Texas A&M Transportation Institute
Proving Ground

Test Report No. 617741-01-1

MASH 4-12 EVALUATION OF SINGLE SLOPE CONCRETE BRIDGE RAIL WITH FENCE SYSTEM MOUNTED ON TOP

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16. Abstract

This research was performed to develop and crash test a design of fence system mounted on top of a single slope concrete bridge rail. The design was developed using extensive finite element simulation analysis, followed by full-scale crash testing to verify the crashworthiness of the fence system mounted on top of a 36-inch tall permanent single slope concrete bridge rail. The performance of the fence and barrier system was assessed in accordance with the safety-performance evaluation guidelines included in the second edition of the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*1*). The crash test was performed in accordance with *MASH* Test 4-12 requirements for Test Level 4 (TL-4). This involves a 10000S single unit truck weighing 22,046 lb impacting the barrier system at an angle of 15 degrees while traveling at a speed of 56 mi/h.

This report provides details and results of the finite element analysis. It also provides the details of the fence and single slope bridge rail system, the crash tests and results, and the performance assessment of the fence and single slope bridge rail system for *MASH* Test 4-12 for longitudinal barriers.

The single slope bridge rail system with fence mounted on top met the performance criteria for *MASH* Test 4-12 for longitudinal barriers.

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MASH 4-12 Evaluation of Single Slope Concrete Bridge Rail with Fence System Mounted on Top

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The results reported herein apply only to the article tested. The full-scale crash test was performed according to TTI Proving Ground quality procedures and American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware, Second Edition (*MASH*) guidelines and standards.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

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

*SI is the symbol for the International System of Units

Chapter 1. INTRODUCTION

It is sometimes desirable to install a chain link fence on top of a concrete barrier. In a past research project, Texas A&M Transportation Institute (TTI) performed crash testing of a 36-inch tall single slope median barrier with a chain link fence system installed on top (*2*). The posts of the fence system were installed at the centerline of the single slope median barrier. This system passed American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware's* (*MASH*) Test 4-11 with the pickup truck. However, it failed to pass Test 4-12 with the single unit truck. The posts of the fence system engaged the cab as the vehicle leaned over the barrier during redirection. This led to excessive occupant compartment deformation and protrusion of the fence posts into the occupant compartment through the windshield.

Based on the above-mentioned tests, it was concluded that the median single slope barrier with the fence installed on top is acceptable for *MASH* Test Level 3 (TL-3). However, it was not acceptable for *MASH* Test Level 4 (TL-4) due to the unsuccessful performance with the single unit truck.

While the fence system mounted on top of a median barrier failed to meet MASH TL-4, there was a possibility to design a fence system that could be mounted on a roadside concrete barrier or a bridge rail. This system could offset the fence posts away from the impact side of the barrier, thus reducing the interaction of the fence system with the single unit truck.

The objective of this project was to design and crash test a fence system mounted on top of a rigid single slope concrete bridge rail. The height of the single slope bridge rail was selected to be 36 inches. This report presents details of the design of this system using finite element (FE) simulation analysis and the evaluation of the final design through full-scale crash testing.

Details of the design and simulation analysis are presented in Chapter 2. Details of the crash testing are presented in Chapters 3 through 7. The crash test reported herein assessed the performance of the Single Slope Concrete Bridge Rail with Fence System Mounted on Top according to the safety-performance evaluation guidelines included in the AASHTO *MASH*, Second Edition (*1*). The crash test was performed in accordance with *MASH* Test 4-12 evaluation criteria.

Chapter 2. SIMULATION AND DESIGN

2.1. INTRODUCTION

As described in the previous chapter, a past MASH Test 4-12 of a fence system installed on top of a 36-inch tall single slope median barrier failed due to excessive occupant compartment deformation (*2*). Figure 2.1 shows the vehicle damage during and after the test. The posts of the fence system struck the cab during the test and penetrated the front windshield as the vehicle passed. The measured maximum occupant compartment deformation was 10.0 inches at the midpoint of the collapsed left A-pillar.

Figure 2.1. Vehicle Damage during and after Test No. 613131-03-2.

In this research project, the research team developed a design of a new fence system that can be installed on a roadside rigid single slope concrete barrier or a bridge rail. The research team first developed an FE model of the previously failed fence system (Figure 2.1) and performed impact simulation to evaluate the validation of the model. The researchers made several improvements to the vehicle and fence models to get better correlation with the failed test of the fence installed on the median barrier. The researchers then developed a model of the roadside fence system concept using the same fence and barrier modeling techniques to have greater confidence in the capability of the model to predict the crash performance of the fence and barrier system with the single unit truck model. The researchers used the simulation analysis to improve the design and made design recommendations for full scale crash testing. Details of the modeling and simulation are presented next.

2.2. FINITE ELEMENT MODEL VALIDATION

Prior to designing a new system, the FE model was calibrated and improved to achieve a more realistic estimation. To calibrate the FE model, it was set up with the same conditions as the full-scale crash test conducted by TTI (Test No. 613131-03-2). Simulation results were compared to the test results and changes to the models were made to enhance the accuracy of the FE model.

2.2.1. Fence Mounted on Top of the Single Slope Concrete Median Barrier

Figure 2.2 shows the fence system mounted on top of the single-slope concrete median barrier (CMB) installed for Test No. 613131-03-2.

Figure 2.2. Fence System Mounted on Top of CMB for Test No. 613131-01-2.

Key design details of the tested system are shown in Figure 2.3. The installation consisted of a 72-inch tall, 2-inch mesh chain link fence mounted on top of 36-inch-tall single-slope concrete barrier. The slope of the barrier was 10.8 degrees. The length of the barrier system was 120 ft and total length of the fence system was 103 ft-¾ inches. The barrier was 10 inches wide at the top. Further details of this system can be found in the full crash test report (*2*).

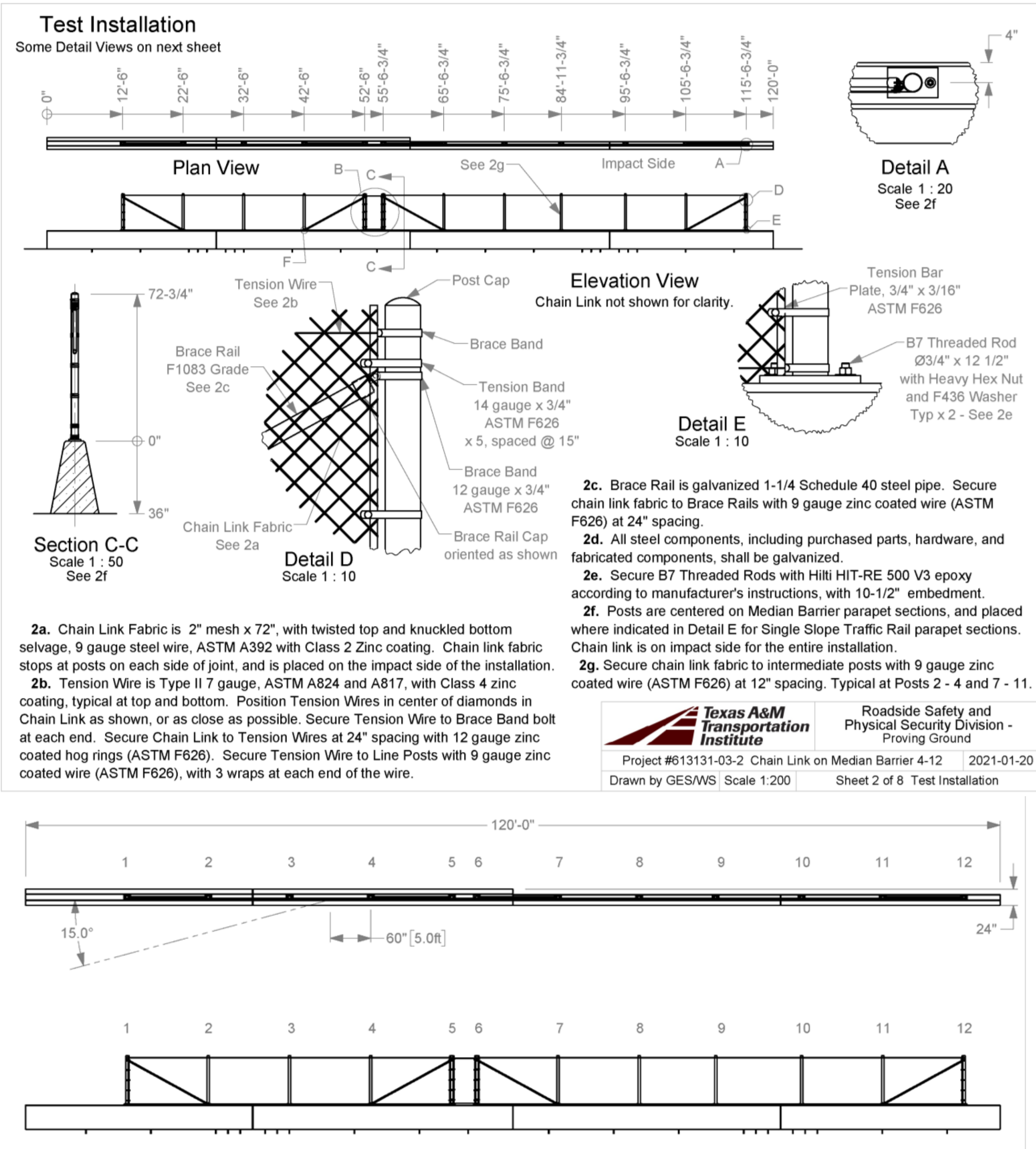
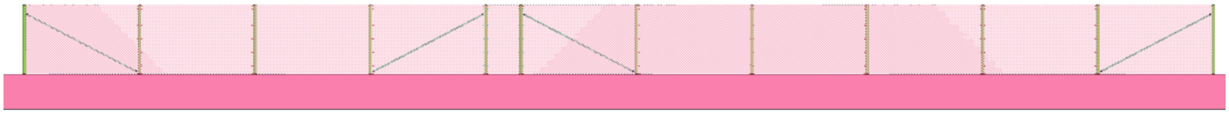


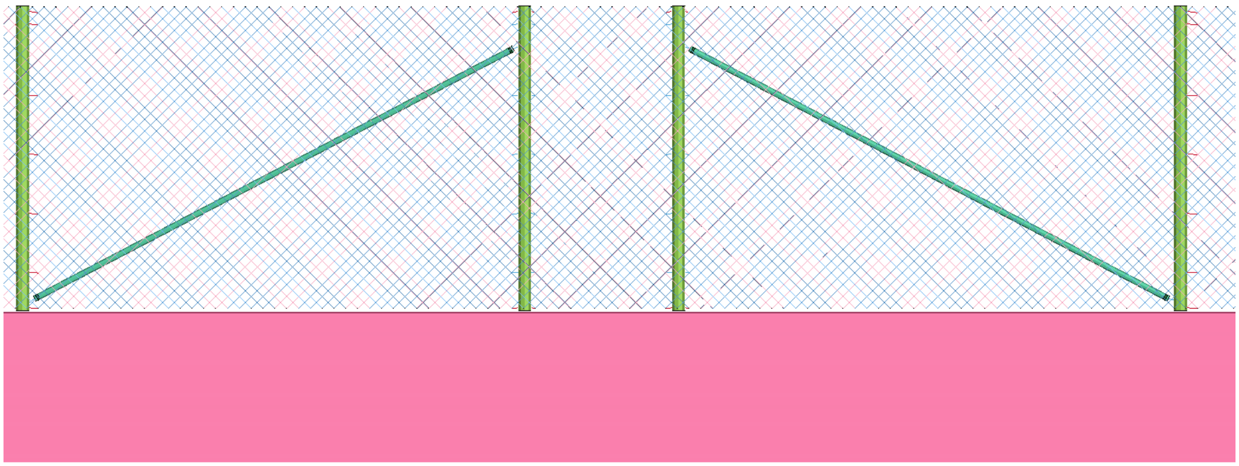
Figure 2.3. Details of Fence System Mounted on Top of CMB and Test Setup.

2.2.2. Test 4-12 Simulation with Fence System Mounted on Top of CMB

Figure 2.4 shows an overview of the FE model representing the fence mounted on top of CMB tested by TTI. The ground and CMB were modeled with a rigid material since no significant damage was observed in the test. Steel posts and chain link fence were modeled with deformable materials with elastic-plastic material properties.



(a) Elevation View



(b) Closeup Model

Figure 2.4. FE Model of the Previously Tested Median Barrier Design.

In the full-scale test, the 2012 International 4300 single-unit truck (SUT) was used. The simulation model of the SUT was based on a 1996 Ford F800. To incorporate the actual test impact conditions, the test impact velocity of 55.91 mi/h and the test impact angle of 15 degrees were used in the impact simulation. Several improvements were made to the vehicle model and the chain link fence model to capture the failure modes observed in the crash testing. Figure 2.5 shows sequential images comparing the behavior of the improved simulation model to the crash test results.

In both the test and FE simulation, the post of the fence interacted with the cab and the box of the vehicle. In the simulation results, the posts struck the cab of the vehicle in a manner similar to what was observed in the crash test. The vehicle in the simulation had more pitch compared to the test vehicle, but the key mode of failure in the crash test, i.e., the fence posts striking the cab to cause excessive occupant compartment deformation, was captured with the simulation model. The model was thus considered suitable for further use in the project to evaluate the modified fence design and determine if it would reduce the fence posts-to-cab interaction.

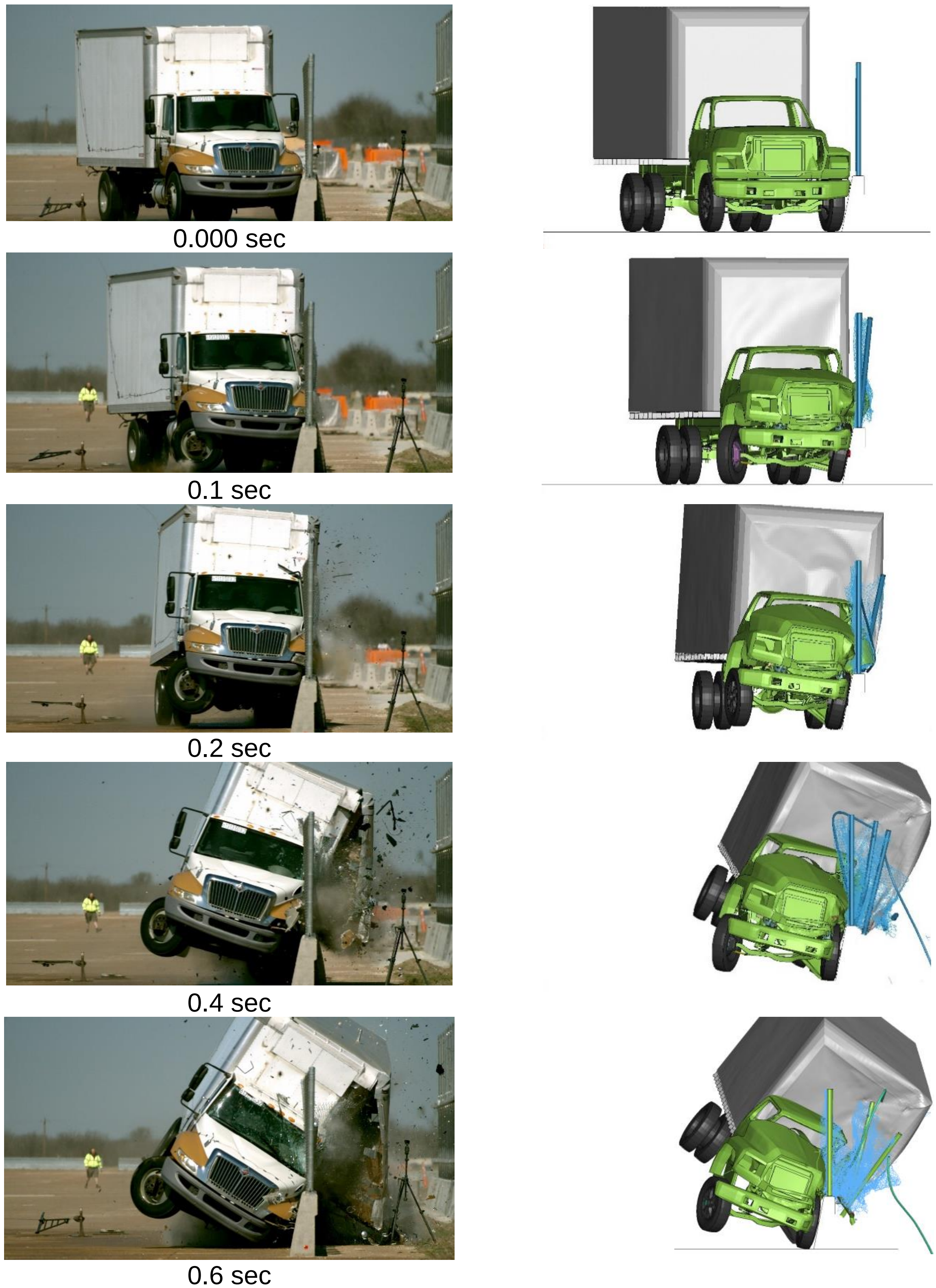


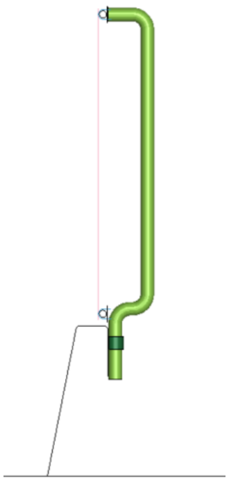
Figure 2.5. Comparison of the FE Simulation with Crash Test of Fence Installed at the Center of the Barrier's Top.

