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MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

MARYLAND DEPARTMENT OF TRANPORTATION
STATE HIGHWAY ADMINISTRATION

RESEARCH REPORT

MASH TEST LEVEL 3 DESIGN, TESTING, AND EVALUATION OF THE ANCHORED MARYLAND TEMPORARY PRECAST SINGLE-FACE F-TYPE CONCRETE BARRIER

Chiara Silvestri Dobrovolny, Sofokli Cakalli, Nauman Sheikh, William J. L. Schroeder, and Darrell L. Kuhn

Texas A&M Transportation Institute Proving Ground

FINAL REPORT

February 2025

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Texas A&M Transportation Institute
Proving Ground

Test Report No. 614271-12

MASH TEST LEVEL 3 DESIGN, TESTING, AND EVALUATION OF THE ANCHORED MARYLAND TEMPORARY PRECAST SINGLE-FACE F-TYPE CONCRETE BARRIER

Sponsored by
Maryland Department of Transportation
State Highway Administration (SHA)

TEXAS A&M TRANSPORTATION INSTITUTE PROVING GROUND
Roadside Safety & Physical Security
Texas A&M University System RELLIS Campus
Building 7091
1254 Avenue A
Bryan, TX 77807

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Name of Contacting Representatives: Jeff Robert, Sharon Hawkins, and Hua Xiang

16. Abstract

The purpose of this project was to develop a design for the anchored Maryland temporary precast single-face F-type concrete barrier and assess its crashworthiness performance according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials *Manual for Assessing Safety Hardware* (*MASH*), Second Edition (*1*). Finite element computer simulations were used to assist with system design and to predict crashworthiness of the anchored barrier design. The barrier was evaluated by performing two crash tests in accordance with *MASH* Test Level 3 (TL-3):

1. ***MASH* Test 3-10:** An 1100C vehicle weighing 2420 lb impacting the longitudinal barrier while traveling at 62 mi/h and 25 degrees.
2. ***MASH* Test 3-11:** A 2270P vehicle weighing 5000 lb impacting the longitudinal barrier while traveling at 62 mi/h and 25 degrees.

This report provides details on the modeling and simulation performed to develop the final design, the crash-tested anchored Maryland temporary precast single-face F-type concrete barrier, the crash tests and results, and the performance assessment of the anchored barrier in accordance with *MASH* TL-3 evaluation criteria for longitudinal barriers.

The anchored Maryland temporary precast single-face F-type concrete barrier met the performance criteria for *MASH* TL-3 for longitudinal barriers.

17. Key Words	18. Distribution Statement
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by

Chiara Silvestri-Dobrovolny, Ph.D.
Research Scientist
Texas A&M Transportation Institute

Sofokli Cakalli
Assistant Research Scientist
Texas A&M Transportation Institute

Nauman M. Sheikh, P.E.
Research Engineer
Texas A&M Transportation Institute

William J. L. Schroeder
Research Engineering Associate
Texas A&M Transportation Institute

and

Darrell L. Kuhn, P.E.
Research Specialist
Texas A&M Transportation Institute

Report 614271-12
Contract No.: PO2087X-1-2
Project Title: *MASH* Test Level 3 Design, Testing, and Evaluation of the Maryland Temporary Precast Single-Face F-Type Concrete Barrier

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June 2023

TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135

DISCLAIMER

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

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REPORT AUTHORIZATION

REPORT REVIEWED BY:

DocuSigned by:
Glenn Schroeder
E692F9CB5047487...

Glenn Schroeder, Research Specialist
Drafting & Reporting

DocuSigned by:
Ken Reeves
60D556935596468...

Ken Reeves, Research Specialist
Electronics Instrumentation

DocuSigned by:
Adam Mayer
F7A06F754E02430...

Adam Mayer, Research Specialist
Construction

DocuSigned by:
Richard Badillo
0F51DA60AB144F9...

Richard Badillo, Research Specialist
Photographic Instrumentation

DocuSigned by:
Robert Kocman
6CF2C47B60EB409...

Robert Kocman, Research Specialist
Mechanical Instrumentation

DocuSigned by:
25F29E1BAD624E8...

William J. L. Schroeder, Research
Engineering Associate
Research Evaluation and Reporting

DocuSigned by:
Bill Griffith
44A122CB271845B...

Bill L. Griffith, Research Specialist
Quality Manager

DocuSigned by:
Matt Robinson
EAA22BFA5BFD417...

Matthew N. Robinson, Research Specialist
Test Facility Manager & Technical Manager

DocuSigned by:
662F8286A604403...

Nauman M. Sheikh, P.E.
Principal Investigator, Research Engineer

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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

The purpose of this project was to develop a design for the anchored Maryland temporary precast single-face F-type concrete barrier and to assess its crashworthiness performance according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*), Second Edition (*1*). Finite element (FE) computer simulations were used to assist with system design and to predict crashworthiness of the proposed barrier design. The crash tests were performed in accordance with *MASH* Test Level 3 (TL-3), which requires two crash tests (as discussed in Chapter 4).

This report provides details on the FE modeling and simulation performed to develop the design for crash testing, the crash-tested design, the crash tests and results, and the performance assessment of the barrier in accordance with *MASH* TL-3 evaluation criteria for longitudinal barriers.

Chapter 2. FINITE ELEMENT ANALYSIS AND SIMULATIONS

2.1. INTRODUCTION

This chapter presents details on the FE modeling and simulation effort conducted to design the anchored Maryland temporary precast single-face F-type concrete barrier and evaluate its crashworthiness.

The researchers first developed an FE model of the initial barrier design that was proposed by the Maryland Department of Transportation State Highway Administration (SHA). This design was comprised of precast barrier segments with an F-shape profile on the traffic side and a single-slope profile on the field side of the barrier. The barrier segments were 12 ft long and were connected to each other using pin-and-loop connections. The barrier system was anchored to the underlying concrete pavement with two hold-down plates per barrier segment. The hold-down plates were bolted to the toe of the F-shape profile and the underlying concrete pavement using epoxy anchors.

The research team developed a detailed FE model of the originally proposed 12-ft barrier segment design, including the pin-and-loop connection and two hold-down plates. The researchers then evaluated the anchored barrier design by performing vehicle impact simulations using the test conditions specified for *MASH* Test 3-11 (i.e., 5000-lb pickup, impacting at 62 mi/h speed and 25 degrees). The results of the initial simulation revealed significant issues with the structural adequacy of the originally proposed design of the barrier. Based on these results, the original design was considered potentially inadequate to meet *MASH* evaluation criteria. The research team then proposed and evaluated several design changes to improve the barrier design.

Among the key changes proposed were improvements to the barrier reinforcement, the hold-down anchor plate design, and the pin-and-loop connection. The researchers improved the barrier design without changing its overall dimensions and while preserving its unique narrow base dimension of 17 inches. A detailed FE model of the modified barrier design was developed and evaluated through vehicle impact simulations under *MASH* TL-3 conditions. Results of the simulations showed that the impacting vehicles were contained and redirected acceptably, and the modified barrier was likely to meet the *MASH* TL-3 evaluation criteria in full-scale crash testing.

Based on the simulation results, the modified barrier design was recommended for full-scale crash testing under *MASH* Test 3-10 and Test 3-11 conditions. Details on the FE modeling and simulations of the Maryland temporary precast single-face F-type concrete barrier system are provided in the sections below.

2.2. FINITE ELEMENT ANALYSIS OF ORIGINAL DESIGN

A detailed FE model of the originally proposed anchored Maryland temporary precast single-face F-type concrete barrier system with two hold-down plates was developed based on standard drawings provided by MDOT SHA and is shown in Figure 2.1 through Figure 2.3. A third middle hole in the barrier was included in the design so it could be used if anchoring with two hold-down plates was deemed insufficient.

The original barrier had a height of 32 inches and a base width of 17 inches. The concrete reinforcement consisted of a 6-inch × 6-inch W2.9 × W2.9 welded wire fabric. The barrier segments were connected through a pin-and-loop connection, with two loops on each barrier end. The loops were made of ¾-inch diameter steel rods, while the connector pin was a 1¼-inch diameter steel rod with threads on both ends. Heavy hexagonal nuts were used to lock the connector pin from both ends. The 5⁄16-inch thick anchor hold-down plate was comprised of an angle welded to a plate. To connect the anchor plate to the barrier, a coil insert with an ASTM A325 bolt was used. To connect to the underlying concrete, epoxy anchors or through-deck bolting was proposed.

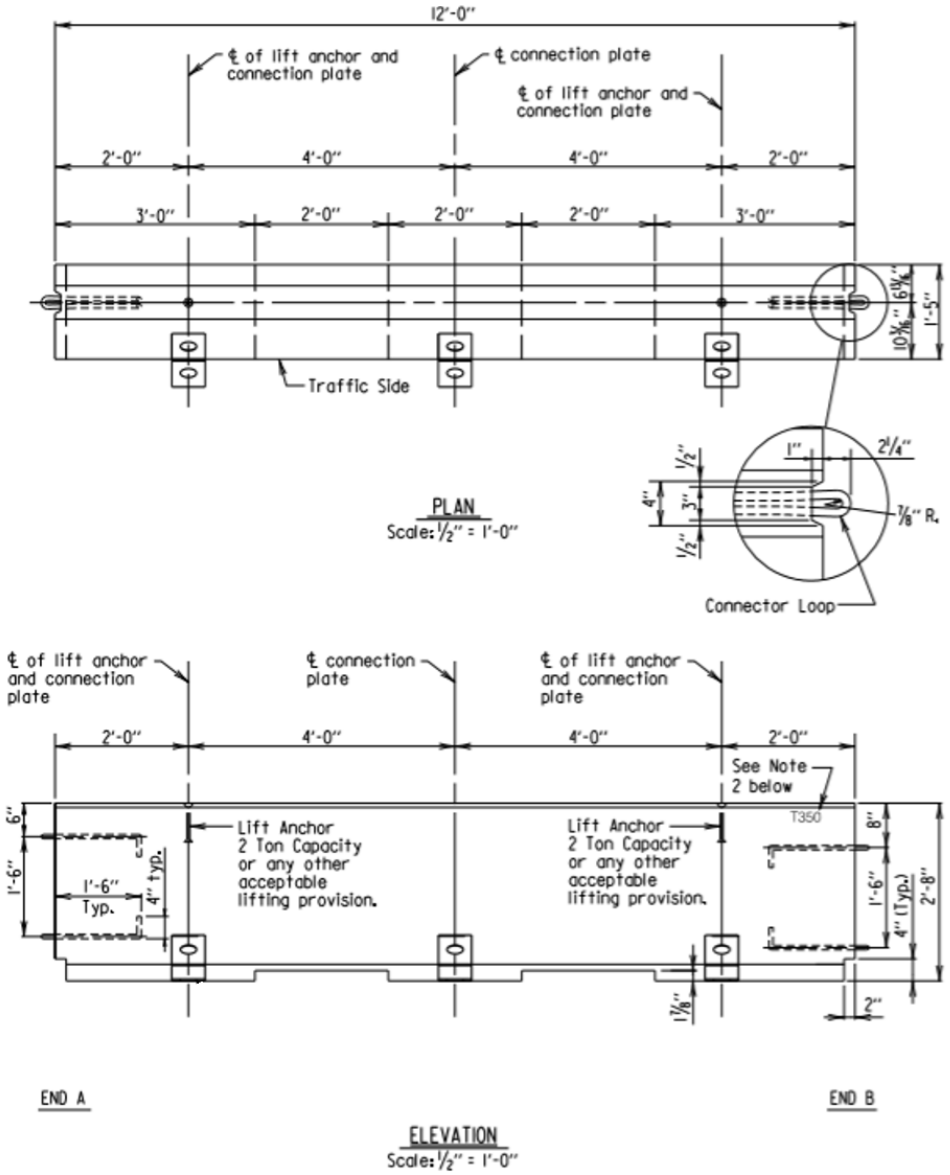


Figure 2.1. Originally Proposed Design (Not to Be Used for Construction)—General Geometry Details.

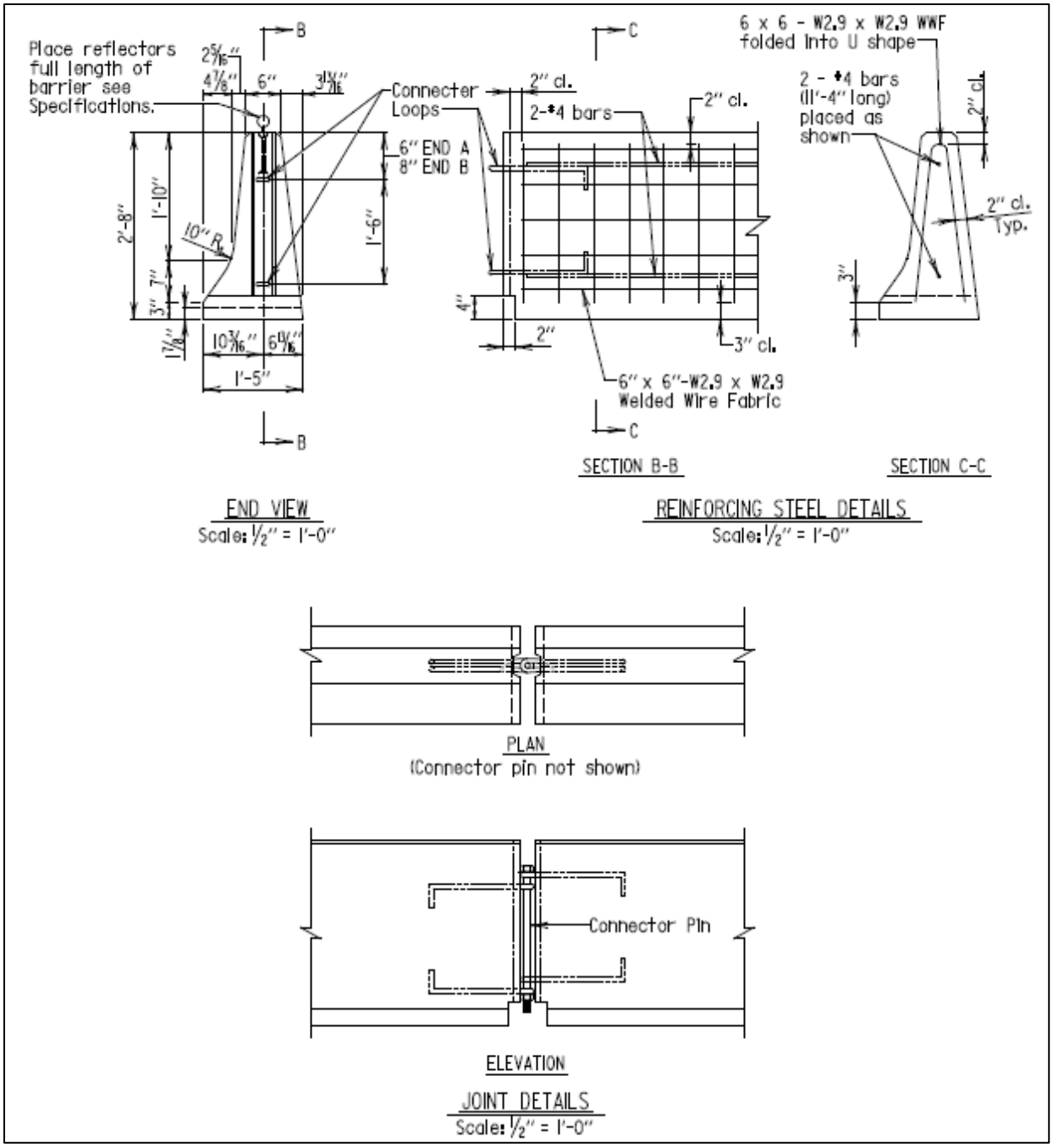


Figure 2.2. Originally Proposed Design (Not to Be Used for Construction)—Reinforcement and Joint Details.

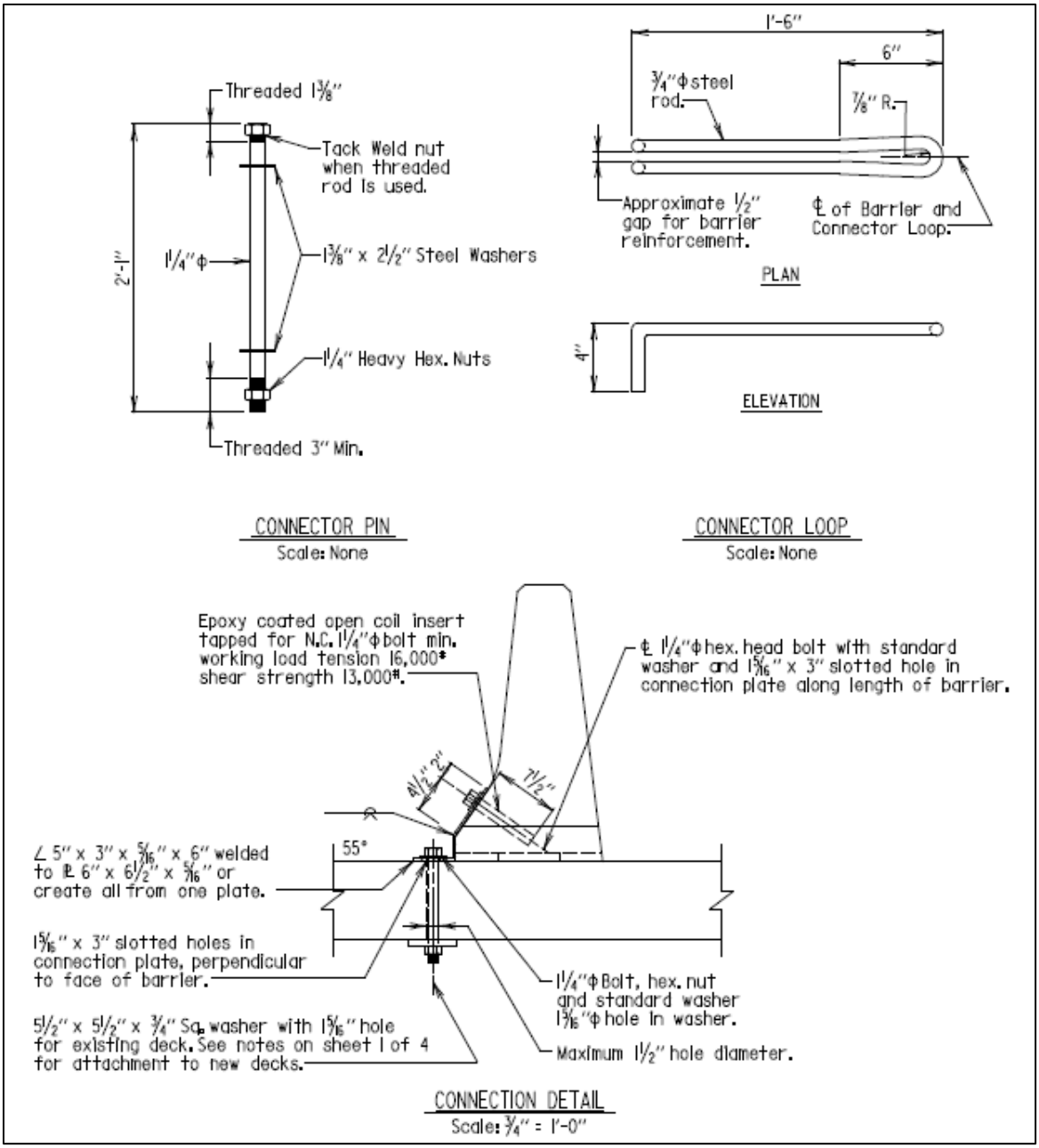


Figure 2.3. Originally Proposed Design (Not to Be Used for Construction)—Connector Details.

The concrete in the FE model was comprised of deformable solid elements with a continuous surface cap material model in LS-DYNA, which has the capability to model concrete damage. The barrier model is shown in Figure 2.4. The reinforcement within the deformable concrete elements was modeled with beam elements, as shown in Figure 2.5. The model also incorporated the pin-and-loop connection and the hold-down anchor plate, which were modeled with a combination of shell and beam elements, as shown in Figure 2.6 and Figure 2.7, respectively. Elastic-plastic material properties were assigned to the reinforcement, anchorage, and connection parts.

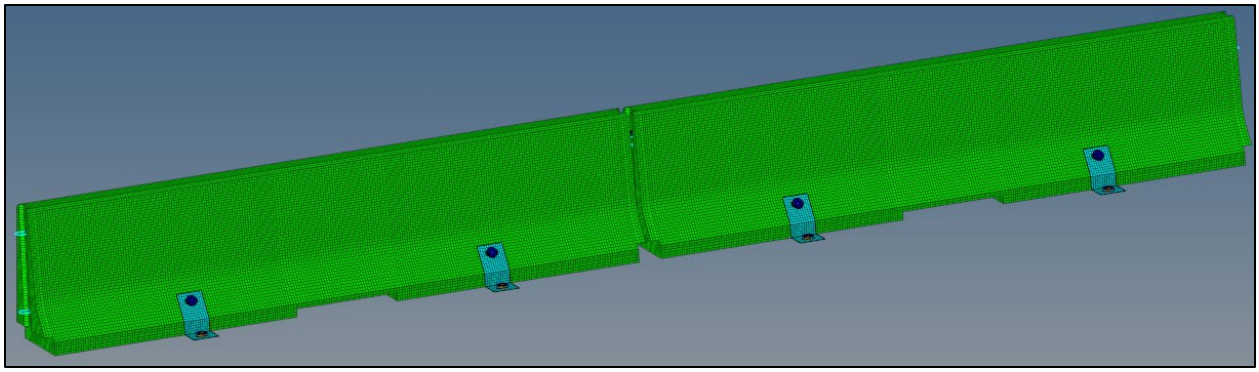


Figure 2.4. FE Model of Concrete Barrier Segments.

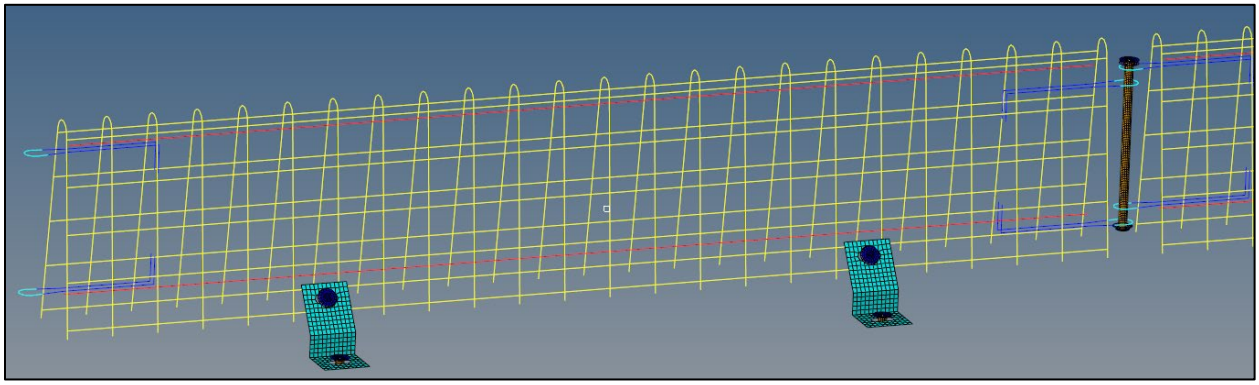


Figure 2.5. FE Model of the Steel Reinforcement.

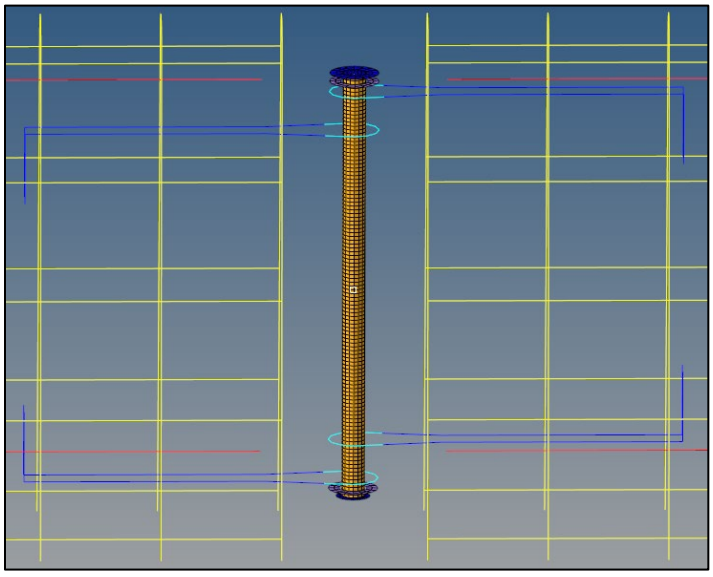


Figure 2.6. FE Model of Pin-and-Loop Connection.

