Roadside Safety Pooled Fund

Texas A&M Transportation Institute
Proving Ground

Test Report No. 616151-01
Test Report Date: August 2022

DESIGN AND EVALUATION OF A *MASH* TL-2 PERMANENT LOW-PROFILE BARRIER

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16. Abstract

The purpose of the tests reported herein was to assess the performance of the Permanent Low-Profile Barrier according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware, Second Edition (*MASH*) (1). The crash tests were performed in accordance with *MASH* Test Level 2 (TL-2), which requires two crash tests

1. ***MASH* Test 2-10:** An 1100C vehicle weighing 2420 lb impacting the longitudinal barrier while traveling at 44 mi/h and 25 degrees.
2. ***MASH* Test 2-11:** A 2270P vehicle weighing 5000 lb impacting the longitudinal barrier while traveling at 44 mi/h and 25 degrees.

This report provides details on the Permanent Low-Profile Barrier, the crash tests and results, and the performance assessment of the Permanent Low-Profile Barrier for *MASH* TL-2 longitudinal barrier evaluation criteria.

The Permanent Low-Profile Barrier met the performance criteria for *MASH* TL-2 longitudinal barriers.

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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		
in2	square inches	645.2	square millimeters	mm2
ft2	square feet	0.093	square meters	m2
yd2	square yards	0.836	square meters	m2
ac	acres	0.405	hectares	ha
mi2	square miles	2.59	square kilometers	km2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft3	cubic feet	0.028	cubic meters	m3
yd3	cubic yards	0.765	cubic meters	m3
	NOTE: volumes greater than 1000L shall be shown in m3			
		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/in2	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		
mm2	square millimeters	0.0016	square inches	in2
m2	square meters	10.764	square feet	ft2
m2	square meters	1.195	square yards	yd2
ha	hectares	2.47	acres	ac
km2	Square kilometers	0.386	square miles	mi2
		VOLUME		
mL	milliliters	0.034	fluid ounces	oz
L	liters	0.264	gallons	gal
m3	cubic meters	35.314	cubic feet	ft3
m3	cubic meters	1.307	cubic yards	yd3
		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/in2

*SI is the symbol for the International System of Units

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Chapter 1. INTRODUCTION

The purpose of the tests reported herein was to assess the performance of a TL-2 Permanent Low-Profile Barrier as contracted by the Roadside Safety Pooled Fund via the Florida Department of Transportation (WsDOT) according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware, Second Edition (*MASH*) (1). The crash tests were performed in accordance with *MASH* Test Level 2, which requires two crash tests (see section 4.1 for details on the tests performed).

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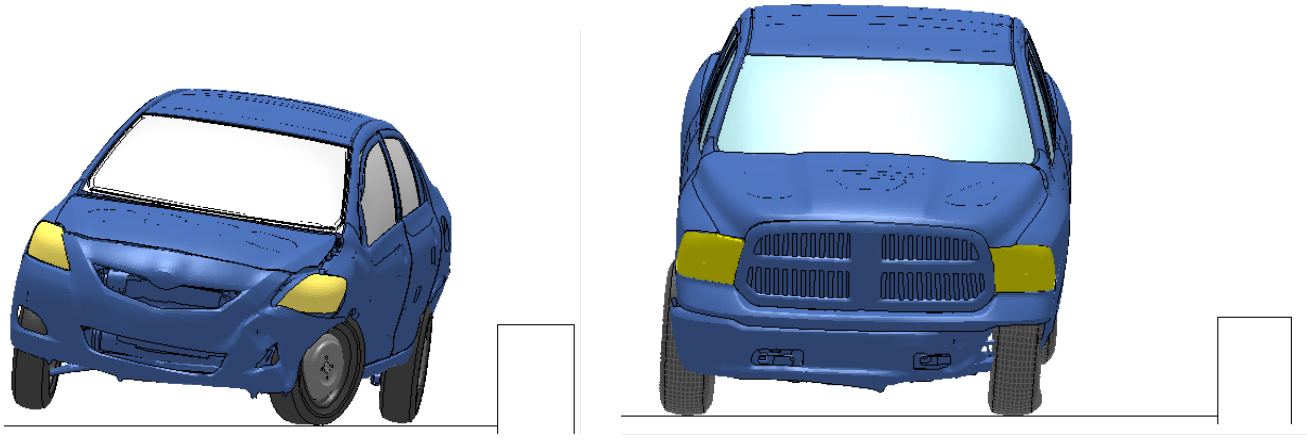
Chapter 2. DESIGN DEVELOPMENT

To develop a permanent low-profile barrier, the research team investigated various low-profile concrete barrier shapes and concluded that a rectangular shape is a good candidate to be utilized due to its simplicity in construction. The research team took into account various criteria to develop a design and to evaluate the system, considering also*MASH* requirements. These criteria included height, occupant risk factors, and structural adequacy. The availability of a gutter at the toe of the barrier was investigated, and the researchers concluded that not having a gutter is a more critical case. While the typical shape of the gutter is expected not to significantly influence the behavior and stability of the impacting vehicles, the absence of the gutter would effectively decrease the effective height of the barrier, making it more critical for vehicle containment and stability. The analysis methodologies used to evaluate these criteria are presented below.

For a barrier system to meet *MASH* requirements, its height must be sufficient to contain and redirect the impacting vehicle in a stable manner. Currently, there is no published information regarding a minimum recommended height for *MASH* TL-2. Most Departments of Transportation (DOTs) employ barriers within a height range of 18 to 22 inches at low-speed locations to improve sight distance as well as to provide an alternate solution that will unobtrusively integrate with the adjacent surroundings[2].

The research team evaluated *MASH* TL-2 impacts against various barrier heights and concluded that the 20-inch tall vertical face design provided satisfactory vehicle stability under TL-2 impact conditions (Figure 2.1).



(a) (b)

Figure 2.1. Post-impact vehicle stability (a) Small Passenger Car, (b) Pickup Truck

Another design element to keep in mind was the Working Width (i.e., Zone of Intrusion) upon impact. Utilizing predictive computer simulation, the research team investigated the working width to report on system characteristics. Figures 2.2 and 2.3 illustrate the working widths and their heights for a pickup truck and a small car, respectively.

Figure 2.2. Predicted working width for the pickup truck under TL-2 impact condition.

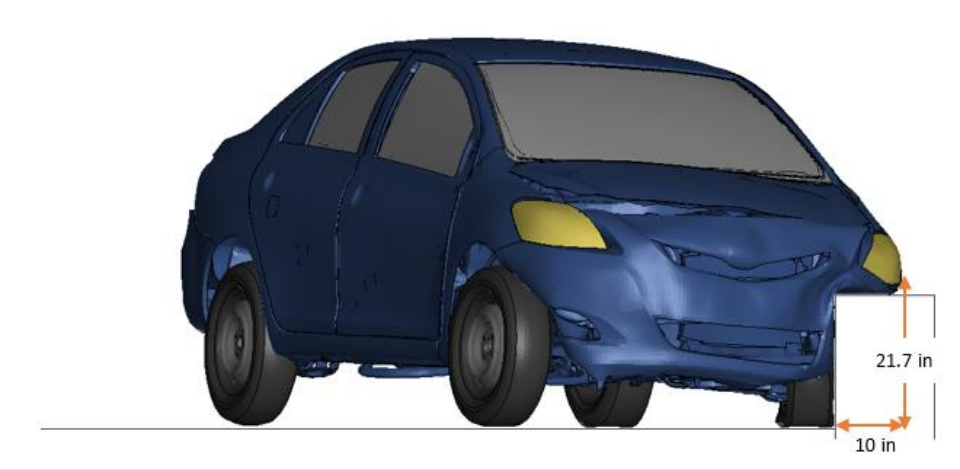


Figure 2.3. Predicted working width for the small car under TL-2 impact condition.

Furthermore, the research team recorded the occupant risk factors from the computer simulation effort. The predicted values are presented in Tables 2.1 and 2.2, and all were well within *MASH* limits.

Table 2.1. Predicted Occupant Risk Factors for Test 2-11 (Pickup Truck Impact).

Evaluation Criteria		Value	MASH 2016 Limits
OIV, m/s (ft/s)	Longitudinal	3.8 (12.5)	12.2 (40)
	Lateral	5.4 (17.7)	12.2 (40)
ORA, g's	Longitudinal	2.8	20.49
	Lateral	8.5	20.49
Max. Angular Disp., deg.	Roll	18.1	75
	Pitch	6.4	75
	Yaw	32.4	not required

Table 2.2. Predicted Occupant Risk Factors for Test 2-10 (Small Car Impact).

Evaluation Criteria		Value	MASH 2016 Limits
OIV, m/s (ft/s)	Longitudinal	5.4 (17.7)	12.2 (40)
	Lateral	6.6 (21.6)	12.2 (40)
ORA, g's	Longitudinal	1.5	20.49
	Lateral	9.8	20.49
Max. Angular Disp., deg.	Roll	14.6	75
	Pitch	3.7	75
	Yaw	34.7	not required

The structural adequacy of the system was evaluated according to AASHTO LRFD Section 13. The analysis of the 20-in tall barrier revealed that the proposed design presented in the next chapter provides adequate resistance and meets the design criteria for MASH TL-2 impact conditions.

Chapter 3. SYSTEM DETAILS

3.1. TEST ARTICLE AND INSTALLATION DETAILS

The installation consisted of two cast-in-place, steel reinforced, low-profile concrete parapets cast onto a steel reinforced concrete deck. The upstream (south) low-profile parapet measured 20 inches tall, 12 inches wide, and 40 feet long, and had a 1-inch chamfer running along its traffic and field side top edges. The parapet's field side was set flush with the field side edge of the reinforced concrete deck, which measured 30 inches wide, 16 inches deep in the ground, and 80 feet 2 inches long. The downstream parapet (north) was cast in-line with the upstream (south) parapet, with a 2-inch gap between the two. The downstream parapet was identical to the first, with the only difference being a barrier height of 22 inches. The downstream parapet height was constructed to provide an alternative system with a taller height, in case of containment failure of the 20-inch parapet portion.

Figure 3.1 presents the overall information on the Permanent Low-Profile Barrier, and Figure 3.2 provides photographs of the installation. Appendix A provides further details on the Permanent Low-Profile Barrier. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by MBC Management and supervised by TTI Proving Ground personnel.

3.2. DESIGN MODIFICATIONS DURING TESTS

No modifications were made to the installation during the testing phase.

3.3. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to install/construct the Permanent Low-Profile Barrier. Table 3.1 shows the average compressive strengths of the concrete on the day of the first test on May 19, 2022:

Table 3.1 Concrete Strength.

Location	Design Strength (psi)	Avg. Strength (psi)	Age (days)	Detailed Location
Deck	3400	3905	30	Left half of deck
Deck	3400	4497	17	Right half of deck and left half of Parapet
Parapet	3400	4560	20	Right half of Parapet

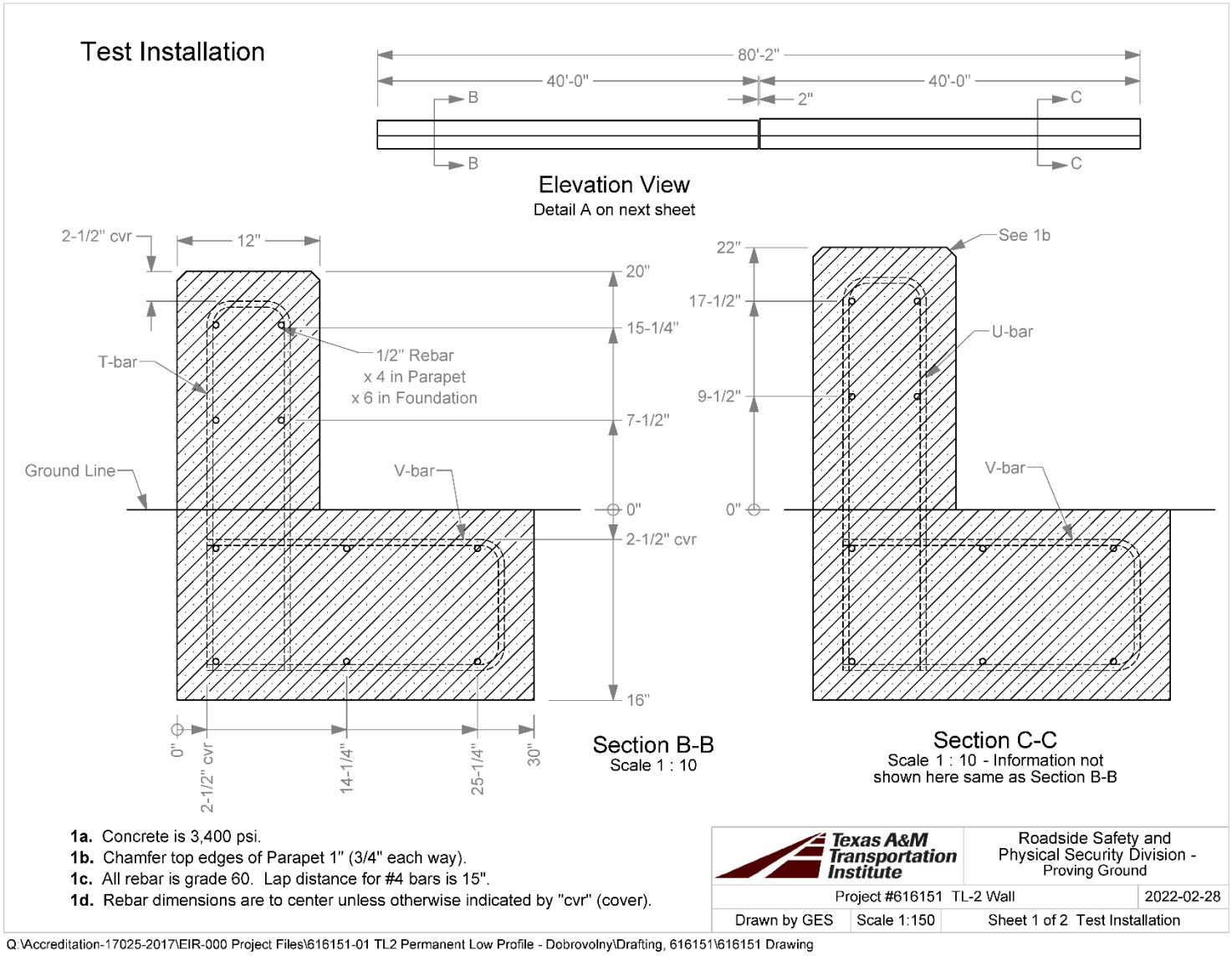


Figure 3.1 Details of Permanent Low-Profile Barrier.

