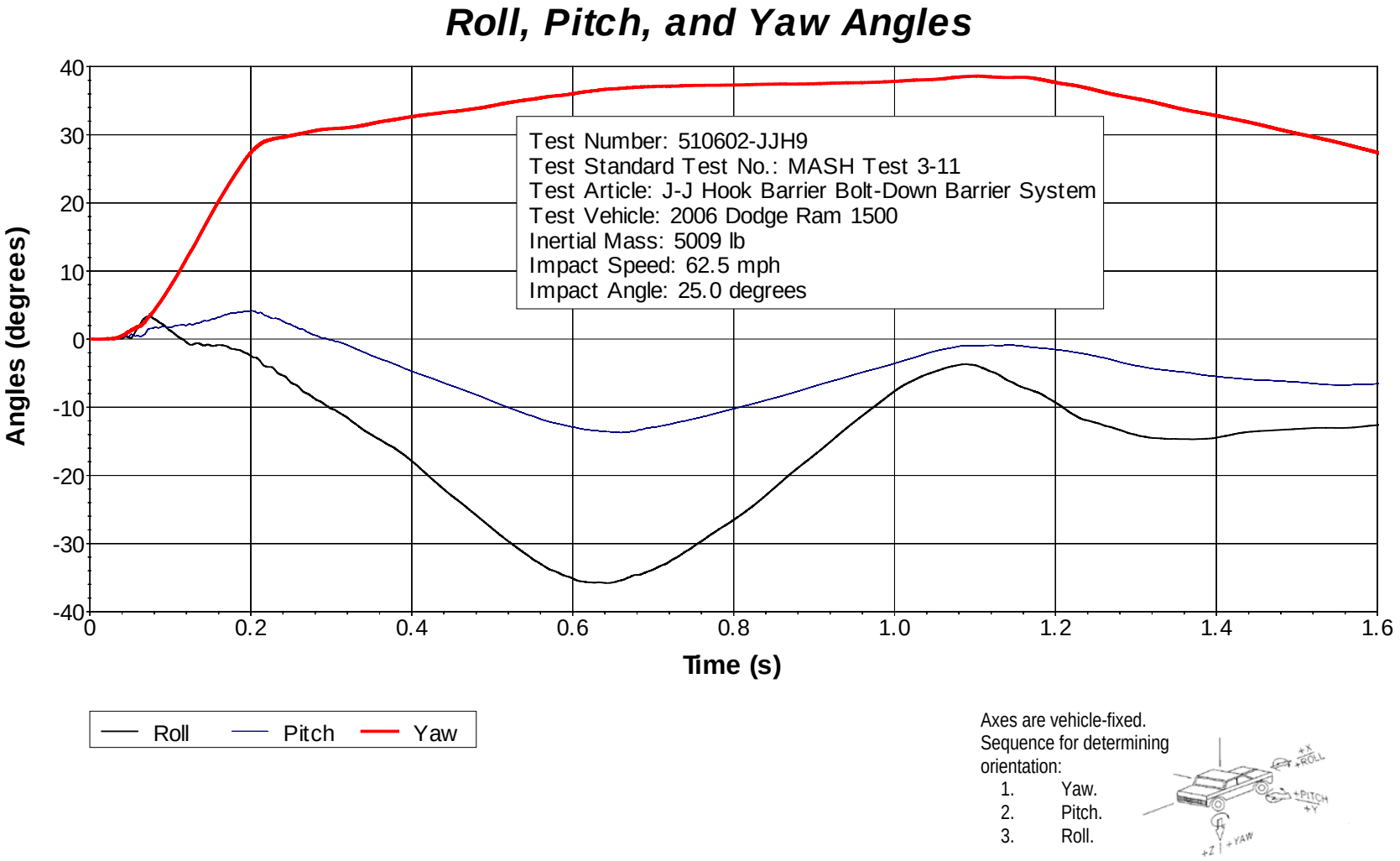


Figure C3. Vehicle angular displacements for test 510602-JJH9.

