Texas A&M Transportation Institute

Proving Ground

Test Report No.: 690900-IRS B2
Test Report Date: December 2020

ASTM F3016-19 EVALUATION OF SLOWSTOP® BOLLARD

by

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Contract No.: 2004494
Test Nos.: 690900-IRS B2
Test Date: 2020-10-26

Sponsored by
Impact Recovery Systems, Inc.®

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ISO 17025 Laboratory
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16. Abstract

The tests reported herein were performed and evaluated in accordance with *ATSM F3016-19, Standard Test Method for Surrogate Testing of Vehicle Impact Protective Devices at Low Speeds*.

The objective of the *ASTM F3016-19* tests reported herein was to determine if the SlowStop® Bollard manufactured by Impact Recovery Systems, Inc.® is capable of arresting a 5000-lb surrogate test vehicle according to Condition Designations/Penetration Ratings of *ASTM F3016-19*. This report presents the construction details of the SlowStop® Bollard and respective foundation, details of the surrogate test vehicle used in the tests, details of the tests performed, and the assessment of each of the test results.

ASTM F3016-19 provides a range of Condition Designations and Penetration Ratings that allow agencies to select protective devices that satisfy their specific facility needs. The amount of dynamic penetration of the protective device or surrogate test vehicle at the required impact velocity determines the dynamic Penetration Rating for each Condition Designation.

During the S10 test, the maximum penetration of the vehicle was 9.8 inches, and the maximum dynamic penetration of the bollard was 12.6 inches. According to *ASTM F3016-19*, the bollard design met the Condition Designation/Penetration Rating of S10-P2, which allows penetration of 1-4 ft when impacted by the surrogate test vehicle at an impact speed of 9.0-18.9 mi/h.

17. Key Words	18. Distribution Statement
vehicle impact protective device; impact; crash testing; bollard	Copyrighted. Not to be copied or reprinted without consent from Impact Recovery Systems, Inc.®

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APPROXIMATE CONVERSTIONS 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 CONVERSTIONS 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. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

1. INTRODUCTION

1.1 BACKGROUND

The test reported herein was performed and evaluated in accordance with *ATSM F3016-19, Standard Test Method for Surrogate Testing of Vehicle Impact Protective Devices at Low Speeds* (*1*).

1.3 OBJECTIVES/SCOPE OF RESEARCH

The objective of the *ASTM F3016-19* test reported herein was to determine if the SlowStop® Bollard manufactured by Impact Recovery Systems, Inc.® is capable of arresting a 5000-lb surrogate test vehicle according to Condition Designations/Penetration Ratings of *ASTM F3016-19*. This report presents the construction details of the SlowStop® Bollard, and respective foundation, details of the surrogate test vehicle used in the test, details of the test performed, and the assessment of each of the test results.

2. TEST CONDITIONS AND EVALUATION CRITERIA

2.1 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) / International Electromechanical Commission (IEC) 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 developed for ISO/IEC 17025 accreditation and according to the *ASTM F3016-19* guidelines and standards.

The test facilities at the Texas A&M Transportation Institute's Proving Ground consist of a 2000-acre complex of research and training facilities situated 10 miles northwest of the main campus of Texas A&M University. The site, formerly an 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, durability and efficacy of highway pavements, and evaluation of roadside safety hardware and perimeter protective devices. The site selected for installation of the SlowStop® Bollard was between two sections of an out-of-service apron. The apron consists of an unreinforced jointed concrete pavement in 12.5 ft × 15 ft blocks nominally 6-8 inches deep. The aprons were built in 1942, and the joints have some displacement, but are otherwise flat and level.

2.1 TEST PROCEDURES

The test reported herein was performed in accordance with *ASTM F3016-19*. Appendix A presents a brief description of the procedures followed for each test.

2.2 TEST CONDITIONS

According to *ASTM F3016-19,* SlowStop® Bollard can be rated according to one of three impact condition designations when tested with a surrogate test vehicle, as shown in Table 2.1. The test conditions establish a range for penetration performance ratings, which may be used to identify appropriate penetration performance for specific needs of the end user. Actual vehicle weight and speed must be within a permissible range to receive the specific impact condition designation. The impact speed ratings are shown in the last column of Table 2.1, as taken from *ASTM F3016-19*.

Table 2.1. Impact Condition Designations According to *ASTM F3016-19*.

Surrogate Test Vehicle Weight, lb	*Nominal Minimum Test Velocity mi/h*	*Permissible Speed Range, mi/h*	*Impact Speed Rating*
5000 ±110	*10*	*9.0-18.9*	*S10*
	20	*19.0-27.4*	*S20*
	30	*27.5-32.5*	*S30*

2.5 SURROGATE TEST VEHICLE

The surrogate test vehicle, or bogie, is modeled after an American Association of State Highway and Transportation Officials (AASHTO) *MASH* 2270P pickup truck. This vehicle represents the 90th percentile in terms of vehicle weight for all passenger vehicles sold in 2002. The surrogate test vehicle shown in Figures 2.1 was used for each crash test. Gross static weight of the vehicle was 4980 lb. The height to the lower edge of the vehicle front bumper was 17.25 inches, and the height to the upper edge of the front bumper was 29.25 inches. The height of the center of gravity was 28.0 inches. Appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into each installation using a reverse-pull cable system and guidance cable. The vehicle was released and was unrestrained and free-wheeling 10 ft prior to impact.

Figure 2.1. Test Vehicle prior to Testing.

2.6 EVALUATION CRITERIA

According to *ASTM F3016-19*, up to two tests are recommended to evaluate a protective device. For the first test, the protective device is to be embedded in washed sand. This installation represents the situation where the protective device would be installed in a weak soil condition. This installation represents any situation where the protective device would be installed in a strong soil condition or embedded within a pavement material such as asphalt or concrete. *ASTM F3016-19* provides guidelines that define a stiff concrete slab for testing. A second test is only required if the foundation's horizontal displacement at grade is greater than 1 inch when the protective device is tested in the washed sand. Alternatively, the protective device may be tested under a specific set of installation conditions whereby the Condition Designation/Penetration Rating are only valid if these conditions are met when installed in the field.

Dynamic penetration during the crash event includes the greater of the maximum dynamic displacement of any portion of the protective device into the protected area or the maximum dynamic penetration of any part of the surrogate test vehicle into the protected area referenced to the inside, protected side of the barrier. Penetration ratings according to *ASTM F3016-19* are shown in Table 2.2.

Table 2.2. Penetration Ratings According to *ASTM F3016-19*.

Penetration Designation	*Dynamic Penetration Rating*
P1	*≤ 1.0 ft*
P2	*1 ft - 4 ft*
Failure	*>4 ft*

3 TEST ARTICLE DESIGN

3.1 TEST ARTICLE – DESIGN AND CONSTRUCTION

The installation consisted of a single 5-inch, schedule 40, brushed stainless steel, SlowStop® Bollard set into an elastomer base, which was secured with 6 anchor bolts to a steel reinforced concrete slab measuring 15 ft long, 12.5 ft wide, and 6 inches thick. The top of the bollard measured 42 inches above grade, and the bollard was not filled with concrete. This area slab was cast on top of native soil. Impact Recovery Systems, Inc.® provided the materials and the drawings of the bollard, and TTI Proving Ground provided the drawings for the foundation and installed the bollards for testing.

Figure 3.1 provides a general overview of the installation, and Figure 3.2 shows the completed installation. Further details on the installation may be found in Appendix C and Appendix D.

3.2 MATERIAL SPECIFICATIONS

Concrete compressive strength was 4760 psi for the foundation (4000 psi design strength), which was aged 31 days as of October 26, 2020. Concrete information is provided in Appendix E.

For further information on material specifications, certification documents are provided in Appendix E.