2.3. DEVELOPMENT AND EVALUATION OF NEW FENCE DESIGN ON CONCRETE BRIDGE RAIL

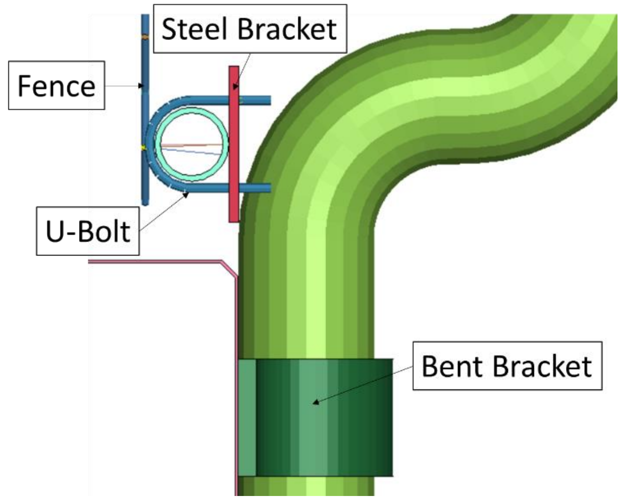
To prevent the fence posts from striking the cab and causing excessive occupant compartment deformation, the research team attached the fence posts to the field side of the concrete bridge rail, and further offset them away from the impact side by bending them at the bottom. The posts were bent back toward the impact side at the top of the fence, resulting in a shallow U-shape posts. Adjacent fence posts were connected at the top using a horizontal pipe that helped in moving the posts further away from the vehicle's cab as the box of the single unit truck impacted the horizontal pipe. The FE model of this design concept is shown in Figure 2.6. This design was based on a previously developed concept of a fence system that prevented motorcyclists from interacting with the fence posts during motorcycle impacts (*3*).

The chain link fence was attached to the front of bent posts by attaching it the top and bottom horizontal pipes. The horizontal pipes were attached to the fence posts using steel bracket plates and U-bolts as shown in Figure 2.6. The fence posts were attached to the back of the concrete bridge rail using a bent bracket and epoxy anchor bolts. In the FE model, each steel component was modeled with their corresponding elastic-plastic material properties, while the concrete barrier was modeled as rigid. The chain link fence model was based on previously developed model with further improvements to allow material failure due to excessive plastic strain (*3*).

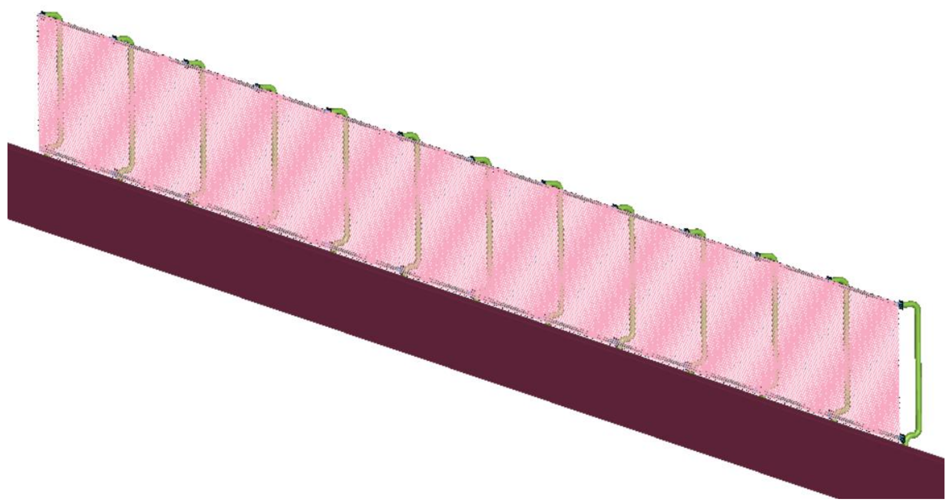
The researchers performed *MASH* Test 4-12 impact simulations with the fence and bridge rail system. The vehicle impacted the barrier at a speed and angle of 56 mi/h and 15 degrees, respectively. The sequential images from the simulation are shown in Figure 2.7.



(a) Cross-Section View



(b) Connection Details



(c) Isometric View of System Model

Figure 2.6. FE Model of the Offset Fence System Design Mounted on Concrete Bridge Rail.

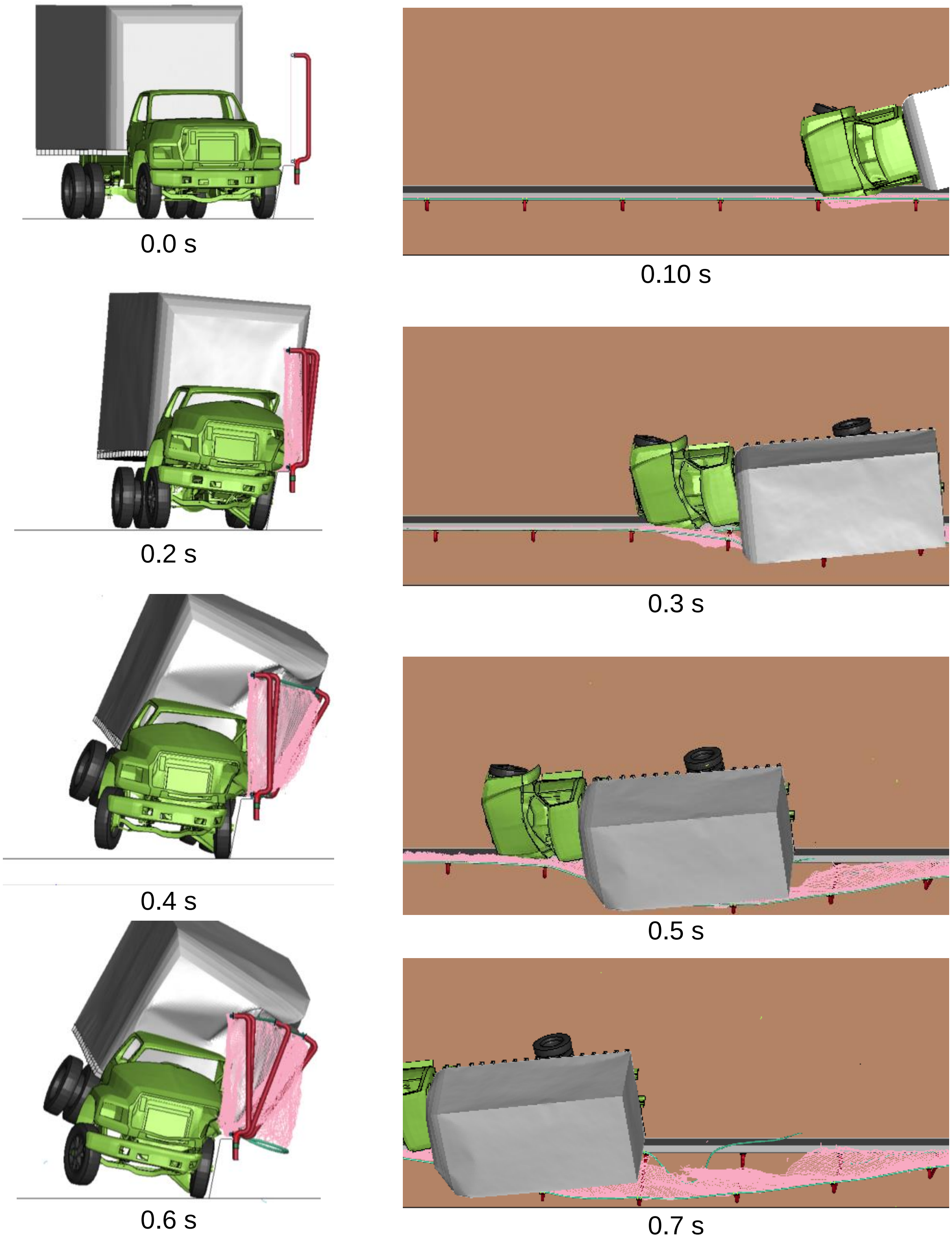
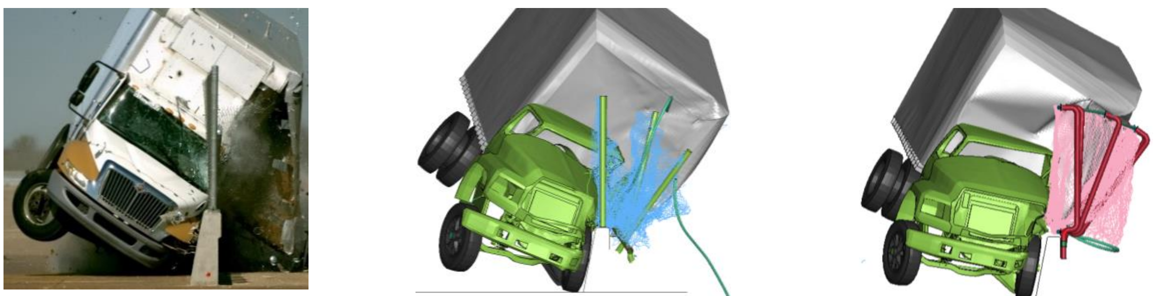


Figure 2.7. MASH Test 4-12 Impact Simulation Results with Offset Fence System Mounted on Concrete Bridge Rail.

The vehicle damage was significantly reduced with the offset posts of the new fence design. The posts did not strike the cab or the A-pillar of the single unit truck during the impact. A comparison of the design improvement with the offset posts is shown in Figure 2.8. Since the primary mode of failure in Test 6136131-03-2 was the excessive occupant compartment deformation due to the fence posts striking the cab and the vehicle's A-pillar, the mitigation of these issues in the offset-post design simulation indicated a reasonable probability of the design to meet MASH Test 4-12 criteria. The researchers thus recommended performing this test to verify simulation results and the performance of the fence and the barrier system.

During the design review phase after the initial design, the chain link fence was moved laterally to attach to the fence posts. This was considered an improvement of the design that would provide better support for the fence as opposed to being supported just at the top and bottom. Details of the crash tested system and full scale crash testing results are presented in the following chapters.



Failed
Test 613131-03-2

Simulation of
Test 613131-03-2

Simulation of New
Roadside Design

Figure 2.8. Comparison of Fence Post Interaction.

Chapter 3. SYSTEM DETAILS

3.1. TEST ARTICLE AND INSTALLATION DETAILS

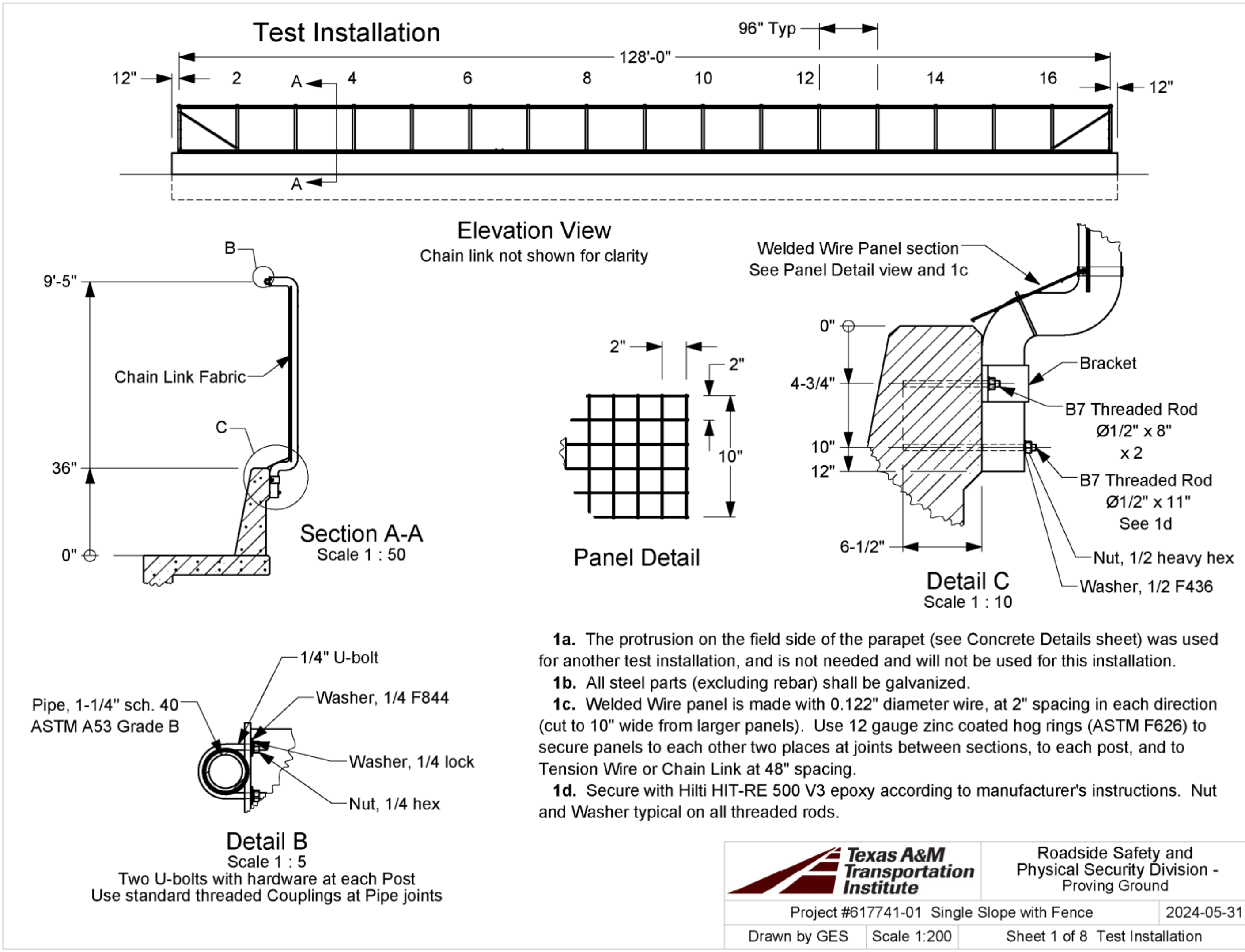
The installation consisted of a 128 foot long fence system mounted on a 130 foot long single-slope concrete bridge rail. The bridge rail was 36 inches tall, 7.5 inches wide on the top, and 13 inches wide at the bottom. The sloped face of the bridge rail was on the impact side. The fence system was attached to the non-impact side of the bridge rail and extended 9 feet 5 inches above the top of the concrete bridge rail. The main portion of the fence mesh was chain link fabric mounted to fence posts that were spaced at 96 inches center to center. Near the top of the concrete bridge rail, the fence posts were offset toward the field side. At top of the fence posts, the post pipes were bent toward the impact side and connected to adjacent fence posts by a series of longitudinal pipes that were spliced together. A welded wire mesh panel was attached to the bent fence posts to cover the gap between the top of the concrete bridge rail and the chain link fence.

Figure 3.1 presents the overall information on the Fence System Mounted to Concrete Bridge Rail, and Figure 3.2 thru Figure 3.7 provide photographs of the installation. Appendix A provides further details on the fence and bridge rail system. Drawings of the test installation were developed by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

The concrete bridge rail used in this test was also used for another crash test that involved constructing a steel-reinforced concrete mounting block on the non-impact side of the single slope bridge rail at one of the locations. It is noted that this mounting block was not incorporated in the concrete bridge rail design for the purposes of evaluating the performance of the Fence System Mounted to the Concrete Bridge Rail.

3.2. DESIGN MODIFICATIONS DURING TESTS

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



S:\Accreditation-17025-2017\EIR-000 Project Files\617741-01 - Fence Mounted System - Sheikh\Drafting, 617741-01\617741-01 Drawing

Figure 3.1. Details of Fence System Mounted to Concrete Bridge Rail.

Figure 3.2. Fence System Mounted to Concrete Bridge Rail Prior to Testing.

Figure 3.3. In-Line View of the Fence System Mounted to Concrete Bridge Rail Prior to Testing.

Figure 3.4. Elevation View of the Fence System Mounted to Concrete Bridge Rail at Impact Prior to Testing.

Figure 3.5. Fence System Mounted to Concrete Bridge Rail Mesh Detail Prior to Testing.

Figure 3.6. Field Side of the Fence System Mounted to Concrete Bridge Rail Prior to Testing.

Figure 3.7. Field Side Fence Post Attachment to Concrete Bridge Rail Prior to Testing.

3.3. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to install/construct the Fence System Mounted to Concrete Bridge Rail. Table 3.1 shows the average compressive strengths of the concrete.

Table 3.1. Concrete Strength[a].

Location	Design Strength	Avg. Strength	Age	Detailed Location
Foundation Wall	4000 psi	4447 psi	17 days	Downstream 100 feet of the foundation wall.
Deck	4000 psi	4297 psi	17 days	Downstream 100 feet of the deck.
Deck and Foundation Wall	4000 psi	3953 psi	17 days	Remainder of deck and foundation wall.
Single Slope Bridge Rail and Mounting Block	3600 psi	3363 psi	7 days	A complete 40-foot section of the bridge rail was poured starting at the upstream end of the rail, then 50 percent of the bridge rail was poured over the next 70 feet. This section included the mounting block.
Bridge Rail and Mounting Block	3600 psi	3667 psi	7 days	The remaining half of the 70-foot section of bridge rail from the previous pour, including the mounting block, and 100 percent of the last 20 feet of the barrier on the downstream end.

[a] The concrete barrier used was repurposed from a previous crash test (Project 440863-01-3), and the mounting block referred to was not used for this test. The strengths and ages represent the values from the day of the crash test for the prior project on 2023-06-22.

Chapter 4. TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1. CRASH TEST PERFORMED

Table 4.1 shows the test conditions and evaluation criteria for *MASH* Test 4-12 for a longitudinal barrier. The target critical impact point (CIP) for the test was 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* Test 4-12 on the Fence System Mounted to Concrete Bridge Rail.

Table 4.1. Test Conditions and Evaluation Criteria Specified for *MASH* Test 4-12 for Longitudinal Barriers.

Test Designation	Test Vehicle	Impact Speed	Impact Angle	Evaluation Criteria
4-12	10000S	56 mi/h	15º	A, D, G

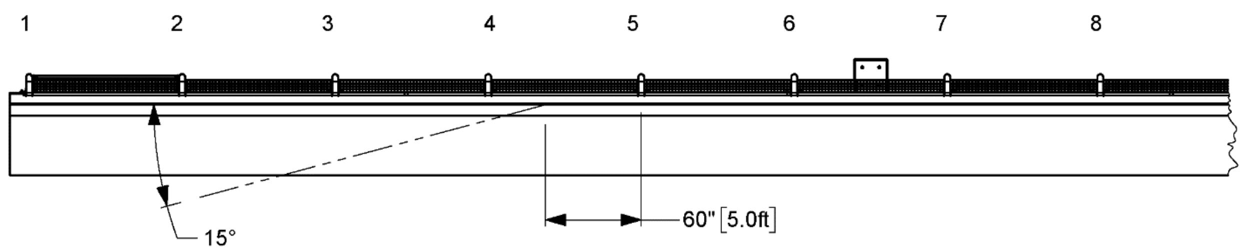


Figure 4.1. Target CIP for *MASH* Test 4-12 on Fence System Mounted to Concrete Bridge Rail.