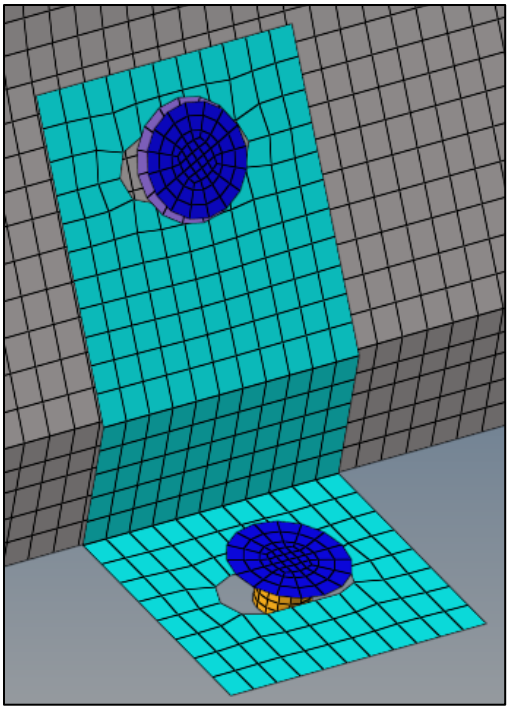


Figure 2.7. FE Model of Hold-Down Anchor Plate.

Figure 2.8 shows the full system model of the originally proposed anchored barrier design. It was comprised of eight barrier segments, for a total system length of 96 ft. In the system model, only the impacted barrier segments were modeled with deformable concrete material, while the remaining system segments were modeled with rigid material representation to reduce computational time needed to complete a simulation. The segments modeled with rigid material were expected to have negligible or no concrete damage, thus having no effect on the simulation results.

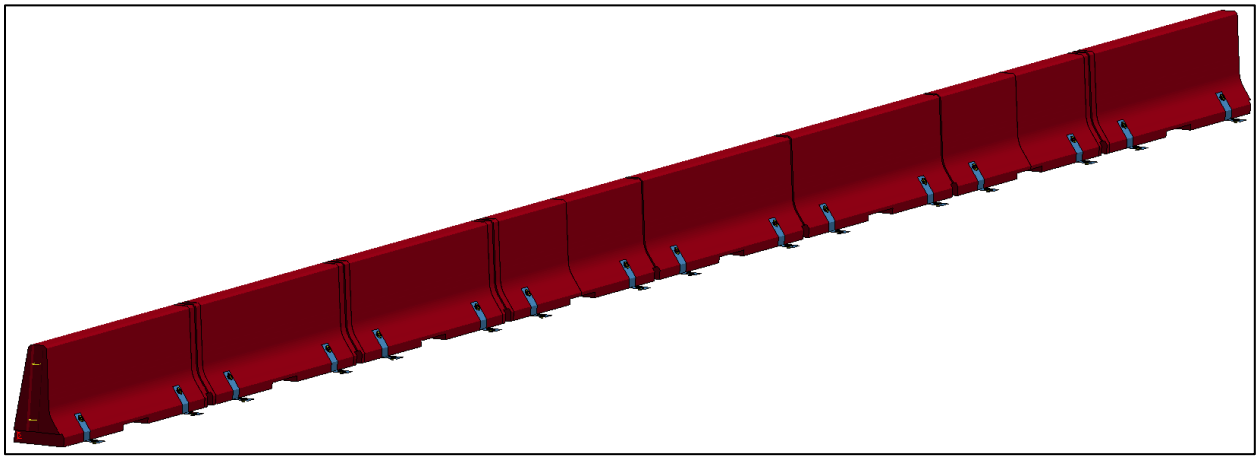


Figure 2.8. Full System FE Model of Originally Proposed Barrier Design.

The research team used a Dodge RAM pickup truck and a Toyota Yaris passenger car as the FE models to represent the *MASH* design vehicles for *MASH* Test 3-11 and Test 3-10 simulations, respectively. These FE vehicle models were originally developed by the Center for

Collision Safety and Analysis (*2*, *3*). They were further modified in house by the Texas A&M Transportation Institute (TTI) over the course of various projects to improve their robustness and validation for roadside safety crash analyses.

The originally proposed barrier system was evaluated under *MASH* Test 3-11 impact conditions with use of the pickup truck model. The 2018 RAM model impacted the system at 62 mi/h and an angle of 25 degrees. The impact point was 4.3 ft upstream of the joint between barrier 4 and barrier 5, which is a typically selected upstream impact distance recommended in *MASH*. The simulation setup is shown in Figure 2.9.

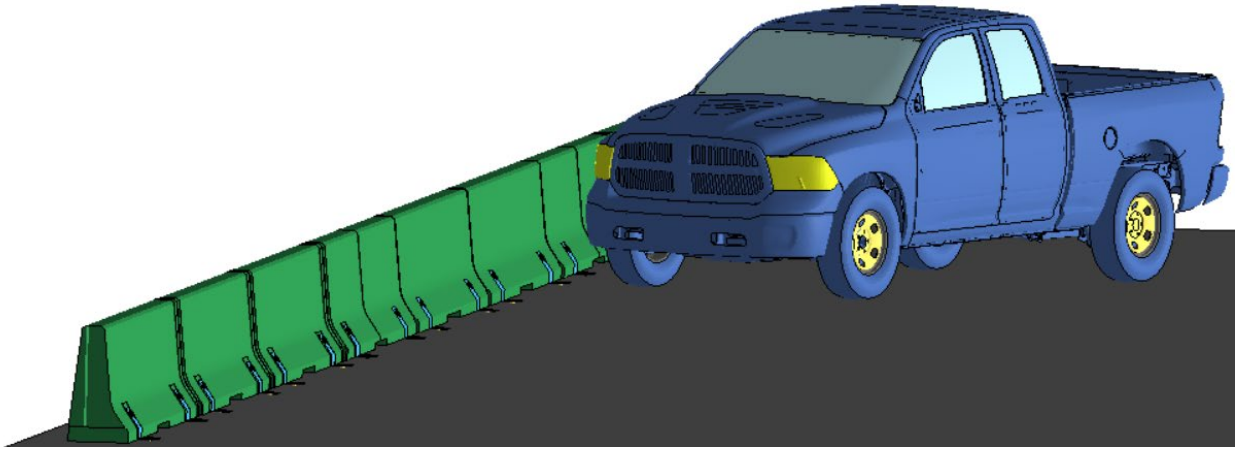


Figure 2.9. *MASH* Test 3-11 Simulation Setup for the Originally Proposed Barrier Design.

Results from the simulation showed severe damage to the barrier concrete and reinforcement after the impact, compromising its structural integrity (Figure 2.10). Large deformations of the anchor plates and the pin were also observed, as shown in Figure 2.10 and Figure 2.11. The vehicle was contained and redirected, but the maximum dynamic deflection of the barrier system was about 23 inches, which was well above the target 12-inch maximum deflection desired by MDOT. Using the results of the simulation, the researchers concluded that the anchorage system and the concrete reinforcement were under-designed and needed improvement.

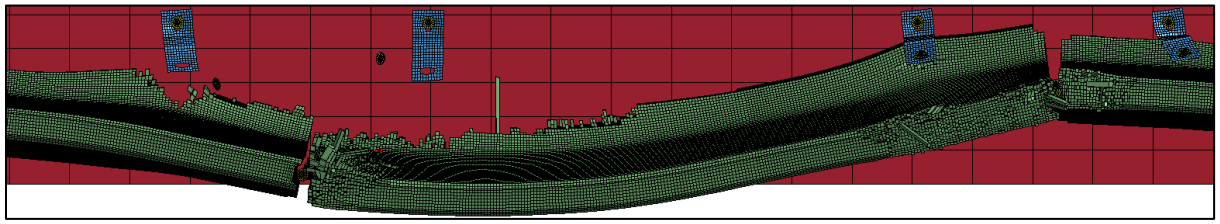


Figure 2.10. Concrete and Anchorage Damage after *MASH* Test 3-11 Impact (Top View).

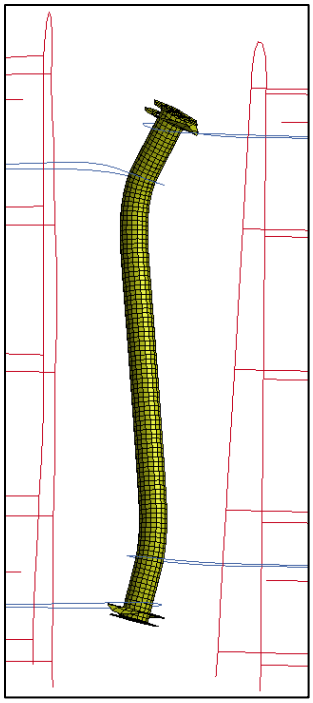


Figure 2.11. Deformation of Connection.

2.3. DESIGN MODIFICATIONS

Based on the results of the Test 3-11 simulation, the research team made several changes to the originally proposed barrier design. The researchers recommended using ½-inch diameter rebar for lateral and longitudinal concrete reinforcement to improve the barrier's structural capacity. To reduce the damage in the anchoring connection area, a U-bar was placed around the precast inserts for anchor bolts in the barrier segments.

The originally proposed design had cut-outs in the barrier toes near the ends. These gaps allowed greater rotation at the barrier joints, which resulted in additional lateral barrier deflection. The researchers recommended removing the cut-out toes. To strengthen the pin-and-loop connection, the researchers recommended adding two additional loops in the connection to achieve two sets of three loops instead of the two sets of two loops in the originally proposed design. To reduce hold-down anchor plate deformation, the researchers proposed using a thicker ½-inch plate. A summary of the changes is presented in Table 2.1.

Table 2.1. Summary of Changes between Original and Modified Barrier Design.

Feature	Original Design	Modified Design
Concrete reinforcement	6-inch × 6-inch W2.9 × W2.9 welded wire used as concrete reinforcement. Resulted in excessive concrete damage.	½-inch diameter rebars used for longitudinal and lateral reinforcement. A U-bar added around the anchor bolt insert in the barrier.
Cut-out toe	Cut-out toes in both ends of the barrier. Allowed excessive rotation of adjacent segments.	Removed cut-out toes to reduce barrier rotation.
Pin-loop connection	Two sets of two loops. Resulted in excessive connection damage.	Changed to two sets of three loops to strengthen the connection.
Anchor plate	5⁄16-inch thick welded anchor plate. Had excessive damage and did not provide adequate anchorage.	Thicker ½-inch plate used to improve anchorage capacity.

2.4. FINITE ELEMENT ANALYSIS OF MODIFIED DESIGN

A detailed full-scale FE model of the modified Maryland temporary precast single-face F-type concrete barrier was developed as shown in Figure 2.12. A closer isometric view of the barrier end model is shown in Figure 2.13. Reinforcement details are also shown in Figure 2.14.

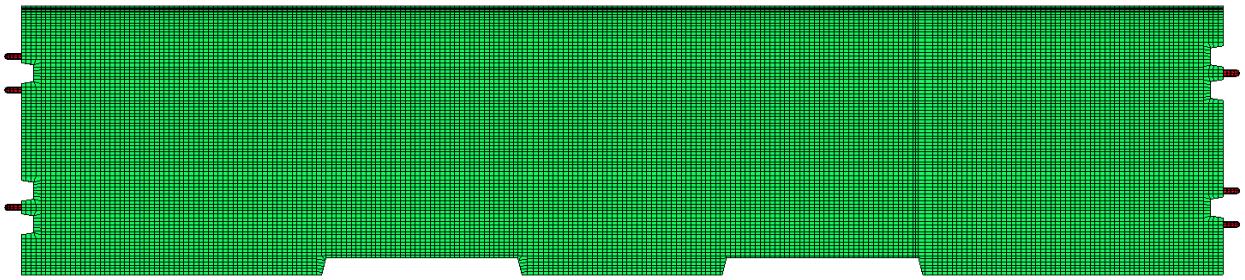


Figure 2.12. FE Model of Modified Barrier Segment.

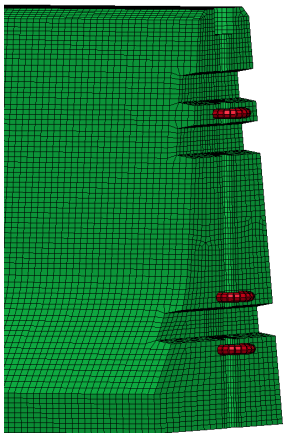


Figure 2.13. Isometric View of Modified Barrier Segment FE Model.

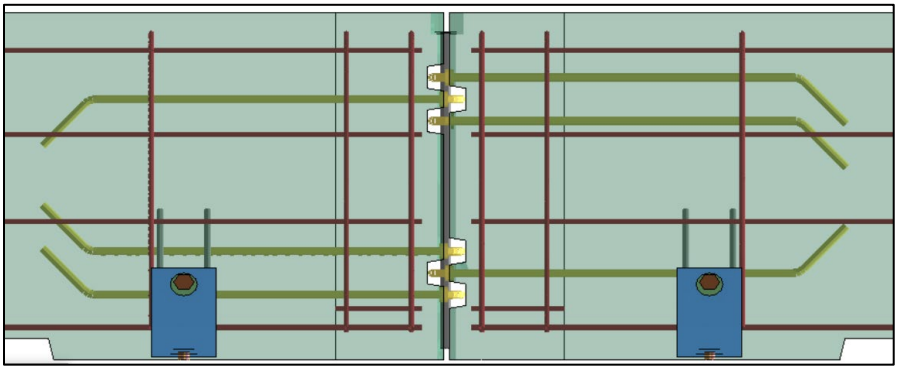


Figure 2.14. Reinforcement Details of Modified Barrier Model.

Impact simulations for *MASH* TL-3 conditions were performed on the modified barrier system. The modified barrier system was comprised of eight segments, for a total length of 96 ft and 10 inches, as shown in Figure 2.15.

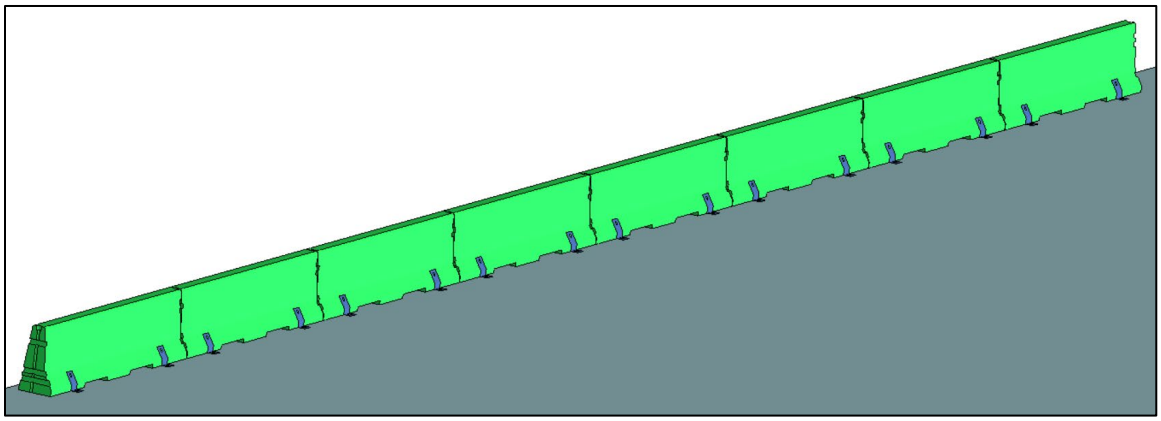
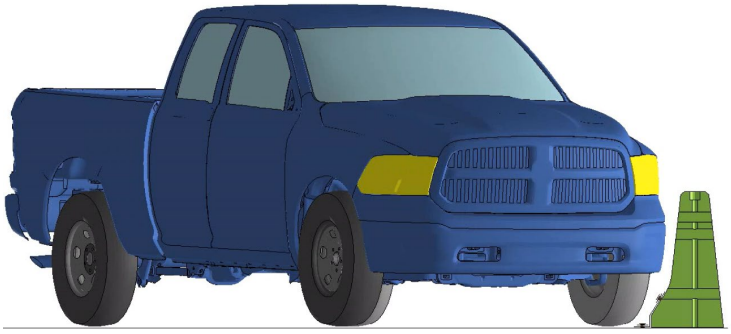


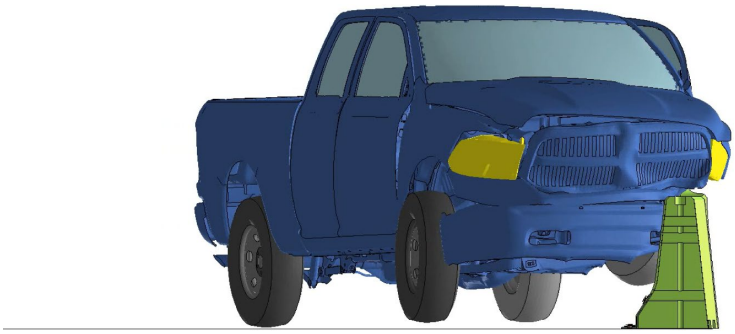
Figure 2.15. Modified Barrier System with Eight Segments.

For *MASH* Test 3-11, the pickup truck model impacted the system at 62 mi/h and an angle of 25 degrees. The impact point was 4.3 ft upstream of the joint between barrier 4 and barrier 5, as recommended in *MASH*. The modified barrier system successfully contained and

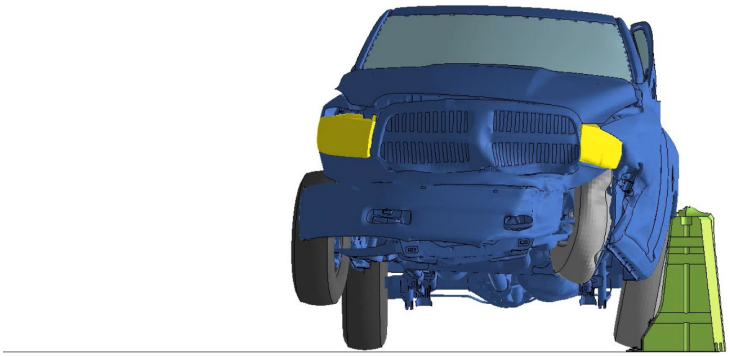
redirected the vehicle. All occupant risk metrics were within *MASH* limits. The maximum occupant impact velocity (OIV) was 33.3 ft/s, and the ridedown acceleration was 17.8 g. The dynamic and permanent barrier deflections were 3.4 inches and 2.6 inches, respectively. Front- and top-view sequential frames from the *MASH* Test 3-11 simulation with the pickup truck are shown in Figure 2.16 and Figure 2.17, respectively.



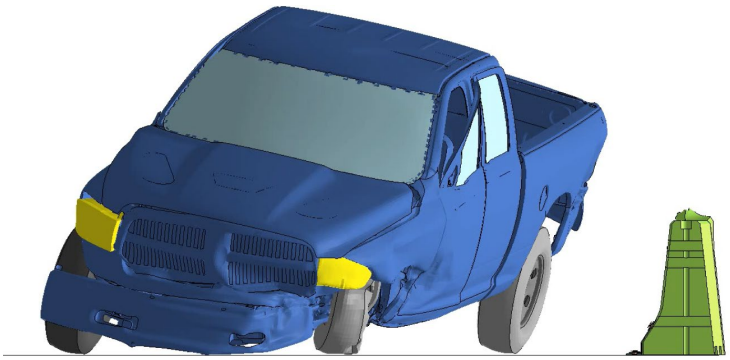
a. Vehicle Impacting the System



b. Vehicle Front Impact Side Interacting with System at 0.12 s

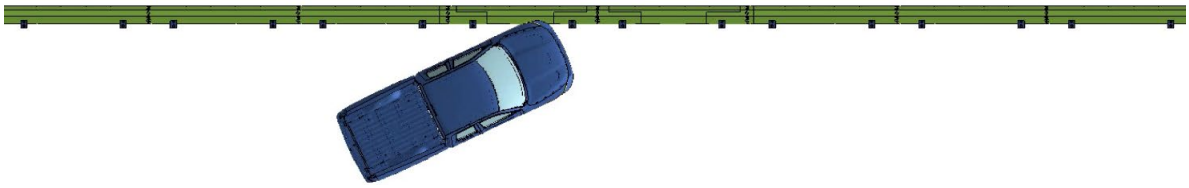


c. Vehicle Rear Impact Side Backslapping the System at 0.3 s

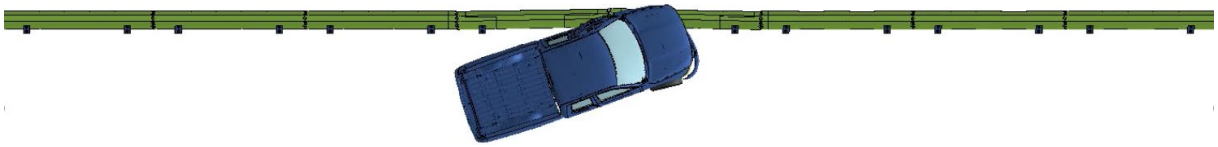


d. Vehicle Redirecting in Stable State at 0.63 s

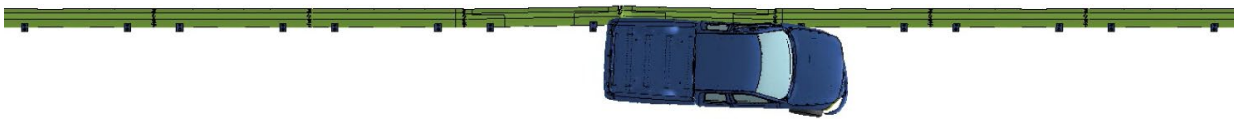
Figure 2.16. Front-View Simulation Frames of *MASH* Test 3-11 for Modified Barrier Design.



a. Vehicle Impacting the System



b. Vehicle Front Impact Side Interacting with System at 0.12 s



c. Vehicle Rear Impact Side Backslapping the System at 0.3 s

d. Vehicle Redirecting in Stable State at 0.63 s

Figure 2.17. Top-View Simulation Frames of *MASH* Test 3-11 for Modified Barrier Design.

Moderate concrete damage around the impact area was observed for the *MASH* Test 3-11 simulation, as shown in Figure 2.18 and Figure 2.19, where the red color shows full concrete damage and the blue or no color represents no concrete damage. The anchor plates and pin-and-loop connections successfully prevented the system from excessive deflection.

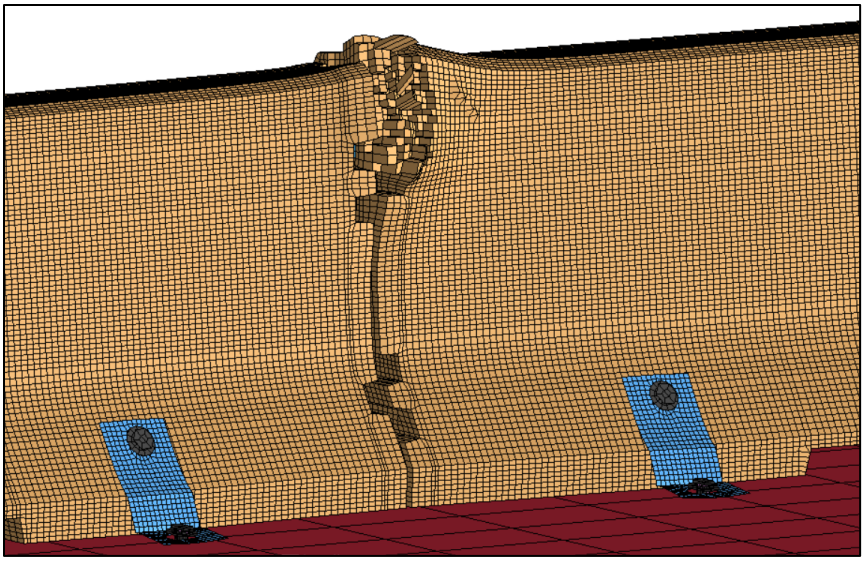
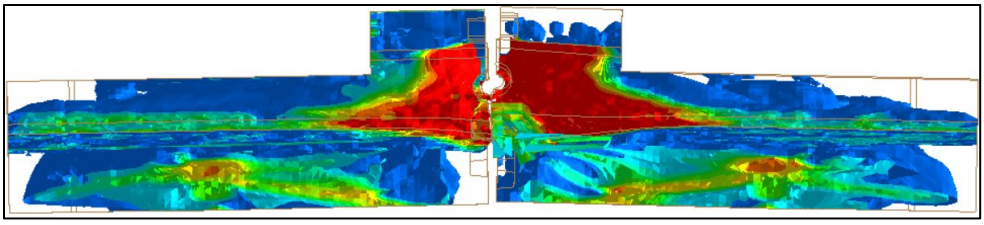
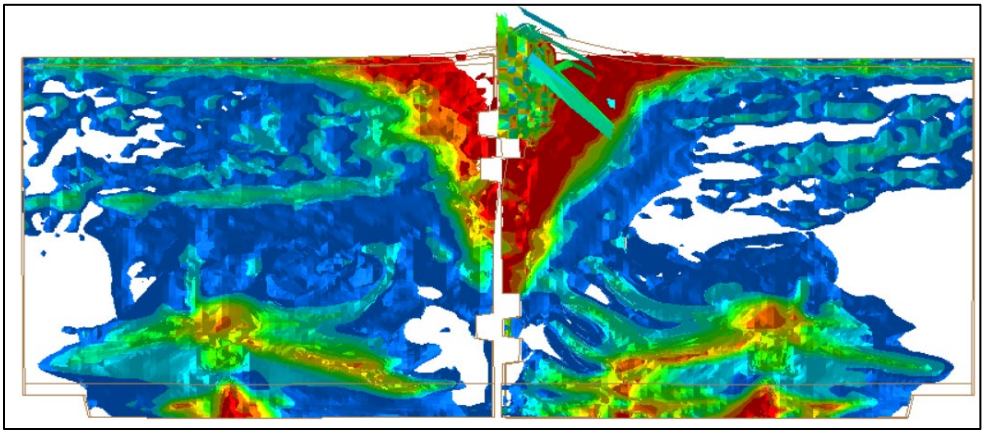


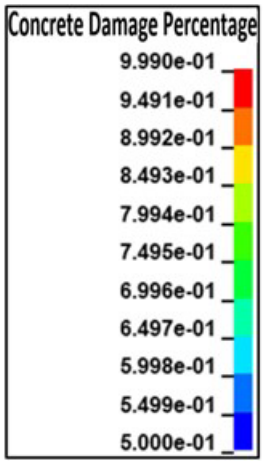
Figure 2.18. Isometric View of Impacted Area after *MASH* Test 3-11.



a. Top View of Concrete Damage



b. Front View of Concrete Damage



c. Concrete Damage Scale

Figure 2.19. Concrete Damage of Modified Barrier Design after *MASH* Test 3-11.