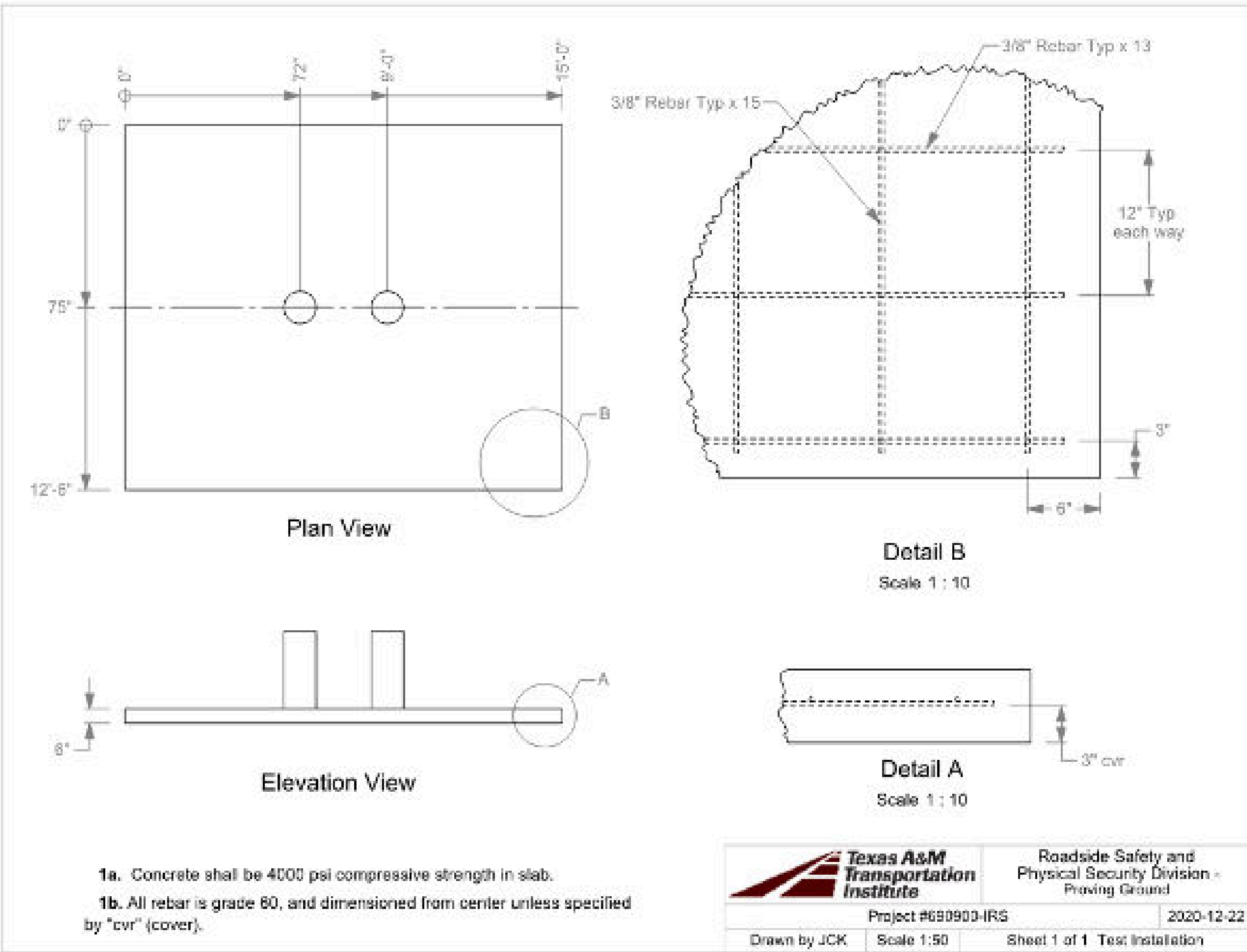


Figure 3.1. General Layout of SlowStop® Bollard.

Figure 3.2. SlowStop® Bollard prior to Testing.

4 *ASTM F3016-19* TEST S10 ON SLOWSTOP® BOLLARD (TEST NO. 690900-IRS B2)

4.1 TARGET TEST CONDITIONS

ASTM F3016-19 Test S10 was performed on the SlowStop® Bollard. Target speed was between 9.0 and 18.9 mi/h at an impact angle of 90 degrees, and target impact height of 28 inches. Actual impact speed was 10.4 mi/h and actual impact angle was 90.5 degrees, and impact height was 28.2 inches. Target and actual impact point was the centerline of the bogie aligned with the centerline of the bollard.

Figure 4.1. Bogie and Installation Geometrics for Test No. 690900-IRS B2.

4.2 WEATHER CONDITIONS

The crash test was performed the morning of October 26, 2020. Weather conditions at the time of testing were: Wind Speed: 5 mi/h; Wind Direction: 167 degrees (vehicle travelling at a heading of 170 degrees); Temperature: 74°F; Relative Humidity: 90 percent.

4.3 IMPACT DESCRIPTION

The surrogate vehicle was traveling at an impact speed of 10.4 mi/h when it impacted the bollard at an impact angle of 90.5 degrees. Table 4.1 lists events that occurred during Test No. 690900-IRS B2. Figure F.1 and F.2 in Appendix F.1 shows sequential photographs of the test period.

Table 4.1. Events during Test No. 690900-IRS B2.

TIME	EVENTS
0.0000	Bogie impacts the bollard
0.2250	Bogie reaches maximum compression on honeycomb and maximum intrusion
0.2250	Bollard at maximum deflection
0.2460	Bogie begins to rebound
0.4688	Bogie loses contact with the bollard while traveling at 2.7 mi/h backwards

4.4 DAMAGE TO TEST ARTICLE

Figure 4.2 shows the damage to the bollard. The lean angle of the bollard was initially 89.5 degrees from horizontal to the protected side, and after the test, the bollard was 88.7 degrees from horizontal. Maximum dynamic deflection of the bollard during the test was 12.6 inches toward the protected side measured at the top of the bollard. The base of the bollard at grade showed only slight movement toward the protected side. The foundation around the base of the bollard was not cracked or spalled.

Figure 4.2. Installation after Test No. 690900-IRS B2.

4.5 VEHICLE DAMAGE

Damage to the vehicle is shown in Figure 4.3. Table 4.2 provides the honeycomb compression on the bogie. The initial overall length of the bogie's nose was 59.75 inches, and after impact it was 42.5 inches. Total crush of the honeycomb nose of the surrogate test vehicle was 17.25 inches. The maximum penetration of the vehicle was 9.8 inches, and it rebounded to 31.5 ft in front of the bollard. No debris from either the surrogate test vehicle or the test installation penetrated into the protected area.

Figure 4.3. Vehicle after Test No. 690900-IRS B2.

Table 4.2. Deformation of Honeycomb Nose after Test No. 690900-IRS B2.

Honeycomb Position	Thickness Before (inches)	Thickness After (inches)
1	3.25	3.00 top – 0.75 bottom
2	2.50	0.13
3	2.25	0.13
4	2.25	0.25
5	2.38	0.38
6	3.25	0.50
7	3.13	1.00
8	3.13	1.50
9	3.25	1.50
10	3.00	3.00
11	3.00	3.00
12	3.00	3.00
13	3.13	3.13
14	3.13	3.13
15	3.00	3.00
16	3.00	3.00

4.6 OCCUPANT RISK FACTORS

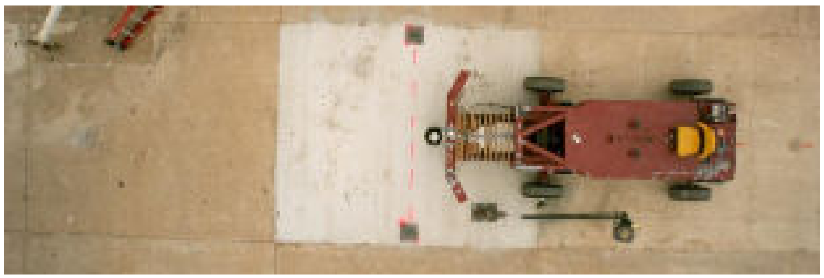
Data from the accelerometer, located near the vehicle center of gravity, were digitized for informational purposes only. These data and other pertinent information from the test are summarized in Figure 4.4. Figures F.3 in Appendix F show vehicle acceleration versus time traces.

