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Development of Approach Transition from Box Beam Guardrail to Concrete Parapet

Final Report

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16. Abstract

This research is a step in the Wyoming Department of Transportation's ongoing efforts to implement the *Manual for Assessing Safety Hardware* (*MASH*) to enhance roadside safety and reduce the severity of run-off-road crashes. The objective of this research was to develop a *MASH* Test Level 3 (TL-3) compliant stiffness transition from box beam roadside guardrail to concrete parapet or bridge rail. Shape transitions were developed to transition the vertical concrete profile to which the box beam transition is attached to a New Jersey or single slope profile.

The Concrete Parapet Shape Transition and box beam transition to concrete parapet met the performance criteria for *MASH* TL-3 transitions. Both transition systems are considered *MASH* compliant.

This report provides details on the development of the Concrete Parapet Shape Transition and box beam approach transition, the crash tests and results, and the performance assessment of the transitions for *MASH* TL-3 evaluation criteria.

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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

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List of Abbreviations

A2LA	American Association for Laboratory Accreditation
AASHTO	American Association of State Highway and Transportation Officials
ASI	Acceleration Severity Index
CDC	Collision Deformation Classification
CG	Center of Gravity
CIP	Critical Impact Point
FE	Finite Element
FHWA	Federal Highway Administration
ft	feet
HSS	Hollow Structural Section
IS	Impact Severity
ISO	International Standards Organization
lb	pounds
lbf	pounds force
kip-ft	thousand foot pounds
LON	Length of Need
MASH	*Manual for Assessing Safety Hardware*
mi/h	miles per hour
NIST	National Institute of Standards Technology
OCDI	Occupant Compartment Deformation Index
OIV	Occupant Impact Velocity
psi	pounds pressure per square inch
RA	(Occupant) Ridedown Acceleration
TDAS	Tiny Data Acquisition System
THIV	Theoretical Head Impact Velocity
TL-3	Test Level 3
TRAP	Test Risk Assessment Program
TTI	Texas A&M Transportation Institute
VDS	Vehicle Damage Scale
WYDOT	Wyoming Department of Transportation
x	Longitudinal
y	Lateral
z	Vertical

Chapter 1. INTRODUCTION

1.1. BACKGROUND

The Wyoming Department of Transportation (WYDOT) Mission Statement is to "provide a safe, high quality and efficient transportation system." One of the goals within the mission statement is to "improve safety on the state transportation system." Implementation of roadside safety devices that comply with the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware (MASH)* is an important part of achieving this goal. *MASH* prescribes the performance criteria that a device must meet when impacted under specified impact conditions (*1*). Full implementation of *MASH*-compliant roadside safety devices will provide an enhanced level of safety that will help reduce the severity of roadway departure crashes that represent over 75 percent of highway fatalities in Wyoming.

This research addresses one important element of roadside safety design—the transition from an approach roadside guardrail to a bridge rail. The purpose of the transition section is to transition the stiffness from the more flexible approach guardrail to the more rigid bridge rail. Stiffness transitions provide continuity of motorist safety from *MASH* guardrail systems to *MASH* bridge rail systems. A stiffness transition has two distinct transition points that need to be considered in the design process. The first is the transition from the approach guardrail to the upstream end of the transition section. The second is the transition from the downstream end of the transition section to the bridge rail. A transition design and its connection details must include consideration of strength to resist impact loads and geometry to reduce vehicle snagging potential from both directions of travel (i.e., onto and off the bridge structure). Variables in transition design include the size and thickness of the rail element(s), post size, post spacing, and post embedment depth. A lower rub-rail or curb element below the primary transition rail is another design consideration.

1.2. OBJECTIVE

This project was jointly funded by WYDOT and Montana DOT with the objective of developing MASH Test Level 3 (TL-3) compliant nonproprietary approach guardrail transition systems. The objective of this phase of the project was to develop a *MASH* Test Level 3 (TL-3) compliant transition from box beam approach guardrail to a vertical concrete parapet. Shape transitions were developed to transition the vertical concrete parapet to which the transition was attached to other concrete barrier profiles that have been used or are planned for use by WYDOT.

1.3. WORK PLAN

The work plan for this phase of the project consisted of five tasks that relate to the design, analysis, testing, evaluation, and documentation of Concrete Parapet Shape Transitions and box beam guardrail transition to concrete parapet. Tasks included transition conceptualization and design, finite element (FE) modeling and impact simulations, test installation construction, full-scale crash testing in accordance with *MASH* TL-3 criteria, and deliverable preparation. Details of this research are described herein.

Chapter 2. CONCRETE PARAPET SHAPE TRANSITION DESIGN

2.1. INTRODUCTION

WYDOT desired to use the box-beam guardrail transition to vertical parapet with 42-inch-tall single slope (SS) and the 32-inch-tall New Jersey (NJ) profile concrete barriers. Due to the differences in heights and shapes of these concrete bridge rails, special shape transitions were needed. The slopes on the traffic face of the SS and NJ profiles result in wider barriers compared to the vertical parapet profile. Furthermore, there is a 10-inch height difference between the vertical parapet and the SS barrier profile. Shape transitions were needed to allow stable redirection of a vehicle impacting the concrete parapet.

The researchers developed designs for transitioning from the vertical concrete parapet to both the SS barrier profile and NJ profile concrete barriers. One of the design objectives was to minimize the length of the concrete transition parapet, with a goal of 10 ft or less. The researchers used finite element (FE) modeling and simulation to evaluate transition design concepts and determine critical impact points for crash testing. This chapter presents details of the modeling and simulation effort related to the development of the Concrete Parapet Shape Transition designs.

2.2. VERTICAL TO SINGLE SLOPE TRANSITION

The researchers developed a design to transition the shape of a vertical parapet to a SS concrete barrier. The conceptualized transition design is shown in Figure 2.1. The vertical parapet is 32 inches tall and transitions to a 42-inch-tall SS barrier. The box beam transition rails are intended to be attached to the vertical parapet. To allow sufficient room for this connection, the length of the vertical portion of the concrete parapet was selected to be 36 inches. The shape transition section was selected to be 72 inches long, providing an overall parapet length of 9 ft. The height transitioned 10 inches from 32 inches at the vertical parapet end to 42 inches at the SS barrier end. The shape transition from vertical to SS profile was achieved by using two triangular planes on the traffic side, as shown in Figure 2.1.

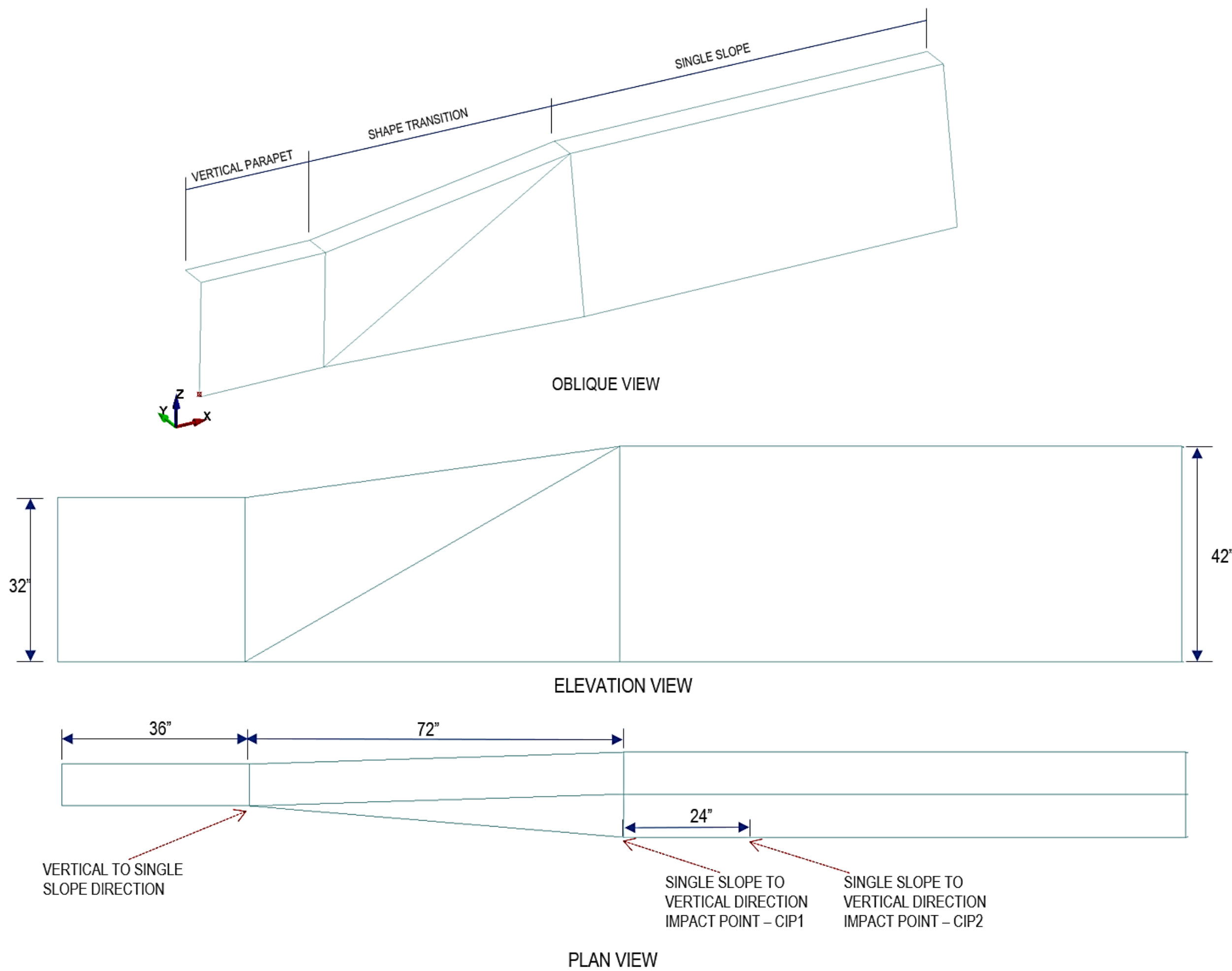

Figure 2.1 Vertical-to-SS Barrier Shape Transition Design and Impact Points.

2.2.1. Pickup Truck Impact Simulations (MASH Test 3-21)

To evaluate the performance of the Concrete Parapet Shape Transition, the researchers developed a model of the transition parapet and adjacent single slope barrier. All simulations were performed using the finite element (FE) method. LS-DYNA, which is a commercially available general purpose FE software, was used for all the analyses.

The transition section and adjacent barrier were modeled using rigid material representation. A 5,000-lb Dodge RAM pickup truck model was used for the impact simulations. Figure 2.1 shows the three impact points at which the impact simulations were performed. The direction of the vehicle and the location of the impact points was as follows:

- **Vertical to SS:** Vehicle impacting the vertical parapet at the point where the shape transition begins.
- **SS to Vertical – CIP1:** Vehicle impacting the SS barrier at the point where the shape transition begins.
- **SS to Vertical – CIP2:** Vehicle impacting the SS barrier 2 ft upstream of the point where the shape transition begins.

Figure 2.2 shows the model of the vehicle positioned to impact the barrier and the shape transition for SS to Vertical – CIP2.

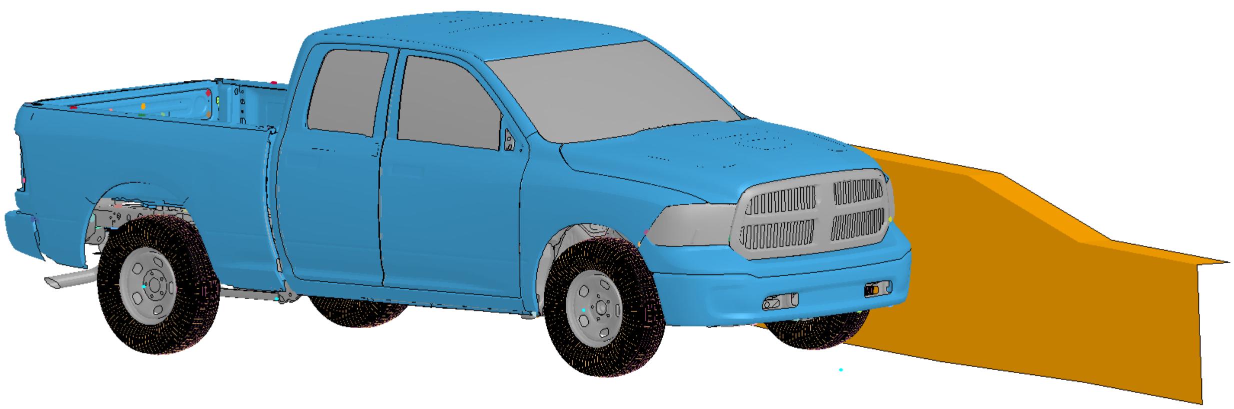

Figure 2.2. FE model prior to vehicle impact with shape transition.

The researchers performed impact simulations using MASH Test 3-21 impact conditions for all three impact points described above. This test involves the pickup truck model impacting the barrier system at an impact speed and angle of 62 mi/h and 25 degrees. In all three simulations, the vehicle was successfully contained and redirected. Table 2.1 shows the maximum Occupant Impact Velocity (OIV) and Ridedown Acceleration (RA) values calculated from the simulation data for all three impact points, along with the maximum vehicle roll angle in each simulation. Figure 2.3 shows the vehicles at the point of maximum kinematic instability for each of the impact points simulated.

All three simulations satisfied MASH criteria. The impact from the direction of the vertical parapet to the SS barrier was determined to be the critical impact point for Test 3-21 for this shape transition. This impact point resulted in maximum climb of the vehicle and also had the highest RA value.

Table 2.1. Results for Test 3-21 Simulation of Transition to SS barrier.

Direction of Impact and Impact Point	Max. Ridedown Acceleration (g)	Maximum Occupant Impact Velocity (ft/s)	Maximum Vehicle Roll (degrees)
Vertical to SS	13.2	28.3	7.2
SS to Vertical – CIP1	9.9	29.5	8.5
SS to Vertical – CIP2	9.4	28.0	5.7

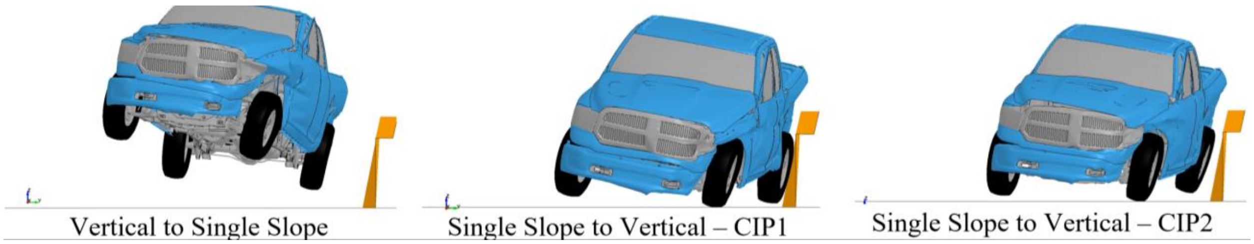

Figure 2.3. Vehicles at maximum kinematic instability during simulations of various impact points.

2.2.2. Passenger Sedan Impact Simulations (MASH Test 3-20)

The researchers performed impact simulations on the shape transition from the vertical parapet to SS barrier with a small passenger sedan using the impact conditions of MASH Test 3-20. This test involves impacting the transition with a 2,420-lb passenger sedan at an impact speed and angle of 62 mph and 25 degrees. The vehicle model used in the simulations was a Toyota Yaris model.

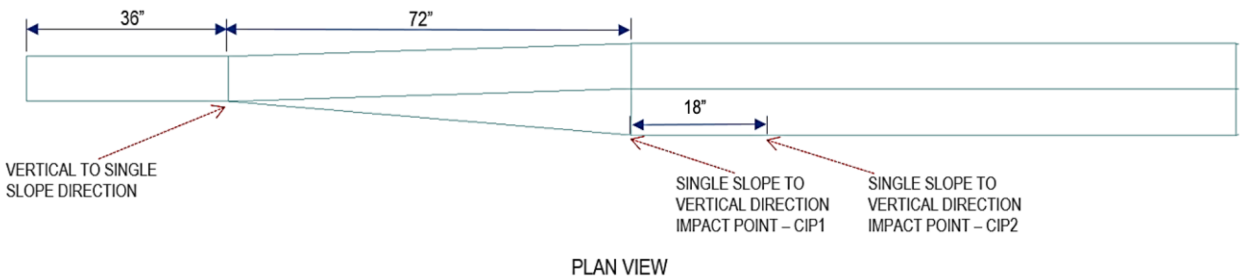

Figure 2.4. Impact Points for Test 3-20 Simulations of the Vertical to SS Barrier Shape Transition.

Figure 2.4 shows the three impact points at which the impact simulations with MASH Test 3-20 conditions were performed. The direction of the vehicle and the location of the impact points were as follows:

- **Vertical to SS:** Vehicle impacting the vertical parapet at the point where the shape transition begins.
- **SS to Vertical – CIP1:** Vehicle impacting the SS barrier at the point where the shape transition begins.
- **SS to Vertical – CIP2:** Vehicle impacting the SS barrier 1.5 ft upstream of the point where the shape transition begins.

In all three simulations, the vehicle was successfully contained and redirected. Table 2.2 shows the results of the maximum Occupant Impact Velocity (OIV), Ridedown Acceleration (RA), and vehicle roll angle in each simulation.

Table 2.2. Results for Test 3-20 Simulation of Transition to SS barrier.

Direction of Impact and Impact Point	Max. Ridedown Acceleration (g)	Maximum Occupant Impact Velocity (ft/s)	Maximum Vehicle Roll (degrees)
Vertical to SS	6.4	40.3	12.8
SS to Vertical – CIP1	15.0	30.6	8.4
SS to Vertical – CIP2	12.1	29.2	10.4

Figure 2.5 shows the vehicles at the point of maximum kinematic instability for each of the impact points simulated for the passenger sedan. The impact from the direction of the vertical parapet to the SS barrier resulted in slightly greater vehicle instability. It also had the highest OIV and vehicle roll, and was thus selected to be the critical impact point for Test 3-20 for this shape transition.

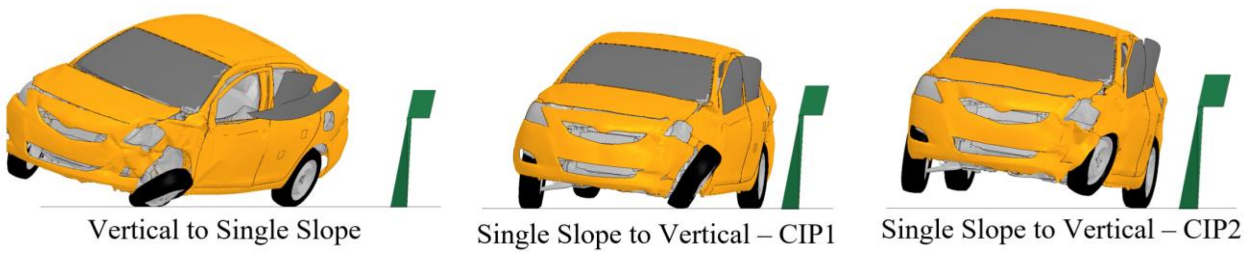

Figure 2.5. Vehicles at maximum kinematic instability during simulations of various impact points.

2.3. VERTICAL TO NEW JERSEY SAFETY SHAPE TRANSITION

The researchers also developed a design to transition the shape between a vertical parapet and a NJ profile concrete barrier. This transition design is shown in Figure 2.6. The 32-inch-tall vertical parapet transitioned to a 32-inch-tall NJ profile barrier. The length of the vertical parapet was selected to be 36 inches to allow connection of the box beam approach transition. The shape transition section was 72 inches long,providing an overall parapet length of 9 ft. The shape transition from vertical to NJ profile was achieved using triangular planes on the traffic side, as shown in Figure 2.6.

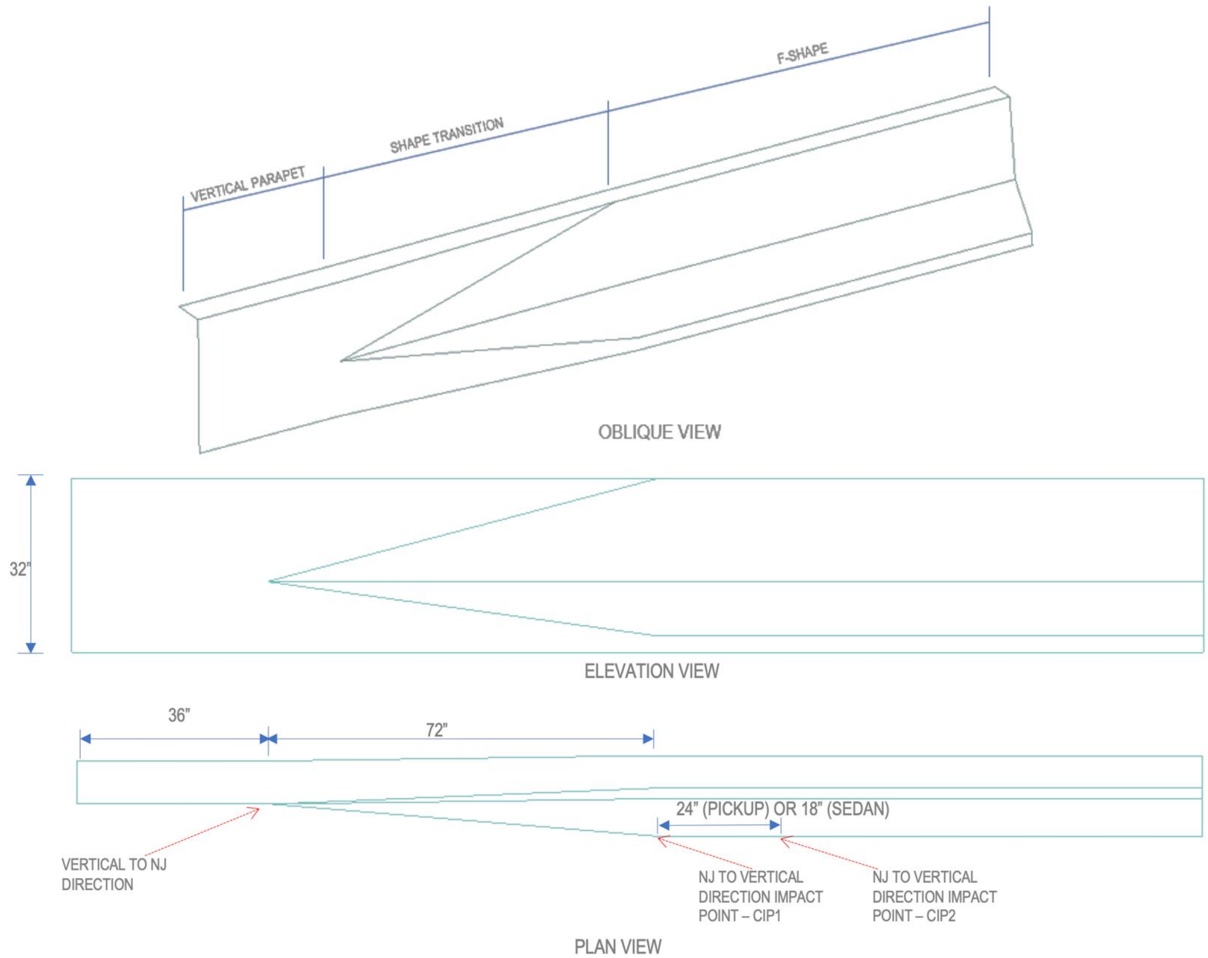

Figure 2.6. Vertical to NJ Barrier Shape Transition Design and Impact Points.

2.3.1. Pickup Truck Impact Simulations (MASH Test 3-21)

The researchers performed impact simulations with the shape transition from vertical to NJ profile barrier with a pickup truck model using the impact conditions of MASH Test 3-21. This test involves a 5,000-lb pickup truck impacting the transition at an impact speed and angle of 62 mph and 25 degrees. Figure 2.6 shows the three impact points at which the impact simulations were performed. The direction of the vehicle and the location of the impact points were as follows:

- **Vertical to NJ:** Vehicle impacting the vertical parapet at the point where the shape transition begins.
- **NJ to Vertical – CIP1:** Vehicle impacting the NJ barrier at the point where the shape transition begins.
- **NJ to Vertical – CIP2:** Vehicle impacting the NJ barrier 2 ft upstream of the point where the shape transition begins.

In all three simulations, the vehicle was successfully contained and redirected and MASH criteria were satisfied. Table 2.3 shows the maximum OIV, RA, and vehicle roll angle from each simulation.

Table 2.3. Simulation Results of Test 3-21 Impacts with Vertical to NJ Transition.

Direction of Impact and Impact Point	Maximum Occupant Impact Velocity (ft/s)	Maximum Ride Down Acceleration (g)	Maximum Vehicle Roll (deg.)
Vertical to NJ	27.6	12.2	15.4
NJ to Vertical – CIP1	29.4	9.6	11.2
NJ to Vertical – CIP2	29.9	11.0	10.3

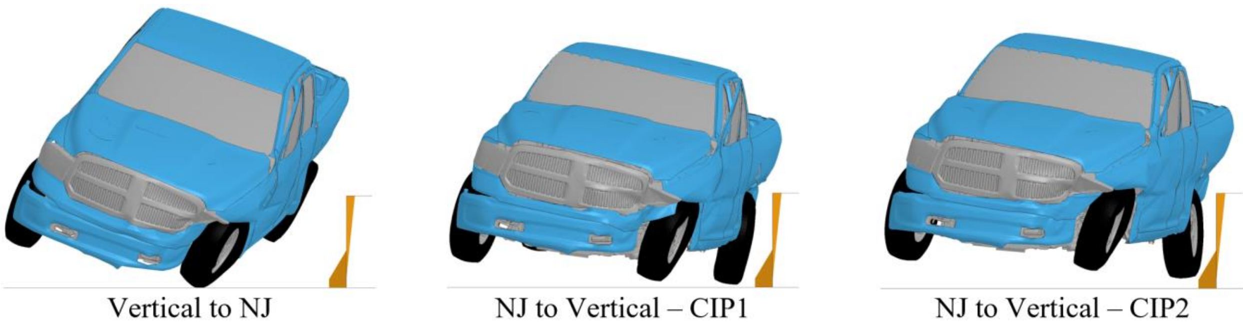

Figure 2.7. Vehicles at maximum kinematic instability during simulations of various impact points.

Figure 2.7 shows the vehicles at their approximate points of maximum kinematic instability for each of the impact points simulated. The overall stability of the vehicle and its kinematics during and after the impact were similar for all three impact points. The impact from the direction of the vertical parapet to the NJ barrier resulted in slightly greater vehicle instability. It also had the highest RA and vehicle roll, and was thus selected to be the critical impact point for Test 3-21 for this shape transition.

2.3.2. Small Sedan Impact Simulations (MASH Test 3-20)

The researchers also performed impact simulations with the shape transition from the vertical parapet to the NJ profile barrier with a small passenger sedan using the impact conditions of MASH Test 3-20. Figure 2.6 shows the three impact points at which the impact simulations with MASH Test 3-20 conditions were performed. The direction of the vehicle and the location of the impact points were as follows.

- **Vertical to NJ:** Vehicle impacting the vertical parapet at the point where the shape transition begins.
- **NJ to Vertical – CIP1:** Vehicle impacting the NJ barrier at the point where the shape transition begins.
- **NJ to Vertical – CIP2:** Vehicle impacting the NJ barrier 1.5 ft upstream of the point where the shape transition begins.

In all three simulations, the vehicle was successfully contained and redirected, and MASH criteria were satisfied. Table 2.4 shows the maximum OIV, RA, and vehicle roll for each simulation.

Table 2.4. Simulation Results of Test 3-20 Impacts with Vertical to NJ Transition.

Direction of Impact and Impact Point	Maximum Occupant Impact Velocity (ft/s)	Maximum Ride Down Acceleration (g)	Maximum Vehicle Roll (deg.)
Vertical to NJ	30.4	5.6	20.7
NJ to Vertical – CIP1	31.2	9.5	10.0
NJ to Vertical – CIP2	30.6	12.2	17.1

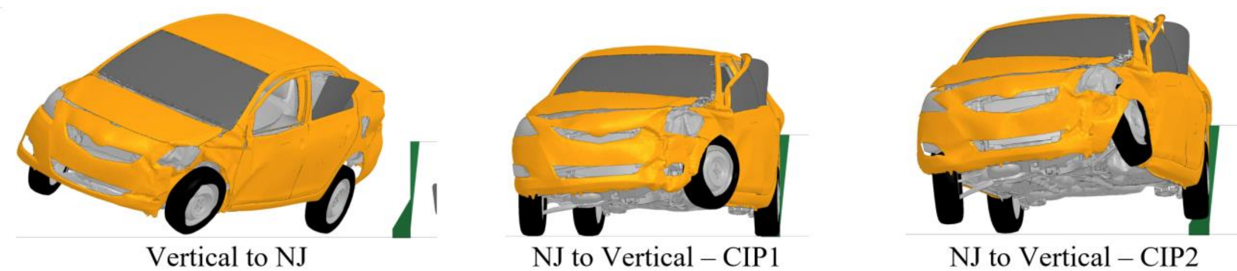

Figure 2.8. Vehicles at maximum kinematic instability during simulations of various impact points.

Figure 2.8 shows the vehicles at their approximate points of maximum kinematic instability for each of the impact points simulated. The overall stability of the vehicle and its kinematics during and after the impact were similar for all three impact points. The impact from the direction of the vertical parapet to the NJ barrier resulted in slightly greater vehicle instability and also had the highest vehicle roll. In comparison, the impact "NJ to Vertical – CIP2" had slightly less roll angle, about same OIV, and higher RA. While both impact points were contenders for the critical impact point and direction, the researchers believe that vehicle stability should be given precedence over occupant risk in the case of the shape transition. Since the impact from the vertical to NJ barrier resulted in higher roll, the researchers selected this location to be the critical impact point and direction for Test 3-20 for this shape transition.

2.4. CRASH TESTING RECOMMENDATIONS

Ideally, both shape transition systems could be crash tested for MASH Test 3-20 and Test 3-21. However, the scope of the current project included testing one of the two shape transition systems. Subject to this constraint, the research team developed the recommendations for crash testing presented below.

2.4.1. MASH Test 3-21

For Test 3-21 with a pickup truck, the research team considered the transition from vertical to NJ barrier to be more critical since it had higher maximum vehicle roll and similar maximum OIV and RA to the transition from vertical to SS barrier. Even though the OIV and RA of the vertical to SS transition were slightly higher, vehicle stability was considered a more important factor for the shape transitions. Therefore, for Test 3-21, the researchers recommended testing the vertical to NJ barrier transition. The critical impact point, as discussed previously, was the point where the vertical parapet starts transitioning to the NJ profile barrier. The direction of impact for this point was from the vertical parapet to the NJ profile barrier.

2.4.2. MASH Test 3-20

For Test 3-20 with a small passenger sedan, the point on the vertical parapet at the beginning of the SS shape transition had an OIV that was at the MASH threshold of 40 ft/s. On the other hand, the vehicle roll angle for the transition from vertical to NJ barrier was 7.9 degrees higher than the vehicle roll for the vertical to SS barrier transition.

The small car simulation model is known to be conservative in predicting OIV values. Thus, even though the OIV value for the vertical to SS transition was at the MASH threshold, it was expected to stay within the MASH limits in a crash test. Furthermore, as mentioned previously, vehicle stability is usually a more critical design factor compared to occupant risk for rigid concrete barrier shape transitions. Therefore, the research team recommended testing the vertical to NJ profile barrier transition for Test 3-20. The critical impact point was where the shape transition starts at the end of the vertical parapet. The direction of impact was from the vertical parapet to the NJ profile barrier.

Chapter 3. BOX BEAM TRANSITION TO CONCRETE PARAPET DESIGN

3.1. INTRODUCTION

The research team utilized finite element computer simulations to design and investigate the impact performance of an approach transition from box beam guardrail to a vertical concrete parapet. The transition system was evaluated in accordance with *MASH* TL-3 impact conditions and criteria.

The box beam guardrail transition to vertical concrete parapet consists of components and details similar to those utilized in the box beam guardrail transition to C2P bridge rail (2). Figure 3.1 and Figure 3.2 show elevation view and plan views of the box beam transition concept, respectively. The box beam rail is supported by strong steel posts, and the spacing of the posts decreases as the concrete parapet is approached. A rub rail is present below the box beam rail to help reduce vehicle snagging on the strong transition posts and parapet end. The box beam transition is connected to a 32-inch vertical concrete parapet. The shape transition on the concrete parapet was not included in these simulations as the purpose was to investigate the transition from the box beam rail to the vertical concrete parapet. Figure 3.3 shows the entire transition system including the parapet.

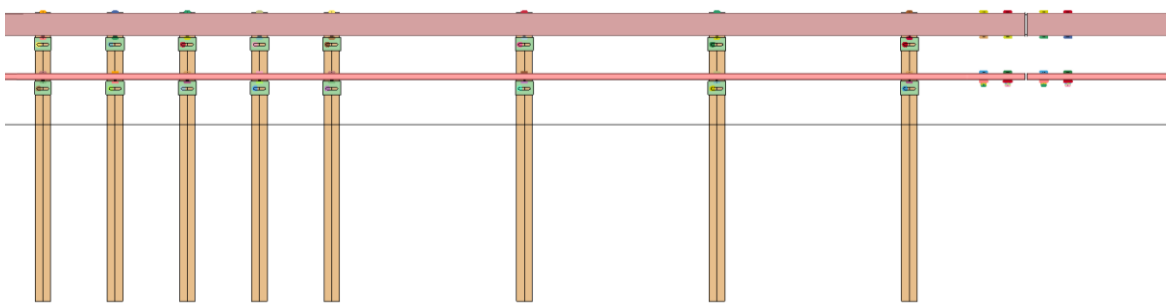

Figure 3.1. Box Beam Rail Section – Elevation View.

Figure 3.2. Box Beam Rail Section – Plan View.

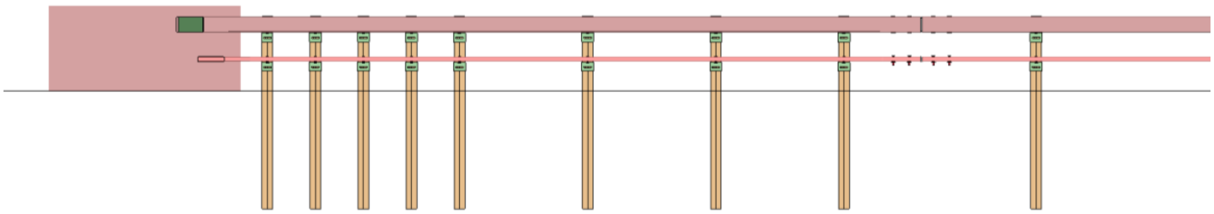

Figure 3.3. Box Beam Transition to Concrete Parapet.

The box beam rail and lower rub rail are attached to the concrete parapet using two anchors on each rail. The first anchor for each rail is located 6 inches from the parapet edge and the second anchor for each rail is located 12 inches from the parapet edge. Each rail has a tapered end to mitigate snagging in a reverse direction impact. The tapered end of the wider upper box beam rail is additionally covered with a plate. Figure 3.4 shows the transition connection at the parapet. The anchors are not shown.

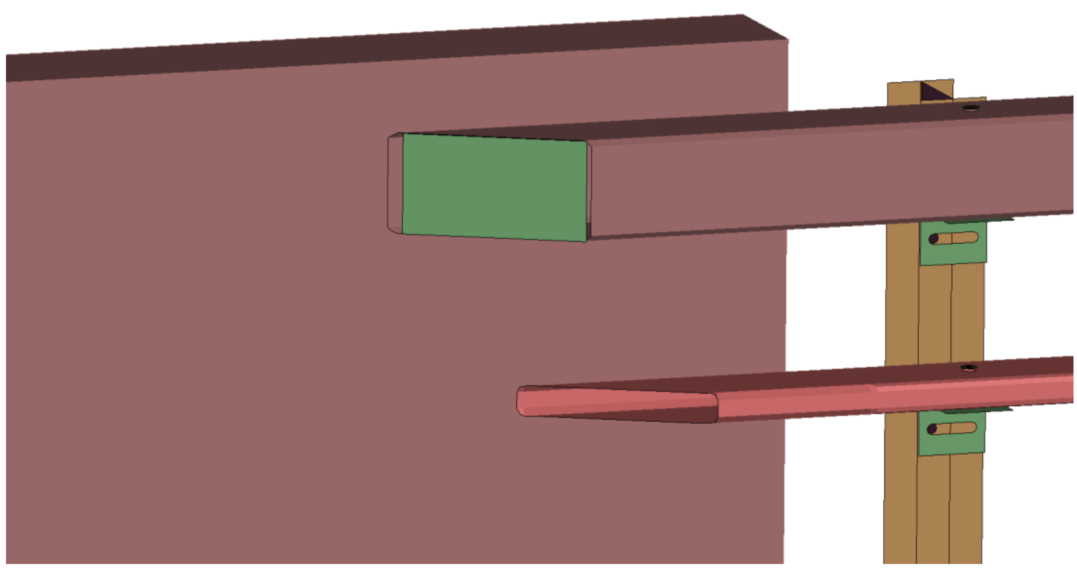

Figure 3.4. Box Beam Transition Connection.

3.2. DESIGN MODIFICATIONS

Design changes were made to the box beam transition section to address performance issues identified during the computer simulation effort. Details of these modifications are documented below. After the box beam transition design was finalized, simulations were performed at different locations on the final design to determine the critical impact locations for *MASH* testing.

3.2.1. Anchor Bolts

The initial computer simulations indicated satisfactory performance for MASH Test 3-20 and Test 3-21 evaluation criteria. However, deformation of the box beam rail led to exposed connection bolts that could snag the impacting vehicle. Figure 3.5 shows the exposed bolts resulting from local deformation of the box beam rail during one of the MASH Test 3-21 simulation runs.

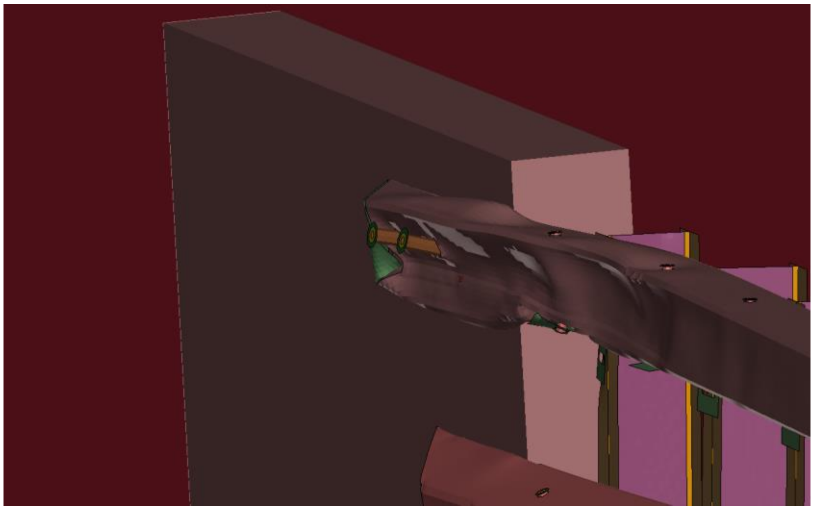

Figure 3.5. Exposed Anchor Bolts.

To mitigate the potential for bolt head snagging, the bolt anchors going into the concrete parapet were modified. The bolt heads were moved off the traffic face of the box beam rail to the inside of the box beam rail. Figure 3.6 shows the modified anchor bolt with the head of the bolt located inside the rail. This eliminates the potential for vehicle snagging on the bolts.

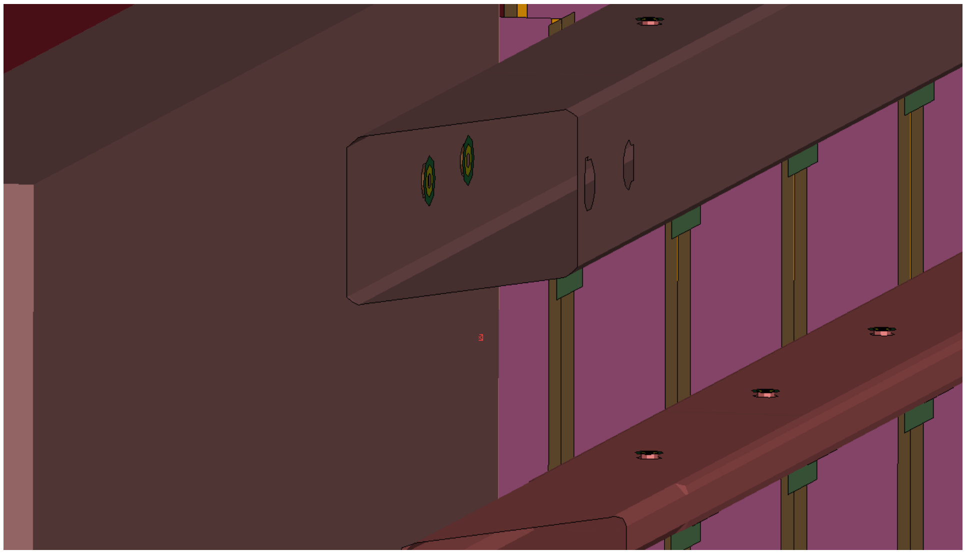

Figure 3.6. Modified Anchor Bolts.

The modification of the bolted connection did prevent vehicle snagging. However, the new connection detail permitted more rotational movement and deflection of the box beam rail. This additional deflection resulted in rollover of the pickup truck vehicle. Figure 3.7 shows the deflection of the box beam rail after the pickup truck impact.

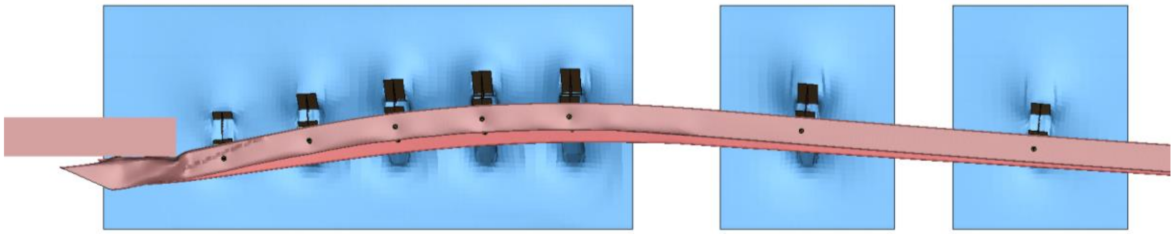

Figure 3.7. Deflection of System with Modified Anchor Bolts.

3.2.2. Additional W6x9 Steel Posts

The box beam transition section was stiffened to reduce the dynamic deflection through the addition of a W6x9 post in the downstream transition region. Additionally, the length of the W6x9 posts was increased from 72 inches to 78 inches. Figure 3.8 shows the modified transition system.

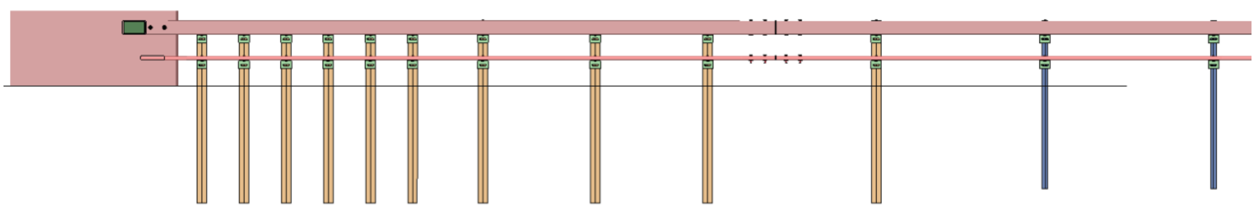

Figure 3.8. Box Beam Transition with 78-inch W6x9 posts.

In the subsequent MASH Test 3-21 simulation, the pickup truck did not roll over onto its side, but the roll of the pickup truck was significant as it exited the system. Figure 3.9 shows an image from the simulation at the time the pickup truck is at its maximum roll angle.

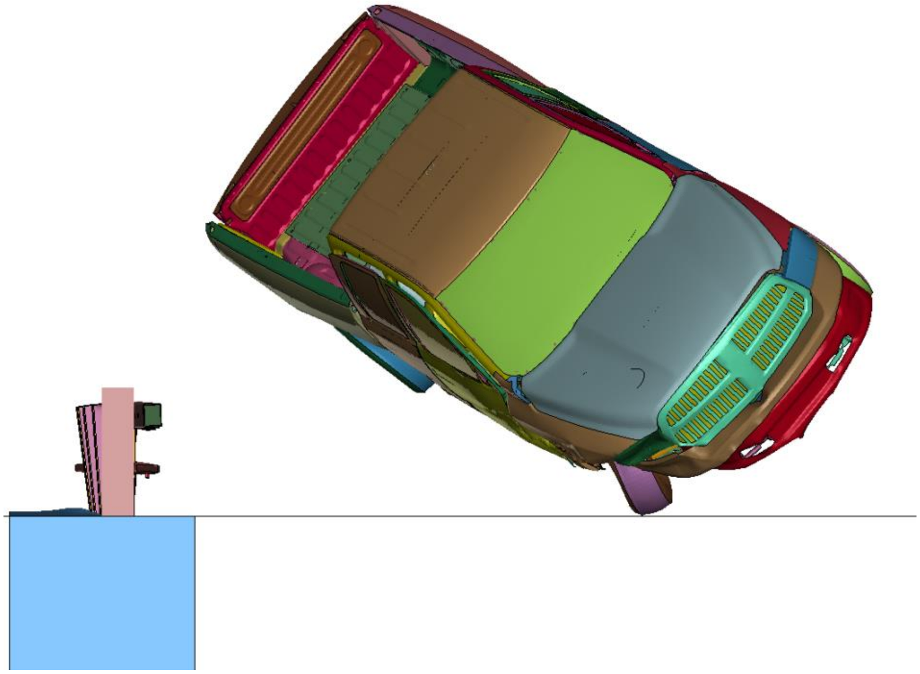

Figure 3.9. Pickup Truck at Maximum Roll Angle.

3.2.3. HSS4x3 Rubrail

It was desired to further reduce this roll angle to increase confidence in the impact performance of the transition system prior to performing full-scale crash tests. It was observed that during the deflection of the transition system, the rubrail extends beyond the main box beam rail in the lateral direction. Figure 3.10 shows the deflection of the transition system from overhead.

The box beam transition design was further modified by changing the rubrail from an HSS6x2 rail member to an HSS4x3 rail member. The traffic face of this rubrail section is inset two inches from the traffic face of the box beam rail. In addition to the modified rubrail, a smaller HSS tube was placed inside the main rail and spanned from the end of the rail at the parapet to the first steel post. Part of this added HSS tube was the addition of a third anchor bolt for the main rail. Figure 3.11 shows the updated overall transition system.

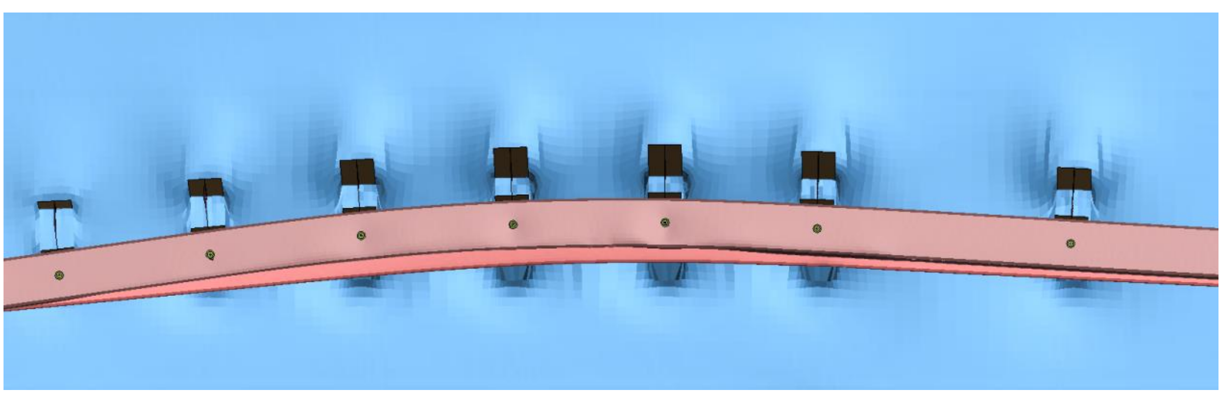

Figure 3.10. Deflection of Box Beam Transition System.

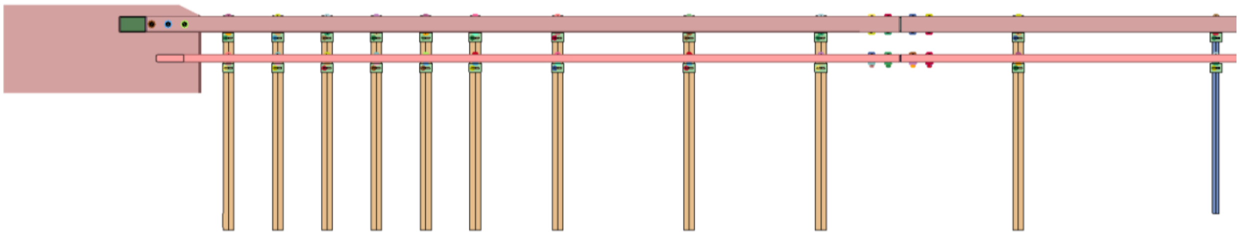

Figure 3.11. Box Beam Transition with HSS4x3 Rubrail.

The stability of the pickup truck was improved in the simulation with the HSS4x3 rubrail. Figure 3.12 shows a comparison of the maximum pickup truck roll angle for the HSS6x2 rubrail and HSS4x3 rubrail.

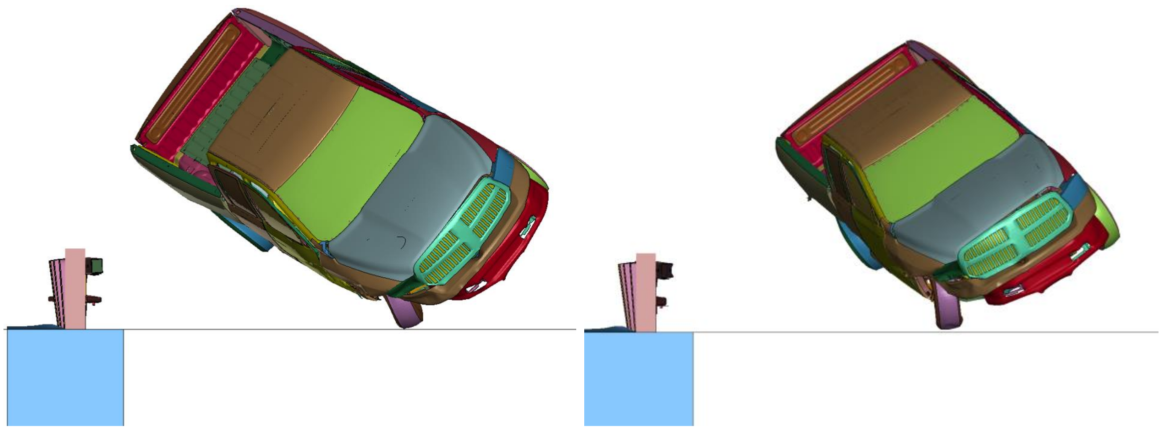

Figure 3.12. HSS6x2 (left) and HSS4x3 (right) Pickup Truck at Maximum Roll Angle.

3.3. FINAL EVALUATION AND CIP DETERMINATION

Simulations were conducted on the final transition design to verify performance of the system for MASH Tests 3-20 and 3-21 evaluation criteria. Additionally, simulations were conducted at different impact locations for each test condition to determine the critical impact location for full-scale crash testing.

The two primary MASH evaluation factors are structural adequacy and occupant risk. In all simulations, the vehicle was successfully contained and redirected. Table 3.1 and Table 3.2 show the occupant risk values for the simulations of MASH Tests 3-20 and 3-21, respectively.

Table 3.1. MASH Test 3-20 Occupant Risk Results.

CIP Location	OIV-x (m/s)	OIV-y (m/s)	RDA-x (g's)	RDA-y (g's)	Roll (°)	Pitch (°)	Yaw (°)
2ft upstream of Parapet End	5.2	8.9	-4	-14.2	6.3	-4.1	-27.4
3ft upstream of Parapet End	5.8	8.8	-4.5	-8.9	7.2	-4.6	-35.9
4ft upstream of Parapet End	6.5	9.4	-3.9	-13.3	9	-5.2	-39.8
5ft upstream of Parapet End	**6.7**	**9.8**	**-4.6**	**-15.1**	**10.4**	**-5.2**	**-44.8**
6ft upstream of Parapet End	7	9.8	-5.3	-16.2	9.9	-4.6	-44.5

Table 3.2. MASH Test 3-21 Occupant Risk Results.

CIP Location	OIV-x (m/s)	OIV-y (m/s)	RDA-x (g's)	RDA-y (g's)	Roll (°)	Pitch (°)	Yaw (°)
6ft upstream of Parapet End	7	9.2	-5.8	-10.8	24.8	-18.5	-38.5
7ft upstream of Parapet End	**7.1**	**9.5**	**-7.3**	**-10.1**	**34.9**	**-19**	**-55.2**
8ft upstream of Parapet End	6.6	8.9	-8.2	10	43	-11.3	-59.9
9ft upstream of Parapet End	6.2	8.6	-7.5	-10.1	35.3	-11.1	-43.4
10ft upstream of Parapet End	5.9	8.3	8	-9.6	36.2	-12.8	-43.9

For MASH Test 3-20, the CIP was determined to be 5 ft upstream of the parapet end. This simulation resulted in one of the higher OIV and RDA metrics and had the highest roll angle. The impact point 6 ft upstream of the parapet end had similar high OIV and RDA metrics, but there was less potential for vehicle interaction with the parapet end.

For MASH Test 3-21, the CIP was determined to be 7 ft upstream of the parapet end. This simulation resulted in the highest OIV, roll angle, and pitch angle.

3.4. UPSTREAM TRANSITION EVALUATION

It was initially planned for the design details of the upstream end of the box beam approach guardrail transition to vertical concrete parapet to be similar to those of the MASH compliant box beam transition to C2P bridge rail that was developed under Phase I of this research (*2*). This system incorporated an HSS6×2 rubrail, and specific termination details for that rubrail at the upstream end of the transition. However, as described above, the rubrail in the box beam transition to vertical concrete parapet was changed to an HSS4×3 to address stability concerns with the pickup truck observed in the impact simulations.

Consequently, a decision was made to evaluate the MASH impact performance of the upstream end of the transition with the HSS4x3 rubrail modification using computer simulation. MASH Test 3-20 and Test 3-21 computer simulations were performed on the upstream end of the transition system with the HSS4x3 rubrail and associated termination details.

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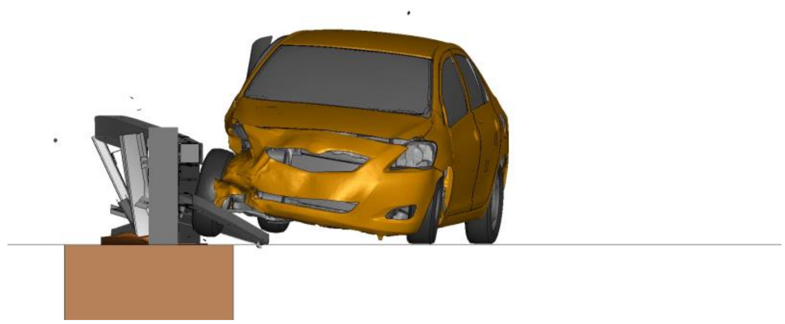

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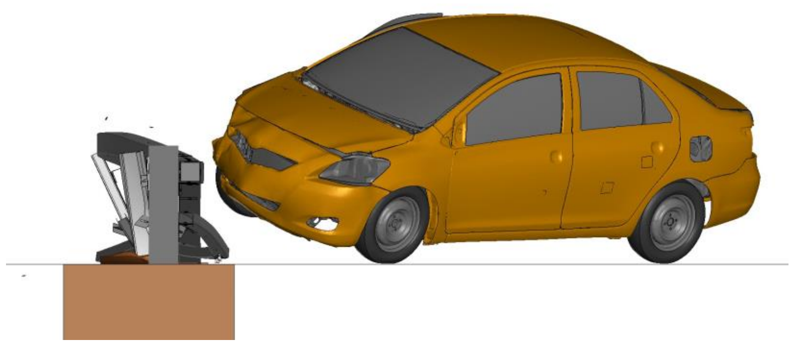

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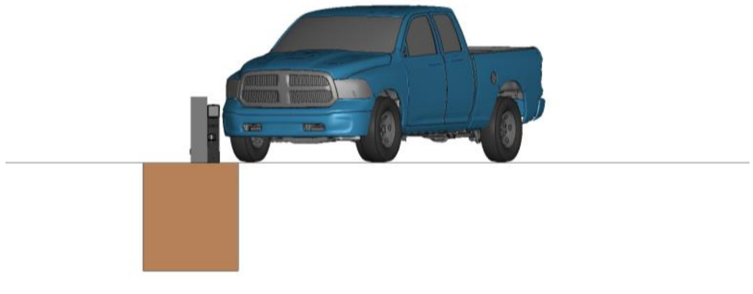
Figure 3.13 and



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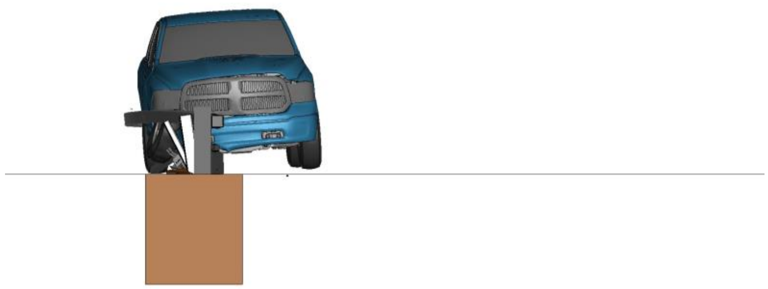

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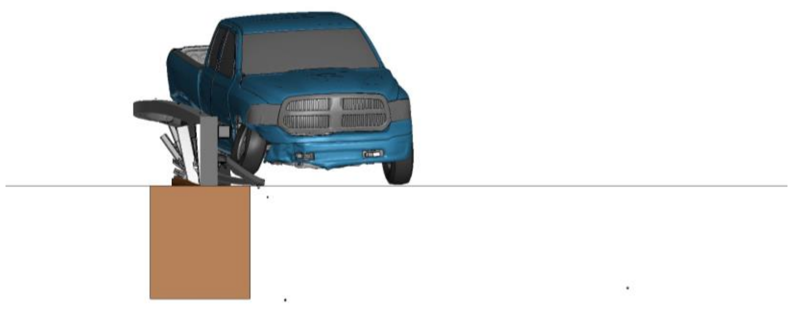

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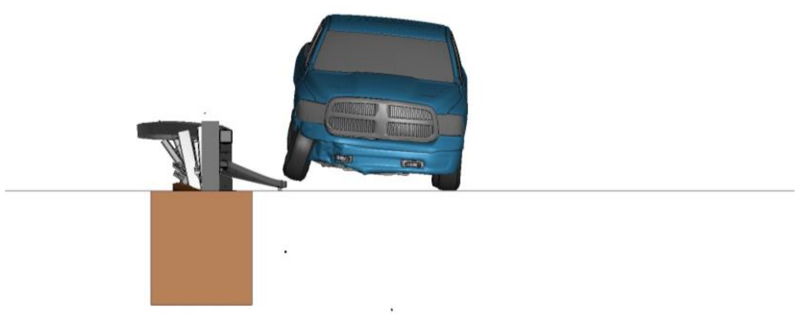

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Figure 3.14 show sequential images for Test 3-20 and Test 3-21 impact simulations, respectively. The impact locations were the same as those conducted in the previous crash tests (*2*).