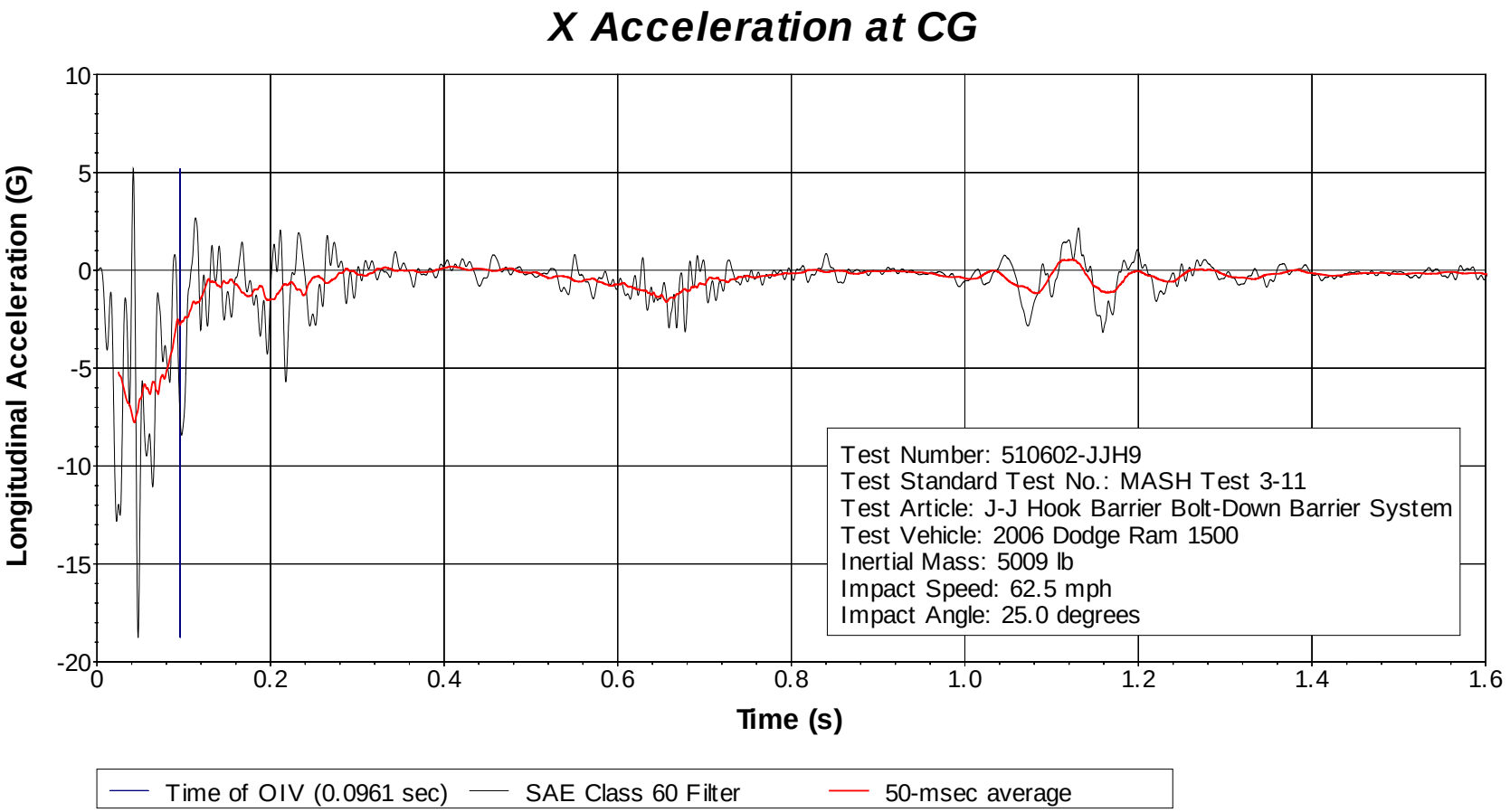


Figure C4. Vehicle longitudinal accelerometer trace for test 510602-JJH9 (accelerometer located at center of gravity).