0.000 s

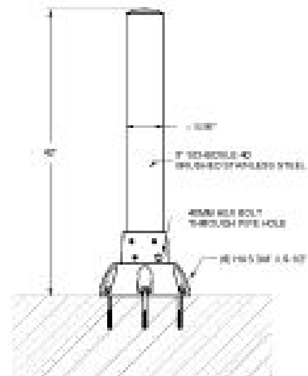
0.100 s

0.200 s

0.400 s



Near maximum deflection of bollard



General Information
Test Agency...................... Texas A&M Transportation Institute (TTI)
Test Standard Test No. .... ASTM F3016-19 S10
Test No. 690900-IRS B2
Date 2020-10-26

Test Article
Type................................. Low Speed Bollard
Name .... SlowStop® Bollard
Material or Key Elements . 42-inch tall 5-inch schedule 40 brushed stainless steel bollard

Soil/Foundation Type .... Steel reinforced 15-ft long, 12.5-ft wide, 6-inch thick concrete slab on native soil

Test Vehicle
Type...............................Low-Speed Bogie
Designation....................Surrogate (S)
Model ....ASTM F3016-19 Bogie
Test Inertial Mass ....4980 lb

Impact Conditions
Speed ....10.4 mi/h
Angle..............................90.45 degrees

Occupant Risk Values
Longitudinal OIV ....17.7 ft/s
Lateral OIV......................0.7 ft/s
Longitudinal RDA............0.8 g
Lateral RDA ....0.2 g

Max. 0.050-s Average
Longitudinal ....−3.4 g
Lateral............................−0.2 g
Vertical...........................0.4 g

Debris Field .... No debris

Final Rest of Bogie .... 31.5 ft twd impact side

Dynamic Bogie Nose Crush.......... 17.25 inches

Rotation/Translation of Bollard (static after impact).................... 1 degree (bollard 88.7° fr Horiz)

Horizontal Movement of Foundation .... None
Uplift of Foundation .... None

Dynamic Penetration of Bollard ... 12.6 inches
Dynamic Penetration of Bogie...... 9.8 inches
Penetration Rating........................ S10-P2

Figure 4.4. Summary of Results for *ASTM F3016-19* Test S10 on SlowStop® Bollard.

5 SUMMARY AND CONCLUSIONS

5.1 ASSESSMENT OF TEST RESULTS

***ASTM F3016-19* Test S10 on SlowStop® Bollard (Test No. 690900-IRS B2)**

The 4980-lb (5000-lb nominal) surrogate test vehicle impacted the bollard at 90.5 degrees with the centerline of the vehicle aligned with the centerline of the bollard. The acceptable range for impact speed for this S10 test was 9.0-18.9 mi/h, and the actual impact speed was 10.4 mi/h. Maximum dynamic penetration of the bollard during the test was 12.6 inches toward the protected side measured at the top of the bollard, and the maximum penetration of the vehicle was 9.8 inches. After impact, the bollard was leaning 89 degrees from horizontal toward the protected side. No movement of the base or foundation was observed, and there was no debris from the vehicle or bollard.

5.2 CONCLUSIONS

ASTM F3016-19 provides a range of Condition Designations and Penetration Ratings that allow agencies to select protective devices that satisfy their specific facility needs. The amount of dynamic penetration of the protective device or surrogate test vehicle at the required impact velocity determines the dynamic Penetration Rating for each Condition Designation.

During the S10 test, the maximum penetration of the vehicle was 9.8 inches, and the maximum dynamic penetration of the bollard was 12.6 inches. According to *ASTM F3016-19*, the bollard design met the Condition Designation/Penetration Rating of S10-P2, which allows penetration of 1-4 ft when impacted by the surrogate test vehicle at an impact speed of 9.0-18.9 mi/h.

REFERENCES

1. "Standard Test Method for Surrogate Testing of Vehicle Impact Protective Devices at Low Speeds," *ASTM Designation: F3016-19*, American Standards for Testing Materials International, West Conshohocken, PA, 2019.

APPENDIX A. CRASH TEST PROCEDURES AND DATA ANALYSIS

The crash test and data analysis procedures were in accordance with guidelines presented in *ASTM F3016-19*. Brief descriptions of these procedures are presented as follows.

A.1 ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

The surrogate 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, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle 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 all instrumentation used in the vehicle conforms to all 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 a calibration via a Genesco Rate-of-Turn table with strobe. 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 any time data are suspect. Acceleration data is measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k=2).

TRAP uses the data to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. 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 low-pass digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

A.2 PHOTOGRAPHIC INSTRUMENTATION AND 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 to have a field of view parallel to and aligned with the installation at the downstream end; and
- A third placed to have a field of view perpendicular to impact path and aligned with the P1 distance line.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the bollard. 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.

A.3 TEST VEHICLE PROPULSION AND GUIDANCE

The surrogate 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, and then anchored to the tow vehicle such that the tow vehicle moved away from the test site. A one-to-one speed ratio between the test and tow vehicle existed with this system. The test vehicle was released to be free-wheeling and unrestrained greater than 10 ft prior to impact. The vehicle remained free-wheeling, i.e., no steering or braking inputs.

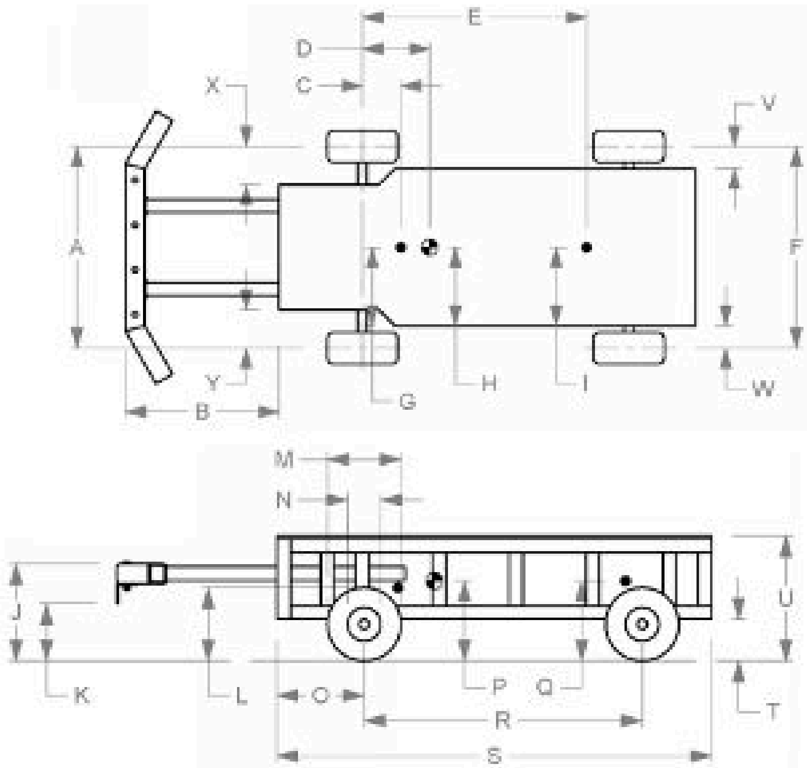
APPENDIX B. TEST VEHICLE PROPERTIES AND INFORMATION

Table B.1. Vehicle Properties for *ASTM F3016-19* Surrogate Bogie Vehicle.