The crash test and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 5 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 test reported herein. Table 4.1 lists the test conditions and evaluation criteria required for *MASH* Test 4-12, and Table 4.2 provides detailed information on the evaluation criteria.

Table 4.2. Evaluation Criteria Required for *MASH* Test 4-12.

Evaluation Factors	Evaluation Criteria
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.
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of *MASH*.
G.	It is preferable, although not essential, that the vehicle remain upright during and after the collision.

Chapter 5. TEST CONDITIONS

5.1. TEST FACILITY

The full-scale crash test reported herein was 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 test was 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/runway 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

The 10000S vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point and through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2:1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released and ran unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site.

5.3. DATA ACQUISITION SYSTEMS

5.3.1. Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a multi-channel data acquisition system (DAS) produced by Diversified Technical Systems Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid-state units designed for crash test service. The data acquisition hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 samples per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit in case the primary battery cable is severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the DAS unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each DAS is returned to the factory annually for complete recalibration and to ensure that all instrumentation used in the vehicle conforms to the specifications outlined by SAE J211. All accelerometers are calibrated annually by means of an ENDEVCO® 2901 precision primary vibration standard. This standard and its support instruments are checked annually and receive a National Institute of Standards Technology (NIST) traceable calibration. The rate transducers used in the data acquisition system receive calibration via a Genisco Rate-of-Turn table. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel per SAE J211. Calibrations and evaluations are also made anytime data are suspect. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k = 2).

TRAP uses the DAS-captured data to compute the occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with an SAE Class 180-Hz low-pass digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

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

5.3.2. Anthropomorphic Dummy Instrumentation

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

5.3.3. Photographic Instrumentation Data Processing

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

- One placed overhead with a field of view perpendicular to the ground and directly over the impact point.
- One placed with a field of view parallel to and aligned with the installation at the downstream end.
- One placed at an oblique angle upstream from the installation on the field side.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Fence System Mounted to Concrete Bridge Rail. 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 4-12 (CRASH TEST 617741-01-1)

6.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 6.1 for details on *MASH* impact conditions for this test, and Table 6.2 for the exit parameters. Figure 6.1 and Figure 6.2 depict the target impact setup.

Table 6.1. Impact Conditions for *MASH* TEST 4-12, Crash Test 617741-01-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	56 mi/h	±2.5 mi/h	58.2 mi/h
Impact Angle	15°	±1.5°	15.1°
Impact Severity	142 kip-ft	≥142 kip-ft	170.7 kip-ft
Impact Location	5 feet upstream from the centerline of fence post 5.	±12 inches	5 feet 1.9 inches upstream from the centerline of post 5.

Table 6.2. Exit Parameters for *MASH* TEST 4-12, Crash Test 617741-01-1.

Exit Parameter	Measured
Speed	The vehicle exited along the fence and barrier. Measurements could not be taken.
Trajectory	The vehicle exited along the fence and barrier. Measurements could not be taken.
Heading	The vehicle exited along the fence and barrier. Measurements could not be taken.
Brakes applied post impact	2.3 seconds
Vehicle at rest position	237 ft downstream of impact point. 31 ft to the field side. Vehicle positioned 85° left relative to the installation.
Comments:	The vehicle remained upright and stable.

Figure 6.1. Fence System Mounted to Concrete Bridge Rail/Test Vehicle Geometrics for Test 617741-01-1.

Figure 6.2. Fence System Mounted to Concrete Bridge Rail/Test Vehicle Impact Location 617741-01-1.

6.2. WEATHER CONDITIONS

Table 6.3 provides the weather conditions for 617741-01-1.

Table 6.3. Weather Conditions for Test 617741-01-1.

Date of Test	2023-11-17
Wind Speed	7 mi/h
Wind Direction	194°
Temperature	65 °F
Relative Humidity	74 %
Vehicle Traveling	335°

6.3. TEST VEHICLE

Figure 6.3, Figure 6.4, and Figure 6.5 show the 2013 International Maxx Force truck used for the crash test. Table 6.4 shows the vehicle measurements. Figure C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

Figure 6.3. Impact Side of Test Vehicle before Test 617741-01-1.

Figure 6.4. Opposite Impact Side of Test Vehicle before Test 617741-01-1.

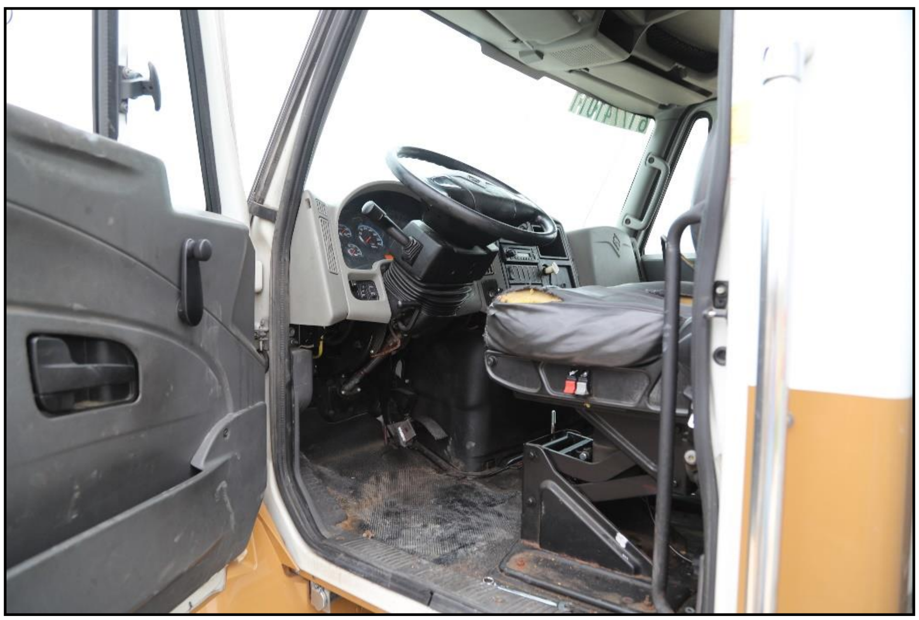


Figure 6.5. Interior of Test Vehicle before Test 617741-01-1.

Table 6.4. Vehicle Measurements for Test 617741-01-1.

Test Parameter	*Specification*	Tolerance	Measured
Curb Weight	13,200 lb	±2200 lb	13,480 lb
Vehicle Inertial Weight	22,046 lb	±660 lb	22,220 lb
Wheelbase	240 inches	≤240 inches	207 inches
Overall Length	394 inches	≤394 inches	329.5 inches
Cargo Bed Height [i]	49 inches	≤2 inches	50 inches
CG of Ballast above Ground[e]	63 inches	≤2 inches	62.5 inches

Note: N/A = not applicable; CG = center of gravity.
i – Without Ballast
e – See section 4.2.1.2 in *MASH* for recommended ballasting procedures

6.4. TEST DESCRIPTION

Table 6.5 lists events that occurred during Test 617741-01-1. Figures C.2, C.3, and C.4 in Appendix C.2 present sequential photographs during the test.

Table 6.5. Events during Test 617741-01-1.

Time (s)	Events
0.000 s	Vehicle impacted the installation
0.034 s	Vehicle began to redirect
0.242 s	Vehicle was parallel with the installation
0.145 s	Drivers side, front corner of box contacted the top rail
0.156 s	Post 5 began to lean toward the field side
0.184 s	Post 6 began to lean toward the field side
0.278 s	Top pipe between posts 6 and 7 broke, and began to bend to field side
0.352 s	Box on the vehicle began to break up
0.643 s	A section of the top pipe began to penetrate through the rear roll-up door of the vehicle from the inside of the box.
0.700 s	Vehicle reached its maximum roll
0.820 s	The top pipe section that penetrated the rear door exits the vehicle
1.608 s	Vehicle lost contact with the installation.

6.5. DAMAGE TO TEST INSTALLATION

The concrete barrier was gouged and scuffed at impact. The top pipe bracket was broken at post 5, and a lower post bracket was broken at posts 7 and 9. The lower wire mesh panel was loose from posts 5 through 8, and the chain link mesh fabric was damaged from posts 5 through 13. Posts 6 through 9 were leaning downstream, with post 9 leaning towards the traffic side as well. The top pipe released from posts 6 through 10 and post 12, with the pipe missing from posts 6 through 9. They landed on the field side and were severely deformed.

Table 6.6 describes the deflection and working width of the Fence System Mounted to Concrete Bridge Rail. Figure 6.6 and Figure 6.7 show the damage to the Fence System Mounted to Concrete Bridge Rail.

Table 6.6. Deflection and Working Width of the Fence System Mounted to Concrete Bridge Rail for Test 617741-01-1.

Test Parameter	Measured
Permanent Deflection/Location	None
Dynamic Deflection	None
Working Width [a] and Height	89.7 inches, at a height of 97.5 inches, at the top pipe between posts 6 and 7.

[a] 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 6.6. Fence System Mounted to Concrete Bridge Rail at Impact Location after Test 617741-01-1.

Figure 6.7. Fence System Mounted to Concrete Bridge Rail at the Point of Maximum Damage after Test 617741-01-1.

6.6. DAMAGE TO TEST VEHICLE

Figure 6.8 and Figure 6.9 show the damage sustained by the vehicle. Figure 6.10 and Figure 6.11 show the interior of the test vehicle. Table 6.7 and Table 6.8 provide details on the occupant compartment deformation and exterior vehicle damage.

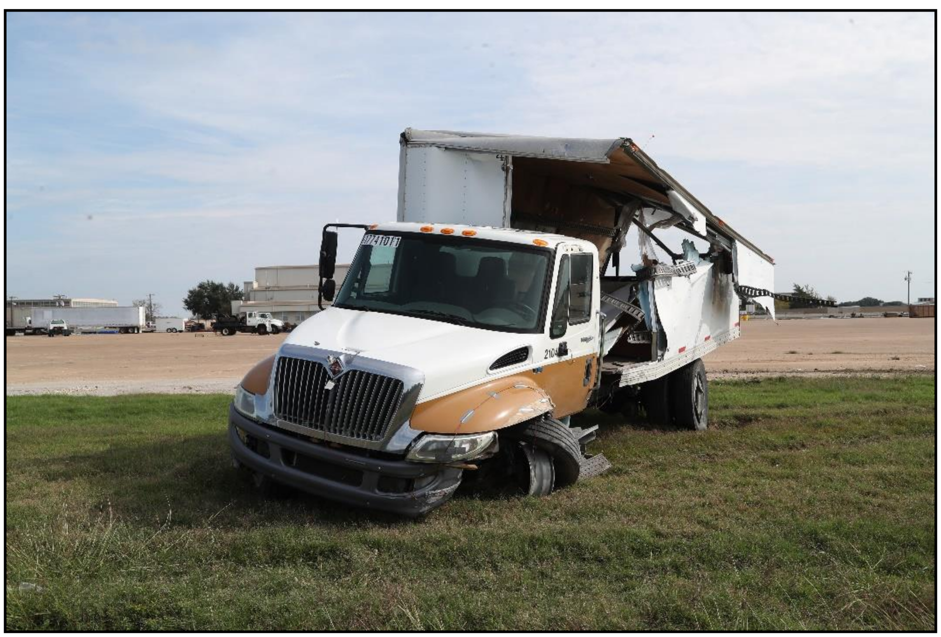


Figure 6.8. Impact Side of Test Vehicle after Test 617741-01-1.

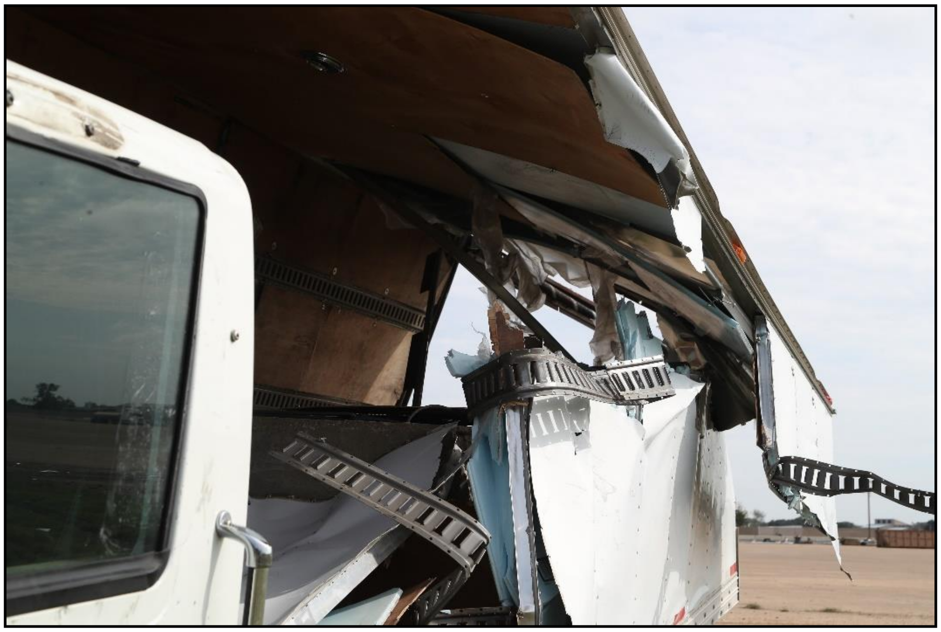


Figure 6.9. Rear Impact Side of Test Vehicle after Test 617741-01-1.

Figure 6.10. Overall Interior of Test Vehicle after Test 617741-01-1.

Figure 6.11. Interior of Test Vehicle on Impact Side after Test 617741-01-1.

Table 6.7. Occupant Compartment Deformation for Test 617741-01-1.

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	7 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

Table 6.8. Exterior Vehicle Damage for Test 617741-01-1.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	16 inches in the front plane at the left corner at bumper height
VDS	11LFQ4
CDC	11FLAW3
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, hood, and left fender were damaged. The front left tire was ripped off, and the wheel bent. The steering control arm was broken. The left side mirror was ripped off, and the left door, side steps, and air tanks were dented. The left side of the box was heavily damaged, and the roll-up door was removed. The left rear wheel was bent, and the tire was punctured.

6.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk and the results are shown in Table 6.9. Figure C.5 in Appendix C.3 shows the vehicle angular displacements, and Figures C.6 through C.8 in Appendix C.4 show acceleration versus time traces.

Table 6.9. Occupant Risk Factors for Test 617741-01-1.

Test Parameter	Measured	Time
OIV, Longitudinal	6.2 ft/s	0.1786 seconds on left side of interior
OIV, Lateral	11.5 ft/s	0.1786 seconds on left side of interior
Ridedown, Longitudinal	3.9 g	0.2847 - 0.2947 seconds
Ridedown, Lateral	8.4 g	0.3081 - 0.3181 seconds
Theoretical Head Impact Velocity (THIV)	4.1 m/s	0.1729 seconds on left side of interior
Acceleration Severity Index	0.7	0.3170 - 0.3670 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal	-2 g	0.0085 - 0.0585 seconds
50-ms MA Lateral	5.8 g	0.2875 - 0.3375 seconds
50-ms MA Vertical	-2.9 g	0.0411 - 0.0911 seconds
Roll	29.8°	0.6442 seconds
Pitch	5.8°	0.8189 seconds
Yaw	15.5	0.8026 seconds

6.8. TEST SUMMARY

Figure 6.11 summarizes the results of *MASH* Test 617741-01-1.

0.000 s

0.200 s

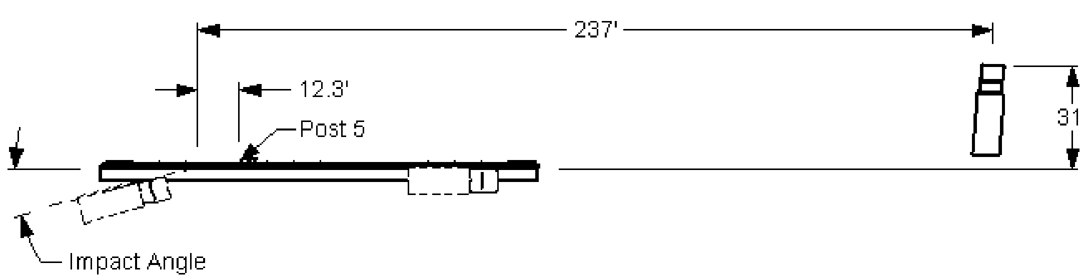
0.400 s

0.600 s

GENERAL INFORMATION	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 4-12
TTI Project No.	617741-01-1
Test Date	2023-11-17
TEST ARTICLE	
Type	Longitudinal Barrier
Name	Fence System Mounted to Concrete Bridge Rail
Length	130 feet
Soil Type and Condition	Concrete, damp
Key Materials	3-inch. Sch. 40 Pipe, 1.25 sch. 40 Pipe, Chain Link Fabric, Wire Panel, Concrete Barrier
TEST VEHICLE	
Type/Designation	10000S
Year, Make and Model	2013 International Maxx Force
Curb Weight	13,480 lb
Inertial Weight	22,220 lb
IMPACT CONDITIONS	
Impact Speed / Impact Angle	58.2 mi/h / 15.1°
Impact Location	5 feet 1.9 inches upstream from centerline of post 5.
Impact Severity	170.7 kip-ft

EXIT CONDITIONS	
Exit Speed	Along Fence and Barrier
Trajectory/Heading Angle	Along Fence and Barrier
Stopping Distance	237 ft downstream 31 ft to the field side
TEST ARTICLE DEFLECTIONS	
Dynamic	None
Permanent	None
Working Width / Height	89.7 inches / 97.5 inches
VEHICLE DAMAGE	
VDS	11LFQ4
CDC	11FLAW3
Max. Ext. Deformation	16 inches
Max Occupant Compartment Deformation	7 inches in the floor pan/transmission tunnel

OCCUPANT RISK VALUES			
Long. OIV	6.2 ft/s	Max 50-ms Long.	-2 g
Lat. OIV	11.5 ft/s	Max 50-ms Lat.	5.8 g
Long. Ridedown	3.9 g	Max 50-ms Vert.	-2.9 g
Lat. Ridedown	8.4 g	Max Roll	29.8°
THIV	4.1 m/s	Max Pitch	5.8°
ASI	0.7	Max Yaw	15.5°



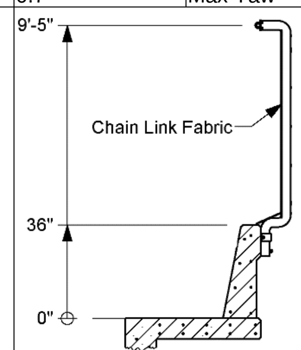


Figure 6.12. Summary of Results for *MASH* Test 4-12 on Fence System Mounted to Concrete Bridge Rail.