Figure 3.2 Permanent Low-Profile Barrier prior to Testing.

Chapter 4. TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1. CRASH TEST PERFORMED/MATRIX

Table 4.1 shows the test conditions and evaluation criteria for *MASH* TL-2 for longitudinal barriers. The target critical impact points (CIPs) for each test were determined using the information provided in *MASH* Section 2.2.1 and Section 2.3.2. Figure 4.1 shows the target CIP for *MASH* Tests 2-10 and 2-11on the Permanent Low-Profile Barrier.

Table 4.1 Test Conditions and Evaluation Criteria Specified for *MASH* TL-2 Longitudinal Barriers.

Test Article	Test Designation	Test Vehicle	Impact Conditions		Evaluation Criteria
			Speed	Angle	
Longitudinal Barrier	2-10	1100C	44 mi/h	25°	A, D, F, H, I
	2-11	2270P	44 mi/h	25°	A, D, F, H, I

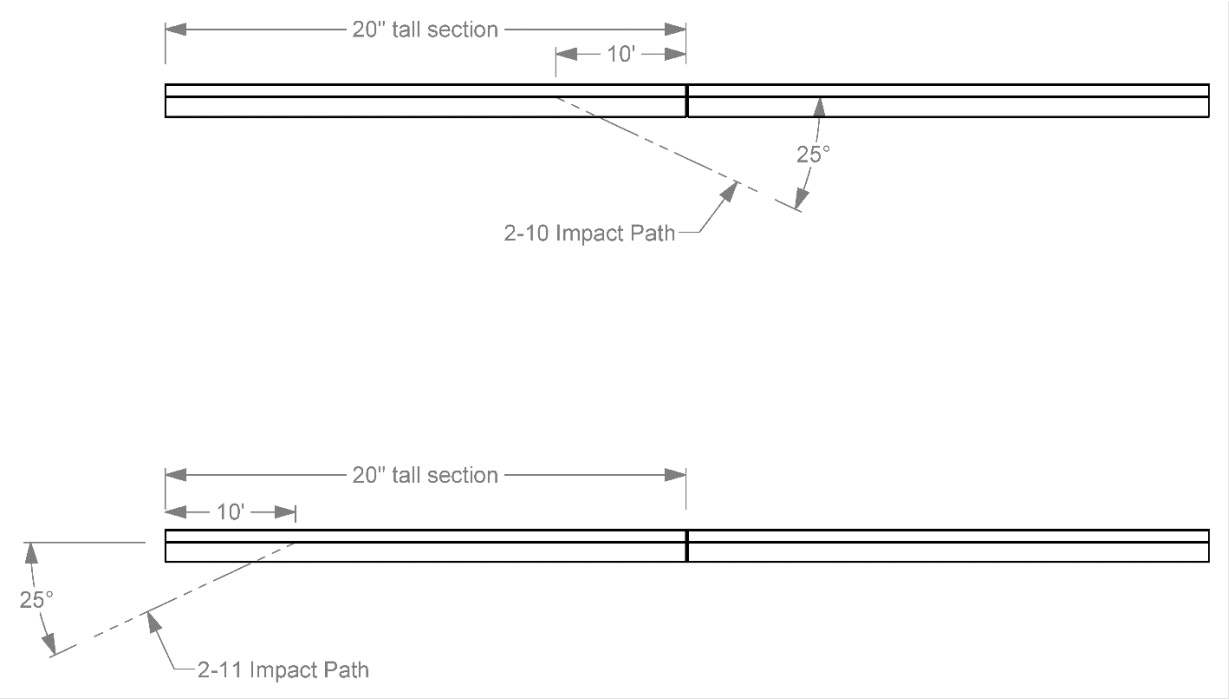


Figure 4.1 Target CIP for *MASH* TL-2 Tests on Permanent Low-Profile Barrier.

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

4.2. 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 4.1 lists the test conditions and evaluation criteria required for *MASH* TL-2, and Table 4.2 provides detailed information on the evaluation criteria.

Table 4.2 Evaluation Criteria Required for *MASH* Testing.

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.	10, 11
Occupant Risk	D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone.	10, 11
		Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of *MASH*.	
	F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	10, 11
	H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	10, 11
	I.	The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	10, 11

Chapter 5. TEST CONDITIONS

5.1. 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 sites selected for construction and testing are along the edge of an out-of-service apron/runway. The apron/runways 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.

5.2. VEHICLE TOW AND GUIDANCE SYSTEM

For the testing utilizing the 1100C and 2270P vehicles, each 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.

5.3. DATA ACQUISITION SYSTEMS

5.3.1. 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 0.0001-s intervals, and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation being initial impact. Rate of rotation data is measured with an expanded uncertainty of ±0.7 percent at a confidence factor of 95 percent (k = 2).

5.3.2. Anthropomorphic Dummy Instrumentation

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

According to *MASH*, use of a dummy in the 2270P vehicle is optional, and no dummy was used in the test.

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5.3.3. 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 Permanent Low-Profile Barrier. 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 6. *MASH* TEST 2-10 (CRASH TEST NO. 616151-01-2)

6.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 6.1 for details on *MASH* impact conditions for this test. Figure 6.1 depicts the target impact setup.

Figure 6.1 Permanent Low-Profile Barrier/Test Vehicle Geometrics for Test 616151-01-2.

Table 6.1 Impact Conditions for *MASH* 2-10 616151-01-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	44	± 2.5 mi/h	45.1
Impact Angle (deg)	25	± 1.5°	24.3
Vehicle Inertial Weight (lbs)	2420	± 55 lbs	2447
Impact Severity (kip-ft)	25	≥25 kip-ft	28.2
Impact Location	120 inches downstream from the edge of the concrete barrier	± 12 inches	124.2 inches downstream from the edge of the concrete barrier
Exit Parameters			
Speed (mi/h)		30.8	
Trajectory (degrees)		7.2	
Heading (degrees)		11.0	
Brakes applied post impact (seconds)		3.6	
Vehicle at rest position		92 ft downstream of impact point 52 ft to the traffic side 90° left	
Comments: Vehicle remained upright and stable Vehicle crossed exit box* 45 ft d/s from loss of contact.			

*not less than 32.8 ft downstream from loss of contact for cars and pickups is optimal

6.2. WEATHER CONDITIONS

Table 6.2 Weather Conditions 616151-01-2.

Date of Test	Temperature (°F)	Relative Humidity (%)
May 23, 2022 AM	76	79
Wind Direction (degrees)	**Vehicle Traveling (degrees)**	**Wind Speed (mi/h)**
42	195	5

6.3. TEST VEHICLE

Figure 6.2 shows the 2017 Nissan Versa used for the crash test. Table 6.3 shows the vehicle measurements. Table C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

Figure 6.2 Test Vehicle before Test 616151-01-2.

Table 6.3 Vehicle Measurements 616151-01-2.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a](lbs)	165	N/A	165
Curb Weight (lbs)	2420	±55	2402
Gross Static[a] (lbs)	2585	±55	2612
Wheelbase (inches)	98	±5	102.4
Front Overhang (inches)	35	±4	32.5
Overall Length (inches)	169	±8	175.4
Overall Width (inches)	65	±3	66.7
Hood Height (inches)	24	±4	30.5
Track Width[b] (inches)	56	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	41.4
CG above Ground[c,d] (inches)	N/A	N/A	N/A

a - If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy
b - Average of front and rear Axles
c - For "test inertial" mass
d – 2270P vehicle must meet minimum c.g. height requirement

6.4. TEST DESCRIPTION

Table 6.4 lists events that occurred during Test No. 616151-01-2. Figures C.1 and C.2 in Appendix C.2 present sequential photographs during the test.

Table 6.4 Events during Test 616151-01-2.

Time (s)	Events
0.0000	Vehicle impacts the installation
0.0360	Vehicle began to redirect
0.0670	Front left side tire lifts off of pavement
0.0940	Rear left side tire lifts off of pavement
0.3620	Front right tire contacts the pavement
0.4870	Vehicle lost contact with the rail and exited the test article traveling 30.8 mi/h at a trajectory of 7.2 degrees and a vehicle heading of 11.0 degrees

6.5. DAMAGE TO TEST INSTALLATION

There was some scuffing and gouging at impact, and the soil was disturbed at the traffic side edge of the deck. No cracking or other damage to the installation was observed. Figure 6.3 shows the damage to the Permanent Low-Profile Barrier. Table 6.5 describes the damage to the Permanent Low-Profile Barrier.

Table 6.5 Damage to Permanent Low-Profile Barrier 616151-01-2.

Test Parameter	Measured
Permanent Deflection/Location	There was no permanent deflection
Dynamic Deflection	0.6 inches toward field side
Working Width* and Height	23.4 inches, at a height of 16.9 inches Front Passenger Side Headlight Unit

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

Figure 6.3 Permanent Low-Profile Barrier after Test 616151-01-2.

6.6. DAMAGE TO TEST VEHICLE

Figure 6.4 and Figure 6.5 shows the damage sustained by the vehicle. Table 6.6 provide details on the interior and exterior damage to the vehicle. Tables C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.

Figure 6.4 Test Vehicle after Test 616151-01-2.

Figure 6.5 Interior of Test Vehicle after Test 616151-01-2.

Table 6.6 Damage to Vehicle 616151-01-2.

Test Parameter	**Specification**	**Measured**
Roof	≤ 4.0 inches	0 inches
Windshield	≤ 3.0 inches	0 inches
A and B Pillars	≤ 5.0 overall / ≤ 3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤ 9.0 inches	1 inch
Floor Pan/Transmission Tunnel	≤ 12.0 inches	0 inches
Side Front Panel	≤ 12.0 inches	0 inches
Front Door (above Seat)	≤ 9.0 inches	1 inch
Front Door (below Seat)	≤ 12.0 inches	0 inches
Side Windows	The side windows remained intact.	
Maximum Exterior Deformation	3 inches in the front plane at the right front corner at bumper height	
VDS 11FRQ3	CDC 11FREW3	
Fuel Tank Damage	None	
Description of Damage to Vehicle: The front bumper, right headlight, right front tire and rim, right strut, right front quarter fender, right rear rim, rear bumper, and windshield were all damaged. The right front door had a 2-inch gap at the top.		

6.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.7 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.

Table 6.7 Occupant Risk Factors for Test 616151-01-2.

Test Parameter	***MASH***	**Measured**	**Time**
OIV, Longitudinal (ft/s)	≤40.0	20.4	0.1000 s on right side of interior
OIV, Lateral (ft/s)	≤40.0	23.2	0.1000 s on right side of interior
Ridedown, Longitudinal (g)	≤20.49	1.9	0.3468 - 0.3568 s
Ridedown, Lateral (g)	≤20.49	3.8	0.3841 - 0.3941 s
THIV (m/s)	N/A	9.4	0.0977 s on right side of interior
ASI	N/A	1.9	0.0599 - 0.1099 s
50ms MA Longitudinal (g)	N/A	-10.6	0.0292 - 0.0792 s
50ms MA Lateral (g)	N/A	-13.3	0.0295 - 0.0795 s
50ms MA Vertical (g)	N/A	-2.7	0.0644 - 0.1144 s
Roll (deg)	≤75	29	3.4999 s
Pitch (deg)	≤75	5	1.4271 s
Yaw (deg)	N/A	92	3.4999 s
Comments:			

0.000 s

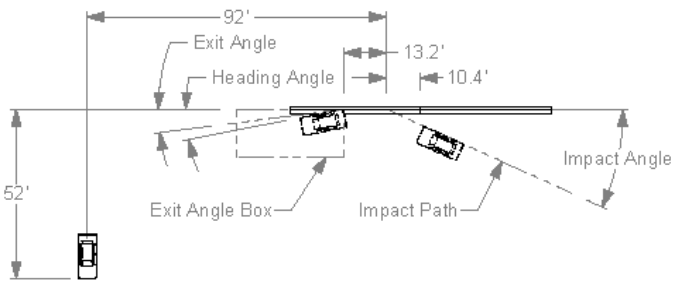
0.100 s

0.200 s

0.300 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 2-10
TTI Project No.	616151-01-2
Test Date	2022-05-23
TEST ARTICLE	
Type	Longitudinal Barrier
Name	TL-2 Permanent Low-Profile Concrete Barrier
Length	80 feet 2 inches
Key Materials	3400 PSI Concrete
Soil Type and Condition	AASHTO M147-65(2004), Type 1, Grade D Crushed Concrete
TEST VEHICLE	
Type/Designation	1100C
Year, Make and Model	2017 Nissan Versa
Curb Weight (lbs)	2402
Inertial Weight (lbs)	2447
Dummy (lbs)	165
Gross Static (lbs)	2612
IMPACT CONDITIONS	
Impact Speed (mi/h)	45.1
Impact Angle (deg)	24.3
Impact Location	124.2 inches downstream from edge of concrete barrier
Impact Severity (kip-ft)	28.2
EXIT CONDITIONS	
Exit Speed (mi/h)	30.8
Trajectory/Heading Angle (deg)	7.2 / 11.0
Exit Box Criteria	Crossed
Stopping Distance	92 feet downstream 52 feet to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	0.6
Permanent (inches)	None
Working Width / Height (inches)	23.4 / 16.9
VEHICLE DAMAGE	
VDS	11FRQ3
CDC	11FREW3
Max. Ext. Deformation	3 inches
Max Occupant Compartment Deformation	1 inch in the right kick panel and above the seat.

OCCUPANT RISK VALUES							
Long.OIV (ft/s)	20.4	Long. Ridedown (g)	1.9	Max 50ms Long. (g)	-10.6	Max Roll (deg)	29
Lat. OIV (ft/s)	23.2	Lat. Ridedown (g)	3.8	Max 50ms Lat. (g)	-13.3	Max Pitch (deg)	5
THIV (m/s)	9.4	ASI	1.9	Max 50ms Vert (g)	-2.7	Max Yaw (deg)	92



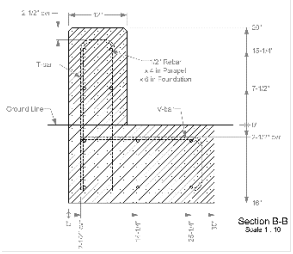


Figure 6.6 Summary of Results for *MASH* Test 2-10 on Permanent Low-Profile Barrier.

Chapter 7. *MASH* TEST 2-11 (CRASH TEST NO. 616151-01-1)

7.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 7.1for details on *MASH* impact conditions for this test. Figure 7.1 depicts the target impact setup.

Figure 7.1 Permanent Low-Profile Barrier/Test Vehicle Geometrics for Test 616151-01-1.