Date: 2020-10-26 Test No.: 690900-IRS1 &2 Model No.: ASTM F3016-14

Tire Inflation Pressure: 65 PSI Tire Size: 225/75R15

Describe any damage to the vehicle prior to test:



Geometry: inches

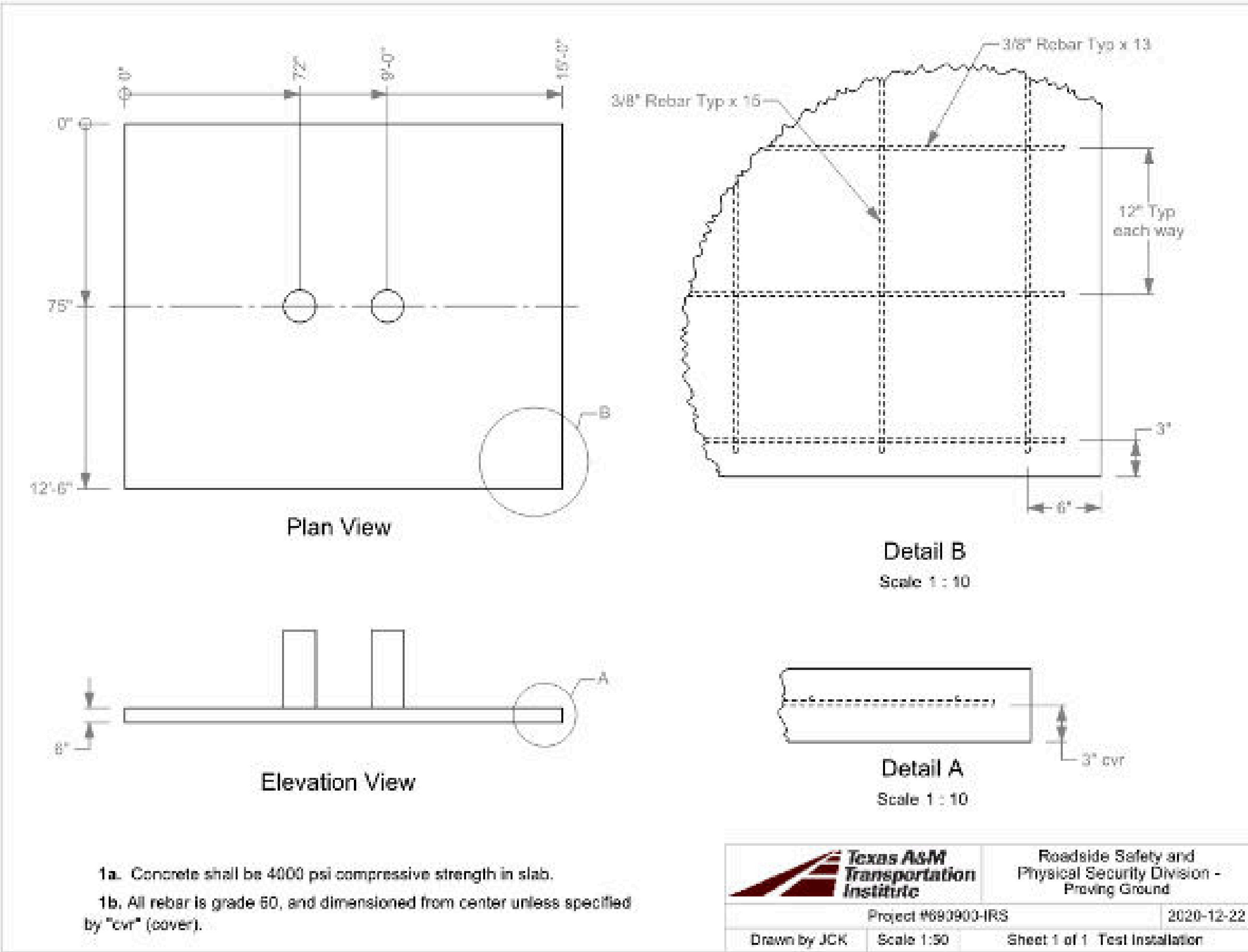
A	69.75	F	71.00	K	17.25	P	28.00	U	39.50
B	59.00	G	24.25	L	28.00	Q	20.25	V	10.50
C	44.00	H	24.54	M	16.25	R	100.00	W	10.25
D	43.37	I	24.25	N	28.00	S	142.00	X	15.00
E	100.00	J	29.25	O	23.00	T	16.00	Y	14.75

Mass Distribution: lb

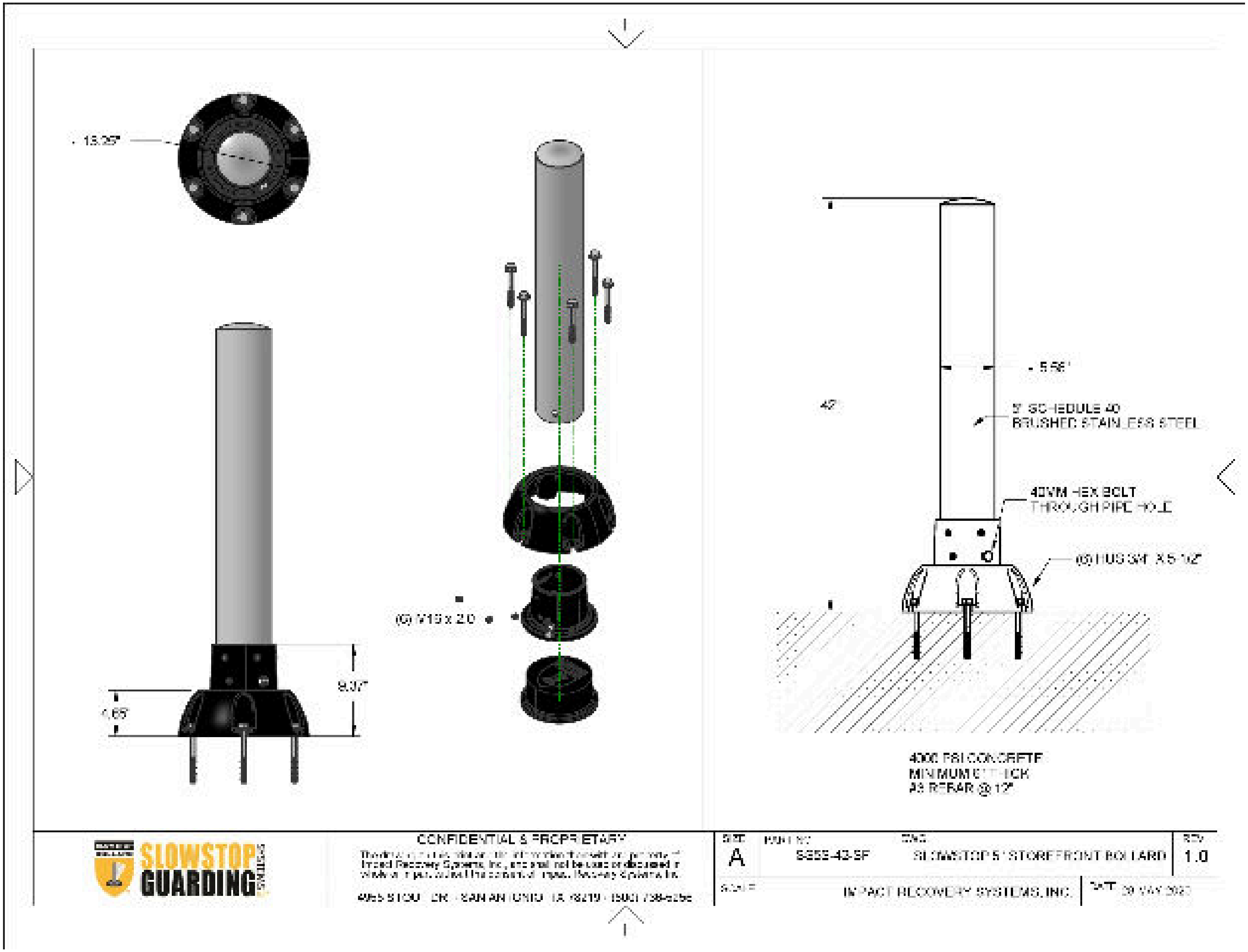
LF:	RF:	LR:	RR:
1390	1430	1070	1090

Mass: lb	Gross Static
M_{front}	2820
M_{rear}	2160
M_{Total}	4980

APPENDIX C. DETAILS OF SURROUNDING CONCRETE AREA SLAB



APPENDIX D. DETAILS OF SLOWSTOP® BOLLARD



SLOWSTOP® STOREFRONT BOLLARD

DETAILED INSTALLATION INSTRUCTIONS

www.slowstop.com/resources/installation

Materials

1—Base
1—Elastomer
1—Adapter with Set-Screws
1—Bollard Pipe
6—Anchors

Tools Required

Hammer Drill
3/4" Hammer Drill Bit
Impact Wrench
1-1/8" Impact Socket
Vacuum or Compressed Air with Nozzle
8mm Allen Wrench
Adjustable Wrench