For both simulations, the occupant risk values were below the MASH limits. In the MASH Test 3-20 impact simulation, the vehicle interacted longer with the transition system and did not exit as quickly compared to the original HSS6×2 rubrail system. However, the 1100C passenger car remained stable throughout the impact event, and the research team considered the performance of the upstream transition system with an HSS4×3 rubrail to be satisfactory.

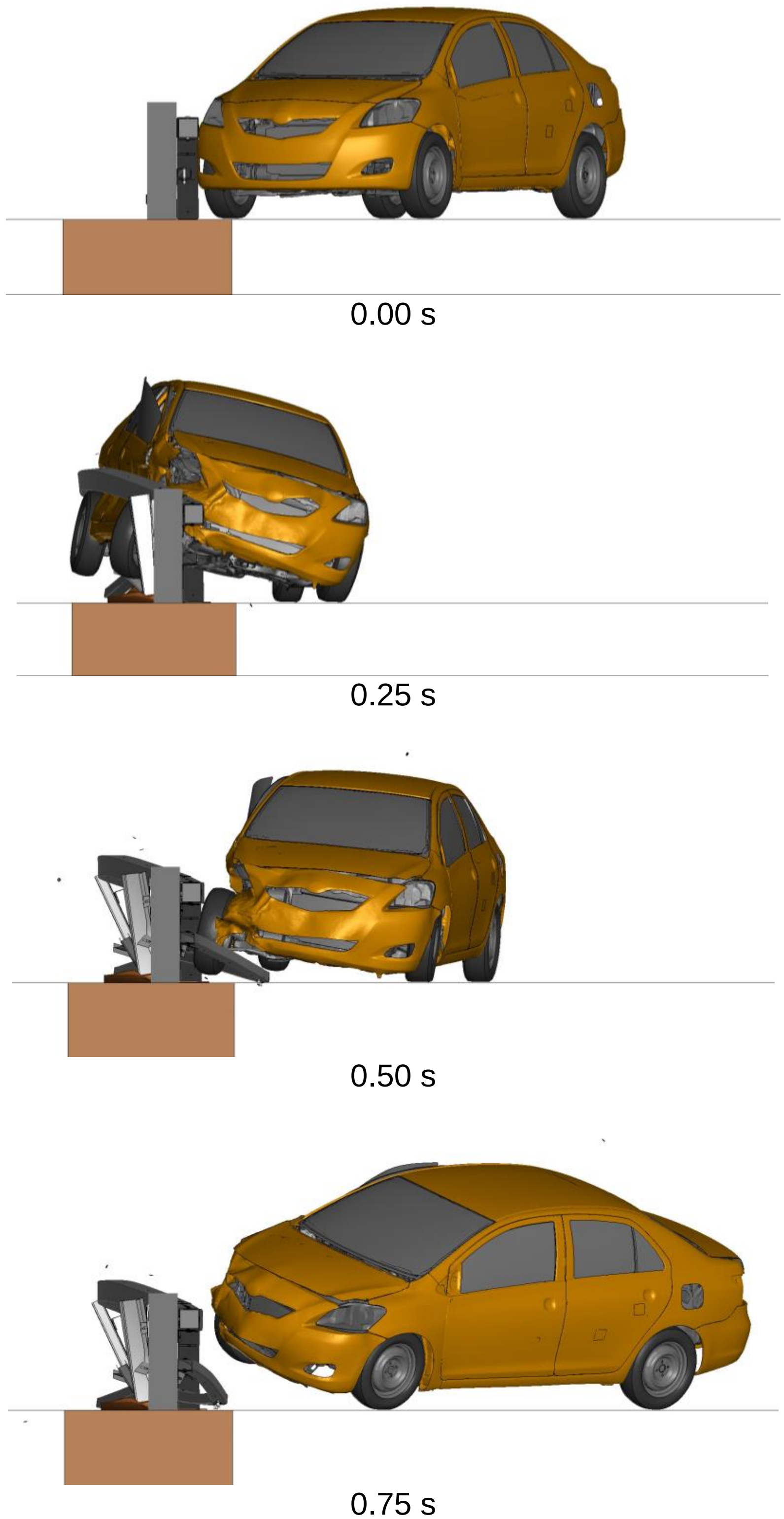

Figure 3.13. MASH 3-20 Simulation – Upstream Section with HSS4x3 Rubrail.

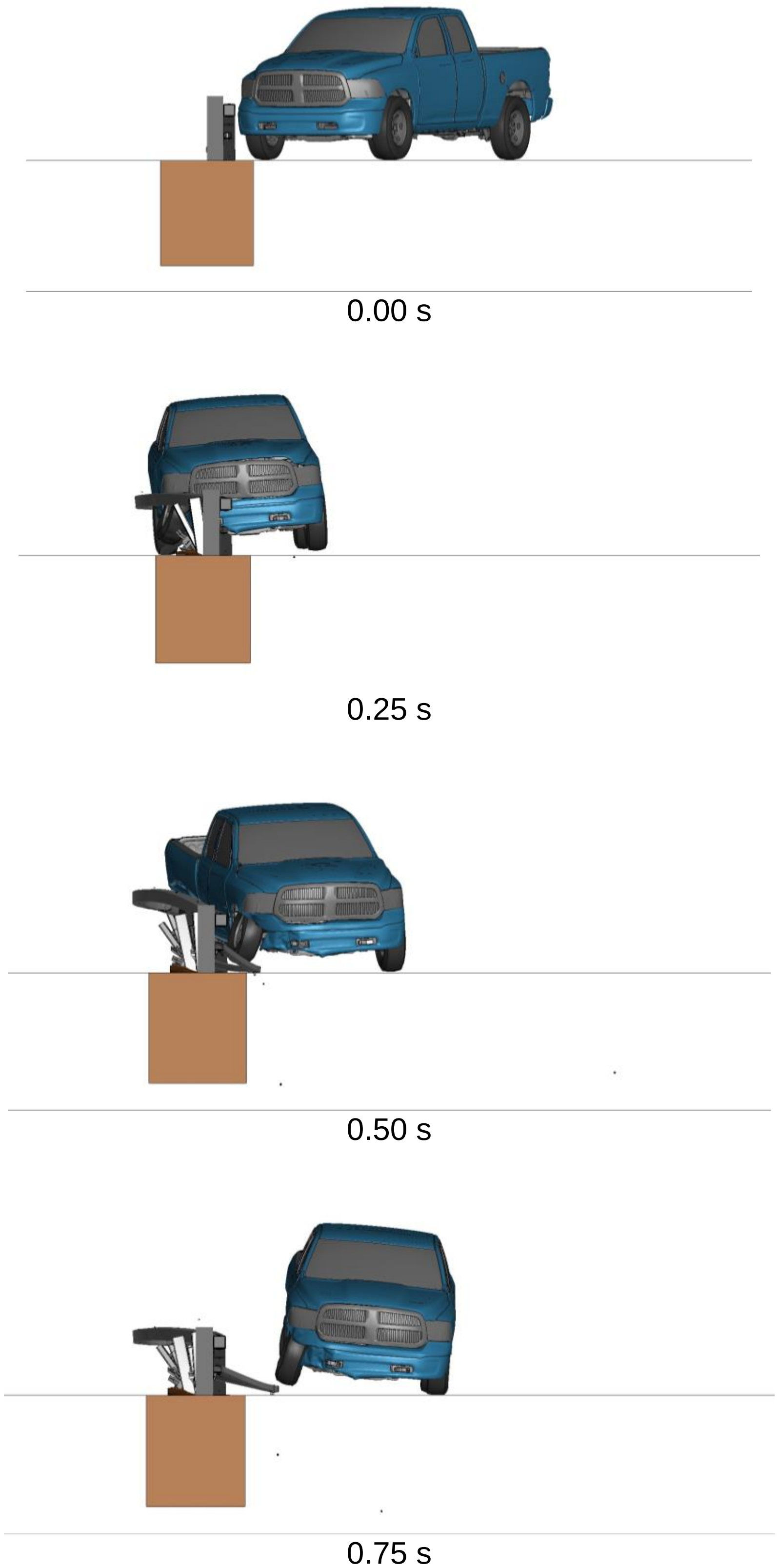

Figure 3.14. MASH 3-21 Simulation – Upstream Section with HSS4x3 Rubrail.

3.5. SUMMARY

Finite element computer simulations were performed to analyze the crashworthiness of a transition system from box beam approach guardrail to a vertical concrete parapet. The impact simulations of the initial transition system concept showed significant snagging potential with the anchor bolts attaching the box beam rail to the concrete parapets. Design modifications were made to the system to improve its impact performance.

After the design was finalized, *MASH* Test 3-20 and Test 3-21 impact simulations were conducted on both the upstream and downstream end to evaluate the transition system according to *MASH* TL-3 criteria and select critical impact points for crash testing.

Overall, the modified box beam transition design to vertical concrete parapet performed acceptably for MASH TL-3 evaluation criteria.

Chapter 4. TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1. CRASH TEST MATRIX

Table 4.1 shows the test conditions and evaluation criteria for *MASH* TL-3 for transitions. The target critical impact points (CIPs) for each test were determined using finite element simulation. Figure 4.1 shows the target CIPs for *MASH* Tests 3-20 and 3-21 on the concrete parapet shape transition. Figure 4.2 shows the target CIPs for *MASH* Tests 3-20 and 3-21 on the box beam guardrail transition to concrete parapet.

Table 4.1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Transition System.

Test Designation	Test Vehicle	Impact Speed	Impact Angle	Evaluation Criteria
3-20	1100C	62 mi/h	25º	A, D, F, H, I
3-21	2270P	62 mi/h	25º	A, D, F, H, I

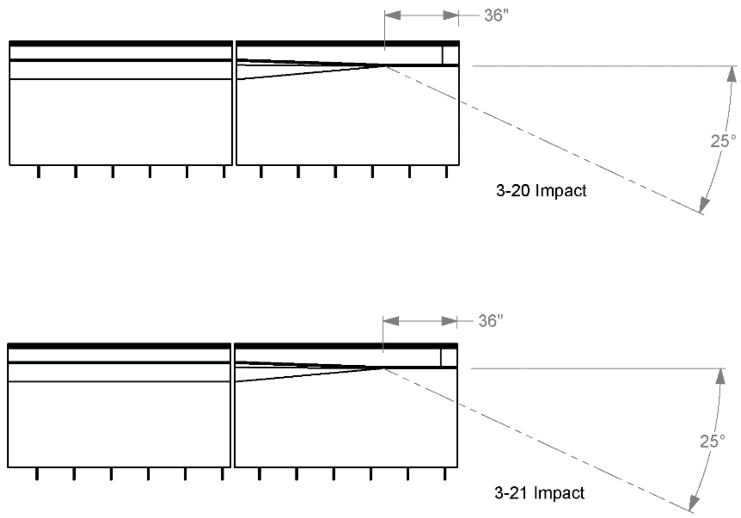

Figure 4.1. Target CIP for *MASH* TL-3 Tests on Concrete Parapet Shape Transition.

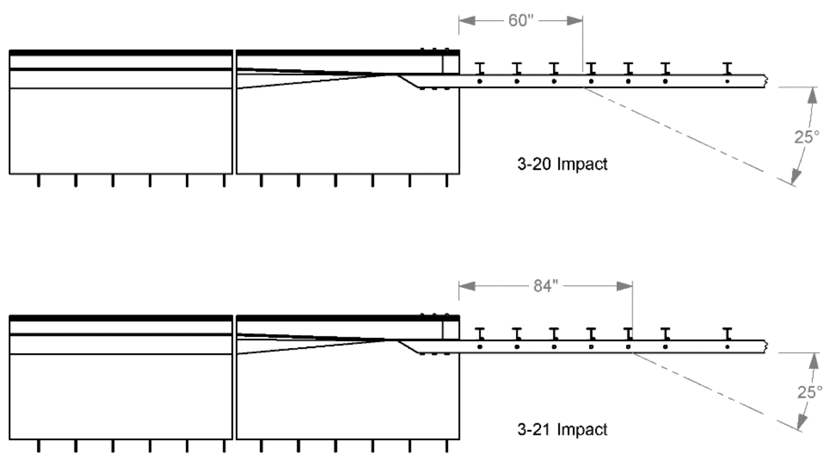

Figure 4.2. Target CIP for *MASH* TL-3 Tests on Box Beam Guardrail Transition to Concrete Parapet.

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 2-2A 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 these evaluation criteria.

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

Evaluation Factors	Evaluation Criteria
A.	Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of *MASH*.
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.
I.	The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.

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 site selected for construction and testing of the transitions was along the edge of an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement but are otherwise flat and level.

5.2. VEHICLE TOW AND GUIDANCE SYSTEM

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

5.3. DATA ACQUISITION SYSTEMS

5.3.1. Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a 16-channel Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid-state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 samples per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit in case the primary battery cable is severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

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

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

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

5.3.2. Anthropomorphic Dummy Instrumentation

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

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

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 Box Beam Guardrail Transition to Concrete Parapet. 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. CRASH TESTING OF CONCRETE PARAPET SHAPE TRANSITION

6.1. CONCRETE PARAPET SHAPE TRANSITION DETAILS

6.1.1. Test Article and Installation Details

The test installation consisted of two independent 9-ft long concrete parapets with a 2-inch open joint between them. The upstream parapet had a vertical profile over the first 3 ft of length followed by a shape transition from a vertical to New Jersey profile over the last 6 ft. The downstream parapet had a New Jersey profile throughout its length. Both parapets were anchored to a separate steel reinforced concrete approach slab.

Figure 6.1 presents overall information on the Concrete Parapet Shape Transition, and Figure 6.2 thru Figure 6.5 provide photographs of the installation for crash tests 611801-03-1 and 611801-03-2. Section A.1. in Appendix A provides further details on the Concrete Parapet Shape Transition. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

6.1.2. Design Modifications during Tests

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

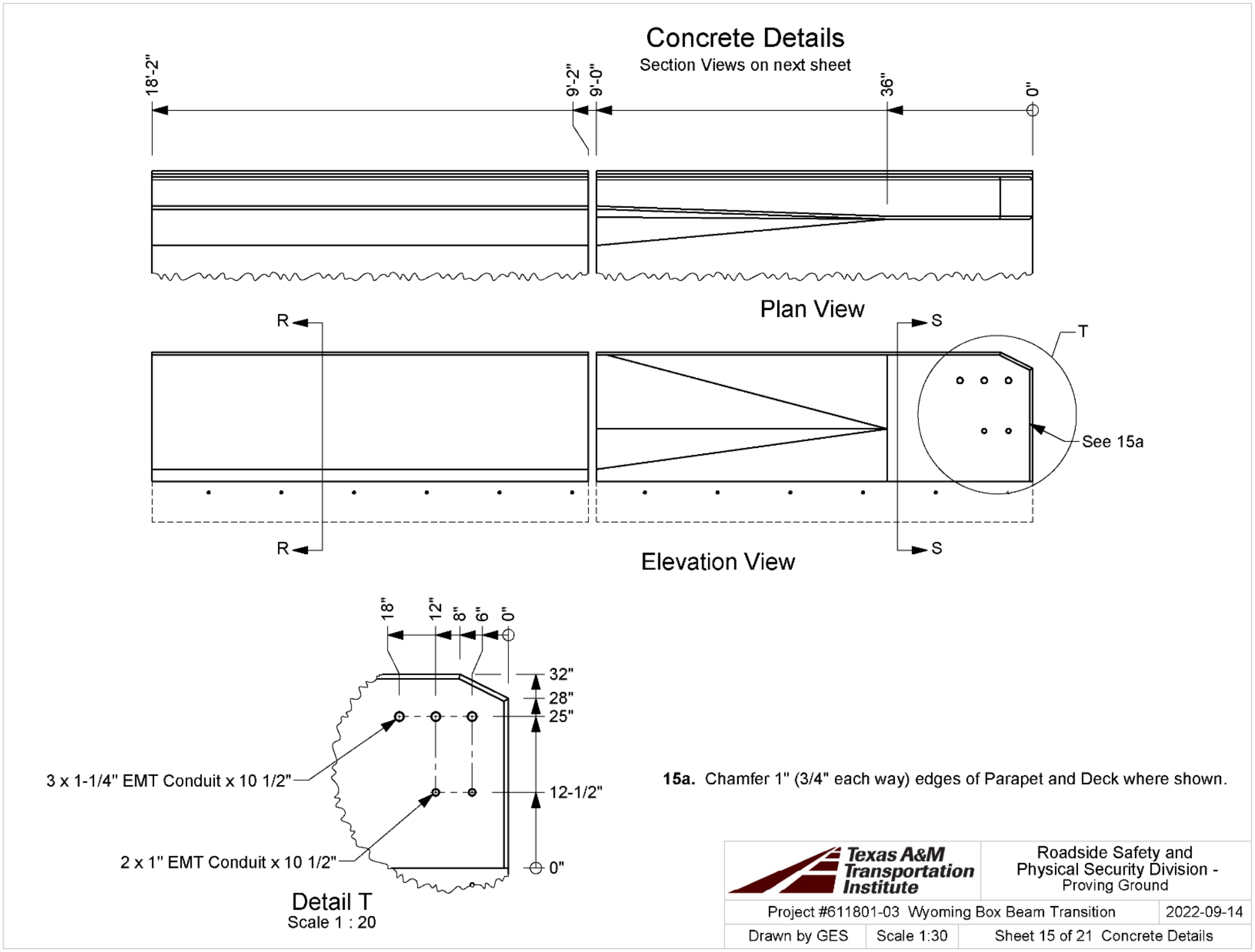

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Figure 6.1. Details of the Concrete Parapet Shape Transition.

Figure 6.2. Concrete Parapet Shape Transition prior to Testing 611801-03-1&2.

Figure 6.3. Concrete Parapet Shape Transition at Impact Prior to Testing 611801-03-1&2.

Figure 6.4. End View of the Concrete Parapet Shape Transition Prior to Testing 611801-03-1&2.

Figure 6.5. Field Side of the Concrete Parapet Shape Transition prior to Testing 611801-03-1&2.

6.1.3. Material Specifications

Appendix B provides material certification documents for the materials used to install/construct the Concrete Parapet Shape Transition. Table 6.1 shows the average compressive strengths of both the parapet and approach slab concrete on the day of the first test (2022-09-15).

Table 6.1. Concrete Strength.

Location	Design Strength (psi)	Avg. Strength (psi)	Age (days)	Detailed Location
Approach Slab	4000	4070	93	100% of Deck
Parapet	4000	4367	77	100% of Parapet

6.2. *MASH* TEST 3-20 (CRASH TEST NO. 611801-03-1)

6.2.1. Test Designation and Actual Impact Conditions

See Table 6.2 for details on impact conditions for this test, and Table 6.3 for the exit parameters. Figure 6.6 and Figure 6.7 depict the target impact setup.

Table 6.2. Impact Conditions for *MASH* 3-20, 611801-03-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	62.1
Impact Angle (deg)	25	±1.5°	24.9
Impact Severity (kip-ft)	51	≥51 kip-ft	55.7
Impact Location	36 inches downstream from the upstream end of the concrete parapet.	± 12 inches	36 inches downstream from the upstream end of the concrete parapet.

Table 6.3. Exit Parameters for *MASH* 3-20, 611801-03-1.

Exit Parameter	Measured
Speed (mi/h)	52.7
Trajectory angle (deg)	5
Heading angle (deg)	9
Brakes applied post impact (s)	Not applied
Vehicle at rest position	155 ft downstream of impact point 74 ft to the traffic side 90° counter-clockwise rotation
Comments:	Vehicle remained upright and stable. Vehicle crossed exit box [a] 62 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 6.6. Concrete Parapet Shape Transition/Test Vehicle Geometrics for Test 611801-03-1.

Figure 6.7. Concrete Parapet Shape Transition/Test Vehicle Impact Location 611801-03-1.

6.2.2. Weather Conditions

Table 6.4 provides the weather conditions for 611801-03-1.

Table 6.4. Weather Conditions 611801-03-1.

Date of Test	2022-09-15 AM
Wind Speed (mi/h)	4
Wind Direction (deg)	100
Temperature (°F)	84
Relative Humidity (%)	63
Vehicle Traveling (deg)	195

6.2.3. Test Vehicle

Figure 6.8 and Figure 6.9 show the 2016 Nissan Versa used for the crash test. Table 6.5 shows key vehicle measurements. Table C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

Figure 6.8. Impact Side of Test Vehicle before Test 611801-03-1.

Figure 6.9. Opposite Impact Side of Test Vehicle before Test 611801-03-1.

Table 6.5. Vehicle Measurements 611801-03-1.

Test Parameter	***MASH***	**Allowed Tolerance**	**Measured**
Dummy (if applicable)[a] (lb)	165	N/A	165
Test Inertial Weight (lb)	2420	±55	2437
Gross Static Weight[a] (lb)	2585	±55	2602
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	41.2
CG above Ground[c,d] (inches)	N/A	N/A	N/A

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

6.2.4. Test Description

Table 6.6 lists events that occurred during Test No. 611801-03-1. Figures C.1 and C.2 in Appendix C.2 present sequential photographs during the test.

Table 6.6. Events during Test 611801-03-1.

Time (s)	Events
0.0000	Vehicle impacted installation
0.0330	Vehicle began to redirect
0.0390	Barrier began to lean toward field side
0.0460	Windshield began to fracture due to body flexing and torsion from impact
0.0600	Barrier leaned maximum amount (1 inch) to field side
0.0740	Front and rear driver's side tires left the pavement
0.1660	Vehicle was parallel with installation
0.1830	Rear passenger bumper impacted barrier
0.2740	Vehicle exited the installation at 52.7mi/h with a heading angle of 8.8 degrees and a trajectory angle of 4.9 degrees

6.2.5. Damage to Test Installation

There was a crack along the traffic side toe of the upstream parapet at the deck, and there was some scuffing at the impact point. Table 6.7 describes the damage to the Concrete Parapet Shape Transition. Figure 6.10 and Figure 6.11 show the damage to the Concrete Parapet Shape Transition.

Table 6.7. Damage to Concrete Parapet Shape Transition 611801-03-1.

Test Parameter	Measured
Permanent Deflection/Location	⅜ inches toward field side, at the parapet joint
Dynamic Deflection	1 inch toward field side
Working Width [a] and Height	21.6 inches, at a height of 36.6 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 6.10. Concrete Parapet Shape Transition after Test at Impact Location 611801-03-1.

Figure 6.11. Concrete Parapet Shape Transition after Test at the Parapet Joint 611801-03-1.

6.2.6. Damage to Test Vehicle

Figure 6.12 and Figure 6.13 show the damage sustained by the vehicle. Figure 6.14 and Figure 6.15 show the interior of the test vehicle. Table 6.8 and Table 6.9 provide details on the occupant compartment deformation and exterior vehicle damage. Tables

C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.

Figure 6.12. Impact Side of Test Vehicle after Test 611801-03-1.

Figure 6.13. Rear Impact Side of Test Vehicle after Test 611801-03-1.

Figure 6.14. Overall Interior of Test Vehicle after Test 611801-03-1.

Figure 6.15. Interior of Test Vehicle on Impact Side after Test 611801-03-1.

Table 6.8. Occupant Compartment Deformation 611801-03-1.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	0 inches
Windshield	≤3.0 inches	2.3 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	5 inches
Front Door (above Seat)	≤9.0 inches	5 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 6.9. Exterior Vehicle Damage 611801-03-1.

Side Windows	The right front window shattered due to stresses from the flexing of the car door during impact.
Maximum Exterior Deformation	8 inches in the front plane at the right front corner just above bumper height
VDS	01RFQ4
CDC	01FREW3
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, hood, grill, radiator and support, right front strut and tower, right front tire and rim, right front quarter fender, windshield, right A-pillar, right front door and glass, right front floor pan, roof, right rear door, right rear rim, right rear quarter fender, right tail light, and rear bumper were all damaged. The windshield had a 46-inch by 28-inch break that had a maximum depth of 2.3 inches which was caused by the flexing of the vehicle during impact and not due to penetration of the test article. The right front door had a 6-inch gap at the top. The roof had two dents at the B-pillar. One measured 5 inches by 8 inches by 0.5 inches deep, and the other 6 inches square and 0.5 inches deep.

6.2.7. Occupant Risk Factors

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.10. Figure C.3 in Appendix C.3 shows the vehicle angular displacements, and Figures C.4 through C.6 in Appendix C.4 show acceleration versus time traces.

Table 6.10. Occupant Risk Factors for Test 611801-03-1.

Test Parameter	*MASH* [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	21.4	0.0771 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	31.2	0.0771 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	3.2	0.0771 - 0.0871 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	9.0	0.1994 - 0.2094 seconds
THIV (m/s)	N/A	11.6	0.0756 seconds on right side of interior
ASI	N/A	2.6	0.0484 - 0.0984 seconds
50-ms MA Longitudinal (g)	N/A	-12.2	0.0188 - 0.0688 seconds
50-ms MA Lateral (g)	N/A	-19.5	0.0240 - 0.0740 seconds
50-ms MA Vertical (g)	N/A	3.5	0.0000 - 0.0500 seconds
Roll (deg)	≤75	20	0.4740 seconds
Pitch (deg)	≤75	17	0.7250 seconds
Yaw (deg)	N/A	104	4.9999 seconds

F. *Values in italics are the preferred MASH values*

6.2.8. Test Summary

Figure 6.16 summarizes the results of *MASH* Test 611801-03-1.

0.000 s

0.200 s

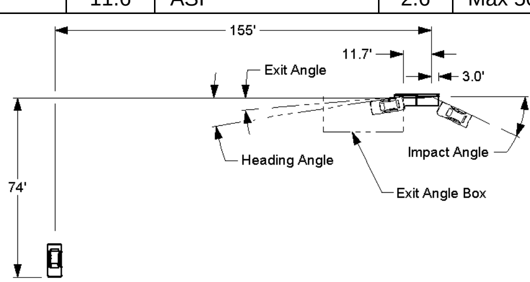
0.400 s

0.600 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-20
TTI Project No.	611801-03-1
Test Date	2022-09-15
TEST ARTICLE	
Type	Transition System
Name	Concrete Parapet Shape Transition
Length	18 feet
Key Materials	32-inch-high concrete parapet and 60-inch wide concrete deck
Soil Type and Condition	Concrete, damp
TEST VEHICLE	
Type/Designation	1100 C
Year, Make and Model	2016 Nissan Versa
Inertial Weight (lb)	2437
Dummy (lb)	165
Gross Static (lb)	2602
IMPACT CONDITIONS	
Impact Speed (mi/h)	62.1
Impact Angle (deg)	24.9
Impact Location	36 inches downstream from the upstream end of the concrete parapet.
Impact Severity (kip-ft)	55.7
EXIT CONDITIONS	
Exit Speed (mi/h)	52.7
Trajectory/Heading Angle (deg)	5 / 9
Exit Box Criteria	Vehicle crossed
Stopping Distance	155 ft downstream 74 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	1
Permanent (inches)	⅜
Working Width / Height (inches)	21.6 / 36.6
VEHICLE DAMAGE	
VDS	01RFQ4
CDC	01FREW3
Max. Ext. Deformation	8
Max Occupant Compartment Deformation	5 inches at the side panel and in the door.

OCCUPANT RISK VALUES

Long. OIV (ft/s)	21.4	Long. Ridedown (g)	3.2	Max 50-ms Long. (g)	-12.2	Max Roll (deg)	20
Lat. OIV (ft/s)	31.2	Lat. Ridedown (g)	9.0	Max 50-ms Lat. (g)	-19.5	Max Pitch (deg)	17
THIV (m/s)	11.6	ASI	2.6	Max 50-ms Vert. (g)	3.5	Max Yaw (deg)	104



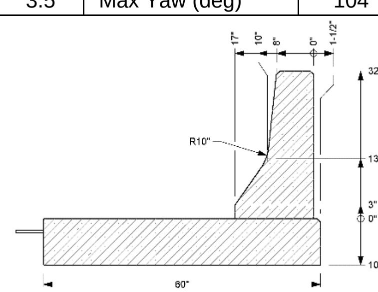


Figure 6.16. Summary of Results for *MASH* Test 3-20 on Concrete Parapet Shape Transition.

6.3. *MASH* TEST 3-21 (CRASH TEST NO. 611801-03-2)

6.3.1. Test Designation and Actual Impact Conditions

See Table 6.11 for details on impact conditions for this test, and Table 6.12 for the exit parameters. Figure 6.17 and Figure 6.18 depict the target impact setup.

Table 6.11. Impact Conditions for *MASH* 3-21 611801-03-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62 mi/h	± 2.5 mi/h	62.6
Impact Angle (deg)	25°	± 1.5°	24.3
Impact Severity (kip-ft)	106 kip-ft	≥106 kip-ft	111.2
Impact Location	36 inches downstream from the upstream end of the concrete parapet.	± 12 inches	43.2 inches downstream from the upstream end of the concrete parapet.

Table 6.12. Exit Parameters for *MASH* 3-21 611801-03-2.

Exit Parameter	Measured
Speed (mi/h)	49.4
Trajectory angle (deg)	2
Heading angle (deg)	7
Brakes applied post impact (s)	2.4
Vehicle at rest position	189 ft downstream of impact point 7 ft to the field side 90° clockwise rotation
Comments:	Vehicle remained upright and stable. Vehicle crossed exit box [a] 101 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 6.17. Concrete Parapet Shape Transition/Test Vehicle Geometrics for Test 611801-03-2.

Figure 6.18. Concrete Parapet Shape Transition/Test Vehicle Impact Location 611801-03-2.

6.3.2. Weather Conditions

Table 6.13 provides the weather conditions for 611801-03-2.

Table 6.13. Weather Conditions 611801-03-2.

Date of Test	2022-09-28 AM
Wind Speed (mi/h)	5
Wind Direction (deg)	137
Temperature (°F)	81
Relative Humidity (%)	37
Vehicle Traveling (deg)	195

6.3.3. Test Vehicle

Figure 6.19 and Figure 6.20 show the 2016 RAM 1500 used for the crash test. Table 6.14 shows key vehicle measurements. Table D.1 in Appendix D.1 gives additional dimensions and information on the vehicle.

Figure 6.19. Impact Side of Test Vehicle before Test 611801-03-2.

Figure 6.20. Opposite Impact Side of Test Vehicle before Test 611801-03-2.

Table 6.14. Vehicle Measurements 611801-03-2.

Test Parameter	***MASH***	**Allowed Tolerance**	**Measured**
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Test Inertial Weight (lb)	5000	± 110	5011
Gross Static Weight[a] (lb)	5000	± 110	5011
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	61.29
CG above Ground[c,d] (inches)	28	≥28	28.5

[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.

6.3.4. Test Description

Table 6.15 lists events that occurred during Test No. 611801-03-2. Figures D.1 and D.2 in Appendix D.2 present sequential photographs during the test.

Table 6.15. Events during Test 611801-03-2.

Time (s)	Events
0.0000	Vehicle impacted installation
0.0250	Concrete Barrier began to lean toward field side
0.0470	Vehicle began to redirect
0.0830	Front drivers side tires left the pavement
0.1030	Barrier leaned maximum amount (3.7 inches) to field side
0.1170	Rear drivers side tires left the pavement
0.2080	Vehicle was parallel with installation
0.2100	Rear passenger bumper impacted barrier
0.4150	Vehicle exited the installation at 49.4 mi/h with a heading angle of 7.5 degrees and a trajectory angle of 1.9 degrees

6.3.5. Damage to Test Installation

The upstream parapet was leaning 0.3° back from vertical prior to impact. After impact, it was leaning 3.0° back. The offset of the two parapets along the top field side edge enlarged from ⅜-inch to 2⅝ inches. There was significant damage to the concrete at the top of the joint with rebar exposed on the upstream end of the downstream parapet. The impacted parapet was pushed back ½-inch at grade and was raised up ½-inch at the joint on the traffic side.

Table 6.16 describes the damage to the Concrete Parapet Shape Transition. Figure 6.21 and Figure 6.22 show the damage to the Concrete Parapet Shape Transition.

Table 6.16. Damage to Concrete Parapet Shape Transition 611801-03-2.

Test Parameter	Measured
Permanent Deflection/Location	2.25 inches toward field side, at the downstream end of the upstream parapet.
Dynamic Deflection	3.7 inches toward field side, at the downstream end of the upstream parapet.
Working Width [a] and Height	29.6 inches, at a height of 62.2 inches (corresponding to the right-side mirror of the vehicle)

[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 6.21. Concrete Parapet Shape Transition after Test at Impact Location 611801-03-2.

Figure 6.22. Concrete Parapet Shape Transition after Test at the Parapet Joint 611801-03-2.

6.3.6. Damage to Test Vehicle

Figure 6.23 and Figure 6.24 show the damage sustained by the vehicle. Figure 6.25 and Figure 6.26 show the interior of the test vehicle. Table 6.17 and Table 6.18 provide details on the occupant compartment deformation and exterior vehicle damage. Tables

D.2 and D.3 in Appendix D.1 provide exterior crush and occupant compartment measurements.

Figure 6.23. Impact Side of Test Vehicle after Test 611801-03-2.

Figure 6.24. Rear Impact Side of Test Vehicle after Test 611801-03-2.

Figure 6.25. Overall Interior of Test Vehicle after Test 611801-03-2.

Figure 6.26. Interior of Test Vehicle on Impact Side after Test 611801-03-2.

Table 6.17. Occupant Compartment Deformation 611801-03-2.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	0.0 inches
Windshield	≤3.0 inches	0.0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0.0 inches
Foot Well/Toe Pan	≤9.0 inches	3.5 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0.0 inches
Side Front Panel	≤12.0 inches	2.5 inches
Front Door (above Seat)	≤9.0 inches	1.5 inches
Front Door (below Seat)	≤12.0 inches	0.0 inches

Table 6.18. Exterior Vehicle Damage 611801-03-2.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	12 inches in the front plane at the right front corner at bumper height
VDS	01RFQ4
CDC	01FREW3
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, grill, right and left headlight, right front quarter fender, windshield, right front door, right front floor pan, right front tire and rim, right rear door, right cab corner, right rear quarter fender, right rear tire and rim, and rear bumper were damaged. The windshield had some minor stress fractures, which were caused by the flexing of the vehicle during impact and not due to penetration of the test article, and the right front door had a 4-inch gap at the top.

6.3.7. Occupant Risk Factors

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.19. Figure D.3 in Appendix D.3 shows the vehicle angular displacements, and Figures D.4 through D.6 in Appendix D.4 show acceleration versus time traces.

Table 6.19. Occupant Risk Factors for Test 611801-03-2.

Test Parameter	***MASH*** [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	23.9	0.0957 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	25.2	0.0957 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	4.4	0.1019 - 0.1119 s
Ridedown, Lateral (g)	≤20.49 *15.0*	7.2	0.2417 - 0.2517 s
THIV (m/s)	N/A	9.7	0.0932 seconds on right side of interior
ASI	N/A	1.8	0.0576 - 0.1076 s
50-ms MA Longitudinal (g)	N/A	-11.0	0.0470 - 0.0970 s
50-ms MA Lateral (g)	N/A	-13.2	0.0322 - 0.0822 s
50-ms MA Vertical (g)	N/A	-2.6	0.0030 - 0.0530 s
Roll (deg)	≤75	36	0.6788 s
Pitch (deg)	≤75	10	0.6729 s
Yaw (deg)	N/A	45	1.0096 s

F. *Values in italics are the preferred MASH values*

6.3.8. Test Summary

Figure 6.27 summarizes the results of *MASH* Test 611801-03-2.

0.000 s

0.200 s

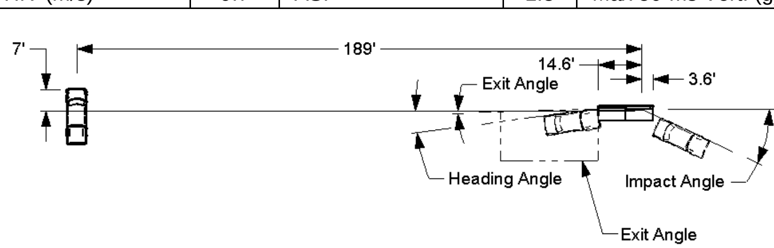
0.400 s

0.600 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-21
TTI Project No.	611801-03-2
Test Date	2022-09-28
TEST ARTICLE	
Type	Transition System
Name	Concrete Parapet Shape Transition
Length	18
Key Materials	32-inch-high concrete parapet and 60-inch wide concrete deck
Soil Type and Condition	Concrete, damp
TEST VEHICLE	
Type/Designation	2270 P
Year, Make and Model	2016 RAM 1500
Inertial Weight (lb)	5011
Dummy (lb)	N/A
Gross Static (lb)	5011
IMPACT CONDITIONS	
Impact Speed (mi/h)	62.6
Impact Angle (deg)	24.3
Impact Location	43.2 inches downstream from the upstream end of the concrete parapet.
Impact Severity (kip-ft)	111.2
EXIT CONDITIONS	
Exit Speed (mi/h)	49.4
Trajectory/Heading Angle (deg)	2 / 7
Exit Box Criteria	Crossed
Stopping Distance	189 ft downstream 7 ft to the field side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	3.7
Permanent (inches)	2¼
Working Width / Height (inches)	29.6 / 62.2
VEHICLE DAMAGE	
VDS	01RFQ4
CDC	01FREW3
Max. Ext. Deformation	12 inches
Max Occupant Compartment Deformation	3 inches in the kick panel

OCCUPANT RISK VALUES

Long. OIV (ft/s)	23.9	Long. Ridedown (g)	4.4	Max 50-ms Long. (g)	-11.0	Max Roll (deg)	36
Lat. OIV (ft/s)	25.2	Lat. Ridedown (g)	7.2	Max 50-ms Lat. (g)	-13.2	Max Pitch (deg)	10
THIV (m/s)	9.7	ASI	1.8	Max 50-ms Vert. (g)	-2.6	Max Yaw (deg)	45



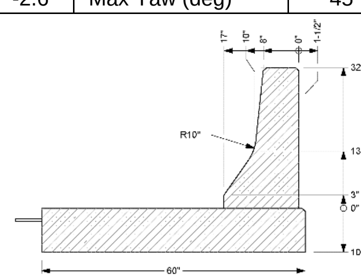


Figure 6.27. Summary of Results for *MASH* Test 3-21 on Concrete Parapet Shape Transition.

Chapter 7. CRASH TESTING OF BOX BEAM GUARDRAIL TRANSITION TO CONCRETE PARAPET

7.1. CONCRETE PARAPET SHAPE TRANSITION DETAILS

7.1.1. Test Article and Installation Details

The test installation consisted of the previously described concrete transition parapet, box beam stiffness transition, box beam guardrail, and box beam guardrail anchorage. The upstream concrete transition parapet was reconstructed prior to the box beam transition tests. The spacing of the anchorage bars was reduced from 6 inches to 5 inches to increase strength and reduce maintenance for direct impacts.

The box beam stiffness transition consisted of an HSS 6×6×3⁄16-inch upper traffic rail and an HSS 4×3×¼-inch lower rub-rail mounted on steel posts of different sizes and spacing using steel angle brackets. The top of the traffic rail was 28 inches above grade, and the top of the rub-rail was at 14 inches above grade. The rub-rail turned back and down at post 17 and was secured to the field side of post 16 near grade level. The transition rails were bolted to the vertical portion of the concrete transition parapet. The ends of the rails were tapered to mitigate vehicle snagging in reverse-direction impacts. A 36-inch long, HSS 5×5×¼-inch stiffening sleeve was inserted inside the downstream end of the HSS 6×6×3⁄16-inch upper traffic rail.

The 72 ft of box beam guardrail attached to the upstream end of the transition was comprised of an HSS 6×6×3⁄16-inch rail mounted 28 inches above grade and attached to S3×5.7 posts with 8×24-inch soil plates using L5×3½-inch angle brackets. The 23-ft 5-inch-long terminal section was comprised of a single HSS 6×6×3⁄16-inch rail that turned down between posts 1 and 2 and was anchored to an unreinforced concrete block via anchor bolts cast into the block.

Figure 7.1 presents overall information on the Box Beam Guardrail Transition to Concrete Parapet, and Figure 7.2 thru Figure 7.5 provide photographs of the installation for crash tests 611801-04-1 and 6110801-04-2 prior to testing. Section A.2. in Appendix A provides further details on the Box Beam Guardrail Transition to Concrete Parapet. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

7.1.2. Design Modifications during Tests

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

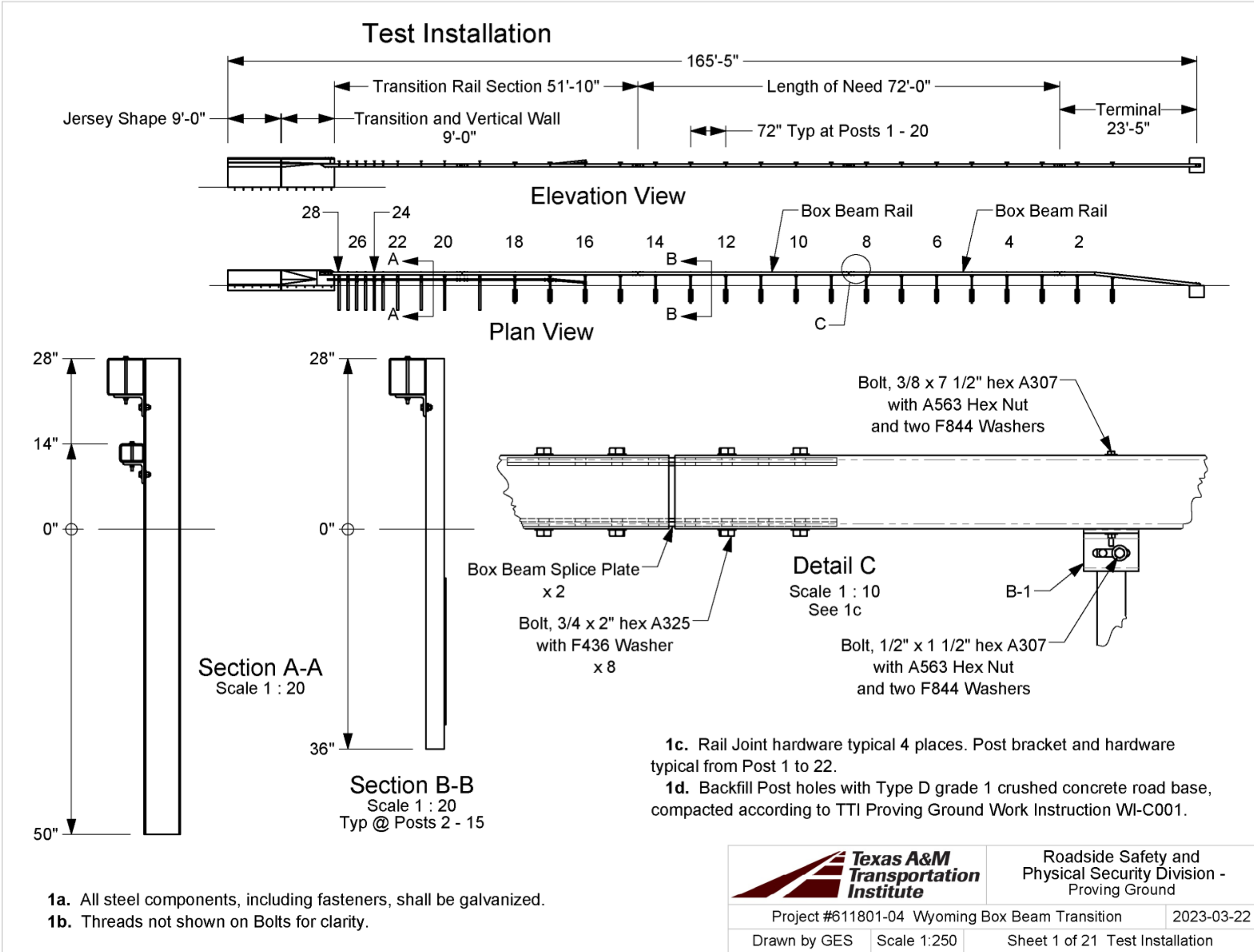


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Figure 7.1. Details of Box Beam Guardrail Transition to Concrete Parapet.

Figure 7.2. Box Beam Guardrail Transition to Concrete Parapet prior to Testing 611801-04-1&2.

Figure 7.3. Box Beam Guardrail Transition to Concrete Parapet at Impact Prior to Testing 611801-04-1&2.

Figure 7.4. Box Beam Guardrail Transition to Concrete Parapet at the Box Beam Transition prior to Testing 611801-04-1&2.

Figure 7.5. Field Side of the Box Beam Guardrail Transition to Concrete Parapet prior to Testing 611801-04-1&2.

7.1.3. Material Specifications

Appendix B provides material certification documents for the materials used to install/construct the Box Beam Guardrail Transition to Concrete Parapet. Table 7.1 shows the average compressive strengths of the reconstructed concrete transition parapet and approach slab on the day of the first box beam transition test (2023-03-23).

Table 7.1. Concrete Strength.

Location	Design Strength (psi)	Avg. Strength (psi)	Age (days)	Detailed Location
Reconstructed Approach Slab	4000	5657	44	100% of Deck
Reconstructed Parapet	4000	5083	33	100% of Parapet

7.1.4. Soil Conditions

The test installation was installed in standard soil meeting Type 1 Grade D of AASHTO standard specification M147-17 “Materials for Aggregate and Soil Aggregate Subbase, Base, and Surface Courses.”

In accordance with Appendix B of *MASH*, soil strength was measured the day of each crash test. During installation of the Box Beam Guardrail Transition to Concrete Parapet for full-scale crash testing, two 6-ft long W6×16 posts were installed in the immediate vicinity of the Box Beam Guardrail Transition to Concrete Parapet using the same fill materials and installation procedures used in the test installation and the standard dynamic test.

The minimum post loads are shown in and

On the day of Test 3-20, 2023-03-23, loads obtained from the post pull test are shown in Table 7.2. The soil in which the Box Beam Guardrail Transition to Concrete Parapet was installed met minimum *MASH* requirements for soil strength.

Table 7.2. Soil Strength Before Test 611801-04-1.

Displacement (in)	Minimum Load (lb)	Actual Load (lb)
5	4420	10,242
10	4981	10,060
15	5282	10,152

On the day of Test 3-21, 2023-03-30, loads obtained from the post pull test are shown in Table 7.3. The soil in which the Box Beam Guardrail Transition to Concrete Parapet was installed met minimum *MASH* requirements for soil strength.

Table 7.3. Soil Strength Before Test 61801-04-2.

Displacement (in)	Minimum Load (lb)	Actual Load (lb)
5	4420	8545
10	4981	9515
15	5282	10,181

7.2. *MASH* TEST 3-20 (CRASH TEST 611801-04-1)

7.2.1. Test Designation and Actual Impact Conditions

See Table 7.4 for details of impact conditions for this test and Table 7.5 for the exit parameters. Figure 7.6 and Figure 7.7 depict the target impact setup.

Table 7.4. Impact Conditions for *MASH TEST 3-20,* Crash Test 611801-04-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	61.8
Impact Angle (deg)	25	±1.5°	25.0
Impact Severity (kip-ft)	51	≥51 kip-ft	55.8
Impact Location	60 inches upstream from the end of the concrete parapet	±12 inches	59.7 inches upstream from the end of the concrete parapet

Table 7.5. Exit Parameters for *MASH TEST 3-20,* Crash Test 611801-04-1.

Exit Parameter	Measured
Speed (mi/h)	48.0
Trajectory angle (deg)	4.5
Heading angle (deg)	5.9
Brakes applied post impact (s)	1.6
Vehicle at rest position	118 ft downstream of impact point 7 ft to the traffic side 175° left
Comments:	Vehicle remained upright and stable. Vehicle did not cross the exit box.

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

Figure 7.6. Box Beam to Concrete Barrier Transition/Test Vehicle Geometrics for Test 611801-04-1.

Figure 7.7. Box Beam to Concrete Barrier Transition/Test Vehicle Impact Location 611801-04-1.

7.2.2. Weather Conditions

Table 7.6 provides the weather conditions for 611801-04-1.

Table 7.6. Weather Conditions 611801-04-1.

Date of Test	2023-03-23 AM
Wind Speed (mi/h)	13
Wind Direction (deg)	198
Temperature (°F)	76
Relative Humidity (%)	84
Vehicle Traveling (deg)	195

7.2.3. Test Vehicle

Figure 7.8 and Figure 7.9 show the 2017 Nissan Versa used for the crash test. Table 7.7 shows key vehicle measurements. Figure E.1 in Appendix E.1 gives additional dimensions and information on the vehicle.

Figure 7.8. Impact Side of Test Vehicle before Test 611801-04-1.

Figure 7.9. Opposite Impact Side of Test Vehicle before Test 611801-04-1.

Table 7.7. Vehicle Measurements for Test 611801-04-1.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	165
Test Inertial Weight (lb)	2420	±55	2448
Gross Static Weight[a] (lb)	2585	±55	2613
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	30.8
Track Width[b] (inches)	59	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	41.9
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.

7.2.4. Test Description

Table 7.8 lists events that occurred during Test 611801-04-1. Figures E.4, E.5, and E.6 in Appendix E.2 present sequential photographs during the test.

Table 7.8. Events during Test 611801-04-1.

Time (s)	Events
0.0000	Vehicle impacted installation
0.0290	Vehicle began to redirect
0.0250	Posts 25 and 26 began to lean toward field side
0.0280	Posts 27 and 28 began to lean toward field side
0.0500	Windshield began to fracture due to body flexing and torsion from the impact
0.1800	Vehicle was parallel with installation
0.3240	Vehicle exited the installation at 48 mi/h with a heading angle of 5.9 degrees and a trajectory angle of 4.5 degrees

7.2.5. Damage to Test Installation

The rails were scuffed at impact, and the traffic rail was deformed at post 27. The parapet was also scuffed. Table 7.9 provides the post soil gap and lean after the test. t/s: traffic side; f/s: field side

Table 7.10 describes the deflection and working width of the Box Beam to Concrete Barrier Transition. Figure 7.10 and Figure 7.11 show the damage to the Box Beam to Concrete Barrier Transition.

Table 7.9. Post Soil Gap and Displacement of the Box Beam to Concrete Barrier Transition for Test 611801-04-1.

Post #	Soil Gap	Post Lean from Vertical
23	Soil Disturbed	0.0°
24	⅛-inch t/s & f/s	0.3°
25	⅛-inch t/s & ¼-inch f/s	0.3°
26	⅛-inch t/s & ¼-inch f/s	0.4°
27	¼-inch f/s	0.4°
28	⅛-inch t/s	0.3°

t/s: traffic side; f/s: field side

Table 7.10. Deflection and Working Width of the Box Beam to Concrete Barrier Transition for Test 611801-04-1.

Test Parameter	Measured
Permanent Deflection/Location	0.25 inches toward field side at post 27
Dynamic Deflection	1.3 inches toward field side, top of rail at post 26
Working Width [a] and Height	17.0 inches at a height of 32.0 inches, representing the top field side edge of the concrete barrier

[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 7.10. Box Beam to Concrete Barrier Transition at Impact Location after Test 611801-04-1.

Figure 7.11. Overall View of the Box Beam to Concrete Barrier Transition after Test 611801-04-1.

7.2.6. Damage to Test Vehicle

Figure 7.12 and Figure 7.13 show the damage sustained by the vehicle. Figure 7.14 and Figure 7.15 show the interior of the test vehicle. Table 7.11 and Table 7.12 provide details on the occupant compartment deformation and exterior vehicle damage. Figures E.2 and E.3 in Appendix E.1 provide exterior crush and occupant compartment measurements.

Figure 7.12. Impact Side of Test Vehicle after Test 611801-04-1.

Figure 7.13. Door on the Impact Side of Test Vehicle after Test 611801-04-1.

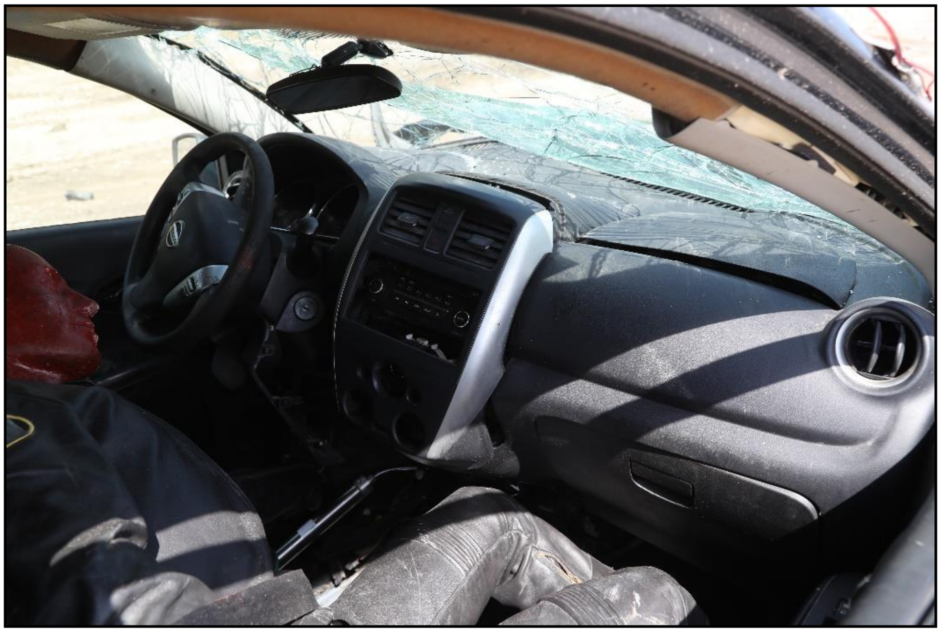


Figure 7.14. Overall Interior of Test Vehicle after Test 611801-04-1.

Figure 7.15. Interior of Test Vehicle on Impact Side after Test 611801-04-1.

Table 7.11. Occupant Compartment Deformation 611801-04-1.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	0.0 inches
Windshield	≤3.0 inches	Video shows cracking in the windshield due to the vehicle impacting the barrier, however, the majority of the windshield damage was from a secondary impact with an object not part of the test. This can be seen in the Real Time video.
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0.0 inches
Foot Well/Toe Pan	≤9.0 inches	1.0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0.0 inches
Side Front Panel	≤12.0 inches	1.0 inches
Front Door (above Seat)	≤9.0 inches	3.0 inches
Front Door (below Seat)	≤12.0 inches	0.0 inches

Table 7.12. Exterior Vehicle Damage 611801-04-1.

Side Windows	The front side window on the impact side was shattered due to the flexing of the vehicle during impact, and not from contact with or penetration of the test article
Maximum Exterior Deformation	10 inches in the front plate at the right front corner at bumper height.
VDS	01RFQ5
CDC	01FREW3
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, hood, grill, right front strut and tower, right front tire and rim, right front quarter fender, right front door, right front floor pan, right rear door, right rear quarter fender, right rear rim, and right rear bumper were damaged. The right front door had a 5.25-inch gap at the top. From the video we can tell the windshield was cracked from the resultant vehicle body flexing due to the initial impact. After exiting the installation, the vehicle impacted a neighboring installation, which caused damage on the side opposite of impact with the target installation, and a rupture was also created in the windshield. The results of this secondary hit are not recorded in this report, with the exception of the vehicle damage photographs.

7.2.7. Occupant Risk Factors

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 7.13. Figure E.7 in Appendix E.3 shows the vehicle angular displacements, and Figures E.8 through E.10 in Appendix E.4 show acceleration versus time traces.

Table 7.13. Occupant Risk Factors for Test 611801-04-1.

Test Parameter	*MASH* [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	22.1	0.0798 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	33.5	0.0798 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	3.6	0.0962 - 0.1062 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	7.2	0.1981 - 0.2081 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	12.3	0.0786 seconds on right side of interior
Acceleration Severity Index (ASI)	N/A	2.7	0.0530 - 0.1030 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-12.7	0.0278 - 0.0778 seconds
50-ms MA Lateral (g)	N/A	-19.8	0.0253 - 0.0753 seconds
50-ms MA Vertical (g)	N/A	4.3	0.0015 - 0.0515 seconds
Roll (deg)	≤75	4.8	0.0468 seconds
Pitch (deg)	≤75	4.7	0.2602 seconds
Yaw (deg)	N/A	36.4	0.4401 seconds

F. *Values in italics are the preferred MASH values*

7.2.8. Test Summary

Figure 7.16 summarizes the results of *MASH* Test 611801-04-1.