Chapter 7. SUMMARY AND CONCLUSIONS

7.1. ASSESSMENT OF TEST RESULTS AND CONCLUSIONS

The crash test reported herein was performed in accordance with the evaluation criteria for *MASH* Test 4-12 on the Fence System Mounted to Concrete Bridge Rail.

Table 7.1 shows that the Fence System Mounted to Concrete Bridge Rail met the performance criteria for *MASH* Test 4-12 for longitudinal barriers.

Table 7.1. Assessment Summary for *MASH* Test 4-12 on Fence System Mounted to Concrete Bridge Rail.

Evaluation Criteria	Description	Test 617741-01-1
A	Contain, Redirect, or Controlled Stop	S
D	No Penetration into Occupant Compartment	S
G	Rolling is acceptable	S
Overall	Evaluation	Pass

Note: S = Satisfactory
[1] See **Error! Reference source not found.** for details

7.2. IMPLEMENTATION*

MASH TL-4 evaluation criteria requires performing Test 4-10 (with 1100C small car) and Test 4-11 (with 2270P pickup truck) in addition to Test 4-12. Only Test 4-12 was performed for the fence and single slope bridge rail system under this project. Tests 4-10 and 4-11 were not performed since they are not critical tests for this system.

Test 4-11 with the 2270P pickup was performed for the fence system mounted on top of the median single slope barrier, as discussed in Chapter 1. In this test, the fence posts were located at the centerline of the single slope barrier, much closer than the offset posts tested in this new research. Since the pickup truck test passed successfully with the posts installed at the centerline of the barrier, it is expected to also pass with the fence posts installed at an offset away from the traffic side of the barrier.

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

MASH Test 4-10 with a lighter 1100C small car is not likely to impart greater load into the barrier or climb high enough to interact significantly with the offset fence system. Furthermore, based on the performance of the single slope barrier in past testing, this test is not considered critical. As an example, Whitesel et al. preformed a MASH Test 3-10 (same conditions and criteria as MASH Test 4-10) on a permanent single slope barrier which passed the MASH testing criteria (*4*).

Based on the discussion above, the newly designed fence system mounted on a concrete bridge rail or a roadside concrete barrier can be considered MASH TL-4 compliant and are ready for field implementation.

REFERENCES

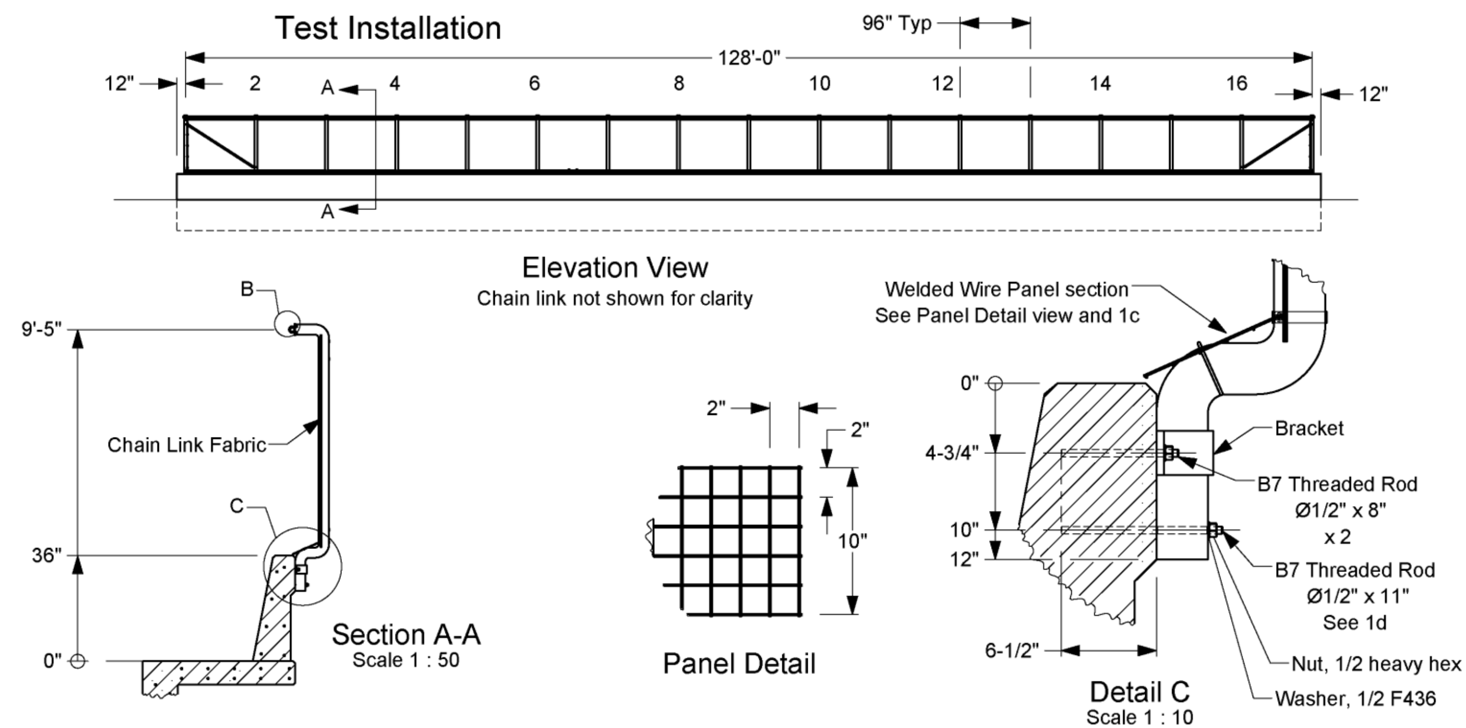
1. AASHTO. *Manual for Assessing Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.

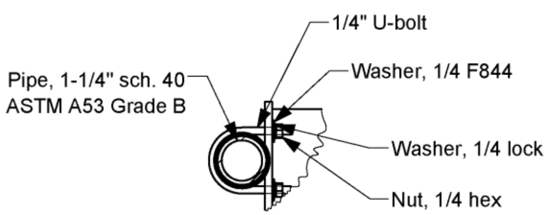
2. C. S. Dobrovolny, R. P. Bligh, J. C. Kover, W. L. Menges, W. Schroeder, B. L. Griffith, and D. L. Kuhn, *"MASH TL-4 Evaluation of Concrete Median Barrier with Fence Mounted on Top."* Test Report No. 613131-03-1 & 2, Texas A&M Transportation Institute, College Station, Texas, 2022.

3. C. S. Dobrovolny, S. Shi, J. C. Kover, R. P. Bligh, D. L. Kuhn, and B. L. Griffith, *"Development and Evaluation of Concrete Barrier Containment Options for Errant Motorcycle Riders."* Report No. 0-6968-R6, Texas A&M Transportation Institute, College Station, Texas, 2019.

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

APPENDIX A. DETAILS OF FENCE SYSTEM MOUNTED TO CONCRETE BRIDGE RAIL





Detail B
Scale 1 : 5
Two U-bolts with hardware at each Post
Use standard threaded Couplings at Pipe joints

1a. The protrusion on the field side of the parapet (see Concrete Details sheet) was used for another test installation, and is not needed and will not be used for this installation.

1b. All steel parts (excluding rebar) shall be galvanized.

1c. Welded Wire panel is made with 0.122" diameter wire, at 2" spacing in each direction (cut to 10" wide from larger panels). Use 12 gauge zinc coated hog rings (ASTM F626) to secure panels to each other two places at joints between sections, to each post, and to Tension Wire or Chain Link at 48" spacing.

1d. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions. Nut and Washer typical on all threaded rods.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #617741-01 Single Slope with Fence		2024-05-31
Drawn by GES	Scale 1:200	Sheet 1 of 8 Test Installation

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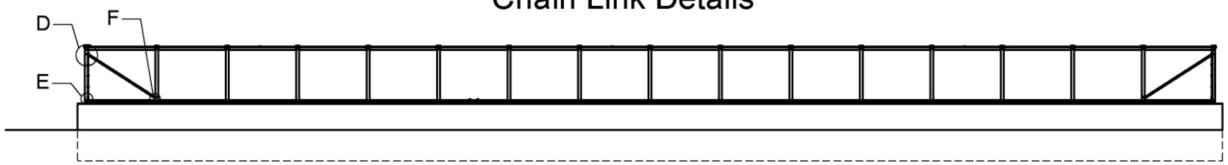
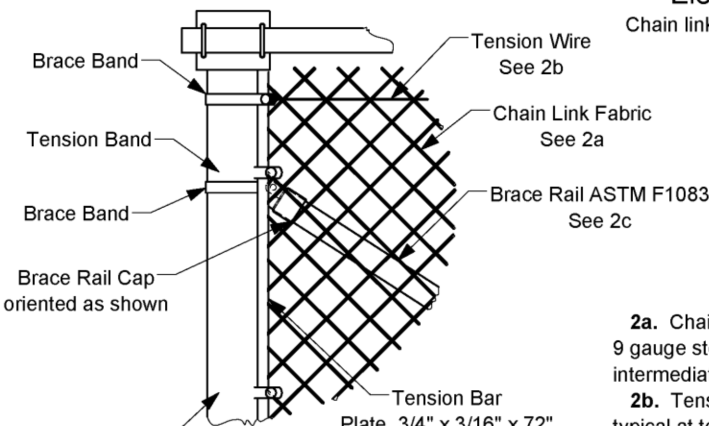
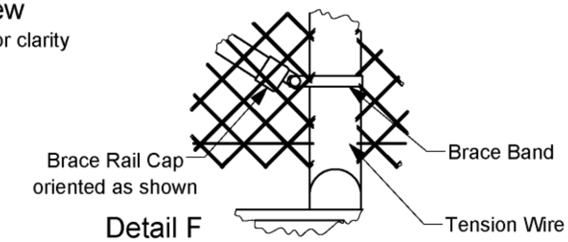
Chain Link Details



Elevation View
Chain link not shown for clarity



Detail D
Scale 1 : 10



Detail F
Scale 1 : 10
Welded Wire Panel not shown for clarity

2a. Chain Link Fabric is 2" mesh x 72", with twisted top and knuckled bottom selvage, 9 gauge steel wire, ASTM A392 with Class 2 Zinc coating. Secure chain link fabric to intermediate posts with 9 gauge zinc coated wire (ASTM F626) at 12" spacing.

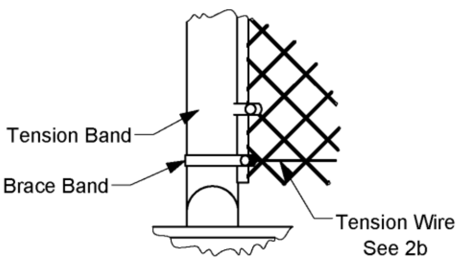
2b. Tension Wire is Type II 7 gauge, ASTM A824 and A817, with Class 4 zinc coating, typical at top and bottom. Position Tension Wires in center of diamonds in Chain Link as shown, or as close as possible. Secure Tension Wire to Brace Band bolt at each end. Secure Chain Link to Tension Wires at 24" spacing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

2c. Brace Rail is galvanized 1-1/4 Schedule 40 steel pipe (∅1.660 OD), cut to fit securely in Brace Rail Caps. Secure chain link fabric to Brace Rails with 9 gauge zinc coated wire (ASTM F626) at 24" spacing.

2d. Brace Bands are 12 gauge x 3/4" ASTM A626. Tension Bands are 14 gauge x 3/4" ASTM A626.

2e. All steel components, including purchased parts, hardware, and fabricated components, but excluding rebar,shall be galvanized.

2f. Components shown in Detail Views are typical each end.



Detail E
Scale 1 : 10
Welded Wire Panel not shown for clarity

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
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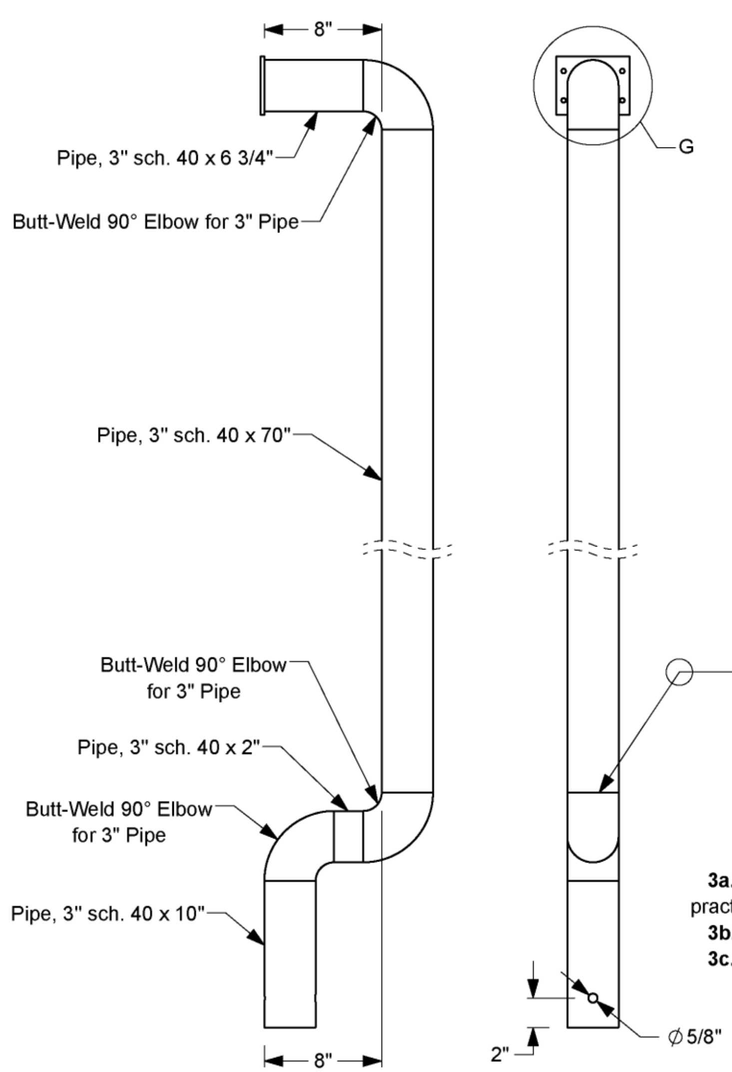
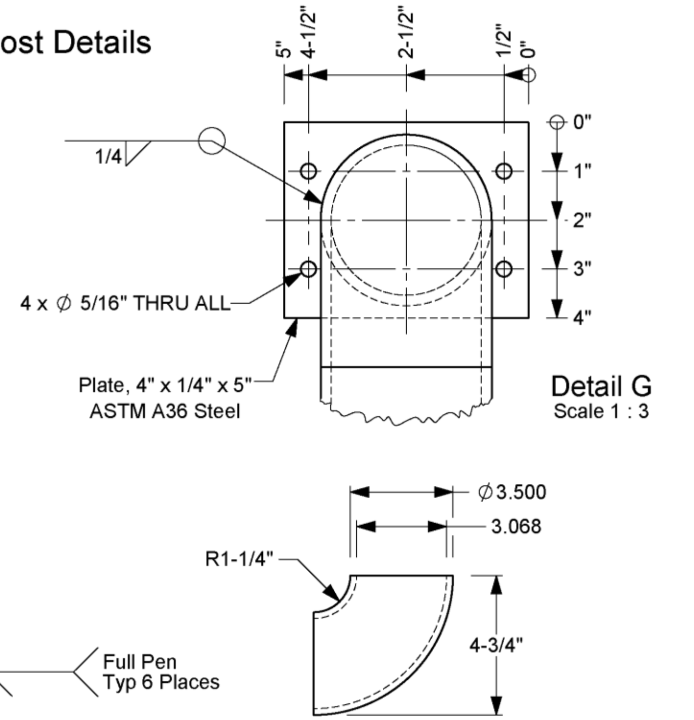
Drawn by GES	Scale 1:200	Sheet 2 of 8 Chain Link Details



Post Details



Butt-Weld 90° Elbow for 3" Pipe
McMaster-Carr Part #43425K187
or equivalent part from another supplier
Scale 1:5

3a. All welding must be performed by certified welders using industry standard practices.
3b. Galvanize after fabrication is complete.
3c. 3" schedule 40 Pipe (3-1/2" OD) is ASTM F1083 Regular Grade (30 ksi yield).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #617741-01 Single Slope with Fence		2024-05-31
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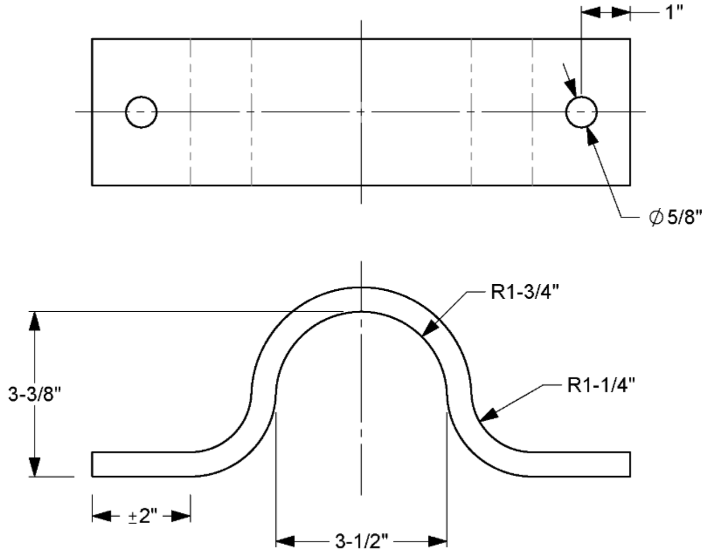
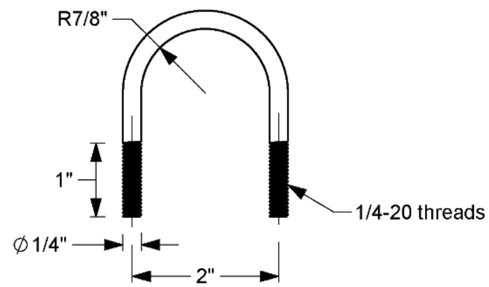


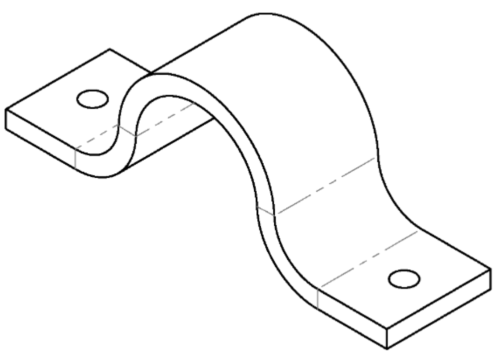
Bracket

Plate, 3" x 1/2" x 14 3/4"