Table 7.1 Impact Conditions for *MASH* 2-11 616151-01-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	44	± 2.5 mi/h	44.2
Impact Angle (deg)	25	± 1.5°	24.9
Vehicle Inertial Weight (lbs)	5000	± 110 lbs	5058
Impact Severity (kip-ft)	52	≥52 kip-ft	58.6
Impact Location	120 inches downstream from the edge of the concrete barrier.	± 12 inches	118.4 inches downstream from the edge of the concrete barrier
Exit Parameters			
Speed		38.8 mi/h	
Trajectory		8°	
Heading		13°	
Brakes applied post impact		Brakes were not applied	
Vehicle at rest position		113 ft downstream of impact point 51 ft to the field side 100° left	
Comments: Vehicle remained upright and stable. Vehicle did not cross exit box			

*not less than 32.8 ft downstream from loss of contact for cars and pickups is optimal

7.2. WEATHER CONDITIONS

Table 7.2 Weather Conditions 616151-01-1.

Date of Test	Temperature (°F)	Relative Humidity (%)
May 19, 2022 AM	84	73
Wind Direction (degrees)	**Vehicle Traveling (degrees)**	**Wind Speed (mi/h)**
192	325	13

7.3. TEST VEHICLE

Figure 7.2 shows the 2017 RAM 1500 used for the crash test. Table 7.3 shows the vehicle measurements. Table C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

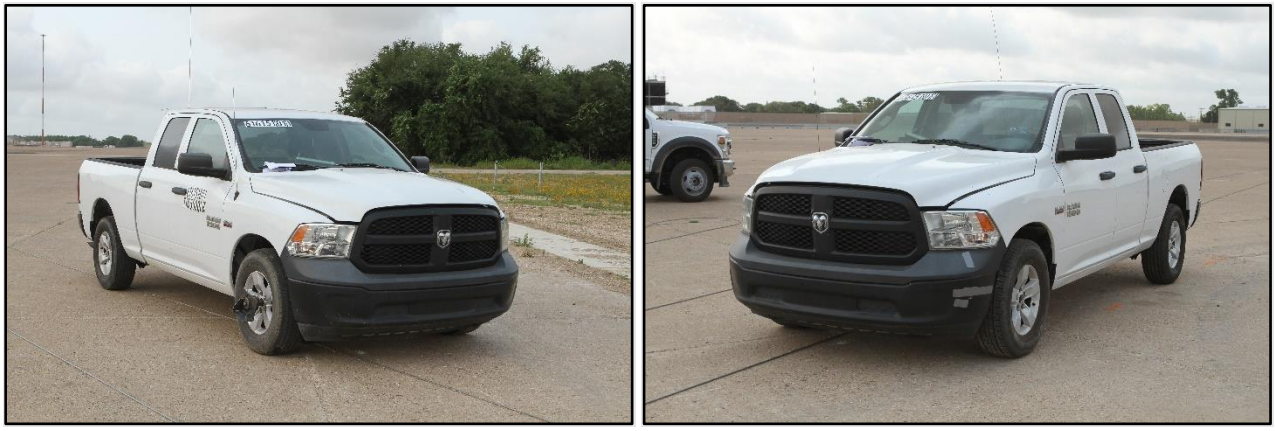


Figure 7.2 Test Vehicle before Test 616151-01-1.

Table 7.3 Vehicle Measurements 616151-01-1.

Test Parameter	*MASH*	Allowed Tolerance	Actual Measured
Dummy (if applicable)[a](lbs)	165	N/A	N/A
Curb Weight (lbs)	5000	N/A	5015
Gross Static[a] (lbs)	5000	± 110	5058
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40.0
Overall Length (inches)	237	±13	227.5
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46.0
Track Width[b] (inches)	67	±1.5	68.3
CG aft of Front Axle[c] (inches)	63	±4	61.7
CG above Ground[c,d] (inches)	28	≥28	28.6

a - If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy
b - Average of front and rear Axles
c - For "test inertial" mass
d – 2270P vehicle must meet minimum c.g. height requirement

7.4. TEST DESCRIPTION

Table 7.4 lists events that occurred during Test No. 616151-01-1. Figures C.1 and C.2 in Appendix C.2 present sequential photographs during the test.

Table 7.4 Events during Test 616151-01-1.

Time (s)	Events
0.0000	Vehicle impacts the installation
0.0770	Vehicle began to redirect
0.0950	Front right side tire lifts off of pavement
0.1400	Rear right tire lifts off of pavement
0.2780	Rear left side bumper contacts the parapet
0.4970	Vehicle lost contact with the rail and exited the test article traveling 38.8 mi/h at a trajectory of 7.8 degrees and a vehicle heading of 12.6 degrees
0.7430	Front right tire contacts the pavement

7.5. DAMAGE TO TEST INSTALLATION

There was some scuffing and gouging at impact, and the soil was disturbed at the traffic side edge of the deck. No cracking or other damage to the installation was observed. Figure 7.3 shows the damage to the Permanent Low-Profile Barrier. Table 7.5 describes the damage to the Permanent Low-Profile Barrier.

Table 7.5 Damage to Permanent Low-Profile Barrier 616151-01-1.

Test Parameter	Measured
Permanent Deflection/Location	There was no permanent deflection
Dynamic Deflection	1.6 inches toward field side
Working Width* and Height	19.1 inches, at a height of 55.2 inches. Right front corner of truck.

* 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 7.3 Permanent Low-Profile Barrier after Test 616151-01-1.

7.6. DAMAGE TO TEST VEHICLE

Figure 7.4 shows the damage sustained by the vehicle. Table 7.6 provides details on the interior and exterior damage to the vehicle. Tables C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.

Figure 7.4 Test Vehicle after Test 616151-01-1.

Table 7.6 Damage to Vehicle 616151-01-1.

Test Parameter	Specification	Measured
Roof	≤ 4.0 inches	0 inches
Windshield	≤ 3.0 inches	0 inches
A and B Pillars	≤ 5.0 overall / ≤ 3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤ 9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤ 12.0 inches	0 inches
Side Front Panel	≤ 12.0 inches	0 inches
Front Door (above Seat)	≤ 9.0 inches	0 inches
Front Door (below Seat)	≤ 12.0 inches	0 inches
Side Windows	The side windows remained intact	
Maximum Exterior Deformation	14 inches in the front plane at the left front corner at bumper height	
VDS 11FLQ2	CDC 11FLEW2	
Fuel Tank Damage	None	

Description of Damage to Vehicle:
The front bumper, left headlight, left front tire and rim, left front quarter fender, left rear quarter fender and rear bumper were damaged.

7.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 7.7. 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.

Table 7.7 Occupant Risk Factors for Test 616151-01-1.

Test Parameter	***MASH***	**Measured**	**Time**
OIV, Longitudinal (ft/s)	≤40.0	14.4	0.1139 s on left side of interior
OIV, Lateral (ft/s)	≤40.0	20.6	0.1139 s on left side of interior
Ridedown, Longitudinal (g)	≤20.49	2.4	0.8592 - 0.8692 s
Ridedown, Lateral (g)	≤20.49	5.9	0.3120 - 0.3220 s
THIV (m/s)	N/A	7.7	0.1110 s on left side of interior
ASI	N/A	1.3	0.0679 - 0.1179 s
50ms MA Longitudinal (g)	N/A	-6.5	0.0416 - 0.0916 s
50ms MA Lateral (g)	N/A	10.2	0.0432 - 0.0932 s
50ms MA Vertical (g)	N/A	-2.0	0.0229 - 0.0729 s
Roll (deg)	≤75	30	0.5229 s
Pitch (deg)	≤75	20	3.5000 s
Yaw (deg)	N/A	40	0.5795 s
Comments:			

0.000 s

0.100 s

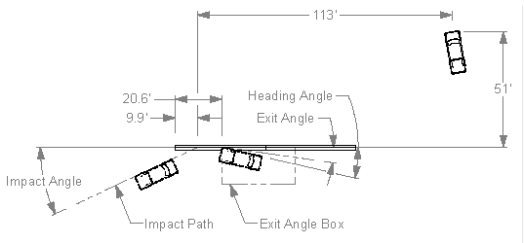
0.200 s

0.300 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 2-11
TTI Project No.	616151-01-1
Test Date	2022-05-19
TEST ARTICLE	
Type	Longitudinal Barrier
Name	TL-2 Permanent Low-Profile Concrete Barrier
Length	80 feet 2 inches
Key Materials	3400 PSI Concrete
Soil Type and Condition	AASHTO M147-65(2004), Type 1, Grade D Crushed Concrete
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2017 RAM 1500
Curb Weight (lbs)	5015
Inertial Weight (lbs)	5058
Dummy (lbs)	N/A
Gross Static (lbs)	5058
IMPACT CONDITIONS	
Impact Speed (mi/h)	44.2
Impact Angle (deg)	24.9
Impact Location	118.4 inches downstream from the edge of the concrete barrier
Impact Severity (kip-ft)	58.6
EXIT CONDITIONS	
Exit Speed (mi/h)	38.8
Trajectory/Heading Angle (deg)	7.8 / 12.6
Exit Box Criteria	Did Not Cross Box
Stopping Distance	113 feet downstream 51 feet to the field side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	1.6
Permanent (inches)	None
Working Width / Height (inches)	19.1 / 55.2
VEHICLE DAMAGE	
VDS	11FLQ2
CDC	11FLEW2
Max. Ext. Deformation	14 inches
Max Occupant Compartment Deformation	None

OCCUPANT RISK VALUES

Long.OIV (ft/s)	14.4	Long. Ridedown (g)	2.4	Max 50ms Long. (g)	-6.5	Max Roll (deg)	30
Lat. OIV (ft/s)	20.6	Lat. Ridedown (g)	5.9	Max 50ms Lat. (g)	10.2	Max Pitch (deg)	20
THIV (m/s)	7.7	ASI	1.3	Max 50ms Vert (g)	-2.0	Max Yaw (deg)	40



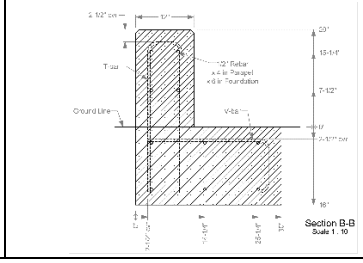


Figure 7.4 Summary of Results for *MASH* Test 2-11 on Permanent Low-Profile Barrier.

Chapter 8. SUMMARY AND CONCLUSIONS

8.1. ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* TL-2, which involves two tests, on the Permanent Low-Profile Barrier. Tables 8.1 and 8.2 provide an assessment of each test based on the applicable safety evaluation criteria for *MASH* TL-2 longitudinal barriers.

8.2. CONCLUSIONS

Table 8.3 shows that the Permanent Low-Profile Barrier met the performance criteria for *MASH* TL-2 longitudinal barriers.

Table 8.1 Performance Evaluation Summary for *MASH* Test 2-10 on Permanent Low-Profile Barrier.

Test Agency: Texas A&M Transportation Institute Test No.: 616151-01-2 Test Date: 2022-05-23

***MASH* Test 2-10 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy		
A. *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*	The Permanent Low-Profile Barrier contained and redirected the 1100CP vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 0.6 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.*	There was no spalling of the test article, so therefore there was no debris which showed potential for penetrating the occupant compartment or that would cause 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.		
F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	The vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 29° and 5°	Pass
H. *Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s (10 ft/s for supports), or maximum allowable value of 40 ft/s (16 ft/s for supports).*	Longitudinal OIV was 20.4 ft/s, and lateral OIV was 23.2 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 1.9 g and lateral occupant ridedown acceleration was 3.8 g.	Pass

Table 8.2 Performance Evaluation Summary for *MASH* Test 2-11 on Permanent Low-Profile Barrier.

Test Agency: Texas A&M Transportation Institute Test No.: 616151-01-1 Test Date: 2022-05-19

***MASH* Test 2-11 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.*	ThePermanent Low-Profile Barrier contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.6 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.*	There was no spalling of the test article, so therefore there was no debris that showed potential for penetrating the occupant compartment or that would cause 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.	There was no occupant compartment deformation.	
F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	The vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 30° and 20°	Pass
H. *Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s (10 ft/s for supports), or maximum allowable value of 40 ft/s (16 ft/s for supports).*	Longitudinal OIV was 14.4 ft/s, and lateral OIV was 20.6 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 2.4 g and lateral occupant ridedown acceleration was 5.9 g.	Pass

Table 8.3 Assessment Summary for *MASH* TL-2 Tests on Permanent Low-Profile Barrier.

Evaluation Factors	Evaluation Criteria	Test No. 616151-01-2	Test No. 616151-01-1
Structural Adequacy	A	S	S
Occupant Risk	D	S	S
	F	S	S
	H	S	S
	I	S	S
Test No.		*MASH* Test 2-10	*MASH* Test 2-11
Pass/Fail		Pass	Pass

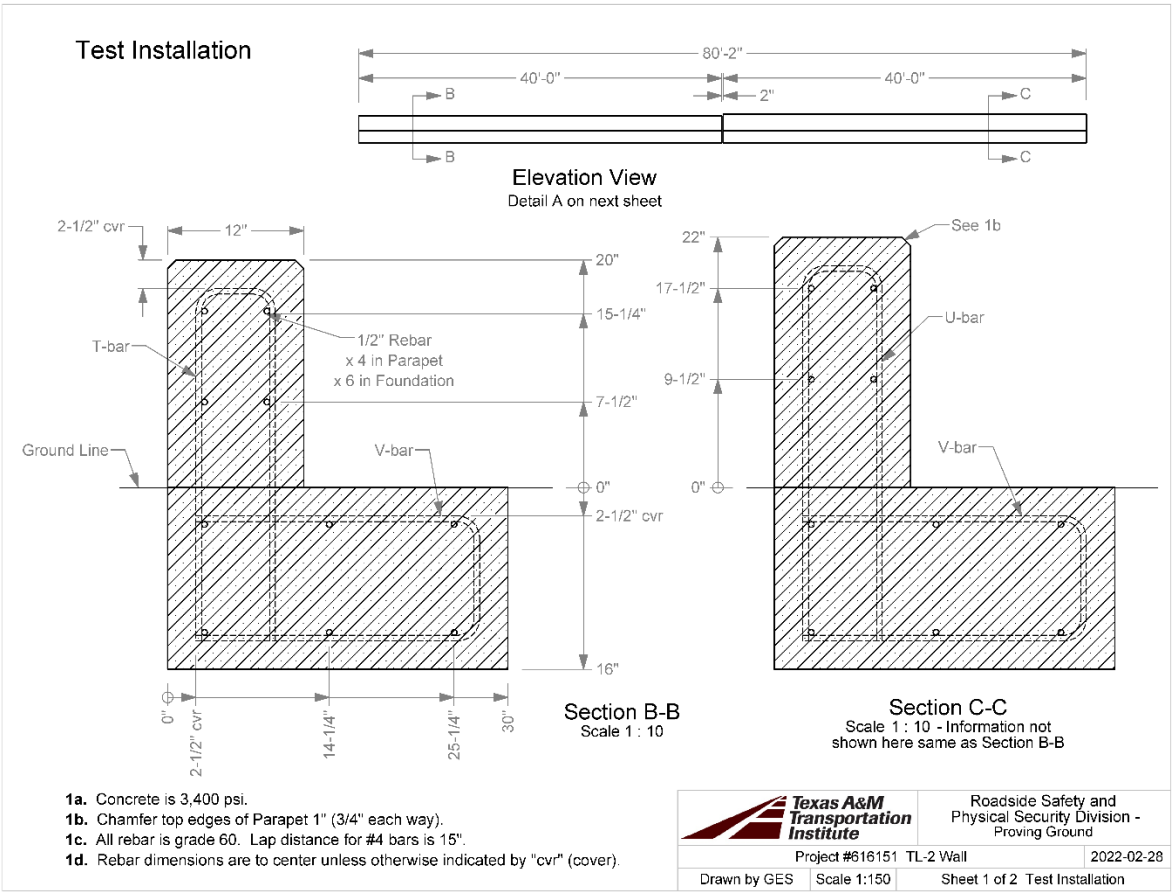
Note: S = Satisfactory; N/A = Not Applicable.