The FE model of the modified barrier system was also evaluated using the impact conditions of *MASH* Test 3-10, which involves a passenger car model impacting the system at a 62 mi/h impact speed and 25-degree orientation angle. From the perspective of the barrier's structural integrity and anchorage design, the impact with the lighter small car is considered less critical than the impact with the heavier pickup truck. The main goal of the simulation with the

small car was to evaluate the stability of the vehicle due to impact and the resulting occupant risk and occupant compartment deformation.

The impact point in the simulation with the small car was 3.6 ft upstream of the joint between barrier 4 and barrier 5, which is typical based on *MASH* recommendations. The modified barrier system successfully contained and redirected the vehicle. All occupant risk metrics except the maximum OIV were within *MASH* limits. The maximum OIV in the simulation was 40.5 ft/s, slightly higher than the allowable *MASH* limit of 40 ft/s. However, based on previous tests and experience using the small car model, the OIV is often overestimated in the simulation due to the lack of suspension and steering failure in the simulation models. Failure of suspension and steering joints and members is very commonly observed in crash testing, which results in reducing the snag of the vehicle with the barrier. Lack of this failure in the simulation results in higher OIV values. Since the OIV in the simulation was very close to the *MASH* threshold, the researchers felt comfortable proceeding with the design without making additional changes.

Deflections of the barrier system for the *MASH* Test 3-11 and Test 3-10 impact simulations are summarized in Table 2.2.

Table 2.2. Modified Barrier System Deflections for *MASH* TL-3 Simulations.

Parameter	*MASH* Test 3-11	*MASH* Test 3-10
Dynamic Deflection	3.9 in	2.0 in
Permanent Deflection	2.6 in	1.7 in

2.5. CONCLUSIONS

The originally proposed design of the anchored Maryland temporary precast single-face F-type concrete barrier was evaluated with full-scale FE impact simulations using *MASH* Test 3-11 impact conditions. The results showed that the original design of the barrier was not adequate to withstand *MASH* TL-3 impact forces.

The research team recommended design modifications to improve the barrier's performance and reach *MASH* TL-3 compliance. The recommendations were implemented in coordination with MDOT, and the modified barrier design was evaluated through full-scale impact simulations using *MASH* TL-3 impact conditions.

The modified anchored barrier model successfully passed *MASH* Test 3-11 and Test 3-10 evaluation criteria in the simulation analyses. Due to the satisfactory performance of the modified design in the simulations, the research team recommended the design for full-scale crash testing.

Chapter 3. SYSTEM DETAILS

3.1. TEST ARTICLE AND INSTALLATION DETAILS

The installation consisted of eight 12-ft long and 32-inch tall concrete barrier segments that had the F-shape profile on the impact side and a single-slope profile on the non-impact side. The segments were connected end-to-end, for a total length of 96 ft 10 inches. Each barrier segment measured 17 inches wide at the bottom, with a 3-inch tall toe on the traffic side of the barrier. The width at the top of the segments was 6½ inches. The barriers were joined with a 1-inch diameter pin that was inserted through three hot-rolled A36 mating loops on each end of the barrier segments. The barrier segments were secured to a 9-inch thick, 12-ft 6-inch wide, 105-ft long unreinforced concrete pavement via bent anchor brackets that were bolted to the traffic side toe of each barrier segment, and then epoxy-anchored to the underlying concrete pavement. Each barrier had two such anchor brackets that were positioned 2 ft from each end of the barrier segment. The barrier was installed at a 2-inch offset from the edge of the underlying concrete pavement.

Figure 3.1 presents the overall information on the anchored Maryland F-type temporary barrier, and Figure 3.2 through Figure 3.7 provide photographs of the installation. Appendix A provides further details on the barrier. Drawings were provided by the TTI Proving Ground, and construction was performed by MBC Management and supervised by TTI Proving Ground personnel.

3.2. DESIGN MODIFICATIONS DURING TESTS

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

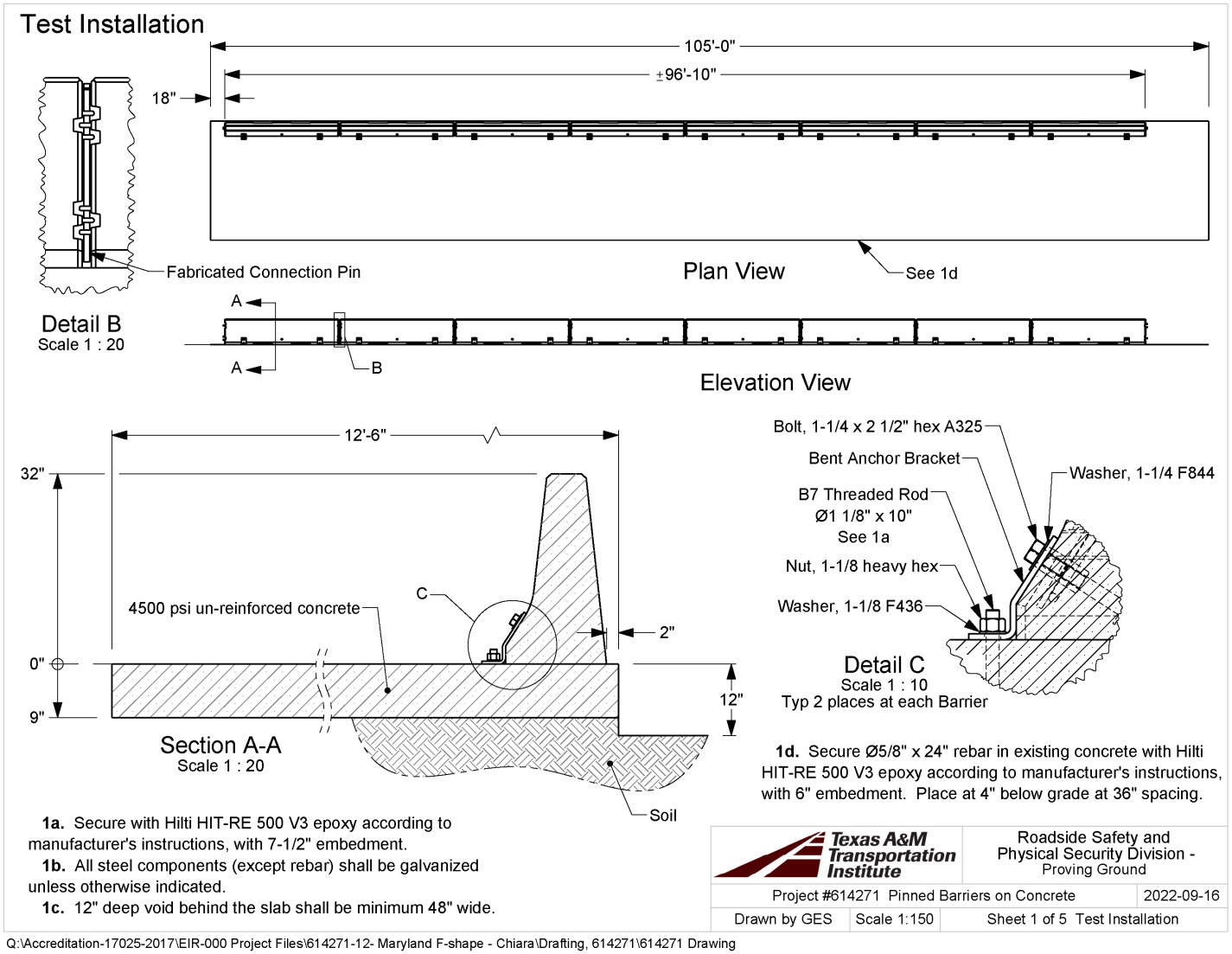


Figure 3.1. Details of Maryland F-Type Temporary Barrier.

Figure 3.2. Maryland F-Type Temporary Barrier prior to Testing—Front View of the Installation.

Figure 3.3. Maryland F-Type Temporary Barrier prior to Testing—Back View of the Installation.

Figure 3.4. Maryland F-Type Temporary Barrier prior to Testing—Lateral View of the Installation.

Figure 3.5. Maryland F-Type Temporary Barrier prior to Testing—Vehicle Tire Trajectory (Orange Line) Aimed at Targeted Barrier-Vehicle Impact Location.

Figure 3.6. Maryland F-Type Temporary Barrier prior to Testing—Ground Connection Details.

Figure 3.7. Maryland F-Type Temporary Barrier prior to Testing—Segment Connection Details.

3.3. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to install/construct the Maryland F-type temporary barrier. Table 3.1 shows the average compressive strengths of the concrete on the day of the first test, November 1, 2022.

Table 3.1. Concrete Strength.

Location	Design Strength (psi)	Avg. Strength (psi)	Age (days)	Detailed Location
Deck	4500	4478	29	100% of the Concrete Pavement
Barrier 4 Core	4500	4660	Not Known	Precast Barrier from Test 3-10
Barrier 5 Core	4500	5170	Not Known	Precast Barrier from Test 3-10
Barrier 4 Core	4500	4540	Not Known	Precast Barrier from Test 3-11
Barrier 5 Core	4500	4910	Not Known	Precast Barrier from Test 3-11

The strength of the concrete pavement was slightly under the specified minimum. However, it was deemed acceptable for use in the crash test since the difference was very small, and successful testing on slightly reduced pavement concrete strength would still allow use of the barrier on pavements or decks with higher concrete strength.

Chapter 4. TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1. CRASH TEST PERFORMED/MATRIX

Table 4.1 shows the test conditions and evaluation criteria for *MASH* TL-3 for longitudinal barriers. The target critical impact points (CIPs) for each test were determined using the information provided in *MASH* Section 2.2.1 and Section 2.3.2. Figure 4.1 shows the target CIP for *MASH* Tests 3-10 and 3-11 on the anchored Maryland F-type temporary barrier.

Table 4.1. Test Conditions and Evaluation Criteria Specified by *MASH* TL-3 for Longitudinal Barriers.

Test Designation	Test Vehicle	Impact Speed	Impact Angle	Evaluation Criteria
3-10	1100C	62 mi/h	25º	A, D, F, H, I
3-11	2270P	62 mi/h	25º	A, D, F, H, I

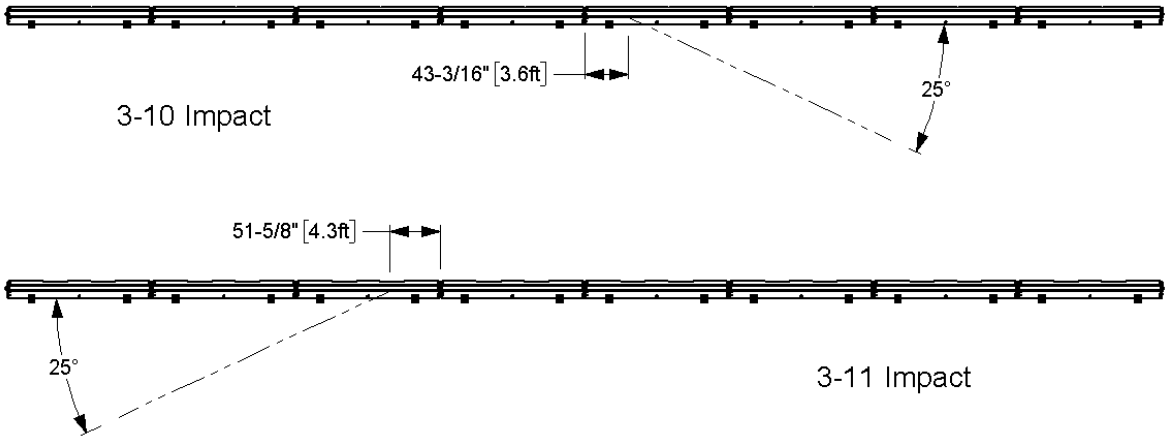


Figure 4.1. Target CIP for *MASH* TL-3 Tests on Maryland F-Type Temporary Barrier.

The crash tests 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 tests reported herein. Table 4.1 lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 4.2 provides detailed information on the evaluation criteria.

Table 4.2. Evaluation Criteria Required for *MASH* Testing.

Evaluation Factors	Evaluation Criteria	*MASH* Test
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.	3-10 & 3-11
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*.	3-10 & 3-11
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	3-10 & 3-11
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.	3-10 & 3-11
I.	The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	3-10 & 3-11

Chapter 5. TEST CONDITIONS

5.1. TEST FACILITY

The full-scale crash tests reported herein were performed at the TTI Proving Ground, an International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing Certificate 2821.01. The full-scale crash tests were performed according to TTI Proving Ground quality procedures, as well as *MASH* guidelines and standards.

The test facilities of the TTI Proving Ground are located on The Texas A&M University System RELLIS Campus, which consists of a 2000-acre complex of research and training facilities situated 10 mi northwest of the flagship campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, highway pavement durability and efficacy, and roadside safety hardware and perimeter protective device evaluation. The sites selected for construction and testing are along the edge of an out-of-service apron/runway. The apron/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 1100C and 2270P vehicles used in the tests were towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point and through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2:1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released and ran unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site.

5.3. DATA ACQUISITION SYSTEMS

5.3.1. Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a 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

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

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

5.3.3. Photographic Instrumentation Data Processing

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

- One located overhead with a field of view perpendicular to the ground and directly over the impact point.
- One placed upstream from the installation at an angle to have a field of view of the interaction of the rear of the vehicle with the installation.
- A third placed with a field of view parallel to and aligned with the installation at the downstream end.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Maryland F-type temporary barrier. The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

Chapter 6. *MASH* TEST 3-10 (CRASH TEST NO. 614271-12-2)

6.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 6.1 for details on *MASH* impact conditions and Table 6.2 for the exit parameters for Test 614271-12-2. Figure 6.1 and Figure 6.2 depict the target impact setup.

Table 6.1. Impact Conditions for *MASH* Test 3-10, Crash Test 614271-12-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	63.2
Impact Angle (deg)	25	±1.5°	25.1
Impact Severity (kip-ft)	51	≥51 kip-ft	58.1
Impact Location	43.2 inches upstream from centerline of joint between barrier 4 and 5	±12 inches	43.5 inches upstream from centerline of joint between barrier 4 and 5

Table 6.2. Exit Parameters for *MASH* Test 3-10, Crash Test 614271-12-2.

Exit Parameter	Measured
Speed (mi/h)	48.9
Trajectory (deg)	5
Heading (deg)	10
Brakes applied post impact (s)	2.7
Vehicle at rest position	257 ft downstream of impact point 2 ft to the field side 60° left
Comments:	Vehicle remained upright and stable. Vehicle crossed exit box[a] 58 ft downstream from loss of contact.

[a] Not less than 32.8 ft downstream from loss of contact for cars and pickups is optimal.

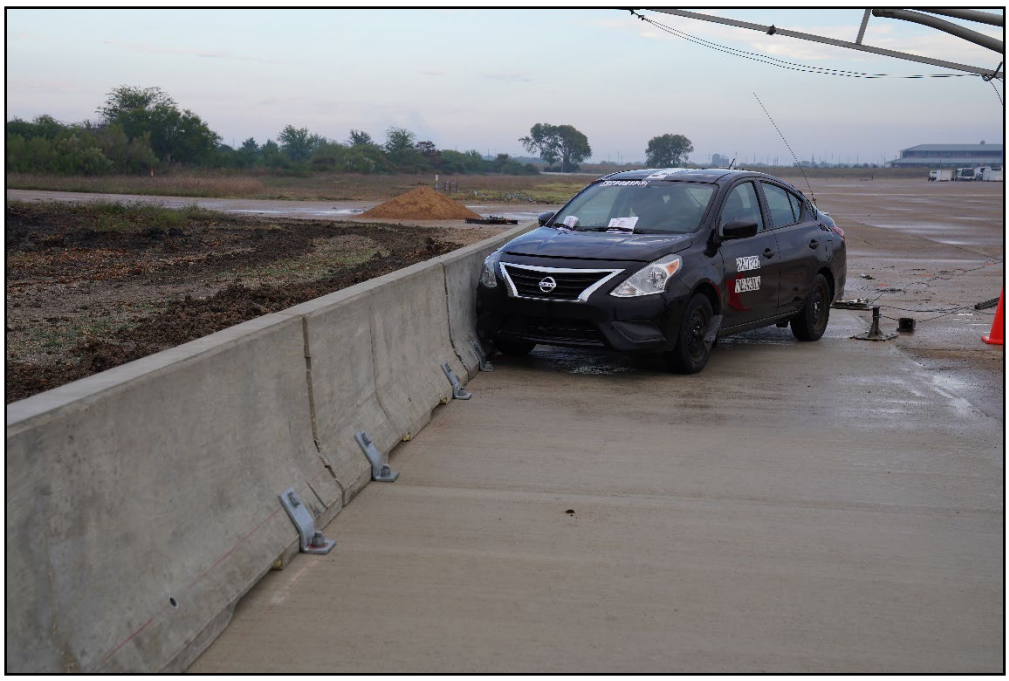


Figure 6.1. Maryland F-Type Temporary Barrier and Test Vehicle Geometrics for Test 614271-12-2.

Figure 6.2. Maryland F-Type Temporary Barrier and Test Vehicle Impact Location for Test 614271-12-2.

6.2. WEATHER CONDITIONS

Table 6.3 provides the weather conditions for Test 614271-12-2.

Table 6.3. Weather Conditions for Test 614271-12-2.

Date of Test	2022-11-01 AM
Wind Speed (mi/h)	4
Wind Direction (deg)	9
Temperature (°F)	73
Relative Humidity (%)	56
Vehicle Traveling (deg)	195

6.3. TEST VEHICLE

Figure 6.3 and Figure 6.4 show the 2018 Nissan Versa 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 614271-12-2.

Figure 6.4. Opposite Impact Side of Test Vehicle before Test 614271-12-2.

Table 6.4. Vehicle Measurements for Test 614271-12-2.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	165
Inertial Weight (lb)	2420	±55	2420
Gross Static[a] (lb)	2585	±55	2585
Wheelbase (inches)	98	±5	102.4
Front Overhang (inches)	35	±4	32.5
Overall Length (inches)	169	±8	175.4
Overall Width (inches)	65	±3	66.7
Hood Height (inches)	28	±4	30.5
Track Width[b] (inches)	59	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	41.7
CG above Ground[c,d] (inches)	N/A	N/A	N/A

Note: N/A = not applicable; CG = center of gravity.
[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.
[b] Average of front and rear axles.
[c] For test inertial mass.
[d] 2270P vehicle must meet minimum CG height requirement.

6.4. TEST DESCRIPTION

Table 6.5 lists events that occurred during Test No. 614271-12-2. Figures C.4 through C.6 in Appendix C.2 present sequential photographs during the test.

Table 6.5. Events during Test 614271-12-2.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0190	Vehicle began to redirect
0.0300	Barrier 4 at joint 4–5 began to move toward the field side
0.0380	Barrier 5 at joint 4–5 began to move toward the field side
0.1730	Rear passenger-side tire impacted the barrier
0.2030	Vehicle was parallel with the installation
0.3540	Vehicle exited the installation at 48.9 mi/h with a heading angle of 10 degrees and a trajectory angle of 5 degrees

6.5. DAMAGE TO TEST INSTALLATION

There was damage at each anchor position for barriers 4 and 5, with cracks at the downstream anchor on barrier 4 and the upstream anchor on barrier 5. Barrier 5 also had some spalling on the field side. Table 6.6 describes the damage to the anchored Maryland F-type temporary barrier. Figure 6.5 and Figure 6.6 show the damage to the barrier.

Table 6.6. Damage to Maryland F-Type Temporary Barrier for Test 614271-12-2.

Test Parameter	Measured
Permanent Deflection/Location	1 inch toward field side, at the joint of barriers 4 and 5
Dynamic Deflection	4.7 inches toward field side at the top of the barrier at the joint of barriers 4 and 5
Working Width[a] and Height	18.7 inches, at a height of 0 inches at the field side toe of the barrier at the joint of barriers 4 and 5

[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 6.5. Maryland F-Type Temporary Barrier after Test near Impact Location for Test 614271-12-2.

Figure 6.6. Maryland F-Type Temporary Barrier after Test at the Joint of Barriers 4 and 5 for Test 614271-12-2.

6.6. DAMAGE TO TEST VEHICLE

Figure 6.7 and Figure 6.8 show the damage sustained by the vehicle. Figure 6.9 and Figure 6.10 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. Figures C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.

Figure 6.7. Impact Side of Test Vehicle after Test 614271-12-2.

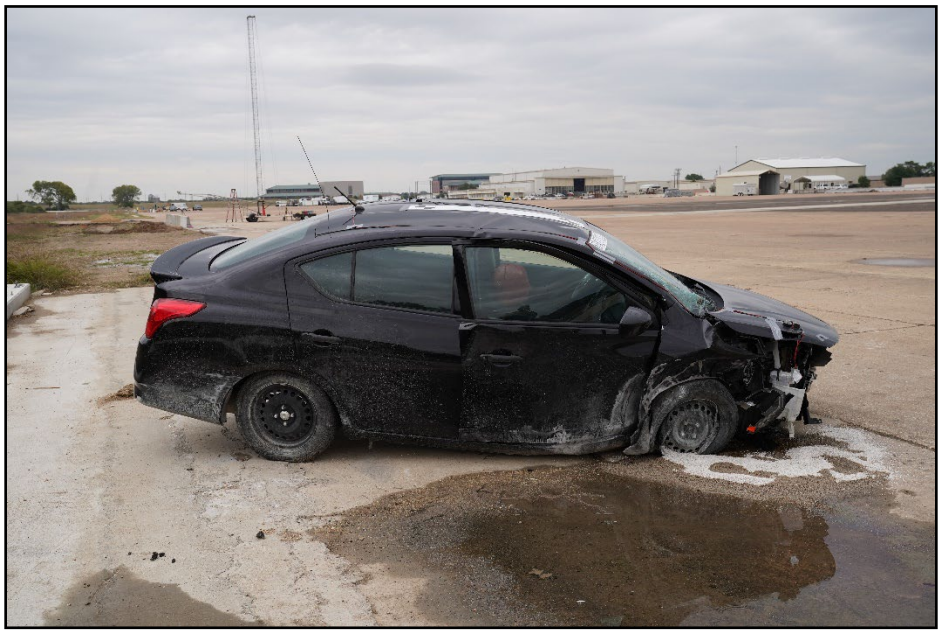


Figure 6.8. Rear Impact Side of Test Vehicle after Test 614271-12-2.