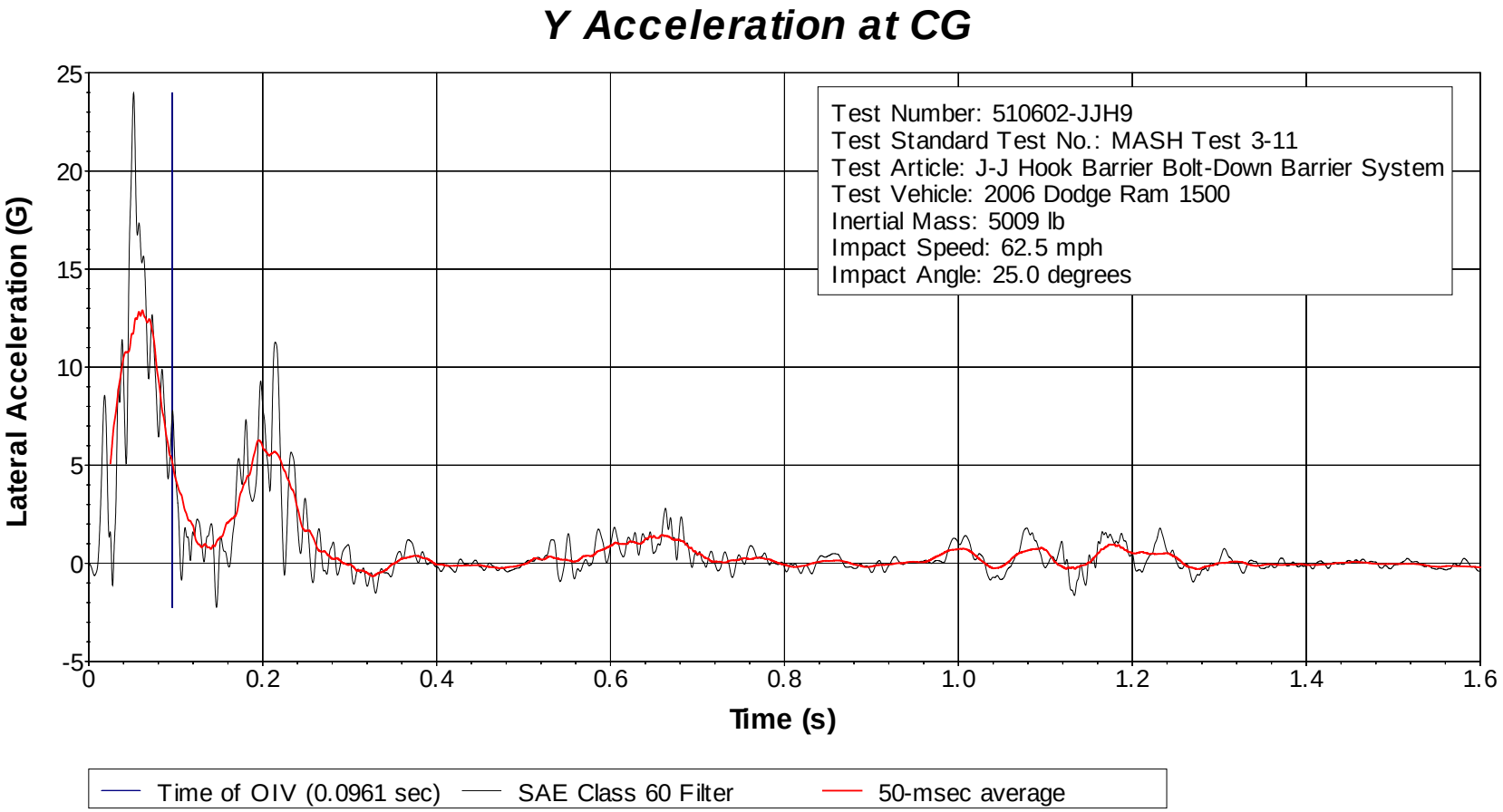


Figure C5. Vehicle lateral accelerometer trace for test 510602-JJH9 (accelerometer located at center of gravity).