Notes

1. Assembly and installation should be performed by qualified personnel only.
2. Installation to be performed in unbroken concrete only. Anchor holes should be 5" from any edge.
3. Bollards must be properly sized for expected loads and speeds. Consult www.slowstop.com.
4. Study Figure 1 to understand the arrangement of all parts.
5. Pipe used must be as specified by SlowStop.

Installation and Assembly

1. Layout and mark final location using the base as a guide. Remove base. *Note: Keep the bollard 0.32 x height away from any solid object to allow for tilting.*
2. Place the elastomer in the center of the location and place adapter on top of elastomer.
3. Fit base over the adapter so that it rests on the adapter flange and covers the elastomer.
4. Again using the base as a guide, drill six holes at least 5-1/2" deep. Clean out the holes from concrete dust.
5. Tighten the concrete screw Anchors in a star pattern, compressing the elastomer and making the base flush to the concrete. Anchor head must be tightened flush to base.
6. Insert the tube into the adapter and align the pipe hole with one screw hole. Insert and tighten the 40mm hex screw through the adapter and that hole. Firmly tighten the rest of the set-screws.
7. When complete, the assembly should appear like Figure 2.

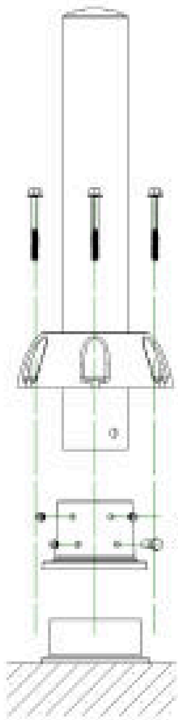


Figure 1

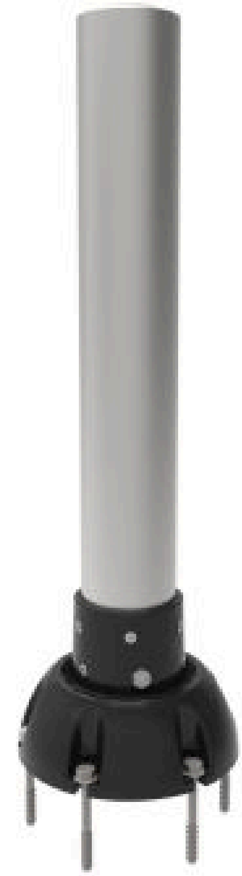


Figure 2

> Note: Do not concrete fill the bollard. The system is designed for the pipe to be the first point of bending

Rev. A(05/20)

WWW.SLOWSTOP.COM
(210)736-4477

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

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

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

Roberto A Davila
Quality Assurance Manager

HEAT NO.:3098967 SECTION: REBAR 10MM (#3) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 09/01/2020 MELT DATE: 08/02/2020 Cert. No.: 83200341 / 098967A353	S O L D T O	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	S H I P T O	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83200341 BOL#: 73758772 CUST PO#: 861133 CUST P/N: DLVRY LBS / HEAT: 4212.000 LB DLVRY PCS / HEAT: 560 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.46%	Bend Test Diameter	1.313IN		
Mn	0.74%				
P	0.010%				
S	0.034%				
Si	0.20%				
Cu	0.31%				
Cr	0.10%				
Ni	0.11%				
Mo	0.034%				
V	0.000%				
Cb	0.003%				
Sn	0.011%				
Al	0.001%				
Yield Strength test 1	72.6ksi				
Tensile Strength test 1	110.1ksi				
Elongation test 1	14%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.52				
Bend Test 1	Passed				

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

REMARKS :

Page 1 OF 1 09/02/2020 13:35:15

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

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

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

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3100064 SECTION: REBAR 13MM (#4) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 09/16/2020 MELT DATE: 09/16/2020 Cert. No.: 83214280 / 100064A130	SOLD TO: CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO: CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900

Delivery#: 83214280
BOL#: 73778492
CUST PO#: 862367
CUST P/N:
DLVRY LBS / HEAT: 48202.000 LB
DLVRY PCS / HEAT: 3608 EA

Characteristic	Value	Characteristic	Value
C	0.44%	Bend Test Diameter	1.750IN
Mn	0.87%		
P	0.009%		
S	0.041%		
Si	0.20%		
Cu	0.27%		
Cr	0.14%		
Ni	0.10%		
Mo	0.042%		
V	0.000%		
Cb	0.001%		
Sn	0.008%		
Al	0.000%		
Yield Strength test 1	65.7ksi		
Tensile Strength test 1	104.2ksi		
Elongation test 1	13%		
Elongation Gage Lgth test 1	8IN		
Tensile to Yield ratio test1	1.59		
Bend Test 1	Passed		

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

REMARKS :

Texas A&M Transportation Institute	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Issue Date: 2018-06-18
Quality Form	Prepared by: Wanda L. Menges Approved by: Darrell L. Kuhn	Revision 6	Page 1 of 1

The information contained in this document is confidential to TTI Proving Ground.

Project No: 690900-IRS **Casting Date:** 9/25/2020 **Mix Design (psi):** 4000 psi

Name of Technician Taking Sample: Teracon

Name of Technician Breaking Sample: Teracon

Signature of Technician Taking Sample: Teracon

Signature of Technician Breaking Sample: Teracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
1	7212	6300513	100% of slab

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
See attached Reports from Terracon					

CUSTOMER'S COPY

TICKET NO.

6300511

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
12:33	12:36	12:56	1:00	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST ________ GAL.
ALLOWABLE WATER (withheld from batch) 13.2 GAL.
TEST CYLINDER TAKEN ☐ YES ☐ NO BY ________
CYLINDER TAKEN ☐ BEFORE ☐ AFTER WATER

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

CUSTOMER SIGNATURE
X

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

CUSTOMER NAME AND DELIVERY ADDRESS
TEXAS A & M UNIVERSI
TTI-RIVERSIDE CAMPUS

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
417	7212	2018	5.0	690900-IR	

DRIVER NAME: CHARLES PALOMBA DATE: 9/25/20

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
783650	9WM50	8.00	8.00

LOAD QUANTITY	PRODUCT CODE		DESCRIPTION	UNIT PRICE	AMOUNT
8.00	CYDS	89240520	CON,RB,2400,AE		
1.00	EA	12902	FREIGHT CHARGE		

SPECIAL DELIVERY INSTRUCTIONS
RIGHT 2818, RIGHT LEONARD, RIGHTHWY 47 LEFT INTO RELLIS CAMPUSTHEY WILL YOU at the round about

SALES TAX

TOTAL

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

FOR OFFICE USE ONLY **FORM:**

Truck 7212 Driver 91C11s User User Disp Ticket Num 6300511 Ticket ID 86740 Time Date 12:23 9/25/20
Load Size 8.00 CYDS Mix Code 89240520 Returned Qty Mix Age Seq D Load ID 87869