0.000 s

0.200 s

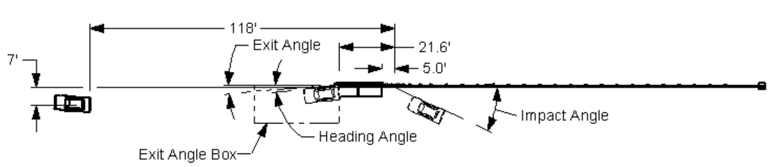
0.400 s

0.600 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-20
TTI Project No.	611801-04-1
Test Date	2023-03-23
TEST ARTICLE	
Type	Transition System
Name	Box Beam to Concrete Barrier Transition
Length	165 ft 5 inches
Key Materials	32-inch-high concrete parapet and 60-inch wide concrete deck. Steel box beam and rub rail. Steel transition posts
Soil Type and Condition	AASHTO M147-17 Type 1 Grade D Crushed Concrete
TEST VEHICLE	
Type/Designation	1100C
Year, Make and Model	2017 Nissan Versa
Inertial Weight (lb)	2448
Dummy (lb)	165
Gross Static (lb)	2613
IMPACT CONDITIONS	
Impact Speed (mi/h)	61.8
Impact Angle (deg)	25.0
Impact Location	59.7 inches upstream from the end of the concrete parapet
Impact Severity (kip-ft)	55.8
EXIT CONDITIONS	
Exit Speed (mi/h)	48.0
Trajectory/Heading Angle (deg)	4.5 / 5.9
Exit Box Criteria	Vehicle did not cross the exit box.
Stopping Distance	118 ft downstream 7 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	1.3
Permanent (inches)	0.25
Working Width / Height (inches)	17.0 / 32.0
VEHICLE DAMAGE	
VDS	01RFQ5
CDC	01FREW3
Max. Ext. Deformation (inches)	10
Max Occupant Compartment Deformation	3 inches in the side panel

OCCUPANT RISK VALUES

Long. OIV (ft/s)	22.1	Long. Ridedown (g)	3.6	Max 50-ms Long. (g)	-12.7	Max Roll (deg)	4.8
Lat. OIV (ft/s)	33.5	Lat. Ridedown (g)	7.2	Max 50-ms Lat. (g)	-19.8	Max Pitch (deg)	4.7
THIV (m/s)	12.3	ASI	2.7	Max 50-ms Vert. (g)	4.3	Max Yaw (deg)	36.4



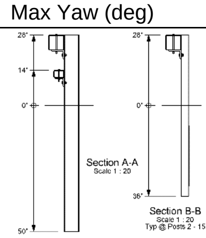


Figure 7.16. Summary of Results for *MASH* Test 3-20 on Box Beam to Concrete Barrier Transition.

7.3. *MASH* TEST 3-21 (CRASH TEST 611801-04-2)

7.3.1. Test Designation and Actual Impact Conditions

See Table 7.14 for details of impact conditions for this test and Table 7.15 for the exit parameters. Figure 7.17 and Figure 7.18 depict the target impact setup.

Table 7.14. Impact Conditions for *MASH* TEST 3-21, Crash Test 611801-04-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	62.1
Impact Angle (deg)	25	±1.5°	25.0
Impact Severity (kip-ft)	106	≥106 kip-ft	116.3
Impact Location	84 inches upstream from the edge of the concrete parapet	±12 inches	83.8 inches upstream from the end of the concrete parapet

Table 7.15. Exit Parameters for *MASH* TEST 3-21, Crash Test 611801-04-2.

Exit Parameter	Measured
Speed (mi/h)	52.1
Trajectory angle (deg)	4.1
Heading angle (deg)	8.1
Brakes applied post impact (s)	2.2
Vehicle at rest position	193 ft downstream of impact point 17 ft to the traffic side 60° right
Comments:	Vehicle remained upright and stable Vehicle crossed the exit box 57 feet downstream from loss of contact

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

Figure 7.17. Box Beam to Concrete Barrier Transition/Test Vehicle Geometrics for Test 611801-04-2.

Figure 7.18. Box Beam to Concrete Barrier Transition/Test Vehicle Impact Location 611801-04-2.

7.3.2. Weather Conditions

Table 7.16 provides the weather conditions for 611801-04-2.

Table 7.16. Weather Conditions 611801-04-2.

Date of Test	2023-03-30 AM
Wind Speed (mi/h)	11
Wind Direction (deg)	156
Temperature (°F)	70
Relative Humidity (%)	90
Vehicle Traveling (deg)	195

7.3.3. Test Vehicle

Figure 7.19 and Figure 7.20 show the 2017 RAM 1500 used for the crash test. Table 7.17 shows key vehicle measurements. Figure F.1 in Appendix F.1 gives additional dimensions and information on the vehicle.

Figure 7.19. Impact Side of Test Vehicle before Test 611801-04-2.

Figure 7.20. Opposite Impact Side of Test Vehicle before Test 611801-04-2.

Table 7.17. Vehicle Measurements 611801-04-2.

Test Parameter	***MASH***	**Allowed Tolerance**	**Measured**
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Test Inertial Weight (lb)	5000	±110	5051
Gross Static Weight[a] (lb)	5000	±110	5051
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	61.7
CG above Ground[c,d] (inches)	28	≥28	28.6

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.

7.3.4. Test Description

Table 7.18 lists events that occurred during Test 611801-04-2. Figures F.4, F.5, and F.6 in Appendix F.2 present sequential photographs during the test.

Table 7.18. Events during Test 611801-04-2.

Time (s)	Events
0.0000	Vehicle impacted installation
0.0320	Vehicle began to redirect
0.0170	Posts 23 thru 27 began to lean toward field side
0.0230	Posts 28 began to lean toward field side
0.1660	Vehicle was parallel with installation
0.2890	Vehicle exited the installation at 52.1 mi/h with a heading angle of 8.2 degrees and a trajectory angle of 4.1 degrees

7.3.5. Damage to Test Installation

The box-beam and rub rail were scuffed and deformed at the impact location. Table 7.19 describes the post soil gap and lean after the test. Table 7.20 describes the deflection and working width of the Box Beam to Concrete Barrier Transition. Figure 7.21 and Figure 7.22 show the damage to the Box Beam to Concrete Barrier Transition.

Table 7.19. Post Soil Gap and Displacement of the Box Beam to Concrete Barrier Transition for Test 611801-04-2.

Post #	Soil Gap	Post Lean from Vertical
21	Soil Disturbed	0.0°
22	¼-inch t/s & ⅛ f/s	0.5°
23	¼-inch t/s & ⅛ f/s	1.0°
24	¾-inch t/s & ⅜- inch f/s	1.0°
25	½-inch t/s & ¼-inch f/s	1.1°
26	⅝-inch t/s & ⅜-inch f/s	1.3°
27	Soil Disturbed	1.0°
28	Soil Disturbed	1.0°

t/s: traffic side; f/s: field side

Table 7.20. Deflection and Working Width of the Box Beam to Concrete Barrier Transition for Test 611801-04-2.

Test Parameter	Measured
Permanent Deflection/Location	1 inch toward field side, between posts 25 and 26
Dynamic Deflection	2.5 inches toward field side, at the top of the rail at post 26
Working Width [a] and Height	22.4 inches, at a height of 49.0 inches, corresponding to the vehicle side view mirror

[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 7.21. Box Beam to Concrete Barrier Transition at Impact Location after Test 611801-04-2.

Figure 7.22. Overall View of the Box Beam to Concrete Barrier Transition after Test 611801-04-2.

7.3.6. Damage to Test Vehicle

Figure 7.23 and Figure 7.24 show the damage sustained by the vehicle. Figure 7.25 and Figure 7.26 show the interior of the test vehicle. Table 7.21 and Table 7.22 provide details on the occupant compartment deformation and exterior vehicle damage. Figures F.2 and F.3 in Appendix F.1 provide exterior crush and occupant compartment measurements.

Figure 7.23. Impact Side of Test Vehicle after Test 611801-04-2.

Figure 7.24. Rear Impact Side of Test Vehicle after Test 611801-04-2.

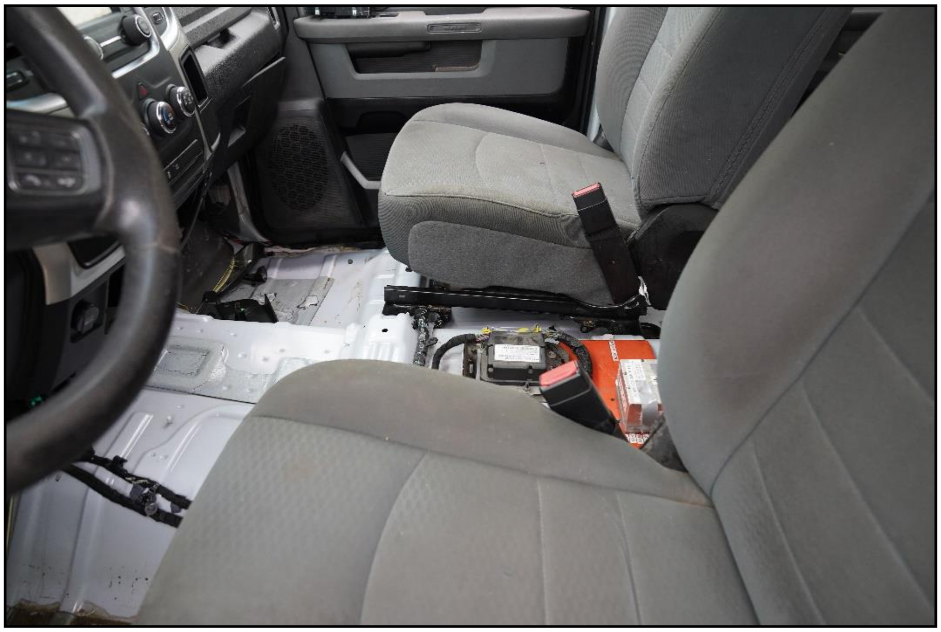


Figure 7.25. Overall Interior of Test Vehicle after Test 611801-04-2.

Figure 7.26. Interior of Test Vehicle on Impact Side after Test 611801-04-2.

Table 7.21. Occupant Compartment Deformation 611801-04-2.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	0.0 inches
Windshield	≤3.0 inches	0.0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0.0 inches
Foot Well/Toe Pan	≤9.0 inches	3.0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0.0 inches
Side Front Panel	≤12.0 inches	0.0 inches
Front Door (above Seat)	≤9.0 inches	2.0 inches
Front Door (below Seat)	≤12.0 inches	0.0 inches

Table 7.22. Exterior Vehicle Damage 611801-04-2.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	14 inches in the front plane at the right front corner at bumper height
VDS	01RFQ4
CDC	01FREW3
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, hood, grill, right and left headlights, radiator and support, right front quarter fender, right front door, right front floor pan, right rear door, right cab corner, right rear quarter fender, right rear tire and rim, and rear bumper were damaged. The fright front door had a 7-inch gap at the top.

7.3.7. Occupant Risk Factors

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 7.23. Figure F.7 in Appendix F.3 shows the vehicle angular displacements, and Figures F.8 through F.10 in Appendix F.4 show acceleration versus time traces.

Table 7.23. Occupant Risk Factors for Test 611801-04-2.

Test Parameter	***MASH*** [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	16.4	0.0925 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	31.8	0.0925 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	5.0	0.1613 – 0.1713 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	11.5	0.2142 – 0.2242 seconds
THIV (m/s)	N/A	10.9	0.0909 seconds on right side of interior
ASI	N/A	2.2	0.0643 – 0.1143 seconds
50-ms MA Longitudinal (g)	N/A	-8.7	0.0449 – 0.0949 seconds
50-ms MA Lateral (g)	N/A	-17.5	0.0423 – 0.0923 seconds
50-ms MA Vertical (g)	N/A	3.6	(0.1615 - 0.2115 seconds)
Roll (deg)	≤75	30.6	0.6239 seconds
Pitch (deg)	≤75	4.1	0.5445 seconds
Yaw (deg)	N/A	49.4	1.1732 seconds

F. Values in italics are the preferred MASH values

7.3.8. Test Summary

Figure 7.27 summarizes the results of *MASH* Test 611801-04-2.

0.000 s

0.200 s

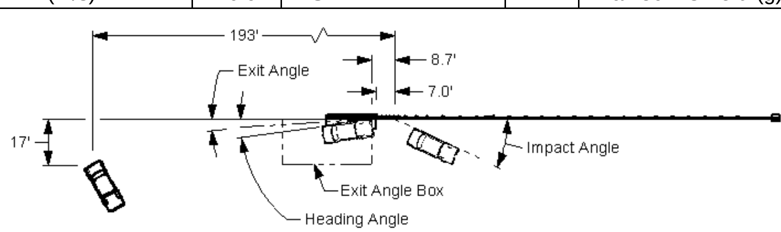
0.400 s

0.600 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-21
TTI Project No.	611801-04-2
Test Date	2023-03-30
TEST ARTICLE	
Type	Transition System
Name	Box Beam to Concrete Barrier Transition
Length	165 ft 5 inches
Key Materials	32-inch-high concrete parapet and 60-inch wide concrete deck. Steel box beam and rub rail. Steel transition posts
Soil Type and Condition	AASHTO M147-17 Type 1 Grade D Crushed Concrete
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2017 RAM 1500
Inertial Weight (lb)	5051
Dummy (lb)	N/A
Gross Static (lb)	5051
IMPACT CONDITIONS	
Impact Speed (mi/h)	62.1
Impact Angle (deg)	25.0
Impact Location	83.8 inches upstream from the end of the concrete parapet
Impact Severity (kip-ft)	116.3
EXIT CONDITIONS	
Exit Speed (mi/h)	52.1
Trajectory/Heading Angle (deg)	4.1 / 8.1
Exit Box Criteria	Vehicle crossed the exit box 57 feet downstream from loss of contact
Stopping Distance	193 ft downstream 17 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic (inches)	2.5
Permanent (inches)	1
Working Width / Height (inches)	22.4 / 49.0
VEHICLE DAMAGE	
VDS	01RFQ4
CDC	01FREW3
Max. Ext. Deformation (inches)	14
Max Occupant Compartment Deformation	3 inches in the right toe pan

OCCUPANT RISK VALUES

Long. OIV (ft/s)	16.4	Long. Ridedown (g)	5.0	Max 50-ms Long. (g)	-8.7	Max Roll (deg)	30.6
Lat. OIV (ft/s)	31.8	Lat. Ridedown (g)	11.5	Max 50-ms Lat. (g)	-17.5	Max Pitch (deg)	4.1
THIV (m/s)	10.9	ASI	2.2	Max 50-ms Vert. (g)	3.6	Max Yaw (deg)	49.4



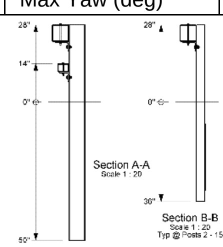


Figure 7.27. Summary of Results for *MASH* Test 3-21 on Box Beam to Concrete Barrier Transition.

Chapter 8. SUMMARY AND CONCLUSIONS

8.1. ASSESSMENT OF TEST RESULTS AND CONCLUSIONS FOR THE CONCRETE PARAPET SHAPE TRANSITION

The crash tests reported in Chapter 6 were performed in accordance with *MASH* TL-3 on the Concrete Parapet Shape Transition.

Table 8.1 shows that the Concrete Parapet Shape Transition met the performance criteria for *MASH* TL-3 longitudinal barriers.

Table 8.1. Assessment Summary for *MASH* TL-3 Tests on the Concrete Parapet Shape Transition.

Evaluation Criteria	Description	Test 611801-03-1	Test 611801-03-2
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	Summary	Pass	Pass

Note: S = Satisfactory; N/A = Not Applicable.
[1] See Table 4.2 for details

8.2. ASSESSMENT OF TEST RESULTS AND CONCLUSIONS FOR THE BOX BEAM TRANSITION TO CONCRETE PARAPET

The crash tests reported in Chapter 7 were performed in accordance with *MASH* TL-3 on the Box Beam Transition to Concrete Parapet.

Table 8.1 shows that the Box Beam Transition to Concrete Parapet met the performance criteria for *MASH* TL-3 longitudinal barriers.

Table 8.2. Assessment Summary for *MASH* TL-3 Tests on the Box Beam Transition to Concrete Parapet.

Evaluation Criteria	Description	Test 611801-04-1	Test 611801-04-2
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	Summary	Pass	Pass

Note: S = Satisfactory; N/A = Not Applicable.
[1] See Table 4.2 for details

Chapter 9. IMPLEMENTATION

This research was a step in WYDOT's efforts to implement MASH to enhance roadside safety and reduce the severity of run-off-road crashes in Wyoming. Specifically, this project addressed the development of a stiffness transition from box beam guardrail to a vertical concrete parapet, and a shape transition of the vertical concrete parapet to a New Jersey profile concrete parapet.

Two different shape transitions were designed and evaluated through finite element impact simulations. These included a 32-inch-tall vertical concrete parapet to a 42-inch-tall single slope concrete parapet, and a 32-inch-tall vertical concrete parapet to a 32-inch-tall New Jersey concrete parapet. MASH criteria were satisfied for both transition systems. The shape transition from vertical to New Jersey profile was selected for full-scale crash testing based on being the more critical of the two shape transitions.

MASH Test 3-20 and Test 3-21 were successfully performed on the Concrete Parapet Shape Transition from vertical to New Jersey profile. The shape transition was accomplished over a length of 6 ft, providing a concrete transition parapet with an overall length of 9 ft including a 3-ft length of vertical parapet for connection of the box beam transition rails. Based on successful finite element simulation and the successful testing of the more critical shape transition from vertical to New Jersey profile, the shape transition from vertical to single slope profile is also considered MASH compliant.

MASH Test 3-20 and Test 3-21 were successfully performed on the downstream end of the box beam guardrail stiffness transition to vertical concrete parapet. It was initially planned for the design details of the upstream end of the transition to be similar to those of the MASH compliant box beam stiffness transition to C2P bridge rail that was developed under Phase I of this research (*2*). However, during the transition design process, the rubrail size in the box beam transition to vertical concrete parapet was changed from HSS6×2 to HSS4×3 to address stability concerns with the pickup truck observed in the impact simulations.

The other design details and rubrail termination methods used for the HSS4×3 rubrail were like those used in the successfully crash tested box beam transition with HSS6×2 rubrail (*2*). Additionally, MASH Test 3-20 and Test 3-21 impact simulations were performed on the upstream end of the box beam stiffness transition system with the HSS4x3 rubrail. Both simulations satisfied MASH criteria.

Based on the successful crash testing of a similar upstream transition, and successful MASH impact simulations on the upstream transition with HSS4x3 rubrail, the research team considers the upstream end of the box beam transition to vertical concrete parapet to be MASH compliant. Consequently, the box beam stiffness transition to vertical concrete parapet is considered MASH compliant.

The results of the research can be implemented through issuance of new or updated WYDOT standard plans. This will make the new MASH transition available for use in highway project plans and lettings. Specifically, the MASH box beam transition will supersede Standard Plan 606-6A—Transitions C&D to Concrete Barrier.

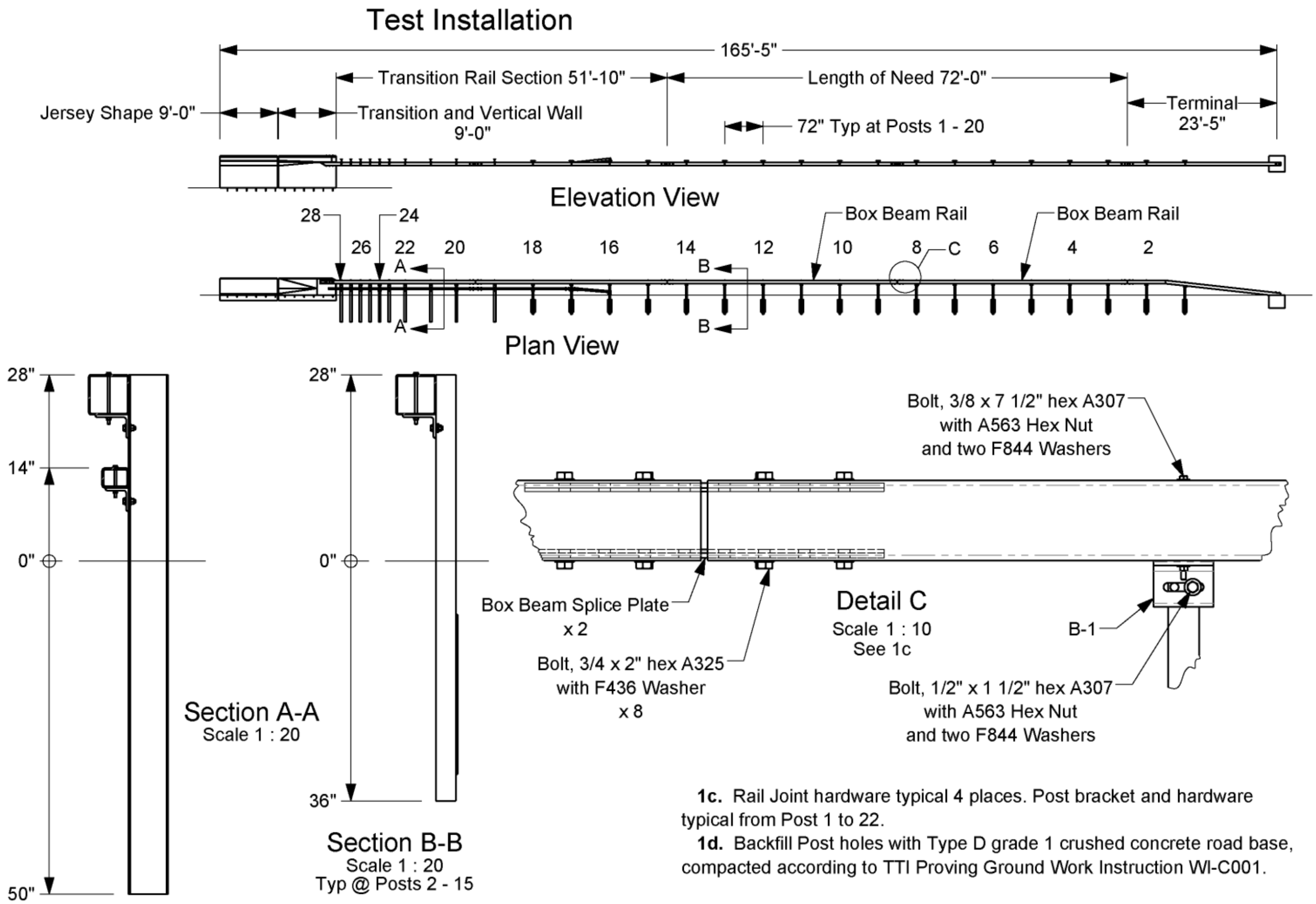
Detailed drawings developed for the Concrete Parapet Shape Transitions and box beam guardrail stiffness transition to vertical concrete parapet under this research project can serve as the basis for updating the relevant standard plans. Drawings for the box beam guardrail stiffness transition to vertical concrete parapet and concrete parapet shape transition from vertical to New Jersey profile are presented in Section A.2 in Appendix A. Drawings for the concrete parapet shape transition from vertical to single slope parapet are presented in Appendix G.

REFERENCES

1. AASHTO. *Manual for Assessing Roadside Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
2. Bligh, R. P., Sheikh, N. M., Schulz, N. D., Kovar, J., Menges, W. L., Schroeder, W., Griffith, B. L., and Wegenast, S., *Development of Approach Guardrail Transition for Box Beam Guardrail System and MGS*, Report No. 611801-02, Wyoming Department of Transportation, Cheyenne, WY, May 2022.

APPENDIX A. DETAILS OF THE CONCRETE PARAPET SHAPE TRANSITION AND THE BOX BEAM TRANSITION TO CONCRETE PARAPET

A.1. DETAILS OF CONCRETE PARAPET SHAPE TRANSITION



1c. Rail Joint hardware typical 4 places. Post bracket and hardware typical from Post 1 to 22.

1d. Backfill Post holes with Type D grade 1 crushed concrete road base, compacted according to TTI Proving Ground Work Instruction WI-C001.

1a. All steel components, including fasteners, shall be galvanized.

1b. Threads not shown on Bolts for clarity.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project #611801-03 Wyoming Box Beam Transition			2022-09-14
Drawn by GES	Scale 1:250	Sheet 1 of 21 Test Installation	

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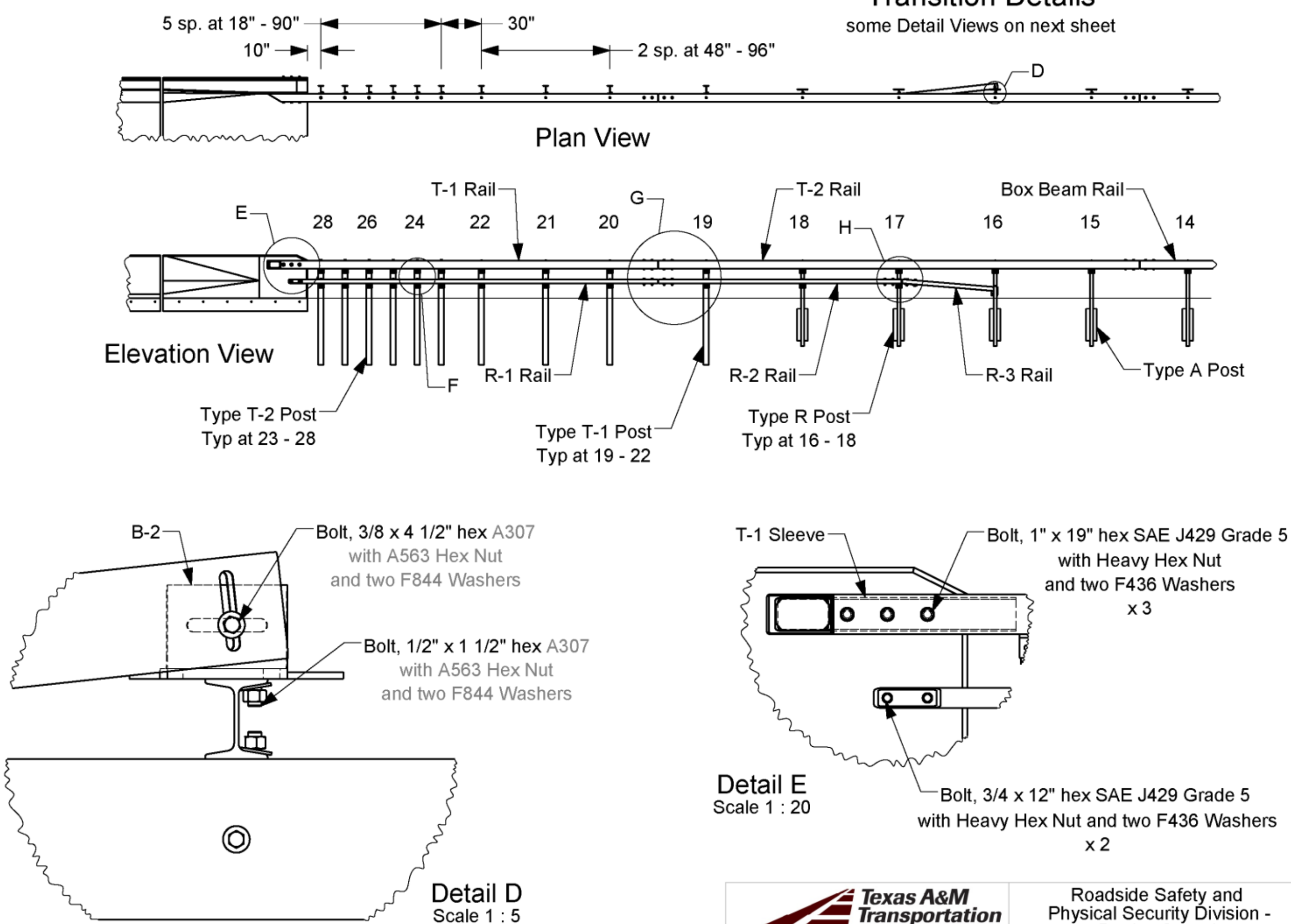
Transition Details

some Detail Views on next sheet



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:100	Sheet 2 of 21 Transition Details

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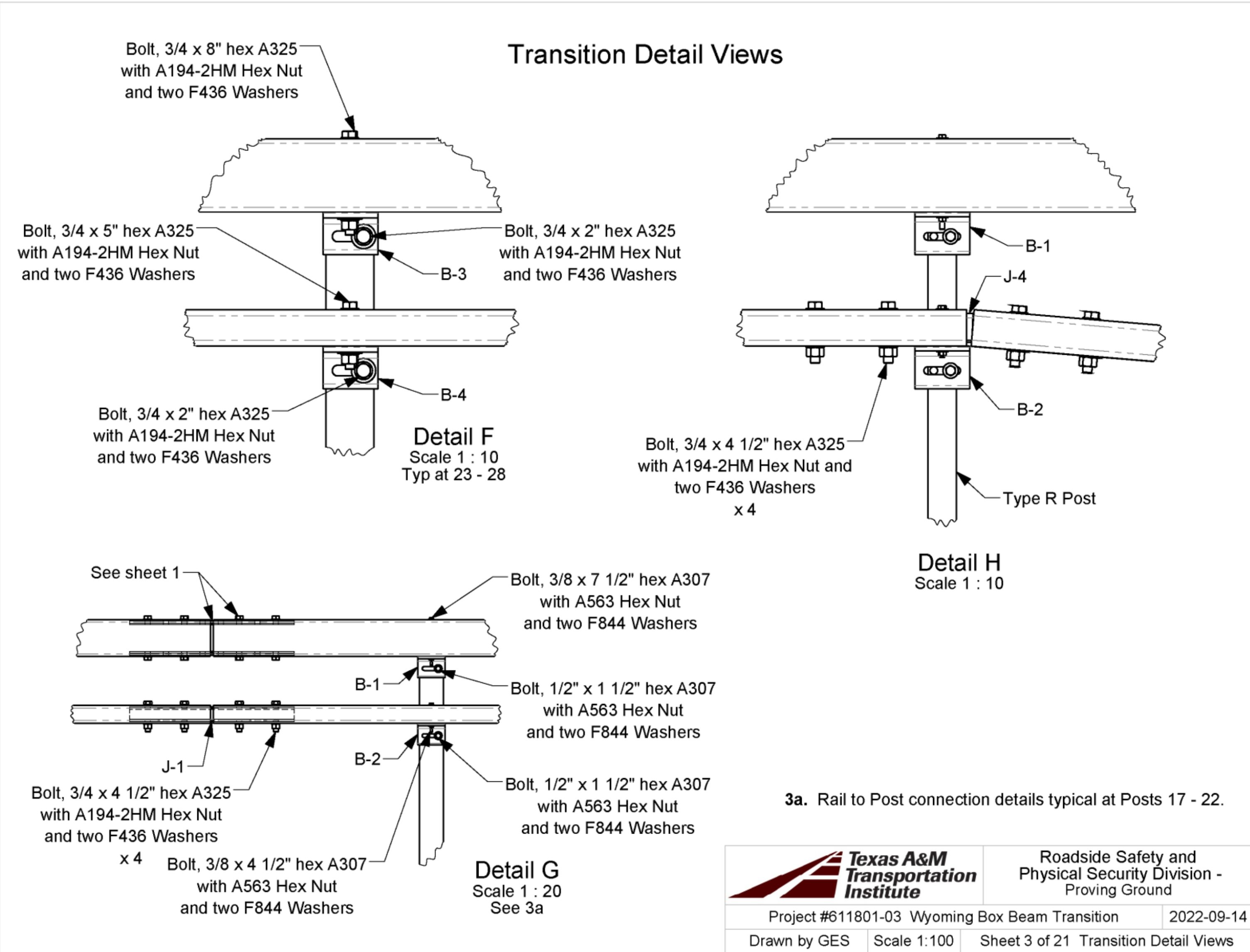

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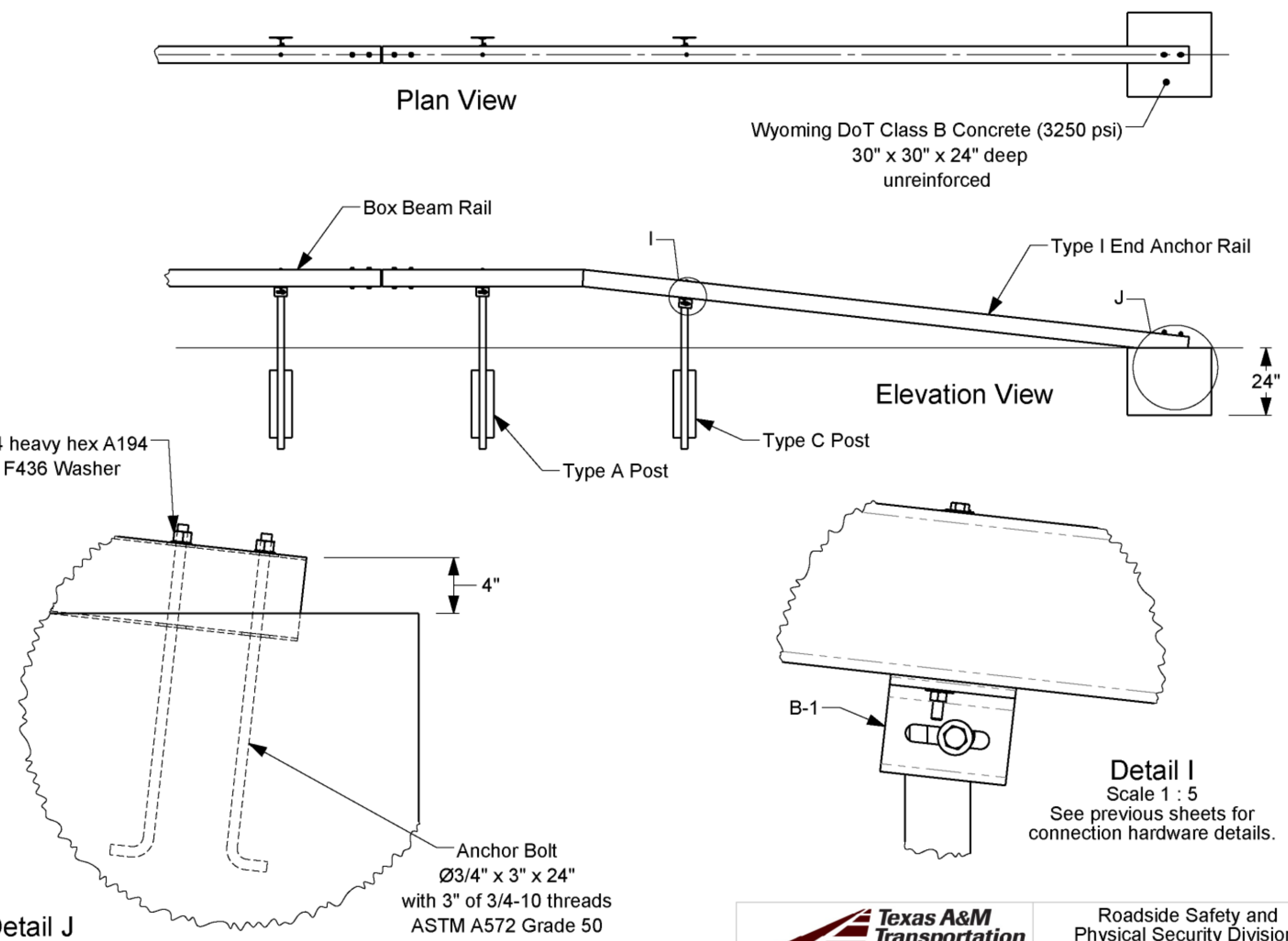
Terminal Details



Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #611801-03 Wyoming Box Beam Transition	2022-09-14
Drawn by GES	Scale 1:50	Sheet 4 of 21 Terminal Details

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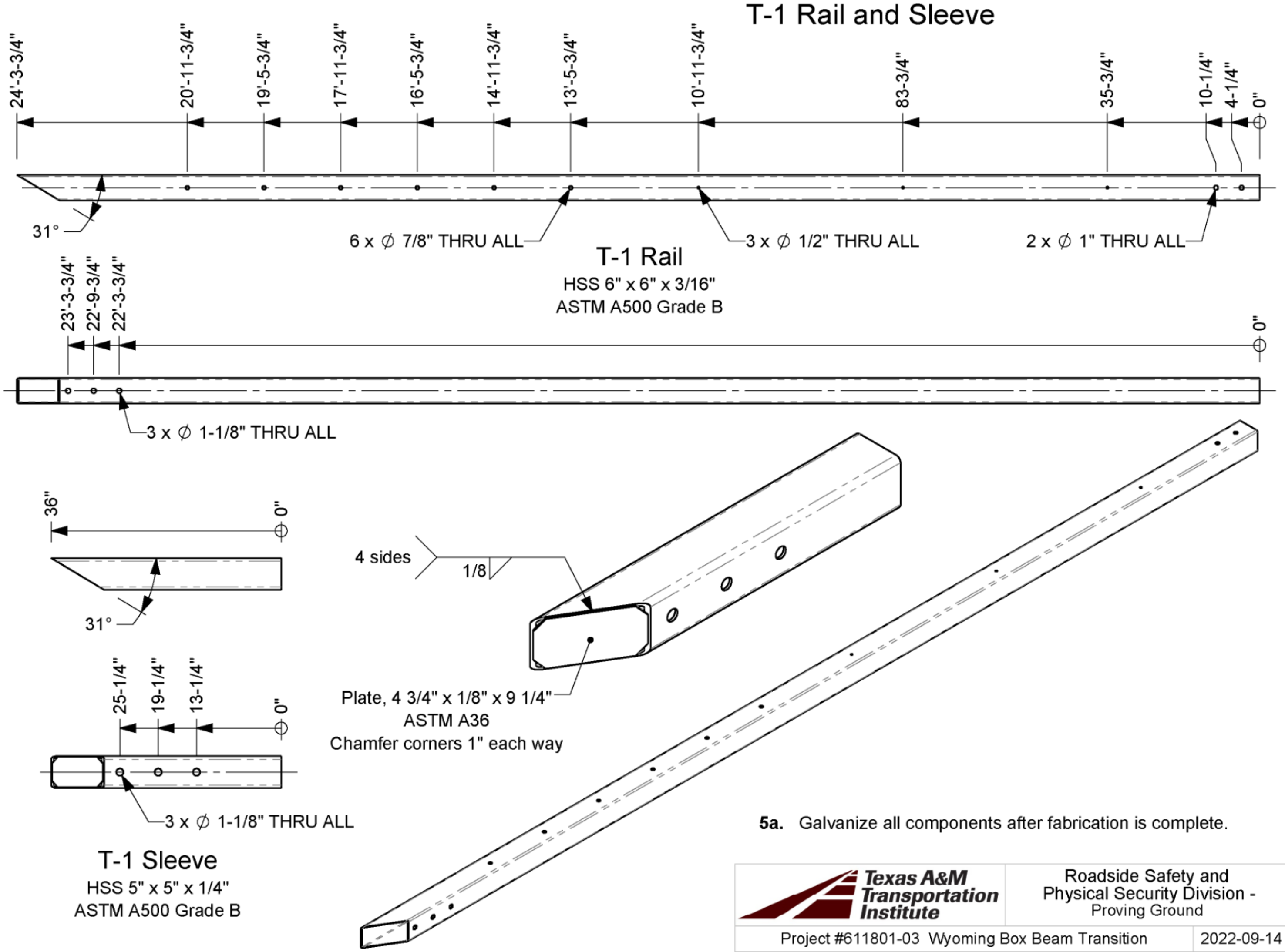
T-1 Rail and Sleeve



5a. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:30	Sheet 5 of 21 T-1 Rail and Sleeve

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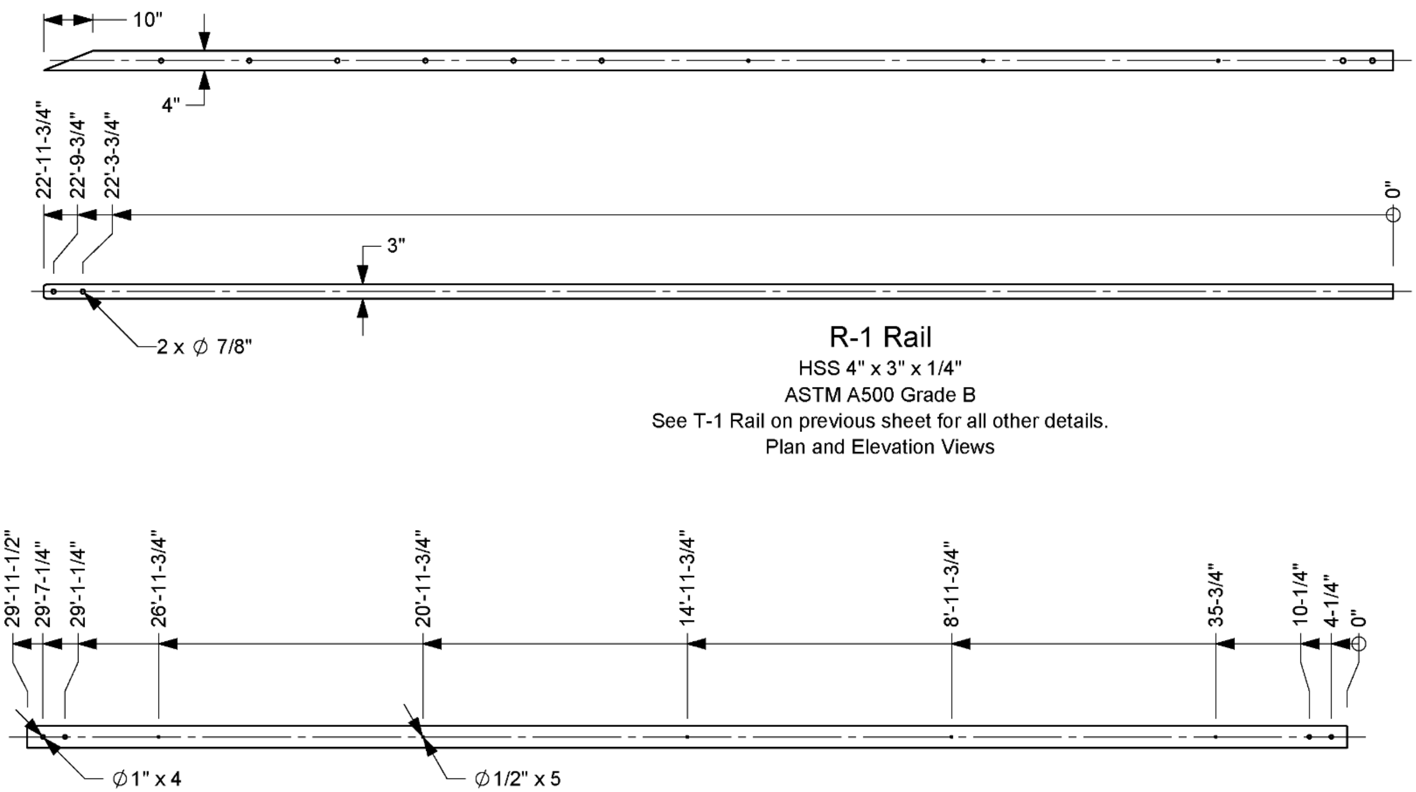
R-1 and T-2 Rails



R-1 Rail
HSS 4" x 3" x 1/4"
ASTM A500 Grade B
See T-1 Rail on previous sheet for all other details.
Plan and Elevation Views

T-2 Rail
HSS 6" x 6" x 3/16"
ASTM A500 Grade B
Plan View - Scale 1:40

6a. Galvanize all components after fabrication is complete.
6b. All holes are through both faces.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:30	Sheet 6 of 21 R-1 and T-2 Rails

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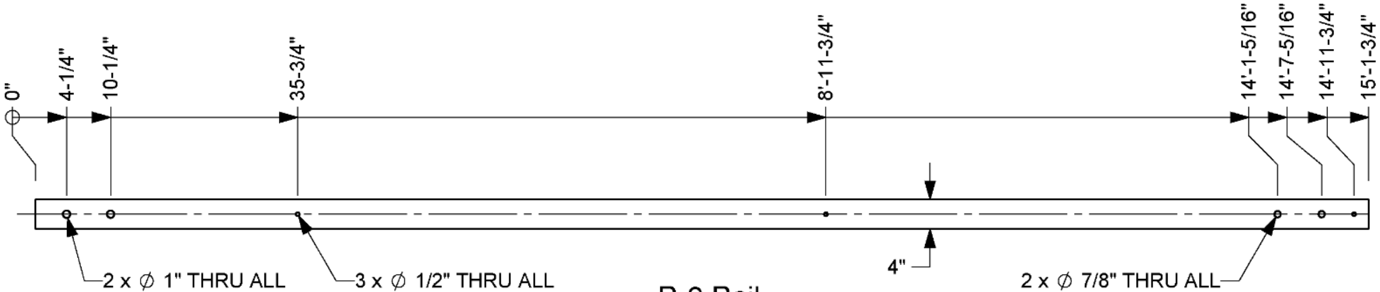
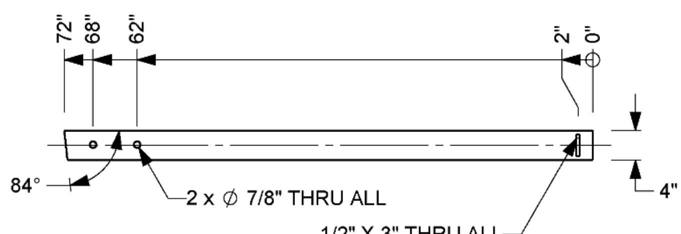
Rub Rails



R-2 Rail
HSS 4" x 3" x 1/4"
ASTM A500 Grade B
Plan View



R-3 Rail
HSS 4" x 3" x 1/4"
ASTM A500 Grade B
Plan View

7a. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:20	Sheet 7 of 21 Rub Rails

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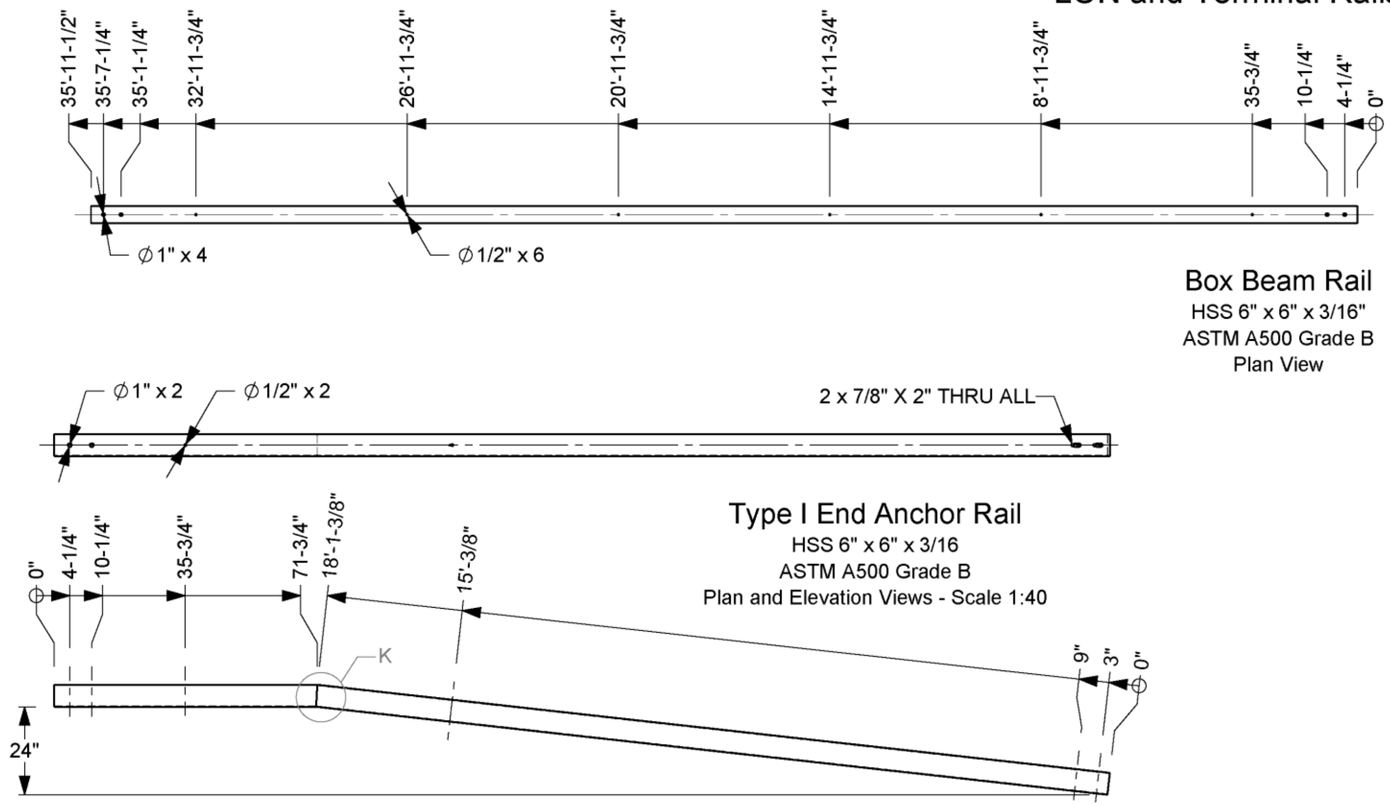
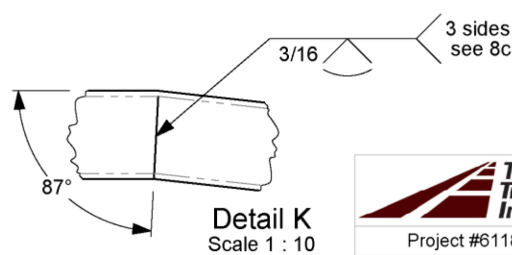
LON and Terminal Rails





8a. All welding must be performed by certified welders using industry standard practices.
8b. Galvanize all components after fabrication is complete.
8c. Cut 3 sides (inverted V-shape, 5/8" wide at bottom), bend, and weld.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground
Project #611801-03 Wyoming Box Beam Transition	2022-09-14
Drawn by GES, Scale 1:50	Sheet 8 of 21 LON and Terminal Rails

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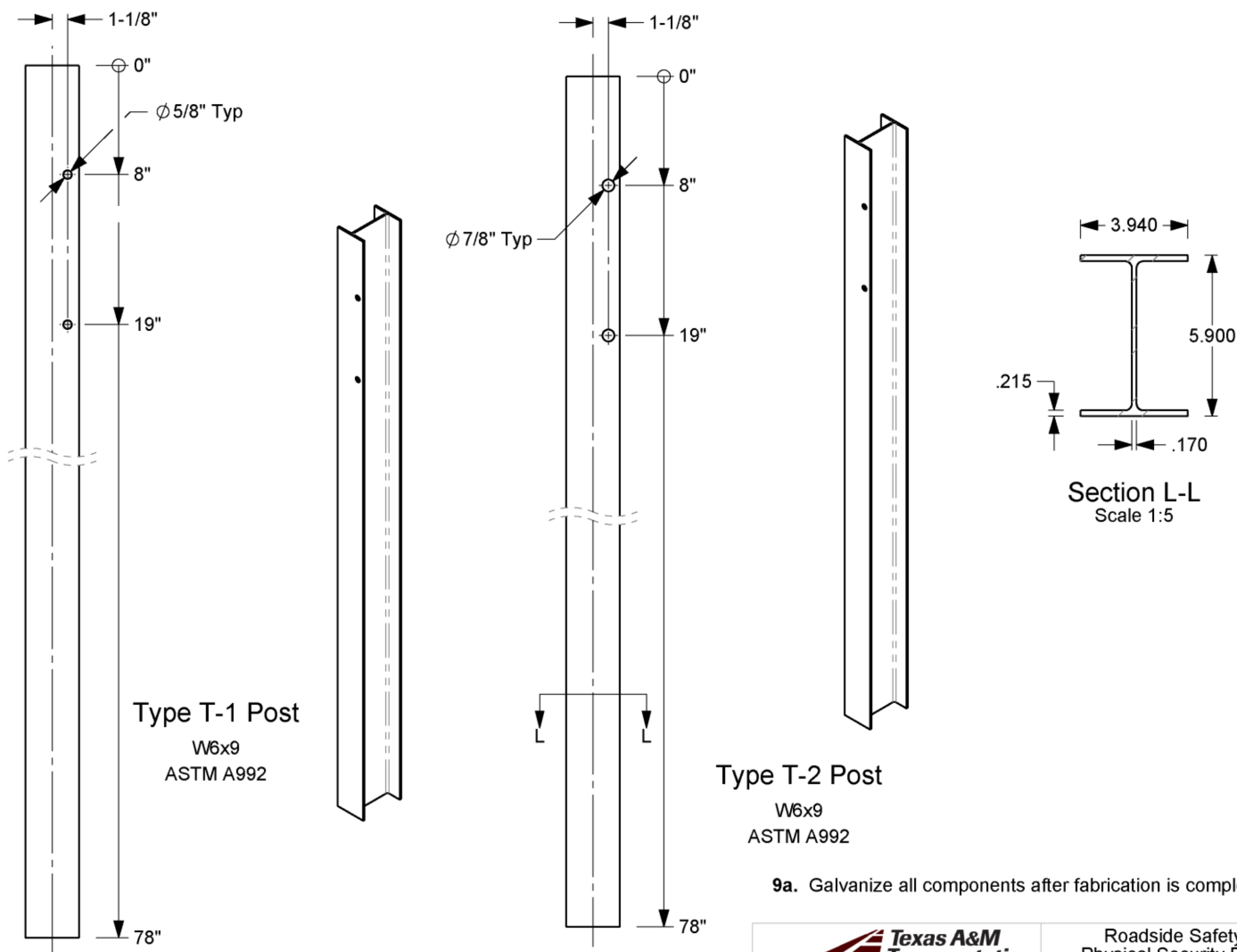

9a. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:10	Sheet 9 of 21 Type T Posts

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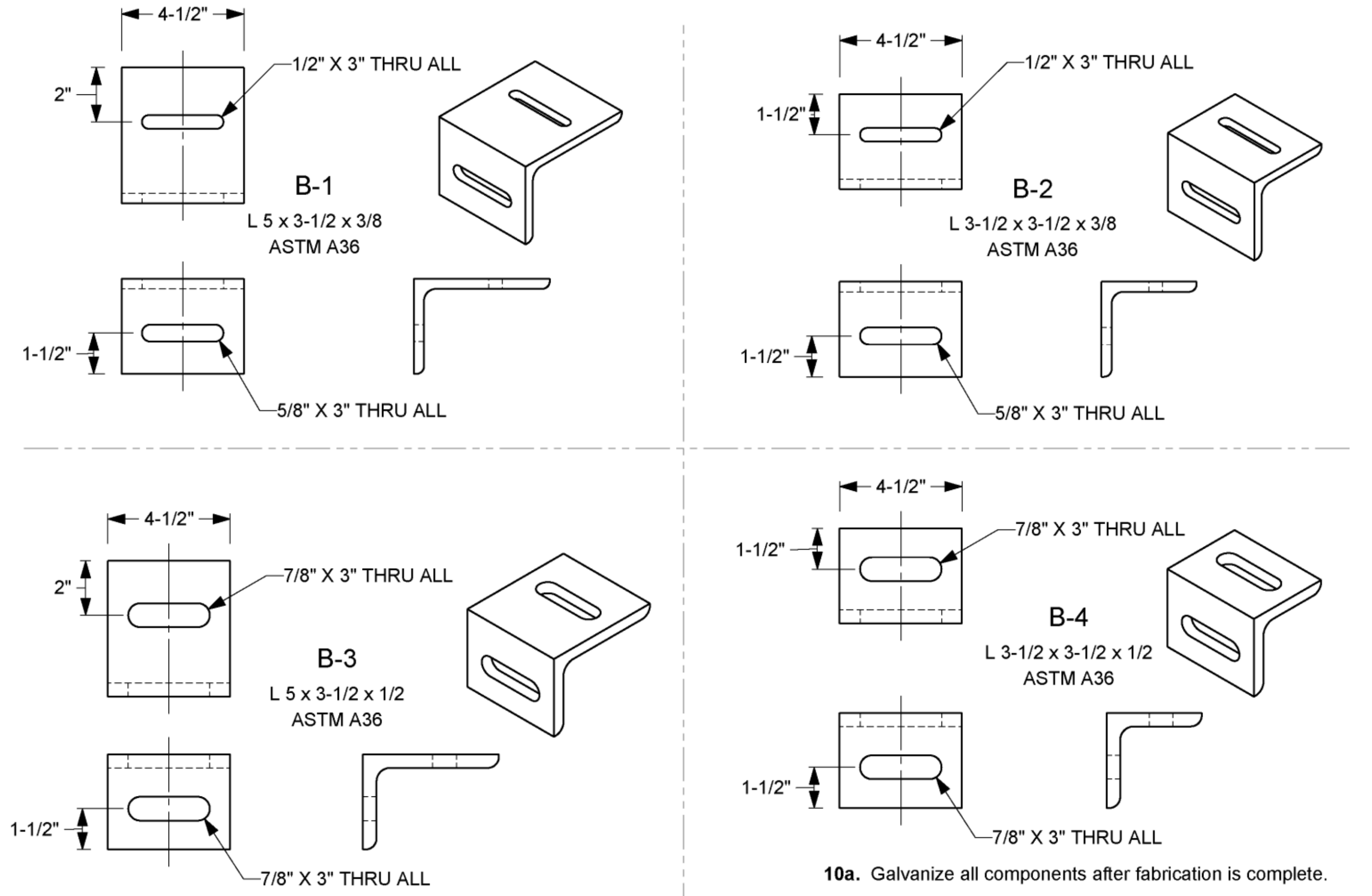
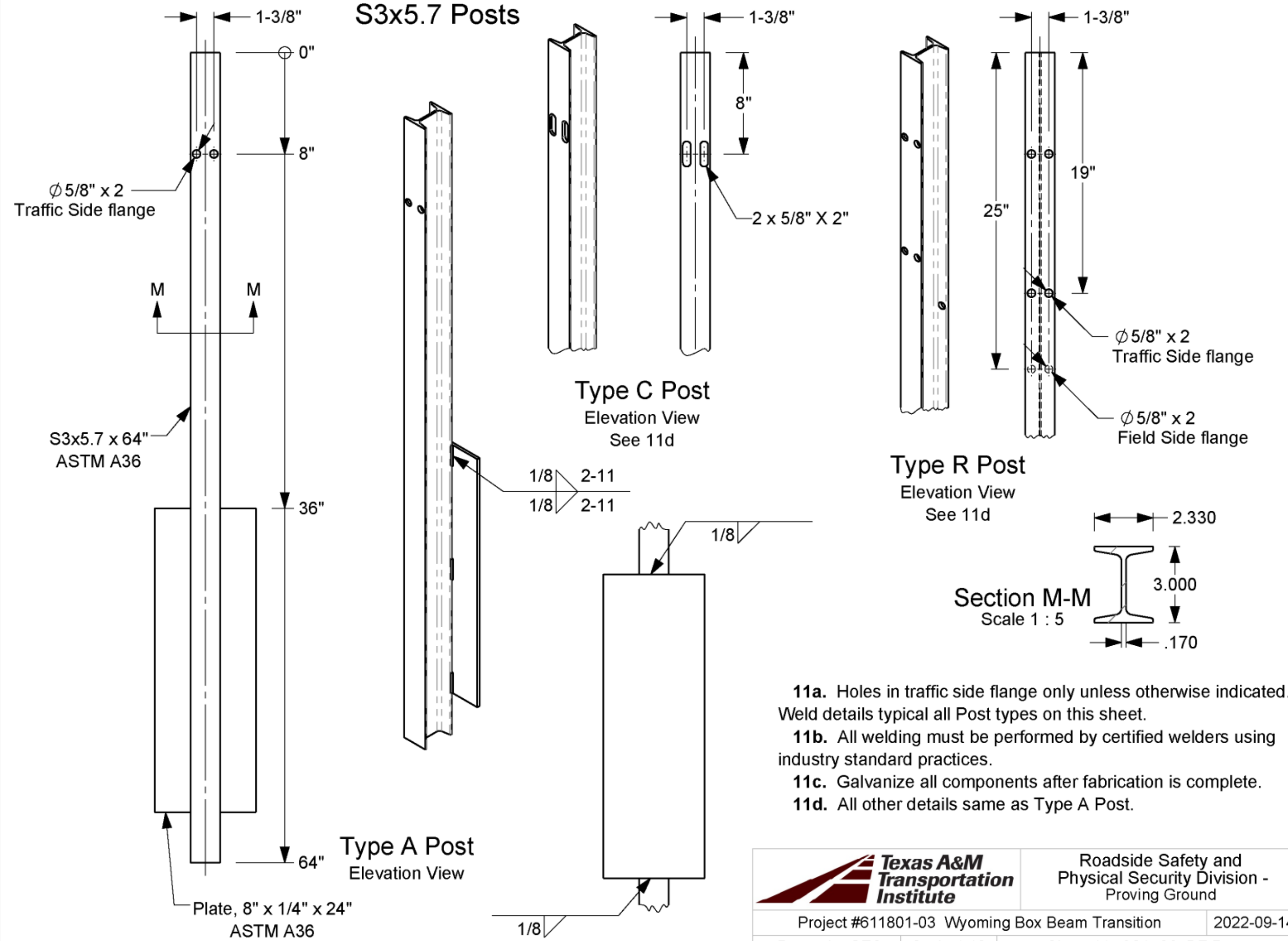


10a. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project #611801-03 Wyoming Box Beam Transition			2022-09-14
Drawn by GES	Scale 1:5	Sheet 10 of 21 Brackets	

S3x5.7 Posts



11a. Holes in traffic side flange only unless otherwise indicated. Weld details typical all Post types on this sheet.