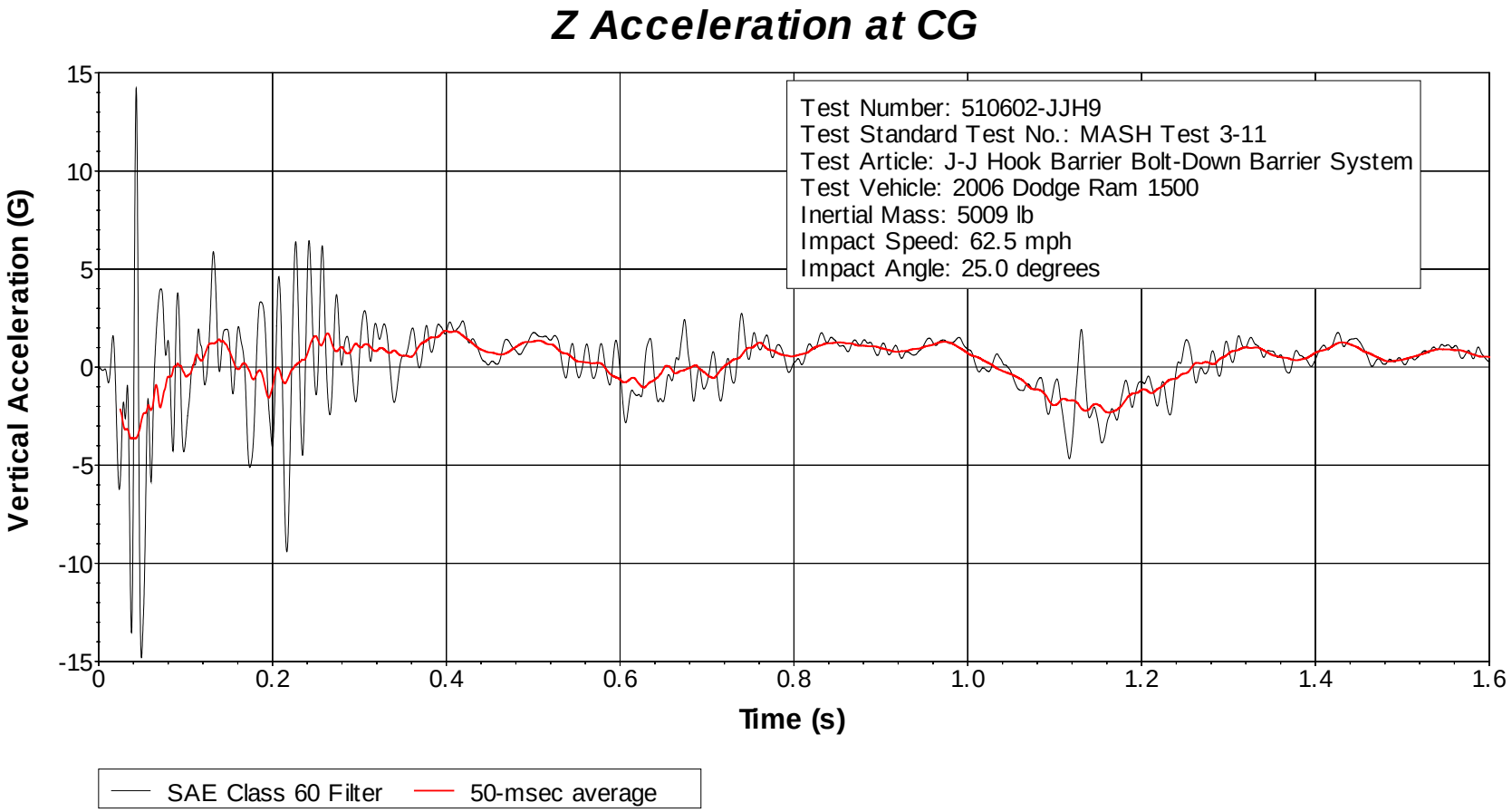


Figure C6. Vehicle vertical accelerometer trace for test 510602-JJH9 (accelerometer located at center of gravity).