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
1"PR	1306 lb	10552 lb	10548 lb	0.17%	0.78% M	9 gl
3/8"PR	507 lb	4083 lb	4108 lb	0.50%	0.60% M	3 gl
SAND-1	1412 lb	11951 lb	11948 lb	-0.11%	3.50% M	75 gl
CMT-I/II	432 lb	3456 lb	3420 lb	-0.63%		
FLYASH-C	108 lb	864 lb	860 lb	* -0.46%		
WTR	258 lb	1142 lb	1132 lb	-0.98%		136 gl
[illegible]	17 oz	128 oz	129 oz	0.55%		

Actual Num Batches: 1
Load Total: 32856 lb Design 0.462 Water/Cement 0.466 ! Design 228.7 gl Actual 226.4 gl To Add: 13.2 gl
Slump: 5.00 in % Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.5 gl CYD

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0142
Service Date: 09/25/20
Report Date: 09/29/20
Task: PO #690900-IRS

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

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

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength: 4,000 psi @ 28 days

Mix ID: R9Z40528
Supplier: Martin Marietta
Batch Time: 1223 **Plant:** 617
Truck No.: 7212 **Ticket No.:** 6300513

Sample Information

Sample Date: 09/25/20 **Sample Time:** 1306
Sampled By: Jonathan Whitmore
Weather Conditions: Clear, No Wind
Accumulative Yards: 8/8 **Batch Size (cy):** 8
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Bollards
Placement Location: 690900-IRS

Field Test Data

Test	Result	Specification
Slump (in):	6 1/4	Not Specified
Air Content (%):	1.1	Not Specified
Concrete Temp. (F):	85	40 - 95
Ambient Temp. (F):	77	40 - 95
Plastic Unit Wt. (pcf):	148.8	Not Specified
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Specimen ID	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Maximum Load (lbs)	Compressive Strength (psi)	Fracture Type	Tested By
1	A	6.00	28.27		10/26/20	31 F	136,340	4,820	1	SLS
1	B	6.00	28.27		10/26/20	31 F	133,510	4,720	2	SLS
1	C	6.00	28.27		10/26/20	31 F	134,060	4,740	2	SLS
1	D					Hold				

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

Comments: F = Field Cured

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Jonathan Whitmore **Start/Stop:** 1230-1330
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Alex Dunigan, P.E.
(1) Texas Transportation Institute, Bill Griffith

Reviewed By:

Alexander Dunigan
Project Manager

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

CR0001, 11-16-12, Rev.6

Page 1 of 1

APPENDIX F. *ASTM F3016-19* TEST S10 ON SLOWSTOP® BOLLARD

F.1 SEQUENTIAL PHOTOGRAPHS

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

0.500 s

0.600 s

0.700 s

Figure F.1. Sequential Photographs for Test No. 690900-IRS B2 (Perpendicular View).

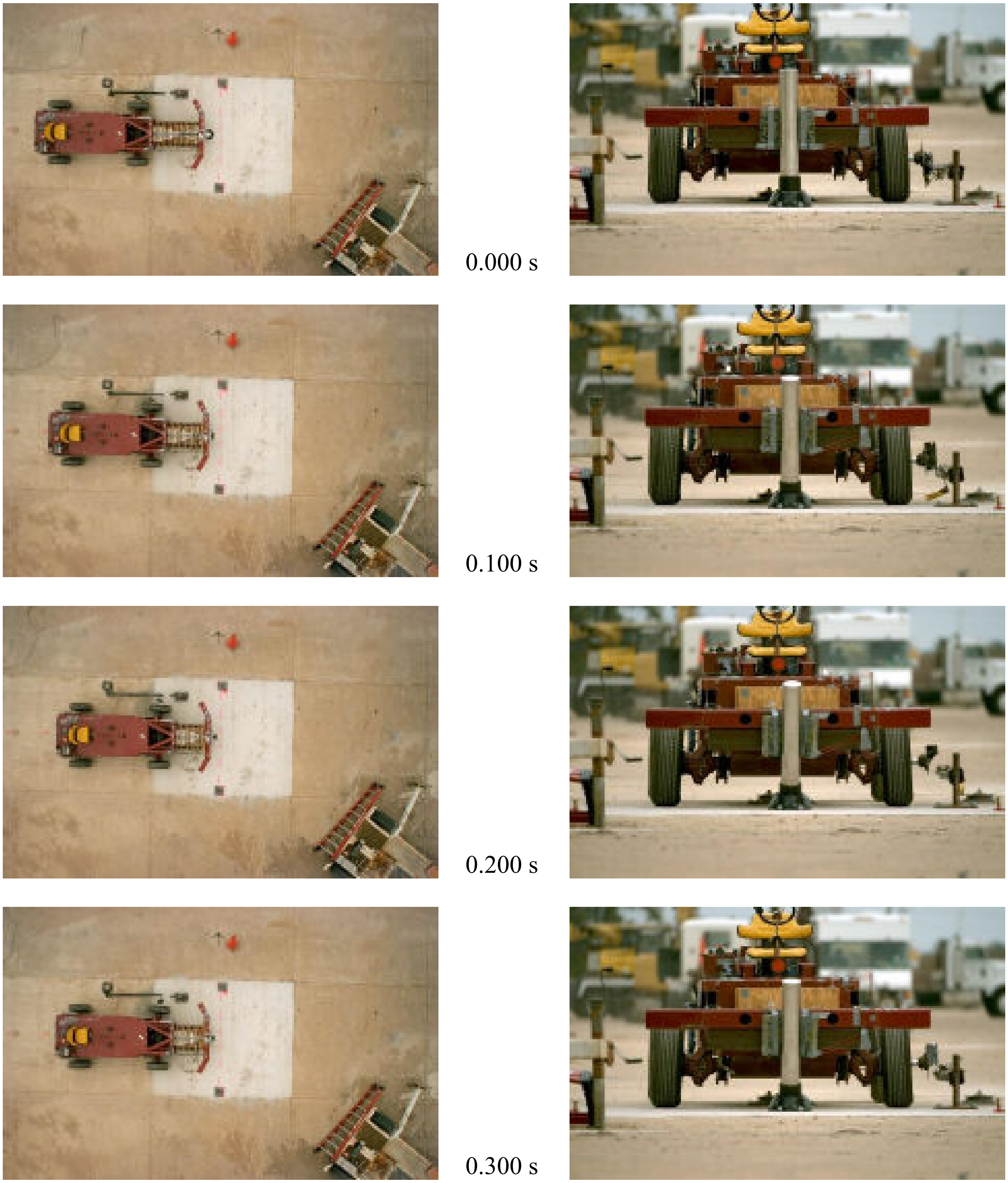


Figure F.2. Sequential Photographs for Test No. 690900-IRS B2 (Overhead and Frontal Views).