11b. All welding must be performed by certified welders using industry standard practices.

11c. Galvanize all components after fabrication is complete.

11d. All other details same as Type A Post.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:10	Sheet 11 of 21 S3x5.7 Posts

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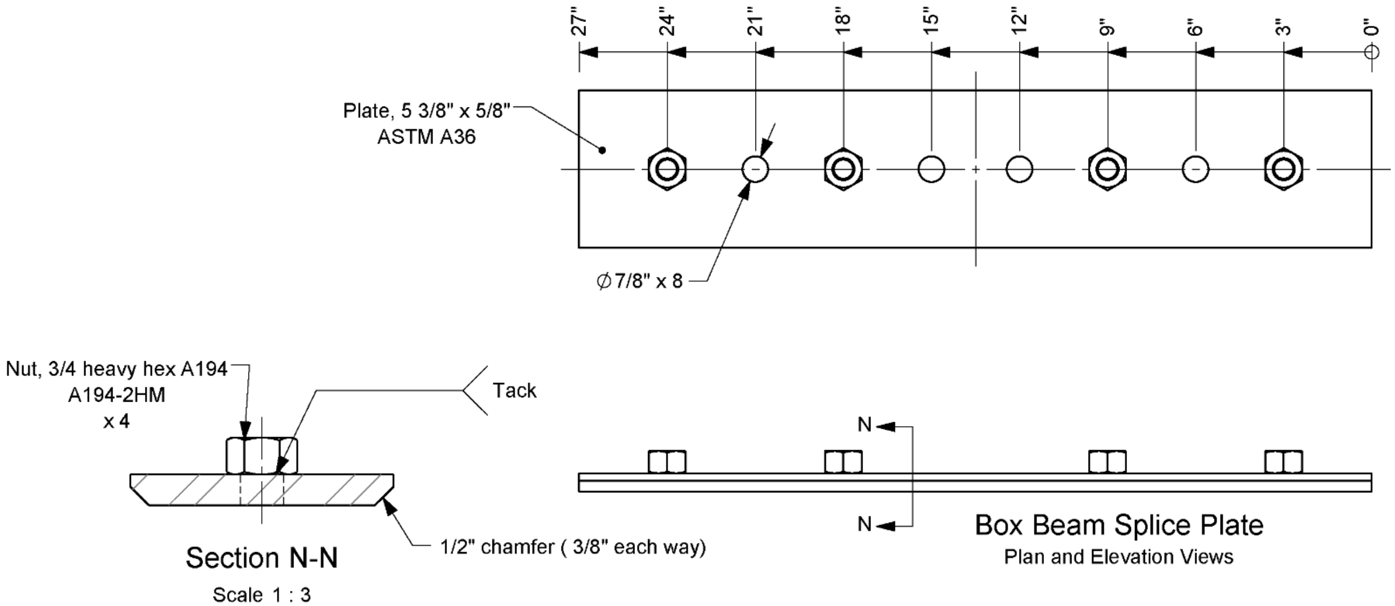
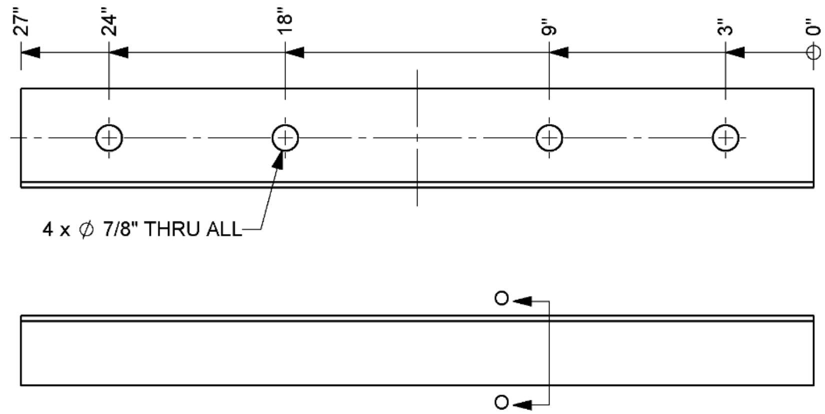
Box Beam Splice Plate



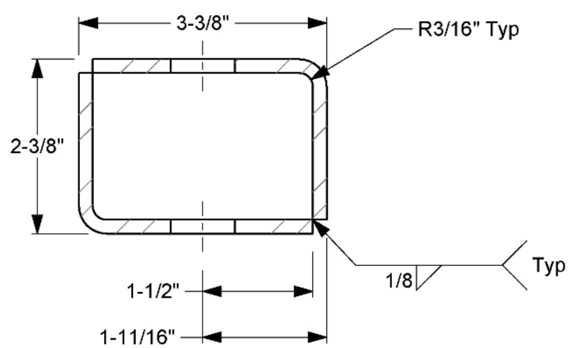
12a. All welding must be performed by certified welders using industry standard practices.

12b. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:5	Sheet 12 of 21 Box Beam Splice Plate



J-1
ASTM A36 Plate, 27" x 3/16"
Plan and Elevation Views



Section O-O
Scale 1 : 2

13a. All welding must be performed by certified welders using industry standard practices.
13b. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:5	Sheet 13 of 21 J-1

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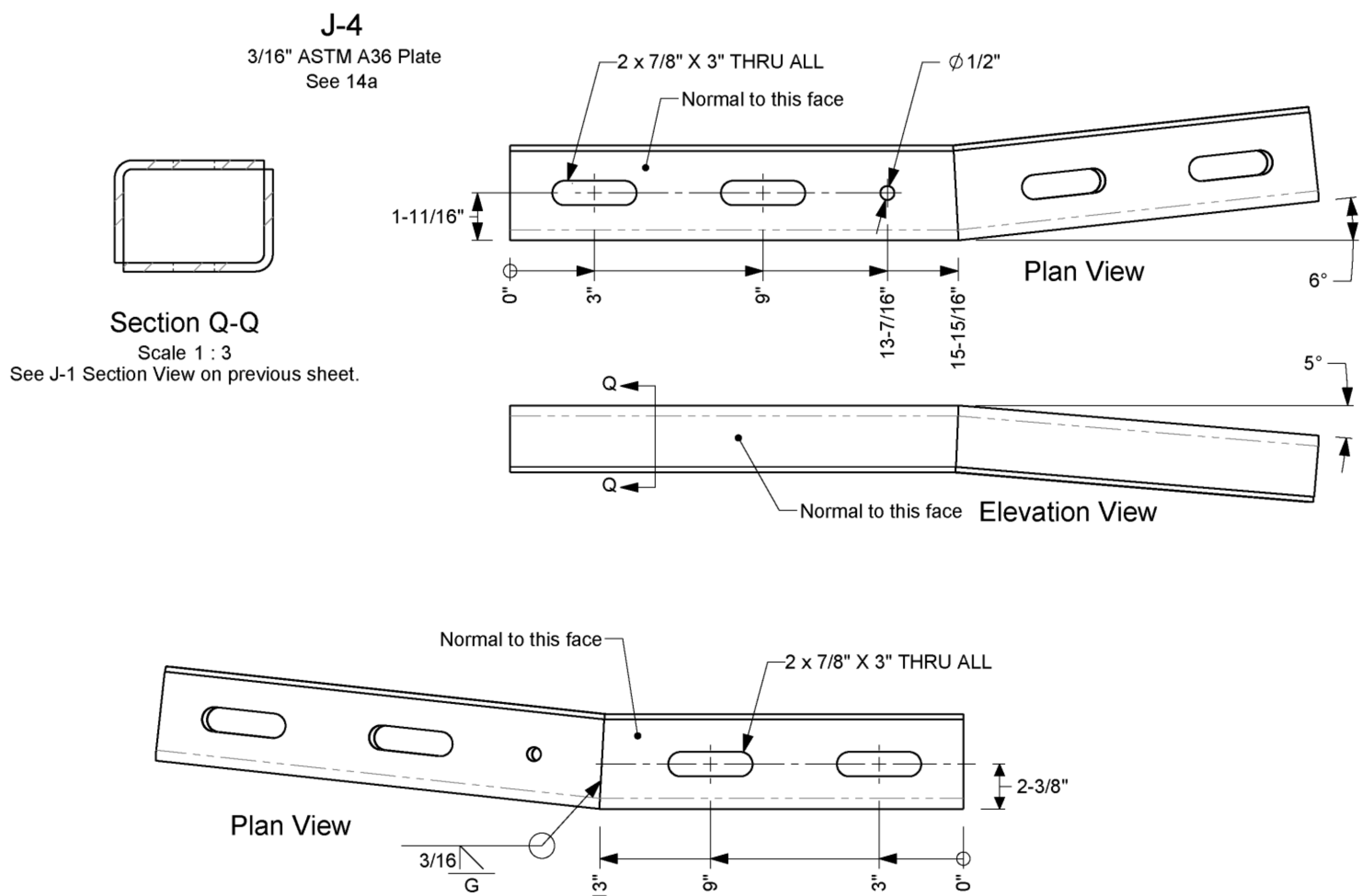

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:5	Sheet 14 of 21 J-4

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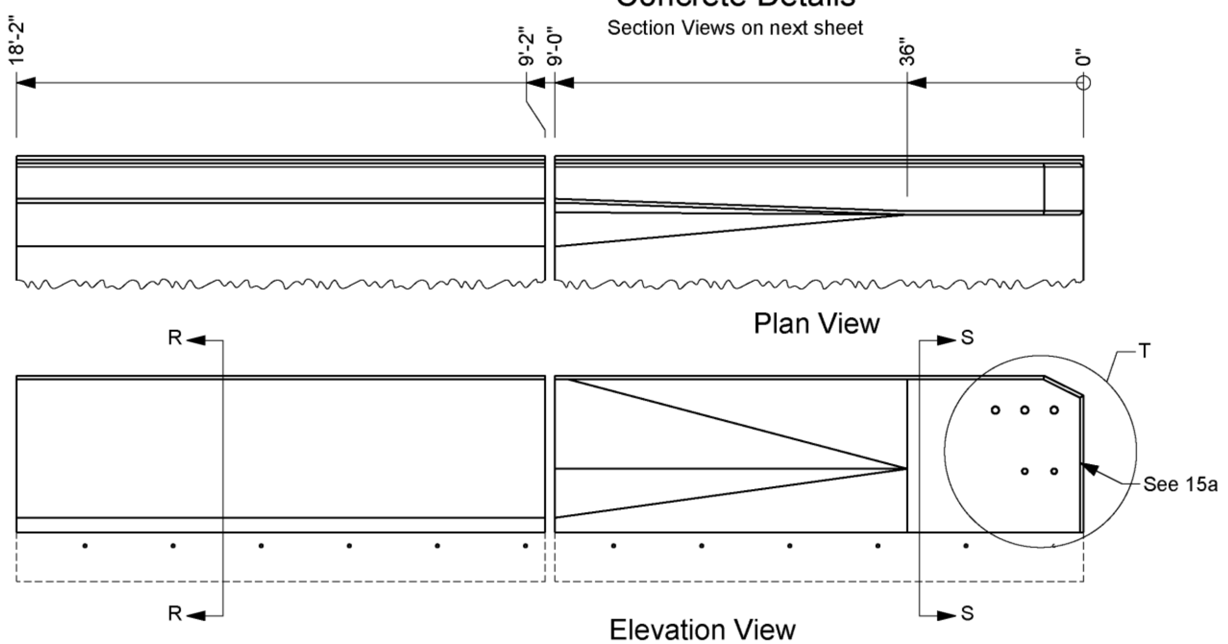
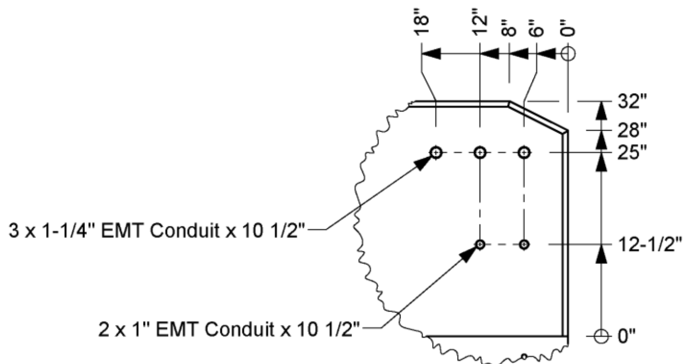
Concrete Details

Section Views on next sheet





Detail T
Scale 1 : 20

15a. Chamfer 1" (3/4" each way) edges of Parapet and Deck where shown.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:30	Sheet 15 of 21 Concrete Details

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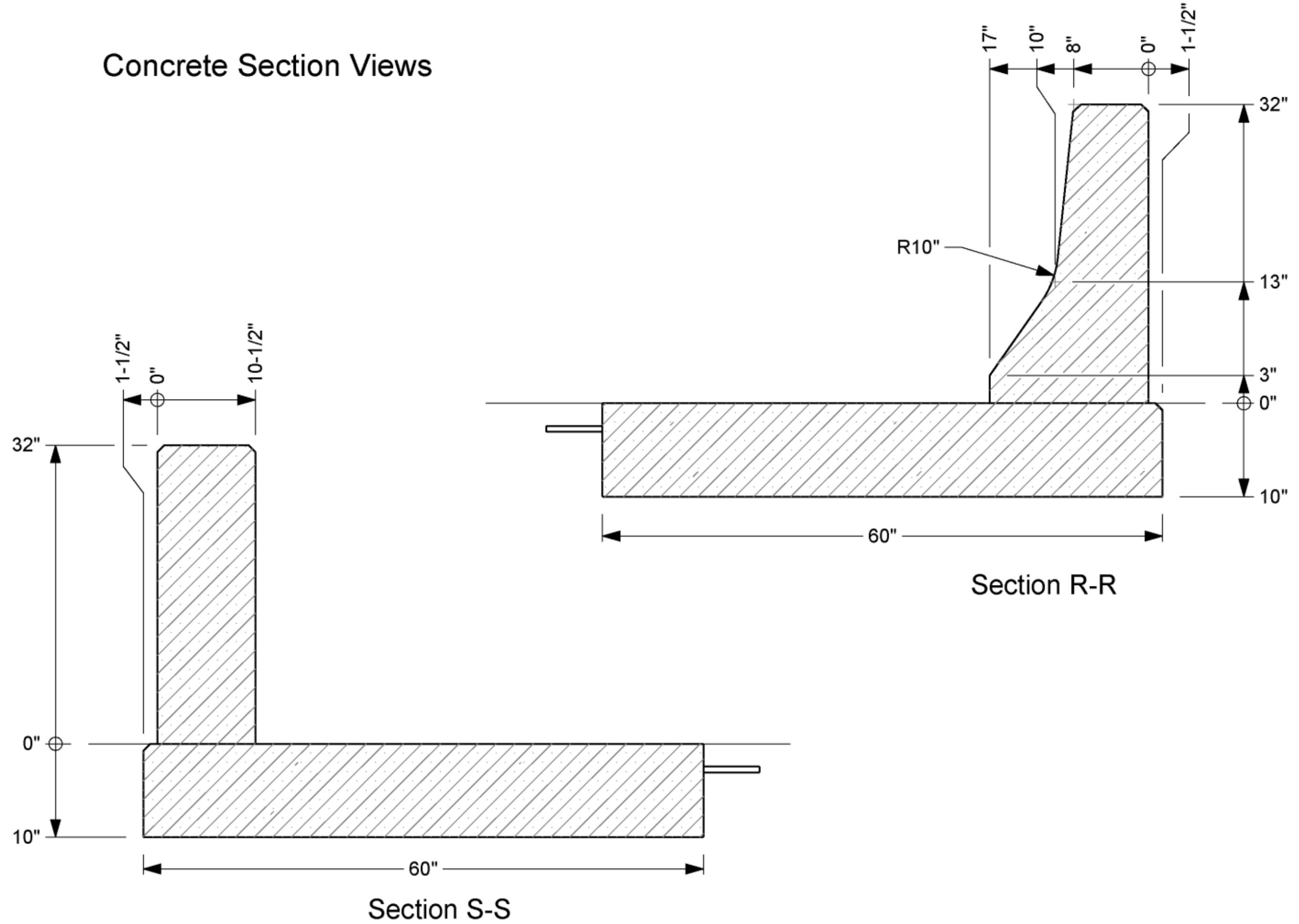
Concrete Section Views



16a. Chamfer 1" (3/4" each way) edges of Parapet and Deck where shown.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project #611801-03 Wyoming Box Beam Transition			2022-09-14
Drawn by GES	Scale 1:15	Sheet 16 of 21 Concrete Section Views	

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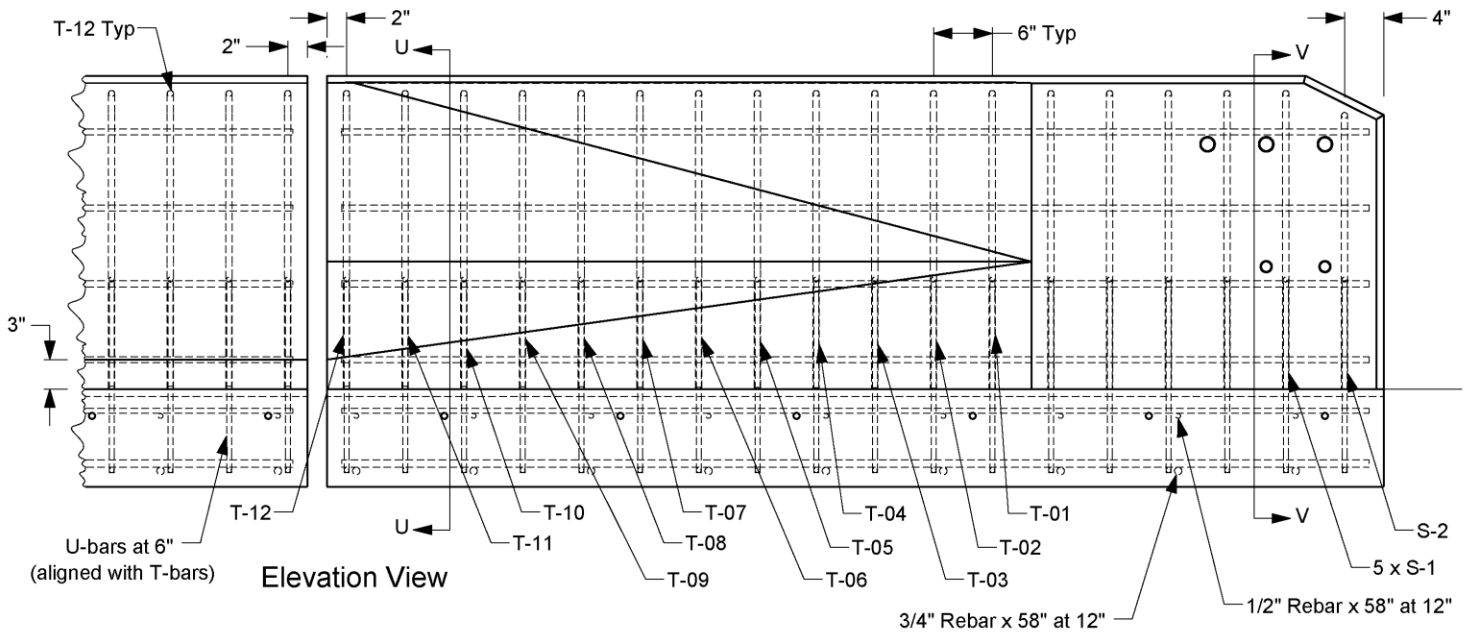
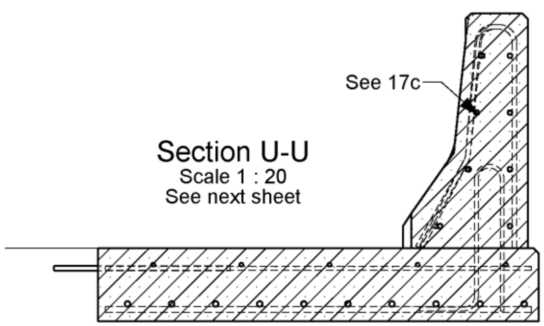
Rebar Details

Section V-V on next sheet



Elevation View



Section U-U
Scale 1 : 20
See next sheet

17a. Concrete is 4,000 psi. Rebar is Grade 60.

17b. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

17c. Field bend traffic side bars in transition section.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition		2022-09-14
Drawn by GES	Scale 1:15	Sheet 17 of 21 Rebar Details

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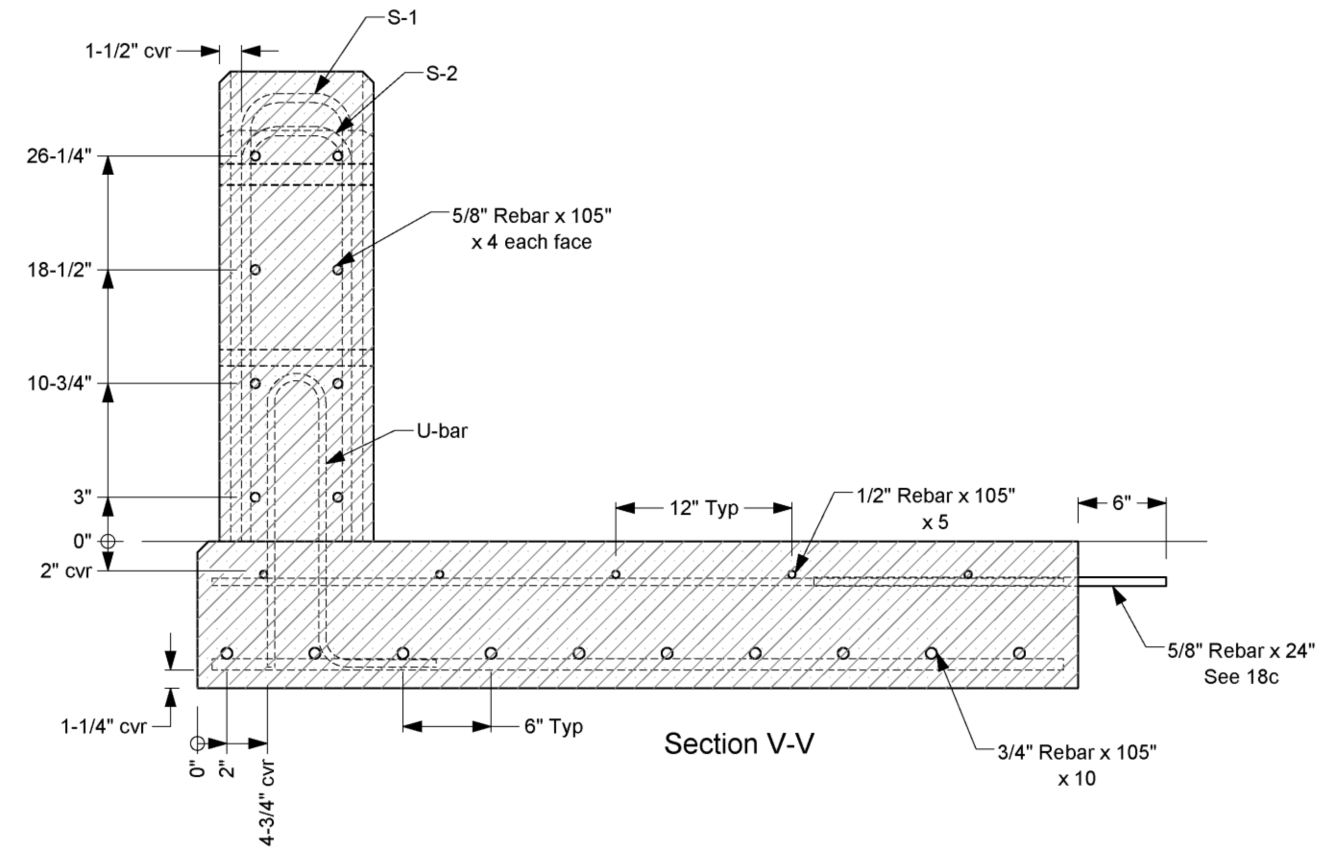


Section V-V

18a. Concrete is 4,000 psi. Rebar is Grade 60.
18b. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).
18c. Field bend traffic side bars as needed.
18c. Secure in existing concrete with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment. Space at 18".

Texas A&M Transportation Institute

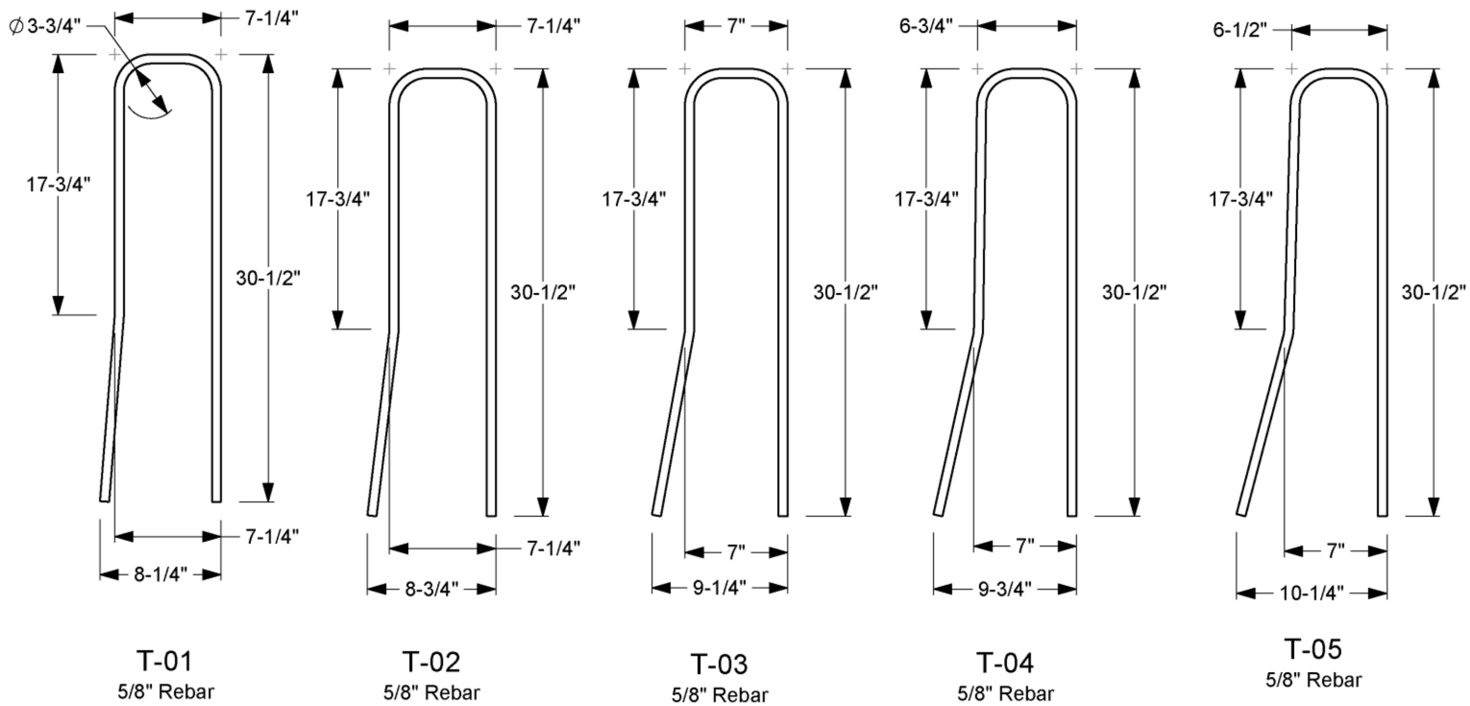
Roadside Safety and Physical Security Division - Proving Ground

Project #611801-03 Wyoming Box Beam Transition | 2022-09-14

Drawn by GES | Scale 1:10 | Sheet 18 of 21 Rebar Section View

Q:\Accreditation-17025-2017\EIR-000 Project Files\611801-03 Wyoming DoT - Bligh & Sheikh\Drafting, 611801-03\611801-03 Drawing

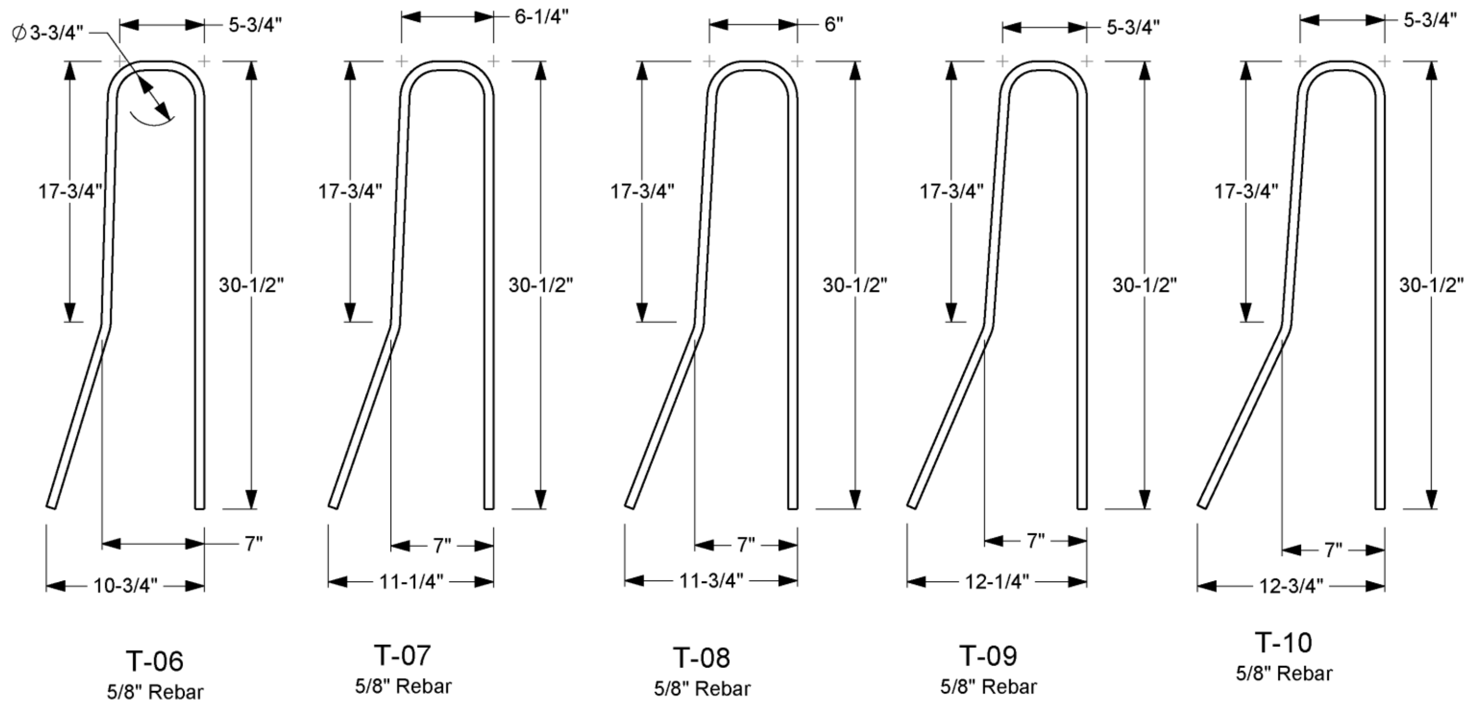
T-1 to T-5



19a. All bends on 5/8" rebar are ∅3-3/4" unless otherwise indicated.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition			2022-09-14
Drawn by GES	Scale 1:10	Sheet 19 of 21 T-1 to T-5	

T-6 to T-10



20a. All bends on 5/8" rebar are ∅3-3/4" unless otherwise indicated.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition			2022-09-14
Drawn by GES	Scale 1:10	Sheet 20 of 21 T-6 to T-10	

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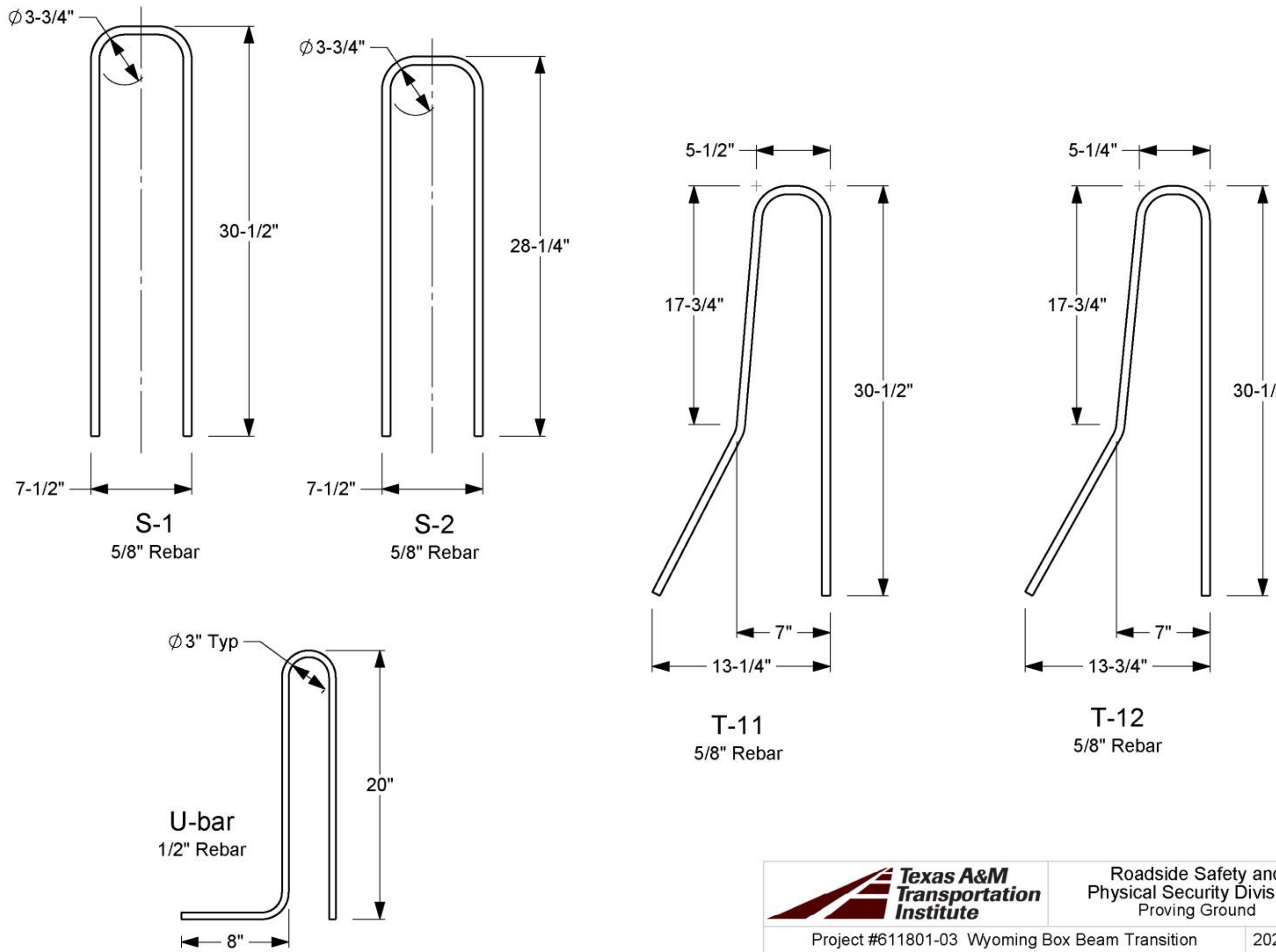

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #611801-03 Wyoming Box Beam Transition	2022-09-14
Drawn by GES	Scale 1:10	Sheet 21 of 21 U-, S-, and T11-12 bars

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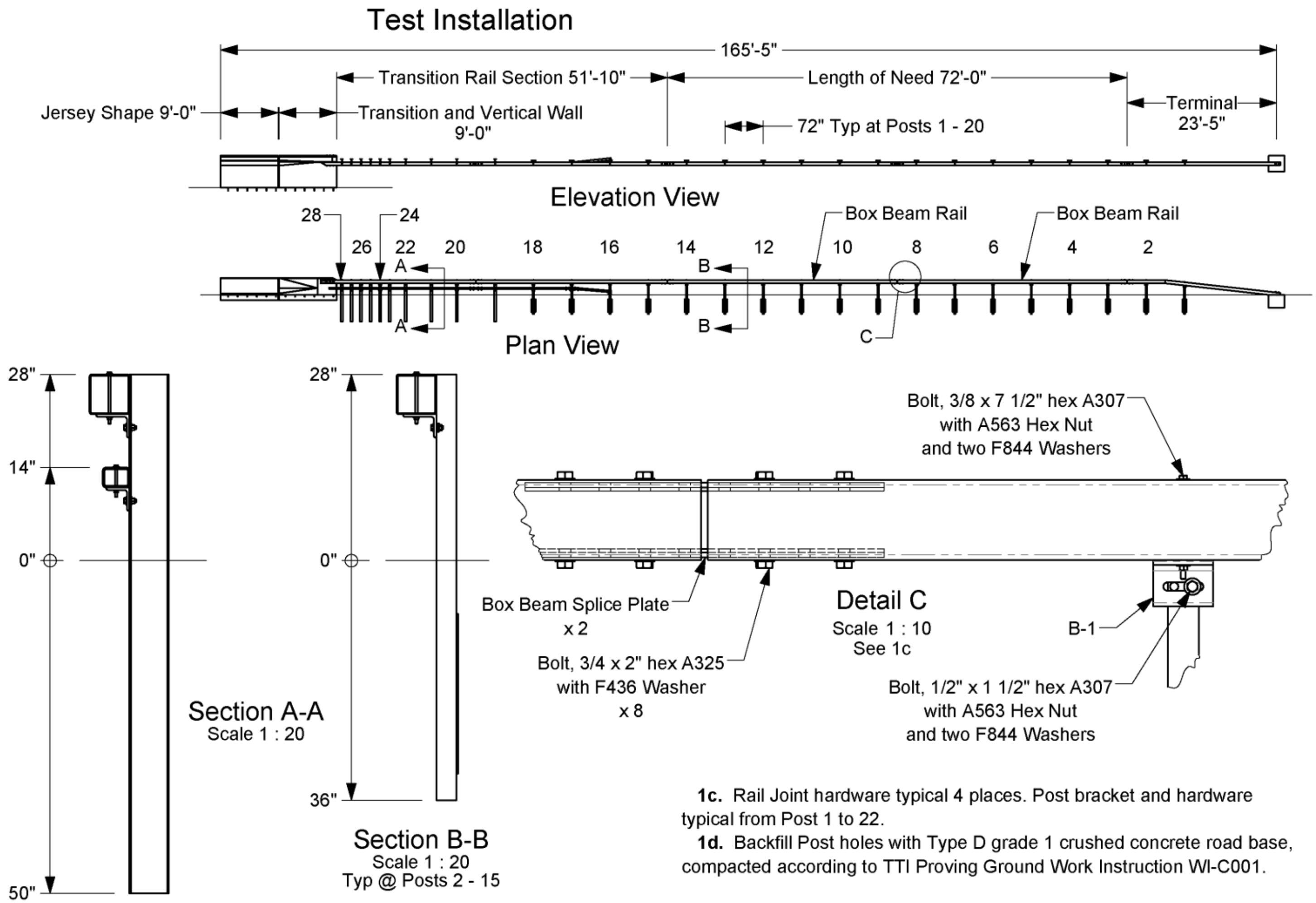
A.2. DETAILS OF BOX BEAM TRANSITION TO CONCRETE PARAPET



1c. Rail Joint hardware typical 4 places. Post bracket and hardware typical from Post 1 to 22.

1d. Backfill Post holes with Type D grade 1 crushed concrete road base, compacted according to TTI Proving Ground Work Instruction WI-C001.

1a. All steel components, including fasteners, shall be galvanized.

1b. Threads not shown on Bolts for clarity.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:250	Sheet 1 of 21 Test Installation

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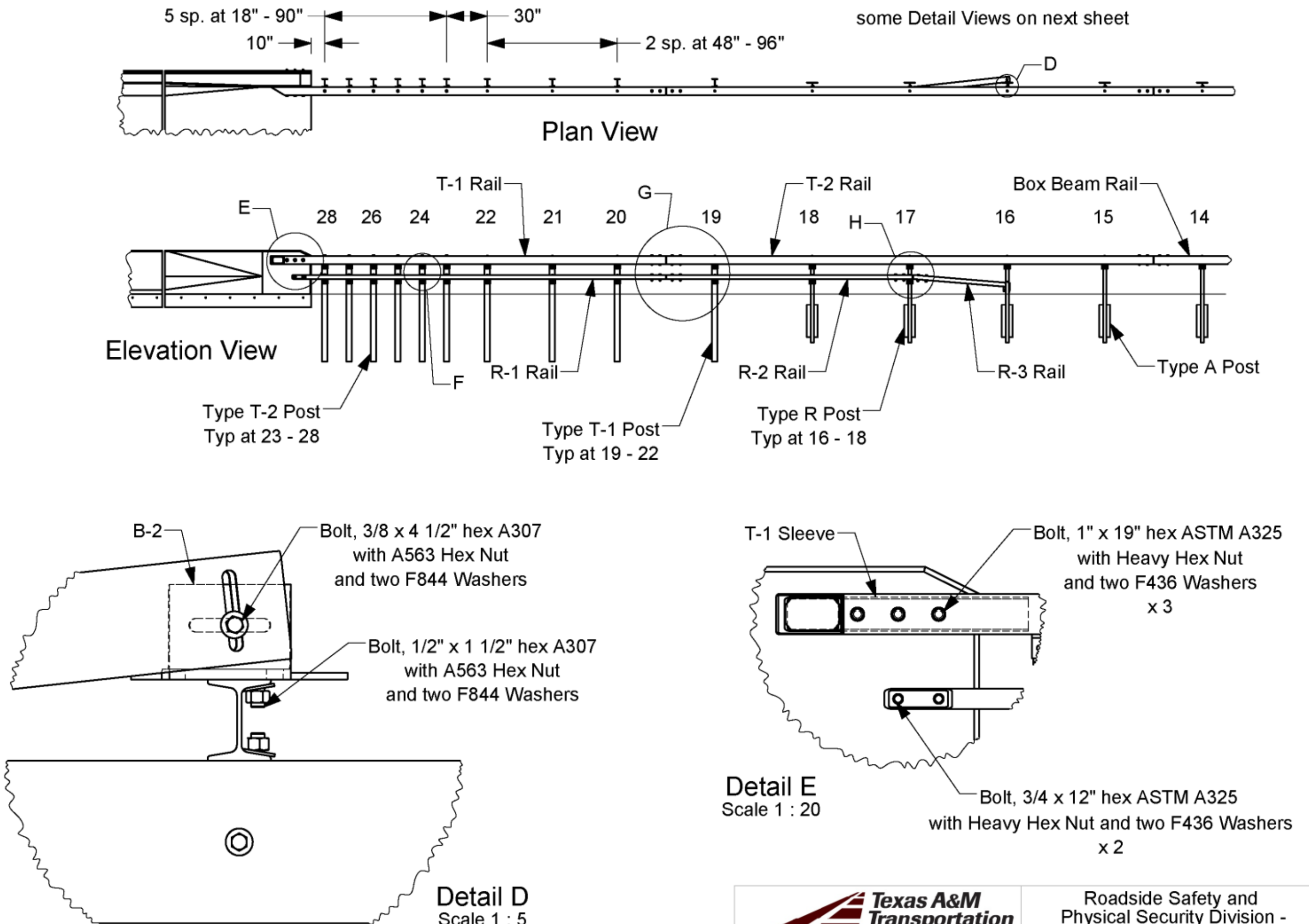
Transition Details

some Detail Views on next sheet



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:100	Sheet 2 of 21 Transition Details

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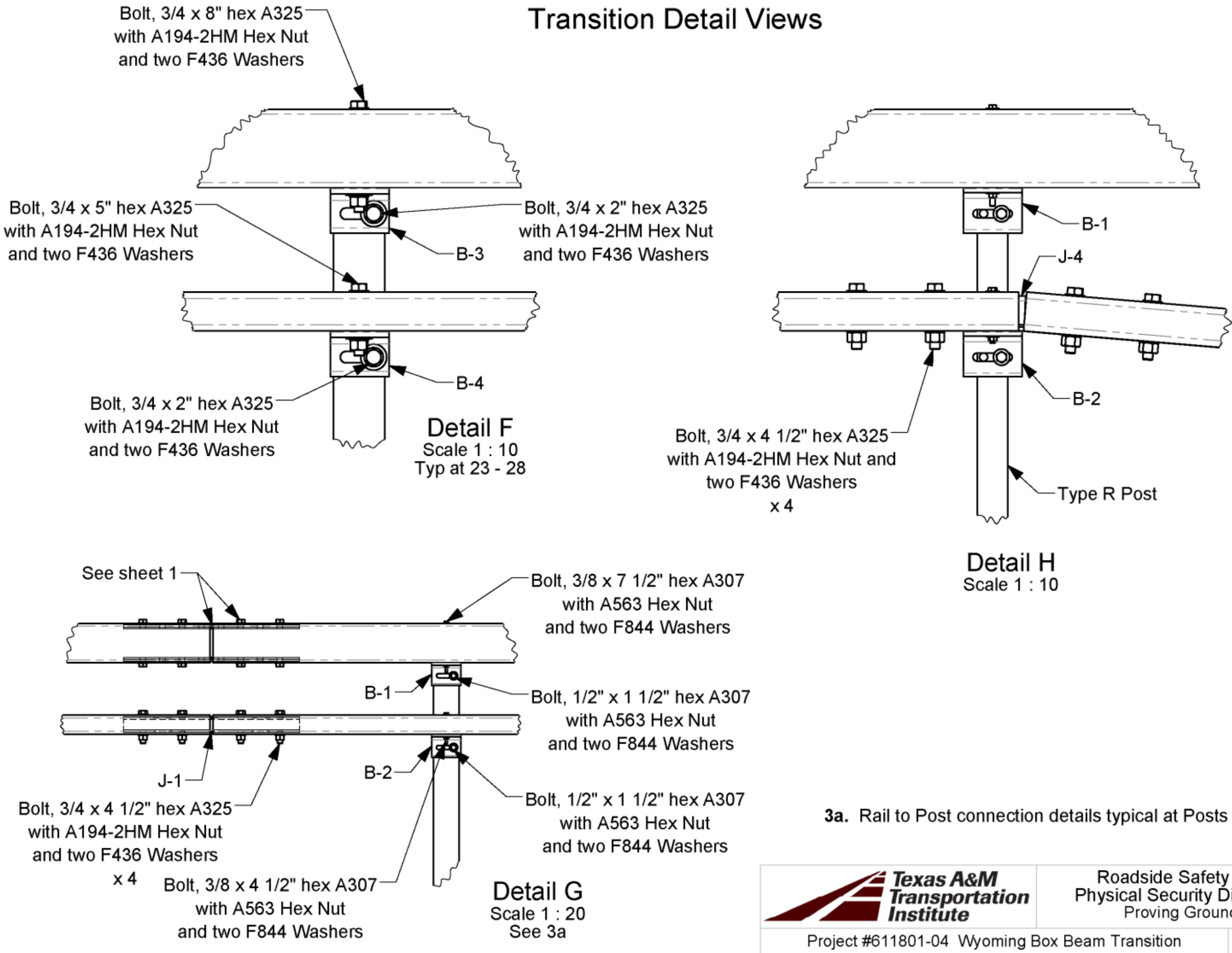
Transition Detail Views



3a. Rail to Post connection details typical at Posts 17 - 22.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:100	Sheet 3 of 21 Transition Detail Views

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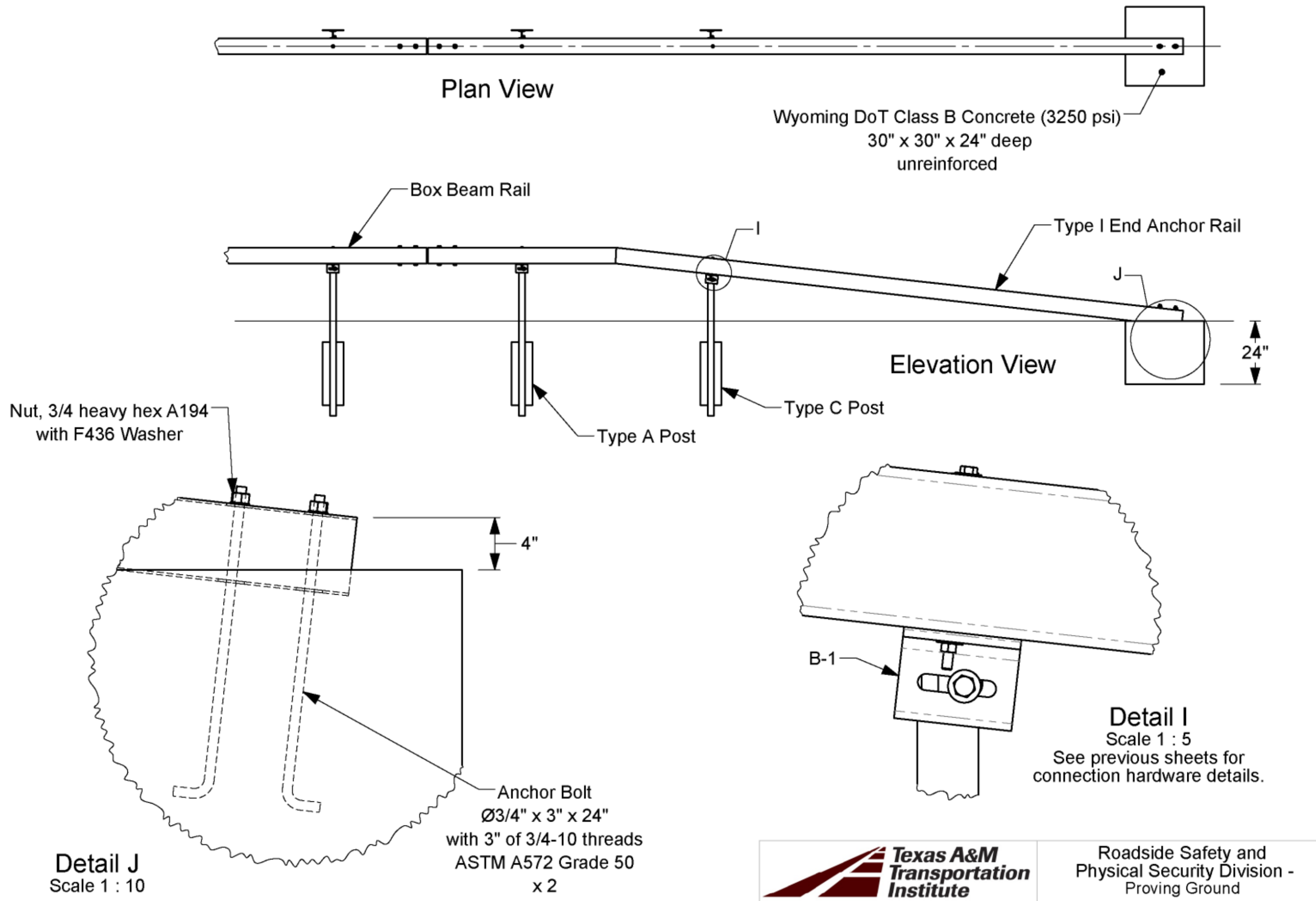
Terminal Details



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:50	Sheet 4 of 21 Terminal Details

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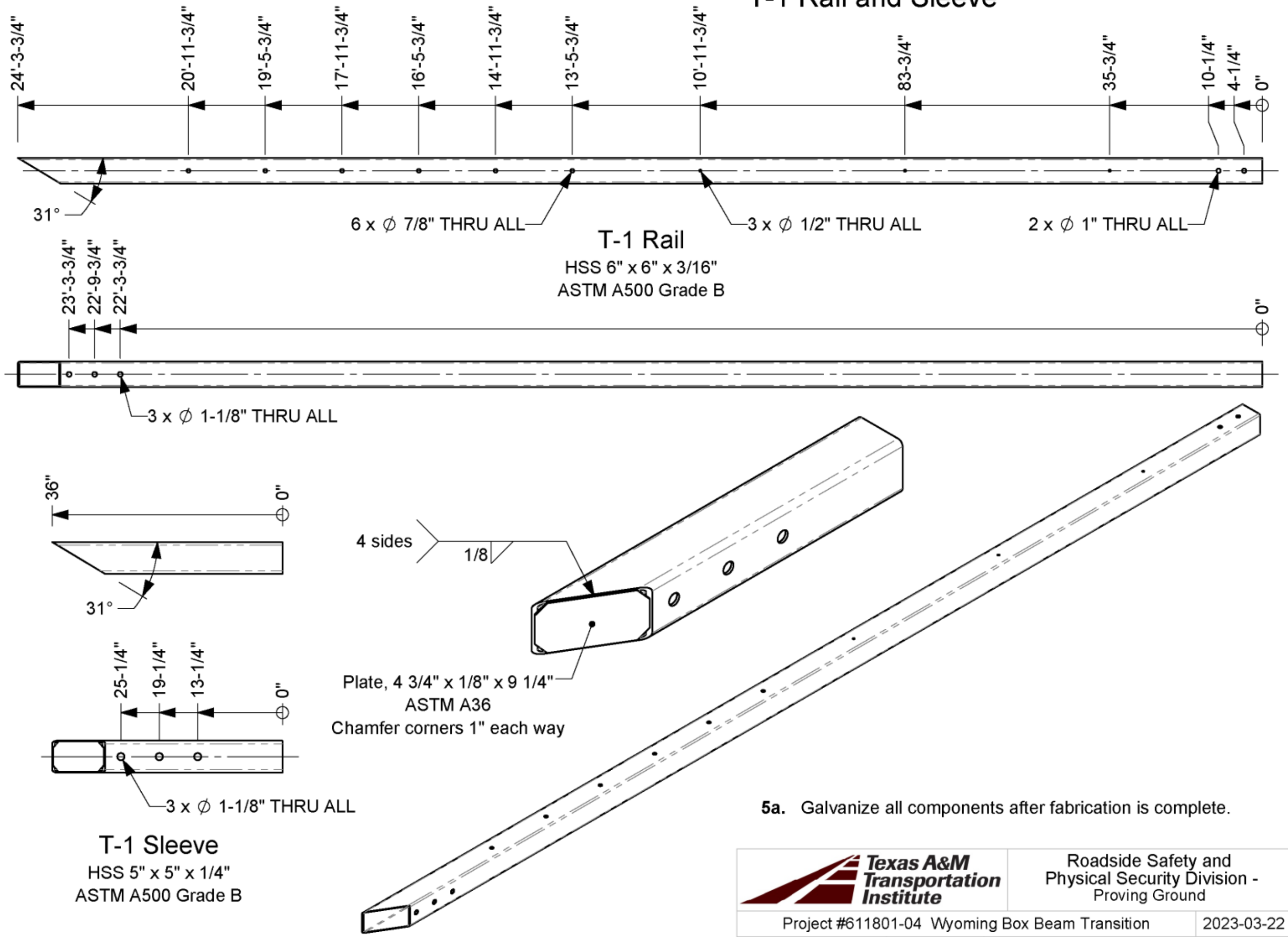
T-1 Rail and Sleeve



5a. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project #611801-04 Wyoming Box Beam Transition			2023-03-22
Drawn by GES	Scale 1:30	Sheet 5 of 21 T-1 Rail and Sleeve	

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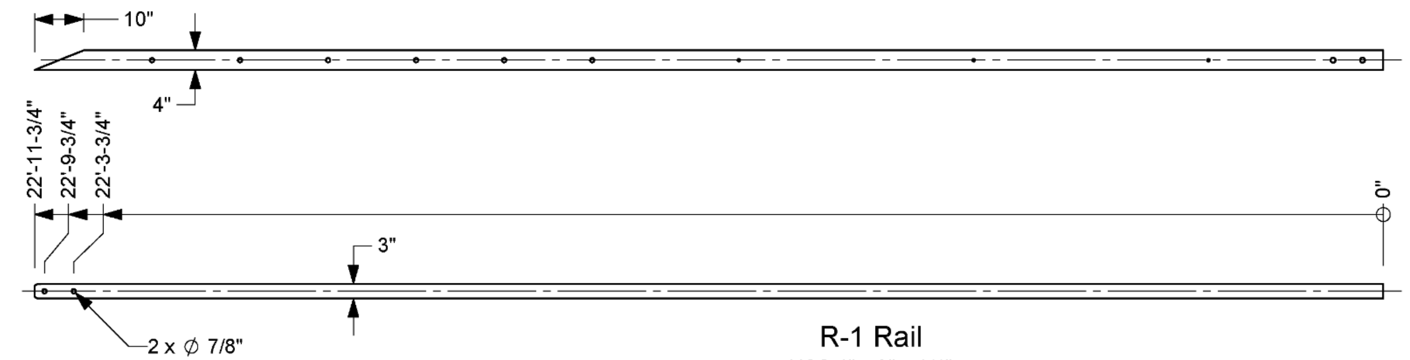
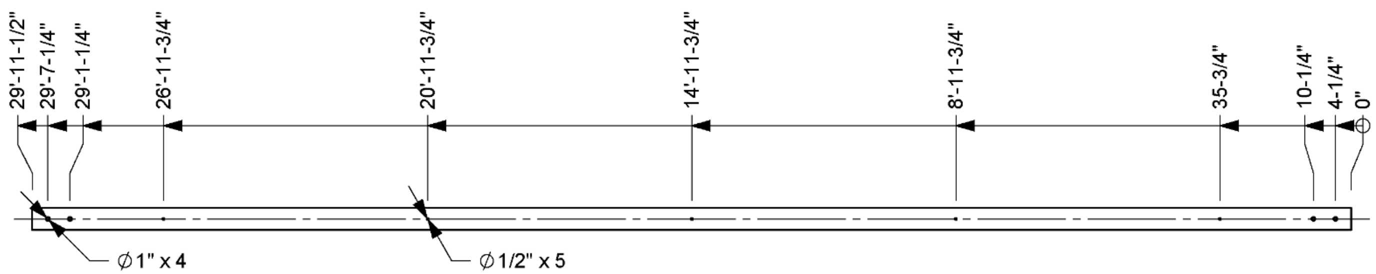
R-1 and T-2 Rails



R-1 Rail

HSS 4" x 3" x 1/4"
ASTM A500 Grade B
See T-1 Rail on previous sheet for all other details.
Plan and Elevation Views



T-2 Rail

HSS 6" x 6" x 3/16"
ASTM A500 Grade B
Plan View - Scale 1:40

6a. Galvanize all components after fabrication is complete.
6b. All holes are through both faces.