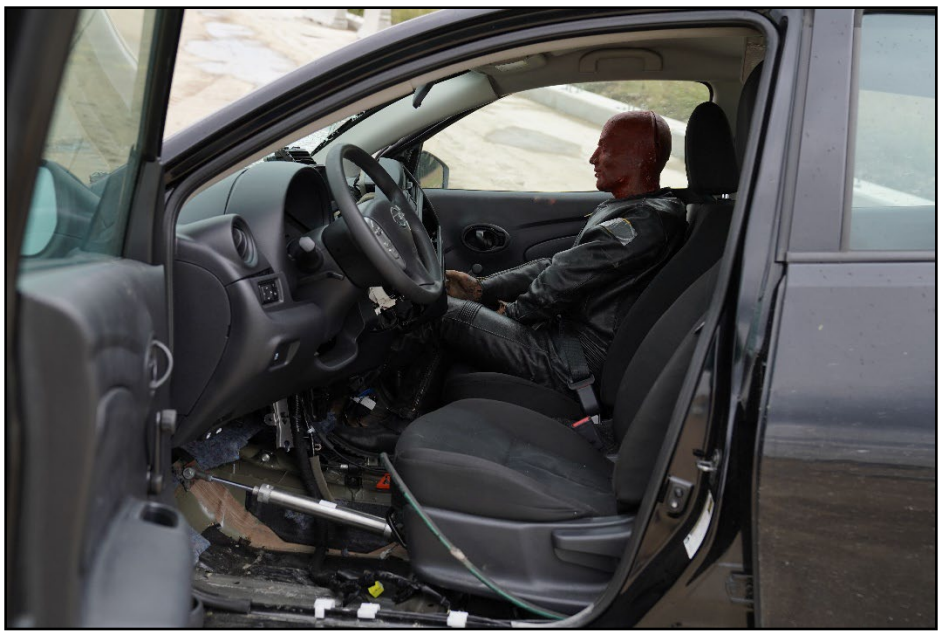


Figure 6.9. Overall Interior of Test Vehicle after Test 614271-12-2.

Figure 6.10. Interior of Test Vehicle on Impact Side after Test 614271-12-2.

Table 6.7. Occupant Compartment Deformation for Test 614271-12-2.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	−2 inches
Windshield	≤3.0 inches	1.5 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	−1 inches
Foot Well/Toe Pan	≤9.0 inches	−2 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	−5 inches
Front Door (above Seat)	≤9.0 inches	−5.5 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 6.8. Exterior Vehicle Damage for Test 614271-12-2.

Side Windows	Intact
Maximum Exterior Deformation	12 inches in the front plane at the right front corner at bumper height
VDS	01RFQ4
CDC	01FREW4
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, hood, grill, right and left headlights, radiator and support, right front quarter panel, right front tire and rim, right front strut and tower, right A pillar, windshield, right front door, right front floor pan and kick panel, and rear bumper were damaged. Damage to the windshield was caused by the flexing of the vehicle body during impact, not from contact with the test article. There was a 40-inch × 30-inch crack in the windshield, but there was no hole in the laminate. The right front door had a 5.5-inch gap at the top. There was a 14-inch × 37-inch × 0.5-inch deep dent in the roof at the B pillar. The floor pan had a seam that separated (5 inches long) at the kick panel.

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.7 in Appendix C.3 shows the vehicle angular displacements, and Figures C.8 through C.10 in Appendix C.4 show acceleration versus time traces. Figure 6.11 summarizes the results of the conducted full-scale crash test for *MASH* Test 3-10.

Table 6.9. Occupant Risk Factors for Test 614271-12-2.

Test Parameter	*MASH*	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*[a]	25.2	0.0861 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	28.4	0.0861 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	6.0	0.0861–0.0961 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	6.7	0.1049–0.1149 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	11.2	0.0835 seconds on right side of interior
Acceleration Severity Index (ASI)	N/A	2.2	0.0485–0.0985 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	−13.9	0.0170–0.0670 seconds
50-ms MA Lateral (g)	N/A	−16.6	0.0175–0.0675 seconds
50-ms MA Vertical (g)	N/A	−5.5	0.0496–0.0996 seconds
Roll (deg)	≤75	29	1.1361 seconds
Pitch (deg)	≤75	10	0.6495 seconds
Yaw (deg)	N/A	56	0.8791 seconds

[a] Values in italics are the preferred *MASH* values.

0.000 s

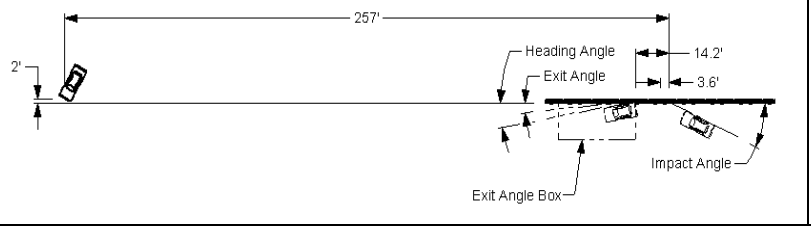
0.200 s

0.400 s

0.600 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-10
TTI Project No.	614271-12-2
Test Date	2022-11-01
TEST ARTICLE	
Type	Longitudinal Barrier
Name	Maryland F-Type Temporary Barrier
Length	96 ft 10 inches
Key Materials	Eight anchored 12-ft F-type barriers; 6-inch × ½-inch ASTM A36 plate anchor brackets; 1-inch diameter connection pins
Soil Type and Condition	Concrete, damp
TEST VEHICLE	
Type/Designation	1100 C
Year, Make and Model	2018 Nissan Versa
Inertial Weight (lb)	2420
Dummy (lb)	165
Gross Static (lb)	2585
IMPACT CONDITIONS	
Impact Speed (mi/h)	63.2
Impact Angle (deg)	25.1
Impact Location	43.5 inches upstream from centerline of joint between barrier 4 and 5
Impact Severity (kip-ft)	58.1
EXIT CONDITIONS	
Exit Speed (mi/h)	48.9
Trajectory/Heading Angle (deg)	5/10
Exit Box Criteria	Vehicle crossed the exit angle box
Stopping Distance	257 ft downstream 2 ft to the field side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	4.7
Permanent (inches)	1
Working Width/Height (inches)	18.7/0
VEHICLE DAMAGE	
VDS	01RFQ4
CDC	01FREW4
Max. Ext. Deformation	12
Max Occupant Compartment Deformation	5.5 inches at the door

OCCUPANT RISK VALUES							
Long. OIV (ft/s)	25.2	Long. Ridedown (g)	6.0	Max 50-ms Long. (g)	−13.9	Max Roll (deg)	29
Lat. OIV (ft/s)	28.4	Lat. Ridedown (g)	6.7	Max 50-ms Lat. (g)	−16.6	Max Pitch (deg)	10
THIV (m/s)	11.2	ASI	2.2	Max 50-ms Vert. (g)	−5.5	Max Yaw (deg)	56



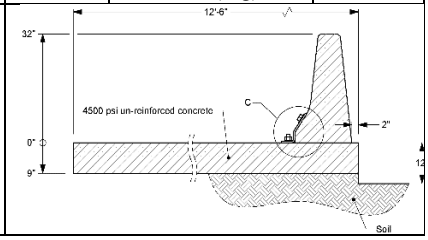


Figure 6.11. Summary of Results for *MASH* Test 3-10 on Anchored Maryland F-Type Temporary Barrier.

Chapter 7. *MASH* TEST 3-11 (CRASH TEST NO. 614271-12-1)

7.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 7.1 for details on *MASH* impact conditions and Table 7.2 for the exit parameters for Test 614271-12-1. Figure 7.1 and Figure 7.2 depict the target impact setup.

Table 7.1. Impact Conditions for *MASH* Test 3-11, Crash Test 614271-12-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62 mi/h	±2.5 mi/h	61.8
Impact Angle (deg)	25°	±1.5°	24.9
Impact Severity (kip-ft)	106 kip-ft	≥106 kip-ft	113.6
Impact Location	51.6 inches upstream from centerline of joint between barrier 3 and 4	±12 inches	54.1 inches upstream from centerline of joint between barrier 3 and 4

Table 7.2. Exit Parameters for *MASH* Test 3-11, Crash Test 614271-12-1.

Exit Parameter	Measured
Speed (mi/h)	51.8
Trajectory (deg)	2
Heading (deg)	9
Brakes applied post impact (s)	2.3
Vehicle at rest position	216 ft downstream of impact point 9 ft to the traffic side 90° left
Comments:	Vehicle remained upright and stable. Vehicle crossed the exit box[a] 77 ft downstream from loss of contact.

[a] Not less than 32.8 ft downstream from loss of contact for cars and pickups is optimal.

Figure 7.1. Maryland F-Type Temporary Barrier and Test Vehicle Geometrics for Test 614271-12-1.

Figure 7.2. Maryland F-Type Temporary Barrier and Test Vehicle Impact Location for Test 614271-12-1.

7.2. WEATHER CONDITIONS

Table 7.3 provides the weather conditions for Test 614271-12-1.

Table 7.3. Weather Conditions for Test 614271-12-1.

Date of Test	2022-11-16 PM
Wind Speed (mi/h)	11
Wind Direction (deg)	46
Temperature (°F)	52
Relative Humidity (%)	54
Vehicle Traveling (deg)	325

7.3. TEST VEHICLE

Figure 7.3 and Figure 7.4 show the 2019 RAM 1500 used for the crash test. Table 7.4 shows the vehicle measurements. Figure D.1 in Appendix D.1 gives additional dimensions and information on the vehicle.

Figure 7.3. Impact Side of Test Vehicle before Test 614271-12-1.

Figure 7.4. Opposite Impact Side of Test Vehicle before Test 614271-12-1.

Table 7.4. Vehicle Measurements for Test 614271-12-1.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Inertial Weight (lb)	5000	±110	5020
Gross Static[a] (lb)	5000	±110	5020
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40.0
Overall Length (inches)	237	±13	227.5
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46.0
Track Width[b] (inches)	67	±1.5	68.25
CG aft of Front Axle[c] (inches)	63	±4	61.2
CG above Ground[c,d] (inches)	28	≥28	28.4

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.
[b] Average of front and rear axles.
[c] For test inertial mass.
[d] 2270P vehicle must meet minimum CG height requirement.

7.4. TEST DESCRIPTION

Table 7.5 lists events that occurred during Test No. 614271-12-1. Figures D.4 through D.6 in Appendix D.2 present sequential photographs during the test.

Table 7.5. Events during Test 614271-12-1.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0190	Barrier 3 began to move toward the field side
0.0410	Vehicle began to redirect
0.0380	Barrier 4 began to move toward the field side
0.1930	Vehicle was parallel with the installation
0.2010	Driver-side rear bumper contacted the barrier
0.3600	Vehicle exited the installation at 51.8 mi/h with a heading angle of 9 degrees and a trajectory angle of 2 degrees

7.5. DAMAGE TO TEST INSTALLATION

There was significant damage to barriers 3 and 4 at the anchor locations, and some rebar was exposed. Barrier 3 also had spalling on the field side with exposed rebar, and it moved ⅛ inch downstream and up 1¼ inch on the field side at the joint of barriers 2 and 3. Barrier 4 sustained a break in the concrete from the traffic side to field side. There was some spalling on the field side of barrier 2 at the joint of barriers 2 and 3. Table 7.6 describes the damage to the anchored Maryland F-type temporary barrier. Figure 7.5 and Figure 7.6 show the damage to the barrier.

Table 7.6. Damage to Maryland F-Type Temporary Barrier for Test 614271-12-1.

Test Parameter	Measured
Permanent Deflection/Location	6.9 inches toward field side at the top of the barrier at the joint of barriers 3 and 4
Dynamic Deflection	8.1 inches toward field side at the top of the barrier at the joint of barriers 3 and 4
Working Width[a] and Height	The side view mirror at 28 inches, at a height of 60.75 inches

[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 7.5. Maryland F-Type Temporary Barrier after Test at Impact Location for Test 614271-12-1.

Figure 7.6. Maryland F-Type Temporary Barrier after Test at the Joint of Barriers 3 and 4 for Test 614271-12-1.

7.6. DAMAGE TO TEST VEHICLE

Figure 7.7 and Figure 7.8 show the damage sustained by the vehicle. Figure 7.9 and Figure 7.10 show the interior of the test vehicle. Table 7.7 and Table 7.8 provide details on the occupant compartment deformation and exterior vehicle damage. Figures D.2 and D.3 in Appendix D.1 provide exterior crush and occupant compartment measurements.

Figure 7.7. Impact Side of Test Vehicle after Test 614271-12-1.

Figure 7.8. Rear Impact Side of Test Vehicle after Test 614271-12-1.

Figure 7.9. Overall Interior of Test Vehicle after Test 614271-12-1.

Figure 7.10. Interior of Test Vehicle on Impact Side after Test 614271-12-1.

Table 7.7. Occupant Compartment Deformation for Test 614271-12-1.

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	−2 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 7.8. Exterior Vehicle Damage for Test 614271-12-1.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	12 inches in the front plane at the left front corner at bumper height
VDS	11LFQ3
CDC	11FLEW2
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, hood, grill, left headlight, left front tire and rim, left front lower control arm, left front quarter fender, left front door, left front floor pan, left rear door, left cab corner, left rear quarter fender, left rear tire and rim, left taillight, and rear bumper were damaged. The left front door had a 1-inch gap at the top.

7.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 7.9. Figure D.7 in Appendix D.3 shows the vehicle angular displacements, and Figures D.8 through D.10 in Appendix D.4 show acceleration versus time traces. Figure 7.11 summarizes the results of the full-scale crash test for *MASH* Test 3-11.

Table 7.9. Occupant Risk Factors for Test 614271-12-1.

Test Parameter	*MASH*	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*[a]	15.1	0.0982 seconds on left side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	24.5	0.0982 seconds on left side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	5.6	0.1020–0.1120 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	10.2	0.2300–0.2400 seconds
THIV (m/s)	N/A	8.8	0.0958 seconds on left side of interior
ASI	N/A	1.5	0.0597–0.1097 seconds
50-ms MA Longitudinal (g)	N/A	−7.1	0.0337–0.0837 seconds
50-ms MA Lateral (g)	N/A	11.9	0.0417–0.0917 seconds
50-ms MA Vertical (g)	N/A	−3.2	0.0250–0.0750 seconds
Roll (deg)	≤75	40	0.7458 seconds
Pitch (deg)	≤75	6	0.7393 seconds
Yaw (deg)	N/A	50	1.2135 seconds

[a] Values in italics are the preferred *MASH* values.

0.000 s

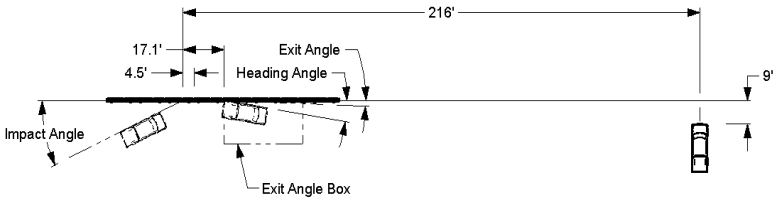
0.200 s

0.400 s

0.600 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-11
TTI Project No.	614271-12-1
Test Date	2022-11-16
TEST ARTICLE	
Type	Longitudinal Barrier
Name	Maryland F-Type Temporary Barrier
Length	96 ft 10 inches
Key Materials	Eight anchored 12 ft F-type barriers; 6-inch × ½-inch ASTM A36 plate anchor brackets; 1-inch diameter connection pins
Soil Type and Condition	Concrete, damp
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2019 RAM 1500
Inertial Weight (lb)	5020
Dummy (lb)	N/A
Gross Static (lb)	5020
IMPACT CONDITIONS	
Impact Speed (mi/h)	61.8
Impact Angle (deg)	24.9
Impact Location	54.1 inches upstream from centerline of joint between barrier 3 and 4
Impact Severity (kip-ft)	113.6
EXIT CONDITIONS	
Exit Speed (mi/h)	51.8
Trajectory/Heading Angle (deg)	2/9
Exit Box Criteria	Vehicle crossed the exit box
Stopping Distance	216 ft downstream 9 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	8.1
Permanent (inches)	6.9
Working Width/Height (inches)	28/60.75
VEHICLE DAMAGE	
VDS	11LFQ3
CDC	11FLEW2
Max. Ext. Deformation	12
Max Occupant Compartment Deformation	2 inches in the floor pan

OCCUPANT RISK VALUES							
Long. OIV (ft/s)	15.1	Long. Ridedown (g)	5.6	Max 50-ms Long. (g)	−7.1	Max Roll (deg)	40
Lat. OIV (ft/s)	24.5	Lat. Ridedown (g)	10.2	Max 50-ms Lat. (g)	11.9	Max Pitch (deg)	6
THIV (m/s)	8.8	ASI	1.5	Max 50-ms Vert. (g)	−3.2	Max Yaw (deg)	50



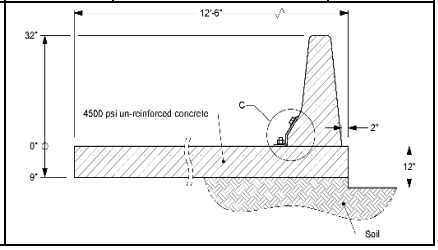


Figure 7.11. Summary of Results for *MASH* Test 3-11 on Maryland F-Type Temporary Barrier.

Chapter 8. SUMMARY AND CONCLUSIONS

8.1. ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* TL-3, which involves two tests, on the anchored Maryland F-type temporary barrier. Table 8.1 provides a summarized assessment of each test's performance for *MASH* TL-3 evaluation criteria for longitudinal barriers.

Table 8.1. Assessment Summary for *MASH* TL-3 Tests on Maryland F-Type Temporary Barrier.

Evaluation Criteria[a]	Description	Test No. 614271-12-2	Test No. 614271-12-1
A	Contain, Redirect, or Controlled Stop	S	S
D	No Penetration into Occupant Compartment	S	S
F	Roll and Pitch Limit	S	S
H	OIV Threshold	S	S
I	Ridedown Threshold	S	S
Overall		Pass	Pass

Note: S = Satisfactory.
[a] See Table 4.2 for details.

8.2. CONCLUSIONS

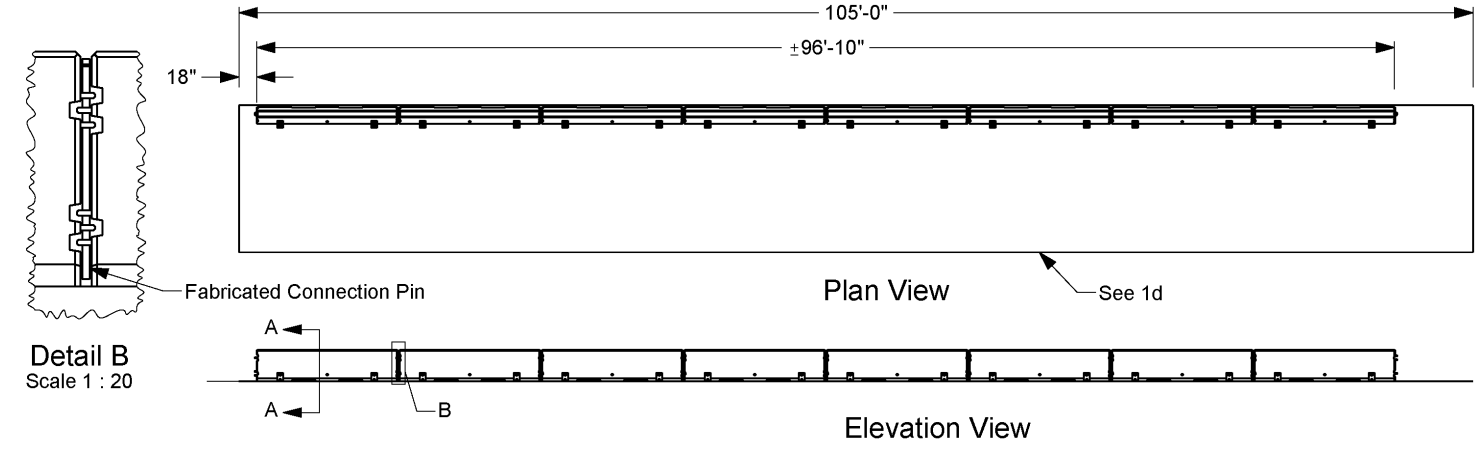
The anchored Maryland F-type temporary barrier met the performance criteria for *MASH* TL-3 for longitudinal barriers.

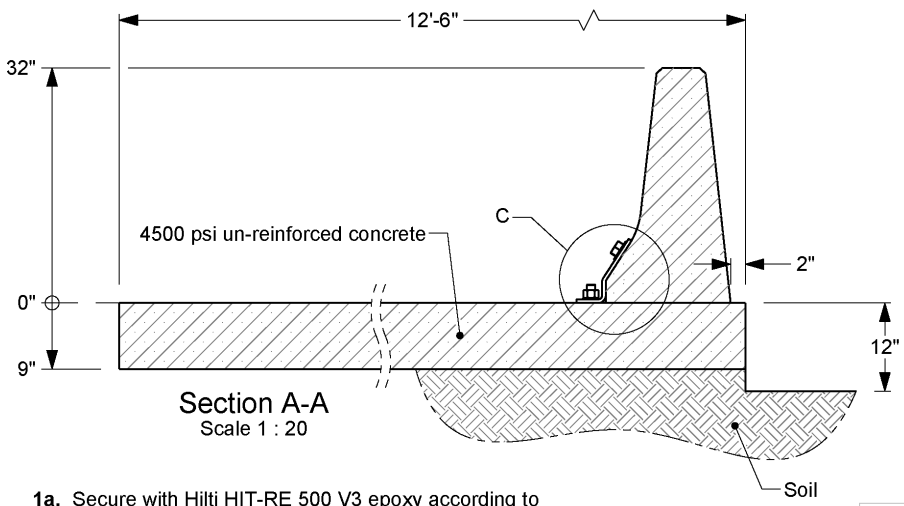
REFERENCES

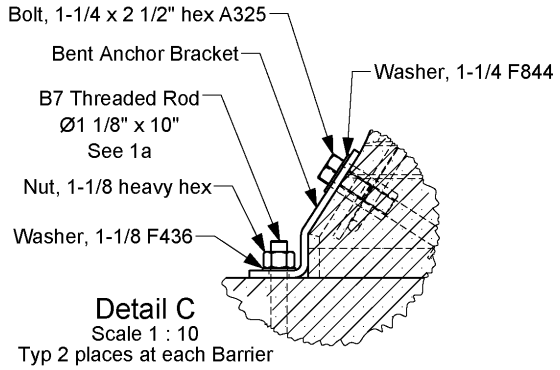
1. AASHTO. *Manual for Assessing Roadside Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
2. George Mason University, Center for Collision Safety and Analysis. *Finite Element Models—2018 Dodge RAM*. https://www.ccsa.gmu.edu/models/2018-dodge-ram/
3. George Mason University, Center for Collision Safety and Analysis. *Finite Element Models—2010 Toyota Yaris*. https://www.ccsa.gmu.edu/models/2010-toyota-yaris/

APPENDIX A. DETAILS OF ANCHORED MARYLAND F-TYPE TEMPORARY BARRIER

Test Installation







1a. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 7-1/2" embedment.

1b. All steel components (except rebar) shall be galvanized unless otherwise indicated.

1c. 12" deep void behind the slab shall be minimum 48" wide.