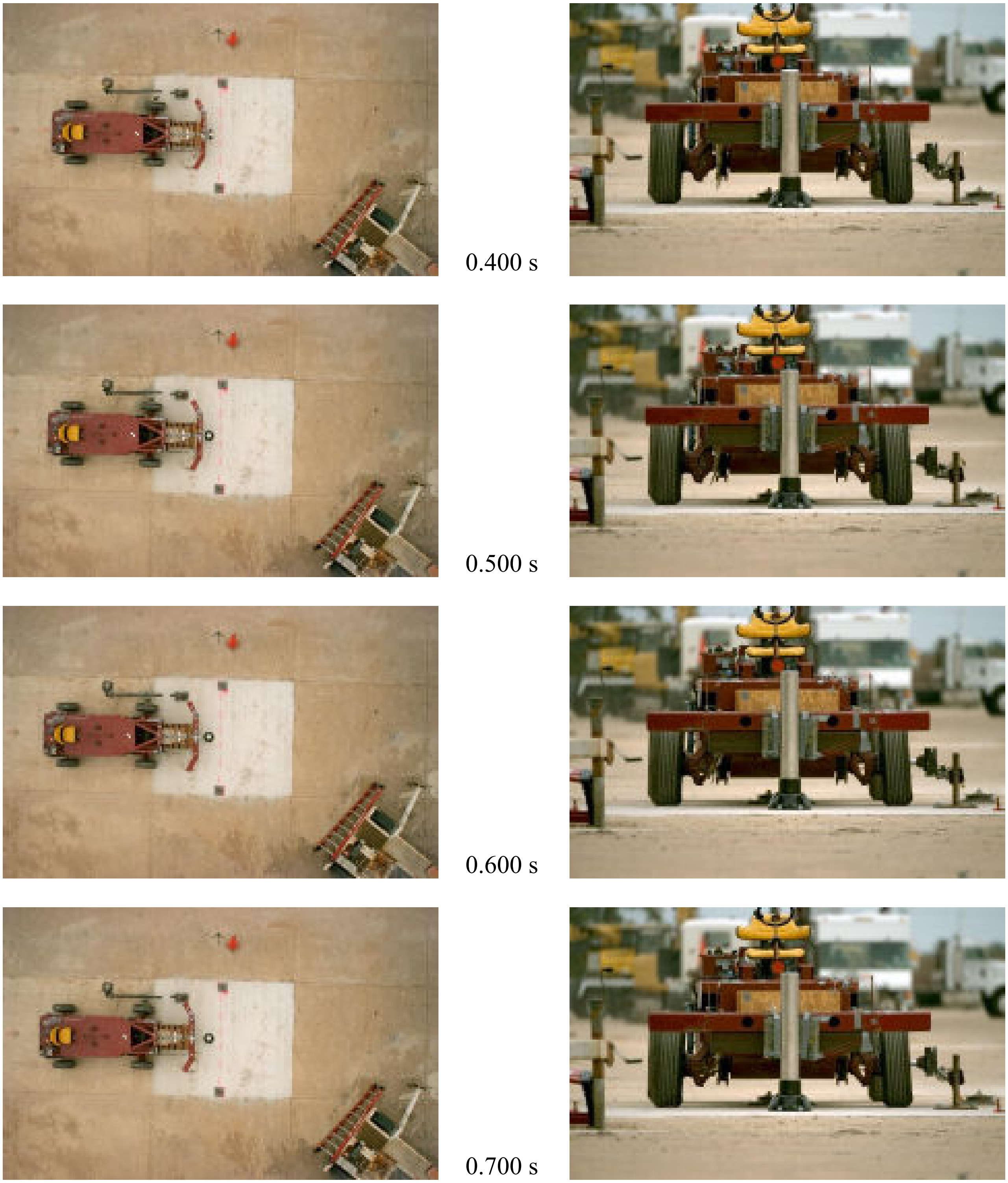
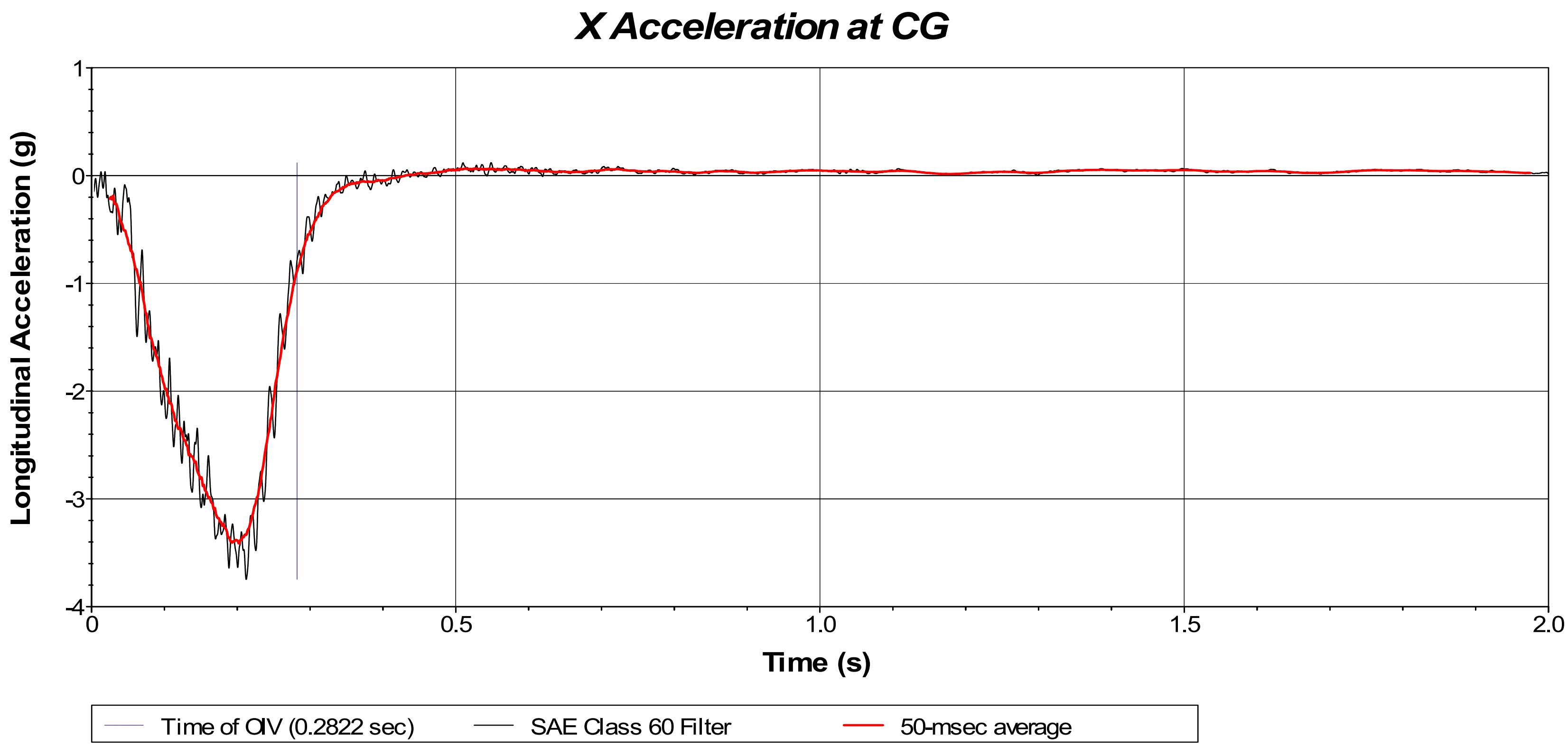
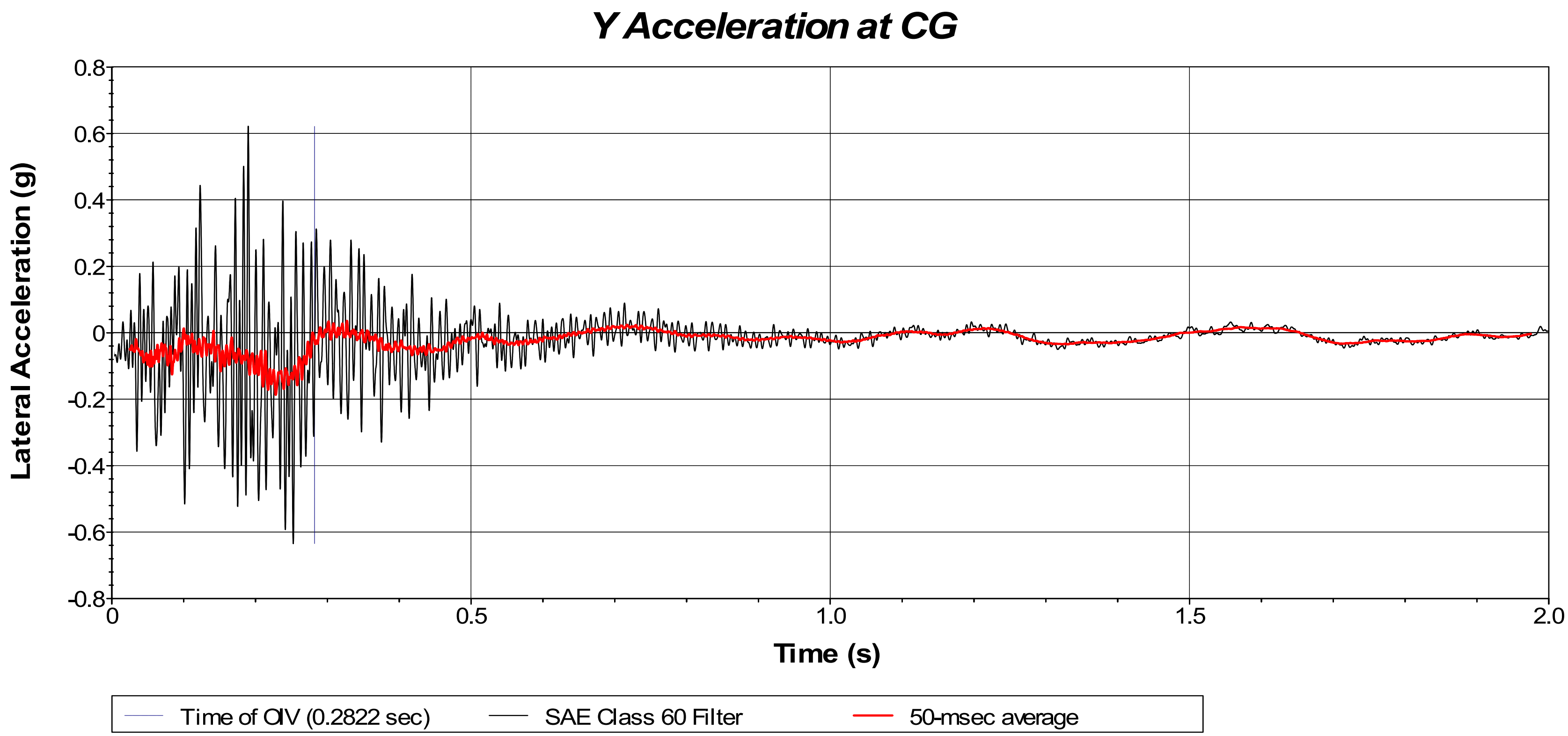