REFERENCES

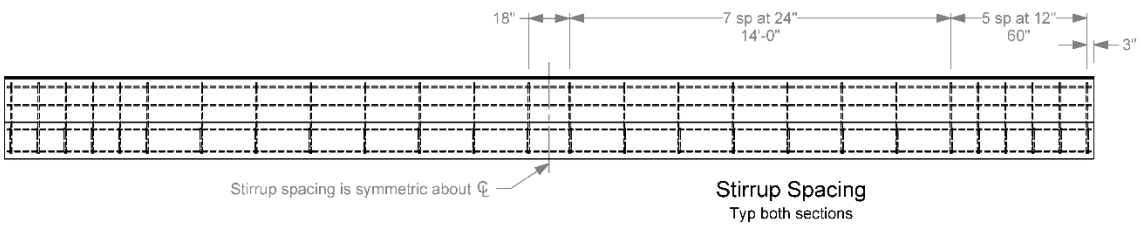
1. AASHTO. Manual for Assessing Roadside Safety Hardware, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.

2. Silvestri Dobrovolny, C., Shi, S., Kovar, J., Bligh, R. P., & Hurlebaus, S. (2019). Development of a New Manual for Assessing Safety Hardware TL-3 Low-Profile Portable Concrete Barrier for High-Speed Applications. Transportation Research Record, 2673(7), 630–640. https://doi.org/10.1177/0361198119845898

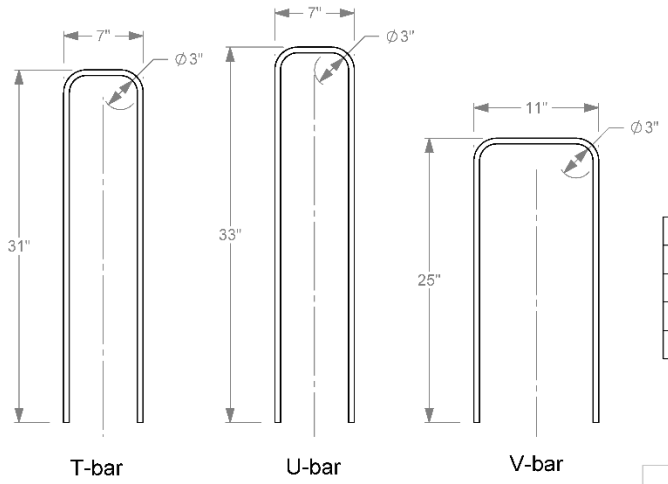
APPENDIX A. DETAILS OF PERMANENT LOW-PROFILE BARRIER



Stirrup Spacing and Stirrups



Stirrup Spacing
Typ both sections



Rebar Bends			
Part Name	Qty.	Description	Material
U-bar	26	1/2" Rebar	Grade 60
V-bar	52	1/2" Rebar	Grade 60
T-bar	26	1/2" Rebar	Grade 60

2a. Rebar dimensions are to center unless otherwise indicated by "cvr" (cover).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project #616151 TL-2 Wall			2022-02-28
Drawn by GES	Scale 1:50	Sheet 2 of 2 Stirrup Spacing and Stirrups	

Q:\Accreditation-17025-2017\EIR-000 Project Files\616151-01 TL2 Permanent Low Profile - Dobrovolny\Drafting, 616151\616151 Drawing

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

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

AT NO.:3110455 CTION: REBAR 16MM (#5) 20'0" 420/60 ADE: ASTM A615-20 Gr 420/60 LL DATE: 11/13/2021 LT DATE: 11/13/2021 rt. No.: 83678308 / 110455A371	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#: 83678308
BOL#: 74510114
CUST PO#: 902945
CUST P/N:
DLVRY LBS / HEAT: 16024.000 LB
DLVRY PCS / HEAT: 768 EA

Characteristic	Value	Characteristic	Value
C	0.43%	Bend Test Diameter	2.188IN
Mn	0.98%		
P	0.011%		
S	0.037%		
Si	0.20%		
Cu	0.30%		
Cr	0.08%		
Ni	0.12%		
Mo	0.039%		
V	0.000%		
Cb	0.001%		
Sn	0.011%		
Al	0.001%		
Yield Strength test 1	66.3ksi		
Tensile Strength test 1	107.4ksi		
Elongation test 1	12%		
Elongation Gage Lgth test 1	8IN		
Tensile to Yield ratio test1	1.62		
Bend Test 1	Passed		

Characteristic Value

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

ARKS :

616151

Page 1 OF 1 12/06/2021 21:01:30

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

	SOLD TO	SHIP TO	
EAT NO.:3111147 ECTION: REBAR 13MM (#4) 20'0" 420/60 RADE: ASTM A615-20 Gr 420/60 OLL DATE: 12/14/2021 ELT DATE: 12/07/2021 ert. No.: 83688434 / 111147A130	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83688434 BOL#: 74525096 CUST PO#: 903828 CUST P/N: DLVRY LBS / HEAT: 10955.000 LB DLVRY PCS / HEAT: 820 EA

Characteristic	Value	Characteristic	Value
C	0.44%	Bend Test Diameter	1.750IN
Mn	0.81%		
P	0.011%		
S	0.049%		
Si	0.18%		
Cu	0.31%		
Cr	0.11%		
Ni	0.16%		
Mo	0.057%		
V	0.000%		
Cb	0.001%		
Sn	0.012%		
Al	0.002%		
Yield Strength test 1	66.6ksi		
Tensile Strength test 1	104.8ksi		
Elongation test 1	13%		
Elongation Gage Lgth test 1	8IN		
Tensile to Yield ratio test1	1.57		
Bend Test 1	Passed		

Characteristic Value

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

IARKS :

Page 1 OF 1 12/17/2021 14:19:47

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

Project No: 616151-01 **Casting Date:** 4/25/2022 **Mix Design (psi):** 3400

Name of Technician Taking Sample: Terracon

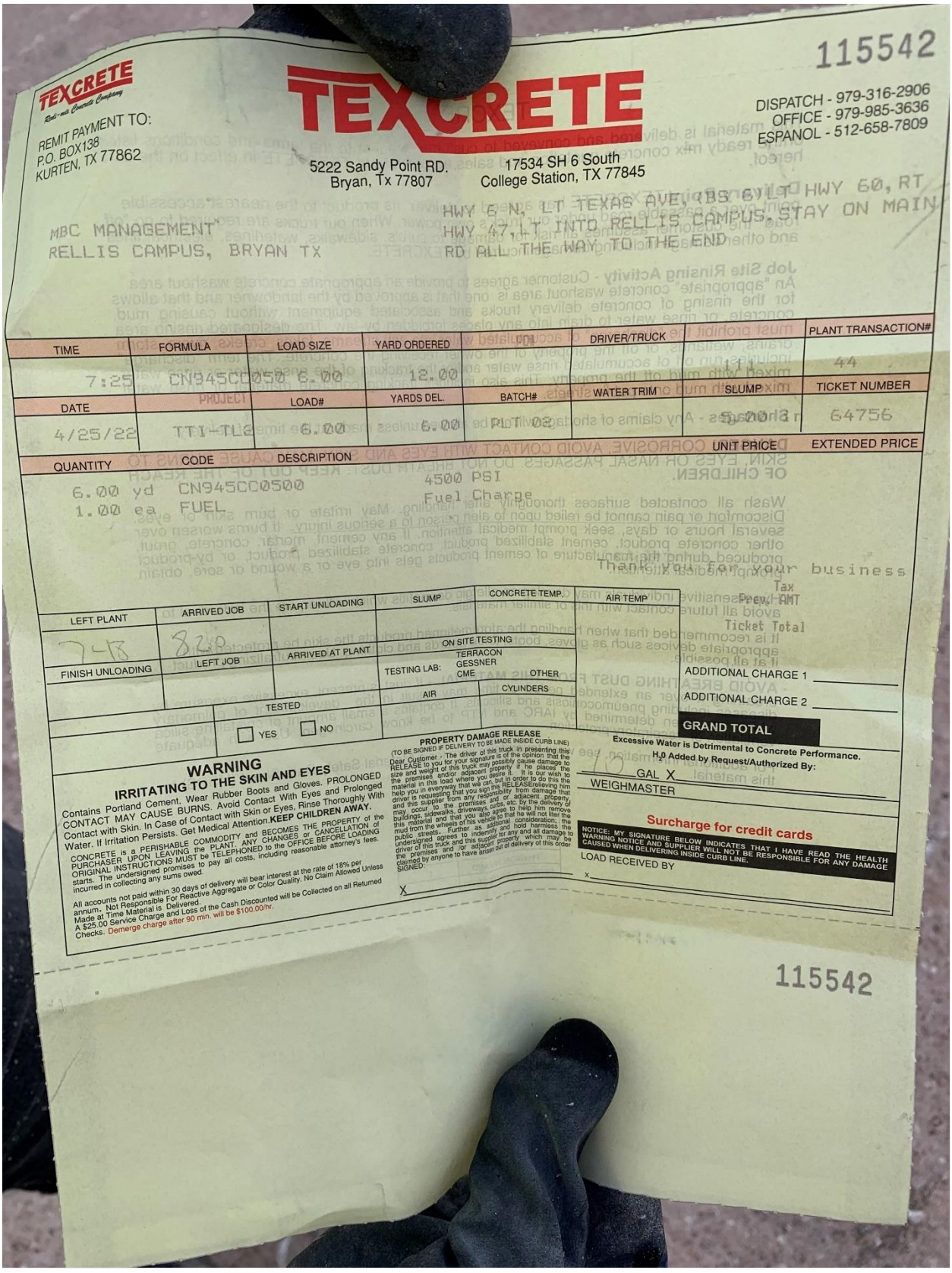
Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: N/A

Signature of Technician Breaking Sample: N/A

Load No.	Truck No.	Ticket No.	Location (from concrete map)
1	111	64756	Left half of deck

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



TEXCRETE
Ready-mix Concrete Company

115542

REMIT PAYMENT TO:
P.O. BOX138
KURTEN, TX 77862

TEXCRETE

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

DISPATCH - 979-316-2906
OFFICE - 979-985-3636
ESPANOL - 512-658-7809

MBC MANAGEMENT
RELLIS CAMPUS, BRYAN TX

HWY 6 N, LT TEXAS AVE, 4BS 6 LT HWY 60, RT
HWY 47, LT INTO RELLIS CAMPUS, STAY ON MAIN
RD ALL THE WAY TO THE END

TIME	FORMULA	LOAD SIZE	YARD ORDERED	DRIVER/TRUCK	PLANT TRANSACTION#
7:25	CN945CC050 6.00		12.00		44
DATE	PROJECT	LOAD#	YARDS DEL.	BATCH#	WATER TRIM	SLUMP	TICKET NUMBER
4/25/22	TTI-TL2	6.00	6.00	PLT 02			64756

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
6.00 yd	CN945CC0500	4500 PSI		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
748	820				
FINISH UNLOADING	LEFT JOB	ARRIVED AT PLANT	ON SITE TESTING		
			TESTING LAB: TERRACON GESSNER CME OTHER		
TESTED			AIR	CYLINDERS	
☐ YES ☐ NO					

Tax
Prev. AMT
Ticket Total
ADDITIONAL CHARGE 1
ADDITIONAL CHARGE 2
GRAND TOTAL

Excessive Water is Detrimental to Concrete Performance.
H2O Added by Request/Authorized By:
GAL X
WEIGHMASTER

Surcharge for credit cards

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY
X

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement. Wear Rubber Boots and Gloves. PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact with Skin. In Case of Contact with Skin or Eyes, Rinse Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE LOADING starts. The undersigned promises to pay all costs, including reasonable attorney's fees. incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum. Not Responsible For Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.
A $25.00 Service Charge and Loss of the Cash Discounted will be Collected on all Returned Checks. Demerge charge after 90 min. will be $100.00/hr.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in everyway that we can, but in order to do this the driver is requesting that you sign this RELEASE relieving him and this supplier from any responsibility from damage that may occur to the premises and or adjacent property, buildings, sidewalks, driveways, curbs, etc. by the delivery of this material and that you also agree to help him remove mud from the wheels of his vehicle. In consideration; the public streets. Further as additional consideration; the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and or adjacent property which may be claimed by anyone to have arisen out of delivery of this order.
SIGNED:
X

115542

Concrete Core Test Report

Report Number: A1171057.0228
Service Date: 05/26/22
Report Date: 05/31/22
Task: PO# 616151-01

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

Client

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

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength:
Specified Length:
Mix ID:
Nominal Maximum Size Aggregate:

Sample Information

Placement Date:
Date Tested: 05/25/22 **Time:** 0000
Sampled By:
Drill Directions: Vertical
Date Core Obtained: 05/25/22 **Time:** 0000
Date Ends Trimmed: 05/25/22 **Time:** 0000
Moisture Conditioning History: According to ASTM C-42

Laboratory Test Data

Core ID	Location	Cored Length (in)	Trim Length (in)	Capped Length (in)	Diam. (in)	Area (sq in)	Length / Diam. Ratio	Max Load (lbs)	Corr. Factor	Comp. Strength (psi)	Fracture Type	Density (pcf)	Tested By
1	South End			7.57	4.00	12.57	1.89	49890	1.000	3970	3		SLS
2	North End			7.74	4.00	12.57	1.94	48310	1.000	3840	3		SLS