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Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:30	Sheet 6 of 21 R-1 and T-2 Rails

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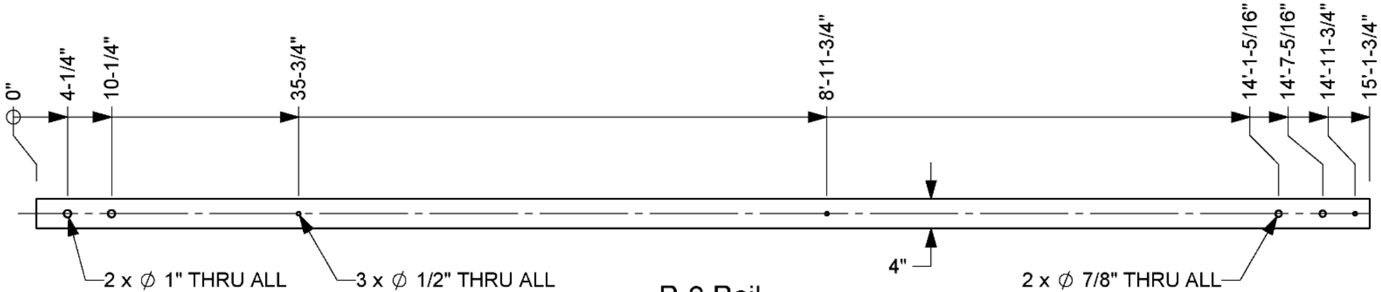
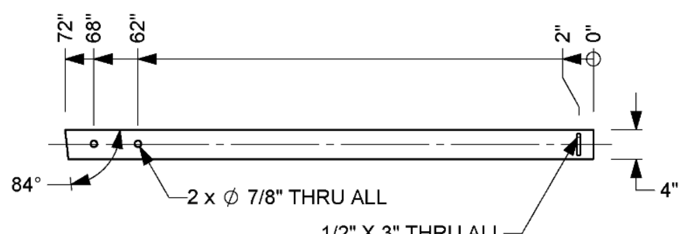
Rub Rails



R-2 Rail
HSS 4" x 3" x 1/4"
ASTM A500 Grade B
Plan View

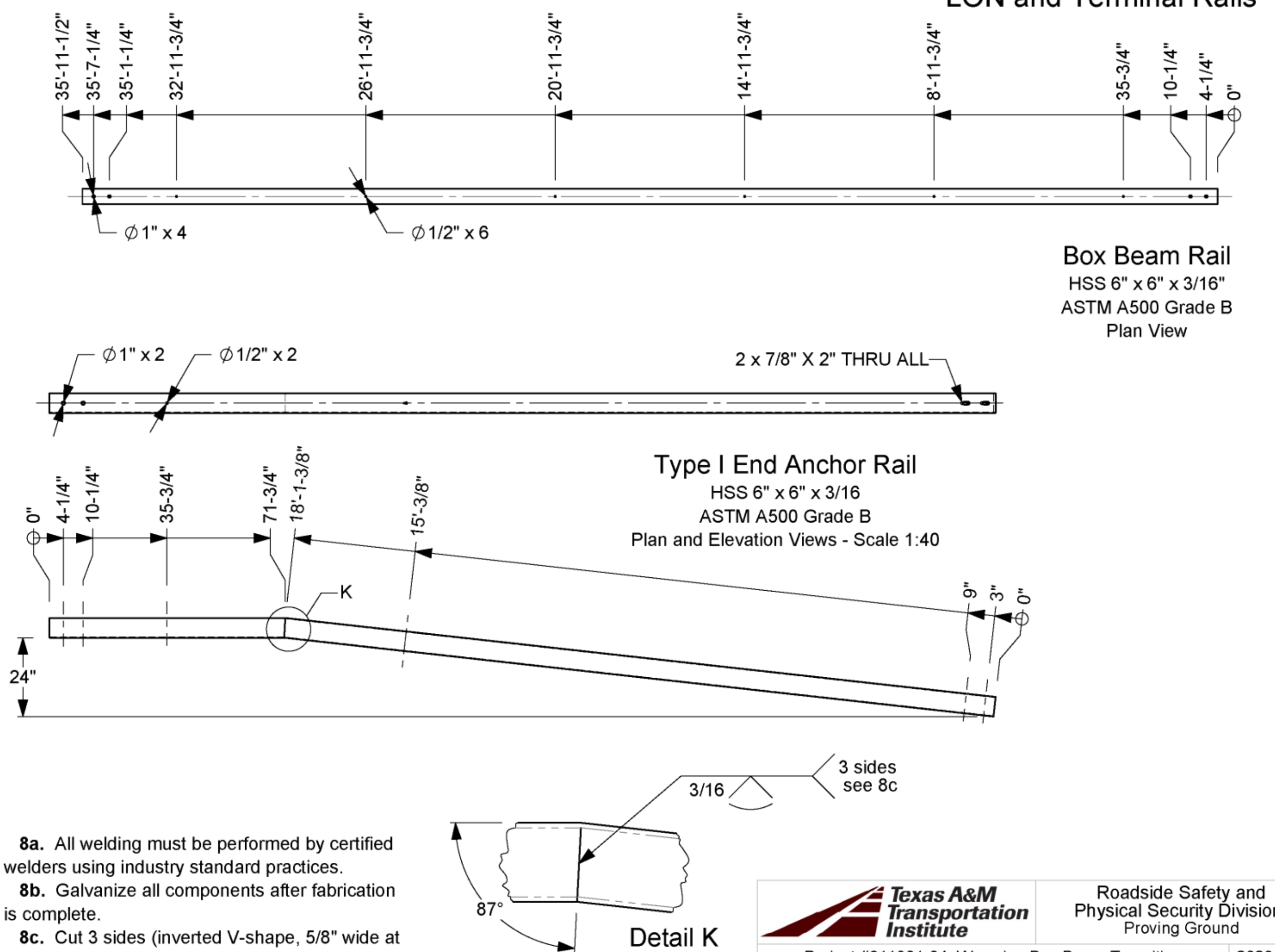


R-3 Rail
HSS 4" x 3" x 1/4"
ASTM A500 Grade B
Plan View

7a. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:20	Sheet 7 of 21 Rub Rails

LON and Terminal Rails



8a. All welding must be performed by certified welders using industry standard practices.
8b. Galvanize all components after fabrication is complete.
8c. Cut 3 sides (inverted V-shape, 5/8" wide at bottom), bend, and weld.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:50	Sheet 8 of 21 LON and Terminal Rails

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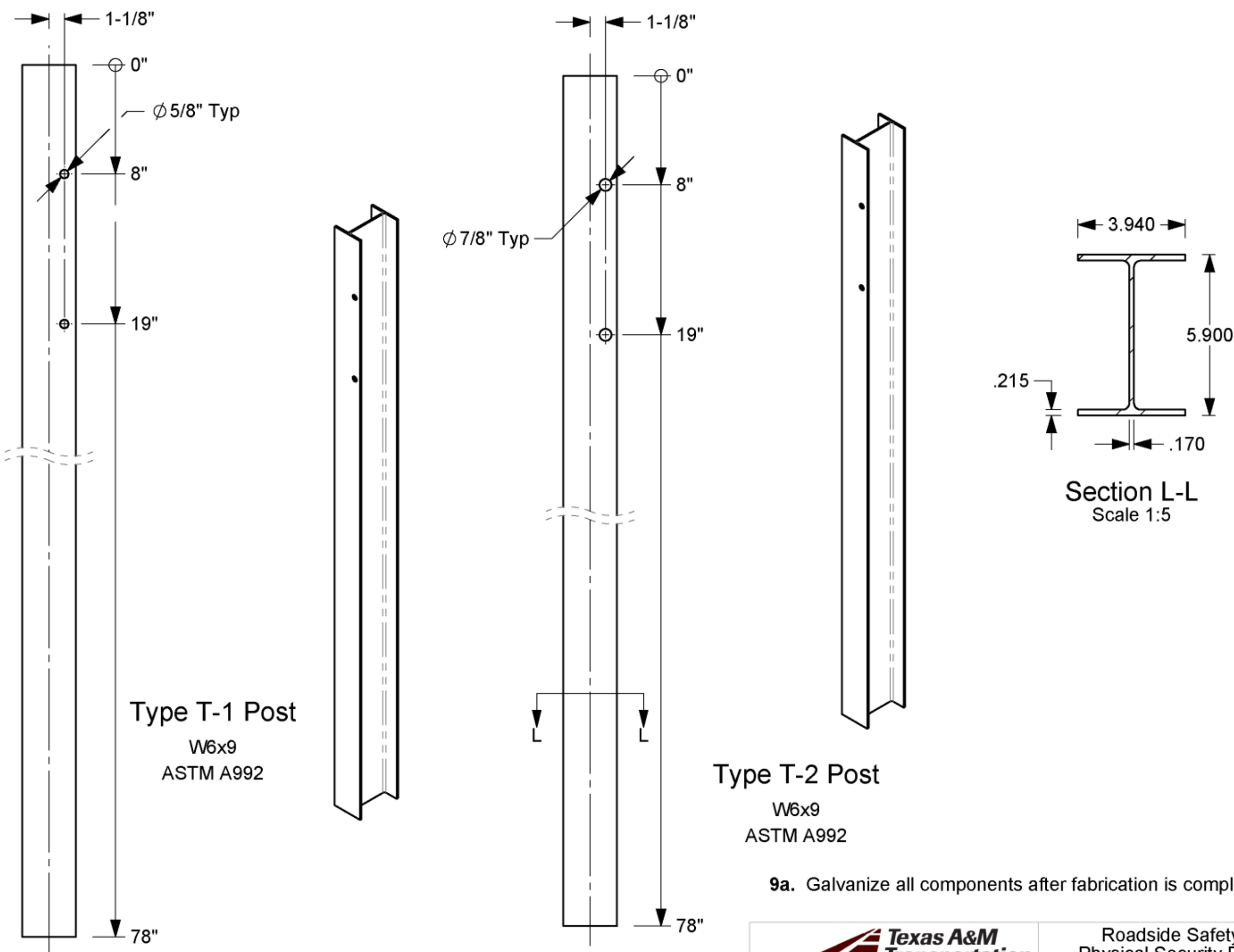

9a. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:10	Sheet 9 of 21 Type T Posts

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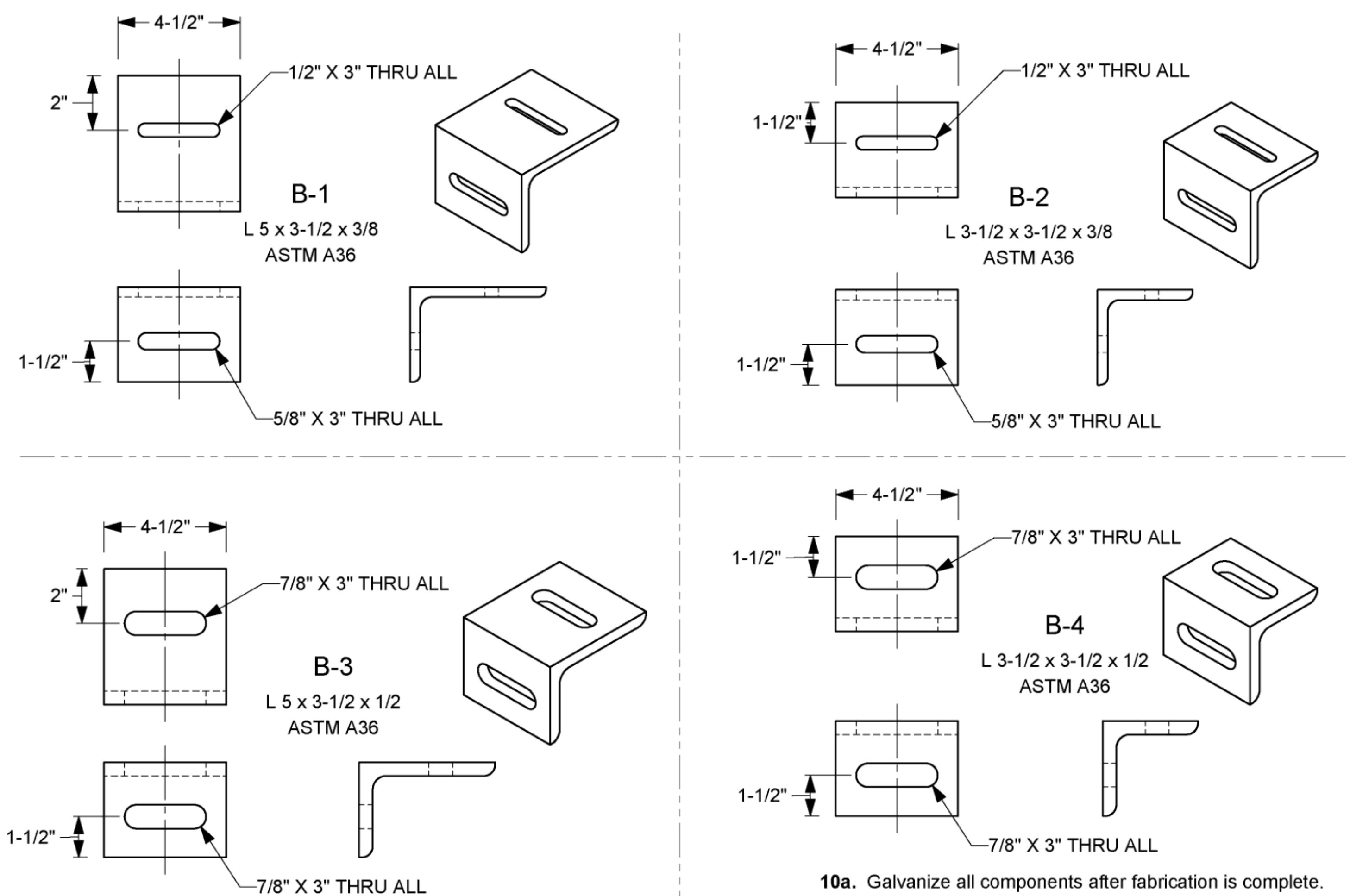

10a. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:5	Sheet 10 of 21 Brackets

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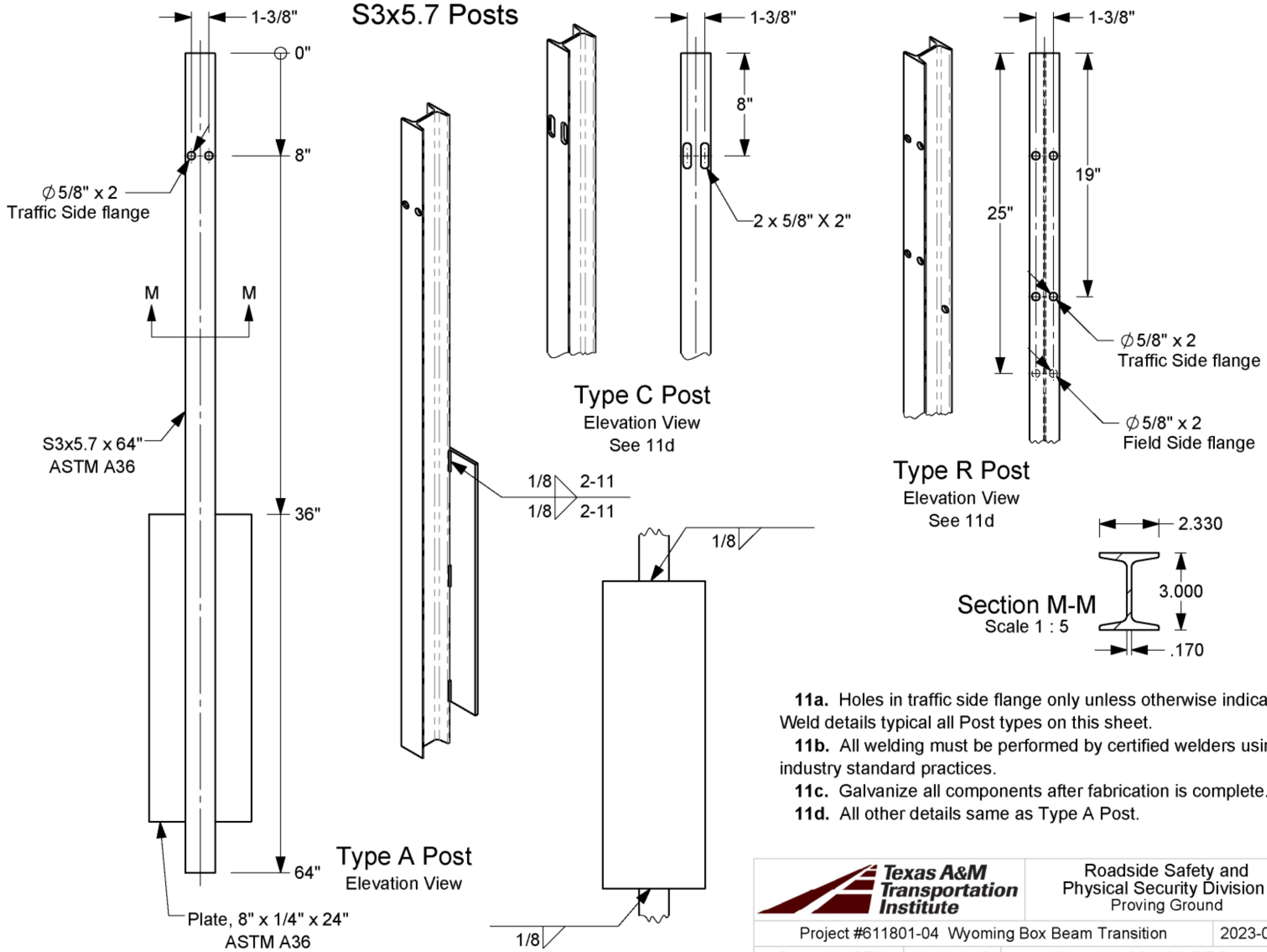
S3x5.7 Posts



11a. Holes in traffic side flange only unless otherwise indicated. Weld details typical all Post types on this sheet.

11b. All welding must be performed by certified welders using industry standard practices.

11c. Galvanize all components after fabrication is complete.

11d. All other details same as Type A Post.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:10	Sheet 11 of 21 S3x5.7 Posts

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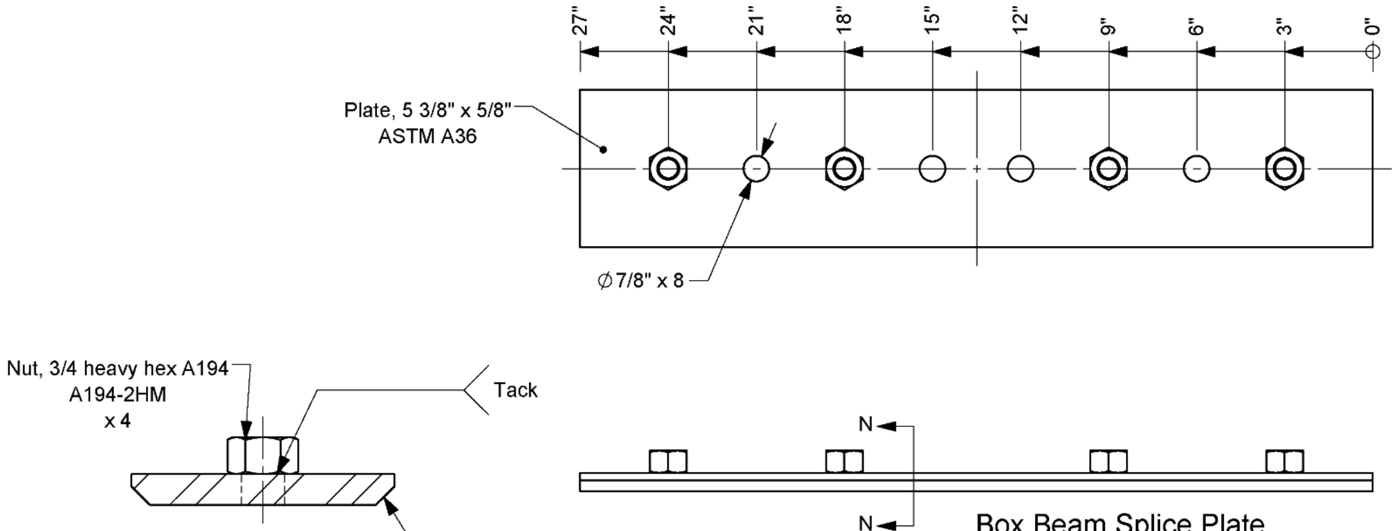
Box Beam Splice Plate



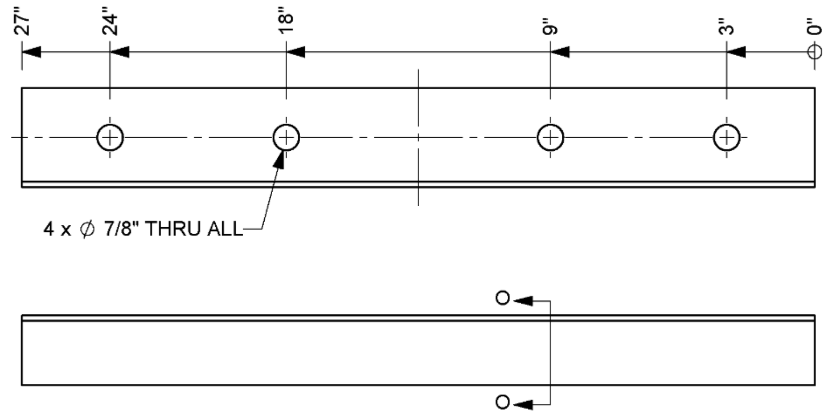
Section N-N
Scale 1 : 3

Box Beam Splice Plate
Plan and Elevation Views

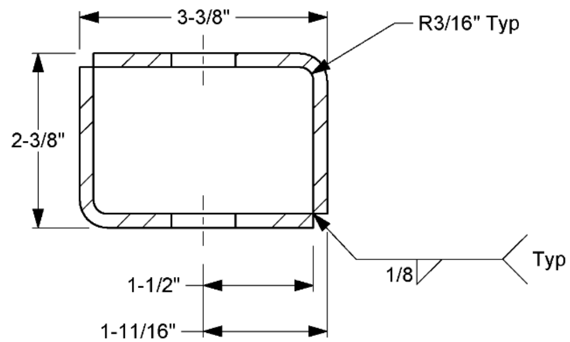
12a. All welding must be performed by certified welders using industry standard practices.
12b. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:5	Sheet 12 of 21 Box Beam Splice Plate

S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



J-1
ASTM A36 Plate, 27" x 3/16"
Plan and Elevation Views

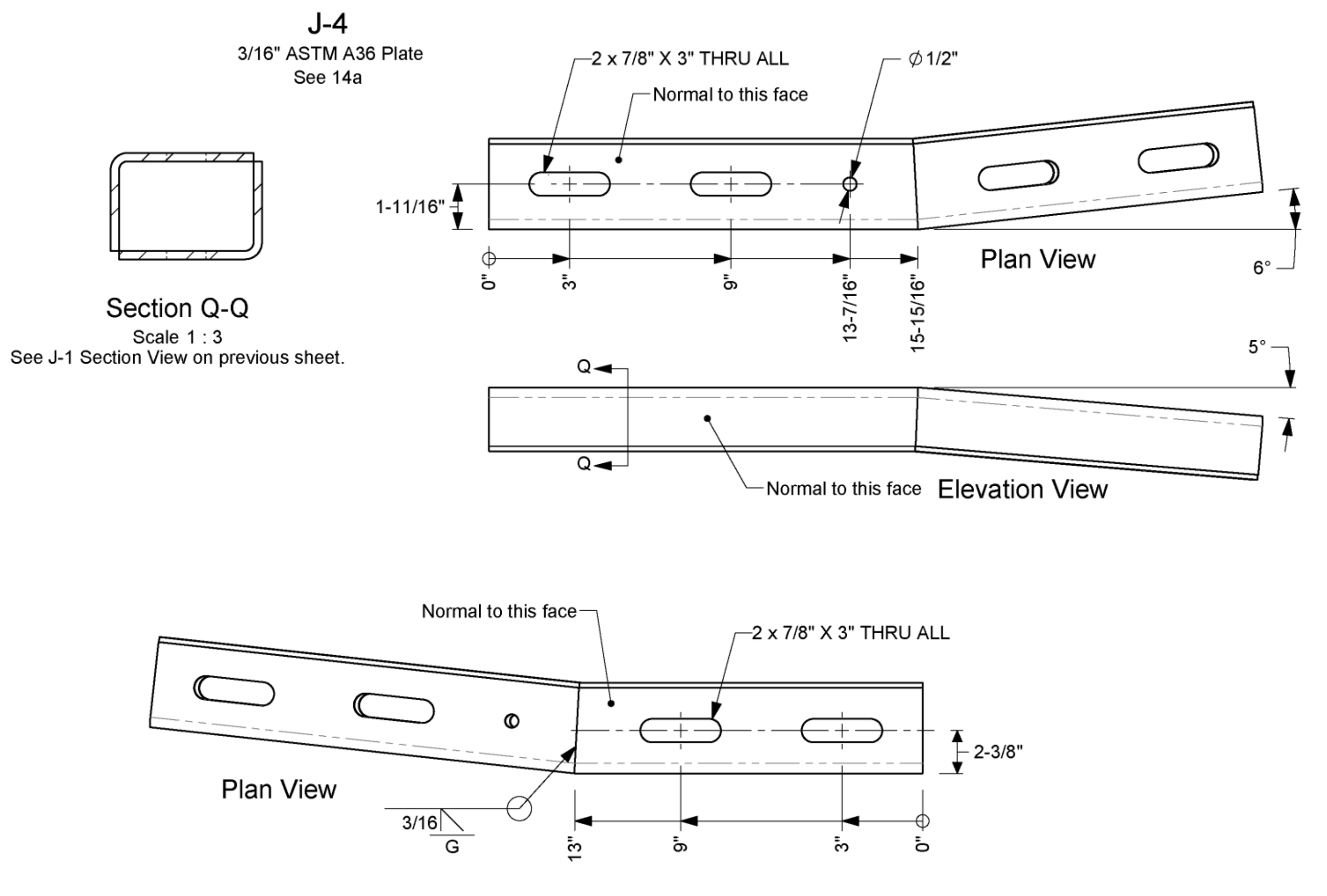


Section O-O
Scale 1 : 2

13a. All welding must be performed by certified welders using industry standard practices.
13b. Galvanize all components after fabrication is complete.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:5	Sheet 13 of 21 J-1

S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing

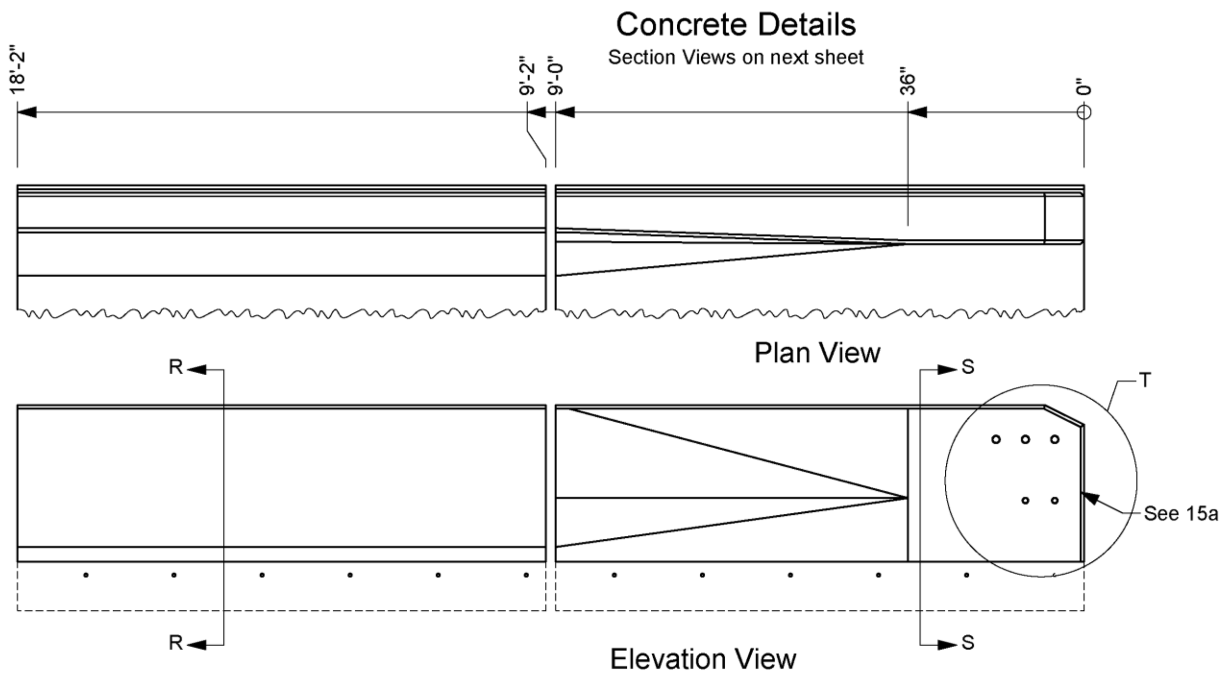


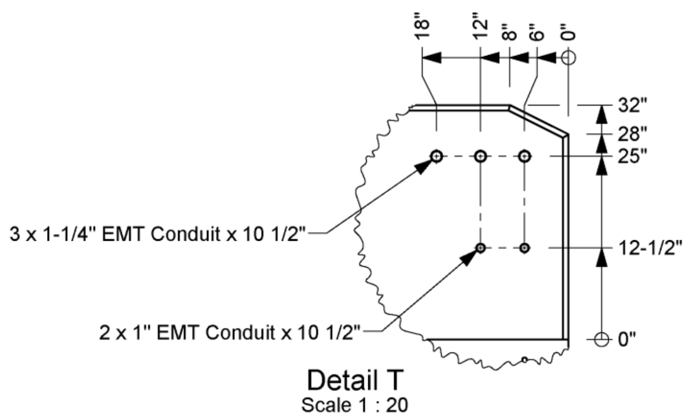
Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #611801-04 Wyoming Box Beam Transition	2023-03-22
Drawn by GES / Scale 1:5	Sheet 14 of 21 J-4

S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing

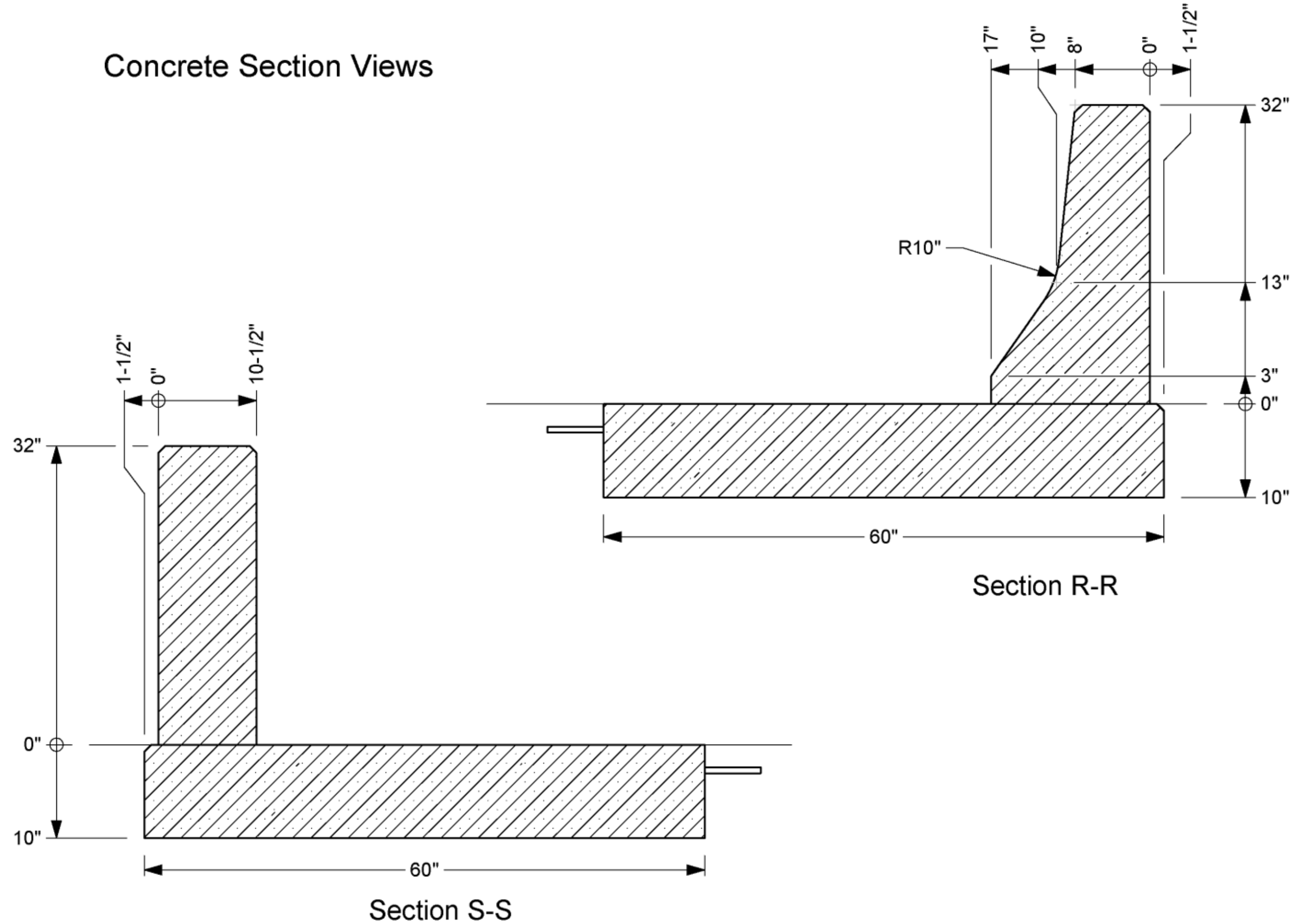




15a. Chamfer 1" (3/4" each way) edges of Parapet and Deck where shown.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:30	Sheet 15 of 21 Concrete Details

Concrete Section Views



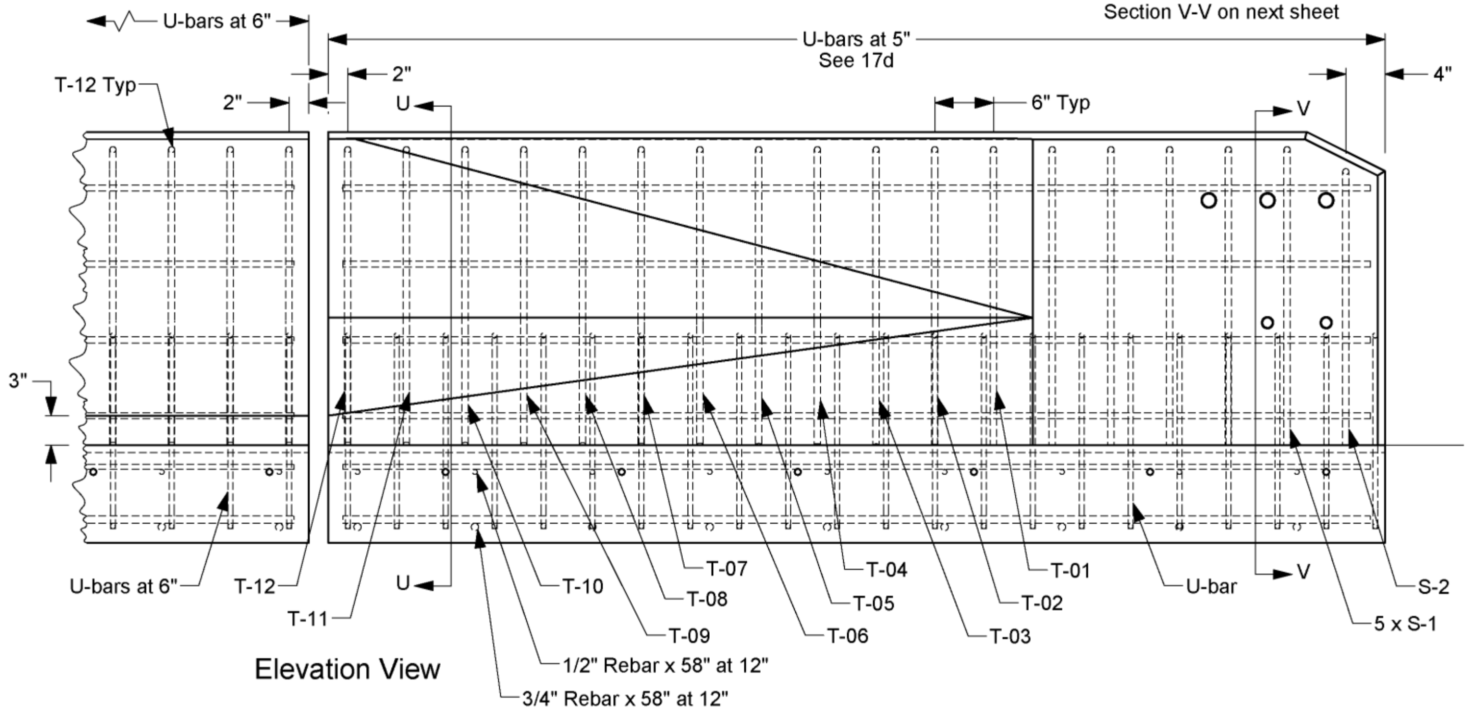
16a. Chamfer 1" (3/4" each way) edges of Parapet and Deck where shown.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:15	Sheet 16 of 21 Concrete Section Views

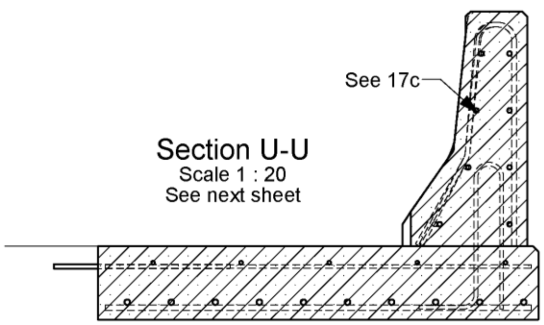
S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing

Rebar Details

Section V-V on next sheet



Elevation View



Section U-U
Scale 1 : 20
See next sheet

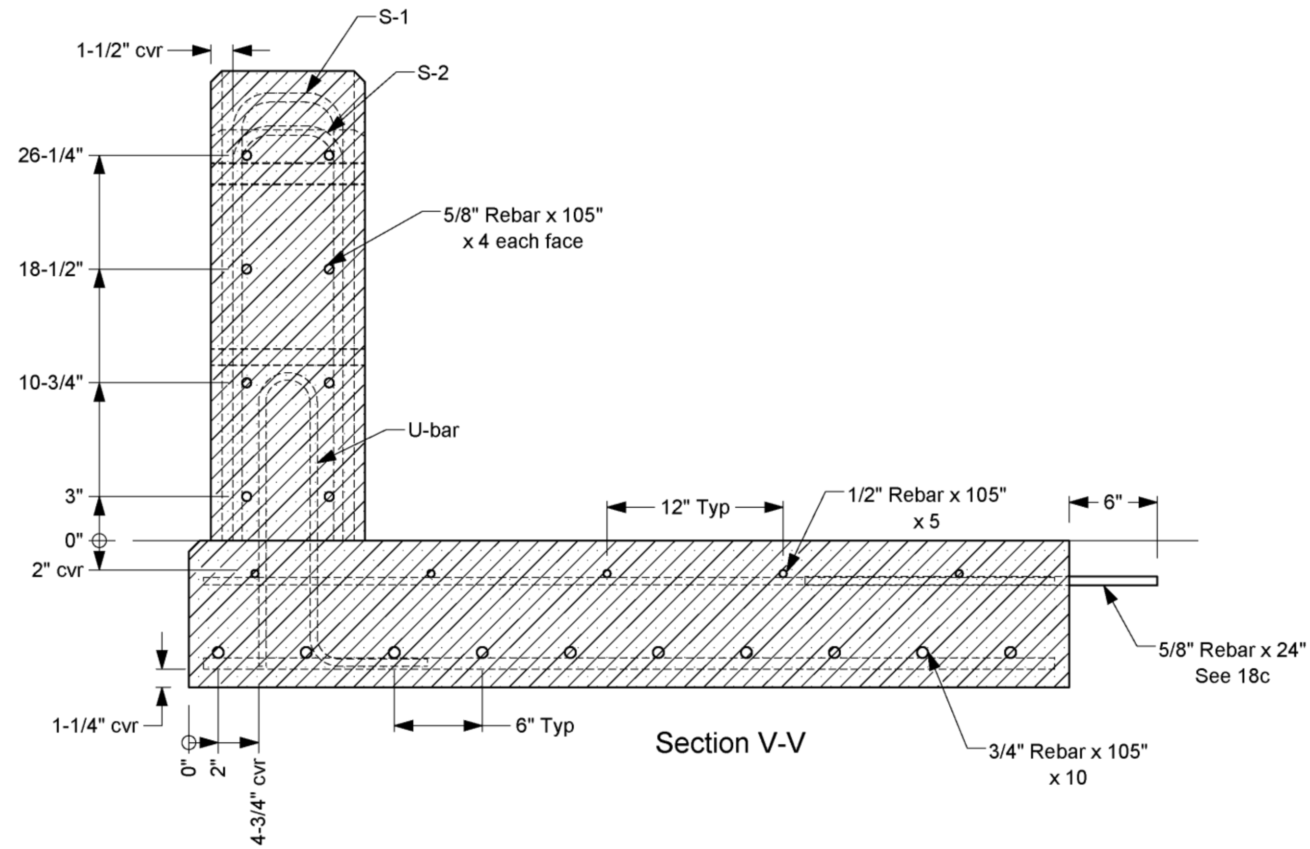
17a. Concrete is 4,000 psi. Rebar is Grade 60.

17b. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

17c. Field bend traffic side bars in transition section.

17d. Adjust U-bar spacing ±1/2" where needed to avoid interference with transverse rebar in deck.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:15	Sheet 17 of 21 Rebar Details

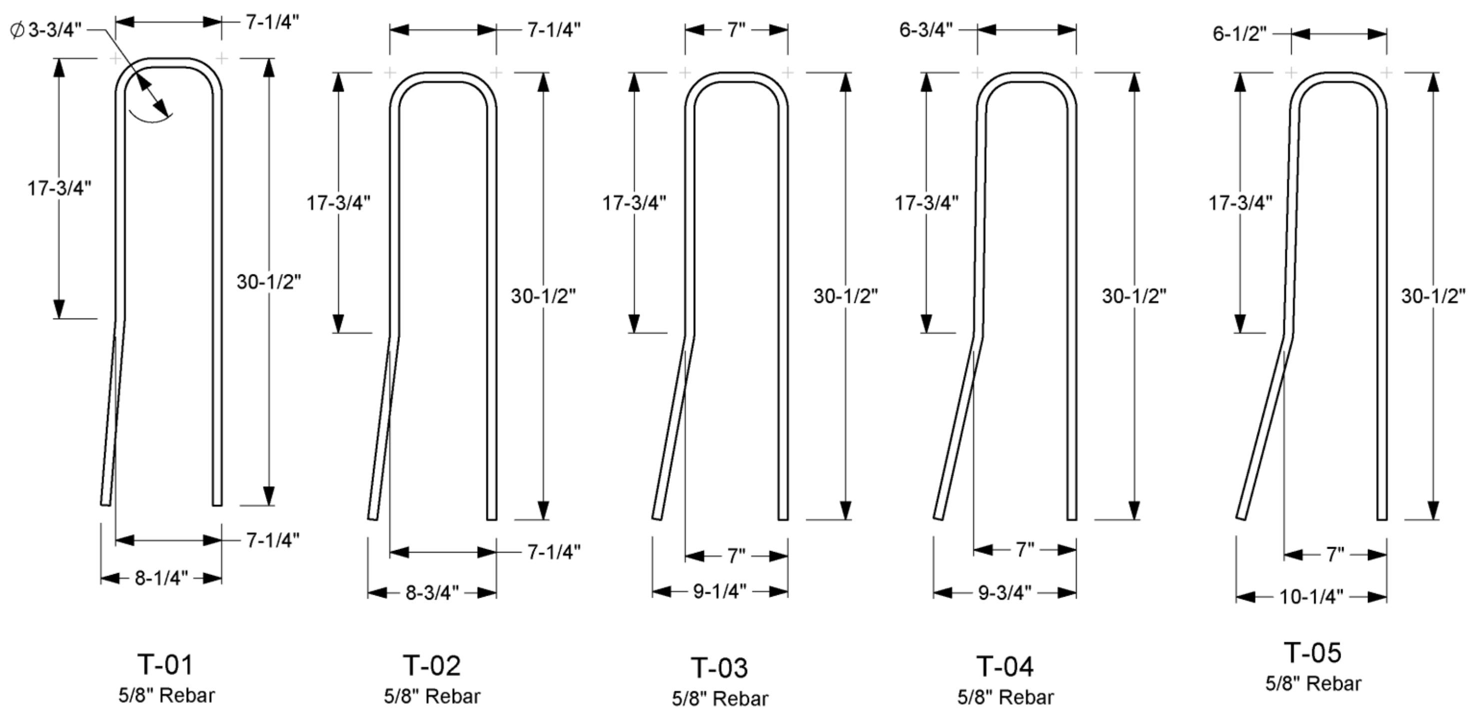


Section V-V

18a. Concrete is 4,000 psi. Rebar is Grade 60.
18b. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).
18c. Field bend traffic side bars as needed.
18c. Secure in existing concrete with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment. Space at 18".

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:10	Sheet 18 of 21 Rebar Section View

T-1 to T-5

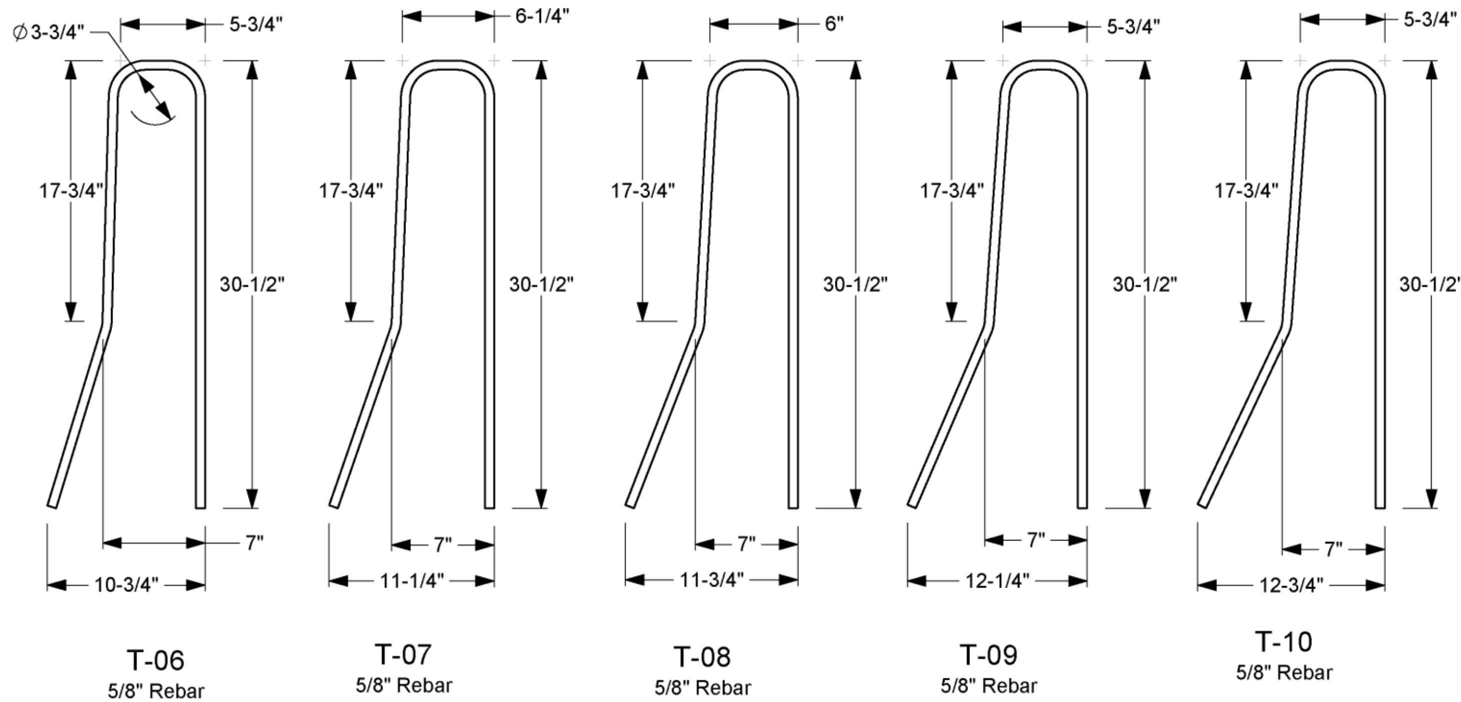


19a. All bends on 5/8" rebar are ∅3-3/4" unless otherwise indicated.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition			2023-03-22
Drawn by GES	Scale 1:10	Sheet 19 of 21 T-1 to T-5	

S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing

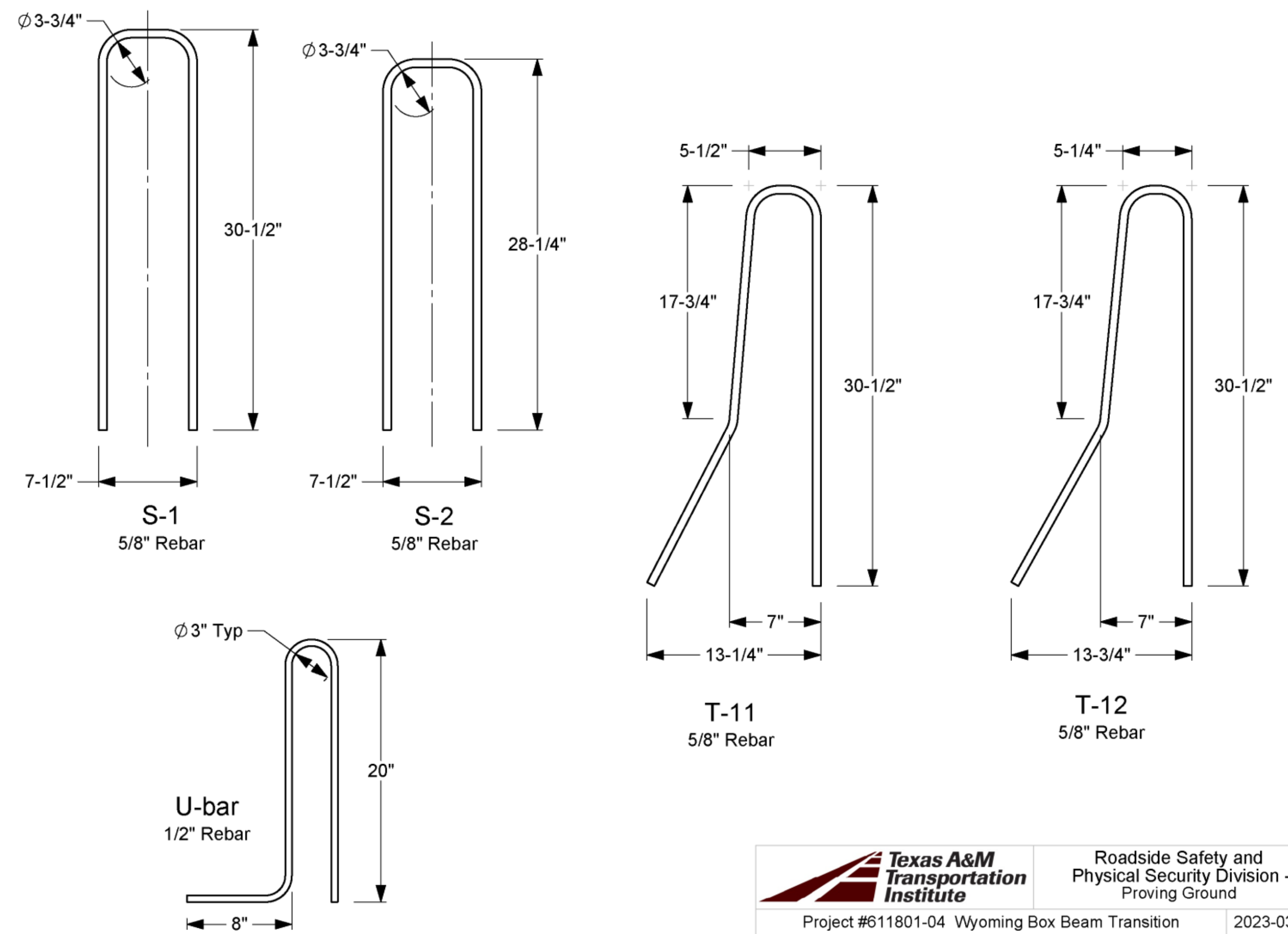
T-6 to T-10



20a. All bends on 5/8" rebar are ∅3-3/4" unless otherwise indicated.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project #611801-04 Wyoming Box Beam Transition			2023-03-22
Drawn by GES	Scale 1:10	Sheet 20 of 21 T-6 to T-10	

S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-04 Wyoming Box Beam Transition		2023-03-22
Drawn by GES	Scale 1:10	Sheet 21 of 21 U-, S-, and T11-12 bars

S:\Accreditation-17025-2017\EIR-000 Project Files\611801-04, Wyoming DoT - Bligh & Sheikh\Drafting, 611801-04\611801-04 Drawing

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

BL WLY-570445-3 9/9/2022
Order WLY-102557-3 Page:1

PO/REL WLY-22-2730/
HEAT: 1076655

ANGLE A-36/A 529 GR50
3-1/2 X 3-1/2 X 3/8 X 20'

1SERIES-BPS®

CMC STEEL ALABAMA
101 S 50TH STREET
BIRMINGHAM AL 35212-3525

CERTIFIED MILL TEST REPORT
For additional copies call
800-637-3227

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

Marcus W. McCluney - CMC Steel AL
Quality Assurance Manager

HEAT NO.:1076655 SECTION: ANG 3 1/2 X 3 1/2x3/8 40'0" A36/52950 GRADE: ASTM A36-19/A529-14 Gr 50 ROLL DATE: 11/13/2021 MELT DATE: 11/11/2021 Cert. No.: 83762071 / 076655B564	SOLD TO: Intsel Steel Distributors LP 11310 W Little York Rd Houston TX US 77041-4917 7139379500 7136977335	SHIP TO: Intsel Steel Distributors LP 11310 W Little York Rd Houston TX US 77041-4917 7139379500 7136977335	Delivery#: 83762071 BOL#: 74631542 CUST PO#: WLY-27795 CUST P/N: DLVRY LBS / HEAT: 20400.000 LB DLVRY PCS / HEAT: 60 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.15%	Elongation test 1	24%		
Mn	0.69%	Elongation Gage Lgth test 1	8IN		
P	0.017%	Yield to tensile ratio test1	0.71		
S	0.022%	Yield Strength test 2	53.1ksi		
Si	0.17%	Tensile Strength test 2	74.9ksi		
Cu	0.36%	Elongation test 2	25%		
Cr	0.14%	Elongation Gage Lgth test 2	8IN		
Ni	0.14%	Yield to tensile ratio test2	0.71		
Mo	0.035%				
V	0.004%				
Cb	0.009%				
Sn	0.012%				
B	0.0003%				
Ti	0.001%				
N	0.0087%				
Carbon Eq A6	0.33%				
Carbon Eq A529	0.36%				
Yield Strength test 1	52.8ksi				
Tensile Strength test 1	74.5ksi				

JERRY GASTON JR
MY COMMISSION EXPIRES JUNE 21, 2023
NOTARY PUBLIC
STATE OF ALABAMA

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

EMARKS : ALSO MEETS ASTM GRADE A36 REV 08, A572-50, A709-36, A709-50, A992, AASHTO GRADE M270-36, M270-50, CSA G40.21-04 GRADE 44W, 50W,
SME SA-36 2008A ADDEND A. HOT ROLLED CARBON STEEL

Page 1 OF 1 02/28/2022 22:59:34

JCOR STEEL - BERKELEY
155 Bagan Avenue
iger, SC 29450
ione: (843) 336-6000

CERTIFIED MILL TEST REPORT

11/23/21 6:31:40

100% EAF MELTED AND MANUFACTURED IN THE USA
Structural sections produced by Nucor-Berkeley are cast and hot rolled to a fully killed and fine grain practice.
Mercury not intentionally added at any point during manufacturing.