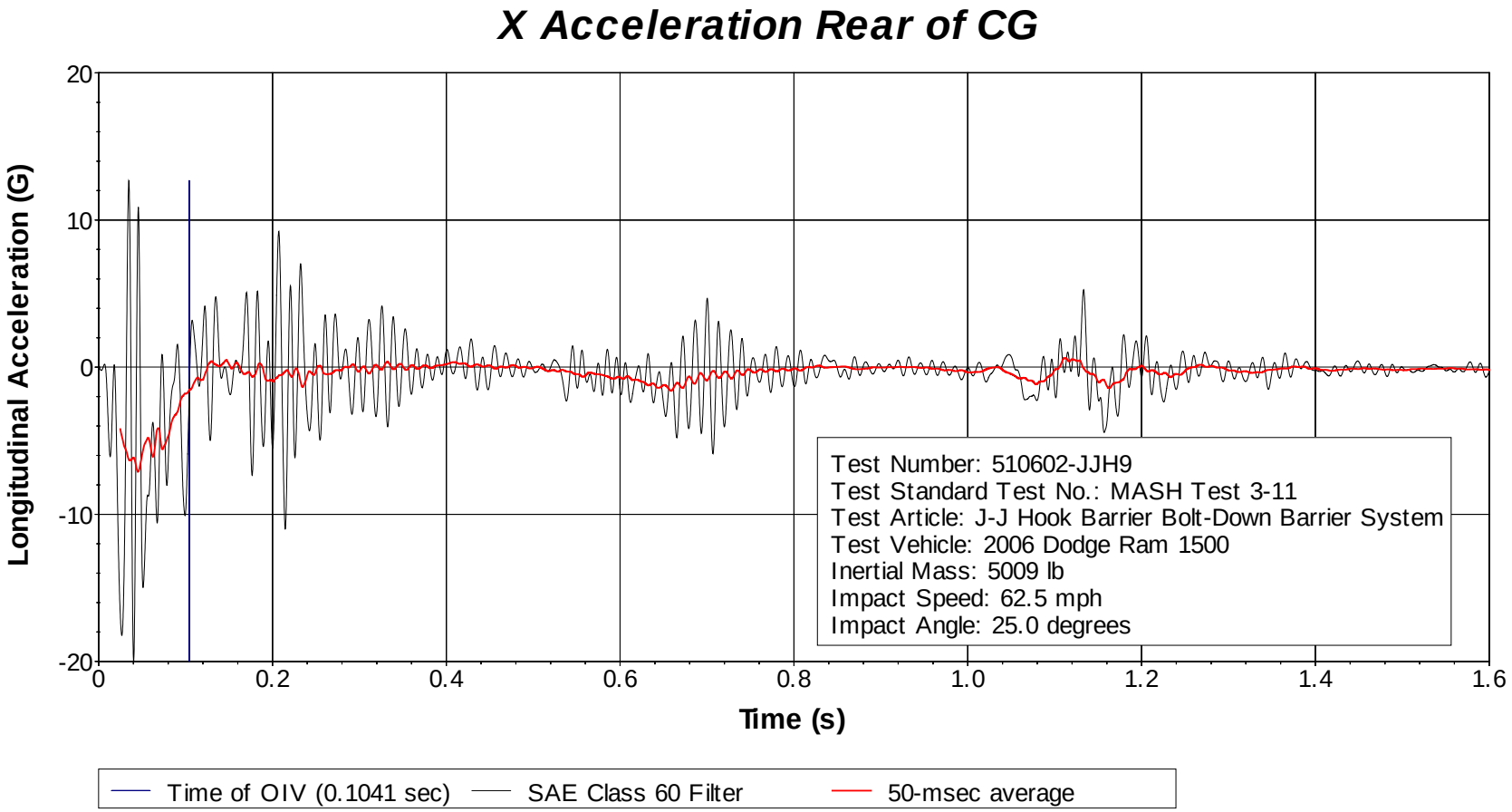


Figure C7. Vehicle longitudinal accelerometer trace for test 510602-JJH9
(accelerometer located rear of center of gravity).