Comments:

Services:
Terracon Rep.: Randolph E. Rohrbach
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Texas Transportation Institute, Bill Griffith

Start/Stop:

Reviewed By: Alexander Dunigan
Project Manager

Test Methods:

The tests were performed in general accordance with applicable ASTM, AASHTO, or DOT test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

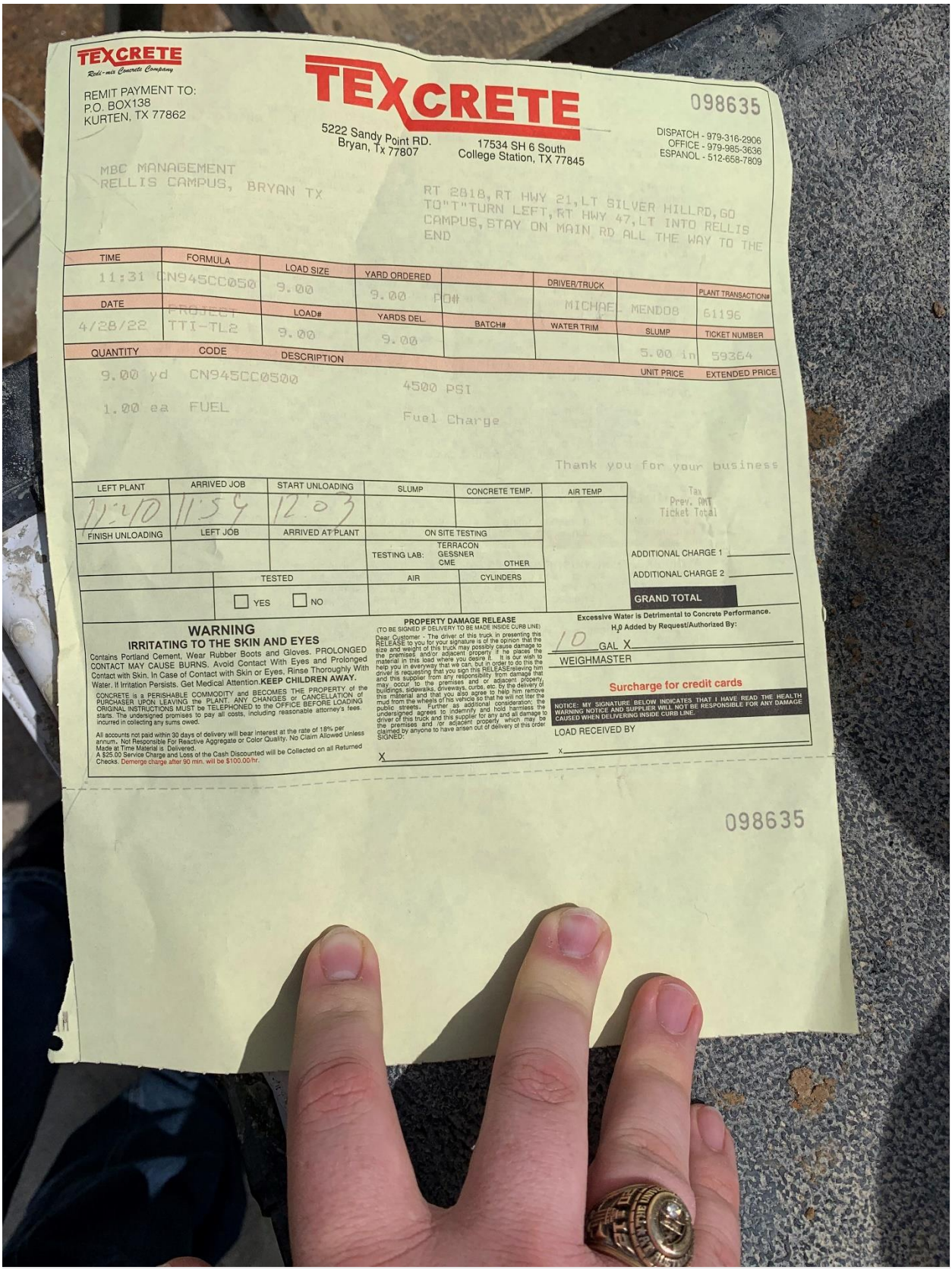
Texas A&M Transportation Institute	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Revision Date: 2020-07-29
Quality Form	Revised by: B.L. Griffith Approved by: D. L. Kuhn	Revision: 7	Page: 1 of 1

Project No: 616151-01 **Casting Date:** 4/28/2022 **Mix Design (psi):** 3400

Name of Technician Taking Sample	Terracon	Name of Technician Breaking Sample	Terracon
Signature of Technician Taking Sample	N/A	Signature of Technician Breaking Sample	N/A

Load No.	Truck No.	Ticket No.	Location (from concrete map)
1	Michael Mend08	59364	Left half of barrier and right half of deck

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



TEXCRETE
Redi-mix Concrete Company

REMIT PAYMENT TO:
P.O. BOX138
KURTEN, TX 77862

TEXCRETE
5222 Sandy Point RD.
Bryan, Tx 77807
17534 SH 6 South
College Station, TX 77845

098635

DISPATCH - 979-316-2906
OFFICE - 979-985-3636
ESPANOL - 512-658-7809

MBC MANAGEMENT
RELLIS CAMPUS, BRYAN TX

RT 2818,RT HWY 21,LT SILVER HILLRD,GO TO"T"TURN LEFT,RT HWY 47,LT INTO RELLIS CAMPUS,STAY ON MAIN RD ALL THE WAY TO THE END

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
11:31	CN945CC050	9.00	9.00	PO#	MICHAEL MENDOS		61196
DATE		LOAD#	YARDS DEL.	BATCH#	WATER TRIM	SLUMP	TICKET NUMBER
4/28/22	PROJECT TTI-TL2	9.00	9.00			5.00 in	59364

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
9.00 yd	CN945CC0500	4500 PSI		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
11:10	11:59	12:03			
FINISH UNLOADING	LEFT JOB	ARRIVED AT PLANT	ON SITE TESTING		
			TESTING LAB: TERRACON GESSNER CME OTHER		
	TESTED		AIR	CYLINDERS	
	☐ YES ☐ NO				

Tax
Prev. AMT
Ticket Total
ADDITIONAL CHARGE 1
ADDITIONAL CHARGE 2
GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES
Contains Portland Cement. Wear Rubber Boots and Gloves. PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact with Skin. In Case of Contact with Skin or Eyes, Rinse Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE LOADING starts. The undersigned promises to pay all costs, including reasonable attorney's fees. incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum. Not Responsible For Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.
A $25.00 Service Charge and Loss of the Cash Discounted will be Collected on all Returned Checks. Demerge charge after 90 min. will be $100.00/hr.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in everyway that we can, but in order to do this the driver is requesting that you sign this RELEASErelieving him and this supplier from any responsibility from damage that may occur to the premises and or adjacent property, buildings, sidewalks, driveways, curbs, etc. by the delivery of this material and that you also agree to help him remove mud from the wheels of his vehicle so that he will not liter the public streets. Further as additional consideration: the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and /or adjacent property which may be claimed by anyone to have arisen out of delivery of this order SIGNED:

X_____

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request/Authorized By:

10 GAL X_____
WEIGHMASTER

Surcharge for credit cards

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

X_____

098635

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0225
Service Date: 04/28/22
Report Date: 05/18/22
Task: PO# 616151-01

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

Client

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

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength:

Mix ID:
Supplier:
Batch Time: **Plant:**
Truck No.: **Ticket No.:**

Sample Information

Sample Date: 04/28/22 **Sample Time:**
Sampled By: Randy Rippstein
Weather Conditions:
Accumulative Yards: **Batch Size (cy):**
Placement Method:
Water Added Before (gal):
Water Added After (gal):
Sample Location:
Placement Location:

Field Test Data

Test	Result	Specification

Air Content (%):
Concrete Temp. (F):
Ambient Temp. (F):
Plastic Unit Wt. (pcf):
Yield (Cu. Yds.):

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	B	Good	6.00	28.27		05/18/22	20	131,880	4,660	3	
1	C	Good	6.00	28.27		05/18/22	20	127,340	4,500	3	
1	D	Good	6.00	28.27		05/18/22	20	127,950	4,530	3	
							Average (20 days)		**4,560**		
1	A		6.00	28.27		05/26/22	28				

Initial Cure: Outside **Final Cure:** Field Cured **Sample Description:** 6-inch diameter cylinders

Comments: **Not tested for plastic unit weight.**
Note: Reported air content does not include Aggregate Correction Factor (ACF).

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Randy Rippstein **Start/Stop:**
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

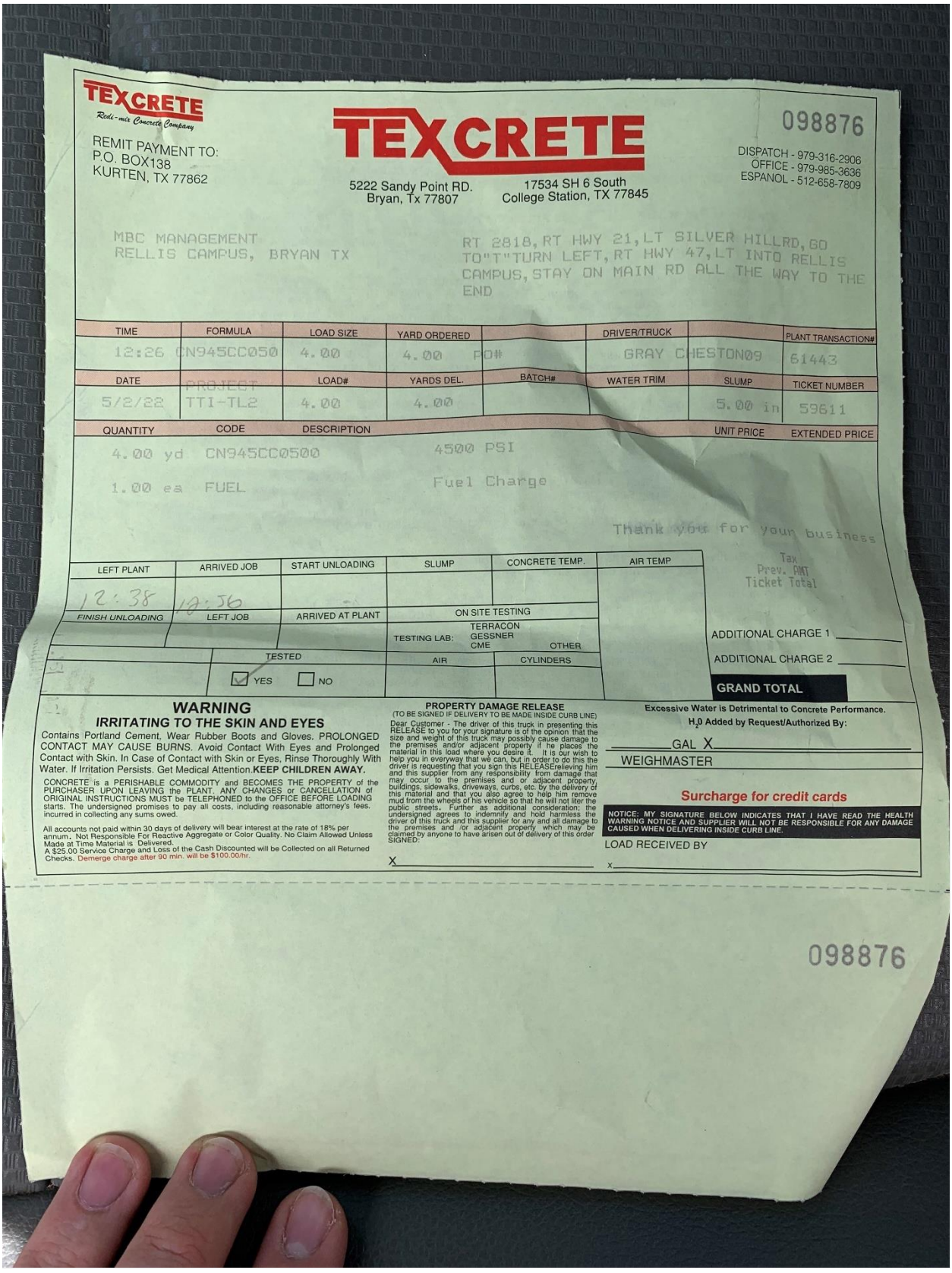
Texas A&M Transportation Institute	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Revision Date: 2020-07-29
Quality Form	Revised by: B.L. Griffith Approved by: D. L. Kuhn	Revision: 7	Page: 1 of 1

Project No: 616151-01 **Casting Date:** 5/2/2022 **Mix Design (psi):** 3400

Name of Technician Taking Sample	Terracon	Name of Technician Breaking Sample	Terracon
Signature of Technician Taking Sample	N/A	Signature of Technician Breaking Sample	N/A

Load No.	Truck No.	Ticket No.	Location (from concrete map)
1	Gray Cheston09	59611	Right half of barrier

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



TEXCRETE
Ready-mix Concrete Company

REMIT PAYMENT TO:
P.O. BOX138
KURTEN, TX 77862

TEXCRETE

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

098876

DISPATCH - 979-316-2906
OFFICE - 979-985-3636
ESPANOL - 512-658-7809

MBC MANAGEMENT
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILLRD, GO TO"T"TURN LEFT, RT HWY 47, LT INTO RELLIS CAMPUS, STAY ON MAIN RD ALL THE WAY TO THE END

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
12:26	CN945CC050	4.00	4.00	PO#	GRAY CHESTON09		61443
DATE	**PROJECT**	**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
5/2/22	TTI-TL2	4.00	4.00			5.00 in	59611

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
4.00 yd	CN945CC0500	4500 PSI		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

Tax
Prev. AMT
Ticket Total

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
12:38	12:56				
FINISH UNLOADING	**LEFT JOB**	**ARRIVED AT PLANT**	**ON SITE TESTING**		
			TESTING LAB: TERRACON GESSNER CME OTHER		
	TESTED		**AIR**	**CYLINDERS**	
	☑ YES ☐ NO				

ADDITIONAL CHARGE 1 _____

ADDITIONAL CHARGE 2 _____

GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement, Wear Rubber Boots and Gloves. PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact with Skin. In Case of Contact with Skin or Eyes, Rinse Thoroughly With Water. If Irritation Persists. Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE LOADING starts. The undersigned promises to pay all costs, including reasonable attorney's fees. incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum. Not Responsible For Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.
A $25.00 Service Charge and Loss of the Cash Discounted will be Collected on all Returned Checks. Demerge charge after 90 min. will be $100.00/hr.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in everyway that we can, but in order to do this the driver is requesting that you sign this RELEASEreliving him and this supplier from any responsibility from damage that may occur to the premises and or adjacent property, buildings, sidewalks, driveways, curbs, etc. by the delivery of this material and that you also agree to help him remove mud from the wheels of his vehicle so that he will not liter the public streets. Further as additional consideration: the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and or adjacent property which may be claimed by anyone to have arisen out of delivery of this order