Sold To: INTSEL STEEL DISTRIBUTORS
PO BOX 21119

HOUSTON, TX 77226

Ship To: INTSEL STEEL DIST
11310 W LITTLE YORK
ZIS 06728
HOUSTON, TX 77041

Customer #.: 1864 - 25

B.O.L. #...: 1596846

MOS: R

?ECIFICATIONS: Tested in accordance with ASTM specification A6/A6M-19 and A370. Tested in accordance with EN10204-2004-3.1.
Quality Manual Rev #16 (4-30-21).
AASHTO : m270-345M270-50-19
ASME : SA-36 13
ASTM : A992-11(15:/A36-19/A529-19-50/A5725021T1/A7093618/A7095018
CSA : G40.21-44w/G40.21-50w/G40.2150WM

escription irt #	Heat# Grade(s) Test/Heat JW	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C Cr xxxxxx	Mn Mo Ti	P Sn xxxxxx	S B xxxxxx	Si V N	Cu Nb xxxxxx	Ni xxxxxx CI	CE1 CE2 Pcm
3X5.7 040' 00.00" 575X8.5 012.1920m	2118669 A992-11(15	.81 .82	53700 370 58000 400	65900 454 70800 488	29.00 24.63	.07 .04	.89 .01 .001	.016 .0046	.021 .0002	.21 .002 .0042	.09 .015	.03 2.72	.24 .2750 .1319
105 Pc(s) 23,940 lbs Customer PO: WLY 27244 BoL#: 1596846													
4x22 045' 00.00" W360X32.9 013.7160m	1119065 A992-11(15	.83 .86	57900 399 59400 410	69700 481 69000 476	31.03 25.40	.07 .03	.84 .00 .001	.013 .0045	.022 .0002	.20 .001 .0048	.08 .028	.03 2.50	.22 .2596 .1218
54 Pc(s) 53,460 lbs Customer PO: WLY-27307 BoL#: 1596846													
.4x22 060' 00.00" W360X32.9 018.2880m	2119019 A992-11(15	.85 .85	60400 416 60200 415	70900 489 71200 491	27.22 28.07	.07 .03	.83 .01 .001	.008 .0054	.019 .0002	.22 .002 .0047	.14 .028	.04 3.52	.23 .2691 .1274
72 Pc(s) 95,040 lbs Customer PO: WLY-27307 BoL#: 1596846													

.ongation based on 8' (20.32cm) gauge length. 'No Weld Repair' was performed.
: = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29Cu*Ni)-(9.10Ni*P)-33.39(Cu*Cu)
:m = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
E1= C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)

'All mechanical testing is performed by the Quality testing lab, which is independent of the production departments'
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

icor certifies that the contents of this report are accurate and orrect. All test results and operations performed by the material anufacturer are in compliance with material specifications, and ien designated by the Purchaser, meet applicable specifications.

Dmitri Nassyrov
Metallurgist/
Quality-Control

BL WLY-570445-6 9/9/2022
Order WLY-102557-6 Page:2

PO/REL WLY-22-2730/
HEAT: 2118669

STANDARD "I" BEAM A 992
3 X 5.7# X 20'

UCOR STEEL - BERKELEY
455 Hagan Avenue
uger, SC 29450
hone: (843) 336-6000

CERTIFIED MILL TEST REPORT

11/23/21 6:31:40

100% EAF MELTED AND MANUFACTURED IN THE USA
Structural sections produced by Nucor-Berkeley are cast
and hot rolled to a fully killed and fine grain practice.
Mercury not intentionally added at any point during manufacturing.

Sold To: INTSEL STEEL DISTRIBUTORS
PO BOX 21119

HOUSTON, TX 77226

Ship To: INTSEL STEEL DIST
11310 W LITTLE YORK
ZIS 06728
HOUSTON, TX 77041

Customer #.: 1864 - 25

B.o.L. #...: 1596846

MOS: R

PECIFICATIONS: Tested in accordance with ASTM specification A6/A6M-19 and A370. Tested in accordance with EN10204-2004-3.1.
Quality Manual Rev #16 (4-30-21).
AASHTO : m270-345M270-50-19
ASME : SA-36 13
ASTM : A992-11(15:/A36-19/A529-19-50/A5725021T1/A7093618/A7095018
CSA : G40.21-44W/G40.21-50W/G40.2150WM
3 Heat(s) for this MTR.

==

longation based on 8' (20.32cm) gauge length. 'No Weld Repair' was peformed.
I = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P-(7.29CuXNi)-(9.10NiXP)-33.39(CuXCu)
cm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
E1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)

'All mechanical testing is performed by the Quality testing lab, which is independent of the production departments'
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

ucor certifies that the contents of this report are accurate and orrect. All test results and operations performed by the material anufacturer are in compliance with material specifications, and hen designated by the Purchaser, meet applicable specifications.

Dmitri Nassyrov
Metallurgist/
Quality Control

04-22-2022 06:02 Load - 4062865 BL - 3916345 blr466

Brazos Industries LLC

Heat - SM1278

Cust. PO -

Order - 21304494

NUCOR TUBULAR PRODUCTS

6226 W. 74TH STREET
CHICAGO, IL 60638
Tel: 708-496-0380
Fax: 708-563-1950

https://www.nucortubular.com
https://www.ntpportal.com
Certificate Number: DCR 752830

Sold By:
NUCOR TUBULAR PRODUCTS INC.
DECATUR DIVISION
2000 INDEPENDENCE AVENUE N.W.
DECATUR, AL 35601
Tel: 256 340-7420
Fax: 256 340-7415

Purchase Order No: 7722972
Sales Order No: DCR 145113 - 16
Bill of Lading No: DCR 105846 - 5
Invoice No:

Shipped: 3/23/2022
Invoiced:

Sold To:
1187 - KLOECKNER METALS - BUDA/HOUSTON
500 COLONIAL PARKWAY
SUITE 500
ROSWELL, GA 30076

Ship To:
1 - KLOECKNER METALS CORP HOUSTON
14200 ALMEDA ROAD
713-433-7211
HOUSTON, TX 77053

CERTIFICATE of ANALYSIS and TESTS

Customer Part No:

TUBING A500 GRADE B(C)
5" SQ X 1/4" X 48'

Certificate No: DCR 752830
Test Date: 3/14/2022

Total Pieces	Total Weight Lbs
16	11,996

Bundle Tag	Mill	Heat	Specs	Y/T Ratio	Pieces	Weight Lbs
622415	40N	NM0839	YLD=68000/TEN=77200/ELG=26	0.8808	12	8,997
622452	40N	SM1278	YLD=64100/TEN=77000/ELG=30	0.8325	4	2,999

Mill #: 40N Heat #: NM0839 Carbon Eq: 0.2473 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	N
0.0600	0.9700	0.0080	0.0020	0.1940	0.0180	0.1000	0.0600	0.0200	0.0050	0.0300	0.0240	0.0073

B	Ti	Ca
0.0001	0.0100	0.0035

Mill #: 40N Heat #: SM1278 Carbon Eq: 0.2907 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	N
0.2000	0.3700	0.0070	0.0040	0.0200	0.0270	0.1400	0.0600	0.0200	0.0020	0.0500	0.0070	0.0074

B	Ti	Ca
0.0003	0.0010	0.0019

T/R FAX

Certification:

I certify that the above results are a true and correct copy of records prepared and maintained by NUCOR TUBULAR PRODUCTS INC. Sworn this day, 3/14/2022.

THE SPECIFICATIONS LISTED BELOW REPRESENT THE CURRENT ISSUED DATES OF THESE STANDARDS. THIS DOES NOT INDICATE THAT THE MATERIAL ABOVE CONFORMS TO EACH OR ALL OF THE STANDARDS. WE CERTIFY THE MATERIAL ABOVE TO THE SPECIFICATION LISTED IN THE LINE DESCRIPTION.

Nora Oukajji
Metallurgist/Quality Supervisor

CURRENT STANDARDS:
A252-19
A500/A500M-21
A513/A513M-20
ASTM A53/A53M-20| ASME SA-53/SA-53M-20
A847/A847M-14
A1085/A1085M-15
IN COMPLIANCE WITH EN 10204 SECTION 4.1
INSPECTION CERTIFICATE TYPE 3.1

Page - 1

CMC

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

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

611801-03

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.:3111040 SECTION: REBAR 19MM (#6) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 12/11/2021 MELT DATE: 12/04/2021 Cert. No.: 83714603 / 111040A619	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#: 83714603 BOL#: 74563715 CUST PO#: 905997 CUST P/N: DLVRY LBS / HEAT: 30282.000 LB DLVRY PCS / HEAT: 1008 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.46%	Bend Test Diameter	3.750IN		
Mn	0.80%				
P	0.013%				
S	0.049%				
Si	0.17%				
Cu	0.39%				
Cr	0.09%				
Ni	0.15%				
Mo	0.054%				
V	0.000%				
Cb	0.000%				
Sn	0.010%				
Al	0.002%				
Yield Strength test 1	67.6ksi				
Tensile Strength test 1	108.6ksi				
Elongation test 1	15%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.61				
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 CFı
*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 01/12/2022 00:57:51

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

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

611801-05

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

Rolando A Davila
Quality Assurance Manager

	SOLD TO	SHIP TO	
HEAT NO.:3111523 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 12/26/2021 MELT DATE: 12/21/2021 Cert. No.: 83702613 / 111523A371	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 83702613 BOL#: 74545773 CUST PO#: 905075 CUST P/N: DLVRY LBS / HEAT: 8012.000 LB DLVRY PCS / HEAT: 384 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.44%	Bend Test Diameter	2.188IN		
Mn	0.94%				
P	0.011%				
S	0.039%				
Si	0.17%				
Cu	0.32%				
Cr	0.10%				
Ni	0.18%				
Mo	0.062%				
V	0.000%				
Cb	0.001%				
Sn	0.016%				
Al	0.001%				
Yield Strength test 1	67.5ksi				
Tensile Strength test 1	107.1ksi				
Elongation test 1	16%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.59				
Bend Test 1	Passed				

The Following is true of the material represented by this MTR:

**Material is fully killed*
**100% melted and rolled in the USA*
**EN10204:2004 3.1 compliant*
**Contains no weld repair*
**Contains no Mercury contamination*
**Manufactured in accordance with the latest version of the plant quality manual*
**Meets the "Buy America" requirements of 23 CFR635.410, 49 CF*
**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 12/29/2021 23:15:42

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

CERTIFIED MILL TEST REPORT

For additional copies call
830-372-8771

611801-03

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.:3111173 SECTION: REBAR 13MM (#4) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 12/19/2021 MELT DATE: 12/08/2021 Cert. No.: 83714604 / 111173A130	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#: 83714604 BOL#: 74563716 CUST PO#: 905998 CUST P/N: DLVRY LBS / HEAT: 10955.000 LB DLVRY PCS / HEAT: 820 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.45%	Bend Test Diameter	1.750IN		
Mn	0.86%				
P	0.010%				
S	0.043%				
Si	0.21%				
Cu	0.30%				
Cr	0.13%				
Ni	0.14%				
Mo	0.053%				
V	0.000%				
Cb	0.001%				
Sn	0.011%				
Al	0.002%				
Yield Strength test 1	71.8ksi				
Tensile Strength test 1	109.8ksi				
Elongation test 1	14%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.53				
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 CF
*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 01/12/2022 00:59:20

CMC STEEL FLORIDA
16770 Rebar Road
Jacksonville FL 32234 4100

CERTIFIED MILL TEST REPORT

For additional copies call
904-266-1468

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

Chad Foltz
Quality Assurance Manager

	SOLD TO		SHIP TO	
HEAT NO.:5023687 SECTION: REBAR 13MM (#4) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 11/15/2022 MELT DATE: 11/05/2022 Cert. No.: 85247413 / 023687K130	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900		CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 85247413 BOL#: 75100408 CUST PO#: 935377 CUST P/N: DLVRY LBS / HEAT: 48096.000 LB DLVRY PCS / HEAT: 3600 EA

Characteristic	Value
C	0.45%
Mn	0.82%
P	0.017%
S	0.042%
Si	0.18%
Cu	0.31%
Cr	0.17%
Ni	0.08%
Mo	0.017%
V	0.003%
Cb	0.001%
Sn	0.009%
Yield Strength test 1	54.8ksi
Yield Strength test 1 (metri	447MPa
Tensile Strength test 1	104.6ksi
Tensile Strength 1 (metric)	721MPa
Elongation test 1	16%
Elongation Gage Lgth test 1	8IN
Tensile to Yield ratio test1	1.61

Characteristic	Value
Elongation Gage Lgth 1(metri	200mm
Bend Test 1	Passed
Rebar Deformation Avg. Spaci	0.327IN
Rebar Deformation Avg. Heigh	0.030IN
Rebar Deformation Max. Gap	0.122IN

Characteristic	Value

The Following is true of the material represented by this MTR:

**Material is fully killed and is Hot Rolled Steel*
**100% melted, rolled, and manufactured 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 : ALSO MEETS AASHTO M31

Page 1 OF 1 12/02/2022 14:23:22

CMC STEEL FLORIDA
16770 Rebar Road
Jacksonville FL 32234-4100

CERTIFIED MILL TEST REPORT

For additional copies call
904 266-1468

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

Chad Foltz
Quality Assurance Manager

HEAT NO.:5023781 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615 20 Gr 420/60 ROLL DATE: 11/09/2022 MELT DATE: 11/09/2022 Cert. No.: 85247415 / 023781K371	SOLD TO	CMC Construction Svcs College Stat. 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#: 85247415 BOL#: 75100412 CUST PO#: 935381 CUST P/N: DLVRY LBS / HEAT: 15024.000 LB DLVRY PCS / HEAT: 768 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.46%	Elongation Gage Lgth 1(metri	200mm		
Mn	1.04%	Bend Test 1	Passed		
P	0.011%	Rebar Deformation Avg. Spaci	0.381IN		
S	0.037%	Rebar Deformation Avg. Heigh	0.037IN		
Si	0.18%	Rebar Deformation Max. Gap	0.130IN		
Cu	0.25%				
Cr	0.12%				
Ni	0.07%				
Mo	0.022%				
V	0.004%				
Cb	0.002%				
Sn	0.013%				
Yield Strength test 1	67.2ksi				
Yield Strength test 1 (metri	463MPa				
Tensile Strength test 1	109.2ksi				
Tensile Strength 1 (metric)	753MPa				
Elongation test 1	14%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.62				

The Following is true of the material represented by this MTR:

**Material is fully killed and is Hot Rolled Steel*
**100% melted, rolled, and manufactured 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 : ALSO MEETS AASHTO M31

Page 1 OF 1 12/02/2022 21:44:54

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

CERTIFIED MILL TEST REPORT

For additional copies call
800-227-6489

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.:3119337 SECTION: REBAR 19MM (#6) 20'0" 420/60 GRADE: ASTM A615-20 Gr 420/60 ROLL DATE: 11/07/2022 MELT DATE: 11/01/2022 Cert. No.: 85233725 / 119337A619	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#: 85233725 BOL#: 75082383 CUST PO#: 934479 CUST P/N: DLVRY LBS / HEAT: 17304.000 LB DLVRY PCS / HEAT: 576 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.50%	Bend Test Diameter	3.750IN		
Mn	0.92%				
P	0.010%				
S	0.044%				
Si	0.24%				
Cu	0.34%				
Cr	0.08%				
Ni	0.13%				
Mo	0.046%				
V	0.000%				
Cb	0.001%				
Sn	0.009%				
Al	0.002%				
Yield Strength test 1	73.6ksi				
Tensile Strength test 1	118.9ksi				
Elongation test 1	10%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.62				
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, rolled, and manufactured 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 :

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BL HOU-934005-1 8/19/2022
Order HOU-39071-1 Page:1

PO/REL HOU-22-2714/
HEAT: 221583

PLATE A36 TEMPER LEVELED
1/4 X 60.0000" X 96.0000"

AHMSA ALTOS HORNOS DE MEXICO

MILL TEST CERTIFICATE **AHMSA:QUALITY WITH THE STRENGTH OF STEEL**

PROLONGACION JUAREZ SIN NUMERO COLONIA LA LOMA MONCLOVA COAHUILA 25770
PHONE +52 1 - 866 649 3400

B548970B

USTOMER

DDRESS

RODUCT HOT ROLLED STEEL IN COILS.

DATE OF ISSUED	PAGE
31.05.2022	1

WE HEREBY CERTIFY THAT CHEMICAL AND / OR TEST SHOW IN THIS REPORT ARE CORRECT AS CONTAINED THE RECORDS OF THE COMPANY.

ING. EMMANUEL DE JESUS AGUILAR LUNA
MECHANICAL TESTS AND CERTIFICATION
EXT. 11920

CHEMICAL COMPOSITION

IEAT	SPECIFICATION	C	Mn	P	S	Si	Cu	Cr	Ni	Mo	Alt	V	Nb(Cb)	Ti
221583	ASTM A 1018 SS 36TIPO 2.REV-18	0.160	0.840	0.017	0.008	0.1100	0.029	0.025	0.020	0.004	0.037	0.003	0.001	0.003

IEAT	N2
221583	0.0056

TEST OF THE PRODUCT

IEAT	COIL NO.	SLAB	THICKNESS(Inch)	Y.STRENGTH	T.STRENGTH	%ELON.	T.ELONG.
221583	5441042	7030	0.4925	46.240(KSI)	66.403(KSI)	45(%)	2
221583	5441045	7040	0.2400	57.260(KSI)	78.832(KSI)	37(%)	2

SHIPPED PRODUCT

EAT	SLAB	COIL NO.	WEIGHT(t)	THICKNESS(Inch)	WIDTH(Inch)	ORDER	ITEM
21583	7040	5441045	19.900	0.2400	60.0000	0000257786	000060

EAT	SLAB	COIL NO.	DELIVERY	CUSTOMER ORD	
21583	7040	5441045	1003092378	PO2099/MAY22	STD DIMENTIONAL ASTM A568/A635

Fine Grain Practice
Country of origin: Steel Heat melted and casted in México

END OF DATA

LO# 37995
1/4 x 60 HR
Heat# 221583

ISSUED : S100944

Plate A36 Temper Leveled 1/4 x 60 x 96

Triple S

Atlas Tube Arkansas
5039N County Road 1015
Blytheville Arkansas USA
72315
Tel:
Fax:

Atlas Tube *A DIVISION OF ZEKELMAN INDUSTRIES*

REF.B/L: 81040210
Date: 08/20/2021
Customer: 1746

MATERIAL TEST REPORT

Sold To
Service Steel Warehouse Co. L.P.
PO Box 9607
HOUSTON TX 77213
USA

Shipped To
Service Steel Warehouse Co., L.P.
8415 Clinton Drive
HOUSTON TX 77029
USA

Material: 6.0x6.0x188x32'0"0(3x3). **Material No:** 60060188 **Made in:** USA

Sales Order: 1683915 **Purchase Order:** SSW121029 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
21104832	0.220	0.760	0.009	0.002	0.030	0.025	0.040	0.002	0.009	0.020	0.020	0.003	0.001	0.0001	0.0094	0.0024

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M500381107	9	059205 Psi	078372 Psi	33 %	ASTM A500-21 GRADE B&C	CE: 0.36

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
21104832	BIGRIVER	Osceola,AR	EAF	76.00%	95.00%	5.00 %	75%	500

Material Note:
Sales Or. Note:

Material: 12.0x4.0x375x40'0"0(1x1)PB **Material No:** 120040375 **Made in:** USA

Sales Order: 1689585 **Purchase Order:** SSW121029 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
21076142	0.210	0.770	0.009	0.001	0.040	0.033	0.100	0.001	0.018	0.050	0.050	0.004	0.001	0.0001	0.0086	0.0028

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M500375810	1	054608 Psi	075792 Psi	38 %	ASTM A500-21 GRADE B&C	CE: 0.37

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
21076142	BIGRIVER	Osceola,AR	EAF	76.00%	95.00%	5.00 %	75%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: [signature]

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements. CE calculated using the AWS D1.1 method. This document is in compliance with the requirements of EN 10204 type 3.1

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 1 of 7

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 3 PO#: 22-2731
Part: T060060183Z* Qty: 1 Heat#: 21104832* Tag: B17091222

Atlas Tube Arkansas
5039N County Road 1015
Blytheville Arkansas USA
72315
Tel:
Fax:

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 81040210
Date: 08/20/2021
Customer: 1746

MATERIAL TEST REPORT

Sold To
Service Steel Warehouse Co. L.P.
PO Box 9607
HOUSTON TX 77213
USA

Shipped To
Service Steel Warehouse Co., L.P.
8415 Clinton Drive
HOUSTON TX 77029
USA

Material: 14.0x14.0x625x32'0"0(1x1)REC **Material No:** 140140625 **Made in:** USA

Sales Order: 1631881 **Purchase Order:** SSW118116 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
21089292	0.200	0.740	0.011	0.002	0.030	0.029	0.090	0.001	0.011	0.040	0.050	0.002	0.001	0.0002	0.0071	0.0031

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
0003484736	1	051796 Psi	077703 Psi	33 %	ASTM A500-21 GRADE B&C	CE: 0.35

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
21089292	BIGRIVER	Osceola,AR	EAF	76.00%	95.00%	5.00 %	75%	500

Material Note:
Sales Or. Note:

Material: 3.0x2.0x250x40'0"0(6x3). **Material No:** 300202504000 **Made in:** USA

Sales Order: 1671861 **Purchase Order:** SSW119562 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
02285C	0.210	0.840	0.010	0.008	0.011	0.046	0.030	0.007	0.000	0.010	0.060	0.000	0.001	0.0000	0.0050	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M400189027	7	061464 Psi	081642 Psi	28 %	ASTM A500-21 GRADE B&C	CE: 0.37

Material Note:
Sales Or. Note:

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 3 PO#: 22-2731
Part: T060601832* Qty: 1 Heat#: 21104832* Tag: B17091222

Authorized by Quality Assurance: [signature]

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method. This document is in compliance with the requirements of EN 10204 type 3.1

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 2 of 7

Atlas Tube Arkansas
5039N County Road 1015
Blytheville Arkansas USA
72315
Tel:
Fax:

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 81040210
Date: 08/20/2021
Customer: 1746

MATERIAL TEST REPORT

Sold To
Service Steel Warehouse Co. L.P.
PO Box 9607
HOUSTON TX 77213
USA

Shipped To
Service Steel Warehouse Co., L.P.
8415 Clinton Drive
HOUSTON TX 77029
USA

Material: 3.0x2.0x250x40'0"0(6x3). **Material No:** 300202504000 **Made in:** USA
Sales Order: 1671861 **Purchase Order:** SSW119562 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
21074851	0.210	0.830	0.010	0.002	0.040	0.027	0.100	0.001	0.012	0.040	0.040	0.003	0.001	0.0002	0.0061	0.0031

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M400189027	8	070547 Psi	081791 Psi	28 %	ASTM A500-21 GRADE B&C	CE: 0.38

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
21074851	BIGRIVER	Osceola,AR	EAF	76.00%	95.00%	5.00 %	75%	500

Material Note:
Sales Or. Note:

Material: 3.0x2.0x250x40'0"0(6x3). **Material No:** 300202504000 **Made in:** USA
Sales Order: 1671861 **Purchase Order:** SSW119562 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
21076222	0.210	0.860	0.011	0.002	0.030	0.029	0.070	0.001	0.015	0.040	0.050	0.004	0.001	0.0001	0.0070	0.0027

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M400189027	3	059512 Psi	082079 Psi	27 %	ASTM A500-21 GRADE B&C	CE: 0.38

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
21076222	BIGRIVER	Osceola,AR	EAF	76.00%	95.00%	5.00 %	75%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements. CE calculated using the AWS D1.1 method. This document is in compliance with the requirements of EN 10204 type 3.1

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 3 of 7

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 3 PO#: 22-2731
Part: T060601832* Qty: 1 Heat#: 21104832* Tag: B17091222

Atlas Tube Arkansas
5039N County Road 1015
Blytheville Arkansas USA
72315
Tel:
Fax:

Atlas Tube — A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 81040210
Date: 08/20/2021
Customer: 1746

MATERIAL TEST REPORT

Sold To
Service Steel Warehouse Co. L.P.
PO Box 9607
HOUSTON TX 77213
USA

Shipped To
Service Steel Warehouse Co., L.P.
8415 Clinton Drive
HOUSTON TX 77029
USA

Material: 3.0x2.0x250x40'0"0(6x3). **Material No:** 300202504000 **Made in:** USA
Sales Order: 1675568 **Purchase Order:** SSW119562 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
21076222	0.210	0.860	0.011	0.002	0.030	0.029	0.070	0.001	0.015	0.040	0.050	0.004	0.001	0.0001	0.0070	0.0027

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M400189018	9	059512 Psi	082079 Psi	27 %	ASTM A500-21 GRADE B&C	CE: 0.38

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
21076222	BIGRIVER	Osceola,AR	EAF	76.00%	95.00%	5.00 %	75%	500

Material Note:
Sales Or. Note:

Material: 3.0x2.0x250x40'0"0(6x3). **Material No:** 300202504000 **Made in:** USA
Sales Order: 1675568 **Purchase Order:** SSW119562 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
21076242	0.220	0.840	0.012	0.005	0.030	0.030	0.080	0.001	0.016	0.040	0.050	0.004	0.001	0.0001	0.0087	0.0023

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M400189018	9	071692 Psi	081363 Psi	28 %	ASTM A500-21 GRADE B&C	CE: 0.39

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
21076242	BIGRIVER	Osceola,AR	EAF	76.00%	95.00%	5.00 %	75%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: *Jason Richard*

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method. This document is in compliance with the requirements of EN 10204 type 3.1

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 4 of 7

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 3 PO#: 22-2731
Part: T0600601832* Qty: 1 Heat#: 21104832* Tag: B17091222

Atlas Tube Arkansas
5039N County Road 1015
Blytheville Arkansas USA
72315
Tel:
Fax:

Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 81040210
Date: 08/20/2021
Customer: 1746

MATERIAL TEST REPORT

Sold To
Service Steel Warehouse Co. L.P.
PO Box 9607
HOUSTON TX 77213
USA

Shipped To
Service Steel Warehouse Co., L.P.
8415 Clinton Drive
HOUSTON TX 77029
USA

Material: 3.0x2.0x250x40'0"0(6x3). **Material No:** 300202504000 **Made in:** USA
Sales Order: 1671861 **Purchase Order:** SSW119562 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
02285C	0.210	0.840	0.010	0.008	0.011	0.046	0.030	0.007	0.000	0.010	0.060	0.000	0.001	0.0000	0.0050	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M400189029	18	061464 Psi	081642 Psi	28 %	ASTM A500-21 GRADE B&C	CE: 0.37

Material Note:
Sales Or. Note:

Material: 4.0x2.0x125x40'0"0(5x5). **Material No:** 400201254000 **Made in:** USA
Sales Order: 1690213 **Purchase Order:** SSW121029 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
SL5150	0.200	0.820	0.006	0.005	0.026	0.034	0.130	0.002	0.010	0.040	0.050	0.004	0.001	0.0004	0.0062	0.0023

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M400188549	25	073089 Psi	082130 Psi	28 %	ASTM A500-21 GRADE B&C	CE: 0.37

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: Jason Richard

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements. CE calculated using the AWS D1.1 method. This document is in compliance with the requirements of EN 10204 type 3.1

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 5 of 7

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 3 PO#: 22-2731
Part: T060601832* Qty: 1 Heat#: 21104832* Tag: B17091222

Atlas Tube Arkansas
5039N County Road 1015
Blytheville Arkansas USA
72315
Tel:
Fax:

Atlas Tube A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 81040210
Date: 08/20/2021
Customer: 1746

MATERIAL TEST REPORT

Sold To
Service Steel Warehouse Co. L.P.
PO Box 9607
HOUSTON TX 77213
USA

Shipped To
Service Steel Warehouse Co., L.P.
8415 Clinton Drive
HOUSTON TX 77029
USA

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 3 PO#: 22-2731
Part: T0600601832* Qty: 1 Heat#: 21104832* Tag: B17091222

Material: 4.0x2.0x125x40'0"0(5x5). **Material No:** 400201254000 **Made in:** USA
Sales Order: 1690213 **Purchase Order:** SSW121029 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
SL5150	0.200	0.820	0.006	0.005	0.026	0.034	0.130	0.002	0.010	0.040	0.050	0.004	0.001	0.0004	0.0062	0.0023

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M400188550	25	073089 Psi	082130 Psi	28 %	ASTM A500-21 GRADE B&C	CE: 0.37

Material Note:
Sales Or. Note:

Material: 6.0x4.0x250x40'0"0(3x3). **Material No:** 600402504000 **Made in:** USA
Sales Order: 1682826 **Purchase Order:** SSW121029 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
02748C	0.210	0.840	0.018	0.008	0.013	0.048	0.060	0.007	0.000	0.020	0.080	0.000	0.001	0.0000	0.0040	0.0000

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M400185946	9	068701 Psi	083620 Psi	34 %	ASTM A500-21 GRADE B&C	CE: 0.37

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
02748C	USSTEEL	GRANITE CITY,IL	BOF	36.90%	19.80%	14.40%	100%	500

Material Note:
Sales Or. Note:

Authorized by Quality Assurance: [signature]

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements. CE calculated using the AWS D1.1 method. This document is in compliance with the requirements of EN 10204 type 3.1

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Page: 6 of 7

Atlas Tube Arkansas
5039N County Road 1015
Blytheville Arkansas USA
72315
Tel:
Fax:

Atlas *Tube*
A DIVISION OF ZEKELMAN INDUSTRIES

REF.B/L: 81040210
Date: 08/20/2021
Customer: 1746

MATERIAL TEST REPORT

Sold To
Service Steel Warehouse Co. L.P.
PO Box 9607
HOUSTON TX 77213
USA

Shipped To
Service Steel Warehouse Co., L.P.
8415 Clinton Drive
HOUSTON TX 77029
USA

Material: 14.0x4.0x250x48'0"0(1x5). **Material No:** 1400402504800 **Made in:** USA

Sales Order: 1687379 **Purchase Order:** SSW121029 **Melted and Poured in:** USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N	Ca
21076402	0.220	0.770	0.017	0.003	0.040	0.031	0.050	0.001	0.011	0.030	0.050	0.004	0.001	0.0002	0.0072	0.0025

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	
M500374036	5	056630 Psi	075109 Psi	33 %	ASTM A500-21 GRADE B&C	CE: 0.37

Heat	MILL	Mill Location	Method	Recycled Content	Post Consumer	Pre-Consumer (Post Industrial)	% Harvested	Within Miles of Location
21076402	BIGRIVER	Osceola,AR	EAF	76.00%	95.00%	5.00 %	75%	500

Material Note:
Sales Or. Note:

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 3 PO#: 22-2731
Part: T0600601832* Qty: 1 Heat#: 21104832* Tag: B17091222

Authorized by Quality Assurance: [signature]

The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method. This document is in compliance with the requirements of EN 10204 type 3.1

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

From: S[illegible]ice Steel Warehouse   Date: 9/13/2022   To: [illegible]K-MAR, LP   SO#: A729549   Ln#: 2   PO#: [illegible]2731
Part: T0b0601830*   Qty: 1   Heat#: 122395*   Tag: B1/091222

FORZA STEEL

MATERIAL TEST REPORT - QUALITY MANAGEMENT SYSTEM

CONSTANCIA DE INSPECCION
INSPECTION CONSTANCY
(EN 10204 3.1 B- ISO10474 3.1B)
FORZA STEEL - PRODUCTION FACILITY:

Carretera Salinas Victoria K.m. 2 s/n Salinas Victoria, Nuevo León , México C.P. 65500 Tel: +52 (51) 1958-3780

Packing List	2528	Cod (Code):	FPD-PR-01-08
		Edition (Edición): 1	Rev: 0
		Date of Rev (Fecha Rev) :	20-01-2021
		Page (Hoja):	1/2

CUSTOMER (Cliente)					PURCHASE ORDER (Orden de Compra)				DELIVERY (Remisión)			DATE (Fecha)		REFERENCE NUMBER (No. Referencia)
SERVICE STEEL WAREHOUSE					SSW121166				5054309			08/09/2021		06082021-19550
PIPE TYPE PRODUCT	FORZA WORK ORDER	SIZE	WALL THICKNESS	HEAT	SPECIFICATION	GRADE	LENGTH	INCHES (Longitud)	MASS (Peso Unitario)		MASS PER METER	HYDROSTATIC TEST	SPECIAL REQUIREMENTS	TUBE NUMBER
Tipo de producto	Orden Interna de Fab.	Diámetro	Cédula/Espesor	No. Colada	Especificación Norma	Grado	Metros	Pies	Lbs	Kg	Peso Lineal kg x metros	Prueba Hidrostatica (psi)	Requerimientos especiales	No. Piezas
HSS	OIF 5000	6x6	0.188	122395	ASTM A500	B/C	9.15	30.02	442.09	200.53	21.93	N/A	N/A	18
Lotes	5000-3-2,5000-2-53,5000-2-62,5000-2-52,5000-2-55A,5000-2-59,5000-2-63,5000-2-49,5000-2-61,5000-2-50,5000-3-4,5000-2-54,5000-2-51,5000-2-58,5000-2-64,5000-2-60,5000-3-3,5000-2-57													

Forza Steel certifica que los productos descritos en este documento fueron fabricados en cumplimiento con los requerimientos de la especificacion descrita, obteniendo resultados satisfactorios en todas sus pruebas e inspecciones incluidas en los planes de calidad de forza steel para cumplir con los requerimientos del pedido en referencia.

--

Forza steel certifies that the products described in this document were manufactured in compliance with the requirements of the specification described, obtaining satisfactory results in all tests and inspections included in the quality plans of Forza Steel to meet the requirements of the order in reference.

Certify By (Autorizó)

Ing. Edgar Eduardo Olivo Hernández

QUALITY ASSURANCE MANAGER

6x6x.188w 30' SQ Tube ASTM A500

Service Steel Warehouse

From: S ice Steel Warehouse Date: 9/13/2022 To: K-MAR, LP SO#: A729549 Ln#: 2 PO#: 2 2731
Part: T0600601830* Qty: 1 Heat#: 122395* Tag: B17091222

FORZA STEEL

MATERIAL TEST REPORT - QUALITY MANAGEMENT SYSTEM

CONSTANCIA DE INSPECCION
INSPECTION CONSTANCY
(EN 10204 3.1 B- ISO10474 3.1B)
FORZA STEEL - PRODUCTION FACILITY:

Carretera Salinas Victoria K.m. 2 s/n Salinas Victoria, Nuevo León , México C.P. 65500 Tel: +52 (51) 1958-3780

Packing List	2528	Cod (Code):	FPD-PR-01-08
		Edition (Edición) :1	Rev: 0
		Date of Rev (Fecha Rev) :	20-01-2021
		Page (Hoja):	2/2

		Chemical Analyses (Análisis Químico)										Mechanical Test (Pruebas mecánicas)		
Heat (Colada)	Tube/Lote	C	Si	Mn	P	S	V	Cr	Cu	Ni	Mo	Yield Strength (KSI) (Límite elástico)	Tensile Strength (KSI) (Última tensión)	Elongation (%) (Elongación)
122395	5000-2-49	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-50	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-51	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-52	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-53	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-54	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-55A	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-57	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-58	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-59	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-60	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-61	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-62	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-63	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-2-64	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-3-2	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-3-3	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35
122395	5000-3-4	0.165	0.015	0.520	0.012	0.005	0.001	0.015	0.020	0.002	0.001	60.15	72.50	35

Forza Steel certifica que los productos descritos en este documento fueron fabricados en cumplimiento con los requerimientos de la especificacion descrita, obteniendo resultados satisfactorios en todas sus pruebas e inspecciones incluidas en los planes de calidad de forza steel para cumplir con los requerimientos del pedido en referencia.

--

Forza steel certifies that the products described in this document were manufactured in compliance with the requirements of the specification described, obtaining satisfactory results in all tests and inspections included in the quality plans of Forza Steel to meet the requirements of the order in reference.

Certify By (Autorizó)

Ing. Edgar Eduardo Olivo Hernández

QUALITY ASSURANCE MANAGER

From: S ice Steel Warehouse Date: 9/13/2022 To: F K-MAR, LP SO#: A729549 Ln#: 1 PO#: 22 731
Part: T0600601828* Qty: 2 Heat#: 2111574* Tag: C02090922

OZDEMIR BORU PROFIL SANAYI VE TICARET ANONIM SIRKETI
ORHANLAR MAH. YALI CAD. NO: 15
THE FIRST FACILITY 1: BÖLÜCEK MAH. 2 NOLU SANAYİ CADDESİ NO: 128
THE SECOND FACILITY 2: HAMZAFAKIHLI MAH. YASAR TETKER BULVARI NO: 2 KDZ EREĞLİ ORGANİZE SANAYİ BÖLGESİ
KDZ EREGLI - TURKEY

ORIGINAL

Date : 23.02.2022

OZDEMİR BORU PROFİL SAN VE TIC AŞ
QUALITY ASSURANCE AND CONTROL DEPARTMENT
BÖLÜCEK MAH. 2 NOLU SANAYİ CADDESİ NO: 128

BUYER
SEBA INTERNATIONAL INC

QUALITY GRADE B/C

CE
11
2195-CPR-1426002
Certificate No: 8572 / 02-2022
Inspection Certificate acc to EN 10204:2004/ 3.1

DESCRIPTION OF GOODS
PRIME NEWLY PRODUCED COLD FORMED, WELDED, STEEL SQUARE AND RECTANGULAR TUBING. QUALITY ASTM A500 GRADE B/C
DURABILITY No performance determined
DANGEROUS SUBSTANCE: No performance determined

CHEMICAL ANALYSIS (%) — TS CEN / EN 10261

SIZE (INCH)	THICKNESS INC	LENGHT (FEET)	HEAT NO	N.OF BUNDLES		C	Si	Mn	P	S	Cr	Al	N	Nb	V	Ti	Ni	Mo	Cu
ORDER NO		SERIAL NUMBER			Max	0,27		1,4	0,045	0,045									
LOT 16947					Min														
2 x 2	0,188	20	2111503	5x6		0,163	0,236	1,106	0,012	0,009		0,037							
2 x 2	0,188	24	2111502	2x25		0,173	0,228	1,104	0,011	0,004		0,042							
2 x 2	0,188	40	2111501	2x25		0,168	0,217	1,010	0,010	0,004		0,033							
2,5 x 2,5	0,188	20	2111506	1x30		0,150	0,211	1,090	0,015	0,004		0,040							
2,5 x 2,5	0,188	24	2111506	1x30		0,150	0,211	1,090	0,015	0,004		0,040							
2,5 x 2,5	0,188	40	2111506	1x3		0,150	0,211	1,090	0,015	0,004		0,040							
2,5 x 2,5	0,188	40	2111506	2x20		0,150	0,211	1,090	0,015	0,004		0,040							
2,5 x 2,5	0,250	20	2111507	3x25		0,164	0,211	1,110	0,014	0,009		0,041							
2,5 x 2,5	0,250	24	2111507	2x25		0,164	0,211	1,110	0,014	0,009		0,041							
2,5 x 2,5	0,250	40	2111507	2x16		0,164	0,211	1,110	0,014	0,009		0,041							
3 x 3	0,188	20	2111512	3x25		0,169	0,007	0,881	0,010	0,012		0,030							
3 x 3	0,188	24	2111512	4x25		0,169	0,007	0,881	0,010	0,012		0,030							
3 x 3	0,188	40	2111511	9x16		0,158	0,007	0,898	0,017	0,005		0,026							

MECHANICAL ANALYSIS — TS EN ISO 6892-1; IMPACT TEST (J) — TS EN ISO 148-1, Type: KV 300, L

CEV	Y.Point PSI (L)	Tensile St. PSI (L)	Elongation % (L)	Temp (°C): +20° 1	2	3	Av	Temp (°C): -20° 1	2	3	Av
	345	427	21	27	27	27	27	27	27	27	27
0,347	55825	76125	32,00								
0,359	64235	83665	32,00								
0,336	61335	81635	30,00								
0,337	55318	79909	28,00								
0,337	55318	79909	28,00								
0,337	55318	79909	28,00								
0,337	55318	79909	28,00								
0,349	53940	75980	36,00								
0,349	53940	75980	36,00								
0,349	53940	75980	36,00								
0,329	63133	74791	29,00								
0,329	63133	74791	29,00								
0,320	50475	69528	30,00								

Invoice .188 W 28' SQ Tubing

From: S[illegible]vice Steel Warehouse Date: 9/13/2022 To: [illegible]K-MAR, LP SO#: A729549 Ln#: 1 PO#: 2[illegible]731
Part: T0[illegible]0601828* Qty: 2 Heat#: 2111574* Tag: C[illegible]2090922

2

3 x 3	0,250	20	2111516	6x25	0,174	0,181	1,106	0,014	0,004	0,032	0,358	56260	78155	34,00
3 x 3	0,250	24	2111515	4x20	0,174	0,189	1,110	0,013	0,005	0,030	0,363	59305	80040	34,00
3 x 3	0,250	24	2111515	1x20	0,174	0,189	1,110	0,013	0,005	0,030	0,363	59305	80040	34,00
3 x 3	0,250	40	2111512	10x12	0,168	0,207	1,106	0,011	0,003	0,038	0,356	60320	81490	34,00
3,5 x 3,5	0,188	20	2111519	2x25	0,161	0,224	1,119	0,014	0,004	0,045	0,349	61915	81490	32,00
3,5 x 3,5	0,188	24	2111519	2x20	0,161	0,224	1,119	0,014	0,004	0,045	0,349	61915	81490	32,00
3,5 x 3,5	0,188	40	2111519	3x16	0,161	0,224	1,119	0,014	0,004	0,045	0,349	61915	81490	32,00
3,5 x 3,5	0,250	20	2111520	1x20	0,151	0,207	1,110	0,015	0,005	0,041	0,338	59595	79170	28,00
3,5 x 3,5	0,250	24	2111520	1x20	0,151	0,207	1,110	0,015	0,005	0,041	0,338	59595	79170	28,00
3,5 x 3,5	0,250	40	2111520	2x9	0,151	0,207	1,110	0,015	0,005	0,041	0,338	59595	79170	28,00
4 x 4	0,188	20	2111535	9x20	0,168	0,217	1,010	0,010	0,004	0,033	0,336	61335	81635	30,00
4 x 4	0,188	24	2111535	2x20	0,168	0,217	1,010	0,010	0,004	0,033	0,336	61335	81635	30,00
4 x 4	0,188	28	2111535	3x16	0,168	0,217	1,010	0,010	0,004	0,033	0,336	61335	81635	30,00
4 x 4	0,188	40	2111530	7x12	0,158	0,237	1,088	0,013	0,003	0,036	0,339	57565	76850	32,00
4 x 4	0,250	20	2111543	32x16	0,162	0,205	1,108	0,017	0,004	0,035	0,348	55245	76270	34,00
4 x 4	0,250	24	2111542	10x16	0,169	0,214	1,125	0,016	0,004	0,034	0,357	55390	77285	34,00
4 x 4	0,250	30	2111542	2x12	0,169	0,214	1,125	0,016	0,004	0,034	0,357	55390	77285	34,00
4 x 4	0,250	40	2111538	21x9	0,159	0,228	1,083	0,009	0,004	0,035	0,340	57275	76705	32,00
4 x 4	0,250	40	2111538	1x8	0,159	0,228	1,083	0,009	0,004	0,035	0,340	57275	76705	32,00
4 x 4	0,250	48	2111536	5x9	0,164	0,217	1,102	0,015	0,004	0,042	0,348	57130	80185	34,00
4 x 4	0,375	20	2111547	1x1	0,158	0,165	1,210	0,011	0,005	0,023	0,360	58580	78445	32,00
4 x 4	0,375	20	2111547	5x12	0,158	0,165	1,210	0,011	0,005	0,023	0,360	58580	78445	32,00
4 x 4	0,375	24	2111547	2x12	0,158	0,165	1,210	0,011	0,005	0,023	0,360	58580	78445	32,00
4 x 4	0,375	30	2111547	1x9	0,158	0,165	1,210	0,011	0,005	0,023	0,360	58580	78445	32,00
4 x 4	0,375	40	2111547	9x6	0,158	0,165	1,210	0,011	0,005	0,023	0,360	58580	78445	32,00
4 x 4	0,375	48	2111546	5x6	0,164	0,230	1,195	0,019	0,003	0,038	0,363	58290	79315	36,00
5 x 5	0,250	20	2111556	3x16	0,174	0,230	1,130	0,013	0,004	0,035	0,365	57855	79025	32,00
5 x 5	0,250	24	2111556	2x9	0,174	0,230	1,130	0,013	0,004	0,035	0,365	57855	79025	32,00
5 x 5	0,250	30	2111556	3x9	0,174	0,230	1,130	0,013	0,004	0,035	0,365	57855	79025	32,00
5 x 5	0,250	40	2111556	11x9	0,174	0,230	1,130	0,013	0,004	0,035	0,365	57855	79025	32,00
5 x 5	0,313	30	2111558	1x9	0,167	0,186	1,209	0,015	0,004	0,038	0,369	63510	80765	32,00
5 x 5	0,313	40	2111558	1x1	0,167	0,186	1,209	0,015	0,004	0,038	0,369	63510	80765	32,00
5 x 5	0,313	40	2111558	5x6	0,167	0,186	1,209	0,015	0,004	0,038	0,369	63510	80765	32,00
5 x 5	0,375	24	2111559	2x6	0,173	0,228	1,185	0,016	0,004	0,041	0,373	62785	84535	32,00
5 x 5	0,375	30	2111559	1x1	0,173	0,228	1,185	0,016	0,004	0,041	0,373	62785	84535	32,00
5 x 5	0,375	30	2111559	2x6	0,173	0,228	1,185	0,016	0,004	0,041	0,373	62785	84535	32,00
5 x 5	0,375	40	2111559	14x6	0,173	0,228	1,185	0,016	0,004	0,041	0,373	62785	84535	32,00
6 x 6	0,188	20	2111574	2x12	0,163	0,236	1,106	0,012	0,009	0,037	0,347	55825	76125	32,00
6 x 6	0,188	24	2111574	2x12	0,163	0,236	1,106	0,012	0,009	0,037	0,347	55825	76125	32,00
6 x 6	0,188	28	2111574	2x12	0,163	0,236	1,106	0,012	0,009	0,037	0,347	55825	76125	32,00
6 x 6	0,188	40	2111574	3x9	0,163	0,236	1,106	0,012	0,009	0,037	0,347	55825	76125	32,00
6 x 6	0,250	20	2111583	7x12	0,163	0,236	1,106	0,012	0,009	0,037	0,350	55825	76125	32,00
6 x 6	0,250	24	2111582	2x12	0,167	0,209	1,106	0,012	0,008	0,038	0,351	52200	76125	34,00

From: S[illegible]vice Steel Warehouse Date: 9/13/2022 To: [illegible]K-MAR, LP SO#: A729549 Ln#: 1 PO#: 2[illegible]731
Part: T0[illegible]0601828* Qty: 2 Heat#: 2111574* Tag: C02090922

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6 x 6	0,250	30	2111582	3x9	0,167	0,209	1,106	0,012	0,008	0,038	0,351	52200	76125	34,00
6 x 6	0,250	32	2111582	5x6	0,167	0,209	1,106	0,012	0,008	0,038	0,351	52200	76125	34,00
6 x 6	0,250	36	2111582	2x6	0,167	0,209	1,106	0,012	0,008	0,038	0,351	52200	76125	34,00
6 x 6	0,250	40	2111578	22x6	0,167	0,209	1,106	0,012	0,008	0,038	0,351	52200	76125	34,00
6 x 6	0,250	40	2111578	1x3	0,167	0,209	1,106	0,012	0,008	0,038	0,351	52200	76125	34,00
6 x 6	0,250	48	2111575	15x6	0,159	0,228	1,083	0,009	0,004	0,035	0,351	52200	76125	34,00
6 x 6	0,313	24	2111584	2x9	0,161	0,203	1,240	0,016	0,003	0,041	0,340	57275	76705	32,00
6 x 6	0,313	28	2111584	1x6	0,161	0,203	1,240	0,016	0,003	0,041	0,370	67715	83230	34,00
6 x 6	0,313	30	2111584	2x6	0,161	0,203	1,240	0,016	0,003	0,041	0,370	67715	83230	34,00
6 x 6	0,313	40	2111584	9x4	0,161	0,203	1,240	0,016	0,003	0,041	0,370	67715	83230	34,00
6 x 6	0,375	20	2111591	4x9	0,170	0,236	1,216	0,011	0,007	0,035	0,370	67715	83230	34,00
6 x 6	0,375	28	2111591	1x6	0,170	0,236	1,216	0,011	0,007	0,035	0,373	64235	84535	30,00
6 x 6	0,375	30	2111591	5x6	0,170	0,236	1,216	0,011	0,007	0,035	0,373	64235	84535	30,00
6 x 6	0,375	32	2111591	4x4	0,170	0,236	1,216	0,011	0,007	0,035	0,373	64235	84535	30,00
6 x 6	0,375	34	2111591	3x4	0,170	0,236	1,216	0,011	0,007	0,035	0,373	64235	84535	30,00
6 x 6	0,375	36	2111591	3x4	0,170	0,236	1,216	0,011	0,007	0,035	0,373	64235	84535	30,00
6 x 6	0,375	40	2111588	18x4	0,170	0,199	1,226	0,012	0,004	0,044	0,373	64235	84535	30,00
6 x 6	0,375	48	2111586	12x4	0,162	0,240	1,221	0,019	0,007	0,047	0,374	59450	74240	32,00
6 x 6	0,500	28	2111596	2x4	0,158	0,196	1,242	0,015	0,003	0,040	0,367	62495	77865	32,00
6 x 6	0,500	28	2111596	1x2	0,158	0,196	1,242	0,015	0,003	0,040	0,365	65105	83375	30,00
6 x 6	0,500	30	2111596	5x4	0,158	0,196	1,242	0,015	0,003	0,040	0,365	65105	83375	30,00
6 x 6	0,500	40	2111594	1x6	0,162	0,177	1,221	0,015	0,006	0,033	0,365	65105	83375	30,00
6 x 6	0,500	48	2111592	3x02	0,168	0,249	1,190	0,015	0,004	0,034	0,368	75980	98600	36,00
6 x 6	0,500	48	2111592	5x2	0,168	0,249	1,190	0,015	0,004	0,034	0,366	61335	82215	36,00
8 x 8	0,188	28	2111606	1x9	0,163	0,236	1,106	0,012	0,009	0,037	0,366	61335	82215	36,00
8 x 8	0,188	30	2111606	1x9	0,163	0,236	1,106	0,012	0,009	0,037	0,347	55825	76125	32,00
8 x 8	0,188	40	2111606	1x4	0,163	0,236	1,106	0,012	0,009	0,037	0,347	55825	76125	32,00
8 x 8	0,188	40	2111606	9x6	0,163	0,236	1,106	0,012	0,009	0,037	0,347	55825	76125	32,00
8 x 8	0,188	48	2111606	4x4	0,163	0,236	1,106	0,012	0,009	0,037	0,347	55825	76125	32,00
8 x 8	0,250	20	2111610	3x9	0,164	0,234	1,096	0,013	0,004	0,043	0,347	55825	76125	32,00
8 x 8	0,250	28	2111610	4x6	0,164	0,234	1,096	0,013	0,004	0,043	0,348	60320	79460	28,00
8 x 8	0,250	30	2111610	3x6	0,164	0,234	1,096	0,013	0,004	0,043	0,348	60320	79460	28,00
8 x 8	0,250	30	2111610	1x1	0,164	0,234	1,096	0,013	0,004	0,043	0,348	60320	79460	28,00
8 x 8	0,250	32	2111610	3x6	0,164	0,234	1,096	0,013	0,004	0,043	0,348	60320	79460	28,00
8 x 8	0,250	34	2111610	3x6	0,164	0,234	1,096	0,013	0,004	0,043	0,348	60320	79460	28,00
8 x 8	0,250	36	2111610	2x6	0,164	0,234	1,096	0,013	0,004	0,043	0,348	60320	79460	28,00
8 x 8	0,250	40	2111608	14x4	0,165	0,221	1,135	0,017	0,004	0,034	0,348	60320	79460	28,00
8 x 8	0,250	48	2111607	12x4	0,159	0,228	1,083	0,009	0,004	0,035	0,354	69310	89610	26,00
8 x 8	0,313	28	2111611	2x4	0,167	0,186	1,209	0,015	0,004	0,038	0,340	57275	76705	32,00
8 x 8	0,313	30	2111611	3x4	0,167	0,186	1,209	0,015	0,004	0,038	0,369	63510	80765	32,00
8 x 8	0,313	32	2111611	2x4	0,167	0,186	1,209	0,015	0,004	0,038	0,369	63510	80765	32,00
8 x 8	0,313	40	2111611	7x4	0,167	0,186	1,209	0,015	0,004	0,038	0,369	63510	80765	32,00
8 x 8	0,375	30	2111616	7x4	0,166	0,232	1,215	0,019	0,006	0,044	0,369	63510	83665	34,00

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 1 PO#: 22-2731
Part: T0600601828* Qty: 2 Heat#: 2111574* Tag: C02090922

8 x 8	0,375	32	2111616	4x4	0,166	0,232	1,215	0,019	0,006	0,044	0,369	63510	83665	34,00
8 x 8	0,375	34	2111616	3x4	0,166	0,232	1,215	0,019	0,006	0,044	0,369	63510	83665	34,00
8 x 8	0,375	40	2111613	40x2	0,158	0,237	1,208	0,017	0,005	0,040	0,361	60465	77285	32,00
8 x 8	0,375	48	2111612	20x2	0,164	0,209	1,193	0,014	0,003	0,037	0,363	59305	79170	32,00
8 x 8	0,500	28	2111619	11x4	0,158	0,196	1,242	0,015	0,003	0,040	0,365	65105	83375	30,00
8 x 8	0,500	30	2111619	10x2	0,158	0,196	1,242	0,015	0,003	0,040	0,365	65105	83375	30,00
8 x 8	0,500	40	2111618	19x2	0,162	0,177	1,221	0,015	0,006	0,033	0,368	75980	98600	36,00
10 x 10	0,250	40	2111627	20x4	0,151	0,207	1,110	0,015	0,005	0,041	0,338	59595	79170	28,00
10 x 10	0,250	48	2111626	19x2	0,164	0,205	1,096	0,012	0,006	0,042	0,347	60030	80620	30,00
10 x 10	0,313	30	2111629	3x4	0,168	0,201	1,208	0,015	0,003	0,040	0,369	68730	83665	32,00
10 x 10	0,313	36	2111629	3x2	0,168	0,201	1,208	0,015	0,003	0,040	0,369	68730	83665	32,00
10 x 10	0,313	40	2111629	1x1	0,168	0,201	1,208	0,015	0,003	0,040	0,369	68730	83665	32,00
10 x 10	0,313	40	2111629	17x2	0,168	0,201	1,208	0,015	0,003	0,040	0,369	68730	83665	32,00
10 x 10	0,375	28	2111631	2x4	0,162	0,240	1,221	0,019	0,007	0,047	0,366	62495	77865	32,00
10 x 10	0,375	30	2111631	5x2	0,162	0,240	1,221	0,019	0,007	0,047	0,366	62495	77865	32,00
10 x 10	0,375	32	2111631	5x2	0,162	0,240	1,221	0,019	0,007	0,047	0,366	62495	77865	32,00
10 x 10	0,375	34	2111631	3x2	0,162	0,240	1,221	0,019	0,007	0,047	0,366	62495	77865	32,00
10 x 10	0,375	36	2111631	4x2	0,162	0,240	1,221	0,019	0,007	0,047	0,366	62495	77865	32,00
10 x 10	0,375	40	2111630	23x2	0,164	0,230	1,195	0,019	0,003	0,038	0,363	58290	79315	36,00
10 x 10	0,500	40	2111632	15x2	0,162	0,212	1,212	0,010	0,005	0,035	0,364	63800	81055	34,00
12 x 12	0,250	40	2111641	8x2	0,169	0,229	1,086	0,014	0,007	0,032	0,350	64090	84390	30,00
3 x 2	0,188	20	2111508	3x35	0,169	0,007	0,881	0,010	0,012	0,030	0,329	63133	74791	29,00
3 x 2	0,188	20	2111508	1x3	0,169	0,007	0,881	0,010	0,012	0,030	0,329	63133	74791	29,00
3 x 2	0,188	40	2111508	2x20	0,169	0,007	0,881	0,010	0,012	0,030	0,329	63133	74791	29,00
3 x 2	0,250	20	2111510	1x4	0,167	0,225	1,135	0,013	0,004	0,041	0,358	58870	78155	30,00
3 x 2	0,250	20	2111510	3x30	0,167	0,225	1,135	0,013	0,004	0,041	0,358	58870	78155	30,00
3 x 2	0,250	24	2111510	2x30	0,167	0,225	1,135	0,013	0,004	0,041	0,358	58870	78155	30,00
3 x 2	0,250	40	2111509	10x12	0,162	0,203	1,120	0,013	0,004	0,038	0,358	62568	83897	28,00
4 x 2	0,188	20	2111521	3x24	0,173	0,228	1,104	0,011	0,004	0,042	0,359	64235	83665	32,00
4 x 2	0,188	24	2111521	3x24	0,173	0,228	1,104	0,011	0,004	0,042	0,359	64235	83665	32,00
4 x 2	0,188	28	2111521	2x24	0,173	0,228	1,104	0,011	0,004	0,042	0,359	64235	83665	32,00
4 x 2	0,188	40	2111521	5x12	0,173	0,228	1,104	0,011	0,004	0,042	0,359	64235	83665	32,00
4 x 2	0,250	20	2111522	1x2	0,158	0,214	1,099	0,010	0,004	0,038	0,341	56840	77140	32,00
4 x 2	0,250	20	2111522	4x24	0,158	0,214	1,099	0,010	0,004	0,038	0,341	56840	77140	32,00
4 x 2	0,250	24	2111522	3x24	0,158	0,214	1,099	0,010	0,004	0,038	0,341	56840	77140	32,00
4 x 2	0,250	40	2111522	6x15	0,158	0,214	1,099	0,010	0,004	0,038	0,341	56840	77140	32,00
6 x 2	0,188	20	2111562	1x24	0,164	0,234	1,100	0,013	0,002	0,037	0,348	61770	80475	34,00
6 x 2	0,188	24	2111562	2x24	0,164	0,234	1,100	0,013	0,002	0,037	0,348	61770	80475	34,00
6 x 2	0,188	40	2111562	1x9	0,164	0,234	1,100	0,013	0,002	0,037	0,348	61770	80475	34,00
6 x 2	0,188	40	2111562	3x12	0,164	0,234	1,100	0,013	0,002	0,037	0,348	61770	80475	34,00
6 x 2	0,188	48	2111561	7x8	0,168	0,217	1,010	0,010	0,004	0,033	0,339	61335	81635	30,00
4 x 3	0,188	20	2111524	1x20	0,161	0,224	1,119	0,014	0,004	0,045	0,349	61915	81490	32,00
4 x 3	0,188	24	2111524	6x20	0,161	0,224	1,119	0,014	0,004	0,045	0,349	56550	80475	30,00

From: Service Steel Warehouse Date: 9/13/2022 To: RIK-MAR, LP SO#: A729549 Ln#: 1 PO#: 22-2731
Part: T0600601828* Qty: 2 Heat#: 2111574* Tag: C02090922

4 x 3	0,188	40	2111524	4x12	0,161	0,224	1,119	0,014	0,004	0,045	0,349	56550	80475	30,00
4 x 3	0,250	20	2111529	3x20	0,167	0,202	1,103	0,013	0,004	0,049	0,353	63655	83810	34,00
4 x 3	0,250	24	2111529	3x20	0,167	0,202	1,103	0,013	0,004	0,049	0,353	63655	83810	34,00
4 x 3	0,250	40	2111529	1x1	0,167	0,202	1,103	0,013	0,004	0,049	0,353	63655	83810	34,00
4 x 3	0,250	40	2111529	6x12	0,167	0,202	1,103	0,013	0,004	0,049	0,353	63655	83810	34,00
5 x 3	0,188	20	2111550	2x24	0,168	0,217	1,010	0,010	0,004	0,033	0,336	61335	81635	30,00
5 x 3	0,188	24	2111550	2x20	0,168	0,217	1,010	0,010	0,004	0,033	0,336	61335	81635	30,00
5 x 3	0,188	40	2111550	1x4	0,168	0,217	1,010	0,010	0,004	0,033	0,336	61335	81635	30,00
5 x 3	0,188	40	2111550	3x12	0,168	0,217	1,010	0,010	0,004	0,033	0,336	61335	81635	30,00
5 x 3	0,250	24	2111551	2x12	0,164	0,217	1,102	0,015	0,004	0,042	0,348	57130	80185	34,00
5 x 3	0,250	40	2111551	1x5	0,164	0,217	1,102	0,015	0,004	0,042	0,348	57130	80185	34,00
5 x 3	0,250	40	2111551	6x9	0,164	0,217	1,102	0,015	0,004	0,042	0,348	57130	80185	34,00
6 x 3	0,188	20	2111566	1x18	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 3	0,188	24	2111566	1x18	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 3	0,188	28	2111566	1x15	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 3	0,188	30	2111566	1x15	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 3	0,188	40	2111566	3x12	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 3	0,250	24	2111567	2x12	0,174	0,181	1,106	0,014	0,004	0,032	0,360	56260	78155	34,00
6 x 3	0,250	40	2111567	8x6	0,174	0,181	1,106	0,014	0,004	0,032	0,360	56260	78155	34,00
6 x 3	0,313	40	2111568	6x6	0,168	0,201	1,208	0,015	0,003	0,040	0,369	68730	83665	32,00
6 x 3	0,313	48	2111568	2x6	0,168	0,201	1,208	0,015	0,003	0,040	0,369	68730	83665	32,00
6 x 4	0,188	20	2111569	2x12	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 4	0,188	24	2111569	1x1	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 4	0,188	24	2111569	2x12	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 4	0,188	28	2111569	1x12	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 4	0,188	30	2111569	2x12	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 4	0,188	40	2111569	1x4	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 4	0,188	40	2111569	4x9	0,161	0,208	1,087	0,013	0,004	0,038	0,344	60755	79170	34,00
6 x 4	0,250	20	2111571	4x12	0,170	0,203	1,140	0,020	0,004	0,036	0,362	58725	80185	32,00
6 x 4	0,250	24	2111571	2x12	0,170	0,203	1,140	0,020	0,004	0,036	0,362	58725	80185	32,00
6 x 4	0,250	30	2111571	1x12	0,170	0,203	1,140	0,020	0,004	0,036	0,362	58725	80185	32,00
6 x 4	0,250	40	2111570	1x2	0,169	0,204	1,087	0,013	0,005	0,036	0,350	59450	83375	30,00
6 x 4	0,250	40	2111570	6x6	0,169	0,204	1,087	0,013	0,005	0,036	0,350	59450	83375	30,00
6 x 4	0,375	24	2111573	1X2	0,168	0,201	1,208	0,015	0,003	0,040	0,373	65105	84535	34,00
8 x 4	0,250	24	2111600	2X12	0,167	0,187	1,146	0,017	0,008	0,029	0,360	63800	83230	30,00
8 x 4	0,250	40	2111600	14X6	0,167	0,187	1,146	0,017	0,008	0,029	0,360	63800	83230	30,00
8 x 4	0,375	24	2111600	1X1	0,167	0,187	1,146	0,017	0,008	0,029	0,360	63800	83230	30,00
8 x 4	0,375	40	2111601	4X4	0,165	0,233	1,186	0,019	0,002	0,035	0,371	61712	82897	36,00
8 x 4	0,375	40	2111601	1X3	0,165	0,233	1,186	0,019	0,002	0,035	0,371	61712	82897	36,00
10 x 4	0,250	24	2111620	1X10	0,164	0,205	1,096	0,012	0,006	0,042	0,347	60030	80620	30,00
10 x 4	0,250	30	2111620	1X1	0,164	0,205	1,096	0,012	0,006	0,042	0,347	60030	80620	30,00
10 x 4	0,250	30	2111620	1X8	0,164	0,205	1,096	0,012	0,006	0,042	0,347	60030	80620	30,00
10 x 4	0,250	40	2111620	3X6	0,164	0,205	1,096	0,012	0,006	0,042	0,347	60030	80620	30,00

10 x 4	0,250	40	2111620	1X1		0,164	0,205	1,096	0,012	0,006		0,042	0,347	60030	80620	30,00
12 x 4	0,375	40	2111634	11X3		0,165	0,226	1,222	0,015	0,004		0,046	0,371	59450	78590	34,00
7 x 5	0,188	40	2111597	7X6		0,170	0,175	1,173	0,013	0,008		0,028	0,366	64235	83665	24,00
8 x 6	0,313	40	2111603	12X4		0,161	0,203	1,240	0,016	0,003		0,041	0,368	67715	83230	34,00
8 x 6	0,313	40	2111603	1X3		0,161	0,203	1,240	0,016	0,003		0,041	0,368	67715	83230	34,00
8 x 6	0,375	40	2111604	1X3		0,158	0,237	1,208	0,017	0,005		0,040	0,361	60465	77285	32,00
8 x 6	0,375	40	2111604	10X4		0,158	0,237	1,208	0,017	0,005		0,040	0,361	60465	77285	32,00
8 x 6	0,500	40	2111605	6X2		0,168	0,249	1,190	0,015	0,004		0,034	0,366	61335	82215	36,00
10 x 6	0,250	40	2111621	6X4		0,159	0,228	1,083	0,009	0,004		0,035	0,340	57275	76705	32,00
10 x 6	0,375	40	2111622	10X2		0,166	0,232	1,215	0,019	0,006		0,044	0,369	63510	83665	34,00
10 x 6	0,500	40	2111623	8X2		0,168	0,249	1,190	0,015	0,004		0,034	0,366	61335	82215	36,00
12 x 6	0,250	40	2111635	7X4		0,174	0,181	1,106	0,014	0,004		0,032	0,360	56260	78155	34,00
12 x 6	0,250	40	2111635	1X2		0,174	0,181	1,106	0,014	0,004		0,032	0,360	56260	78155	34,00
12 x 6	0,375	24	2111636	2X4		0,164	0,230	1,195	0,019	0,003		0,038	0,365	58290	79315	36,00
12 x 6	0,375	30	2111636	1X1		0,164	0,230	1,195	0,019	0,003		0,038	0,365	58290	79315	36,00
12 x 6	0,375	30	2111636	1X4		0,164	0,230	1,195	0,019	0,003		0,038	0,365	58290	79315	36,00
12 x 6	0,375	40	2111636	9X2		0,164	0,230	1,195	0,019	0,003		0,038	0,365	58290	79315	36,00
12 x 6	0,500	40	2111637	1X1		0,168	0,249	1,190	0,015	0,004		0,034	0,366	61335	82215	36,00
12 x 6	0,500	40	2111637	12X2		0,168	0,249	1,190	0,015	0,004		0,034	0,366	61335	82215	36,00
12 x 8	0,250	30	2111638	2X4		0,167	0,202	1,103	0,013	0,004		0,049	0,353	63655	83810	34,00
12 x 8	0,250	32	2111638	2X4		0,167	0,202	1,103	0,013	0,004		0,049	0,353	63655	83810	34,00
12 x 8	0,250	40	2111638	1X2		0,167	0,202	1,103	0,013	0,004		0,049	0,353	63655	83810	34,00
12 x 8	0,250	40	2111638	4X4		0,167	0,202	1,103	0,013	0,004		0,049	0,353	63655	83810	34,00
12 x 8	0,500	40	2111640	6X2		0,178	0,174	1,228	0,011	0,006		0,035	0,383	64960	83665	32,00

L: Longitudinally (Direction of the test pieces)

The tubes used in the production of the above materials were melted and poured in Turkiye from Erdemir Iron and Steel Industry Trade and Co.Inc.