1/4" U-bolt

for 1-1/4" pipe
6 1/2" long before bending
Scale 1:2



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #617741-01 Single Slope with Fence		2024-05-31
Drawn by GES	Scale 1:3	Sheet 4 of 8 Bracket and U-bolt

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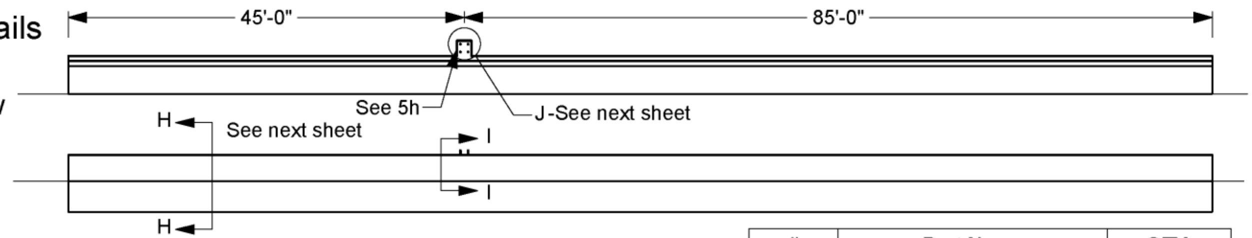
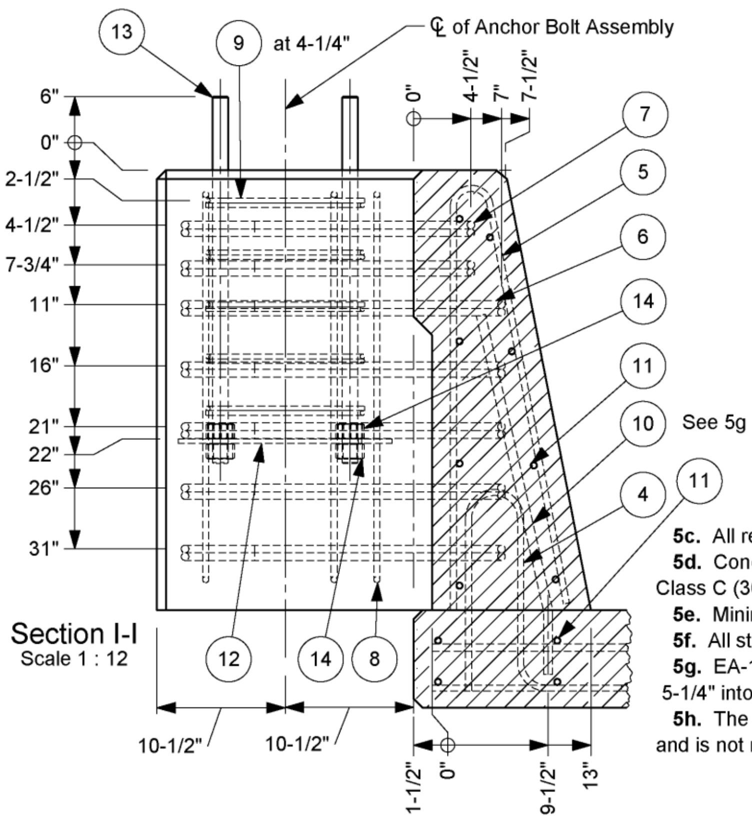
Concrete Details





Section I-I
Scale 1 : 12

#	Part Name	QTY.
1	Tie Bar	-
2	L-2 bar	-
3	L-1 bar	-
4	U bar	-
5	S Bar	-
6	UL-1 bar	-
7	UL-2 bar	-
8	C bar	-
9	SL bar	-
10	EA-1 bar	-
11	1/2" Rebar	*
12	Anchor Plate	-
13	Anchor Rod	-
14	Nut, 1-1/4" heavy hex	8
21	Washer, 1-1/4 lock	-

5c. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

5d. Concrete shall be TxDOT Class S (4000 psi) for the Wall and Deck, and TxDOT Class C (3600 psi) for the Parapet.

5e. Minimum rebar lap is 19" for #4 bars. All rebar is grade 60.

5f. All steel components, excluding rebar, shall be galvanized unless otherwise indicated.

5g. EA-1 bars at 10" spacing, 30" each way from center of Luminaire concrete. Embed 5-1/4" into deck and secure with Hilti HIT RE-500 epoxy adhesive.

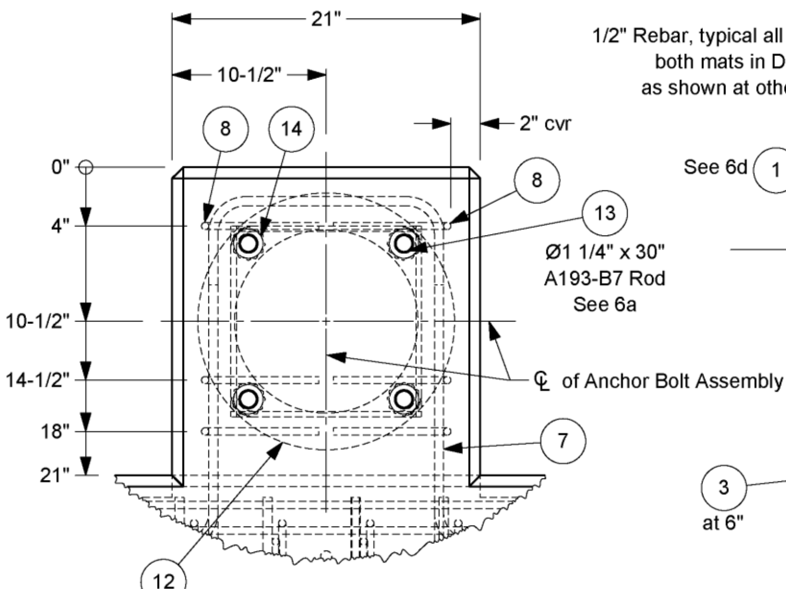
5h. The protrusion on the field side of the parapet was used for another test installation, and is not needed and will not be used for this one.

5a. UL- and SL Bars are in pairs. Alternate laps on SL bars.

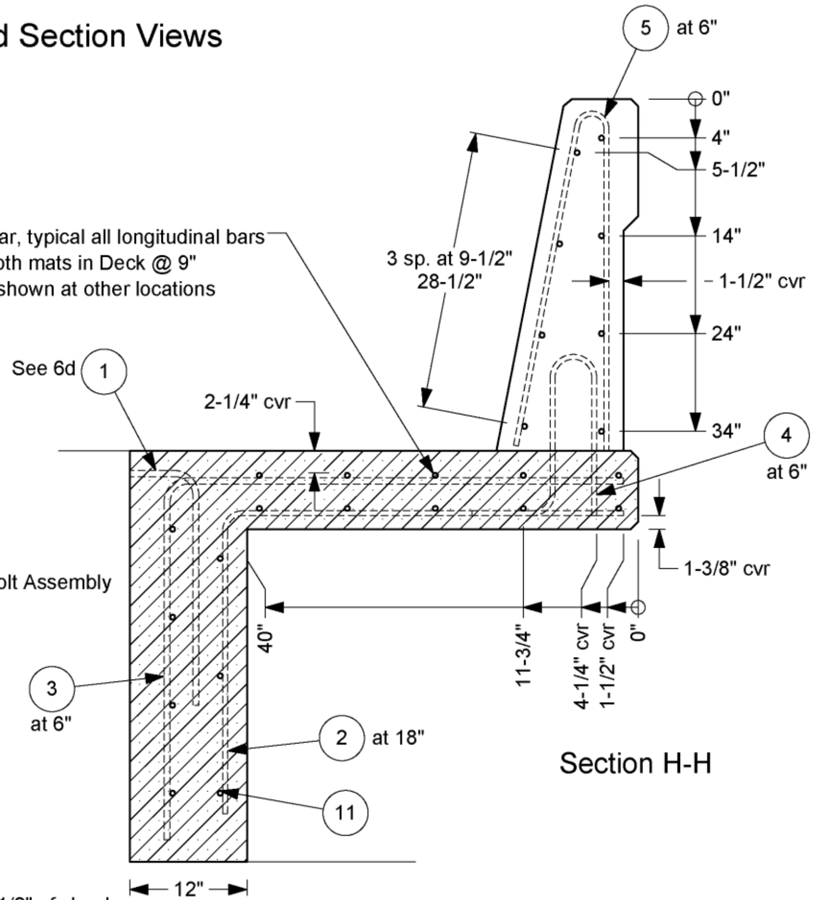
5b. Chamfer concrete edges 1" (3/4" each way) where shown.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #617741-01 Single Slope with Fence		2024-05-31
Drawn by GES	Scale 1:200	Sheet 5 of 8 Concrete Details

Detail and Section Views



Detail J
Scale 1 : 10



Section H-H

6a. Thread bottom 4" and top 5-1/2" of Anchor Rods. Leave 1/4" to 1/2" of shank exposed above concrete.

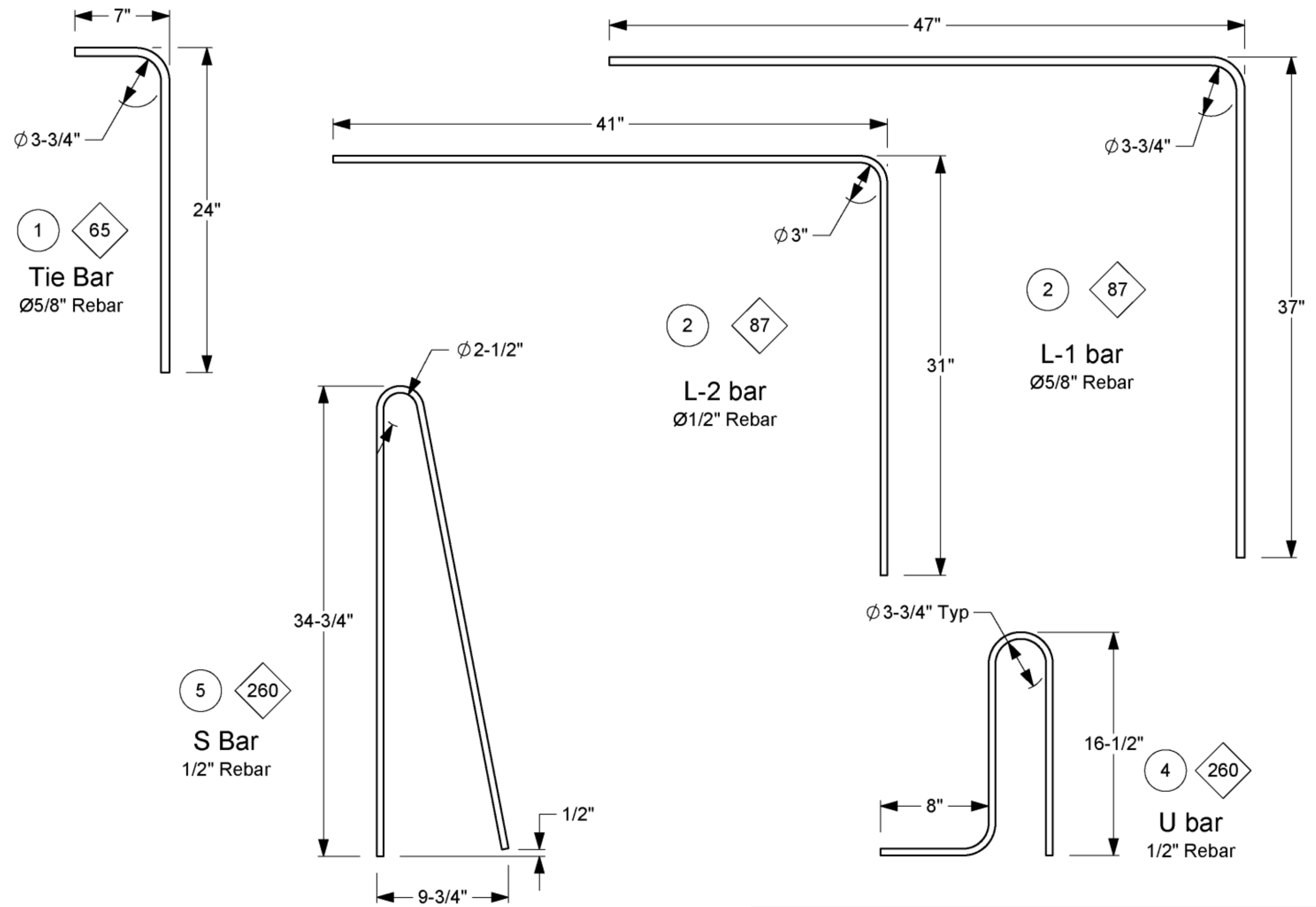
6b. Chamfer concrete edges 1" (3/4" each way) where shown.

6c. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

6d. Secure each Tie Bar to existing rebar protruding from the runway (not shown here) with a 3" long weld. Space at maximum 18".

6e. Luminaire concrete block must be placed monolithically with Single Slope parapet.

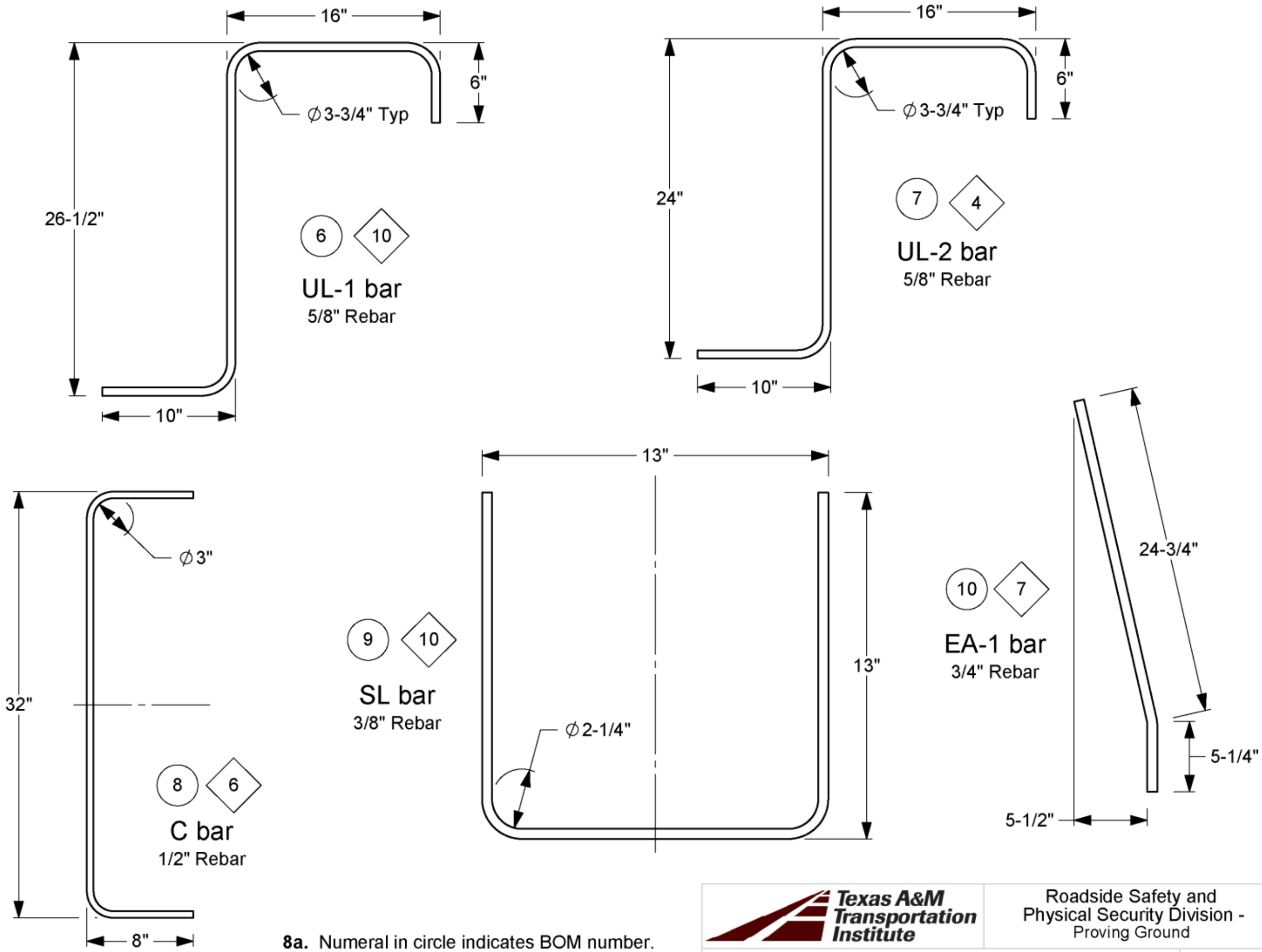
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #617741-01 Single Slope with Fence		2024-05-31
Drawn by GES	Scale 1:15	Sheet 6 of 8 Detail and Section Views



7a. Numeral in circle indicates BOM number.
Numeral in diamond indicates quantity needed.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #617741-01 Single Slope with Fence		2024-05-31
Drawn by GES	Scale 1:10	Sheet 7 of 8 Rebar Details-1

S:\Accreditation-17025-2017\EIR-000 Project Files\617741-01 - Fence Mounted System - Sheikh\Drafting, 617741-01\617741-01 Drawing



8a. Numeral in circle indicates BOM number.
Numeral in diamond indicates quantity needed.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #617741-01 Single Slope with Fence		2024-05-31
Drawn by GES	Scale 1:10	Sheet 8 of 8 Rebar Details-2

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

Portland Bolt
& MANUFACTURING COMPANY
800-547-6758 | www.portlandbolt.com

FOR	TEXAS A&M TRANSPORTATION INST
PB INVOICE	166890
CUSTOMER PO	617741
EST. SHIP DATE	9/26/2023

Certificate of Conformance

We certify that the following items were manufactured and tested in accordance with the chemical, mechanical, dimensional and thread fit requirements of the specifications referenced.