SIGNED: X_____

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request/Authorized By:

_____GAL X_____
WEIGHMASTER

Surcharge for credit cards

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

x_____

098876

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0226
Service Date: 05/02/22
Report Date: 05/18/22
Task: PO# 616151-01

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

Client

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

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength: 4,500 psi @ 18 days

Mix ID: CN945CC0500
Supplier: Texcrete
Batch Time: 1226 **Plant:** Bryan
Truck No.: 09 **Ticket No.:** 59611

Sample Information

Sample Date: 05/02/22 **Sample Time:** 1305
Sampled By: Randy Rippstein
Weather Conditions: Cloudy, Heavy wind
Accumulative Yards: 4 **Batch Size (cy):** 4
Placement Method: Direct Discharge
Water Added Before (gal): 9
Water Added After (gal): 0
Sample Location: Wall
Placement Location: Divider wall on west side of runway

Field Test Data

Test	Result	Specification
Slump (in):	4 1/2	
Air Content (%):	1.8	
Concrete Temp. (F):	93	
Ambient Temp. (F):	86	
Plastic Unit Wt. (pcf):	1482.0	
Yield (Cu. Yds.):	4.0	

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	A	Good	6.00	28.27		05/19/22	17 F	127,400	4,510	4	
1	B	Good	6.00	28.27		05/19/22	17 F	127,290	4,500	3	
1	C	Good	6.00	28.27		05/19/22	17 F	126,740	4,480	2	
1	D		6.00	28.27		05/19/22	17 F				
1	E		6.00	28.27		05/19/22	17 F				

Initial Cure: Outside Plastic Lids **Final Cure:** Field Cured **Sample Description:** 6-inch diameter cylinders

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

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).
Terracon Rep.: Randy Rippstein **Start/Stop:** 1145-1500
Reported To: Bill at TTI
Contractor: MBC Management
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

APPENDIX C. *MASH* TEST 2-10 (CRASH TEST NO. 616151-01-2)

C.1 VEHICLE PROPERTIES AND INFORMATION

Table C.1. Vehicle Properties for Test No. 616151-01-2.

Date: 2022-05-23 Test No.: 616151-01-2 VIN No.: 3NICN7AP5HK434456

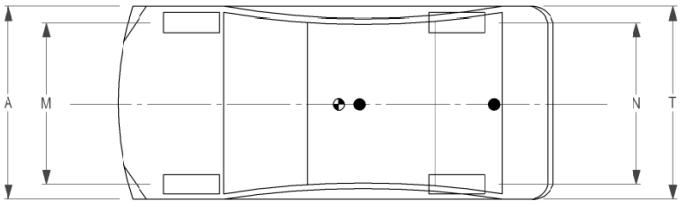
Year: 2017 Make: Versa Model: Nissan

Tire Inflation Pressure: 36 PSI Odometer: 112855 Tire Size: P185/65R15

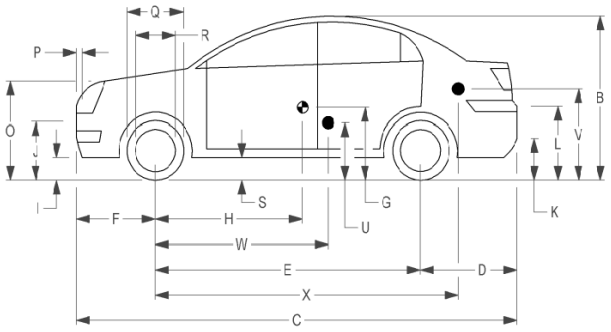
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None



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



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

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G		L	26.00	Q	24.00	V	21.25
C	175.40	H	41.38	M	58.30	R	16.25	W	41.30
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -0.08

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1455	1458	1543
Back	1687	M_{rear}	947	989	1069
Total	3389	M_{Total}	2402	2447	2612

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

Mass Distribution:
lb LF: 762 RF: 696 LR: 494 RR: 495

Performed by: RK Date: 2022-05-23

Table C.2. Exterior Crush Measurements for Test No. 616151-01-2.

Date: 2022-05-23 Test No.: 616151-01-2 VIN No.: 3NICN7AP5HK434456

Year: 2017 Make: Versa Model: Nissan

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	AT FT BUMPER	16	3	26	-	-	-	-	-	-	+19
2	SAME	16	3	40	-	-	-	-	-	-	52
	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.

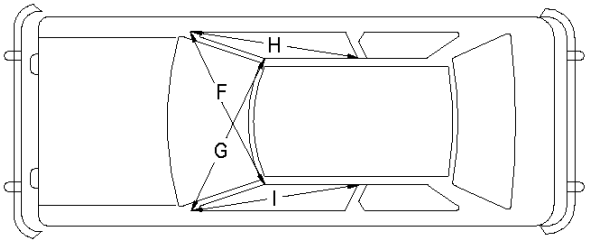
Note: Use as many lines/columns as necessary to describe each damage profile.

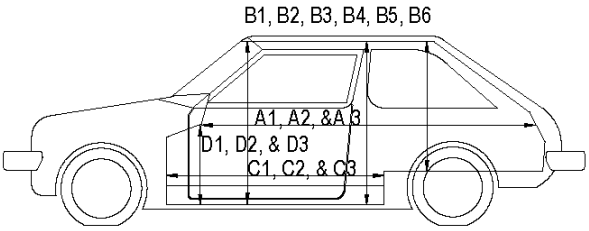
Performed by: ***RK*** Date: 2022-05-23

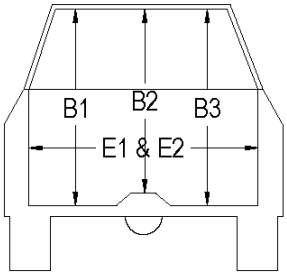
Table C.3. Occupant Compartment Measurements for Test No. 616151-01-2.

Date: 2022-05-23 Test No.: 616151-01-2 VIN No.: 3NICN7AP5HK434456

Year: 2017 Make: Versa Model: Nissan







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	25.00	-1.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	50.50	-1.00
E2	51.00	52.00	1.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	50.50	-0.50

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

Performed by: *RK* Date: 2022-05-23

C.2. SEQUENTIAL PHOTOGRAPHS

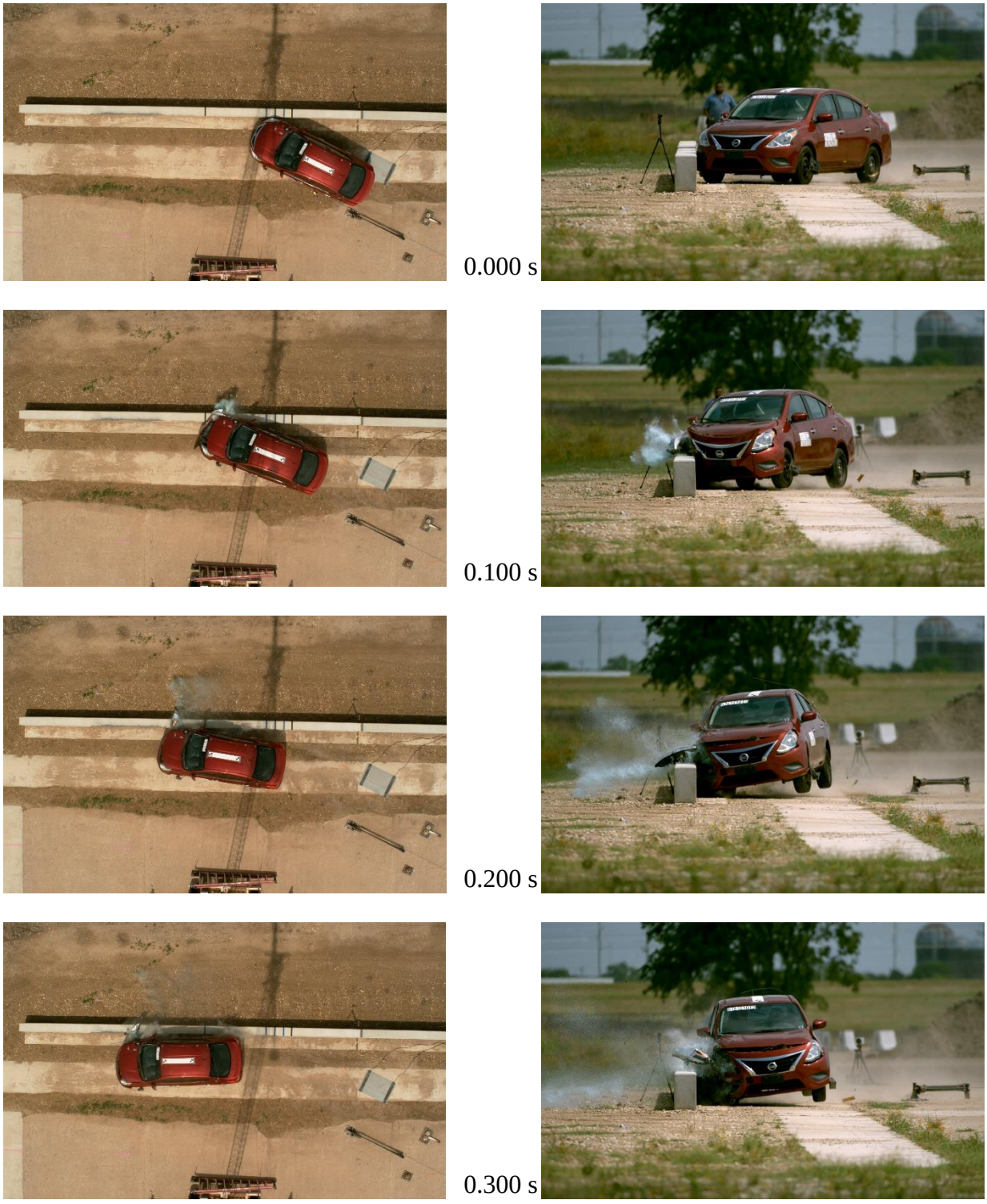


Figure C.1. Sequential Photographs for Test No. 616151-01-2 (Overhead and Frontal Views).


0.400 s



0.500 s



0.600 s



0.700 s


Figure C.1. Sequential Photographs for Test No. 616151-01-2 (Overhead and Frontal Views) (Continued).


0.000 s


0.400 s


0.100 s


0.500 s


0.200 s

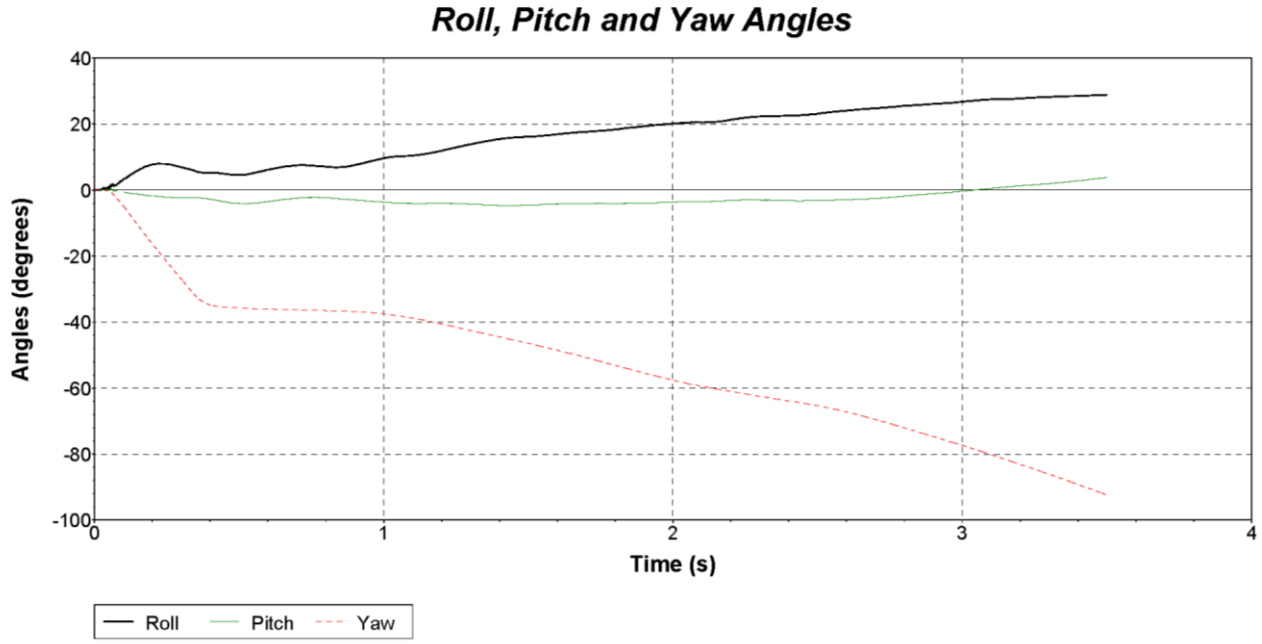

0.600 s


0.300 s


0.700 s

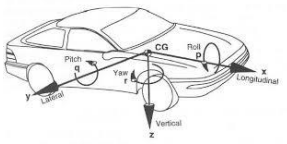
Figure C.2. Sequential Photographs for Test No. 616151-01-2 (Rear View).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

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



Test Number: 616151-01-2
Test Standard Test Number: *MASH* Test 2-10
Test Article: Permanent Low-Profile Barrier
Test Vehicle: 2017 Nissan Versa
Inertial Mass: 2447 lbs
Gross Mass: 2612 lbs
Impact Speed: 45.1 mi/h
Impact Angle: 24.3°

Figure C.3. Vehicle Angular Displacements for Test No. 616151-01-2.