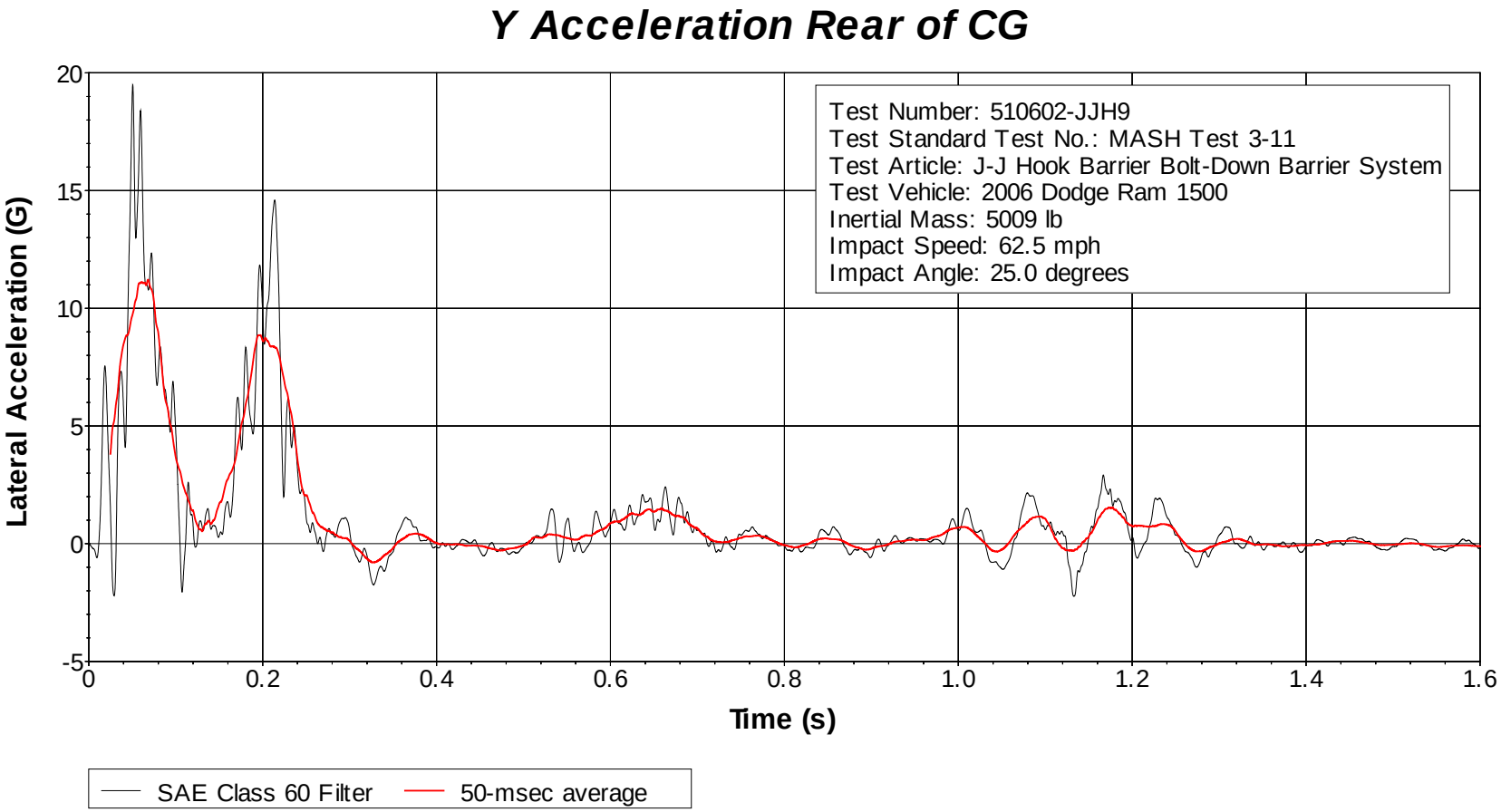


Figure C8. Vehicle lateral accelerometer trace for test 510602-JJH9 (accelerometer located rear center of gravity).