WE CONFIRM HEREWITH THAT THE DELIVERED MATERİAL COMPLIES WITH TERMS OF THE ORDER

Authorised Representative
Sezai ORHAN

MANUFACTURER : OZDEMIR BORU PROFIL SANAYI VE TICARET ANONIM SIRKETI

ÖZDEMİR BORU PROFİL SANAYİ VE TİCARET A.Ş.
Orhanlar Mah. Vali Cad. No:15 Kdz.EREĞLİ
Tel:(0372) 323 58 00 (Sırat) 316 16 57 - 316 18 82
Fax: (0372) 312 58 88 - 322 60 56
Anadolu Kurumlar VD.681 063 4176

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: 611801-03 **Casting Date:** 6/13/2022 **Mix Design (psi):** 4000

Name of Technician Taking Sample: Terracon

Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	Raymond G. 125	127217	100% 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

127217

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

TEXAS A&M TRANSPORTATIO
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT THE "T", RT HWY 47, LT INTORELLIS ENTRANCE, STAY STRAIGHTALL THE WAY DOWN TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
9:55	BCSN40500	4.00	4.00	PO#	RAYMOND G. 125		63704
DATE		**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
6/13/22	PROJECT TTIRELL	4.00	4.00			5.00 in	61872

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
4.00 yd	BCSN40500	MUN, 4000, 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
10:10	10:24				
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 RELEASErelieving him and this supplier from any responsibility from damage that may occur to the premises and or adjacent property, buildings, sidewalks, driveways, curbs, etc. by the delivery of this material and that you also agree to help him remove mud from the wheels of his vehicle so that he will not liter the public streets. Further as additional consideration; the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and /or adjacent property which may be claimed by anyone to have arisen out of delivery of this order
SIGNED:

X____________________

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

______GAL X____________________

WEIGHMASTER

Surcharge for credit cards

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

LOAD RECEIVED BY

x____________________

127217

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0230
Service Date: 06/13/22
Report Date: 09/15/22
Task: PO# 611801-3

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

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

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength: 4,000 psi @ 28 days

Mix ID: BCSN40500
Supplier: Texcrete
Batch Time: 0955 **Plant:** 63704
Truck No.: 125 **Ticket No.:** 61872

Field Test Data

Test	Result	Specification
Slump (in):	5 1/2	
Air Content (%):	1.5	
Concrete Temp. (F):	92	
Ambient Temp. (F):	91	
Plastic Unit Wt. (pcf):		
Yield (Cu. Yds.):		

Sample Information
Sample Date: 06/13/22 **Sample Time:** 1035
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: Main runway, SW side of runway on the side of the runway
Placement Location: Main runway, SW side of runway on the side of the runway

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		09/14/22	93 F	127,900	4,520	5	SCG
1	B	Good	6.00	28.27		09/14/22	93 F	132,230	4,680	3	SCG
1	C	Good	6.00	28.27		09/14/22	93 F	85,230	3,010	3	SCG
1	D						Hold				

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).
NA

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 at TTI
Contractor: MBC Management
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith

Start/Stop: **

Reviewed By:
Alexander Dunigan
Project Manager

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

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

Project No: 611801-03 **Casting Date:** 6/29/2022 **Mix Design (psi):** 4000

Name of Technician Taking Sample: Terracon

Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	ChesterMoori 3	126474	100% Parapet

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

126474

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

TEXAS A&M TRANSPORTATIO
1288 AVE A BRYAN

RT 2818 RT HWY 21 U TURN JUST PAST 47 RT INTO RELLIS LFT AT STOPSIGN RT AVE A, RT 4TH ST, RT FLIGHT LN RD, RT FLIGHT LINE RD JOB ON RT TTI OFFICE BUILDING

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
8:40	BCSN40500	3.00	3.00	PO#	CHESTER MOORI3		64754
DATE	**PROJECT**	**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
6/29/22	TTIRELL	3.00	3.00			5.00 in	62927

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
3.00 yd	BCSN40500	MUN, 4000, 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
[illegible]	9:04				
FINISH UNLOADING	**LEFT JOB**	**ARRIVED AT PLANT**	**ON SITE TESTING**		
			TESTING LAB: TERRACON GESSNER CME	OTHER	
	TESTED		AIR	CYLINDERS	
	☐ YES ☐ NO				

Tax
Prev. AMT
Ticket Total

ADDITIONAL CHARGE 1 ________
ADDITIONAL CHARGE 2 ________
GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

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

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

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

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

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

X ______________________

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

______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______________________

126474

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0232
Service Date: 06/29/22
Report Date: 09/15/22
Task: PO# 611801-3

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

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

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength: 4,000 psi @ 28 days

Mix ID: Bcsn40500
Supplier: Texcrete
Batch Time: 0840 **Plant:** 2
Truck No.: 13 **Ticket No.:** 64754

Sample Information
Sample Date: 06/29/22 **Sample Time:** 0920
Sampled By: Brian Maass
Weather Conditions: Clear light wind
Accumulative Yards: 10-10 **Batch Size (cy):** 10
Placement Method: Direct Discharge
Water Added Before (gal): 5
Water Added After (gal): 0
Sample Location: Upper half middle
Placement Location: West barrier

Field Test Data

Test	Result	Specification
Slump (in):	6 1/4	
Air Content (%):	2.4	
Concrete Temp. (F):	87	
Ambient Temp. (F):	81	
Plastic Unit Wt. (pcf):	145.2	
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	A	Good	6.00	28.27		09/14/22	77 F	116,030	4,100	3	SCG
1	B	Good	6.00	28.27		09/14/22	77 F	131,370	4,650	3	SCG
1	C	Good	6.00	28.27		09/14/22	77 F	122,860	4,350	5	SCG
1	D						Hold				

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

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

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

Terracon Rep.: Brian Maass
Reported To:
Contractor: MBC Management
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith

Start/Stop: 0815-1000

Reviewed By: [signature]
Alexander Dunigan
Project Manager

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

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

Project No: 611801-03 **Casting Date:** 2/6/2023 **Mix Design (psi):** 4000

Name of Technician Taking Sample: Terracon

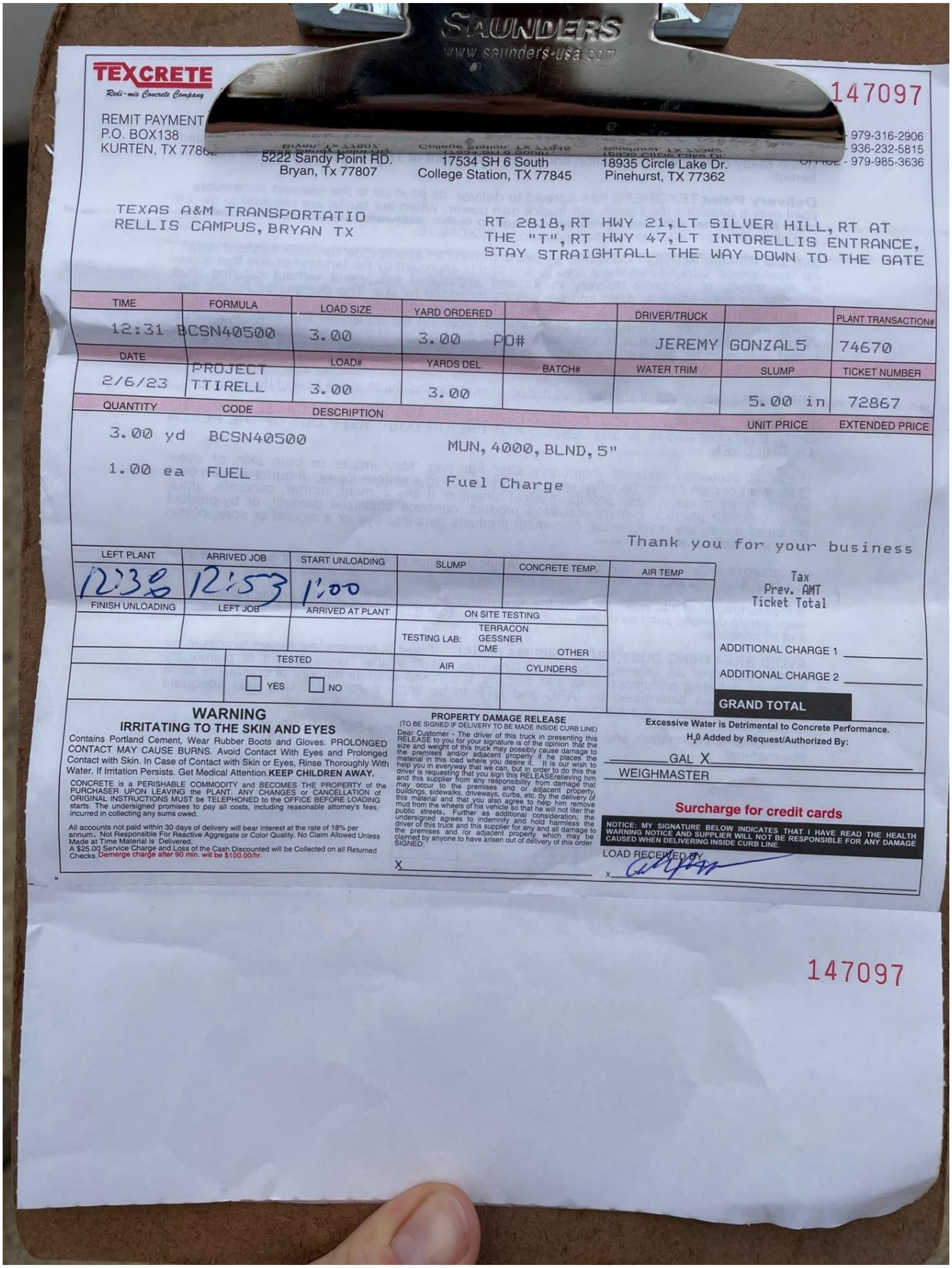
Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	Jeremy Gonzal5	72867	100% of Deck

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



TEXCRETE
Redi-mix Concrete Company

REMIT PAYMENT
P.O. BOX138
KURTEN, TX 7786

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

147097

979-316-2906
936-232-5815
979-985-3636

TEXAS A&M TRANSPORTATIO
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT THE "T", RT HWY 47, LT INTORELLIS ENTRANCE, STAY STRAIGHTALL THE WAY DOWN TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
12:31	BCSN40500	3.00	3.00	PO#	JEREMY	GONZAL5	74670
DATE		**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
2/6/23	PROJECT TTIRELL	3.00	3.00			5.00 in	72867

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
3.00 yd	BCSN40500	MUN, 4000, BLND, 5"		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
12:38	12:53	1:00			
FINISH UNLOADING	**LEFT JOB**	**ARRIVED AT PLANT**	**ON SITE TESTING**		
			TESTING LAB: TERRACON GESSNER CME OTHER		
	TESTED		AIR	CYLINDERS	
	☐ YES ☐ NO				

Tax
Prev. AMT
Ticket Total

ADDITIONAL CHARGE 1 ______

ADDITIONAL CHARGE 2 ______

GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

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

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

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

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

X ______

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

______ GAL X ______

WEIGHMASTER

Surcharge for credit cards

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

LOAD RECEIVED BY

x ______

147097

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0265
Service Date: 02/06/23
Report Date: 03/23/23
Task: PO# 611801

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

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

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength: 4,000 psi @ 28 days

Mix ID: Bcsb40500
Supplier: Texcrete
Batch Time: 1343 **Plant:**
Truck No.: **Ticket No.:** 72767

Sample Information
Sample Date: 02/06/23 **Sample Time:** 1300
Sampled By: Blake Youngblood
Weather Conditions: Sunny, windy
Accumulative Yards: 3 **Batch Size (cy):** 3
Placement Method: Chute
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Slab
Placement Location: Slab
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	4	
Air Content (%):	2.0	
Concrete Temp. (F):	70	
Ambient Temp. (F):	72	
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		03/22/23	44 F	170,360	6,030	2	AWD
1	B	Good	6.00	28.27		03/22/23	44 F	159,900	5,660	3	AWD
1	C	Good	6.00	28.27		03/22/23	44 F	149,230	5,280	3	AWD
1	D						Hold				

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

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.: Blake Youngblood **Start/Stop:** 1245-1400
Reported To:
Contractor: MDC
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Reviewed By: [signature]
Alexander Dunigan
Project Manager

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

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

Project No: 611801-03 **Casting Date:** 2/17/2023 **Mix Design (psi):** 4000

Name of Technician Taking Sample: Terracon

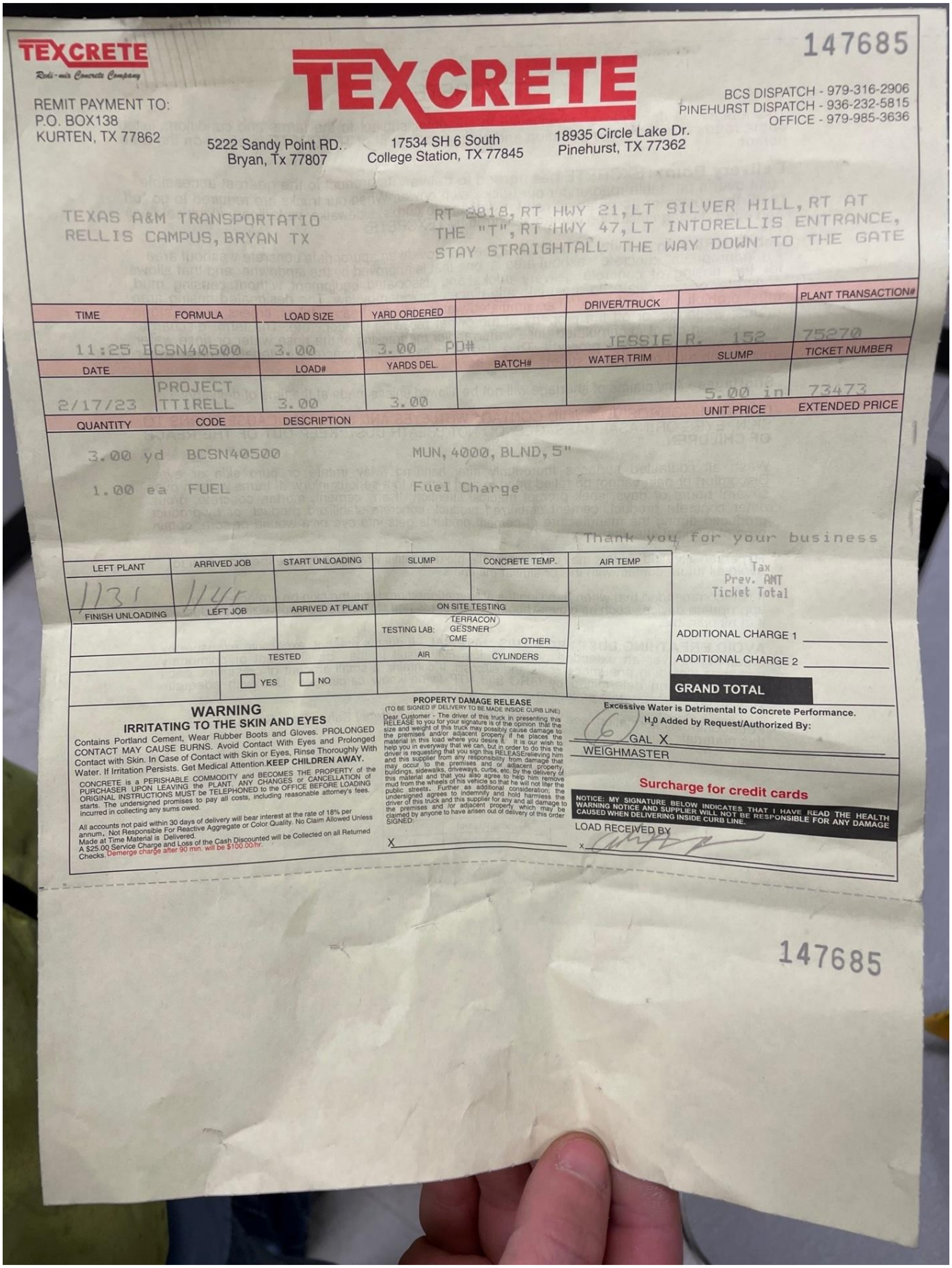
Name of Technician Breaking Sample: Terracon

Signature of Technician Taking Sample: Terracon

Signature of Technician Breaking Sample: Terracon

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	Jessie R. 152	73473	100% of Parapet

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



TEXCRETE
Redi-mix Concrete Company

147685

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

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

TEXAS A&M TRANSPORTATIO
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT THE "T", RT HWY 47, LT INTORELLIS ENTRANCE, STAY STRAIGHTALL THE WAY DOWN TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
11:25	BCSN40500	3.00	3.00	PO#	JESSIE R.	152	75270
DATE		LOAD#	YARDS DEL.	BATCH#	WATER TRIM	SLUMP	TICKET NUMBER
2/17/23	PROJECT TTIRELL	3.00	3.00			5.00 in	73473

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
3.00 yd	BCSN40500	MUN, 4000, BLND, 5"		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
1131	1145				

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

TESTED: ☐ YES ☐ NO — AIR — CYLINDERS

Tax
Prev. AMT
Ticket Total

ADDITIONAL CHARGE 1 ______
ADDITIONAL CHARGE 2 ______
GRAND TOTAL

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

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

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

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

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

147685

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0267
Service Date: 02/17/23
Report Date: 03/23/23
Task: PO# 611801

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

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

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength: 4,000 psi @ 28 days

Mix ID: BCSN40500
Supplier: Texcrete
Batch Time: 1125 **Plant:** 75270
Truck No.: 152 **Ticket No.:** 147685

Sample Information
Sample Date: 02/17/23 **Sample Time:** 1205
Sampled By: Steven Savala
Weather Conditions: Clear
Accumulative Yards: 3 **Batch Size (cy):** 3
Placement Method: Chute
Water Added Before (gal): 6
Water Added After (gal): 0
Sample Location: Concrete stopper on runway
Placement Location: Runway
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	5 1/4	
Air Content (%):	1.3	
Concrete Temp. (F):	74	
Ambient Temp. (F):	51	
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		03/22/23	33 F	150,070	5,310	3	AWD
1	B	Good	6.00	28.27		03/22/23	33 F	139,670	4,940	5	AWD
1	C	Good	6.00	28.27		03/22/23	33 F	141,270	5,000	5	AWD
1	D						Hold				

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

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: Will with TTI
Contractor: TTI
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Start/Stop: 1000-1300

Reviewed By: Alexander Dunigan
Project Manager

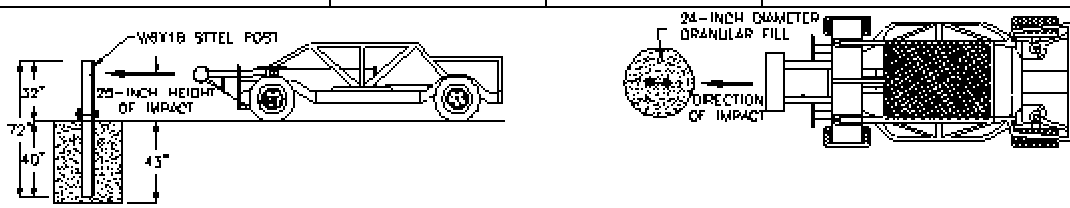
Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Dynamic Test Setup

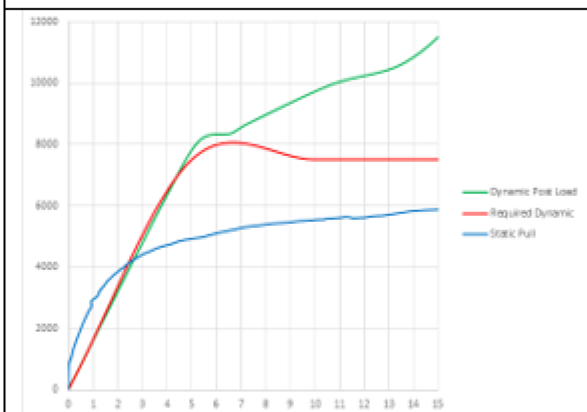
Post-Test Photo of post

Static Load Test

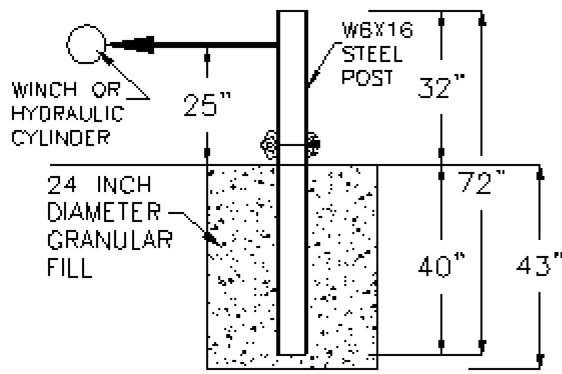
Post-Test Photo



Dynamic Test Installation Details



Comparison of Load vs. Displacement



Static Load Test Installation Details

Date	2020-02-02
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	Type 1 Grade D Crushed Concrete Road Base
Description of Fill Placement Procedure	12-inch lifts tamped with a pneumatic compactor for 20 sec
Bogie Weight	2020 lb
Impact Velocity	19.2 mph

Crushed Concrete Soil Strength Performance Test

MASH, Appendix B

Project Number: 611801-04-1

Date of Crash Test: 2023-03-23

Post No. 1 of 1 Fill Moisture: n/a % Native Moisture: n/a %

Temperature: 72 ° F Humidity: 95%

File Name: Soil Strength_33.ASC

Displacement (in.)	*Pull Force (Lbf)	Minimum Force (Lbf)	Pass / Fail
5	10,242	4420	P
10	10,060	4981	P
15	10,152	5282	P

*Do not exceed 10,000 lbf

Test Post Location: 25 ft ☐ South ☒ North of terminal post
ft ☐ East ☐ West of terminal post

Performed by: e-brackin & m-robinson Date: 2023-03-23

Texas A&M Transportation Institute	LF-SST1 Crushed Concrete Soil Strength Performance Test Record	Doc. No. LF-SST2	Revision Date: 2021-04-05
Laboratory Form	Revised by: B.L.Griffith Approved by: D. L. Kuhn	Revision: 0	Page: 1 of 1

Crushed Concrete Soil Strength Performance Test

***MASH*, Appendix B**

Project Number: 611801-04-2

Date of Crash Test: 2023-03-30

Post No. 1 of 1 Fill Moisture: n/a % Native Moisture: n/a %

Temperature: 65 ° F Humidity: 92%

File Name: Soil Strength_35.ASC

Displacement (in.)	*Pull Force (Lbf)	Minimum Force (Lbf)	Pass / Fail
5	8545	4420	P
10	9515	4981	P
15	10,181	5282	P

*Do not exceed 10,000 lbf

Test Post Location: 15 ft ☐ South ☒ North of terminal post
_____ ft ☐ East ☐ West of terminal post

Performed by: e-brackin & m-robinson Date: 2023-03-30

APPENDIX C. *MASH* TEST 3-20 (CRASH TEST NO. 611801-03-1)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2022-09-15 Test No.: 611801-03-1 VIN No.: 3N1CN7P4GL840091

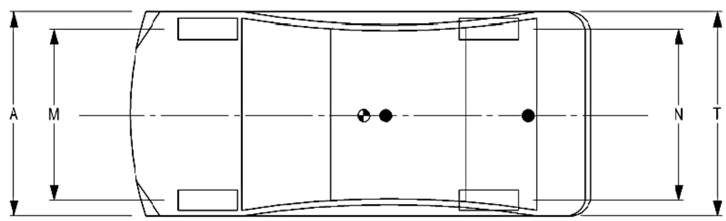
Year: 2016 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 85337 Tire Size: P185/65R15

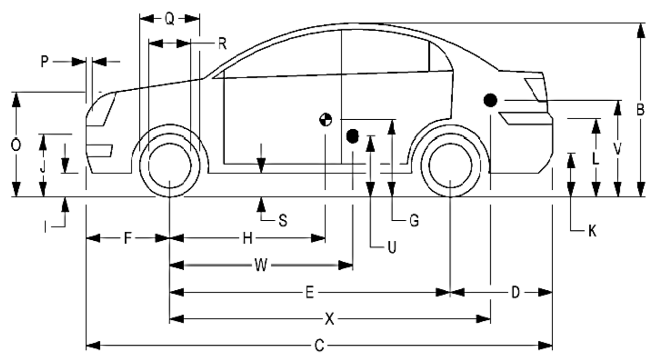
Describe any damage to the vehicle prior to test: None

● 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:

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	41.17	M	58.30	R	16.25	W	
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 -41.17

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}	1420	1457	1542
Back	1687	M_{rear}	938	980	1060
Total	3389	M_{Total}	2358	2437	2602

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

Mass Distribution:
lb LF: 712 RF: 745 LR: 500 RR: 480

Figure C.1. Vehicle Properties for Test No. 611801-03-1.

Date:	2020-09-15	Test No.:	611801-03-1	VIN No.:	3N1CN7AP4GL840091
Year:	2016	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 Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	14	7	36							-10
2	APOVE FT BUMPER	14	8	48							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).

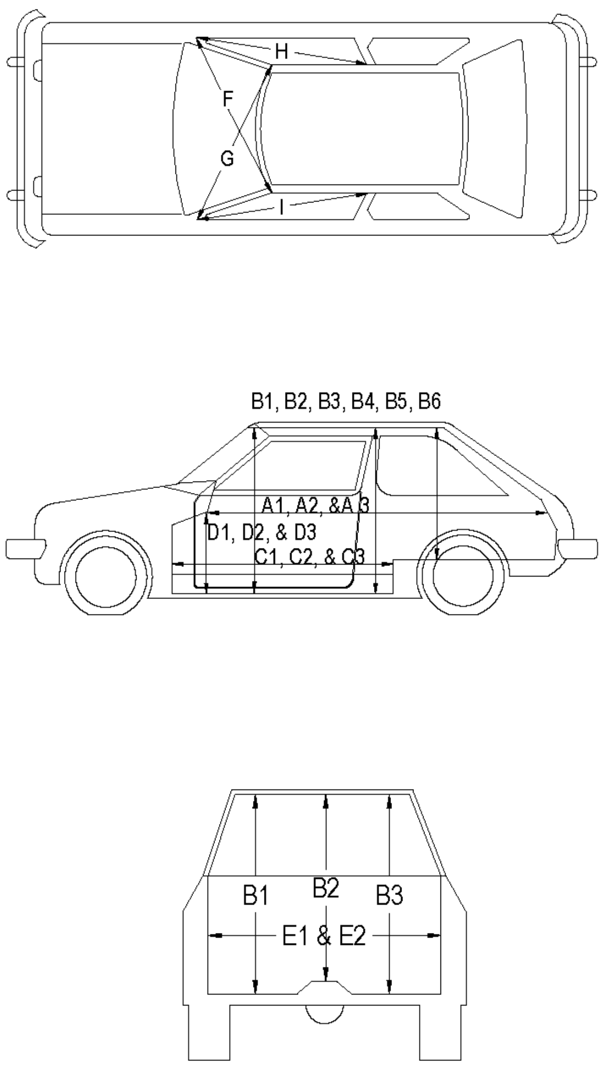
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Figure C.2. Exterior Crush Measurements for Test No. 611801-03-1.

Date: 2020-09-15 Test No.: 611801-03-1 VIN No.: 3N1CN7AP4GL840091

Year: 2016 Make: Nissan Model: Versa



OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

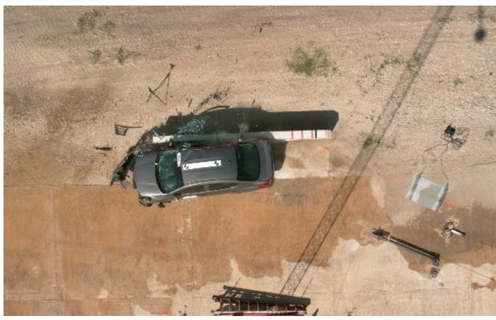
	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	24.00	-2.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	46.50	-5.00
E2	51.00	54.50	3.50
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	46.00	-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. 611801-03-1.

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. 611801-03-1 (Overhead Views).


(a) 0.000 s (b) 0.100 s


(c) 0.200 s (d) 0.300 s


(e) 0.400 s (f) 0.500 s


(g) 0.600 s (h) 0.700 s

Figure C.5. Sequential Photographs for Test No. 611801-03-1 (Frontal Views).

(a) 0.000 s

(b) 0.100 s

(c) 0.200 s

(d) 0.300 s

(e) 0.400 s

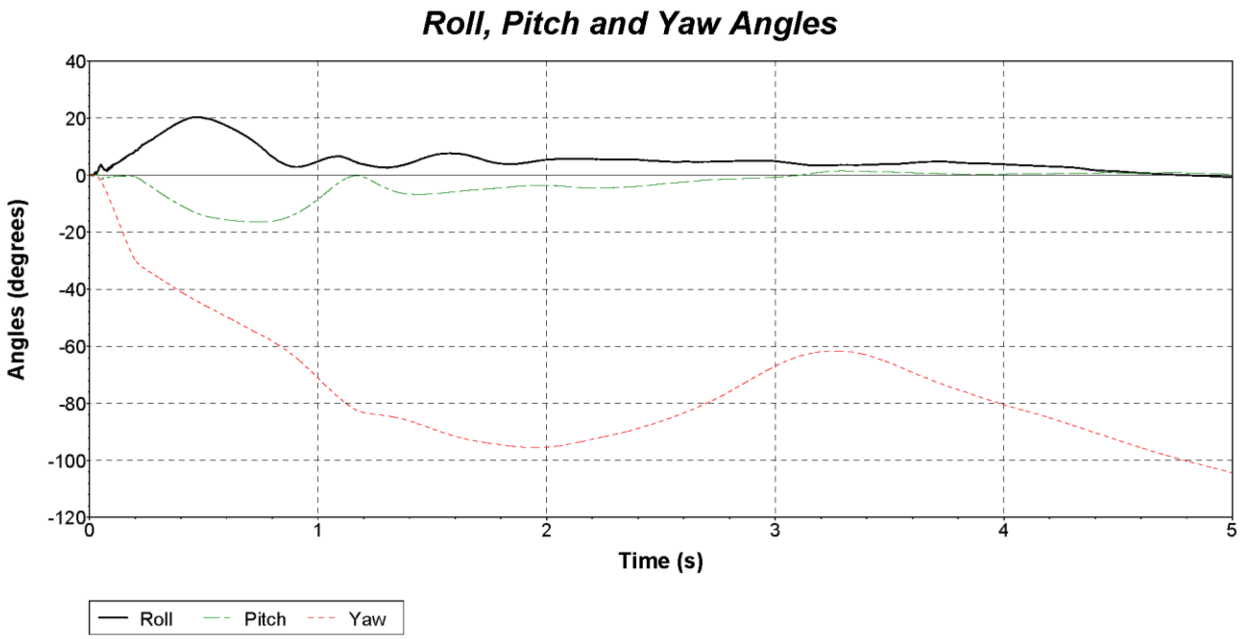
(f) 0.500 s

(g) 0.600 s

(h) 0.700 s

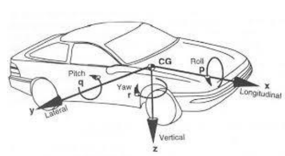
Figure C.6. Sequential Photographs for Test No. 611801-03-1 (Rear Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

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



Test Number: 611801-03-1
Test Standard Test Number: *MASH* Test 3-10
Test Article: Guardrail Transition for Box Beam Rail
Test Vehicle: [Test Vehicle #1]
Inertial Mass: [Inertial Weight #1]
Gross Mass: [Gross #1]
Impact Speed: 62.1

Figure C.7. Vehicle Angular Displacements for Test No. 611801-03-1.

C.4. VEHICLE ACCELERATIONS

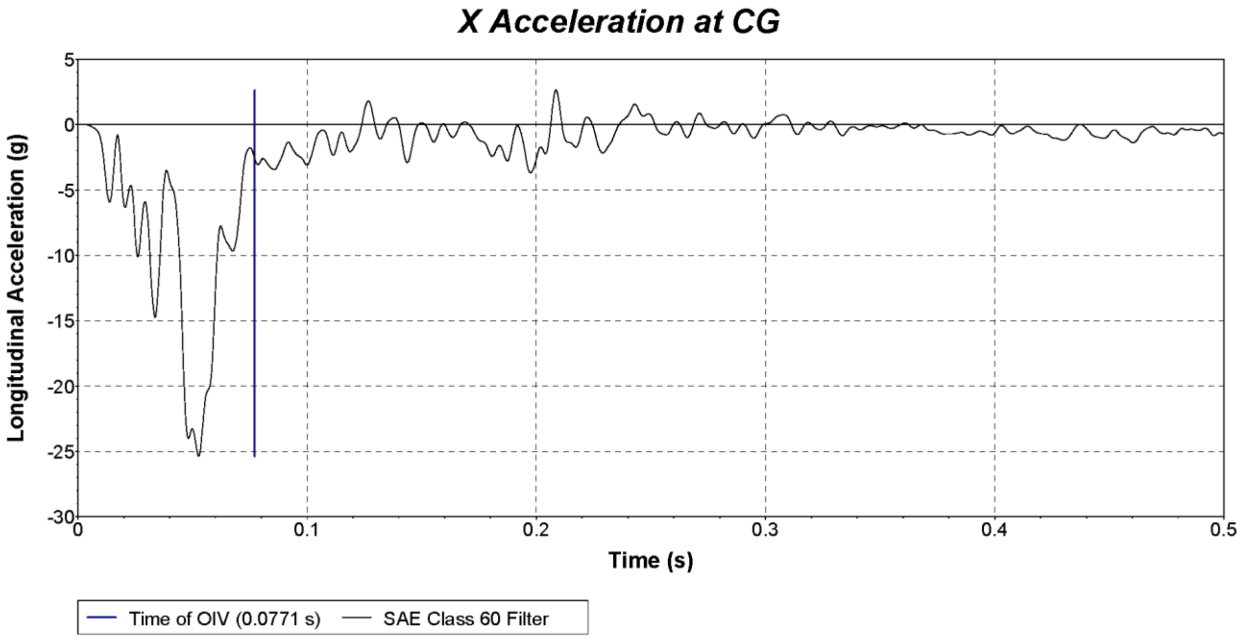


Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-03-1 (Accelerometer Located at Center of Gravity).

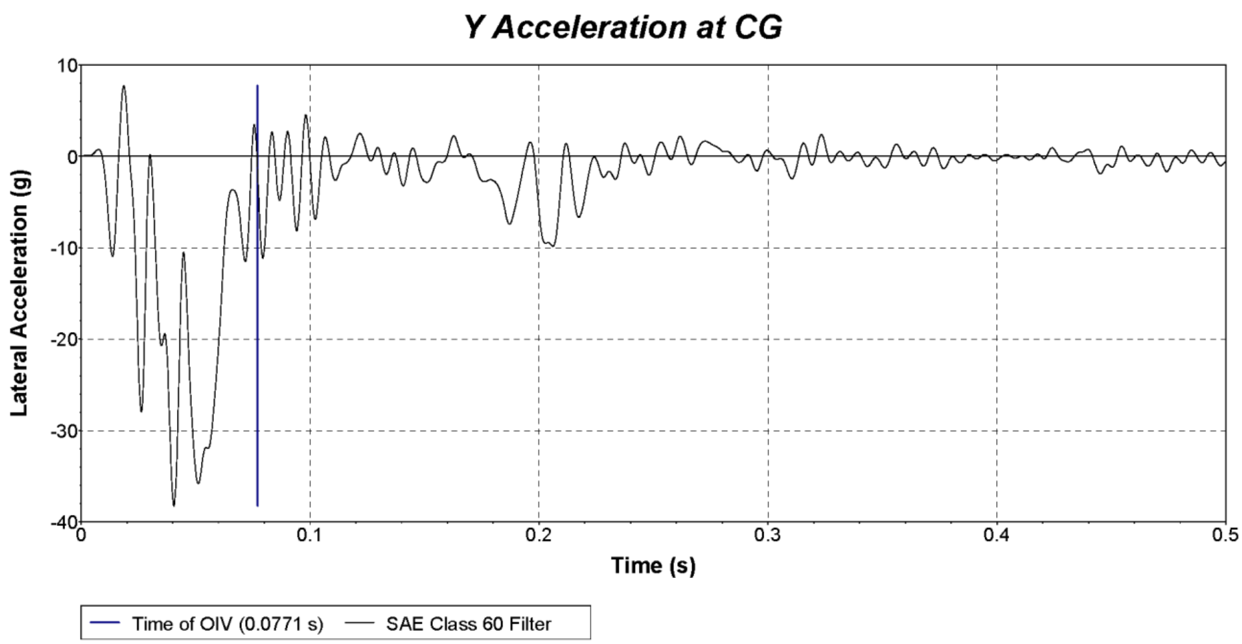


Figure C.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-03-1 (Accelerometer Located at Center of Gravity).

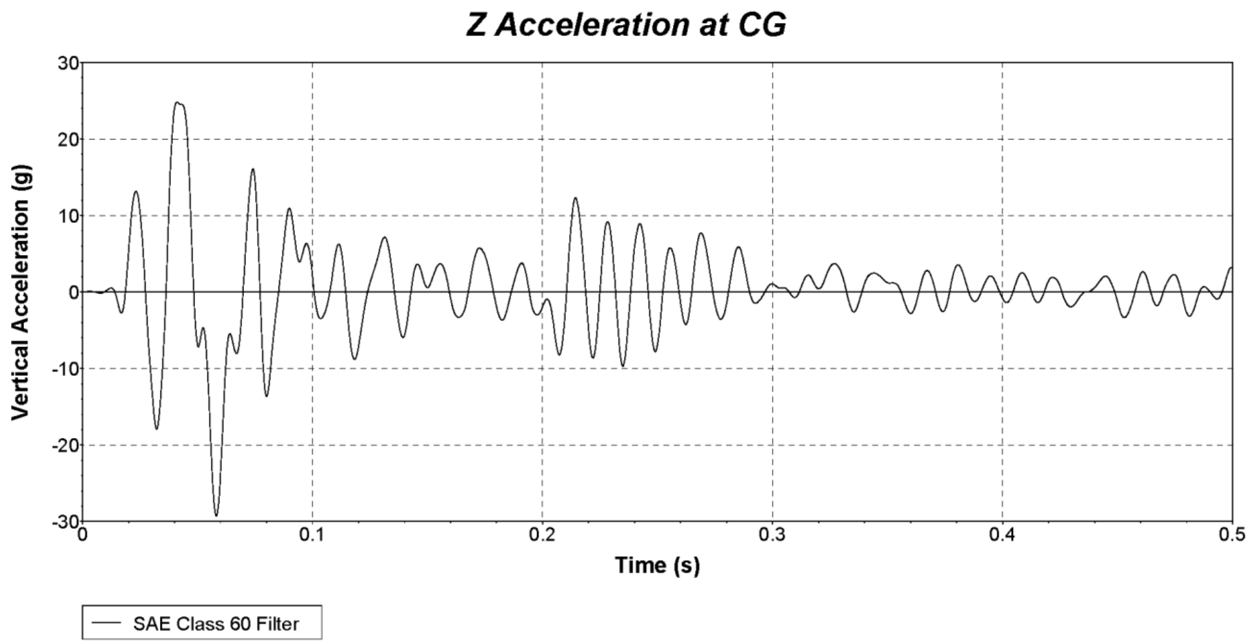


Figure C.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-03-1 (Accelerometer Located at Center of Gravity).

APPENDIX D. *MASH* TEST 3-21 (CRASH TEST NO. 611801-03-2)

D.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2022-09-28 Test No.: 611801-03-2 VIN No.: 1C6RR6GT4GS133477

Year: 2016 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 111002

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

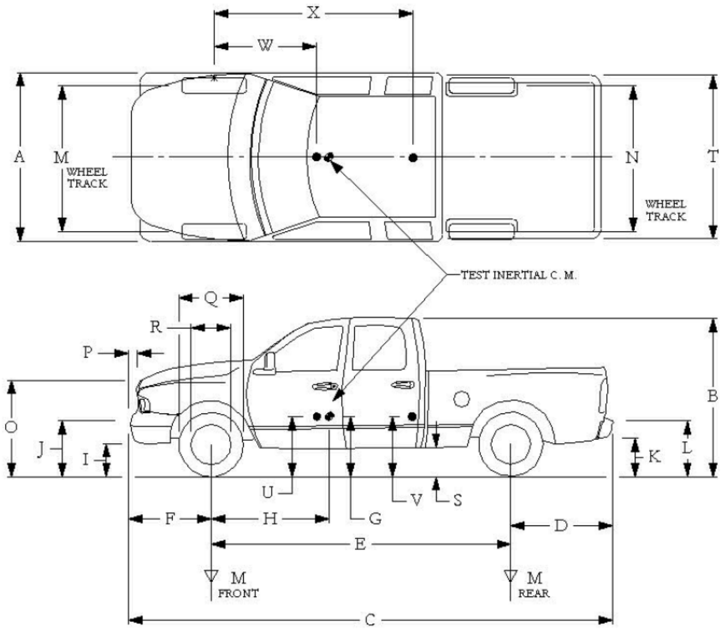
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type:
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.50	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.29	M	68.50	R	18.00	W	61.25
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}	2960	2825	
Back	3900	M_{rear}	2075	2186	
Total	6700	M_{Total}	5035	5011	5011

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

Mass Distribution:
lb LF: 1425 RF: 1400 LR: 1110 RR: 1076

Figure C.1. Vehicle Properties for Test No. 611801-03-2.

Date:	2022-09-28	Test No.:	611801-03-2	VIN No.:	1C6RR6GT4GS133477
Year:	2016	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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 Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	24	12	36							-18
2	SAME	24	12	72							64
	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).

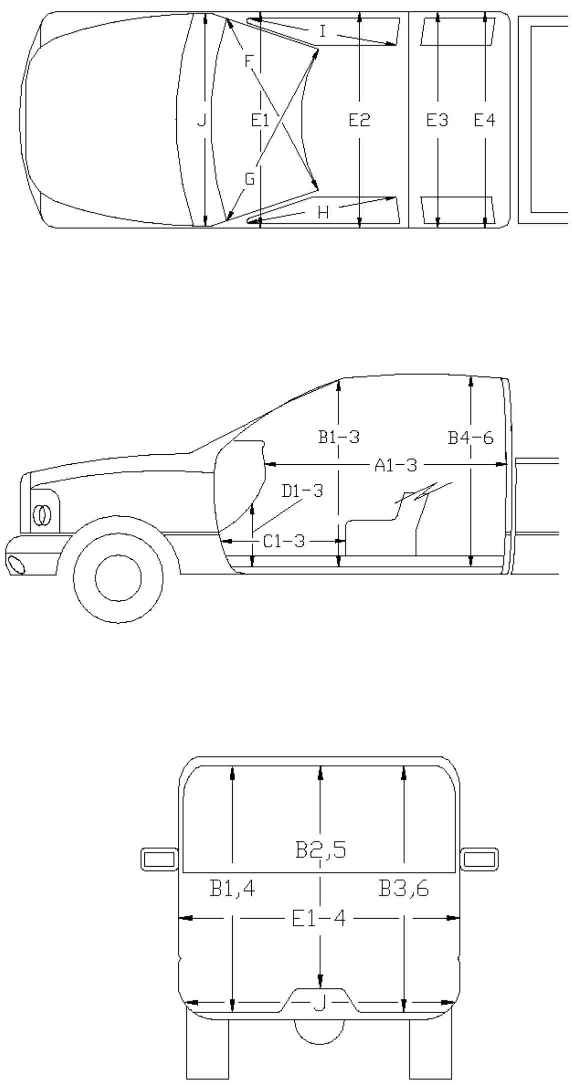
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Figure D.2. Exterior Crush Measurements for Test No. 611801-03-2.

Date: 2022-09-28 Test No.: 611801-03-2 VIN No.: 1C6RR6GT4GS133477

Year: 2016 Make: RAM Model: 1500



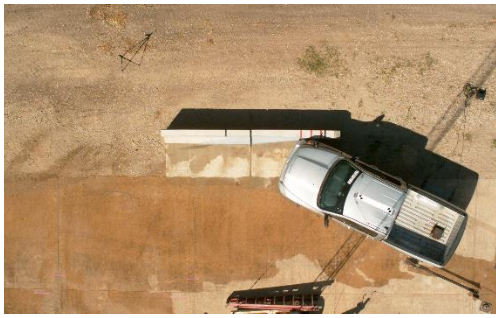
*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	22.50	-3.50
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	57.00	-1.50
E2	63.50	65.00	1.50
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*	24.00	21.50	-2.50

Figure D.3. Occupant Compartment Measurements for Test No. 611801-03-2.

D.2. SEQUENTIAL PHOTOGRAPHS




(a) 0.000 s (b) 0.100 s


€ 0.200 s (d) 0.300 s


€ 0.400 s (f) 0.500 s


(g) 0.600 s (h) 0.700 s

Figure D.4. Sequential Photographs for Test No. 611801-03-2 (Overhead Views).

(a) 0.000 s

(b) 0.100 s

€ 0.200 s

(d) 0.300 s

€ 0.400 s

(f) 0.500 s

(g) 0.600 s

(h) 0.700 s

Figure D.5. Sequential Photographs for Test No. 611801-03-2 (Frontal Views).


(a) 0.000 s (b) 0.100 s

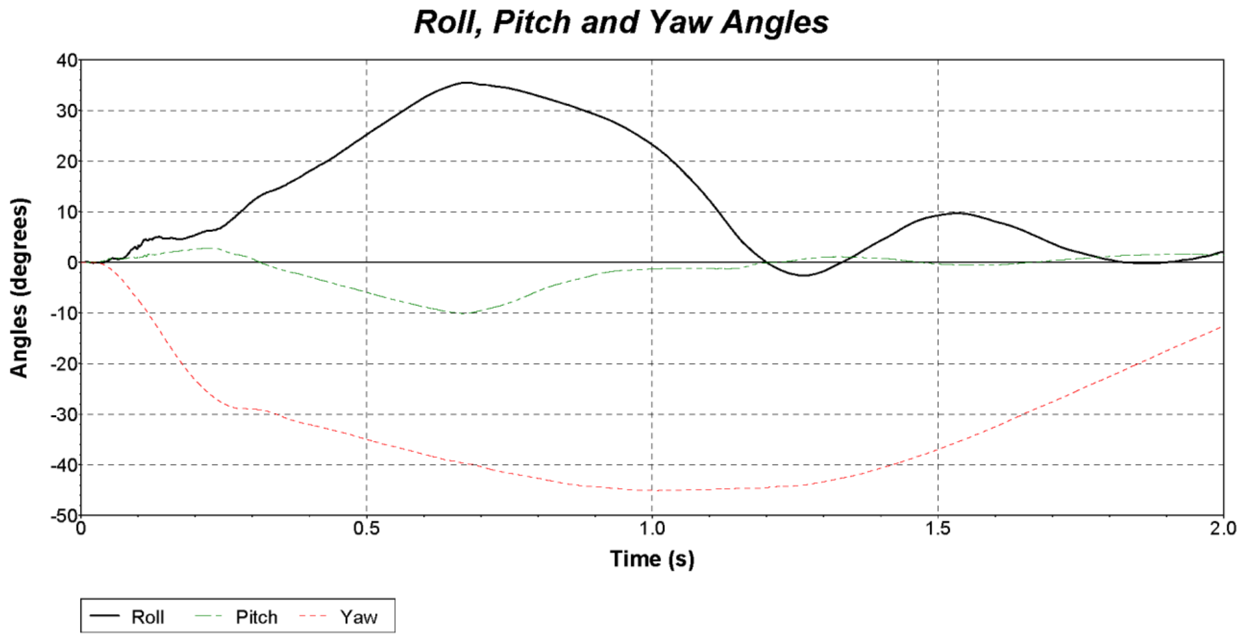

€ 0.200 s (d) 0.300 s


€ 0.400 s (f) 0.500 s


(g) 0.600 s (h) 0.700 s

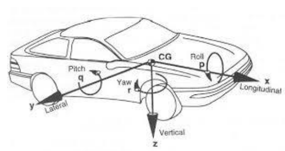
Figure D.6. Sequential Photographs for Test No. 611801-03-2 (Rear Views).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

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



Test Number: 611801-03-2
Test Standard Test Number: *MASH* Test 3-11
Test Article: Guardrail Transition for Box Beam Rail
Test Vehicle: Test Vehicle #2]
Inertial Mass: 5011
Gross Mass: 5011
Impact Speed: 62.6

Figure D.7. Vehicle Angular Displacements for Test No. 611801-03-2.

D.4. VEHICLE ACCELERATIONS

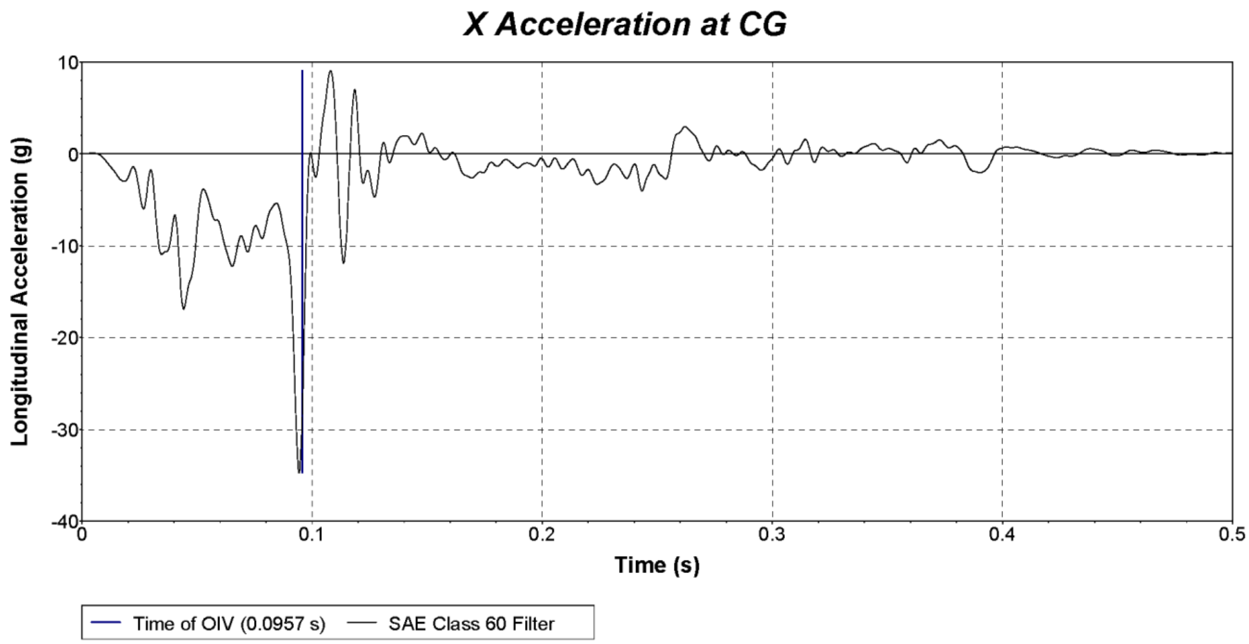


Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-03-2 (Accelerometer Located at Center of Gravity).