C.4. VEHICLE ACCELERATIONS

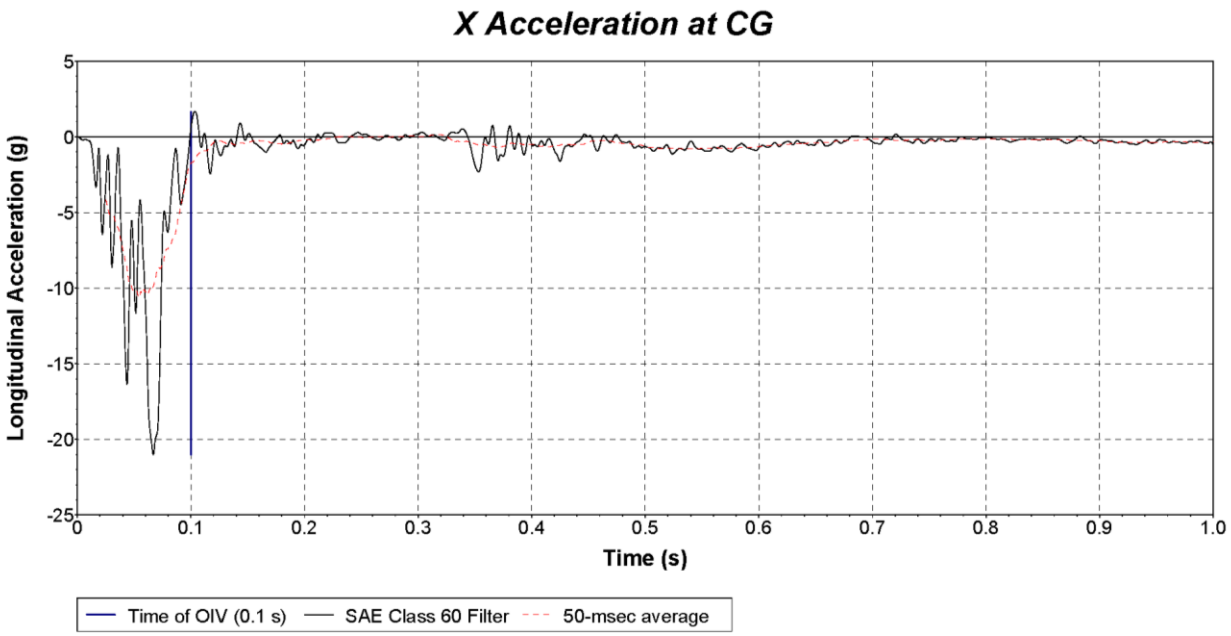


Figure C.4. Vehicle Longitudinal Accelerometer Trace for Test No. 616151-01-2 (Accelerometer Located at Center of Gravity).

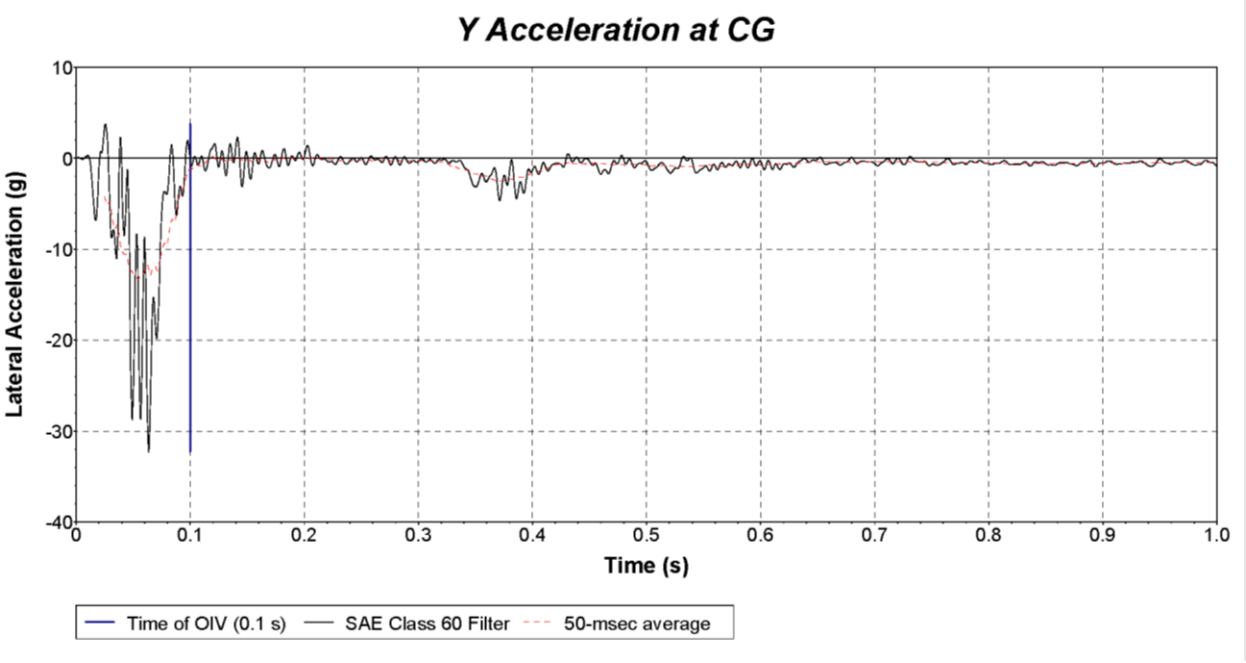


Figure C.5. Vehicle Lateral Accelerometer Trace for Test No. 616151-01-2 (Accelerometer Located at Center of Gravity).

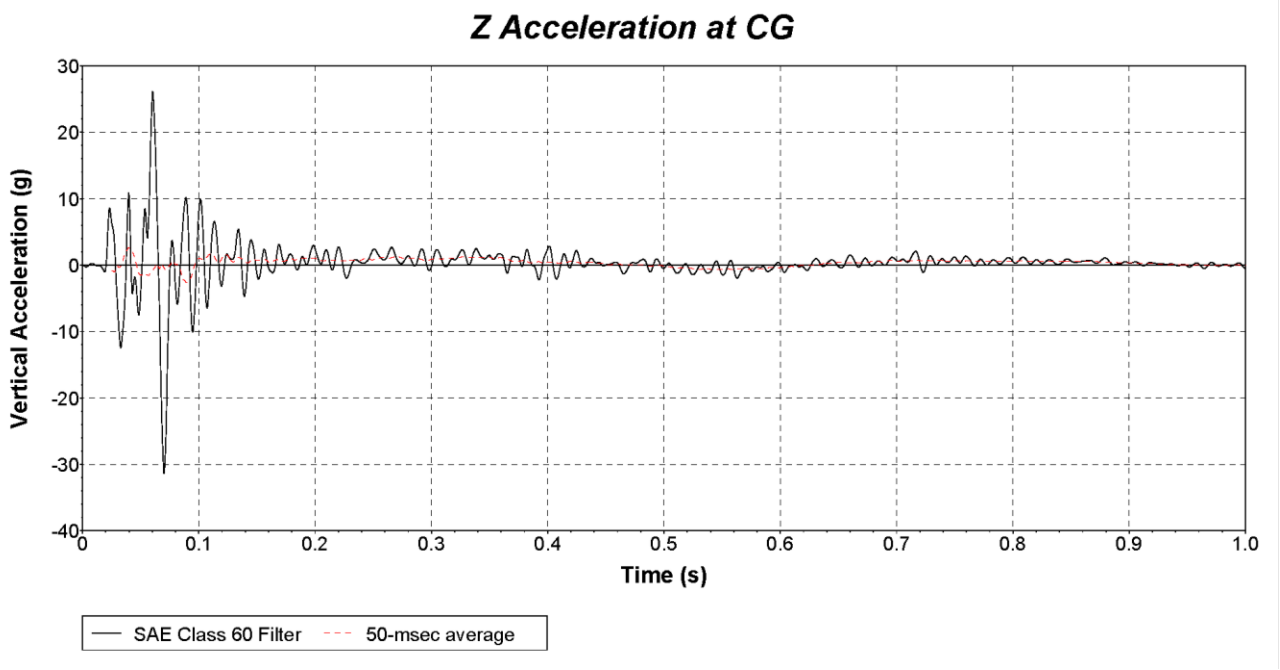


Figure C.6. Vehicle Vertical Accelerometer Trace for Test No. 616151-01-2 (Accelerometer Located at Center of Gravity).

APPENDIX D. *MASH* TEST 2-11 (CRASH TEST NO. 616151-01-1)

D.1 VEHICLE PROPERTIES AND INFORMATION

Table D.1. Vehicle Properties for Test No. 616151-01-1.

Date: 2022-05-19 Test No.: 616151-01-1 VIN No.: 1C6RR6FT6HS542888

Year: 2017 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 113760

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

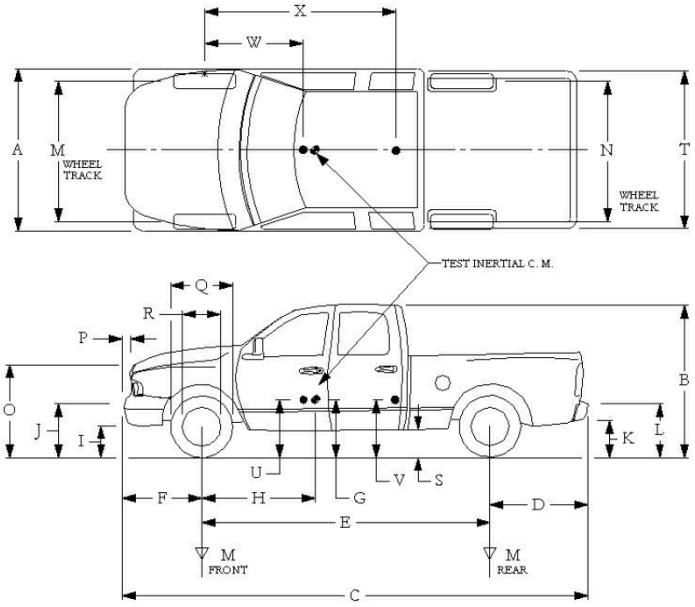
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: NONE
Mass: 0 lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.60	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.70	M	68.50	R	18.00	W	61.70
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}	2910	2836	2836
Back	3900	M_{rear}	2105	2222	2222
Total	6700	M_{Total}	5015	5058	5058

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

Mass Distribution:
lb LF: 1436 RF: 1400 LR: 1122 RR: 1100

Performed by: RK Date: 2022-05-19

Table D.2. Exterior Crush Measurements for Test No. 616151-01-1.

Date: 2022-05-19 Test No.: 616151-01-1 VIN No.: 1C6RR6FT6HS542888

Year: 2017 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	AT FT BUMPER	14	12	22							-24
2	AT FRONT BUMPER	14	14	54							78
	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).

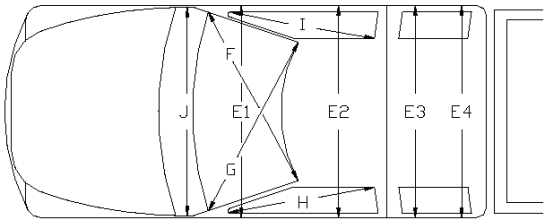
***Measure and document on the vehicle diagram the location of the maximum crush.

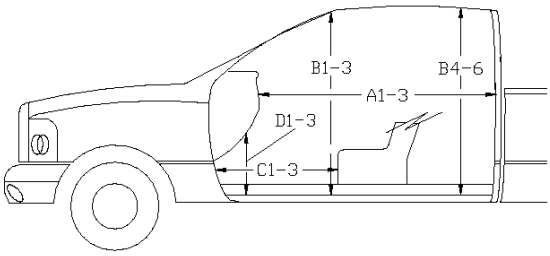
Note: Use as many lines/columns as necessary to describe each damage profile.

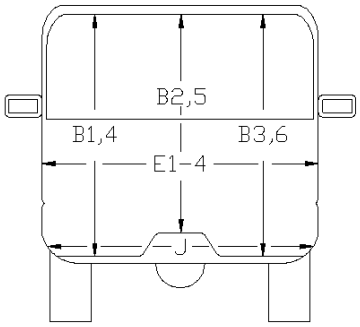
Performed by: RK Date: 2022-05-19

Table D.3. Occupant Compartment Measurements for Test No. 616151-01-1.

Date:	2022-05-19	Test No.:	616151-01-1	VIN No.:	1C6RR6FT6HS542888
Year:	2017	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	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Performed by: RK Date: 2022-05-19

D.2. SEQUENTIAL PHOTOGRAPHS

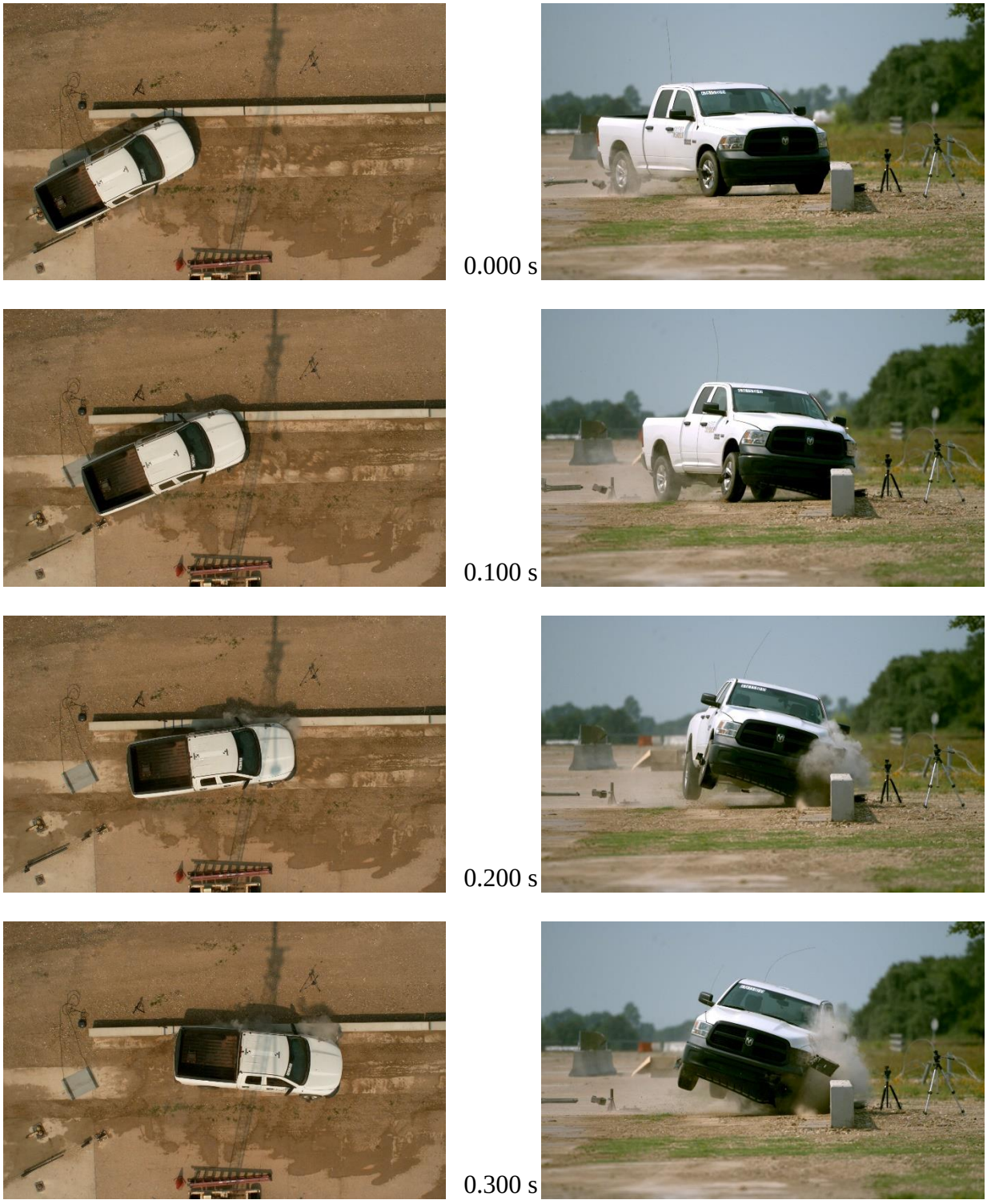


Figure D.1. Sequential Photographs for Test No. 616151-01-1 (Overhead and Frontal Views).