1d. Secure Ø5/8" x 24" rebar in existing concrete with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment. Place at 4" below grade at 36" spacing.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #614271 Pinned Barriers on Concrete		2022-09-16
Drawn by GES	Scale 1:150	Sheet 1 of 5 Test Installation

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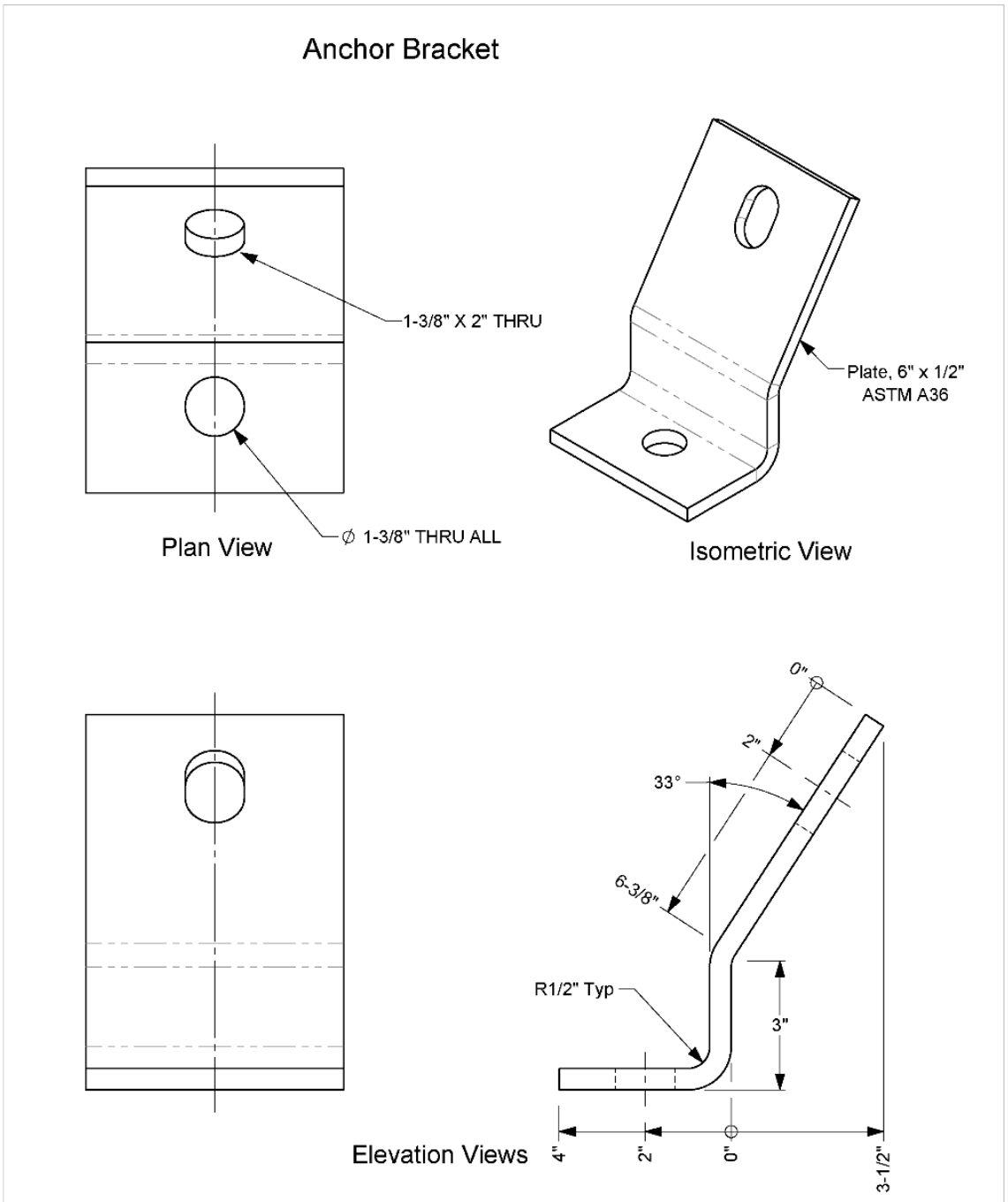
Anchor Bracket
1-3/8" X 2" THRU
Ø 1-3/8" THRU ALL
Plan View
Plate, 6" x 1/2"
ASTM A36
Isometric View
0"
2"
33°
6-3/8"
R1/2" Typ
3"
4"
2"
0"
3-1/2"
Elevation Views
2a. Galvanize after fabrication is complete.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #614271 Pinned Barriers on Concrete
2022-09-16
Drawn by GES
Scale 1:3
Sheet 2 of 5 / Anchor Bracket
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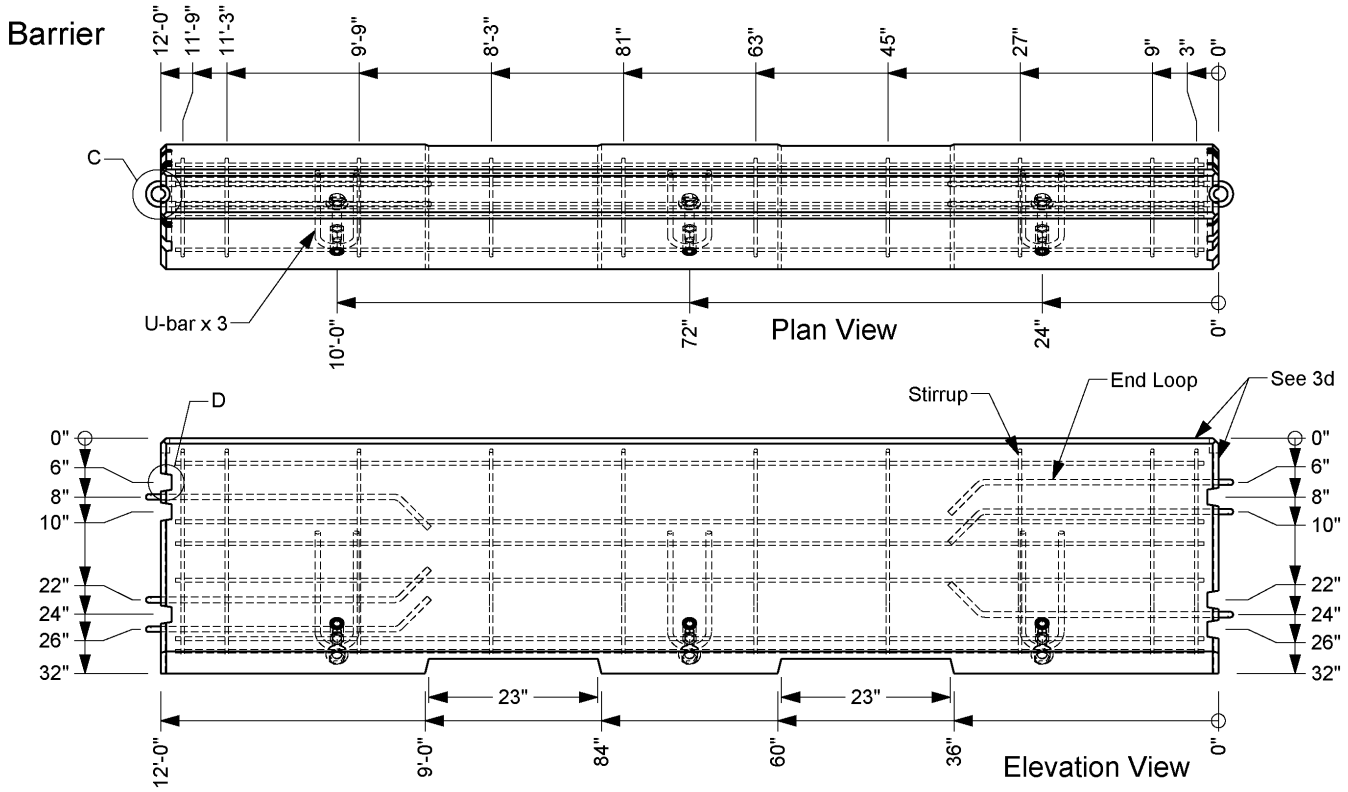

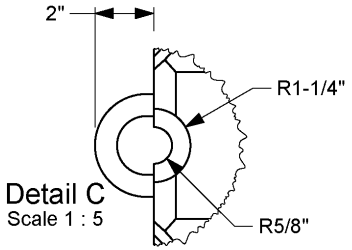

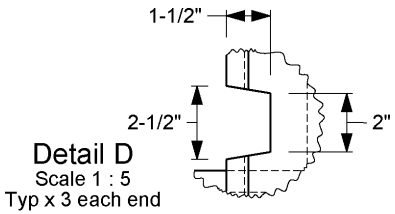

3a. All rebar is grade 60.

3b. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

3c. Concrete is 4,500 psi.

3d. 1" chamfer (3/4" each way) top edges and ends of Barrier.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #614271 Pinned Barriers on Concrete			2022-09-16
Drawn by GES	Scale 1:20	Sheet 3 of 5 Barrier	

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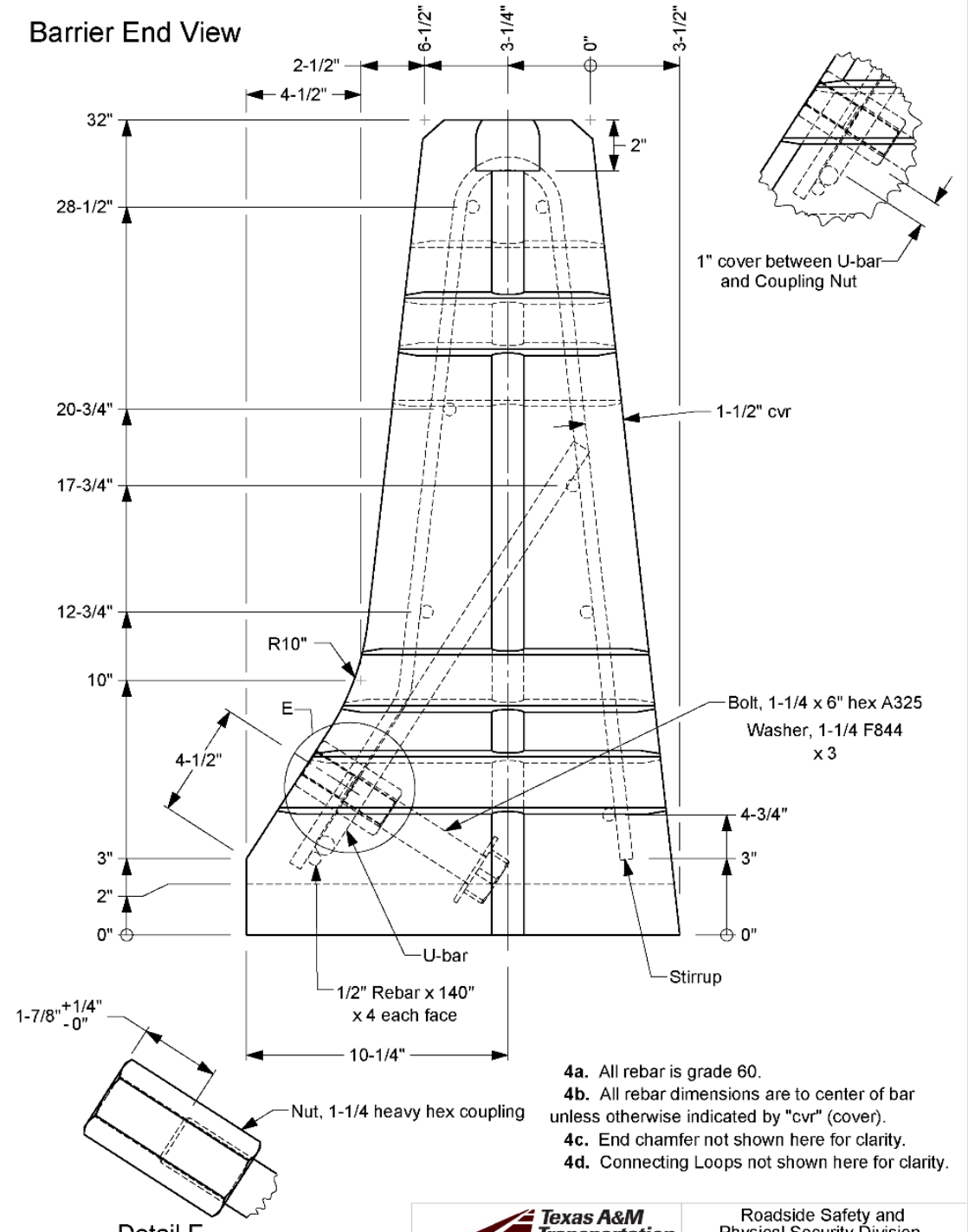
Barrier End View
6-1/2"
3-1/4"
0"
3-1/2"
2-1/2"
4-1/2"
32"
28-1/2"
20-3/4"
17-3/4"
12-3/4"
10"
2"
1" cover between U-bar
and Coupling Nut
1-1/2" cvr
R10"
E
4-1/2"
Bolt, 1-1/4 x 6" hex A325
Washer, 1-1/4 F844
x 3
4-3/4"
3"
2"
0"
3"
0"
U-bar
Stirrup
1/2" Rebar x 140"
x 4 each face
10-1/4"
1-7/8" +1/4" -0"
Nut, 1-1/4 heavy hex coupling
Detail E
Scale 1 : 3
Some components not shown for clarity.
4a. All rebar is grade 60.
4b. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).
4c. End chamfer not shown here for clarity.
4d. Connecting Loops not shown here for clarity.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #614271 Pinned Barriers on Concrete
2022-09-16
Drawn by GES
Scale 1:5
Sheet 4 of 5 / Barrier End View
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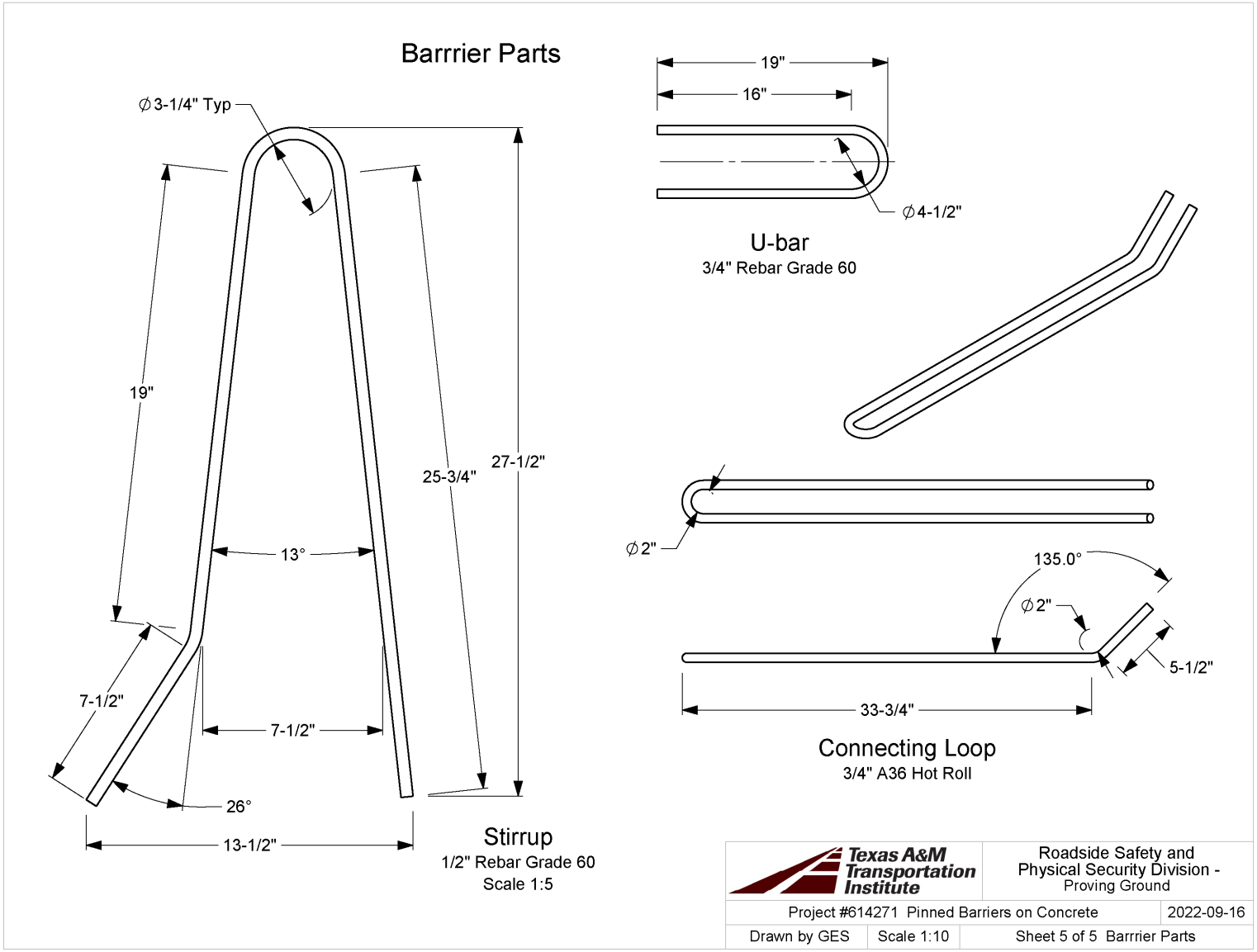
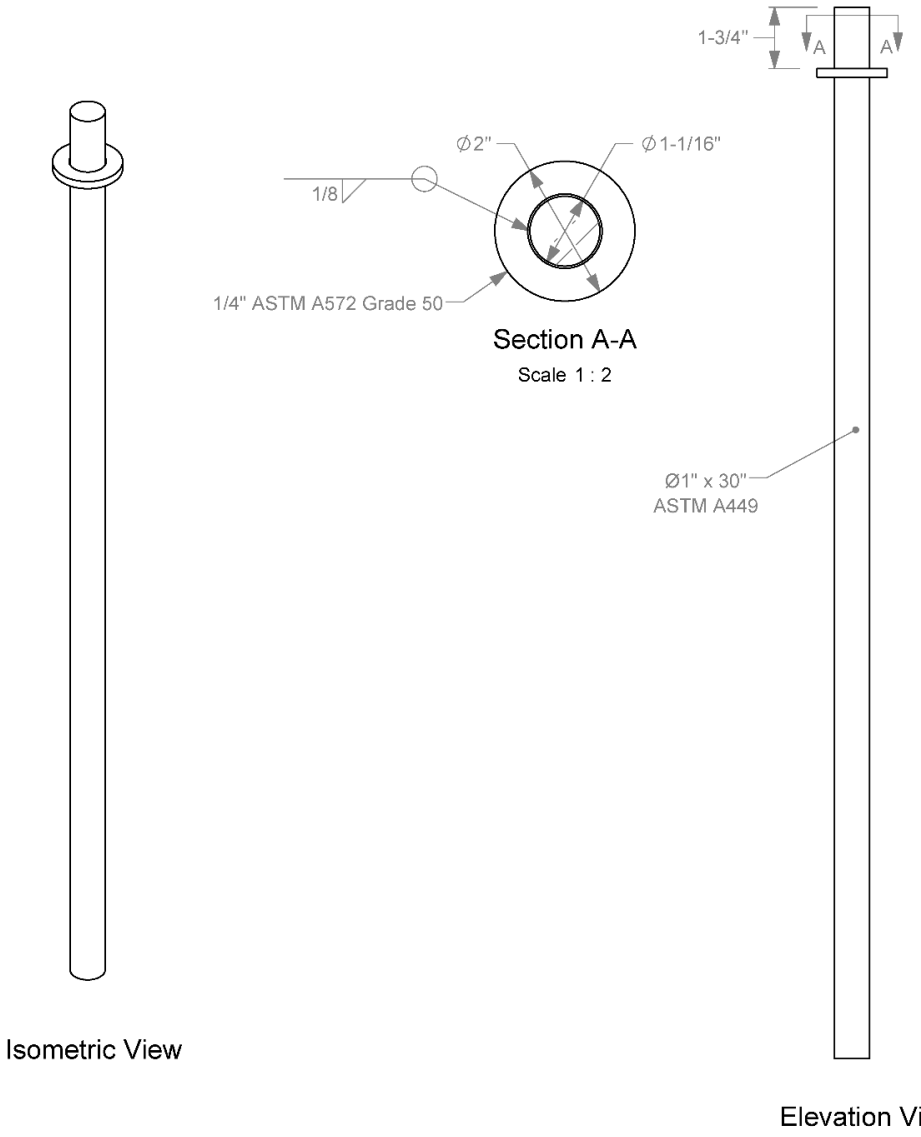

Barrrier Parts
∅3-1/4" Typ
19"
25-3/4"
27-1/2"
13°
7-1/2"
7-1/2"
26°
13-1/2"
Stirrup
1/2" Rebar Grade 60
Scale 1:5
19"
16"
∅4-1/2"
U-bar
3/4" Rebar Grade 60
∅2"
135.0°
∅2"
5-1/2"
33-3/4"
Connecting Loop
3/4" A36 Hot Roll
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #614271 Pinned Barriers on Concrete
2022-09-16
Drawn by GES
Scale 1:10
Sheet 5 of 5 Barrrier Parts
Q:\Accreditation-17025-2017\EIR-000 Project Files\614271-12- Maryland F-shape - Chiara\Drafting, 614271\614271 Drawing

Fabricated Connection Pin



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Fabricated Connection Pin		2021-11-18
Drawn by GES	Scale 1:4	Sheet 1 of 1 / Fabricated Connection Pin

T:\Drafting Department\Solidworks\Standard Parts\Concrete Barriers\Fabricated Connection Pin

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

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

FOR	TEXAS A&M TRANSPORTATION INST
PB INVOICE	154742
CUSTOMER PO	614271
SHIP DATE	8/15/2022

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 STUD
- ASTM F3125 GRADE A325 HEAVY HEX STRUCTURAL BOLT

Nuts

- ASTM A194 GRADE 2H HEAVY HEX NUT

Washers

- ASTM F436 TYPE 1 HARDENED WASHER

Coatings

- ITEMS HOT-DIP GALVANIZED PER ASTM F2329

Certification Department Quality Assurance
Dane McKinnon

ALLOY & STAINLESS FASTENERS

11625 CHARLES ROAD
HOUSTON, TX 77041
ADMIN 713-466-3460
SALES 713-466-3031
SALES 713-466-9591 FAX

* C E R T I F I C A T E *
* O F T E S T *

To: PORTLAND BOLT & MFG. CO.
3441 NORTHWEST GUAM STREET
PORTLAND, OR 97210

Customer P/O # 57287

Our Order # 841711

Line	Qty	UOM	Description	LOT
1	21	EA	1 1/8-8 x 10 O/A ALL THREAD STUD ASTM A193 B7 ASTM SPEC DATE: 20 TEMPERING TEMP: 1346 DEG F/QUENCH & TEMPERED DECARB: 291.4-312.4-315 HV THREAD FORMED AFTER HEAT TREATMENT MERCURY FREE/ NO WELD REPAIR	527311

				CARBON .40	MANGANESE 0.87	
Heat No. B0056265	TENSILE (PSI) 134700	YIELD (PSI) 120610	PHOSPHORUS .017	SULFUR .003	SILICON .24	
ELONGATION 19	RED. OF AREA 57.5	HARDNESS (HB) 279	CHROMIUM 0.89	MOLY. .18		
MACRO ETCH S2/R2/C3	HEAT ID:					

We certify that the material or the fasteners, or both, were manufactured, sampled, tested, and inspected in accordance with the specification listed above and any supplementary requirements or other requirements designated in the purchase/sales order and was found to meet those requirements.

Date: 08/08/22

ALLOY & STAINLESS FASTENERS

By: Stephen Arobadi

Stephen Arobadi
Certification Custodian

1 - L&2US

ALLOY & STAINLESS FASTENERS

11625 CHARLES ROAD
HOUSTON, TX 77041
ADMIN 713-466-3460
SALES 713-466-3031
SALES 713-466-9591 FAX

* C E R T I F I C A T E *
* O F T E S T *

To: PORTLAND BOLT & MFG. CO.
3441 NORTHWEST GUAM STREET
PORTLAND, OR 97210

Customer P/O # 57287

Our Order # 841711

Line	Qty	UOM	Description	LOT
2	20	EA	1 1/8-8 H.D.G. HEAVY HEX NUT ASTM A194 GR.2H	148404

TEMPERING TEMP: 950 DEG F
SAMPLE HARDNESS 1000 DEG F FOR 24 HRS = 91 HRB
PROOF LOAD: 620 KN

				CARBON	MANGANESE
				.45	.67
Heat No. 892065	HEAT CODE	MACRO ETCH S2/R2/C2	PHOSPHORUS .017	SULFUR .014	SILICON .19
NUMBER OF TEST 1	HARDNESS (HB) 286	PROOF LOAD lbf N/A			
ASTM SPEC DATE 16					

We certify that the material or the fasteners, or both, were manufactured, sampled, tested, and inspected in accordance with the specification listed above and any supplementary requirements or other requirements designated in the purchase/sales order and was found to meet those requirements.

Date: 08/08/22

ALLOY & STAINLESS FASTENERS
By: Stephen Arobadi

Stephen Arobadi
Certification Custodian

TECHNICAL STAMPING, INC.

MATERIAL CERTIFICATION

TECHNICAL STAMPING TSI EST. 1991

50600 E. RUSSELL SCHMIDT BLVD
CHESTERFIELD TWP., MI 48051
PH(586)949-3285 ; FX(586)949-5246

CUSTOMER NAME	CUSTOMER ORDER NUMBER	DATE
Portland Bolt & Mfg Co	54763	4/7/2022

PART NUMBER	CUSTOMER LOT NO.	LOT NUMBER	QUANTITY
1-1/8" F436 Hdg		0222-218	2,450

STEEL GRADE	HEAT	C	MN	P	S	SI	AL	REVISION
	121134	.54	.68	.009	.001	.276	.031	F436-19

SPECIFICATION	ACTUAL	GAUGE
O.D - 2.187 - 2.313	2.190 - 2.193	CALIPER
I.D - 1.188 - 1.251	1.213 - 1.216	CALIPER, PIN GAUGE
THICKNESS- .136 - .177	.140 - .143	MICROMETER
FLAT- Max .010	.007	CALIPER
HEAT TREAT - 38 - 45 HRC	40 - 42	
PLATING-	See Attached Cert	
OTHER	N / A	

WE HEARBY CERTIFY THIS PRODUCT WAS PRODUCED UNDER A ISO-9001 2015 QUALITY ASSURANCE SYSTEM. ISO 9001 2015 CERTIFICATION NUMBER:7265 - DATE OF REGIS. JAN. 9, 2013 ALL MATERIALS ARE MADE AND MELTED IN THE U.S.A. THIS PRODUCT WAS MANUFACTURED IN CHESTERFIELD, MICHIGAN, U.S.A. THIS PRODUCT CONFORMS TO ALL REQUIREMENTS FOR WASHERS AS PRODUCED ACCORDING TO A.S.T.M. F-436-19. THE ABOVE TEST RESULTS APPLY ONLY TO THE ITEMS TESTED. THIS TEST REPORT MUST NOT BE REPRODUCED EXCEPT IN FULL WITHOUT PRIOR WRITTEN APPROVAL.