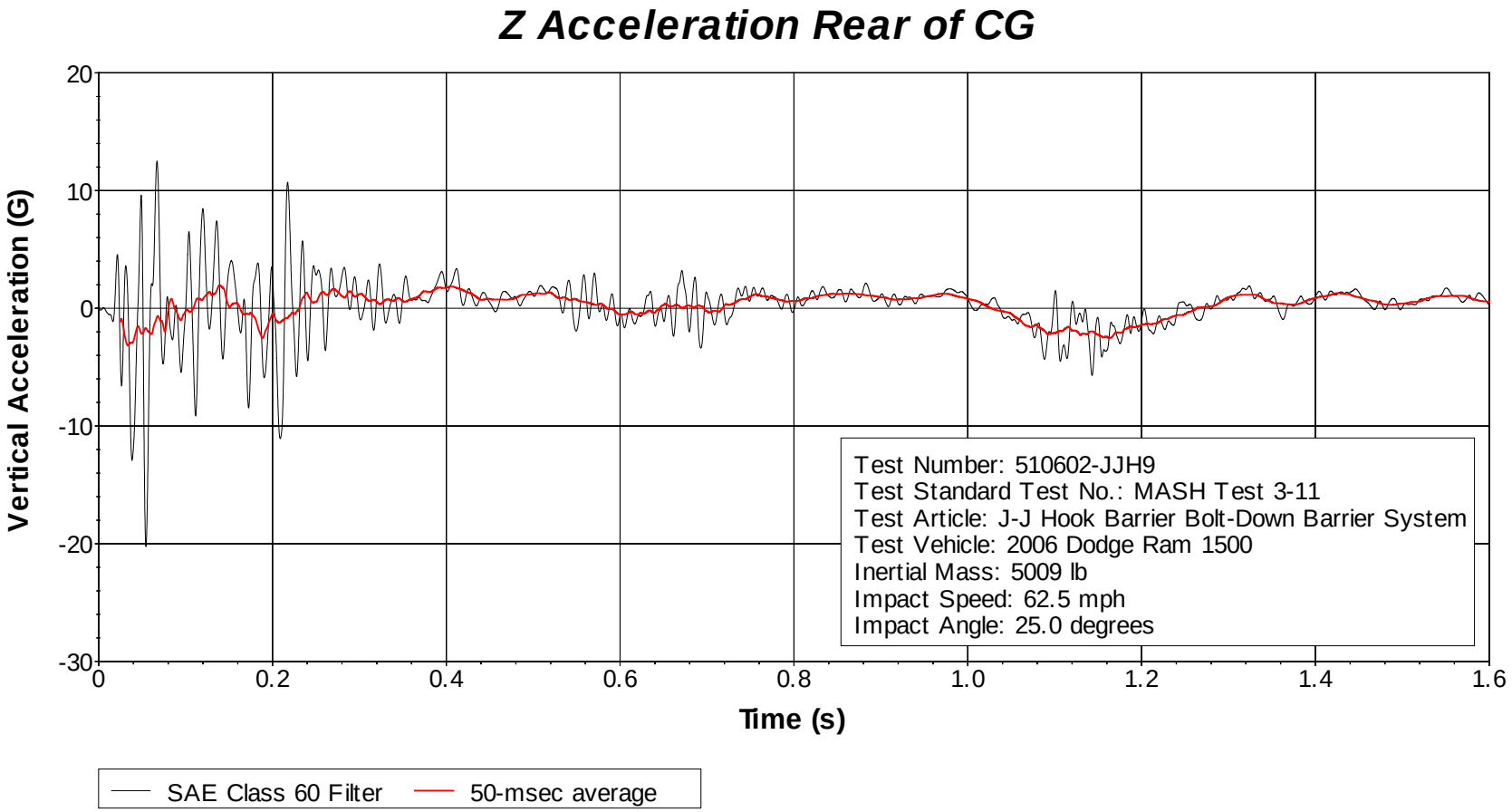


Figure C9. Vehicle vertical accelerometer trace for test 510602-JJH9 (accelerometer located rear of gravity).