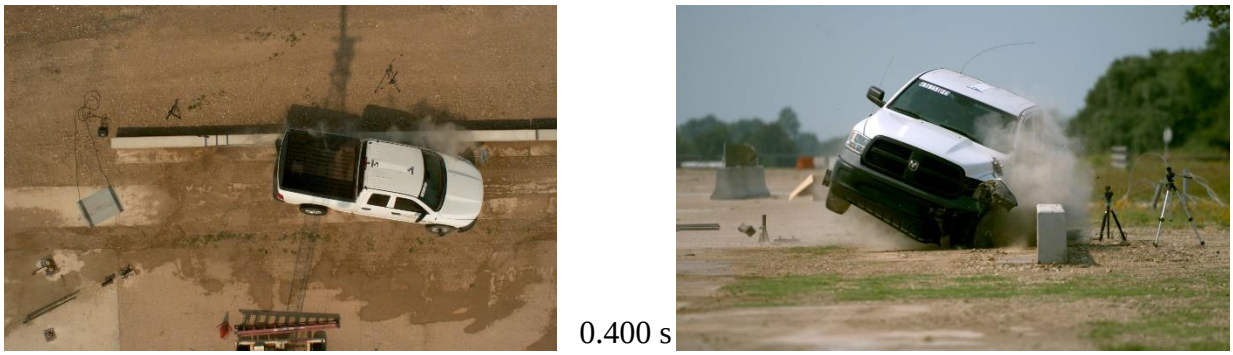


Figure D.1. Sequential Photographs for Test No. 616151-01-1 (Overhead and Frontal Views) (Continued).


0.000 s


0.400 s


0.100 s


0.500 s


0.200 s

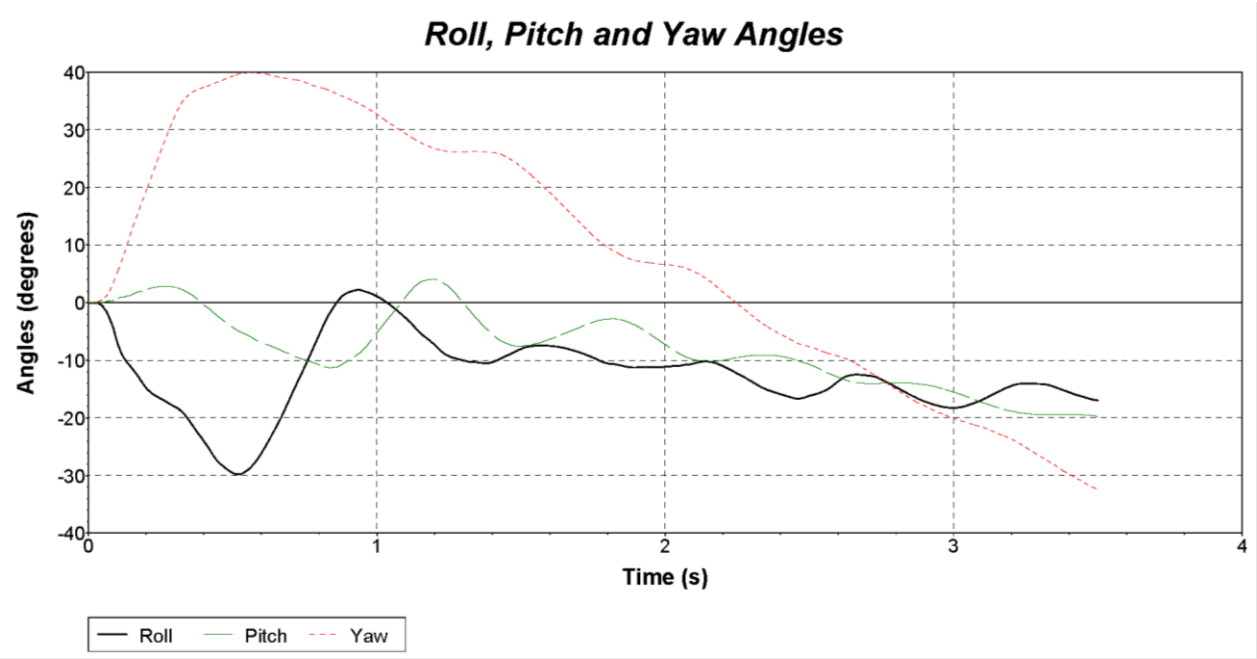

0.600 s


0.300 s


0.700 s

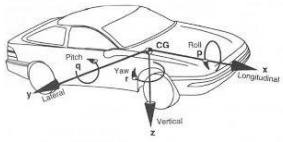
Figure D.2. Sequential Photographs for Test No. 616151-01-1 (Rear View).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

4. Yaw.
5. Pitch.
6. Roll.



Test Number: 616151-01-1
Test Standard Test Number: *MASH* Test 2-11
Test Article: Permanent Low-Profile Barrier
Test Vehicle: 2017 RAM 1500
Inertial Mass: 5058
Gross Mass: 5058
Impact Speed: 44.2
Impact Angle: 24.9°

Figure D.3. Vehicle Angular Displacements for Test No. 616151-01-1.

D.4. VEHICLE ACCELERATIONS

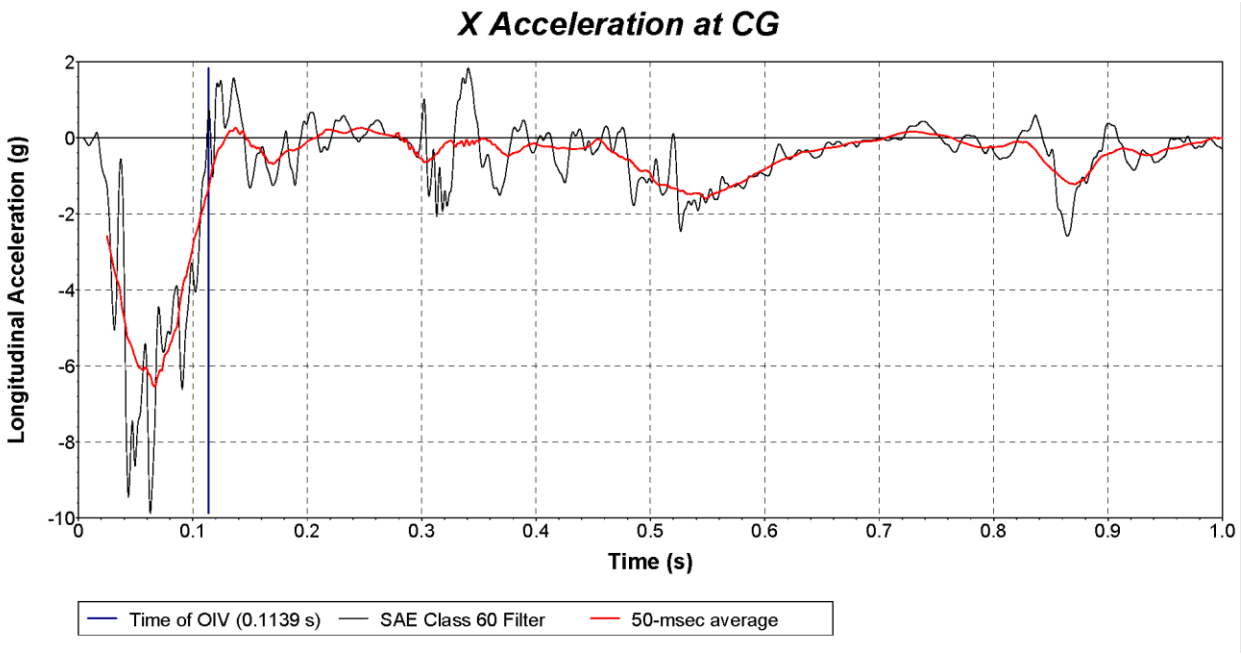


Figure D.4. Vehicle Longitudinal Accelerometer Trace for Test No. 616151-01-1 (Accelerometer Located at Center of Gravity).

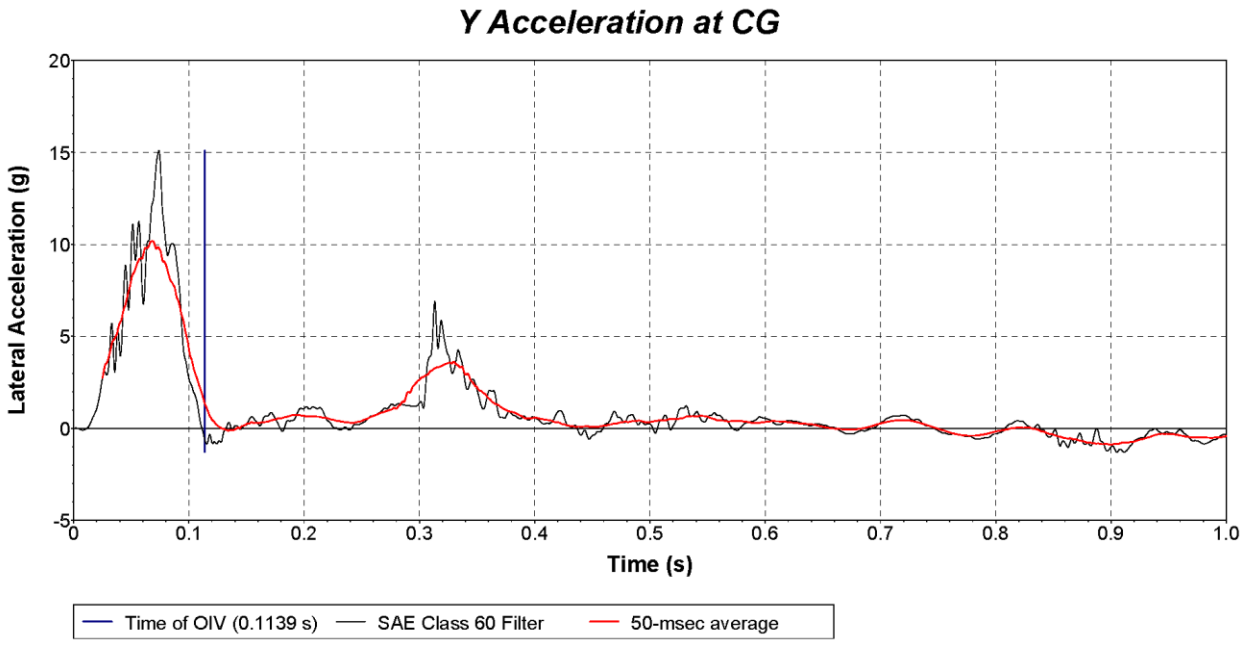


Figure D.5. Vehicle Lateral Accelerometer Trace for Test No. 616151-01-1 (Accelerometer Located at Center of Gravity).

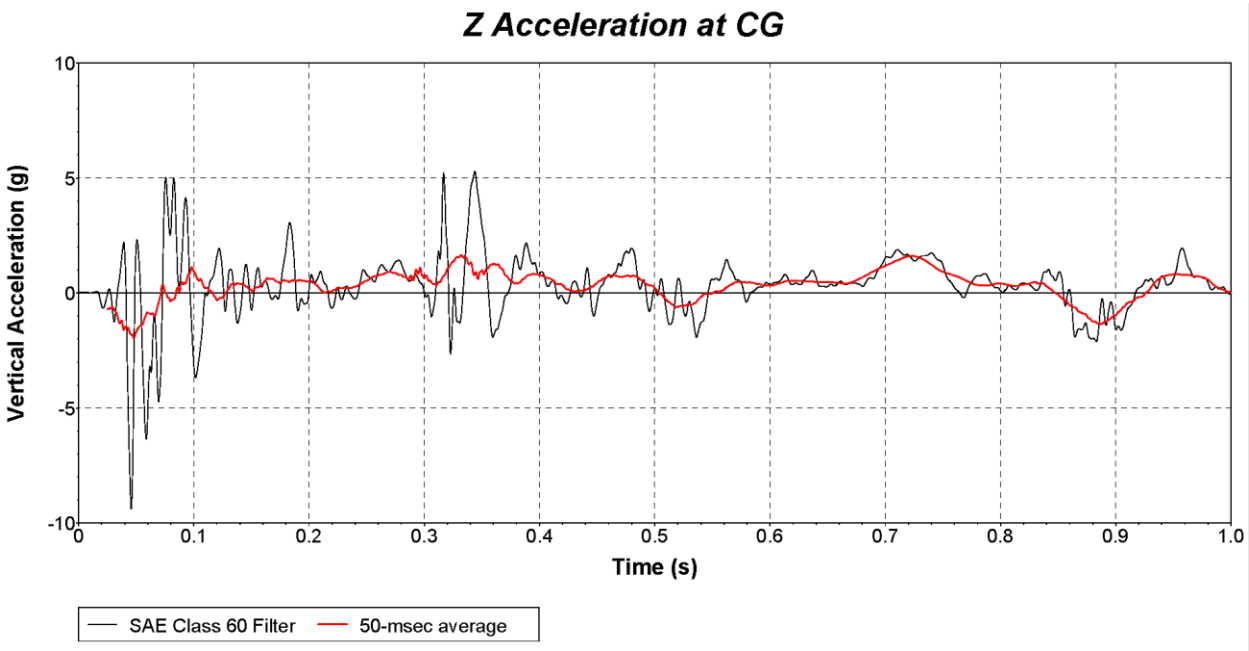


Figure D.6. Vehicle Vertical Accelerometer Trace for Test No. 616151-01-1 (Accelerometer Located at Center of Gravity).