AUTHORIZED SIGNATURE

CERTIFIED ISO 9001

"MADE AND MANUFACTURED IN THE USA"

QTY 3008 Rev. 2 11/26/01

8-3115

1660

INDUSTRIAL STEEL TREATING COMPANY, INC

613 Carroll Street Jackson, MI 49202
P.O. Box 98 Jackson MI, 49204
Voice: 517-787-6312 Fax: 517-787-6441

HEAT TREAT CERTIFICATION

Customer:
TECHNICAL STAMPING, INC.
Attn: SHANNON SCHAFFNER
50600 E. RUSSELL SCHMIDT
CHESTERFIELD, MI 48051

Certification Date:
02/21/2022

Order Details

Part Number: F0118
Packing Slip: 1812
Purchase Order:
IST Order Number: 347850-1
Lot Number: 0222-218
Heat Number: 121135

Blue Print Rev: 1279
Material Type: 1030 - 1050
Quantity: 175,535
Net Weight: 17,729.0
Part Desc: WASHER
Comments: 14 TUBS#73,1023,708
1013,082,1425,210
404,3701,026,300,3800

SPECIFICATIONS

HRC 38 - 45
HEAT TREATED IN THE USA

RESULTS

HRC 40-42
HEAT TREATED IN THE USA

Approved:
Tom Levy
Tom Levy - Quality Assurance Supervisor

Contact
Tom Levy - Quality Assurance Supervisor
Voice: 517-780-9043 Fax: 517-787-6441
E-Mail: tolevy@indstl.com

Load

CERTIFICATE OF CONFORMANCE

SABRE STEEL INC.
23680 RESEARCH DRIVE
FARMINGTON HILLS, MI 48335
248-615-0500

SABRE STEEL INC

2/8/2022 9:23:43 AM

Sold To: TECHNICAL STAMPING
50600 E. RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051

Ship To: TECHNICAL STAMPING
50600 RUSSELL SCHMIDT BLVD.
CHESTERFIELD TWP., MI 48051

Cust PO: S91633

Sales Order: 81718

Ship Date: 2/9/2022

Weight: 31,640#

CHEMICAL ANALYSIS

Heat Number:	121135						
C:	.54	Mn:	.68	P:	.009	S:	.001
Si:	.276	Ti:	.003	Cr:	.092	Mo:	.02
Cu:	.102	Al:	.031	Cb:	.001	Va:	.006
Ni:	.059	B:	.0005	Sn:	.009	N:	.005

PHYSICAL PROPERTIES

YS: TS: E:

Chemistry: C1050

Line: 1 **Item:** .136min x 2.40 HRPO C1050
Grade: HRP&O High Carbon
Part: F0118M

Comment: Tags 069825 D thru K Made & Melted In the US

WE HEREBY CERTIFY THE ABOVE FIGURES ARE ACCURATELY STATED, MEET YOUR MATERIAL REQUIRMENTS AND ARE TRACEABLE IN OUR RECORDS BACK TO THE PRODUCER AND/OR AN ACCREDITED TEST LABORATORY.

Quality Assurance Manager

NUCOR

Nucor Steel Indiana
4537 South Nucor Road
Crawfordsville, IN 47933-0907

METALLURGICAL TESTING CERTIFICATION

1660

K359084

Certificate Number: 963995
Date Issued: 01/21/2022

Page: 1 of 1

Order Number: 355425 - 0004 HOT ROLLED BAND
Order Dimensions: 0.1360 in X 51.5000 in
HOT ROLLED BAND,C1050,MILL

Dimensional tolerances from ASTM A568-19A
SAE J403-14 1050

Customer Name: SABRE STEEL INC
Customer Address: 23680 RESEARCH DR
FARMINGTON HILLS MI 48335

Release Order:
Cust PO Number: 69621

Coil Number
2684731.000

	TAIL
Rockwell B:	88

Part Number
ITEM-4
Weight: 45,910 LBS

CHEMICAL ANALYSIS

Heat	Slab	C	Mn	P	S	Si	Cu	Sn	Ni	Cr	Mo	Al	N	V	Nb	Ti	B	Sb
121135	05	0.54	0.680	0.009	0.001	0.275	0.102	0.009	0.059	0.092	0.020	0.031	0.005	0.006	0.001	0.003	<0.0005	<0.001

WE HEREBY CERTIFY THE ABOVE IS CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION
MELTED AND ROLLED IN THE USA

QF-0261 04/01/2019

1-765-364-1323

NUCOR QUALITY ASSURANCE

Eric E. Gallo

AZZ
ROCKFORD

April 1, 2022

Technical Stamping
50600 E. Russell Schmidt
Chesterfield TWP, MI 48051

To Whom It May Concern:

This is to certify that the hot dip galvanizing of the following washers on your Purchase Order number 1680 conforms to specification ASTM A-153. The following sizes and lot numbers comply with the coating, workmanship, finish, and appearance requirements of ASTM F2329 specifications. The hot dip galvanizing is ROHS compliant. The galvanizing process was conducted in a temperature range of 830F to 850F.

PIECES	PART#	DESCRIPTION	LOT NUMBER	AVERAGE COATING WT IN MILS.
13606	F0118	1 – 1/8" WASHER	0222-218	4.33

This certification in no way implies anything other than the quality of our hot dip galvanizing as it pertains to your order.

This product was galvanized in Rockford, IL USA

Yours very truly,

AZZ Galvanizing Rockford, IL

Maria Pinedo

Maria Pinedo
Office Clerk

NUCOR
FASTENER DIVISION

LOT NO.
236091A

Post Office Box 6100
Saint Joe, Indiana 46785
Telephone 260/337-1600

TEST REPORT SERIAL# FB301821
TEST REPORT ISSUE DATE 1/24/08
MANUFACTURE DATE 1/14/08
NAME OF LAB SAMPLER: PHILLIP A. TITLER, LAB TECHNICIAN

A325T
n

**********CERTIFIED MATERIAL TEST REPORT**********

PART NO.	LOT NO.	DESCRIPTION
164086	236091A	1 1/4-7 X 2 1/2 A325-T HVY HX STRUC SCREW PLAIN

--CHEMISTRY MATERIAL GRADE -1039ML

MATERIAL NUMBER	HEAT NUMBER	**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER C	MN	P	S	SI	CR
RM024080	NU 842689	.38	.76	.010	.014	.23	.46
	MIN	.30	.60			.15	
	MAX	.52		.040	.050	.30	

NUCOR STEEL - NEBRASKA
2911 EAST NUCOR RD
NORFOLK, NE 68701
A2LA NO: 780.01 EXP: 2008-11-30
FOR CHEMICAL TESTING

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A325-06

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD N/A (LBS)	TENSILE STRENGTH DEG-WEDGE STRESS (PSI)
N/A	21.6	N/A	N/A
N/A	23.5	N/A	N/A
N/A	23.6	N/A	N/A
N/A	23.3	N/A	N/A
AVERAGE VALUES FROM TESTS			
	23.0	TOO SHORT TO TEST	

PRODUCTION LOT SIZE 4500 PCS

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A325-06 4 PCS. SAMPLED LOT PASSED

--HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

--DIMENSIONS PER ASME B18.2.6-2003

CHARACTERISTIC	#SAMPLES TESTED	MINIMUM	MAXIMUM
Width Across Corners	4	2.2780	2.2810
Head Height	4	0.7800	0.7940
Threads	4	PASS	PASS

ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION. NO HEATS TO WHICH BISMUTH, SELENIUM, TELLURIUM, OR LEAD WAS INTENTIONALLY ADDED HAVE BEEN USED TO PRODUCE THE BOLTS.
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
PRODUCT COMPLIES WITH DFARS 252.225-7014. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY. THIS CERTIFIED MATERIAL TEST REPORT RELATES ONLY TO THE ITEMS LISTED ON THIS DOCUMENT AND MAY NOT BE REPRODUCED EXCEPT IN FULL. CERTIFICATION FORMAT MEETS EN10204 3.1

A2LA ACCREDITED
MECHANICAL FASTENER
CERTIFICATE NO. A2LA 139-01
EXPIRATION DATE 02/29/08

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION

JAMES G ALAMAS
TECHNICAL SERVICES MANAGER

24080

ATTN: CRYSTAL BL#-0272737 P.O.-102743

Date: 10/01/07

Nucor Corporation

Heat Number: 842689

Nucor Steel Division
Post Office Box 309 Norfolk, Nebraska 68702 Phone (402) 644-0200
Mill Certification

A2LA ACCREDITED
Chemical Testing
Certificate: 0780-01*Chemical Analysis
Expires: 11/30/08

Test conform to ASTM A29-05, ASTM E415 and ASTM E1019-resulphurized grades
Spec: 1039ML Size: 1 17/64 Rounds
1.2656

C	.38	P	.010	Mo	.01	Sn	.015
Mn	.76	Cu	.08	Al	.002	B	.0001
Si	.23	Cr	.46	V	.001		
S	.014	Ni	.04	Nb	.001		

Physical Properties

	Imperial			Metric		
Yield	63,516	------	psi	438	------	MPA
Tensile	102,576		psi	707		MPA
% Elongation	14		% in 8"	14		% in 203.3 mm

Strand Cast

Reduction Ratio: 35:1

Sellenium,Tellurium or Lead were not intentionally added to this heat.

Chemistry Verification Checks

Part # 5020 RM # 24080

	Checked By	Date
Receiving OK:	MB 020	10/3/07
Certifications OK:	375	10-4-07

NUCOR FASTENER - IN
P. O. BOX 6100
ST JOE,IN 46785

Jim Hill Division Metallurgist

All Manufacturing processes, including melting have been performed in the U.S.A. Mercury, in any form, has not been used in the production or testing of this material. Welding or weld repair was not performed on this material. This material conforms to the specifications described on this document and may not be reproduced except in full, without written approval of Nucor Corporation. This product is NAFTA certified under Paragraph "B" of the NAFTA rules of origin.

Form 10F002 *Within Our A2LA Accreditation Scope HT3000R

K-T Galvanizing Company, Inc.
P.O. Box 560 – 5105 East 3rd Street
Katy, Texas 77492
Ph: 281-391-9201 Fax 281-391-5819
www.ktgalvanizing.com

January 1, 2022

Gulf Coast Fasteners
41291 Park 290 Drive
Waller, TX 77484

RE: Certificate of Compliance 2022 Blanket Certification

To Whom It May Concern:

This certification letter is in reference to hardware that we, K-T Galvanizing Company, Inc., hot-dip galvanized for the company listed above.

We certify that all products coated at our facilities were done in accordance with ASTM A153 Active Standard (Latest Edition) – Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware and ASTM F2329 Active Standard (Latest Edition) – Standard Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners.

In addition, we certify that all coatings supplied were applied in the United States of America in compliance with the Buy America requirements of the Surface Transportation Assistance Act of 1982 (23 CFR 635.410) and all subsequent revisions and invocations.

Sincerely,

Jennifer Logan
Vice President

JL/tw

TIANJIN PINGYUAN HARDWARE CO., LTD.

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

CERTIFICATE OF INSPECTION

PURCHASER :	BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC.		
ADDRESS :	NO. 122 YILIN ROAD, RENDE DIST., TAINAN CITY 71752, TAIWAN		
DESCRIPTION :	ASTM F436M -18 TYPE 1 WASHERS（ ASTM F2329-15 HDG)		
INSP. DATE :	12/20/2021	ISSUED DATE:	12/20/2021
PO # :	U92054	LOT NO . :	S54221113723A
INVOICE NO :	FPB21101137-19	CERT. NO . :	201405270000114
MATERIAL TYPE :	45C/4.0mm	MANU. DATE :	10/20/2021
SAMPLE SIZ E :	720 PCS	SIZE :	ASTM F436M -18 1-1/4"
HEAT NO :	14406608	LOT SIZE :	3600 PCS
MANUFACTURER: TIANJIN PINGYUAN HARDWARE CO., LTD.		PART NO .:	357132

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

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACCE.	REJE.
VISUAL APPEARANCE	ASTM F2329-15	PASSED	29	0
INSIDE:	34.93 - 35.72	35.54-35.62	8	0
OUTSIDE:	62.71 - 64.29	63.40-63.52	8	0
THICKNESS:	3.45-4.50	3.51-3.64	8	0
HEAD MARKING	F436 PY	F436 PY	8	0

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

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACCE.	REJE.
HARDNESS	ASTM F436M -18	38-45 HRC	39-42	4	0
FINISH	ASTM F2329-15 HDG	55um	56um	4	0

CHEMICAL COMPOSITION % TEST FACILITY:S

C	Si	Mn	P	S	Cu	Ni	Cr	B	V
0.45	**0.25**	**0.54**	**0.021**	**0.017**	**0.03**	**0.03**	**0.08**	**0.0000**	**0.00**

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

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

REMARKS Xianjing Country of Origin： CHINA

DIMENSION=mm, TENSILE=Mpa

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

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

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

TEMPERING TEMPERATURE CONFORM TO THE REQUIREMENT OFASTM F436-11

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

华凌

凌源钢铁股份有限公司
产品质量证明书
LINGYUAN IRON&STEEL CO., LTD.
CERTIFICATE OF QUALITY AND QUANTITY

收货用户 凌源钢源工贸有限公司
到站地址

LG-JL-KJ-33

订货用户 CUSTOMER	凌源钢源工贸有限公司	标准 STANDARD	GB/T711-2008	交货状态 CONDITION OF DELIVERY	热轧	证明书号 CERTIFICATE NO.	20141208000042
产品名称 PRODUCT	中宽热带	牌号 STEEL GRADE	45	发货日期 DATE OF DELIVERY	20141208	合同号 CONTRACT NO.	XN-D4C08E0057201

炉号 HEAT NO.	材料号 COIL NO	规格 DIMENSIONS mm * mm	数量 QUANTITY 件(卷) PIECES	重量 WEIGHT 吨(T)	化学成分(%) CHEMICAL COMPOSITION C ×10⁻²	Si ×10⁻²	Mn ×10⁻²	P ×10⁻³	S ×10⁻³	Cr ×10⁻²	Ni ×10⁻²	Cu ×10⁻²	×10	×10	×10	×10	力学工艺性能 MECHANICAL PROPERTIES ReH MPa	Rm MPa	A %	A11.3	Akv J	冷弯 BEND TEST	脱碳层 (mm)	晶粒度 (级)	车号 VEHICLE NO.
1441207209	H14C0185036	3.4 * 690	1	6.505	43	22	53	13	13	4	2	2						645	20.0						蒙D70690
1441207210	H14C0185037	3.25 * 710	1	7.83	43	22	53	13	13	4	2	2						640	20.5						蒙D70690
1441207212	H14C0185039	3.25 * 710	1	7.905	43	22	53	13	13	4	2	2						640	20.5						蒙D70690
1441207304	H14C0185045	3.25 * 710	1	7.915	43	23	53	16	17	5	2	2						649	19.0						蒙D70590
1441207305	H14C0185046	3.25 * 710	1	7.915	43	23	53	16	17	5	2	2						649	19.0						蒙D70590
1441207307	H14C0185048	3.25 * 710	1	7.92	43	23	53	16	17	5	2	2						649	19.0						蒙D70590
1441207403	H14C0185056	5 * 710	1	7.905	44	24	57	19	14	5	2	2						680	25.5						蒙D70590
1441207615	H14C0186034	4.9 * 710	1	7.93	45	24	57	10	14	5	2	2						676	18.0						蒙D70590
																	以下空白								
合计 TOTAL			8	61.825	备注 REMARK	1.本证明书加盖产品质量专用章后方可生效; 2.销售部门(现代理商)出具本证明书复印件时必须由实际销售单位名称、日期、品名、规格、材质、重量、并加盖其公章原件后方可生效。用途:结构件																			公证章 QUALITY PROVE SEAL

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

电话: 0421-5838168
TEL: 0421-5838168

开证员 OPERATOR 赵兰

日期 DATE 20141208

第1页共1页

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 # 154742

DATE 8/1/2022
PAGE 1 of 1

SALESPERSON Jessica Kalebaugh
DIRECT PHONE 800.599.2943
EMAIL jessica@ portlandbolt.com

SOLD TO

TEXAS A&M TRANSPORTATION INST
TTI FINANCIAL SERVICES
3135 TAMU
COLLEGE STATION, TX, 77843-3135
Phone: 979.317.2755 | Fax: 979.227.7710

SHIP TO

Texas A&M Transportation Insti
3100 HWY 47 South
BLDG. 7091
Bryan, TX, 77807

ATTN	**Adam Mayer** <a-mayer@tti.tamu.edu>	CUSTOMER PO	614271
SHIP DATE	**8/15/2022**	SHIP VIA	UPS Ground

LINE	QTY. ORDERED	DESCRIPTION
1	20	1-1/8"-8 x 10" galv. A193-B7 stud
2	20	1-1/8"-8 imp. galv. A194-2H heavy hex nut
3	20	1-1/8" dom. galv. F436-1 hard washer
4	20	1-1/4" x 2-1/2" galv. F3125-A325 heavy hex structural bolt
5	20	1-1/4" imp. galv. F436-1 hard washer

***

AM/NS Calvert LLC
1 AM/NS Way
Calvert, Al. , AL 36513 USA

AM/NS CALVERT

39/9573

Mill Certificate

CUSTOMER ORIGINAL

Order - Item	Certificate Number	Delivery No	Ship Date	Page
233429-20	1194811950	83147684-10	02/19/2022	1 of 1

Customer No: 10213 | Cust PO: HTX-7707911

Customer Part No:

Customer Sold to:	Customer Ship to:	Contact - Stan Bevans
Kloeckner Metals Corp.- Tulsa Kloeckner Metals Corp 3123 E. Apache TULSA OK 74110 USA	Kloeckner Metals Corp. 7400 Mesa Dr. HOUSTON TX 77028 USA	AM/NS Calvert LLC 1 AM/NS Way CALVERT AL 36513 USA Email: Stanley.Bevans@ArcelorMittal.com Ph : 1-251-289-3000

Steel Grade / Customer Specification
Hot Roll Black Coil Conv to A36 / 0.4900 " X 48.0000 " ACCORDING TO A1018 {Hvy 0.230"(6)-1"(25.4)}-Hot Roll Base

Type of Product/Surface
Hot Roll Black Dry Unexposed GENERAL STOCK, CTL SHEET

07/01/2022

TEST METHOD — Melted in Brazil — Manufactured in USA
ASTM

MATERIAL DESCRIPTION

	ORDERED	Heat No	Coil No.	Weight Net LB	Weight Gross LB
(mm)	12.446	3916421	1194811950	45,437.000	45,437.000
(in)	0.4900				

CHEMICAL COMPOSITION OF THE LADLE *

Heat No.	C	Si	Mn	P	S	Al	Cr	Cu	Mo	N
3916421	0.2080	0.01	0.83	0.019	0.006	0.038	0.02	0.006	0.002	0.0050

Ni	Nb	Ti	B	V	Ca
0.007	0.000	0.000	0.0000	0.000	0.0003

TENSILE TEST

Test Direction	Yield Strength	Tensile Strength	% Total Elong.
T	50 ksi	71 ksi	34

AM/NS Calvert LLC certify that the material herein described has been manufactured, sampled, tested and inspected in accordance with the contract requirements and is fully in compliance.

* - This test is not covered by our current A2LA accreditation

Yasunori Iwasa
Quality Management Director
AM/NS Calvert

Rev.

Kloeckner

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

CERTIFIED MILL TEST REPORT
For additional copies call
830-372-8771

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

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3115121 SECTION: REBAR 13MM (#4) 40'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 05/08/2022 MELT DATE: 05/08/2022 Cert. No.: 85025025 / 115121A371	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 85025025 BOL#: 74755196 CUST PO#: 915579 CUST P/N: DLVRY LBS / HEAT: 46389.000 LB DLVRY PCS / HEAT: 1736 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.47%	Bend Test Diameter	1.750IN		
Mn	0.85%				
P	0.011%				
S	0.046%				
Si	0.21%				
Cu	0.33%				
Cr	0.07%				
Ni	0.17%				
Mo	0.065%				
V	0.000%				
Cb	0.001%				
Sn	0.014%				
Al	0.001%				
Yield Strength test 1	65.5ksi				
Tensile Strength test 1	104.7ksi				
Elongation test 1	15%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.60				
Bend Test 1	Passed				

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

REMARKS :

Page 1 OF 1 05/09/2022 18:26:17

CMC STEEL OKLAHOMA
2353 E Main St
Durant OK 74701-4806

CERTIFIED MILL TEST REPORT
For additional copies call
830-372-8771

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

Robert Booth
Quality Assurance Manager

HEAT NO.:6033015 SECTION: SPOOL REBAR 13MM (#4) 420/60 3.5T GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 06/06/2022 MELT DATE: 06/06/2022 Cert. No.: 85074736 / 033015J037	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 85074736 BOL#: 74835612 CUST PO#: 921198 CUST P/N: DLVRY LBS / HEAT: 6831.000 LB DLVRY PCS / HEAT: 1 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.27%	Elongation test 1	11%		
Mn	1.24%	Elongation Gage Lgth test 1	8IN		
P	0.011%	Tensile to Yield ratio test1	1.37		
S	0.038%	Bend Test 1	Passed		
Si	0.22%	Rebar Deformation Avg. Spaci	0.317IN		
Cu	0.44%	Rebar Deformation Avg. Heigh	0.027IN		
Cr	0.16%	Rebar Deformation Max. Gap	0.138IN		
Ni	0.22%	Bend Test Diameter	1.750IN		
Mo	0.038%	Strain at Peak Stress test 1	8.3%		
V	0.005%				
Sn	0.012%				
Al	0.000%				
NB	0.000%				
N	0.0079%				
Carbon Eq A6	0.56%				
Yield Strength test 1	74.5ksi				
Yield Strength test 1 (metri	514MPa				
Tensile Strength test 1	102.0ksi				
Tensile Strength 1 (metric)	704MPa				

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

REMARKS : ALSO MEETS AASHTO M31

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

CERTIFIED MILL TEST REPORT
For additional copies call
830-372-8771

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

Rolando A Davila
Quality Assurance Manager

HEAT NO.:3116400 SECTION: REBAR 19MM (#6) 40'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 06/25/2022 MELT DATE: 06/25/2022 Cert. No.: 85085062 / 116400A307	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 85085062 BOL#: 74853370 CUST PO#: 922148 CUST P/N: DLVRY LBS / HEAT: 47586.000 LB DLVRY PCS / HEAT: 792 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.45%	Bend Test Diameter	3.750IN		
Mn	0.85%				
P	0.010%				
S	0.044%				
Si	0.15%				
Cu	0.34%				
Cr	0.09%				
Ni	0.15%				
Mo	0.062%				
V	0.000%				
Cb	0.001%				
Sn	0.011%				
Al	0.001%				
Yield Strength test 1	66.7ksi				
Tensile Strength test 1	106.0ksi				
Elongation test 1	14%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.59				
Bend Test 1	Passed				

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

REMARKS :

A572 PLATE FOR WASHERS

METALLURGICAL TEST REPORT

1455 Hagan Avenue
Huger, SC 29450

Nucor Steel Berkeley
a division of NUCOR corporation

Phone: 843-336-6000
Sales Fax: 843-336-6150
MTR_BER_INQUIRIES@NUCOR.COM

Issuance Date 10/23/19 MTR# 1610508

Sold To: KLOECKNER METALS CORPORATION
500 COLONIAL CTR PKWY
STE 500
ROSWELL, GA 30076

Ship To: COASTAL CARGO
16800 PENINSULA BLVD
CPT CARE TERMINALS
HOUSTON, TX 77067

Ship Date 9/28/19
Bill of Lading # 1437031
Vehicle # BULKMASTER
Rls # BLUE
P/O # 7421846
Mill Order # 470453-2
Part # .24X60 A572GR50

Gauge x Width .2400 MIN X 60.0000 MIN HR HOT ROLL COIL
ASTM A1018 / HSLAS GR50 CL1 / REV: 2018

SUITABLE FOR CONVERSION TO ASTM A572 GRADE 50

Heat	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	V	Nb	N	Ti	B	Ca
2912871	.05	1.14	.010	.003	.19	.08	.03	.03	.01	.007	.032	.007	.034	.007	.013	.000	.002
2912873	.05	1.14	.008	.003	.18	.08	.03	.03	.01	.006	.032	.006	.034	.007	.011	.000	.002

	YIELD STRENGTH (ksi)		TENSILE STRENGTH (ksi)		ELONGATION (% IN 2")		HARDNESS	N Value	
Heat/Coil#	long.	trans.	long.	trans.	long.	trans.	(Rockwell B)	long.	trans.
2912871-2		59.3		72.4		34	83		.13
2912871-4		63.8		72.5		28	84		.13
2912873-2		62.6		72.6		27	82		.13

Coil (tag) 2912871-4
(48600.00 LB)
Coil (tag) 2912873-2
(49160.00 LB)

Mill Test Reports according to EN10204 3.1

All material is sold subject to the description, specifications and terms and conditions set forth on the face and reverse side of Nucor Steel - Berkeley's sales order acknowledgment.