Products

- ASTM A193 GRADE B7 ALL THREAD ROD

Coatings

- ITEMS HOT-DIP GALVANIZED PER ASTM F2329

Other

- ALL ITEMS MELTED & MANUFACTURED IN THE USA

Certification Department Quality Assurance
Dane McKinnon

Vulcan THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 746048 **Job Information** **Certified Date:** 4/7/22

Containers: S19810426 S19816097

Customer: Conklin and Conklin

Vulcan Part No: BAR B7 .446x144 SC

Customer Part No: BAR B7 .445x144

Customer PO No: 20645

Order No: 438631

Note:

PORTLAND BOLT
PO 63070
INV 088676
48 1/2" X 144" B7 ATR HDG
SEPT 6, 2023
1OF3

Ship To: 34201 Seventh Street
Union City, CA 94587

Shipped Qty: 6034 lbs

Line No: 1

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM F1554 Gr 105	2020		
Heat Treat	ASME SA-193/SA-193M B7	2019		
	ASME SA-320/SA-320M L7	2017		
	ASTM A193 B7 S11	2020		
	ASTM A320 L7	2021a		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: 10755170 Lot 1/2 Origin: USA

C	Mn	P	S	Si	Cr	Mo	Ni	V	Cu
0.41	0.82	0.009	0.009	0.31	0.86	0.16	0.06	0.001	0.16
Al	**Nb**	**Sn**	**Ti**	**N**	**B**	**DI**	**RR**	**G.S.**	**Macro S**
0.025	0.003	0.007	0.002	0.0070	0.0001	4.50	154:1	fine	1
Macro R	**Macro C**	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**
1	1	57	57	57	57	57	54	52	50
J9	**J10**	**J12**	**J14**	**J16**	**J18**	**J20**	**J24**	**J28**	**J32**
49	48	45	43	40	39	38	36	34	32

Notes

Processed material is Tempered - Stress Relieved. No weld repair performed on the material. No Mercury used in the production of this material. Melted and Manufactured in the USA.
Grade - 4140/42
EAF Melted

Plex 4/7/22 10:45 AM vulc.seno Page 1 of 2

JV

PORTLAND BOLT
PO 63070
INV 088676
48 1/2" X 144" B7 ATR HDG
SEPT 6, 2023
2OF3

Vulcan THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 746048 **Job Information** **Certified Date:** 4/7/22

Containers: S19810426 S19816097

Test Results

Part No: BAR B7 .446x292 HT

Test No: 70153 **Test:** Heat Treat Info

Description	Austenitizing Temp (F)	Tempering Temp (F)	Run Speed (ft/min)	Quench Temp (F)	Note
	1,732	1,318	23	91	

Test No: 70154 **Test:** Tensile Test

Description	Tensile Strength (ksi)	Yield Strength (ksi)	Elongation (4D) (%)	ROA (%)	Note
	132	117	22	65	
	133	112	23	64	
	132	119	26	65	
	134	113	26	66	
	133	112	28	65	
	134	116	27	63	
	133	119	29	59	
	133	114	28	65	
	132	119	28	65	
	134	113	33	63	
	133	115	20	64	
	133	119	19	65	
	132	121	24	62	
	136	114	23	61	
	132	118	24	63	
	133	113	21	65	

Test No: 70155 **Test:** Hardness Test

Description	Midradius Hardness	Surface Hardness	Core Hardness	Hardness Scale	Note
	29	29	30	HRC	
	29	29	30	HRC	
	29	27	29	HRC	
	31	29	30	HRC	
	30	30	31	HRC	
	29	29	30	HRC	
	29	28	29	HRC	
	30	29	31	HRC	
	29	28	29	HRC	
	30	29	30	HRC	
	30	30	29	HRC	
	29	29	30	HRC	
	29	28	29	HRC	
	30	30	30	HRC	
	29	28	30	HRC	
	29	29	30	HRC	

Test No: 70156 **Test:** Carb/ Decarb Test

Description	Surface Carb.	Partial Surface Decarb.	Note
	Pass	Pass	

The reported test results conform to the specifications listed above.
The reported test results are the actual values measured on the samples taken from the production lot.

PO 63070
INV 088576
48 1/2" X 144" B7 ATR HDG
SEPT 6, 2023
3OF3

Vulcan THREADED PRODUCTS, INC.

Vulcan Threaded Products
10 Cross Creek Trail
Pelham, AL 35124
Tel (205) 620-5100
Fax (205) 620-5150

JOB MATERIAL CERTIFICATION

Job No: 746048	Job Information	Certified Date: 4/7/22

Containers: S19810426 S19816097

Material was manufactured, tested, and inspected as required by the product standard and in accordance with Vulcans ISO 9001:2015 Quality Management System registered June 30th, 2017.
Vulcan Steel Products lab is ISO 17025:2017 accredited for tensile, Brinell and Rockwell hardness, Charpy impact, and carb/decarb testing.
Material was tested in accordance with the current revision of ASTM A370, F606, and F2328 test methods.
This test report shall not be reproduced or distributed, except in full, nor shall it be modified in any way without the written permission of Vulcan Steel Products.
Document is in accordance with EN 10204 - 3.1B of 2004 (3.1).

Sallie Norwood — 4/7/22

Norwood, Sallie - Certification Engineer — Date

Plex 4/7/22 10:45 AM vulc.sano Page 2 of 2

Portland Bolt
& MANUFACTURING COMPANY
800-547-6758 | www.portlandbolt.com

sales@portlandbolt.com Phone: 800.547.6758 | Fax: 503.227.4634
www.portlandbolt.com 3441 NW Guam St. Portland OR, 97210

ORDER #	166890
DATE	9/20/2023
PAGE	1 of 1
SALESPERSON	Shanna McKee
DIRECT PHONE	888.602.8920
EMAIL	shanna@portlandbolt.com

SOLD TO	SHIP TO
TEXAS A&M TRANSPORTATION INST TTI FINANCIAL SERVICES 3135 TAMU COLLEGE STATION, TX, 77843-3135 Phone: 979.317.2755 | Fax: 979.227.7710	Adam Mayer @ 9793172667 1111 Rellis Parkway Bryan, TX, 77807

ATTN **Adam Mayer** <a-mayer@tti.tamu.edu> — CUSTOMER PO 617741

SHIP DATE **9/26/2023** (scheduled) — SHIP VIA UPS Ground

LINE	QTY. ORDERED	DESCRIPTION
1	34	1/2"-13 x 8" domestic hot-dip galvanized ASTM A193 Grade B7 all thread rod
2	17	1/2"-13 x 11" domestic hot-dip galvanized ASTM A193 Grade B7 all thread rod

***

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: 440863-3 **Casting Date:** 2023-05-05 **Mix Design (psi):** 4000

Name of Technician Taking Sample: Terracon

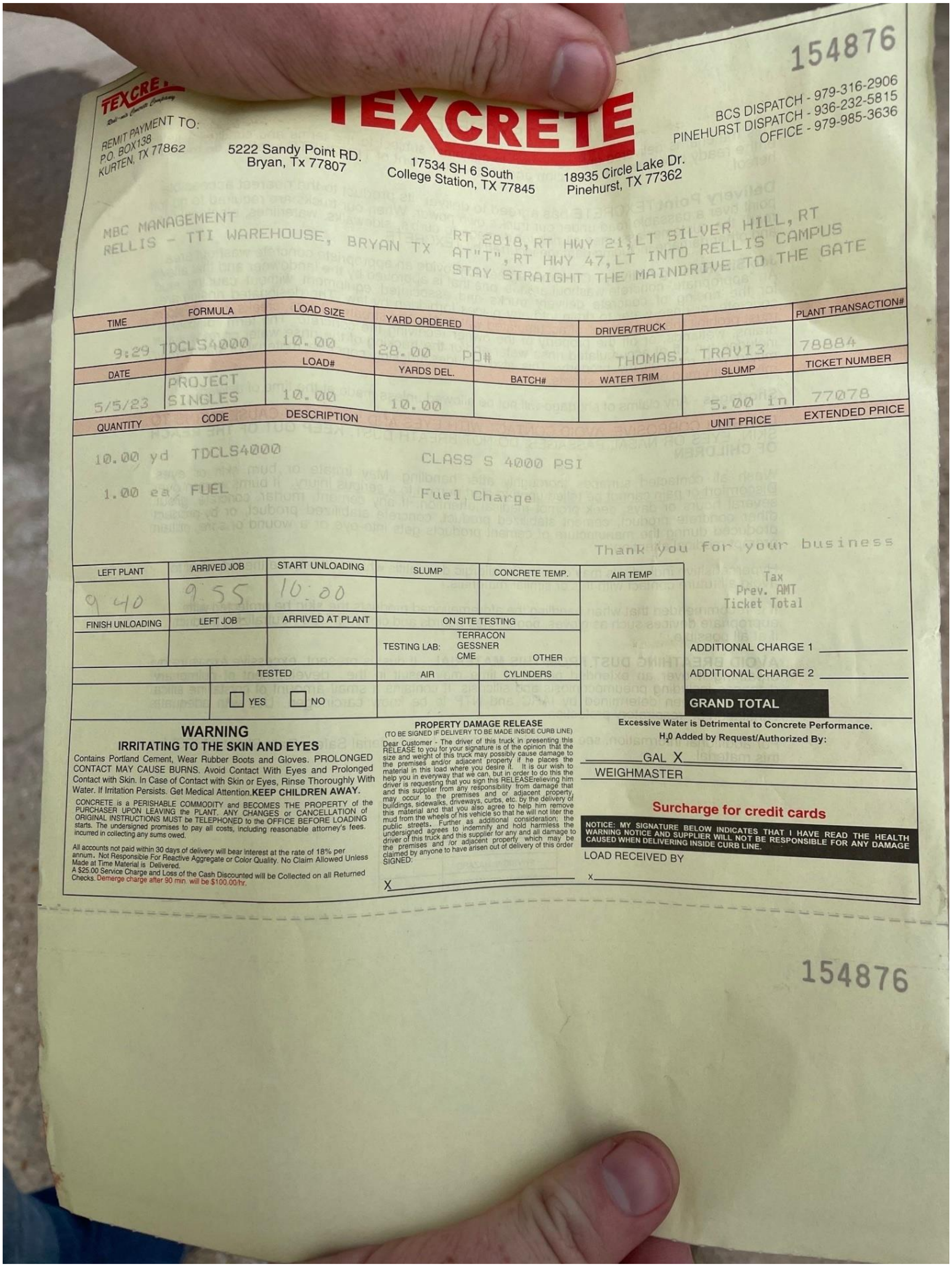
Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
Check	Thomas, Trav13	77078	North Wall to Sensors
Check	Cross, Dwante8	77081	North end of deck to sensors
Check	Burns, Christ0	77085	Remainder of deck and wall

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



154876

TEXCRETE

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

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

MBC MANAGEMENT
RELLIS - TTI WAREHOUSE, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT
AT"T", RT HWY 47, LT INTO RELLIS CAMPUS
STAY STRAIGHT THE MAINDRIVE TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
9:29	TDCLS4000	10.00	28.00	PO#	THOMAS, TRAVIS		78884
DATE		LOAD#	YARDS DEL.	BATCH#	WATER TRIM	SLUMP	TICKET NUMBER
5/5/23	PROJECT SINGLES	10.00	10.00			5.00 in	77078

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
10.00 yd	TDCLS4000	CLASS S 4000 PSI		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
9:40	9:55	10:00			
FINISH UNLOADING	LEFT JOB	ARRIVED AT PLANT	ON SITE TESTING		

Tax
Prev. AMT
Ticket Total

TESTING LAB: TERRACON GESSNER CME OTHER

TESTED ☐ YES ☐ NO — AIR — CYLINDERS

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 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 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 ____

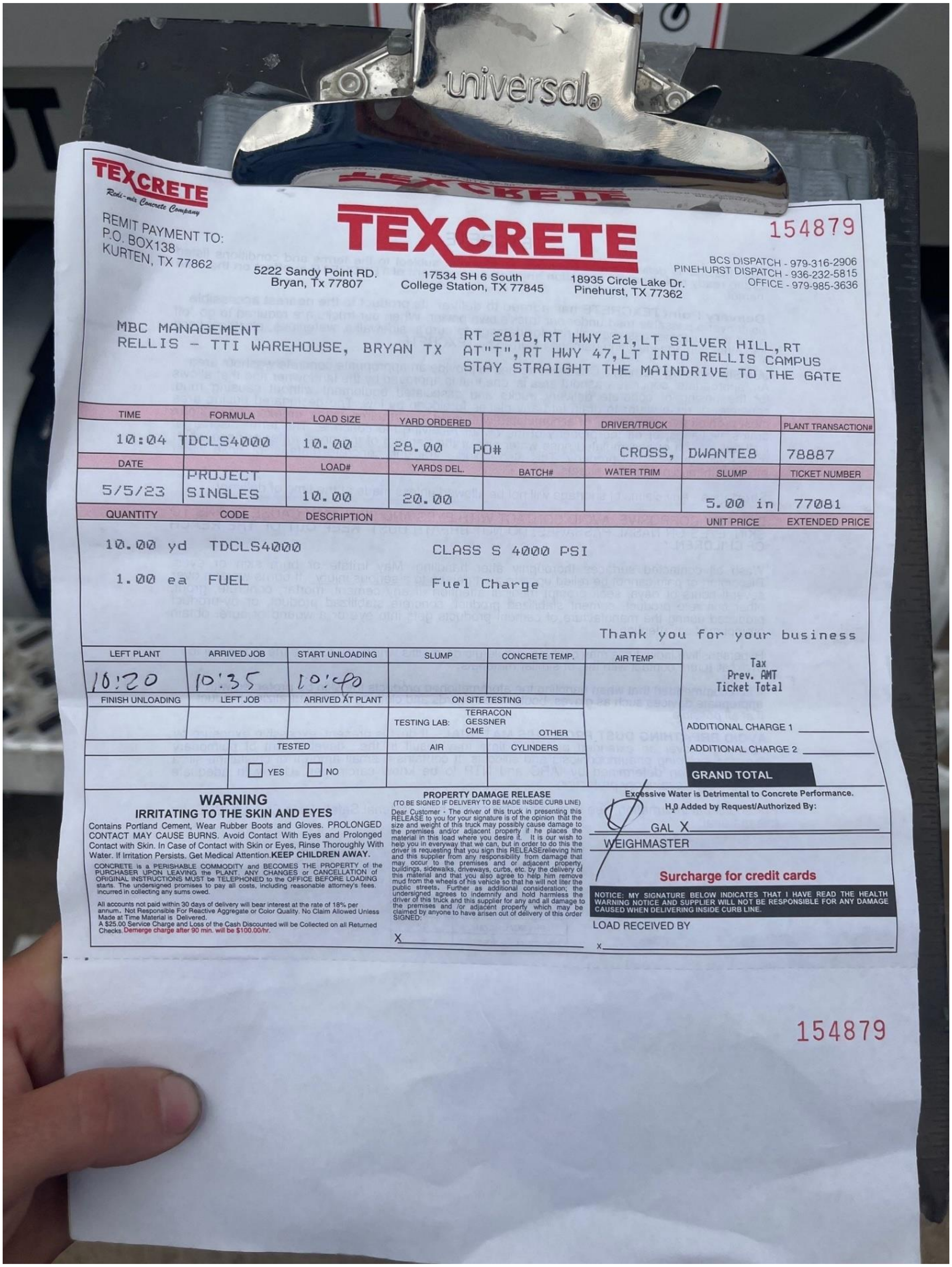
Excessive Water is Detrimental to Concrete Performance.
H_20 Added by Request/Authorized By:
____ GAL X ____
WEIGHMASTER

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 ____

154876



TEXCRETE
Redi-mix Concrete Company

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

TEXCRETE

154879

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

MBC MANAGEMENT
RELLIS - TTI WAREHOUSE, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT"T", RT HWY 47, LT INTO RELLIS CAMPUS STAY STRAIGHT THE MAINDRIVE TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
10:04	TDCLS4000	10.00	28.00	PO#	CROSS,	DWANTE8	78887
DATE		LOAD#	YARDS DEL.	BATCH#	WATER TRIM	SLUMP	TICKET NUMBER
5/5/23	PROJECT SINGLES	10.00	20.00			5.00 in	77081

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
10.00 yd	TDCLS4000	CLASS S 4000 PSI		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
10:20	10:35	10:40			
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.**

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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_20 Added by Request/Authorized By:

______ GAL X ________

WEIGHMASTER

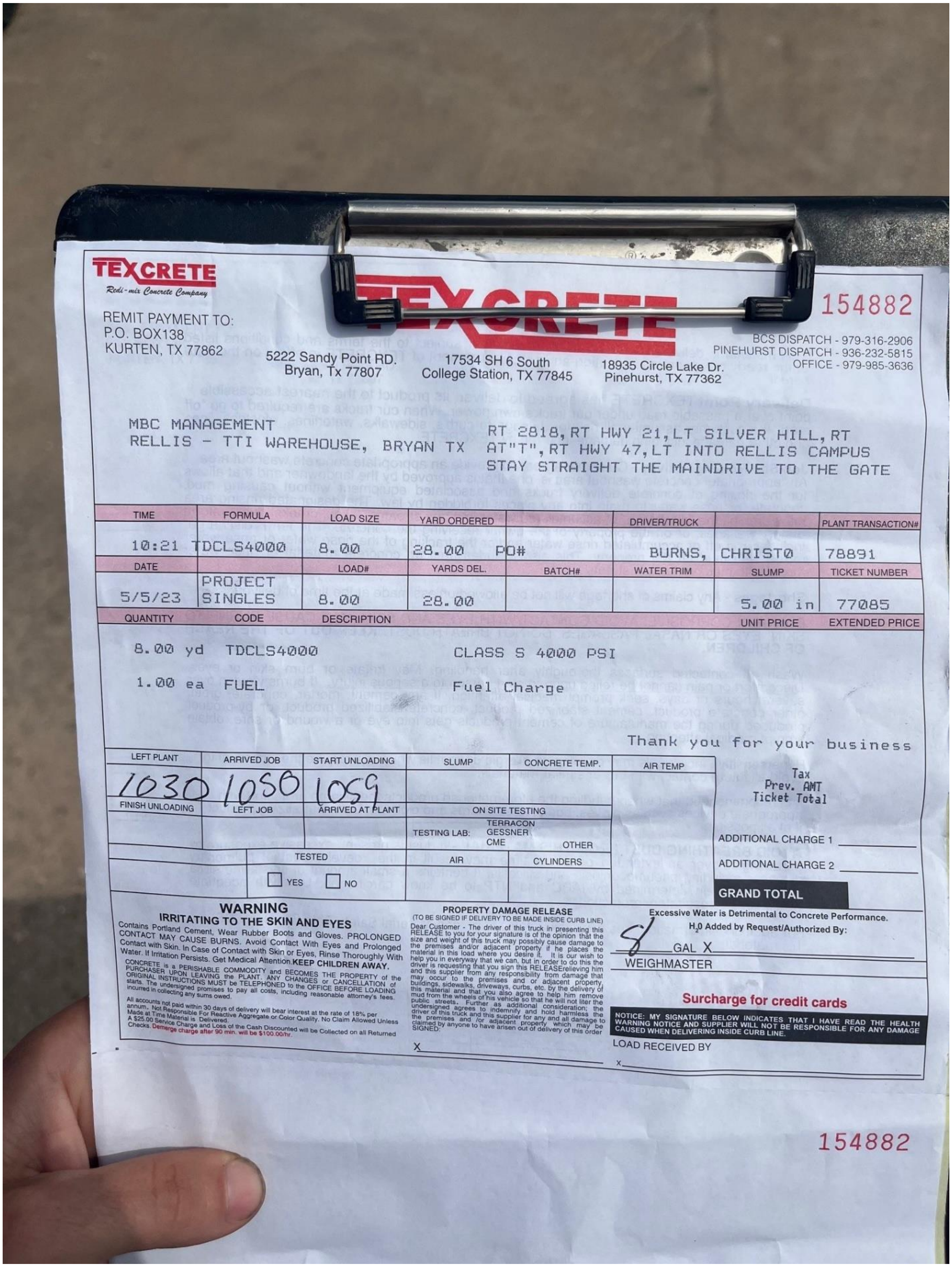
Surcharge for credit cards

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 ________

154879



TEXCRETE
Redi-mix Concrete Company

154882

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

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

MBC MANAGEMENT
RELLIS - TTI WAREHOUSE, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT
AT"T", RT HWY 47, LT INTO RELLIS CAMPUS
STAY STRAIGHT THE MAINDRIVE TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED			DRIVER/TRUCK		PLANT TRANSACTION#
10:21	TDCLS4000	8.00	28.00	PO#		BURNS,	CHRISTO	78891
DATE		LOAD#	YARDS DEL.	BATCH#		WATER TRIM	SLUMP	TICKET NUMBER
5/5/23	PROJECT SINGLES	8.00	28.00				5.00 in	77085