Figure F.2. Sequential Photographs for Test No. 690900-IRS B2 (Overhead and Frontal Views) (Continued).



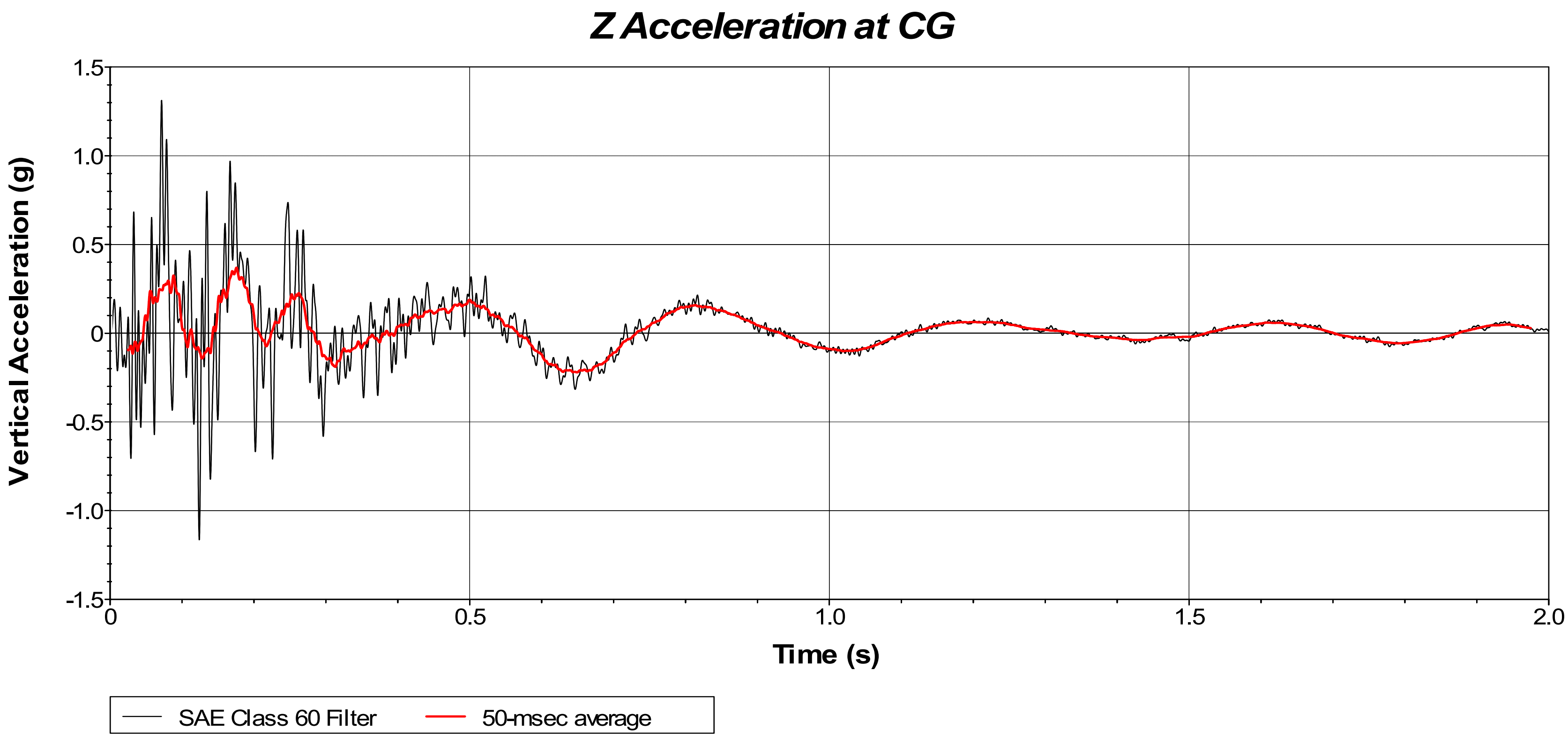
Test Number: 690900-IRS B2
Test Standard Test Number: ASTM F3016-19 Test S10
Test Article: SlowStop® Bollard
Test Vehicle: 4980 lb
Inertial Mass: 4980 lb
Impact Speed: 10.4 mi/h
Impact Angle: 90.5 degrees

Figure F.3. Vehicle Longitudinal Accelerometer Trace for Test No. 690900-IRS B2 (Accelerometer Located at Center of Gravity).



Test Number: 690900-IRS B2
Test Standard Test Number: ASTM F3016-19 Test S10
Test Article: SlowStop® Bollard
Test Vehicle: 4980 lb
Inertial Mass: 4980 lb
Impact Speed: 10.4 mi/h
Impact Angle: 90.5 degrees

Figure F.4. Vehicle Lateral Accelerometer Trace for Test No. 690900-IRS B2 (Accelerometer Located near Center of Gravity).



Test Number: 690900-IRS B2
Test Standard Test Number: ASTM F3016-19 Test S10
Test Article: SlowStop® Bollard
Test Vehicle: 4980 lb
Inertial Mass: 4980 lb
Impact Speed: 10.4 mi/h
Impact Angle: 90.5 degrees

Figure F.5. Vehicle Vertical Accelerometer Trace for Test No. 690900-IRS B2 (Accelerometer Located near Center of Gravity