Tensile Testing, when applicable, is performed in accordance with ASTM A-370 specifications. Specimen is machined to standard rectangular test configuration (Figure 3 of ASTM A-370) with a 2" gage length. Yield Strength is determined at 0.2% offset.

This material has been produced in compliance with the chemistry and established rolling practices of the ordered specification. If material is ordered to a chemical composition only and if

07-20-2022 05:47 Load - 4119590 BL - 3920237 blr466

Custom Fabricators Heat - 8000017503

Cust. PO - 02713 Order - 21595136

3920237

NUCOR

Mill Certification

05/20/2022

MTR#:1036604-5
Lot #:800001750321
300 STEEL MILL RD
DARLINGTON, SC 29540 US
843 393-5841
Fax: 843 395-8701

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

Ship To: KLOECKNER METALS
4606 SINGLETON BLVD
DALLAS, TX 75212 US

Customer PO	7740260	Sales Order #	11045778 - 1.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	3010243
Grade	Nucor Multigrade	Lot #	800001750321
Size	1.5"	Heat #	8000017503
BOL #	BOL-1134937	Load #	1036604
Description	Hot Roll - Merchant Bar Quality Round 1.5" (1 1/2") Nucor Multigrade 20' 0" [240"] 4001-6000 lbs	Customer Part #	MB11/2RNDMA360240
Production Date	04/28/2022	Qty Shipped LBS	14430
Product Country Of Origin	United States	Qty Shipped EA	120
Original Item Description	Hot Roll - Merchant Bar Quality Round 1.5" (1 1/2") Nucor Multigrade 20' 0" [240"]	Original Item Number	1026563

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

Melt Country of Origin : United States

Melting Date: 04/26/2022

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	Nb (%)
0.16	0.66	0.013	0.019	0.205	0.07	0.14	0.02	0.24	0.001	0.048	0.002

Sn (%)
0.008

ASTM A529 S78.2 CE (%) : 0.37

ASTM A992 5.4 CE (%) : 0.33

Reduction Ratio 27.67 : 1

Tensile testing

	Yield (PSI)	Tensile (PSI)	Elongation in 8" (%)
(1)	56600	76800	20.0
(2)	57300	75800	21.0

Comments:
Nucor Multigrade meets the requirements of: ASTM A36/A36M, A529/A529M GR50, A572/A572M GR50(345), A709/A709M GR36(250) & GR50(345), CSA G40.21 GR44W(300W) & GR50W(350W), AASHTO M270/M270M-10 GR36(270) & GR50(345), ASME SA36/SA36M, QQ-S-741D, CAT 1E1883. Produced to a fully killed, fine grain practice.

Welding or weld repair was not performed on this material.

Melted and Manufactured in the U.S.A and complies with the Buy American Act.

Mercury, radium, or alpha source materials not intentionally added at any point during manufacturing or testing of this material.

Material is certified to the most recent revision of the specification(s) and grade indicated at the time of production.

Mark Schmidt, Chief Metallurgist

Page 1 of 1

07/20/2022

Kloeckner - 1 1/2" Round BAR

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: 614271 **Casting Date:** 10/3/2022 **Mix Design (psi):** 4500

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)
T1	108	123435	South 1/4 of deck
T2	106	123440	Southern Mid 1/4 of Deck
T3	107	117831	Northern Mid 1/4 of deck
T4	Nestor De Jes9	123449	North 1/4 of Deck

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

TEXCRETE
Redi-mix Concrete Company

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

TEXCRETE

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

123435

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

MBC MANAGEMENT
RELLIS CAMPUS, BRYAN TX

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

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
7:02	FN945200050	10.00	40.00	PO#	DWAN	108	68960
DATE	**PROJECT**	**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
10/3/22	TTI-MAS	10.00	10.00			5.00 in	67142

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
10.00 yd	FN945200500	COM,4500,BLND,5"		
1.00 ea	ENVIRONM	Environmental Sundry Ch		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
7:15	7:35				

FINISH UNLOADING	LEFT JOB	ARRIVED AT PLANT	ON SITE TESTING
			TESTING LAB: TERRACON GESSNER CME OTHER

TESTED		AIR	CYLINDERS
☐ YES	☐ NO		

Tax
Prev. AMT
Ticket Total

ADDITIONAL CHARGE 1 _____

ADDITIONAL CHARGE 2 _____

GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

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

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

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

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

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in everyway that we can, but in order to do this the driver is requesting that you sign this 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 for 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 _____

#1
South End
1/1

123435

TEXCRETE
Ready-mix Concrete Company

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

TEXCRETE

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

123440

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

MBC MANAGEMENT
RELLIS CAMPUS, BRYAN TX

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

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
7:34	FN945200500	10.00	40.00	PO#	JOSHEPH	106	68965
DATE	**PROD.TEST**	**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
10/3/22	TTI-MAS	10.00	20.00			5.00 in	67147

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
10.00 yd	FN945200500	COM, 4500, BLND, 5"		
1.00 ea	ENVIRONM	Environmental Sundry Ch		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
7:44	8:03				
FINISH UNLOADING	**LEFT JOB**	**ARRIVED AT PLANT**	**ON SITE TESTING**		
			TESTING LAB: TERRACON GESSNER CME OTHER		
TESTED			**AIR**	**CYLINDERS**	
☐ YES ☐ NO					

Tax
Prev. AMT
Ticket Total

ADDITIONAL CHARGE 1 _____

ADDITIONAL CHARGE 2 _____

GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

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

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

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

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

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in everyway that we can, but in order to do this the driver is requesting that you sign this 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_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 _____

#2
Southern Middle 1/1

123440

TEXCRETE
Redi-mix Concrete Company

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

TEXCRETE

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

117831

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

MBC MANAGEMENT
RELLIS CAMPUS, BRYAN TX

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

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
8:05	FN9452000500	10.00	40.00			107	29
DATE		**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
10/3/22	TRI-MAS	10.00	30.00	PLT 02		5.00 in	71571

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
10.00	yd	FN9452000500 COM. 4500, BLND, 5"		
1.00	ea	ENVIRONM Environmental Sundry Ch		
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
819	904				
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 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_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 _____

#3
Middle Nark Section
1/4

117831

TEXCRETE
Redi-mix Concrete Company

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

TEXCRETE

123449

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 CAMPUS, BRYAN TX

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

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
8:47	FN945200050	10.00	40.00	PO#	NESTOR	DE JES9	68974

DATE	PROJECT	LOAD#	YARDS DEL.	BATCH#	WATER TRIM	SLUMP	TICKET NUMBER
10/3/22	TTI-MAS	10.00	40.00			5.00 in	67156

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
10.00 yd	FN945200500	COM, 4500, BLND, 5"		
1.00 ea	ENVIRONM	Environmental Sundry Ch		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
8:50	9:15	9:24			

FINISH UNLOADING	LEFT JOB	ARRIVED AT PLANT	ON SITE TESTING
			TESTING LAB: TERRACON GESSNER CME OTHER

TESTED	AIR	CYLINDERS
☐ YES ☐ NO		

Tax
Prev. AMT
Ticket Total

ADDITIONAL CHARGE 1 _____

ADDITIONAL CHARGE 2 _____

GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

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

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

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

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

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in everyway that we can, but in order to do this the driver is requesting that you sign this RELEASEreleving 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_____
WEIGHTMASTER

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 _____

#4
North 1/4

123449

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0249
Service Date: 10/03/22
Report Date: 11/01/22 Revision 1 - 29-day test results
Task: PO# 614271

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: 4,500 psi @ 28 days

Mix ID: FN945200500
Supplier: Texcrete
Batch Time: 0702 **Plant:** 68960
Truck No.: 108 **Ticket No.:** 123435

Sample Information
Sample Date: 10/03/22 **Sample Time:** 0745
Sampled By: Steven Savala
Weather Conditions: Clear
Accumulative Yards: 10 **Batch Size (cy):** 10
Placement Method: Chute
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Runway
Placement Location: Runway

Field Test Data

Test	Result	Specification
Slump (in):	6	
Air Content (%):	1.8	
Concrete Temp. (F):	88	
Ambient Temp. (F):	54	
Plastic Unit Wt. (pcf):		
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	A	Good	6.00	28.27		10/25/22	22 F	114,000	4,030	4	SCG
1	B	Good	6.00	28.27		10/25/22	22 F	94,460	3,340	4	SCG
1	C	Good	6.00	28.27		10/25/22	22 F	115,990	4,100	4	SCG
1	D	Good	6.00	28.27		11/01/22	29 F	133,430	4,720	3	AWD

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

Comments: **Not tested for plastic unit weight. 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.: Steven Savala **Start/Stop:** 0630-1000
Reported To: Bill
Contractor: MBC Management
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith

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

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0249
Service Date: 10/03/22
Report Date: 11/01/22 Revision 1 - 29-day test results
Task: PO# 614271

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: 4,500 psi @ 28 days

Mix ID: FN945200500
Supplier: Texcrete
Batch Time: 0734 **Plant:** 68960
Truck No.: 106 **Ticket No.:** 123440

Sample Information

Sample Date: 10/03/22 **Sample Time:** 0810
Sampled By: Steven Savala
Weather Conditions: Clear
Accumulative Yards: 20 **Batch Size (cy):** 10
Placement Method: Chute
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Runway
Placement Location: Runway

Field Test Data

Test	Result	Specification
Slump (in):	7	
Air Content (%):	2.0	
Concrete Temp. (F):	89	
Ambient Temp. (F):	54	
Plastic Unit Wt. (pcf):		
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
2	A	Good	6.00	28.27		10/25/22	22 F	107,220	3,790	4	SCG
2	B	Good	6.00	28.27		10/25/22	22 F	108,580	3,840	5	SCG
2	C	Good	6.00	28.27		10/25/22	22 F	92,420	3,270	5	SCG
2	D	Good	6.00	28.27		11/01/22	29 F	130,640	4,620	5	AWD

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

Comments: **Not tested for plastic unit weight. 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.: Steven Savala **Start/Stop:** 0630-1000
Reported To: Bill
Contractor: MBC Management
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith

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

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0249
Service Date: 10/03/22
Report Date: 11/01/22 Revision 1 - 29-day test results
Task: PO# 614271

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: 4,500 psi @ 28 days

Mix ID: FN945200500
Supplier: Texcrete
Batch Time: 0805 **Plant:** 68960
Truck No.: 107 **Ticket No.:** 117831

Sample Information

Sample Date: 10/03/22 **Sample Time:** 0820
Sampled By: Steven Savala
Weather Conditions: Clear
Accumulative Yards: 30 **Batch Size (cy):** 10
Placement Method: Chute
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Runway
Placement Location: Runway

Field Test Data

Test	Result	Specification
Slump (in):	5 1/2	
Air Content (%):	1.6	
Concrete Temp. (F):	89	
Ambient Temp. (F):	70	
Plastic Unit Wt. (pcf):		
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
3	A	Good	6.00	28.27		10/25/22	22 F	100,260	3,550	2	SCG
3	B	Good	6.00	28.27		10/25/22	22 F	100,980	3,570	5	SCG
3	C	Good	6.00	28.27		10/25/22	22 F	96,760	3,420	5	SCG
3	D	Good	6.00	28.27		11/01/22	29 F	125,360	4,430	5	AWD

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

Comments: **Not tested for plastic unit weight. 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.: Steven Savala **Start/Stop:** 0630-1000
Reported To: Bill
Contractor: MBC Management
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith

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

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0249
Service Date: 10/03/22
Report Date: 11/01/22 Revision 1 - 29-day test results
Task: PO# 614271

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: 4,500 psi @ 28 days

Mix ID: FN945200500
Supplier: Texcrete
Batch Time: 0847 **Plant:** 68960
Truck No.: Nestor de **Ticket No.:** 123449

Sample Information

Sample Date: 10/03/22 **Sample Time:** 0905
Sampled By: Steven Savala
Weather Conditions: Clear
Accumulative Yards: 40 **Batch Size (cy):** 10
Placement Method: Pump
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Runway
Placement Location: Runway

Field Test Data

Test	Result	Specification
Slump (in):	8 1/4	
Air Content (%):	2.1	
Concrete Temp. (F):	89	
Ambient Temp. (F):	70	
Plastic Unit Wt. (pcf):		
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
4	A	Good	6.00	28.27		10/25/22	22 F	93,350	3,300	5	SCG
4	B	Good	6.00	28.27		10/25/22	22 F	92,310	3,260	2	SCG
4	C	Good	6.00	28.27		10/25/22	22 F	108,430	3,830	2	SCG
4	D	Good	6.00	28.27		11/01/22	29 F	117,090	4,140	3	AWD

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

Comments: **Not tested for plastic unit weight. 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.: Steven Savala
Reported To: Bill
Contractor: MBC Management
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith

Start/Stop: 0630-1000

Reviewed By: Alexander Dunigan
Project Manager

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

Concrete Core Test Report

Report Number: A1171057.0258
Service Date: 12/07/22
Report Date: 12/14/22
Task: PO# 614271

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

Sample Information

Placement Date:
Date Tested: 12/06/22 **Time:** 0000
Sampled By:
Drill Directions: Vertical
Date Core Obtained: 12/06/22 **Time:** 0000
Date Ends Trimmed: 12/06/22 **Time:** 0000
Moisture Conditioning History: According to ASTM C-42

Laboratory Test Data

Core ID	Location	Cored Length (in)	Trim Length (in)	Capped Length (in)	Avg. Dia. (in)	Area (sq in)	Length / Diam. Ratio	Max Load (lbs)	Corr. Factor	Comp. Strength (psi)	Fracture Type	Density (pcf)
3	Truck Barrier	12.75	7.44	7.64	3.90	11.95	1.96	54230	1.000	4540	4	
4	Truck Barrier	12.00	7.35	7.81	3.90	11.95	2.00	58710	1.000	4910	2	
5	Car Barrier	11.00	6.41	6.71	3.90	11.95	1.72	56920	0.978	4660	4	
6	Car Barrier	14.25	5.83	6.80	3.90	11.95	1.74	63140	0.979	5170	4	

Comments:

Services:
Terracon Rep.: Mateek, James
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith

Start/Stop: 0630-1245

Reviewed By: Alexander Dunigan
Project Manager

Test Methods:

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

APPENDIX C. *MASH* TEST 3-10 (CRASH TEST NO. 614271-12-2)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2022-11-01 Test No.: 614271-12-2 VIN No.: 3N1CN7AP6JL809772

Year: 2018 Make: Nissan Model: Versa

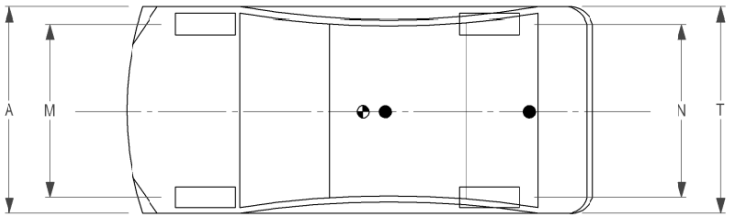
Tire Inflation Pressure: 36 PSI Odometer: 85889 Tire Size: P185/65R15

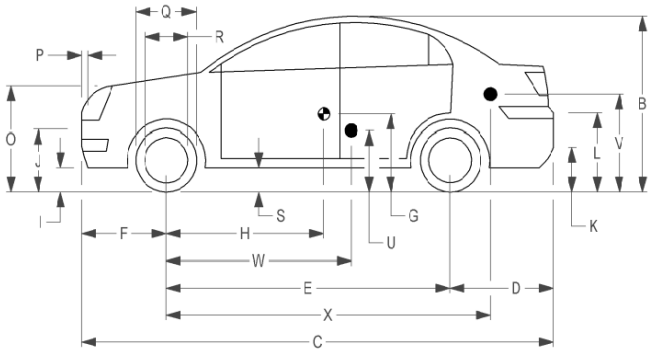
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None

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





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

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G		L	26.00	Q	24.00	V	21.25
C	175.40	H	41.67	M	58.30	R	16.25	W	41.60
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -0.07

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1430	1435	1520
Back	1687	M_{rear}	955	985	1065
Total	3389	M_{Total}	2385	2420	2585

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

Mass Distribution:
lb LF: 670 RF: 765 LR: 470 RR: 515

Figure C.1. Vehicle Properties for Test No. 614271-12-2.

Date: 2022-11-01 Test No.: 614271-12-2 VIN No.: 3N1CN7AP6JL809772

Year: 2018 Make: Nissan Model: Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L***	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max**** Crush								
1	AT FT BUMPER	14	12	38							14
2	SAME	14	8	44							60
	Measurements recorded										
	☑ **inches or** ☐ **mm**										

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

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

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

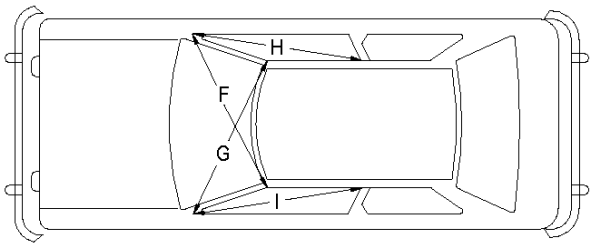
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

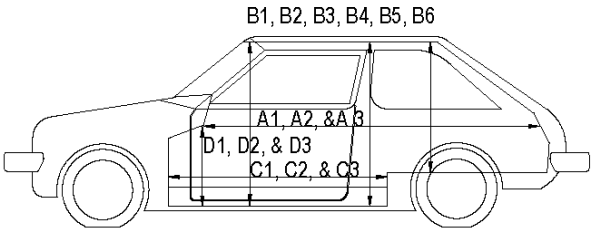
***Measure and document on the vehicle diagram the location of the maximum crush.

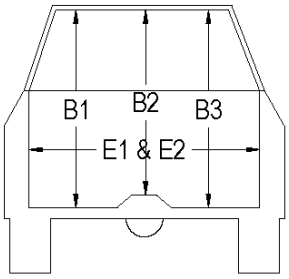
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure C.2. Exterior Crush Measurements for Test No. 614271-12-2.

Date:	2022-11-01	Test No.:	614271-12-2	VIN No.:	3N1CN7AP6JL809772
Year:	2018	Make:	Nissan	Model:	Versa







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	66.50	-1.25
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	38.50	-2.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	24.00	-2.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	46.00	-5.50
E2	51.00	51.00	0.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	36.50	-1.00
J*	49.00	44.00	-5.00

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

Figure C.3. Occupant Compartment Measurements for Test No. 614271-12-2.

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.4. Sequential Photographs for Test No. 614271-12-2 (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.5. Sequential Photographs for Test No. 614271-12-2 (Frontal Views).

(a) 0.000 s (b) 0.100 s

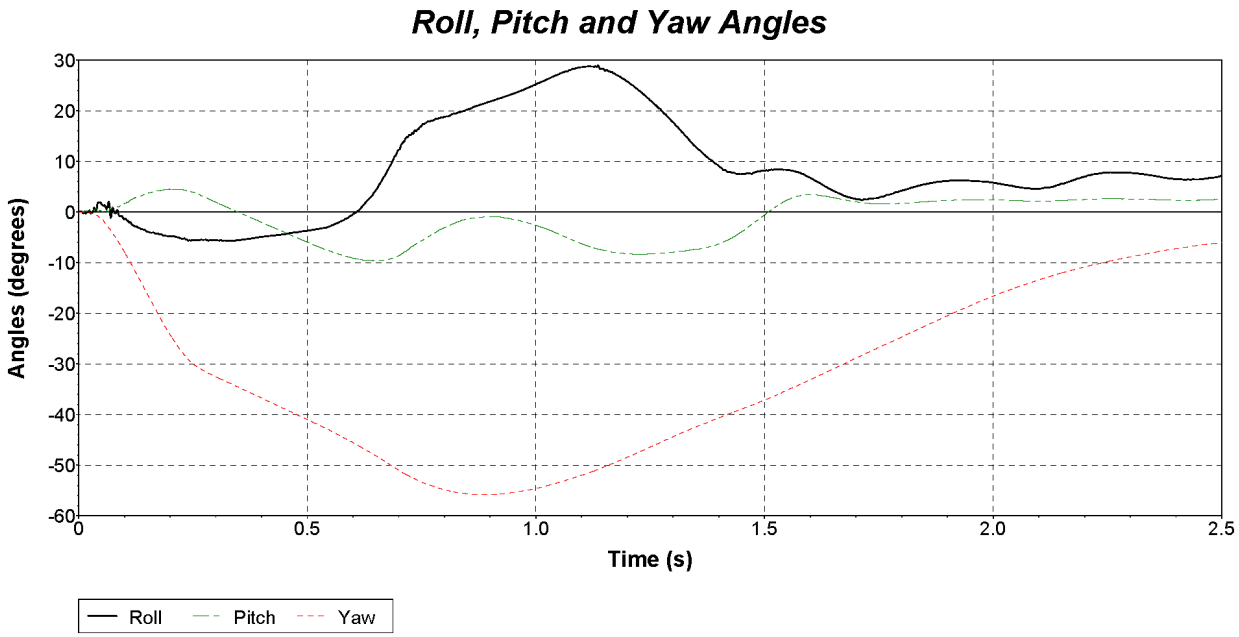
(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

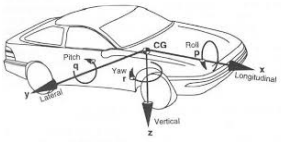
Figure C.6. Sequential Photographs for Test No. 614271-12-2 (Rear Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

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



Test Number: 614271-12-2
Test Standard Test Number: *MASH* Test 3-10
Test Article: Maryland F-Shape Portable Concrete Barrier
Test Vehicle: 2018 Nissan Versa
Inertial Mass: 2420 lb
Gross Mass: 2585 lb
Impact Speed: 63.2 mi/h
Impact Angle: 25.1°

Figure C.7. Vehicle Angular Displacements for Test No. 614271-12-2.

C.4. VEHICLE ACCELERATIONS

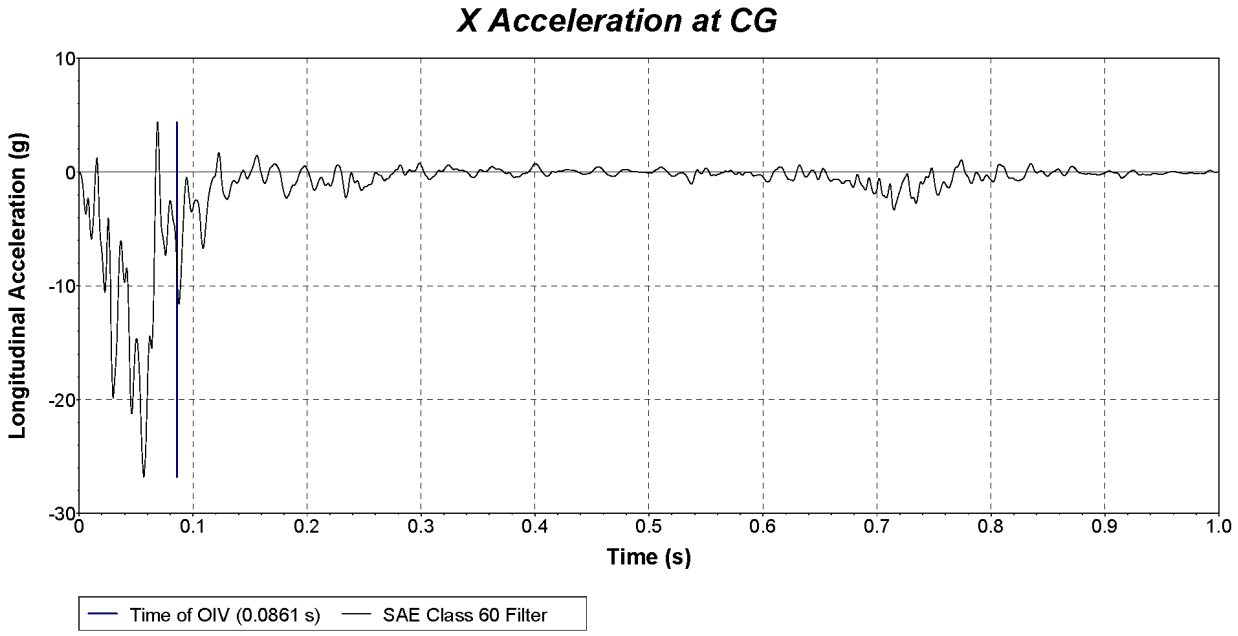


Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test No. 614271-12-2 (Accelerometer Located at Center of Gravity).