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
8.00 yd	TDCLS4000	CLASS S 4000 PSI		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
1030	1050	1059			
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.**

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(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_20 Added by Request/Authorized By:
8 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______

154882

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0272
Service Date: 05/05/23
Report Date: 05/25/23 Revision 1 - 17-day results
Task: PO# 440863-3

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

Client
Texas Transportation Institute
Attn: Bill Griffith
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: TDCLS4000
Supplier: Texcrete
Batch Time: **Plant:**
Truck No.: TEAVI3 **Ticket No.:** 77078

Sample Information
Sample Date: 05/05/23 **Sample Time:** 1010
Sampled By: Justin Maass
Weather Conditions: Clear, light wind
Accumulative Yards: 10/30 **Batch Size (cy):** 10
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: East end
Placement Location: Bridge wall deck
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	5 1/2	
Air Content (%):	2.2	
Concrete Temp. (F):	85	
Ambient Temp. (F):	76	
Plastic Unit Wt. (pcf):	148.0	
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	A	Good	6.00	28.27		05/12/23	7 F	102,700	3,630	2	TJT
1	B	Good	6.01	28.37		05/22/23	17 F	130,610	4,600	2	TJT
1	C	Good	6.01	28.37		05/22/23	17 F	127,730	4,500	2	TJT
1	D	Good	6.01	28.37		05/22/23	17 F	120,400	4,240	3	TJT

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

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

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

Terracon Rep.: Justin Maass **Start/Stop:**
Reported To: Bill w/ TTI
Contractor: MDC
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

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

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0272
Service Date: 05/05/23
Report Date: 05/25/23 Revision 1 - 17-day results
Task: PO# 440863-3

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

Client
Texas Transportation Institute
Attn: Bill Griffith
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: TDCLS4000
Supplier: Texcrete
Batch Time: 1004 **Plant:**
Truck No.: DWANTE8 **Ticket No.:** 77081

Sample Information
Sample Date: 05/05/23 **Sample Time:** 1046
Sampled By: Justin Maass
Weather Conditions: Clear, light wind
Accumulative Yards: 20/30 **Batch Size (cy):** 10
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Middle of wall
Placement Location: Bridge wall deck
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	6	
Air Content (%):	2.0	
Concrete Temp. (F):	84	
Ambient Temp. (F):	75	
Plastic Unit Wt. (pcf):	147.7	
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
2	A	Good	6.01	28.37		05/22/23	17 F	124,390	4,380	2	TJT
2	B	Good	6.01	28.37		05/22/23	17 F	120,780	4,260	2	TJT
2	C	Good	6.01	28.37		05/22/23	17 F	120,460	4,250	2	TJT
2	D						Hold				

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

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

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

Terracon Rep.: Justin Maass **Start/Stop:**
Reported To: Bill w/ TTI
Contractor: MDC
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

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

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0272
Service Date: 05/05/23
Report Date: 05/25/23 Revision 1 - 17-day results
Task: PO# 440863-3

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

Client
Texas Transportation Institute
Attn: Bill Griffith
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: TDCLS4000
Supplier: Texcrete
Batch Time: 1021 **Plant:**
Truck No.: CHEISTO1 **Ticket No.:** 77085

Sample Information
Sample Date: 05/05/23 **Sample Time:** 1100
Sampled By: Justin Maass
Weather Conditions: Clear, light wind
Accumulative Yards: Cloudy, lig **Batch Size (cy):** 10
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: West end of wall
Placement Location: Bridge wall deck
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	6 3/4	
Air Content (%):	1.5	
Concrete Temp. (F):	84	
Ambient Temp. (F):	75	
Plastic Unit Wt. (pcf):	146.8	
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
3	A	Good	6.01	28.37		05/22/23	17 F	113,600	4,000	2	TJT
3	B	Good	6.01	28.37		05/22/23	17 F	112,140	3,950	2	TJT
3	C	Good	6.01	28.37		05/22/23	17 F	110,790	3,910	2	TJT
3	D						Hold				

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

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

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

Terracon Rep.: Justin Maass
Reported To: Bill w/ TTI
Contractor: MDC
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Start/Stop:

Reviewed By:
Alexander Dunigan, P.E.
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: 440863-01-3 **Casting Date:** 2023-05-15 **Mix Design (psi):** 3600

Name of Technician Taking Sample: Terracon

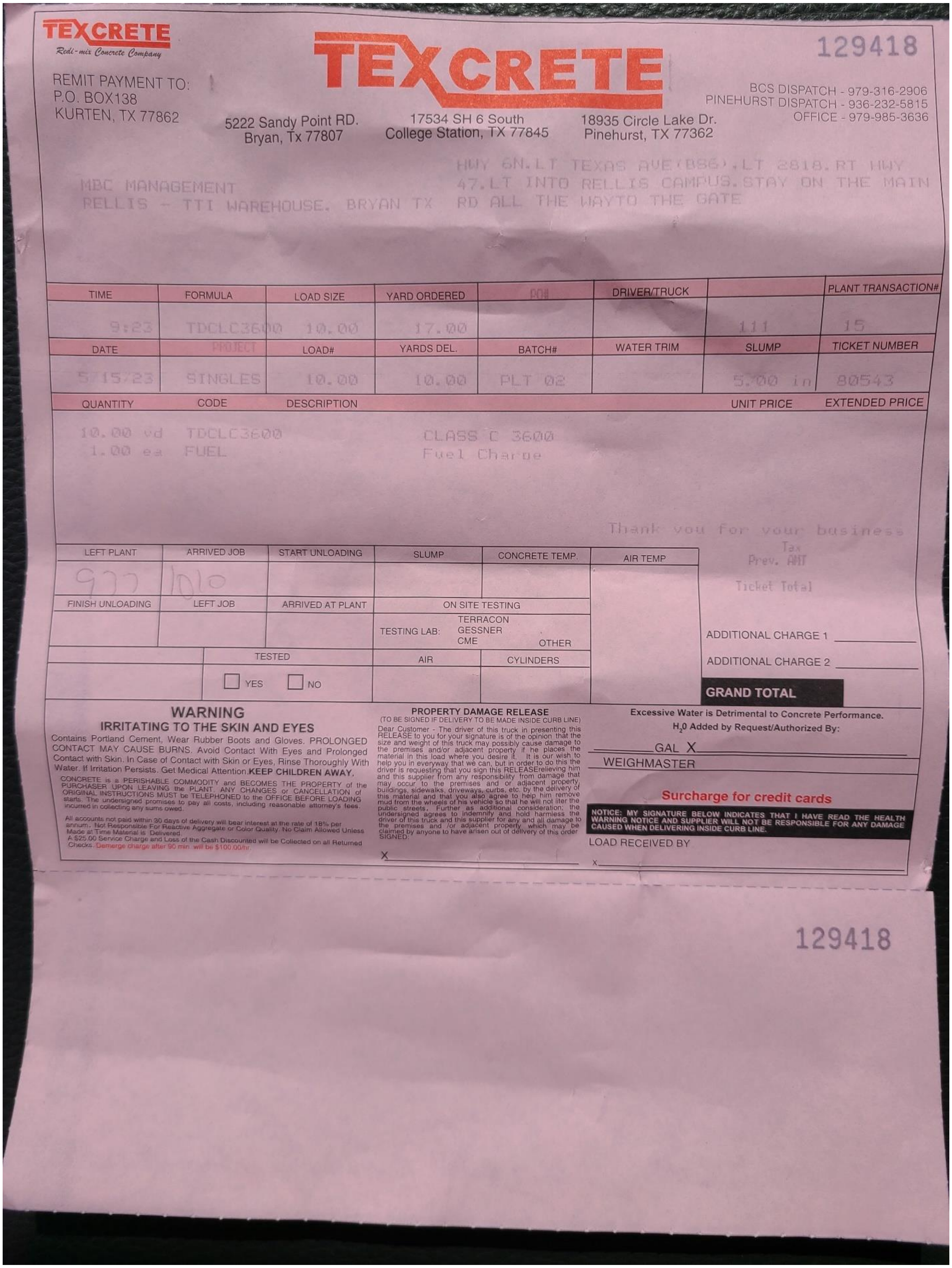
Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
Check	111	80543	Full barrier from south end 40ft north. Half lift till 20 ft from north ..
Check	116	80544	Top half lift starting 40ft from south end. Full barrier 20 ft from north end to north finish

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



TEXCRETE
Redi-mix Concrete Company

TEXCRETE

129418

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

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

MBC MANAGEMENT
RELLIS - TTI WAREHOUSE. BRYAN TX

HWY 6N.LT TEXAS AVE(B86).LT 2818.RT HWY 47.LT INTO RELLIS CAMPUS.STAY ON THE MAIN RD ALL THE WAYTO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED	PO#	DRIVER/TRUCK		PLANT TRANSACTION#
9:23	TDCLC3600	10.00	17.00			111	15
DATE	**PROJECT**	**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
5.15.23	SINGLES	10.00	10.00	PLT 02		5.00 in	80543

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
10.00 yd	TDCLC3600	CLASS C 3600		
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
922	1010				
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 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_2$0 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________

129418

TEXCRETE
Redi-mix Concrete Company

TEXCRETE

129419

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

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

MBC MANAGEMENT
RELLIS - TTI WAREHOUSE, BRYAN TX

HWY 6N.LT TEXAS AVE(BS6).LT 2818.RT HWY
47.LT INTO RELLIS CAMPUS.STAY ON THE MAIN
RD ALL THE WAYTO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED	PO#	DRIVER/TRUCK		PLANT TRANSACTION#
9:41	TDCLC3600	7.00	17.00			116	16
DATE	**PROJECT**	**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
5/15/23	SINGLES	7.00	17.00	PLT 02		5.00 in	80544

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
7.00 yd	TDCLC3600	CLASS C 3600		
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
952	1024				
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 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:

______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____________________

129419

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0273
Service Date: 05/15/23
Report Date: 05/25/23
Task: PO# 440863-3

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

Client
Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength: 3,600 psi @ 28 days

Mix ID: TDCLC3600
Supplier: Texcrete
Batch Time: 0923 **Plant:**
Truck No.: 111 **Ticket No.:** 80543

Sample Information
Sample Date: 05/15/23 **Sample Time:** 1021
Sampled By: Daniel Calvo
Weather Conditions: Sunny
Accumulative Yards: 10.00/17.0 **Batch Size (cy):** 10
Placement Method: Direct Discharge
Water Added Before (gal): 5
Water Added After (gal): 0
Sample Location: Luminaire Bridge Deck 20' North of South end
Placement Location: Luminaire Bridge Deck
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	7 1/2	
Air Content (%):	0.8	
Concrete Temp. (F):	95	
Ambient Temp. (F):	78	
Plastic Unit Wt. (pcf):	147.2	
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	A	Good	6.01	28.37		05/22/23	7	93,380	3,290	3	TJT
1	B	Good	6.01	28.37		05/22/23	7	97,430	3,430	2	TJT
1	C	Good	6.01	28.37		05/22/23	7	95,680	3,370	2	TJT
							Average (7 days)		**3,370**		
1	D						Hold				

Initial Cure: Cure Blanket **Final Cure:** Field Cured

Comments: 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.: Daniel Calvo **Start/Stop:** 0830-1245

Reported To:

Contractor: MBC Management

Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

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

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0273
Service Date: 05/15/23
Report Date: 05/25/23
Task: PO# 440863-3

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

Client
Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength: 3,600 psi @ 28 days

Mix ID: TDCLC3600
Supplier: Texcrete
Batch Time: 0941 **Plant:**
Truck No.: 116 **Ticket No.:** 80544

Sample Information
Sample Date: 05/15/23 **Sample Time:** 1055
Sampled By: Daniel Calvo
Weather Conditions: Sunny
Accumulative Yards: 17.00/17.0 **Batch Size (cy):** 7
Placement Method: Direct Discharge
Water Added Before (gal): 10
Water Added After (gal): 0
Sample Location: Luminaire Bridge Deck 15' South of North end
Placement Location: Luminaire Bridge Deck
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	5 1/4	
Air Content (%):	0.9	
Concrete Temp. (F):	95	
Ambient Temp. (F):	80	
Plastic Unit Wt. (pcf):	147.5	
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
2	A	Good	6.01	28.37		05/22/23	7	101,700	3,580	3	TJT
2	B	Good	6.01	28.37		05/22/23	7	101,730	3,590	2	TJT
2	C	Good	6.01	28.37		05/22/23	7	108,790	3,830	2	TJT
								Average (7 days)	**3,670**		
2	D						Hold				

Initial Cure: Cure Blanket **Final Cure:** Field Cured

Comments: 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.: Daniel Calvo **Start/Stop:** 0830-1245
Reported To:
Contractor: MBC Management
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Reviewed By:
Alexander Dunigan, P.E.
Project Manager

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

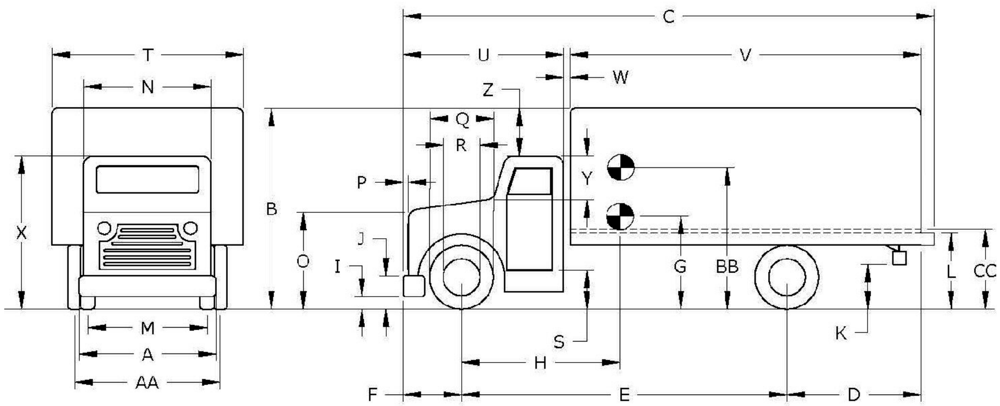
APPENDIX C. *MASH* TEST 4-12 (CRASH TEST 617741-01-1)

C.1. VEHICLE PROPERTIES AND INFORMATION

Texas A&M Transportation Institute Proving Ground 3100 SH 47, Bldg 7091 Bryan, TX 77807 Texas A&M University College Station, TX 77843 Phone 979-845-6375	**LF-VPW:10000S Vehicle Parameters Worksheet for MASH 10000S**	Doc. No. LF-VPW: 10000S	Revision Date: 2019-02-27
Laboratory Form	Revised by: B.L.Griffith Approved by: D. L. Kuhn	Revision: 10	Page: 1 of 2

Vehicle Inventory Number: 1701

Date:	2023-11-17	Test No.:	617741-01-1	VIN No.:	1HTMMAAN4DH156266
Year:	2013	Make:	INTERNATIONAL	Model:	MAXX FORCE
Odometer:	93167	Tire Size Front:	275/80R22.5	Tire Size Rear:	275/80R22.5



Vehicle Geometry: ☑ inches or ☐ mm

A	Front Bumper Width:	92.00	K	Rear Bumper Bottom:	0.00	U	Cab Length:	106.00
B	Overall Height:	134.00	L	Rear Frame Top:	37.25	V	Trailer/Box Length:	224.00
C	Overall Length:	329.50	M	Front Track Width:	81.50	W	Gap Width:	2.00
D	Rear Overhang:	85.00	N	Roof Width:	76.50	X	Overall Front Height:	97.00
E	Wheel Base:	207.00	O	Hood Height:	58.00	Y	Roof-Hood Distance:	29.00
F	Front Overhang:	37.50	P	Bumper Extension:	1.25	Z	Roof-Box Height Difference:	37.00
G	C.G. Height:	49	Q	Front Tire Width:	40.00	AA	Rear Track Width:	86.00
H	C.G. Horizontal Dist. w/Ballast:	126.69	R	Front Wheel Width:	22.50	BB	Ballast Center of Mass:	62.50
I	Front Bumper Bottom:	18.25	S	Bottom Door Height:	37.00	CC	Cargo Bed Height:	50.00
J	Front Bumper Top:	33.50	T	Overall Width:	96.50			

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

Wheel Center Height Front	18.50	Wheel Well Clearance (Front)	8.50	Bottom Frame Height (Front)	25.25
Wheel Center Height Rear	19.50	Wheel Well Clearance (Rear)	6.00	Bottom Frame Height (Rear)	27.00

More information needed on next page

Figure C.1. Vehicle Properties for Test 617741-01-1.