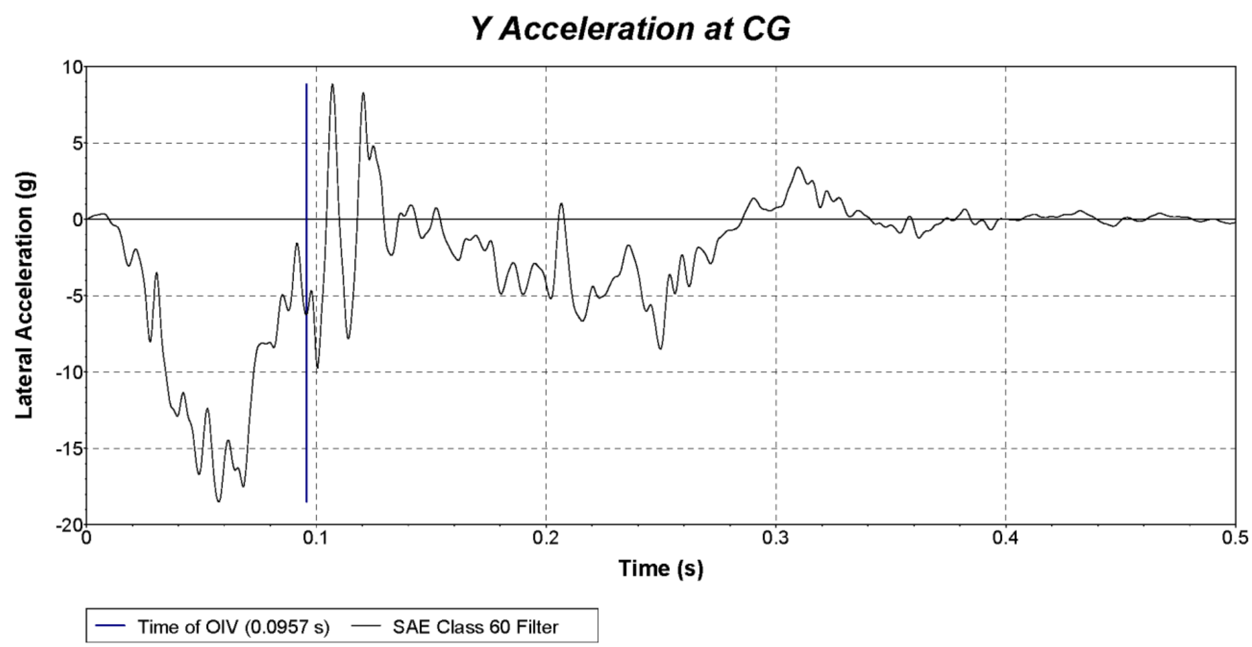


Figure D.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-03-2 (Accelerometer Located at Center of Gravity).

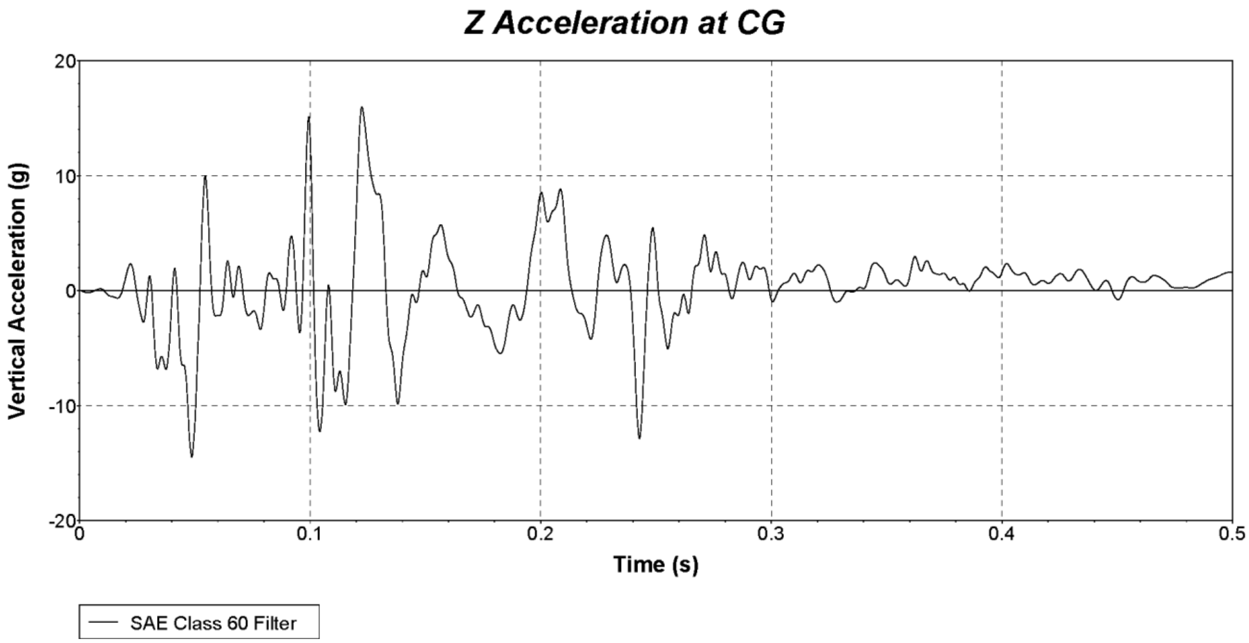


Figure D.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-03-2 (Accelerometer Located at Center of Gravity).

APPENDIX E. *MASH* TEST 3-20 (CRASH TEST NO. 611801-04-1)

E.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-03-27 Test No.: 611801-04-1 VIN No.: 3N1CN7AP4HL801342

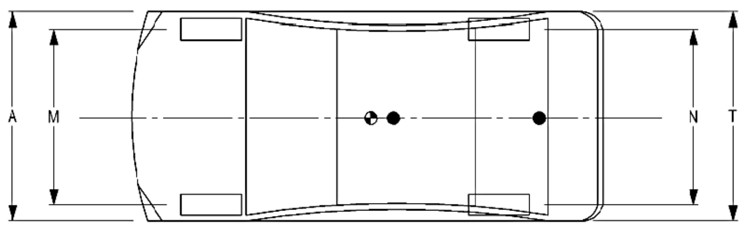
Year: 2017 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 234630 Tire Size: P185/65R15

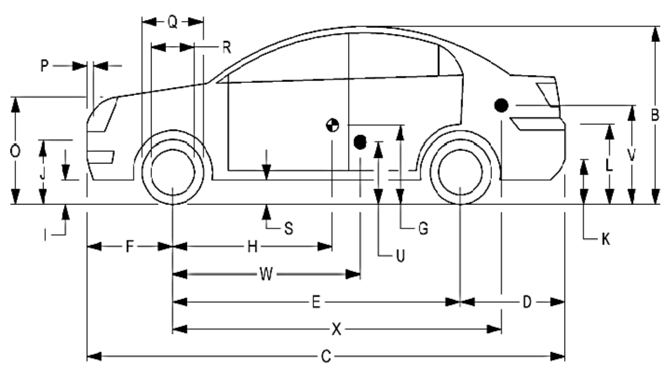
Describe any damage to the vehicle prior to test: None

● 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	41.87	M	58.30	R	16.25	W	41.75
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 -0.12

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}	1421	1447	1532
Back	1687	M_{rear}	988	1001	1081
Total	3389	M_{Total}	2409	2448	2613

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

Mass Distribution:
lb LF: 821 RF: 626 LR: 447 RR: 554

Figure E.1. Vehicle Properties for Test No. 611801-04-1.

Date:		Test No.:	611801-04-1	VIN No.:	3N1CN7AP4HL801342
Year:	2017	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 Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	12	8	56							28
2	ABOVE FT BUMPER	12	10	48							56
	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.

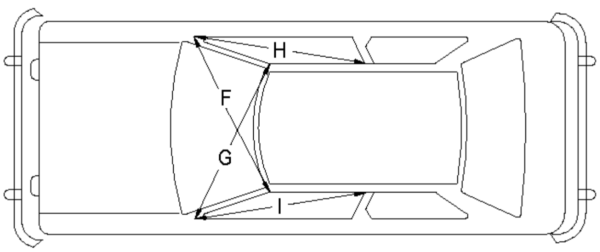
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

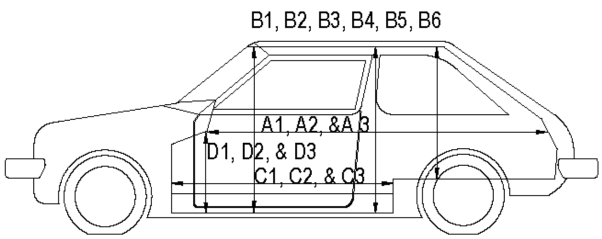
***Measure and document on the vehicle diagram the location of the maximum crush.

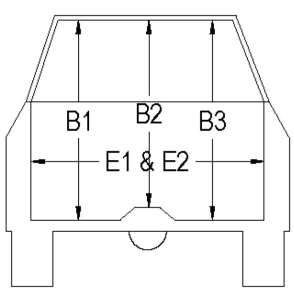
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure E.2. Exterior Crush Measurements for Test No. 611801-04-1.

Date:		Test No.:	611801-04-1	VIN No.:	3N1CN7AP4HL801342
Year:	2017	Make:	Nissan	Model:	Versa







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	25.00	-1.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	48.50	-3.00
E2	51.00	52.00	1.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	50.00	-1.00

Figure E.3. Occupant Compartment Measurements for Test No. 611801-04-1.

E.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 E.4. Sequential Photographs for Test No. 611801-04-1 (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 E.5. Sequential Photographs for Test No. 611801-04-1 (Frontal Views).

(a) 0.000 s

(b) 0.100 s

(c) 0.200 s

(d) 0.300 s

(e) 0.400 s

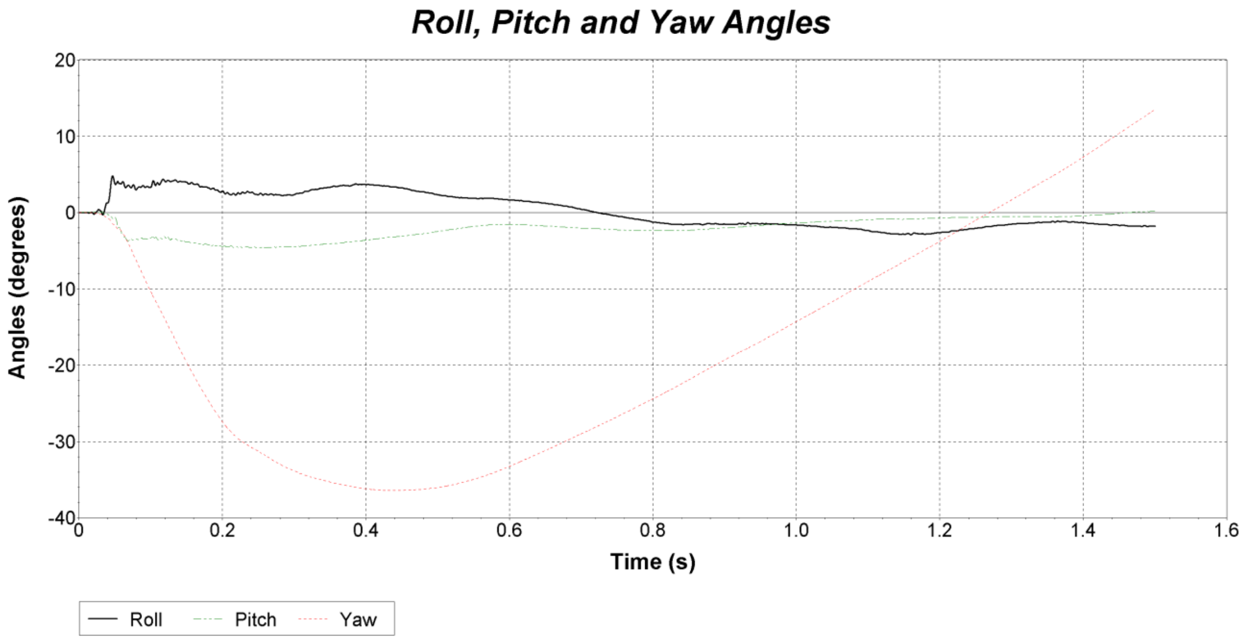
(f) 0.500 s

(g) 0.600 s

(h) 0.700 s

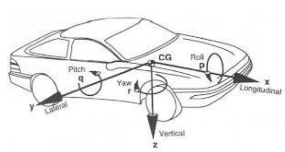
Figure E.6. Sequential Photographs for Test No. 611801-04-1 (Rear Views).

E.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

7. Yaw.
8. Pitch.
9. Roll.



Test Number: 611801-04-1
Test Standard Test Number: *MASH* Test 3-20
Test Article: Guardrail Transition for Box Beam Rail
Test Vehicle: 2018 Nissan Versa
Inertial Mass: 2437 lbs
Gross Mass: 2602 lbs
Impact Speed: 61.8 mi/h
Impact Angle: 25.0°

Figure E.7. Vehicle Angular Displacements for Test No. 611801-04-1.

E.4. VEHICLE ACCELERATIONS

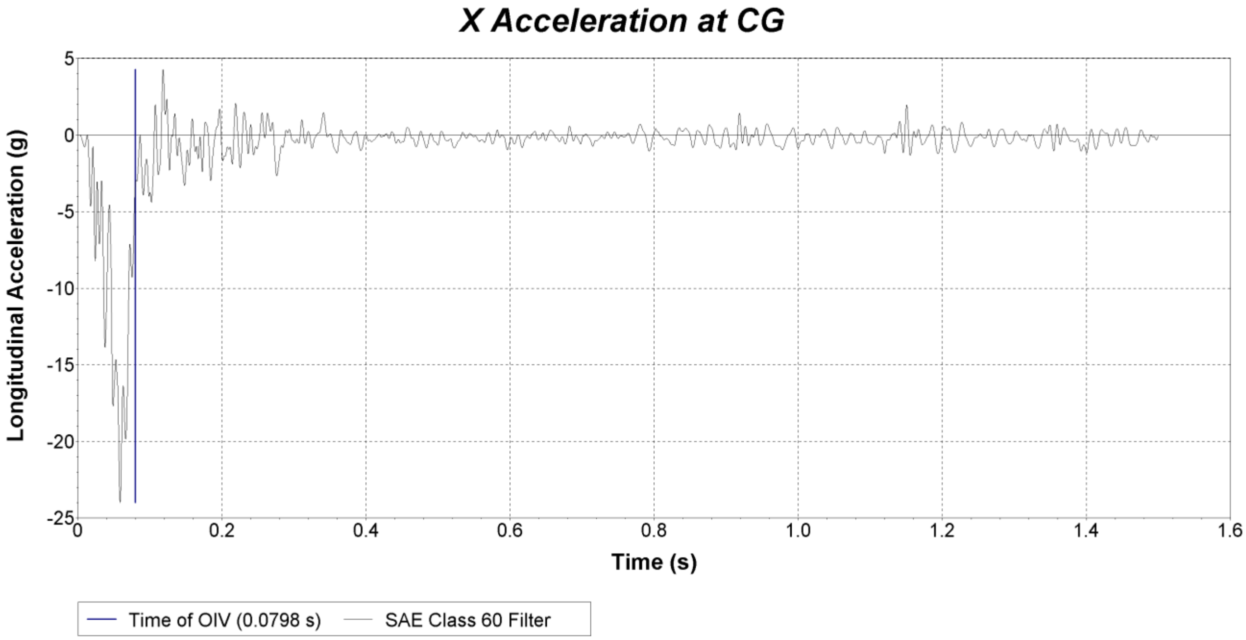


Figure E.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-04-1 (Accelerometer Located at Center of Gravity).

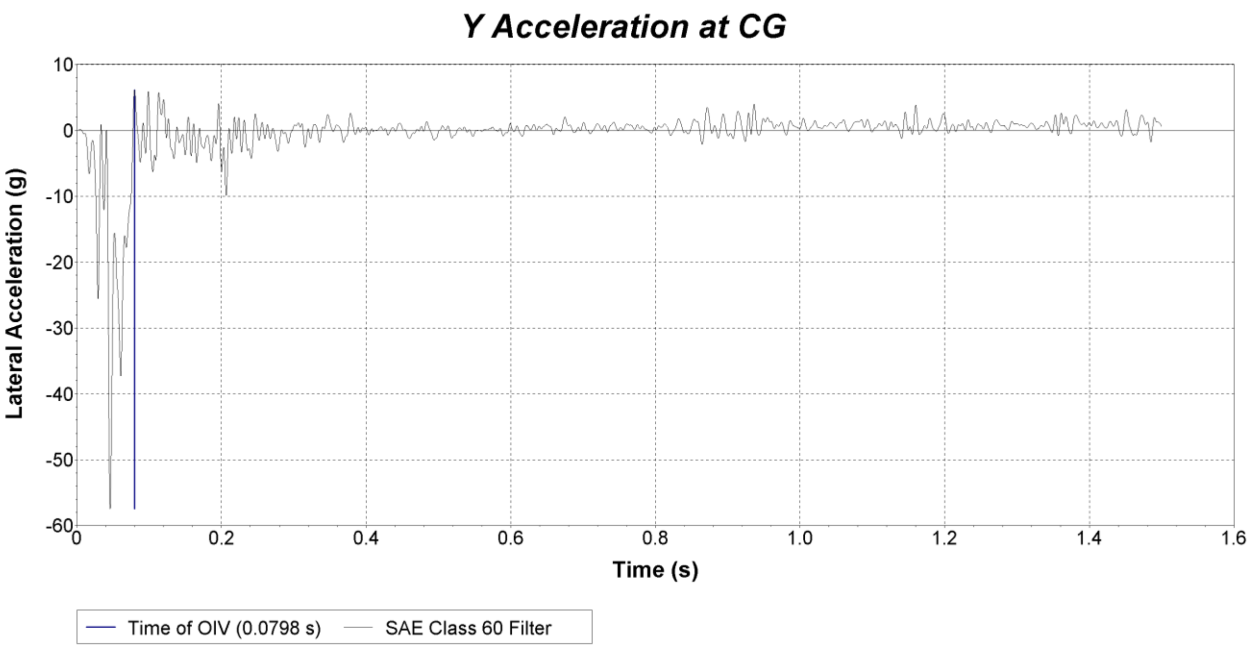


Figure E.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-04-1 (Accelerometer Located at Center of Gravity).

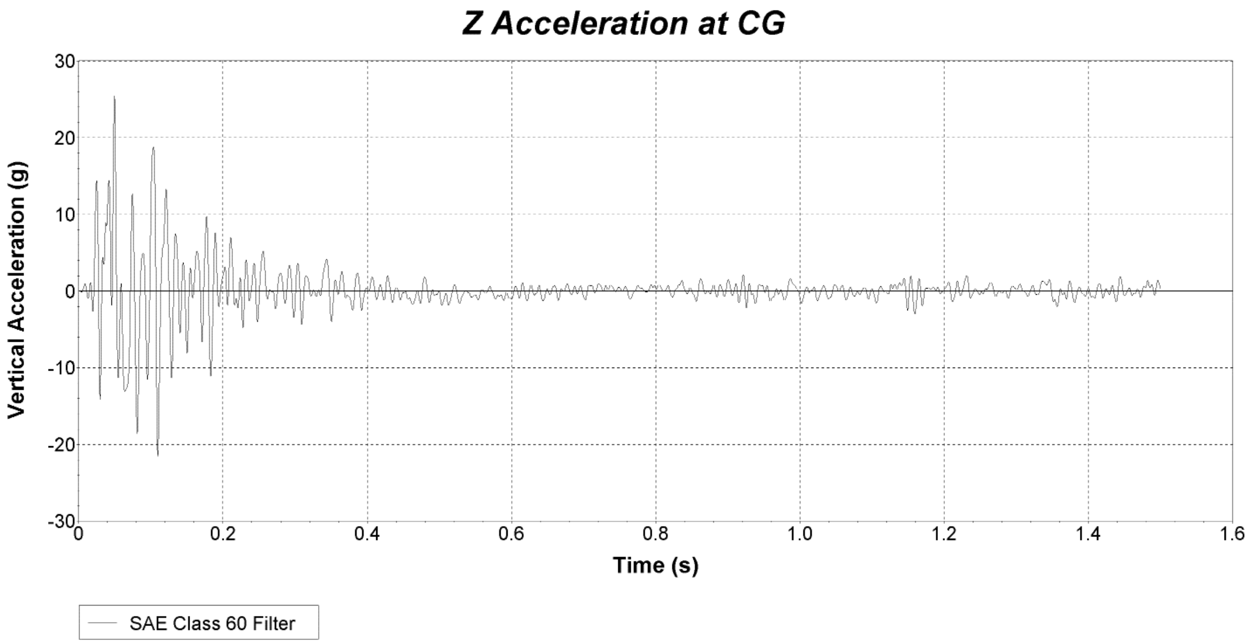


Figure E.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-04-1 (Accelerometer Located at Center of Gravity).

APPENDIX F. *MASH* TEST 3-21 (CRASH TEST NO. 611801-04-2)

F.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-03-30 Test No.: 611801-04-2 VIN No.: 1C6RR6GTXHS512761

Year: 2017 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 154198

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

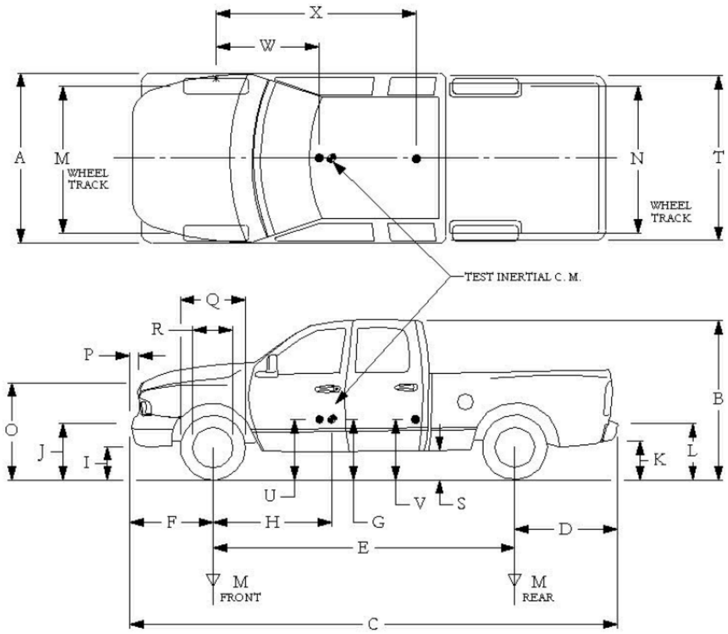
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type:
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.62	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.66	M	68.50	R	18.00	W	61.50
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}	2920	2834	2834
Back	3900	M_{rear}	2145	2217	2217
Total	6700	M_{Total}	5065	5051	5051

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

Mass Distribution:
lb LF: 1401 RF: 1433 LR: 1135 RR: 1082

Figure F.1. Vehicle Properties for Test No. 611801-04-2.

Date:	2023-03-30	Test No.:	611801-04-2	VIN No.:	1C6RR6GTXHS512761
Year:	2017	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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 Width** (CDC)	Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	12	10	36							+18
2	ABOVE FT BUMPER	12	14	64							74
	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.

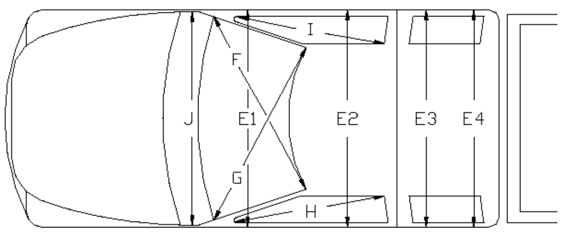
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

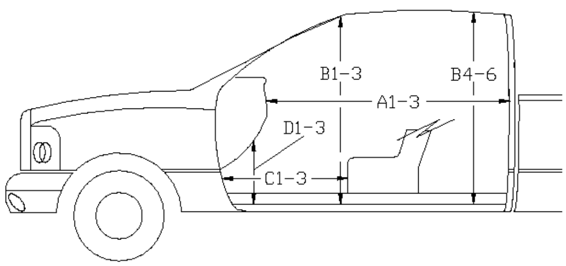
***Measure and document on the vehicle diagram the location of the maximum crush.

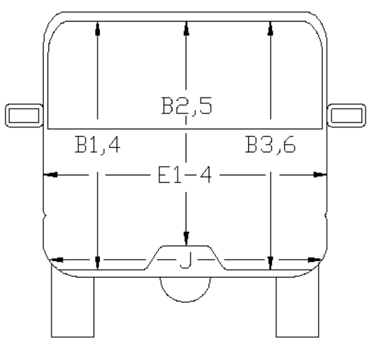
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure F.2. Exterior Crush Measurements for Test No. 611801-04-2.

Date:	2023-03-30	Test No.:	611801-04-2	VIN No.:	1C6RR6GTXHS512761
Year:	2017	Make:	RAM	Model:	1500







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	23.00	-3.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	56.50	-2.00
E2	63.50	64.50	1.00
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 F.3. Occupant Compartment Measurements for Test No. 611801-04-2.

F.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 F.4. Sequential Photographs for Test No. 611801-04-2 (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 F.5. Sequential Photographs for Test No. 611801-04-2 (Frontal Views).

(a) 0.000 s (b) 0.100 s

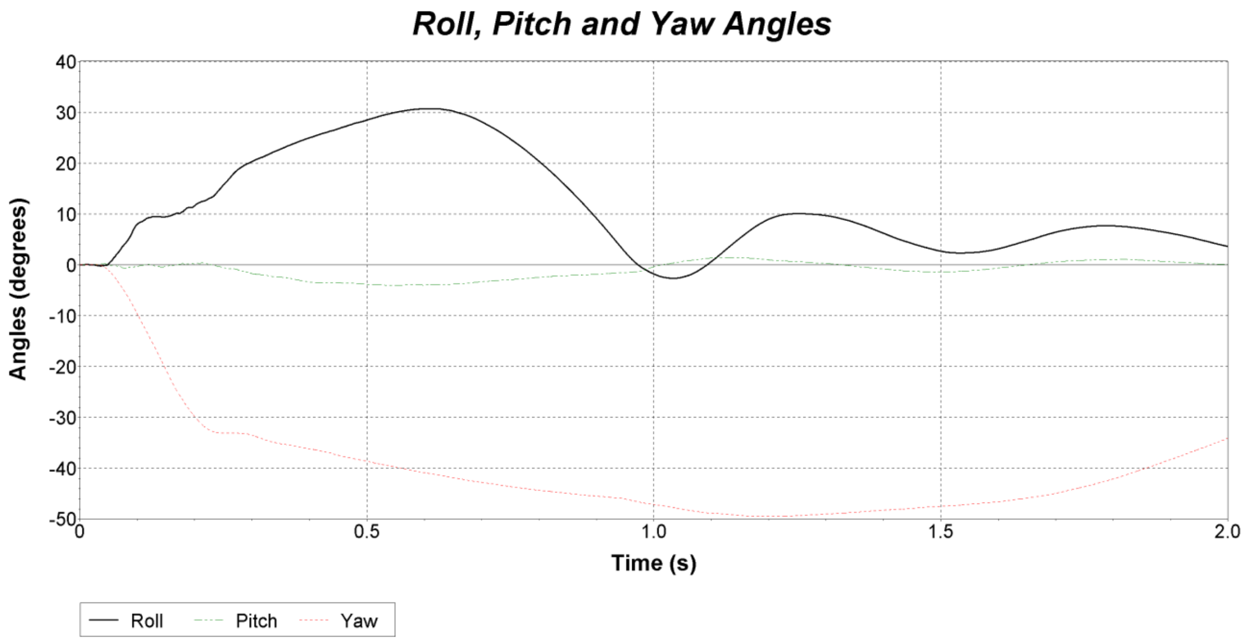
(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

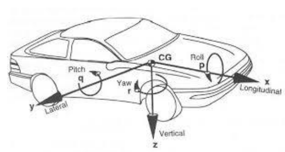
Figure F.6. Sequential Photographs for Test No. 611801-04-2 (Rear Views).

F.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

10. Yaw.
11. Pitch.
12. Roll.



Test Number: 611801-04-2
Test Standard Test Number: *MASH* Test 3-21
Test Article: Guardrail Transition for Box Beam Rail
Test Vehicle: 2017 RAM 1500
Inertial Mass: 5051 lbs
Gross Mass: 5051 lbs
Impact Speed: 62.1 mi/h
Impact Angle: 25.0°

Figure F.7. Vehicle Angular Displacements for Test No. 611801-04-2.

F.4. VEHICLE ACCELERATIONS

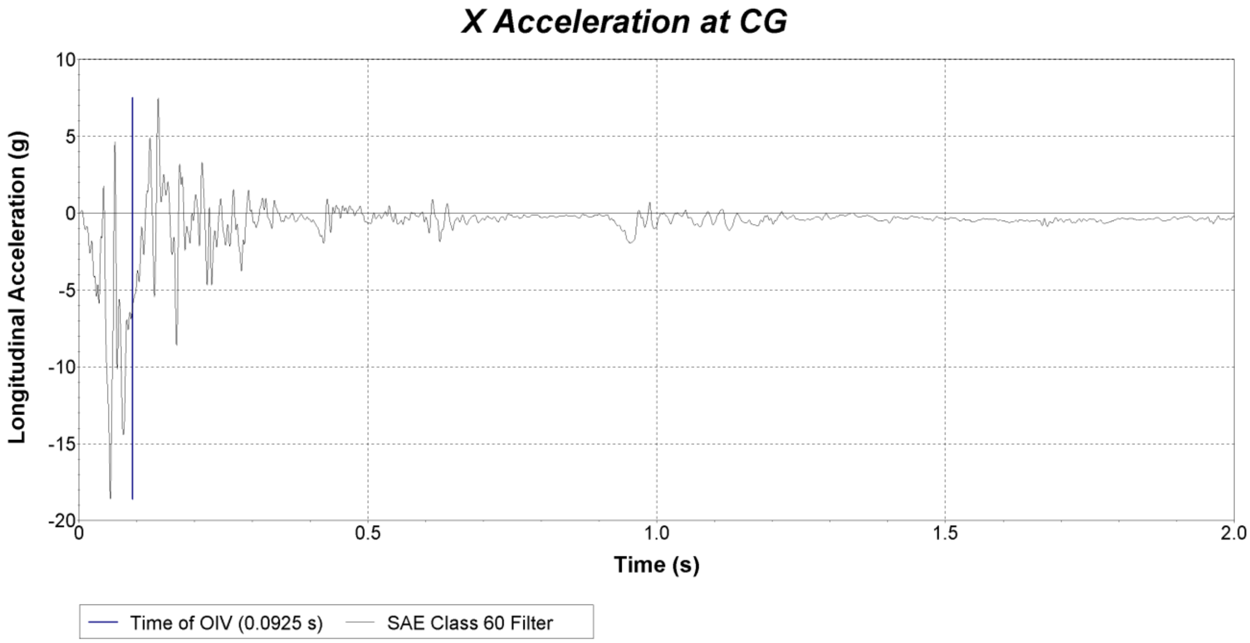


Figure F.8. Vehicle Longitudinal Accelerometer Trace for Test No. 611801-04-2 (Accelerometer Located at Center of Gravity).

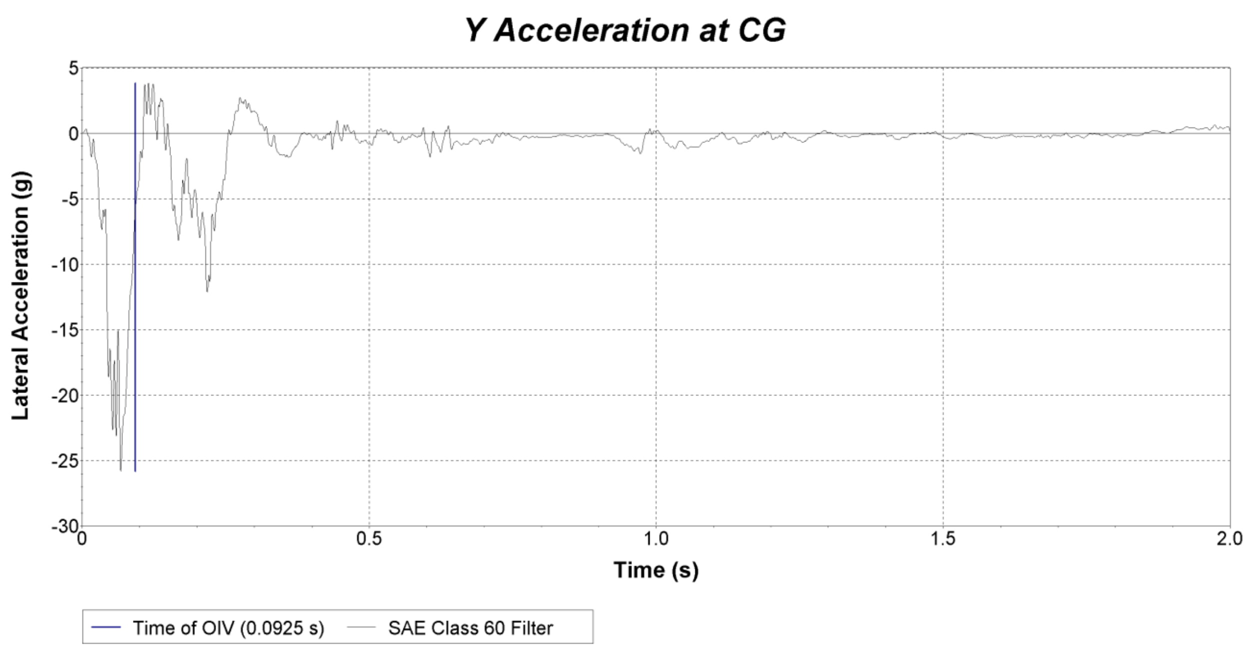


Figure F.9. Vehicle Lateral Accelerometer Trace for Test No. 611801-04-2 (Accelerometer Located at Center of Gravity).

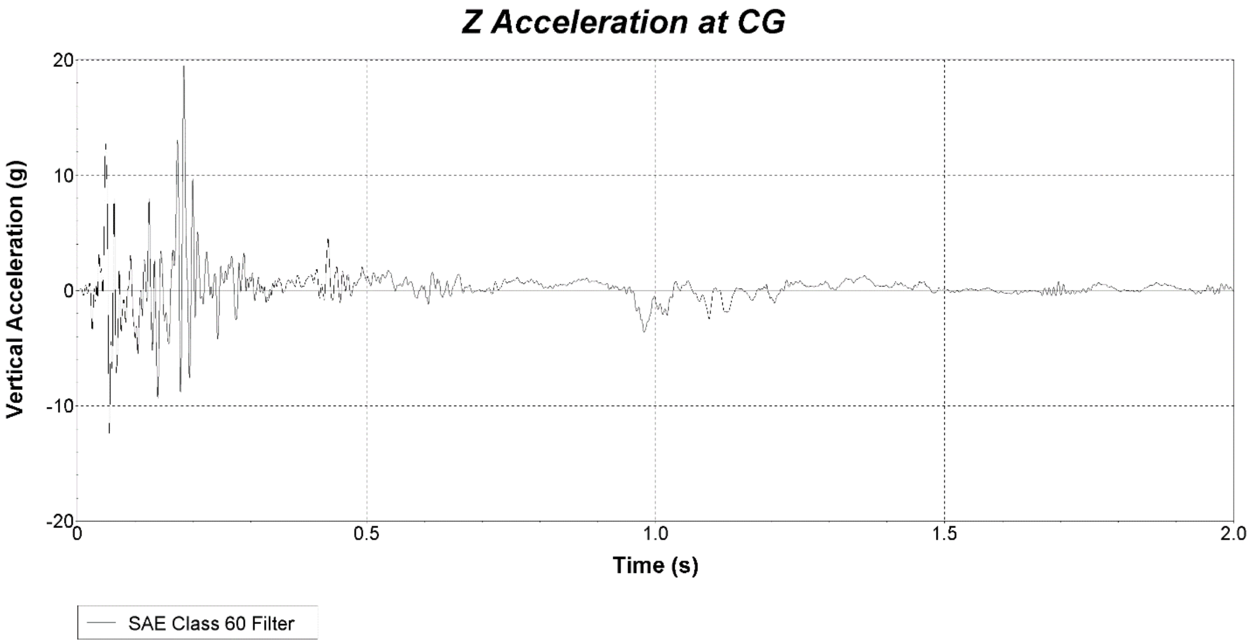
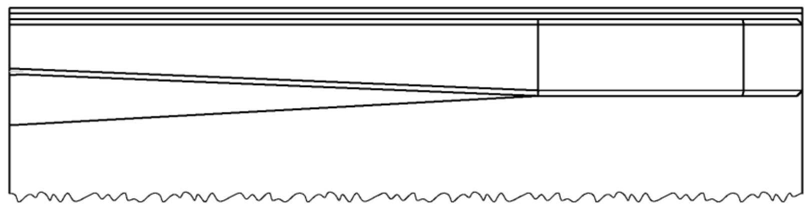


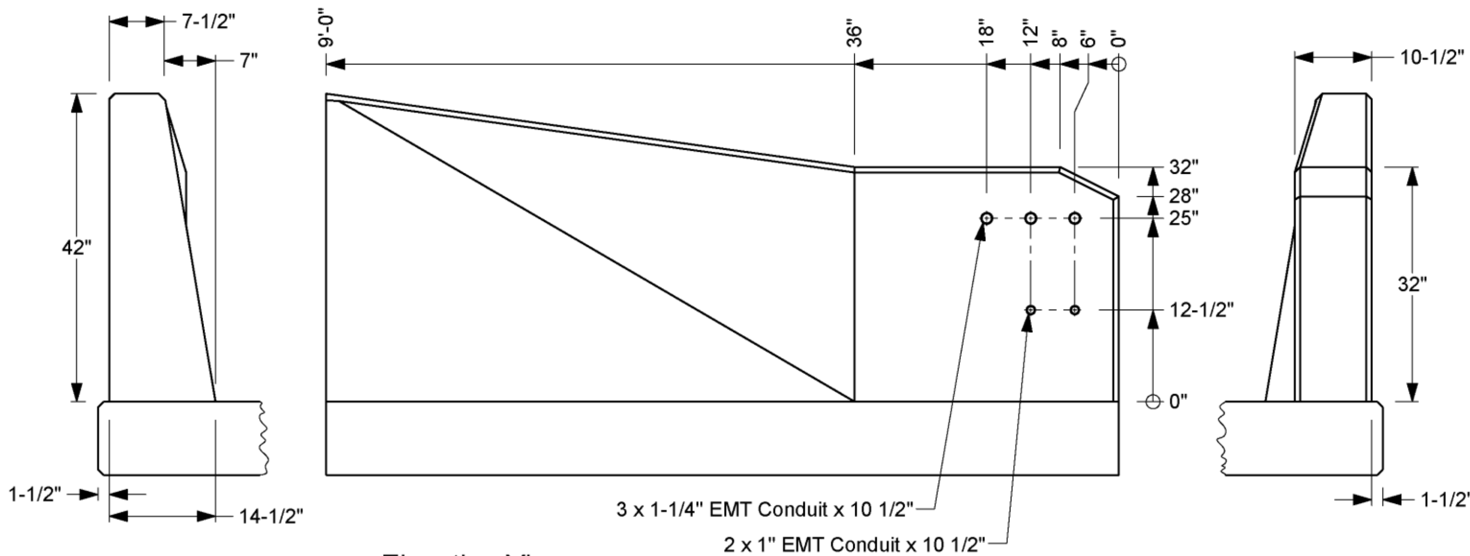
Figure F.10. Vehicle Vertical Accelerometer Trace for Test No. 611801-04-2 (Accelerometer Located at Center of Gravity)

APPENDIX G. DETAILS OF THE CONCRETE SINGLE SLOPE PARAPET TRANSITION

Concrete Details



Plan View



Elevation Views

1a. Concrete is 4,000 psi.
1b. 1" chamfer (3/4" each way) all exposed corners.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801 Vertical Wall to SS Transition		2023-11-07
Drawn by GES	Scale 1:20	Sheet 1 of 6 Concrete Details

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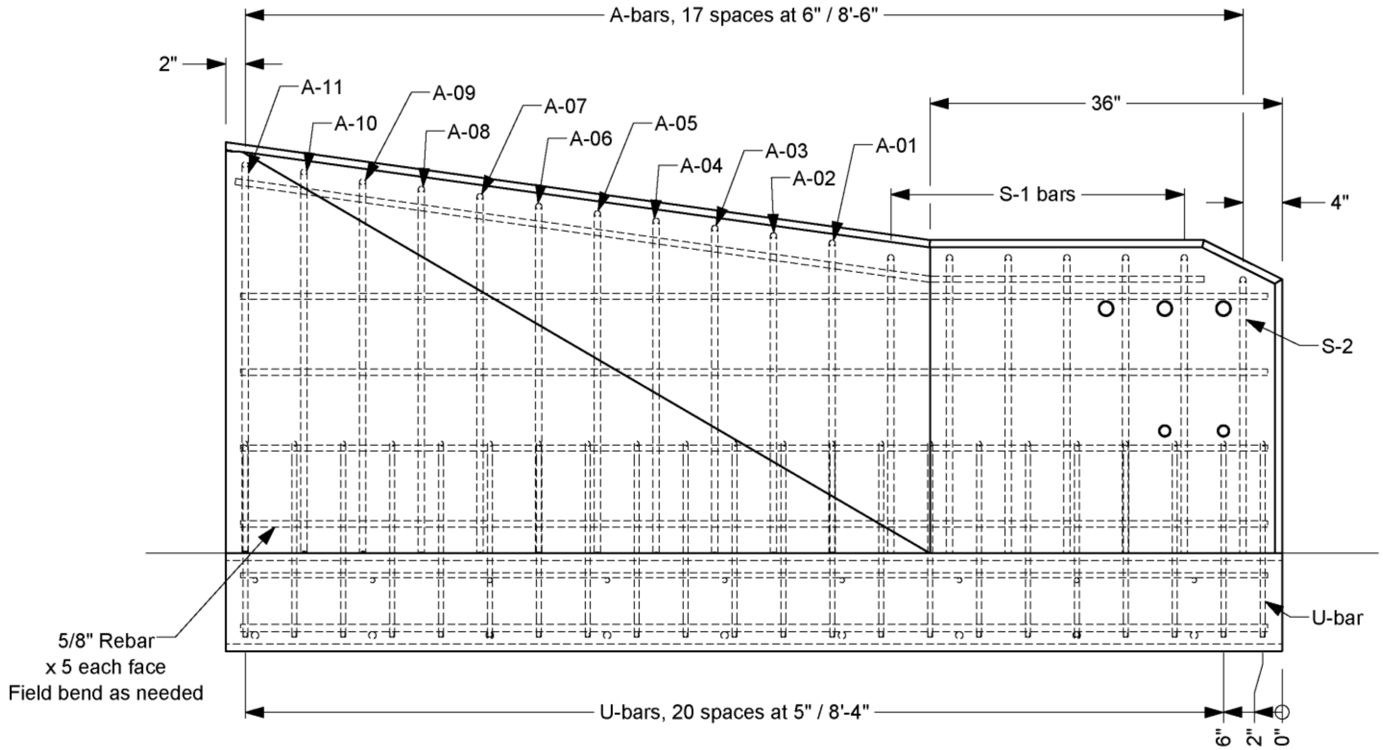
Transition Rebar



Elevation View

2a. Concrete is 4,000 psi.

2b. Adjust U-bar spacing ±1/2" where needed to avoid interference with transverse rebar in deck.

2c. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

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Project #611801 Vertical Wall to SS Transition			2023-11-07
Drawn by GES	Scale 1:15	Sheet 2 of 6 Transition Rebar	

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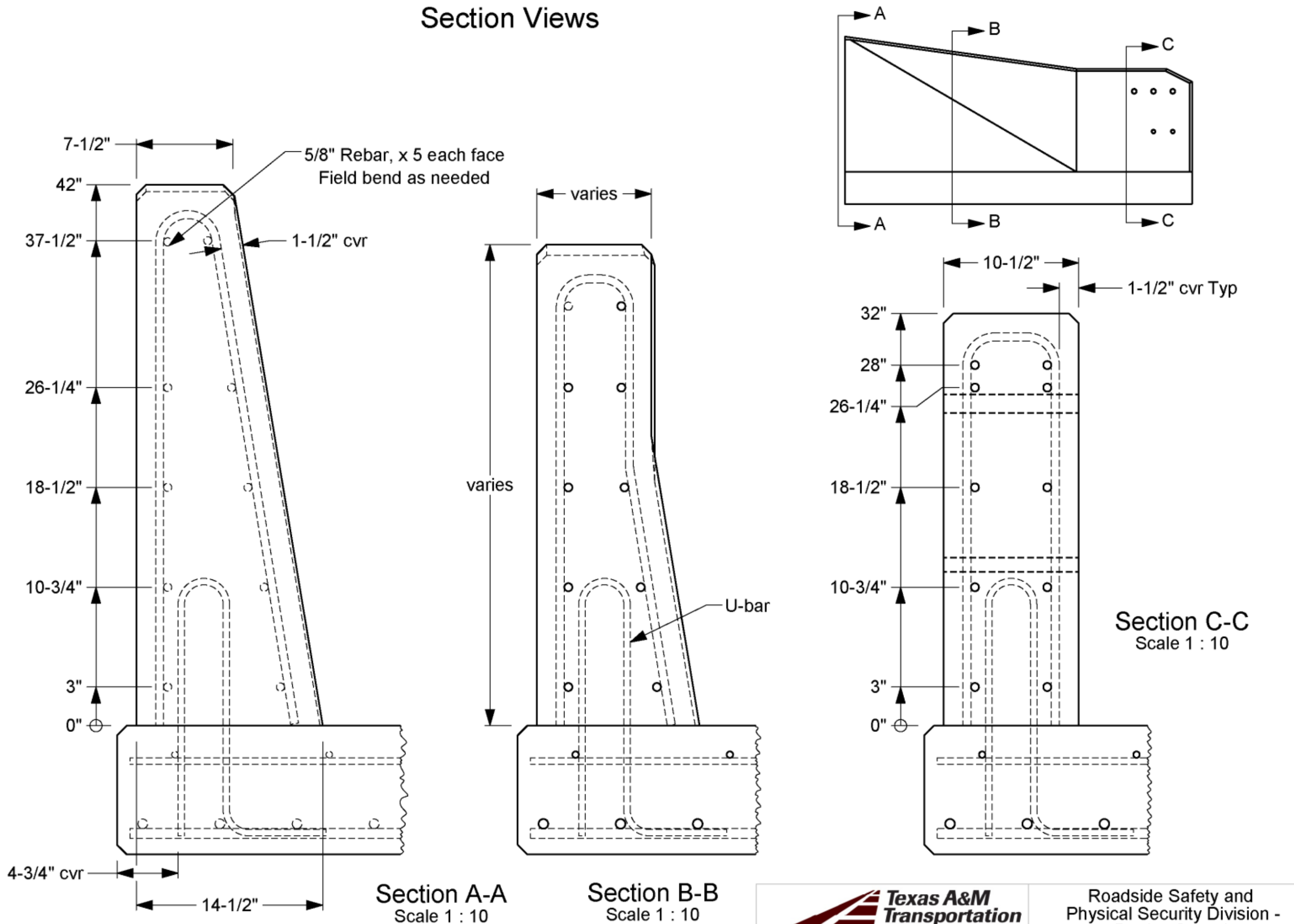
Section Views



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801 Vertical Wall to SS Transition		2023-11-07
Drawn by GES	Scale 1:40	Sheet 3 of 6 Section Views

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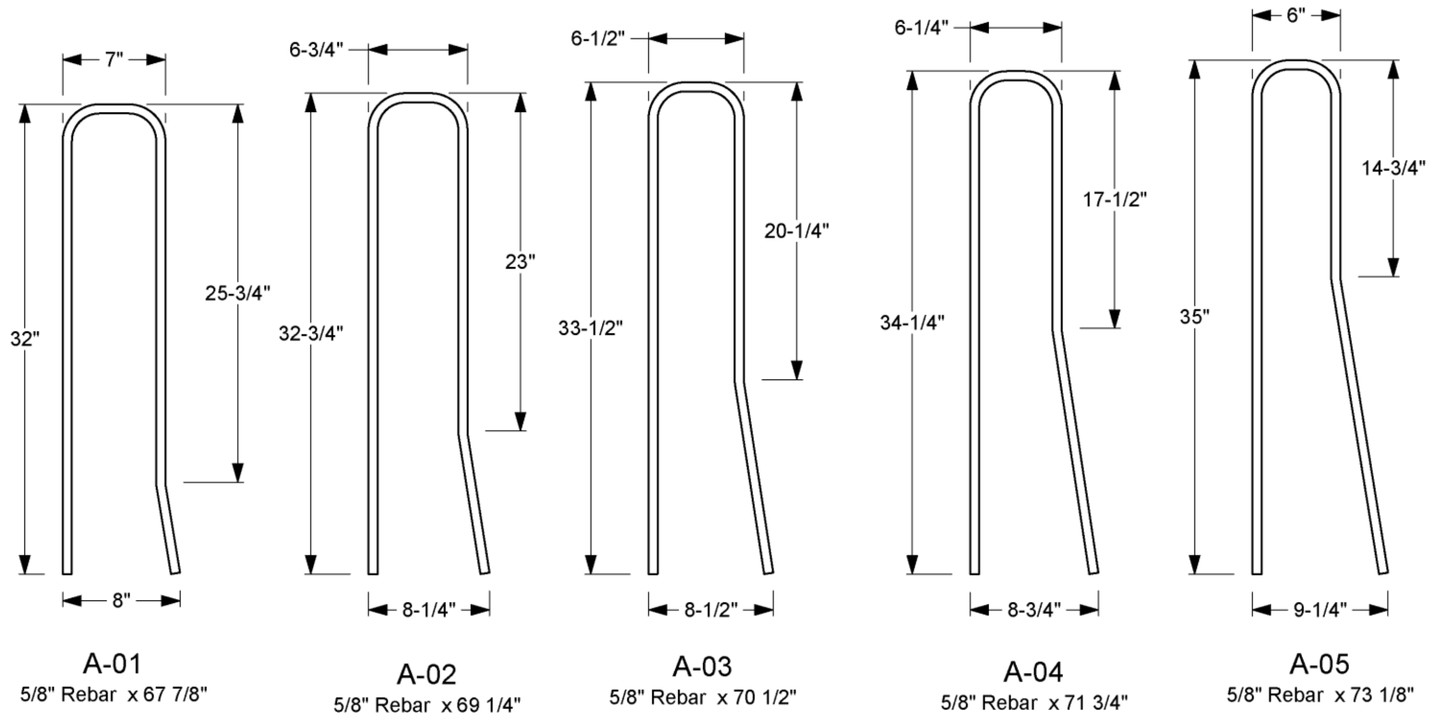
A-01 to A-05



4a. All rebar is grade 60.
4b. All bends on Ø5/8" rebar are Ø3-3/4" unless otherwise noted.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801 Vertical Wall to SS Transition		2023-11-07
Drawn by GES	Scale 1:10	Sheet 4 of 6 A-01 to A-05

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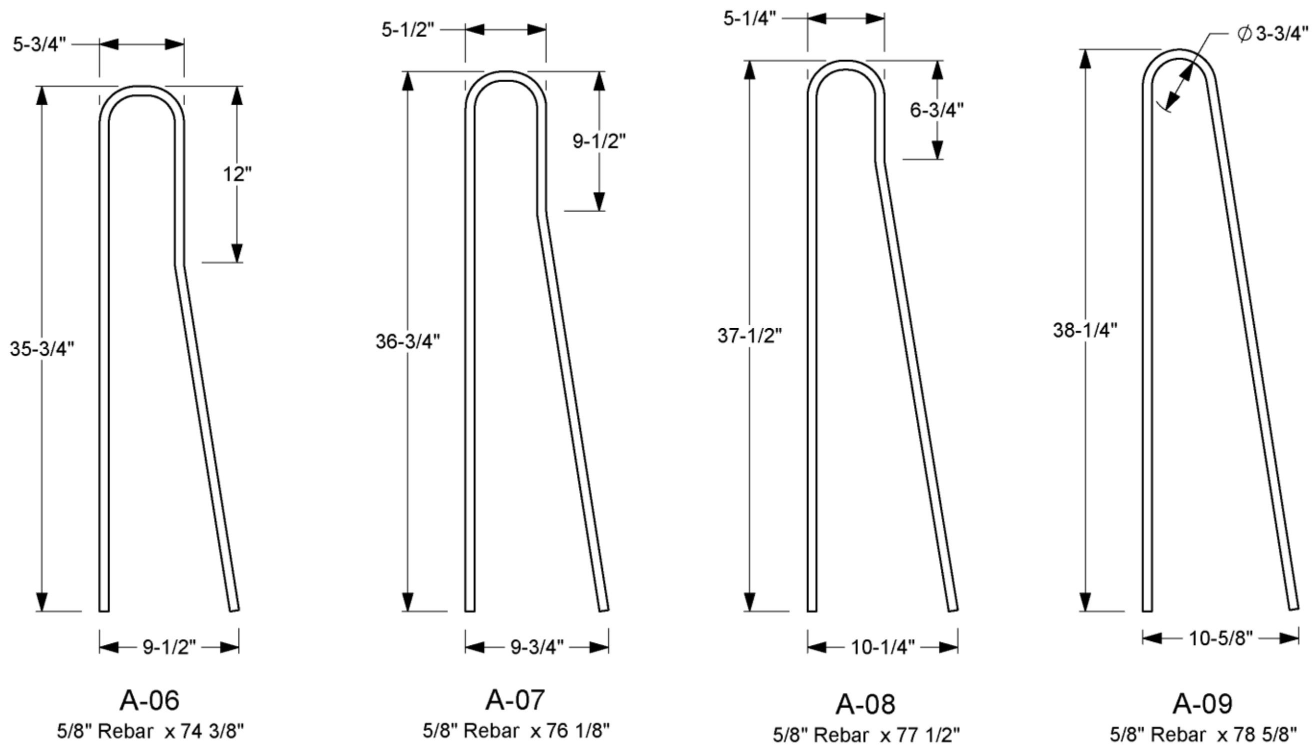
A-06 to A-09



5a. All rebar is grade 60.
5b. All bends on Ø5/8" rebar are ∅3-3/4" unless otherwise noted.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801 Vertical Wall to SS Transition		2023-11-07
Drawn by GES	Scale 1:10	Sheet 5 of 6 A-06 to A-09

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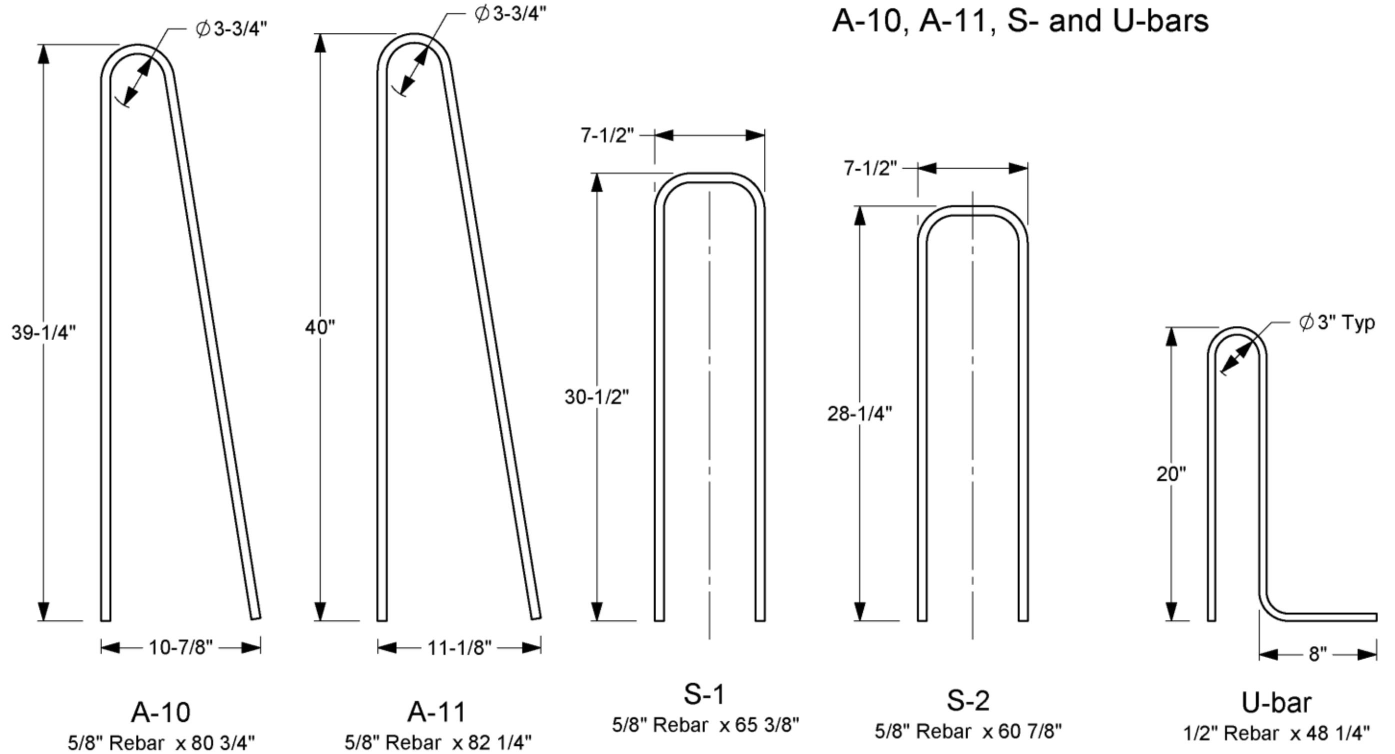
A-10, A-11, S- and U-bars



6a. All rebar is grade 60.
6b. All bends on Ø5/8" rebar are ∅3-3/4" unless otherwise noted.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #611801 Vertical Wall to SS Transition		2023-11-07
Drawn by GES	Scale 1:10	Sheet 6 of 6 A-10, A-11, S- and U-bars