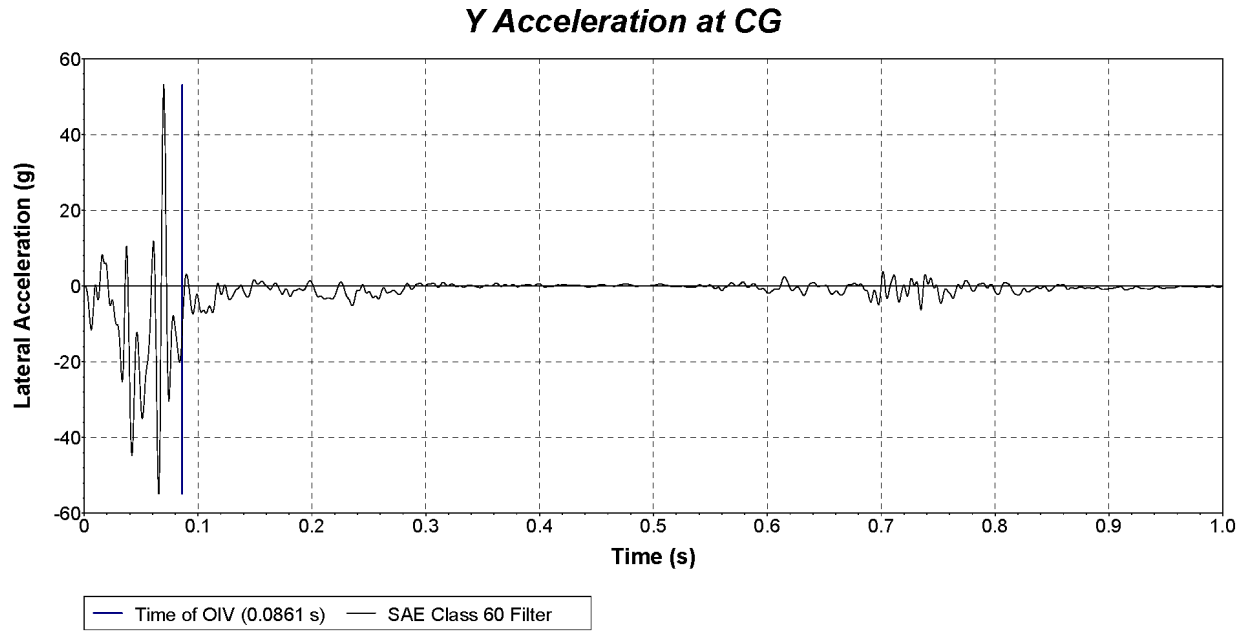


Figure C.9. Vehicle Lateral Accelerometer Trace for Test No. 614271-12-2 (Accelerometer Located at Center of Gravity).

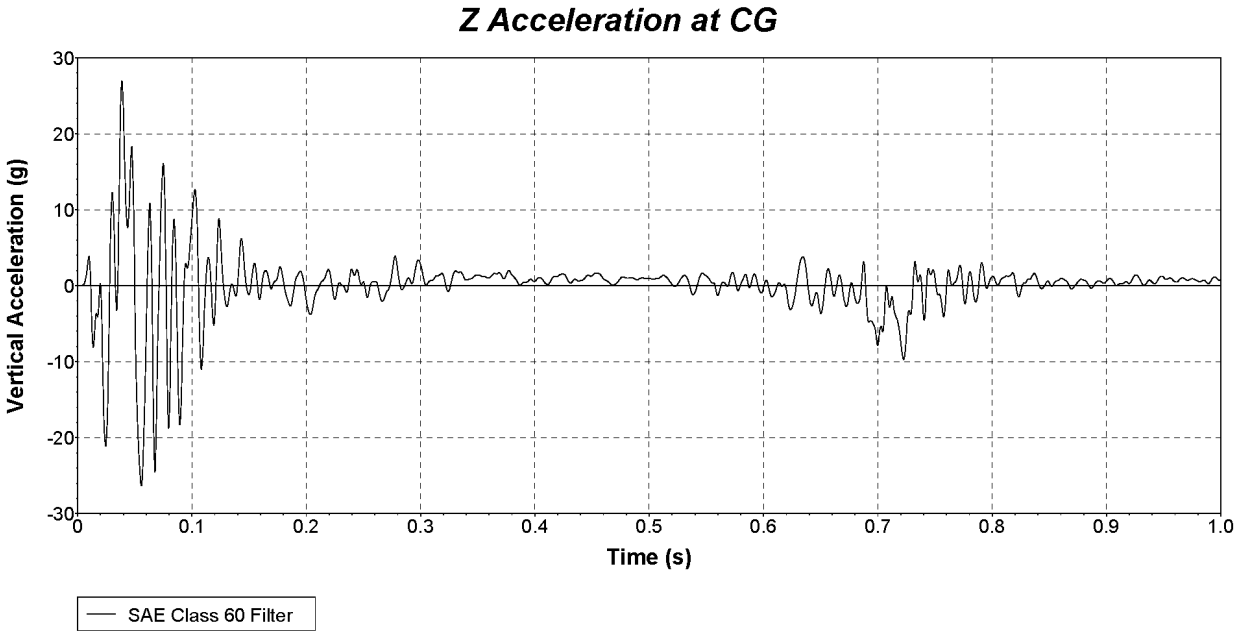


Figure C.10. Vehicle Vertical Accelerometer Trace for Test No. 614271-12-2 (Accelerometer Located at Center of Gravity).

APPENDIX D. *MASH* TEST 3-11 (CRASH TEST NO. 614271-12-1)

D.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2022-11-16 Test No.: 614271-12-1 VIN No.: 1C6RR6FTXKS598582

Year: 2019 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 151167

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

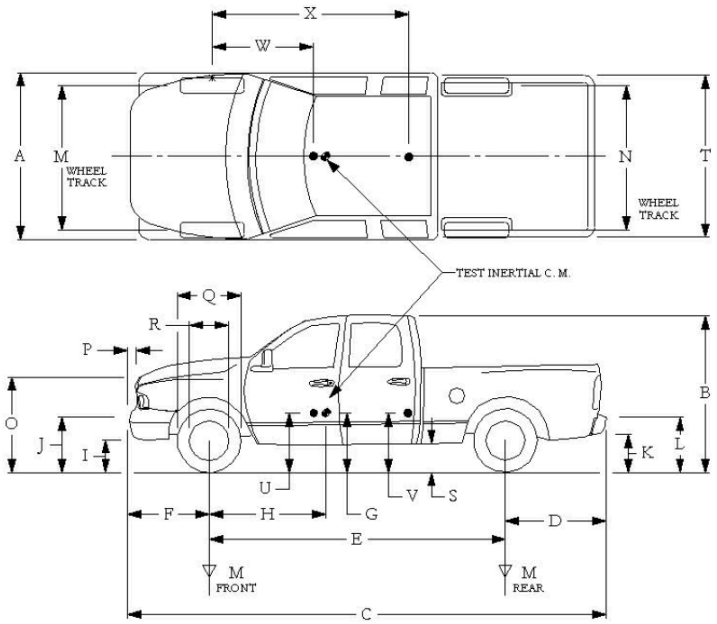
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: NONE
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.40	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.18	M	68.50	R	18.00	W	61.20
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2928	2834	2834
Back	3900	M_{rear}	2011	2186	2186
Total	6700	M_{Total}	4939	5020	5020

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

Mass Distribution:
lb LF: 1425 RF: 1409 LR: 1110 RR: 1076

Figure D.1. Vehicle Properties for Test No. 614271-12-1.

Date:	2022-11-16	Test No.:	614271-12-1	VIN No.:	1C6RR6FTXKS598582
Year:	2019	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L***	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max**** Crush								
1	AT FT BUMPER	15	12	36							-18
2	SAME	15	12	60							70
	Measurements recorded										
	☑ **inches or** ☐ **mm**										

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

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

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

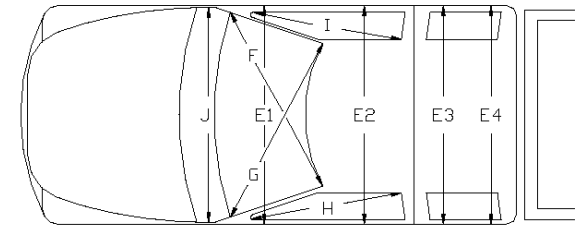
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

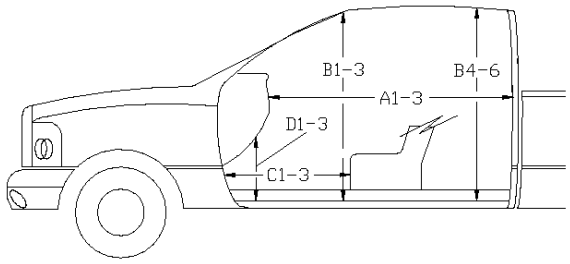
***Measure and document on the vehicle diagram the location of the maximum crush.

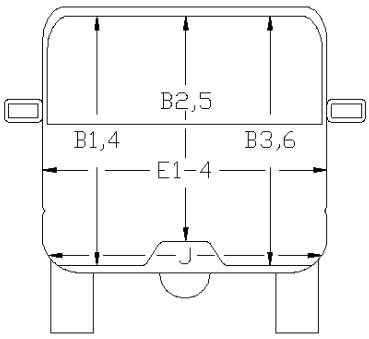
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure D.2. Exterior Crush Measurements for Test No. 614271-12-1.

Date:	2022-11-16	Test No.:	614271-12-1	VIN No.:	1C6RR6FTXKS598582
Year:	2019	Make:	RAM	Model:	1500







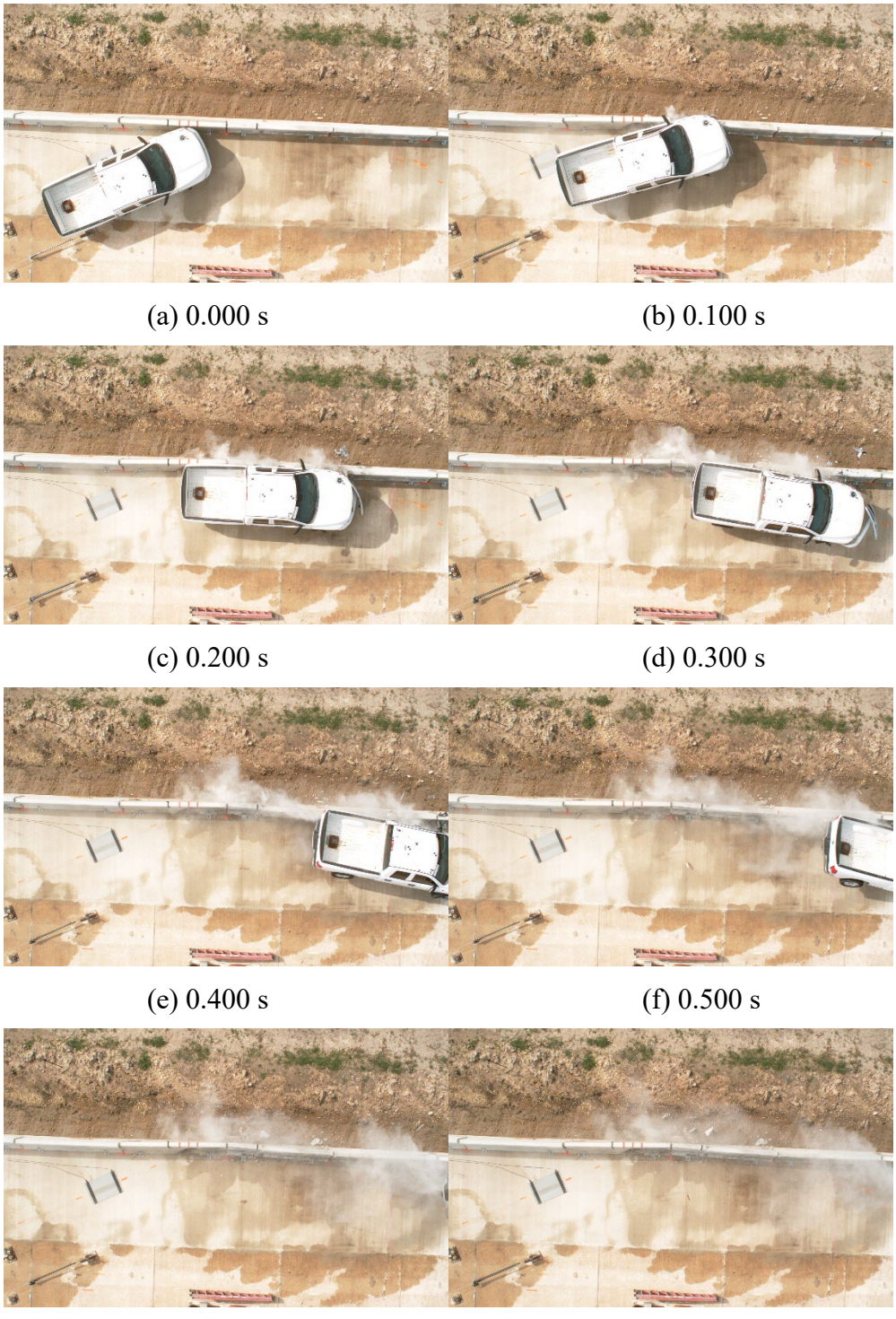
*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	24.00	-2.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Figure D.3. Occupant Compartment Measurements for Test No. 614271-12-1.

D.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 D.4. Sequential Photographs for Test No. 614271-12-1 (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 D.5. Sequential Photographs for Test No. 614271-12-1 (Frontal Views).

(a) 0.000 s (b) 0.100 s

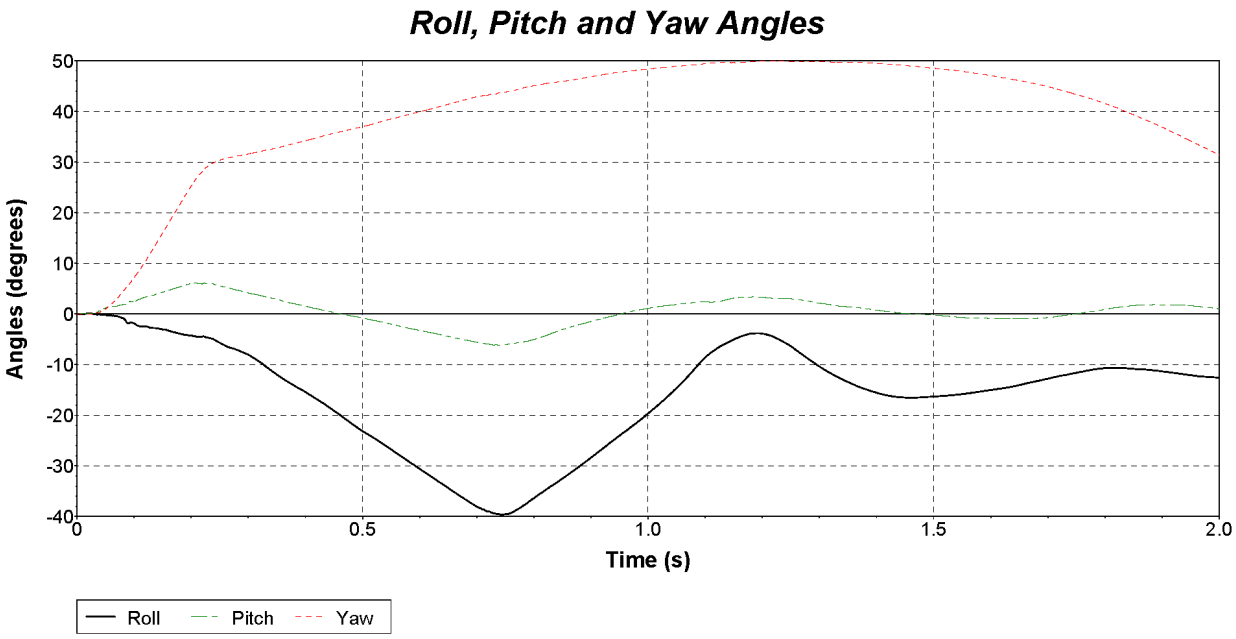
(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

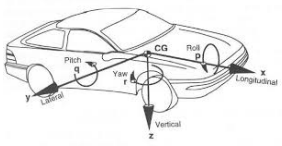
Figure D.6. Sequential Photographs for Test No. 614271-12-1 (Rear Views).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for
determining orientation:

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



Test Number: 614271-12-1
Test Standard Test Number: *MASH* Test 3-11
Test Article: Maryland F-Shape Portable Concrete Barrier
Test Vehicle: 2019 RAM 1500
Inertial Mass: 5020
Gross Mass: 5020
Impact Speed: 61.8 mi/h
Impact Angle: 24.9°

Figure D.7. Vehicle Angular Displacements for Test No. 614271-12-1.

D.4. VEHICLE ACCELERATIONS

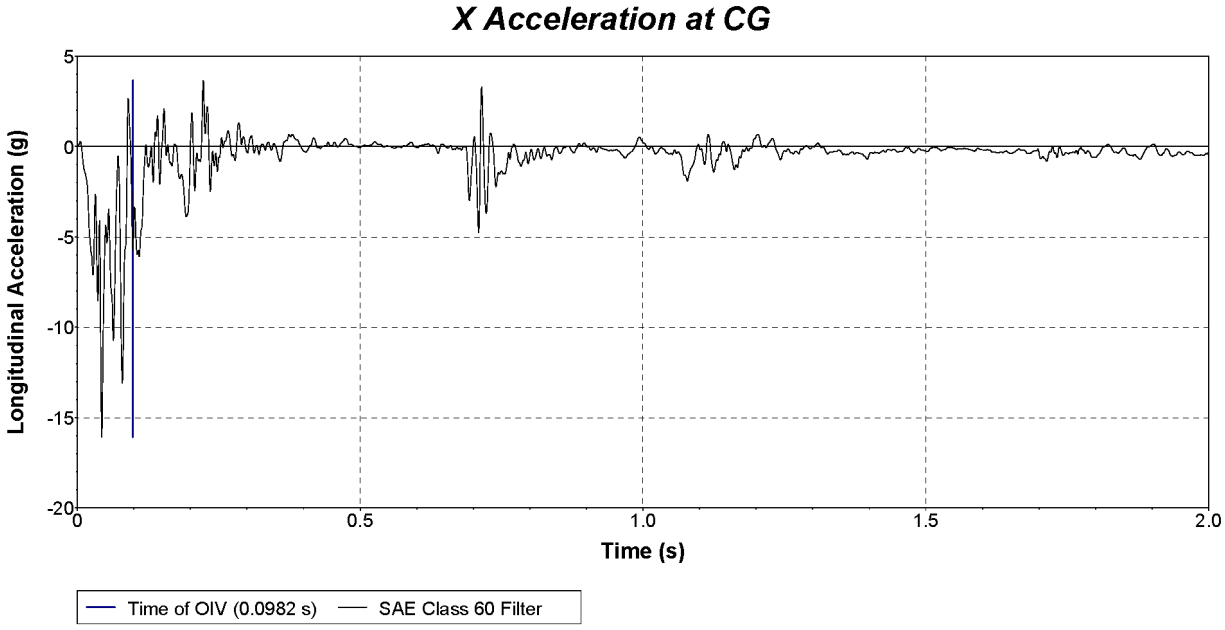


Figure D.8. Vehicle Longitudinal Accelerometer Trace for Test No. 614271-12-1 (Accelerometer Located at Center of Gravity).

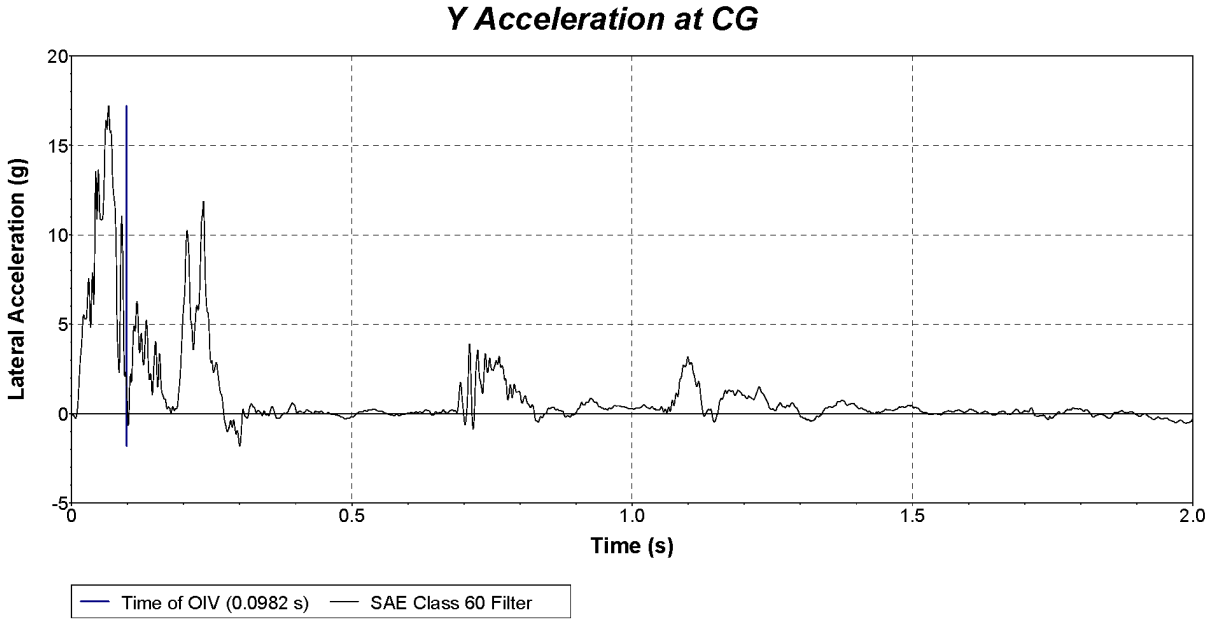


Figure D.9. Vehicle Lateral Accelerometer Trace for Test No. 614271-12-1 (Accelerometer Located at Center of Gravity).

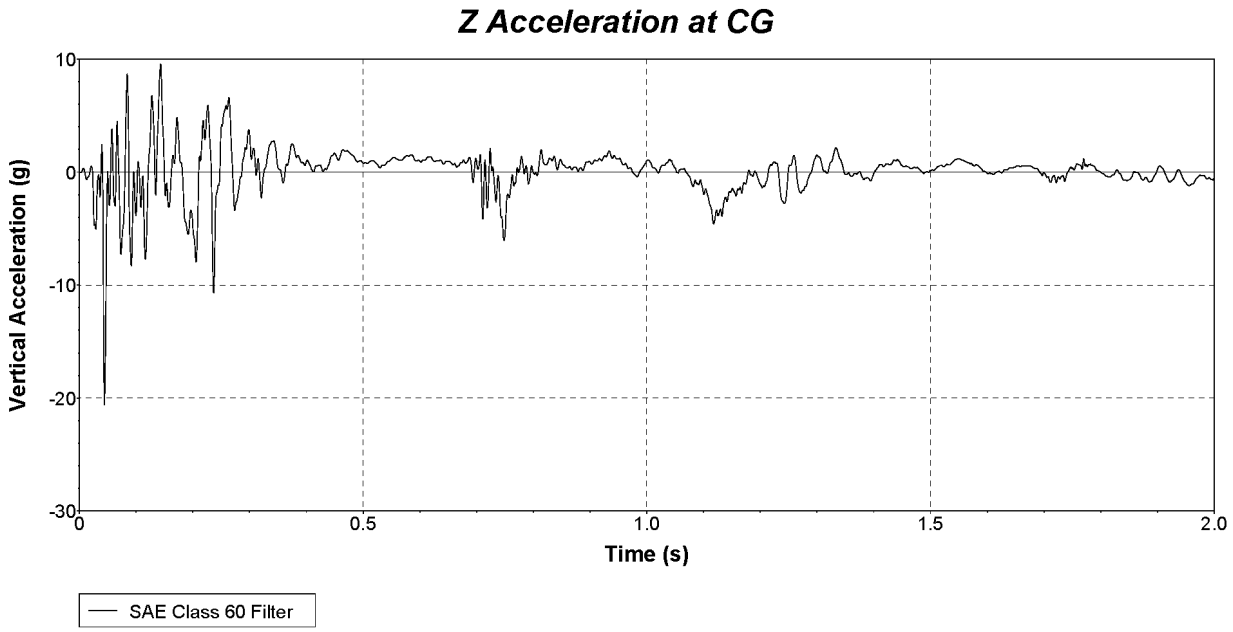


Figure D.10. Vehicle Vertical Accelerometer Trace for Test No. 614271-12-1 (Accelerometer Located at Center of Gravity).