Texas A&M Transportation Institute Proving Ground, 3100 SH 47, Bldg 7091, Bryan, TX 77807 Texas A&M University, College Station, TX 77843, Phone 979-845-6375	LF-VPW:10000S Vehicle Parameters Worksheet for MASH 10000S	Doc. No. LF-VPW: 10000S	Revision Date: 2018-07-27
Laboratory Form	Revised by: W. L. Menges Approved by: D. L. Kuhn	Revision: 9	Page: 2 of 2

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

Vehicle Inventory Number: 1701

Date: 2023-11-17 Test No.: 617741-01-1 VIN No.: 1HTMMAAN4DH156266

Year: 2013 Make: INTERNATIONAL Model: MAXX FORCE

WEIGHTS
(☑ lb or ☐ kg)

	CURB	**TEST INERTIAL**
$W_{front\ axle}$	7320	8620
$W_{rear\ axle}$	6160	13600
W_{TOTAL}	13480	22220

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

Ballast: 8740 (☑ lb or ☐ kg) **(as-needed)** **(See *MASH* Section 4.2.1.2 for recommended ballasting)**

Mass Distribution
(☑ lb or ☐ kg): **LF:** 4310 **RF:** 4310 **LR:** 6870 **RR:** 6730

Engine Type: DT 466
Engine Size: 7.6L

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

Accelerometer Locations (☐ inches or ☐ mm)

	x[1]	**y**	**z**[2]
Front:	0.00	0.00	0.00
Center:	126.69	0.00	50.00
Rear:	256.69	0.00	50.00

Describe any damage to the vehicle prior to test:

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

TWO BLOCKS 30WX30HX60L
CENTERED IN MIDDLE OF BED
TIED DOWN WITH FOUR 3/8 CABLES PER BLOCK
62.5 INCHES FROM GROUND TO CENTER OF BLOCK

Performed by: RK **Date:** 2023-11-17

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

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ISO/IEC 17025:2017

Figure C.1. Vehicle Properties for Test 617741-01-1 (continued).

C.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s

(b) 0.100 s

(c) 0.200 s

(d) 0.300 s

(e) 0.400 s

(f) 0.500 s

(g) 0.600 s

(h) 0.700 s

Figure C.2. Sequential Photographs for Test 617741-01-1 (Overhead Views).

(a) 0.000 s

(b) 0.100 s

(c) 0.200 s

(d) 0.300 s

(e) 0.400 s

(f) 0.500 s

(g) 0.600 s

(h) 0.700 s

Figure C.3. Sequential Photographs for Test 617741-01-1 (Frontal Views).

(a) 0.000 s (b) 0.100 s

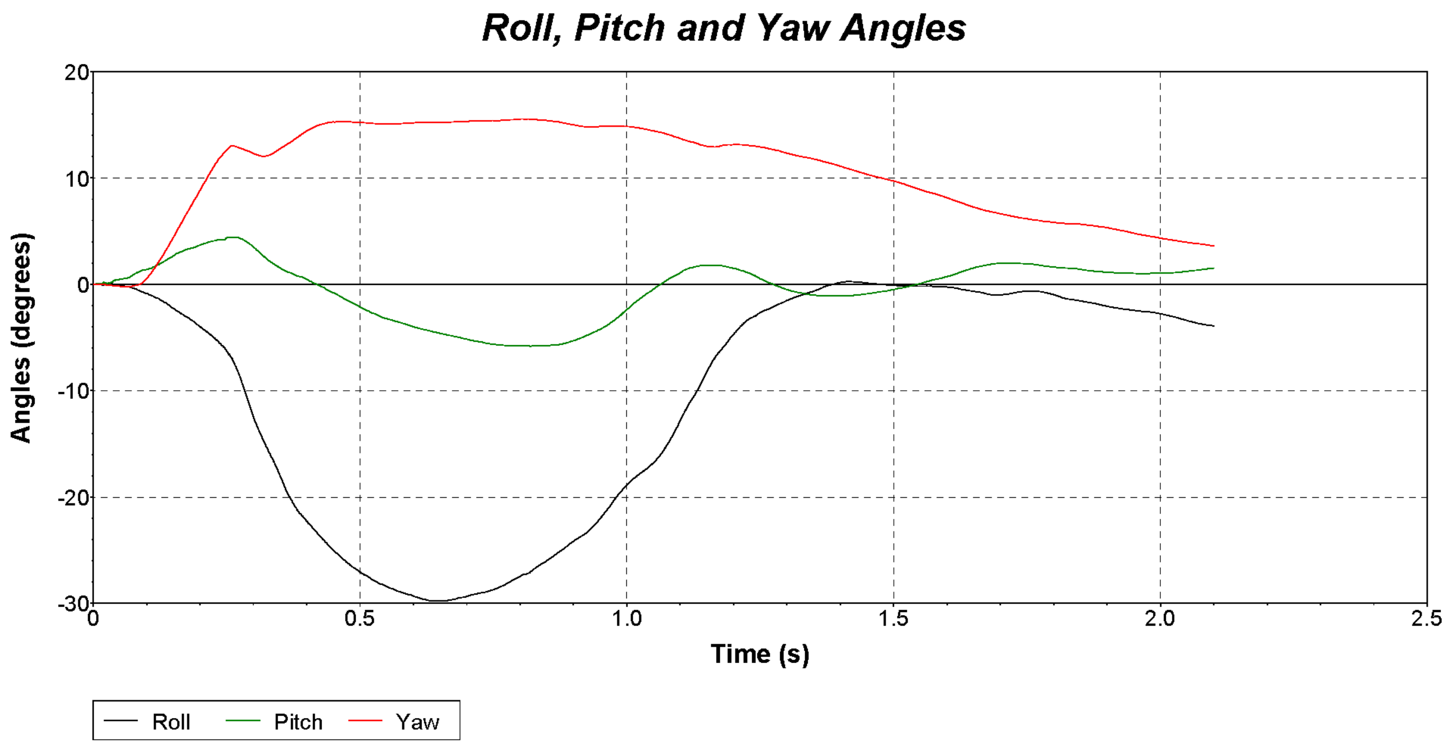
(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

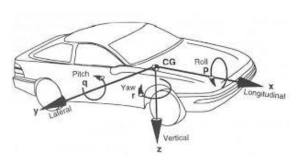
Figure C.4. Sequential Photographs for Test 617741-01-1 (Rear Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

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



Test Number: 617741-01-1
Test Standard Test Number: *MASH* Test 4-12
Test Article: Fence System Mounted to Concrete Bridge Rail
Test Vehicle: Test Vehicle #3]
Curb Mass: 13,480 lbs
Inertial Mass: 22,220 lbs
Impact Speed: 58.2 mi/h
Impact Angle: 15.1°

Figure C.5. Vehicle Angular Displacements for Test 617741-01-1.

C.4. VEHICLE ACCELERATIONS

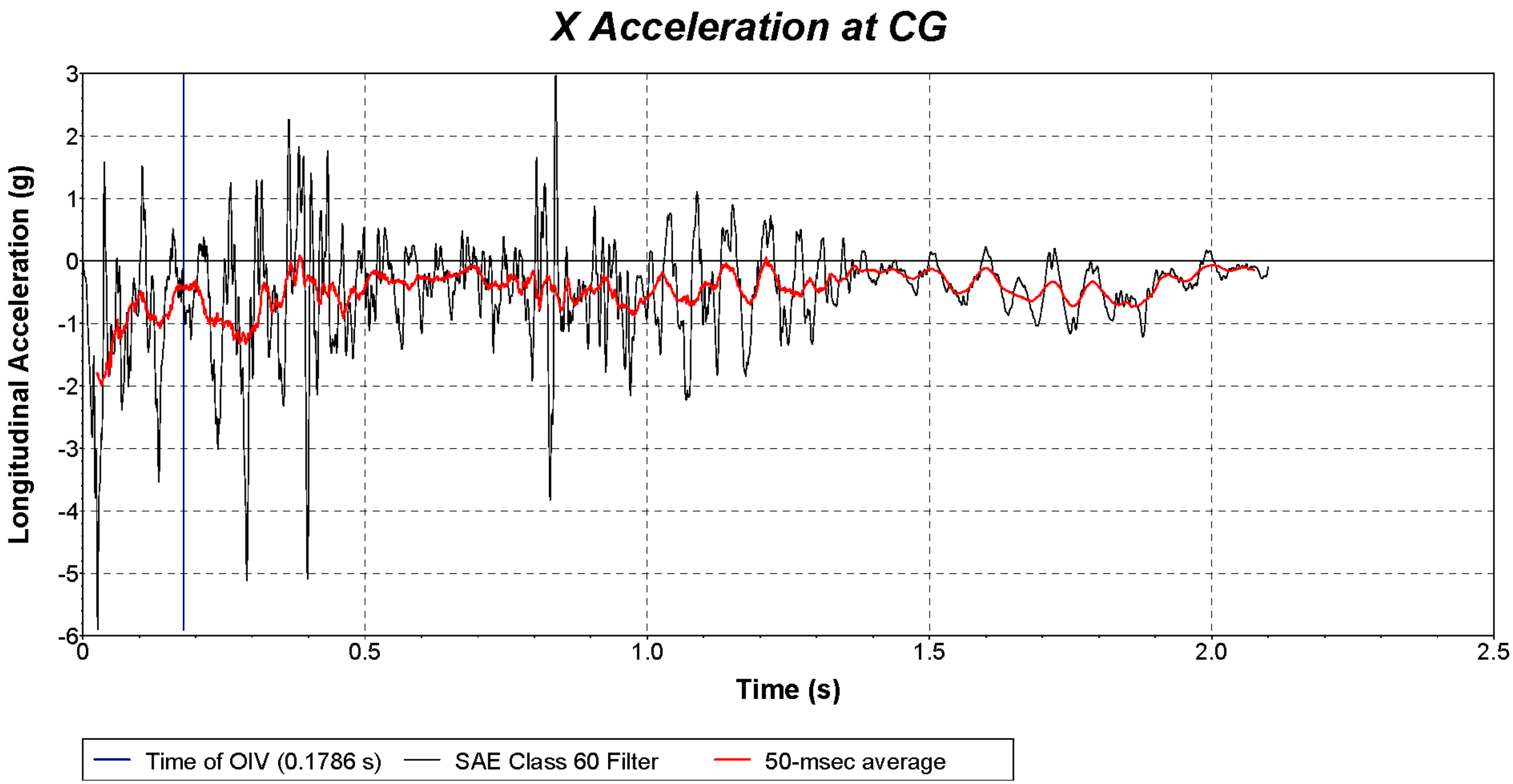


Figure C.6. Vehicle Longitudinal Accelerometer Trace for Test 617741-01-1 (Accelerometer Located at Center of Gravity).

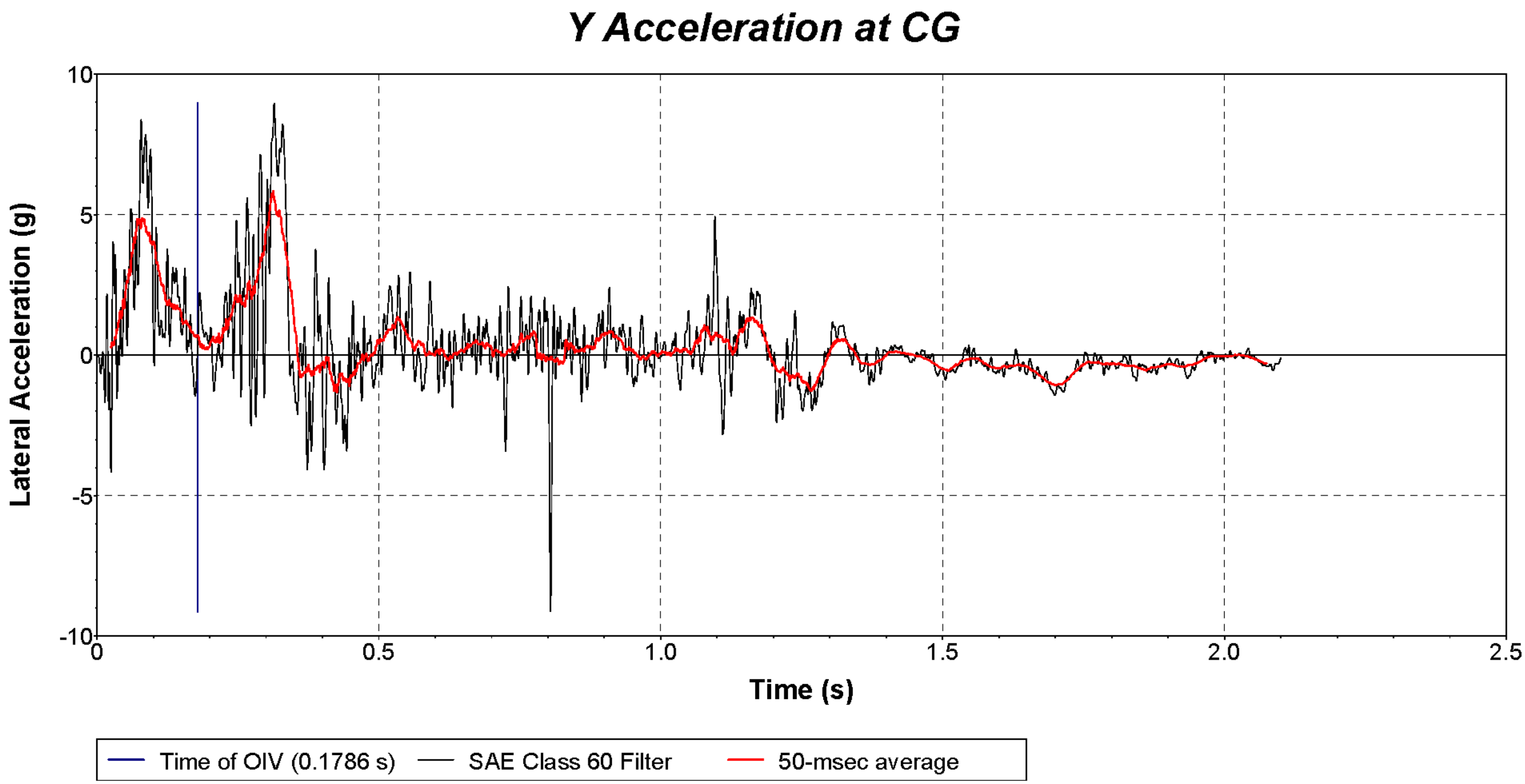


Figure C.7. Vehicle Lateral Accelerometer Trace for Test 617741-01-1 (Accelerometer Located at Center of Gravity).

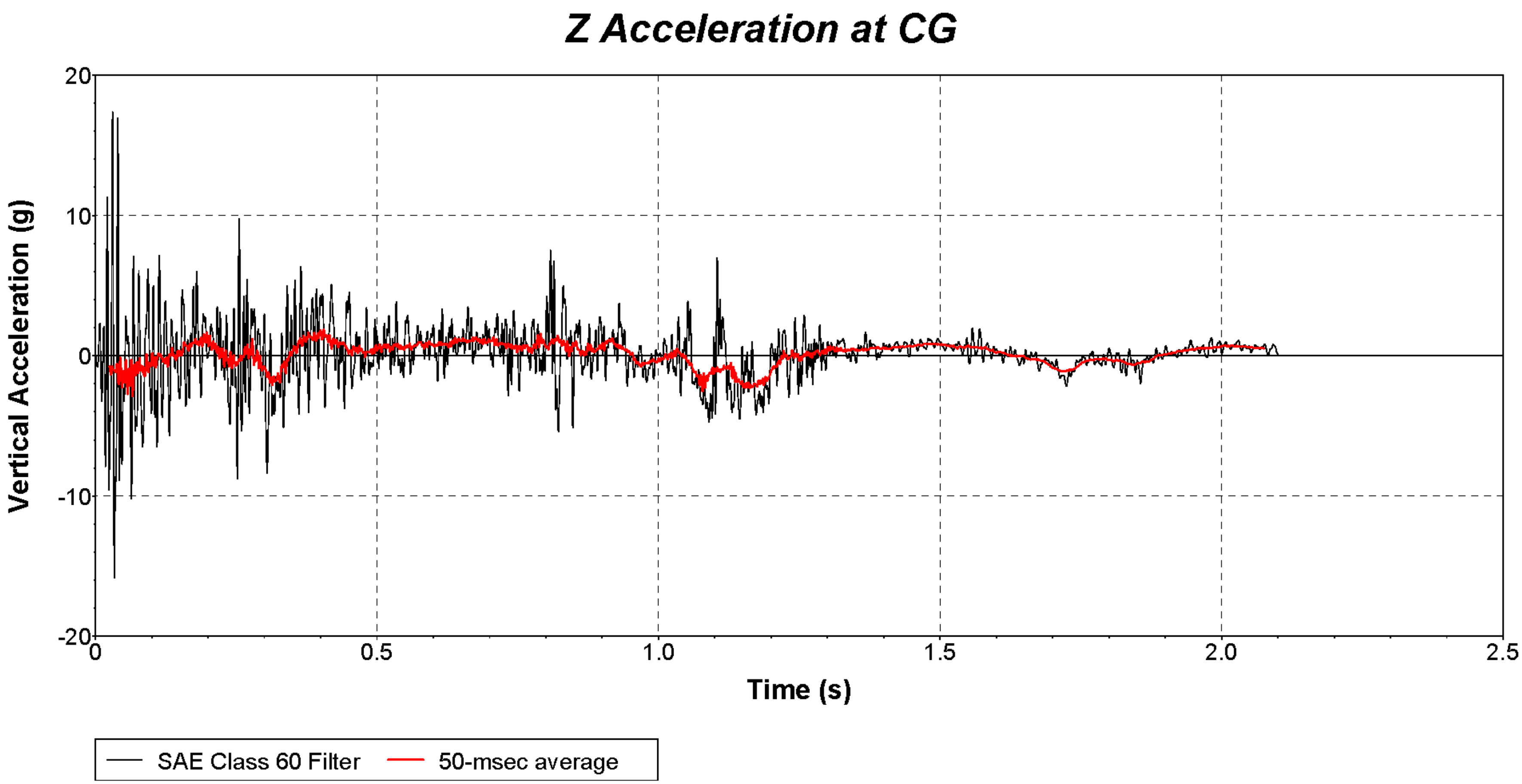


Figure C.8. Vehicle Vertical Accelerometer Trace for Test 617741-01-1 (Accelerometer Located at Center of Gravity)