Roadside Safety Pooled Fund

Texas A&M Transportation Institute Proving Ground

Test Report No. 605641-1
Test Report Date: January 2016

MASH TRANSITION FROM F-SHAPE TEMPORARY CONCRETE BARRIER PINNED ON ASPHALT TO RIGID SINGLE-SLOPE CONCRETE BARRIER

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Contract No.: T4541-CH
Test No.: 605641-1
Test Date: 2015-10-21

Sponsored by
Roadside Safety Research Program Pooled Fund Study No. TPF-5(114)

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ISO 17025 Laboratory
Testing Certificate # 2821.01

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle ***MASH* TRANSITION FROM F-SHAPE TEMPORARY CONCRETE BARRIER PINNED ON ASPHALT TO RIGID SINGLE-SLOPE CONCRETE BARRIER**		5. Report Date January 2016 6. Performing Organization Code
7. Author(s) Nauman M. Sheikh, Wanda L. Menges, and Darrell L. Kuhn		8. Performing Organization Report No. Test Report No. 605641-1
9. Performing Organization Name and Address Texas A&M Transportation Institute Proving Ground 3135 TAMU College Station, Texas 77843-3135		10. Work Unit No. (TRAIS) 11. Contract or Grant No. T4541-CH
12. Sponsoring Agency Name and Address Washington State Department of Transportation Transportation Building, MS 47372 Olympia, Washington 98504-7372		13. Type of Report and Period Covered Technical Report: July 2015 – January 2016 14. Sponsoring Agency Code

15. Supplementary Notes
Project Title: Transition Design for Temporary Concrete Barrier Pinned on Asphalt to Rigid Concrete Barrier
Name of Contacting Representative: John P. Donahue, Washington State Department of Transportation

16. Abstract

This project evaluated the crash safety performance of a transition from a 32-inch tall pinned-down F-shape temporary concrete barrier placed on asphalt to a permanent 42-inch tall single-slope concrete barrier. The test performed was Test 3-21 of the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*). The temporary pinned-down barrier segments were 12.5-ft long and were connected with a pin-and-loop connection. The segments were pinned to a 4-inch thick asphalt pad using three anchoring steel pins per segment. The transition from the pinned to the rigid barrier was comprised of a nested thrie beam cover on the traffic (impact) side of the barriers and a steel strap on the back side of the barriers. A tapering steel cover was bolted to the top of the barriers to allow a smooth transition in the height of the barriers from 32-inch tall F-shape barrier to 42-inch tall single slope barrier.

This report provides details of the anchorage of the temporary concrete barrier pinned on asphalt and the transition from pinned temporary concrete barrier to the rigid concrete barrier. Also included are detailed documentation of the crash test results and an assessment of the performance of the transition as tested according to *MASH* Test 3-21 specifications.

The transition contained and redirected the *MASH* 2270P pickup vehicle. No debris was present to penetrate or show potential for penetrating the occupant compartment or to present hazard to others in the area. Maximum occupant compartment deformation was 4.0 inches in the kick panel area on the driver side. The 2270P vehicle remained upright during and after the collision event. Occupant risk factors were within the preferred limits specified in *MASH*. The transition from temporary concrete barrier pinned on asphalt to rigid concrete barrier performed acceptably for *MASH* Test 3-21 evaluation criteria.

17. Key Words	18. Distribution Statement
Transition Barrier, Temporary Concrete Barrier, Work Zone Barrier, Pinned Down Barrier, Anchored Barrier, Asphalt, Single Slope Barrier, Crash Test, Roadside Safety	Copyrighted. Not to be copied or reprinted without consent from the Roadside Safety Pooled Fund Program.

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	82	

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	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 1000 L 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)		
^{o}F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^{o}C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		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	fl 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 (2000 lb)	T
		TEMPERATURE (exact degrees)		
^{o}C	Celsius	1.8C+32	Fahrenheit	^{o}F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

ACKNOWLEDGMENTS

This research project was performed under a pooled fund program between the State of Alaska Department of Transportation and Public Facilities, California Department of Transportation (Caltrans), Florida Department of Transportation, Illinois Department of Transportation, Louisiana Department of Transportation and Development, Minnesota Department of Transportation, Pennsylvania Department of Transportation, Tennessee Department of Transportation, Texas Department of Transportation, Washington State Department of Transportation, West Virginia Department of Transportation, and the Federal Highway Administration. The authors acknowledge and appreciate their guidance and assistance.

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Revised November 2015

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1. INTRODUCTION

1.1. PROBLEM

Over the years, the pooled fund program has developed a pinned-down concrete barrier design for pinning temporary concrete barriers on asphalt. Additionally, a transition was developed to transition from free-standing barriers to pinned-down barriers placed on asphalt. Currently, there is no transition design that would allow connecting the pinned-down barrier placed on asphalt to a rigid concrete barrier.

A transition was developed under the pooled fund program for the pinned-down barriers placed on concrete. This transition connected the 32-inch tall F-shape pinned-down barriers placed on concrete to a rigid 42-inch tall single-slope barrier (which was determined to be the worst case scenario for the rigid barrier designs used by pooled fund states).

A similar transition design from the pinned down barrier placed on asphalt to a permanent single-slope concrete barrier is needed to accommodate sites with flexible pavement.

1.2. BACKGROUND

In 2008, Texas A&M Transportation Institute (TTI) developed a restrained F-shaped temporary concrete barrier design for placement on concrete pavements or decks (*1*). In 2011, this design was extended for use on asphalt pavements (*2*). The restraint mechanism used three 1.5-inch diameter steel pins that were installed into inclined holes cast in the toe of the barrier segments. The pins passed through the holes in the barrier and continued into the underlying asphalt pavement, thus locking the barrier in place. There is a desire to develop a transition from the pinned-down barrier installed on asphalt to a rigid concrete barrier. The design details of this transition will be kept the same as a previous transition developed by TTI for the pinned barrier installed on concrete (*3*).

1.3. OBJECTIVES/SCOPE OF RESEARCH

The objective of this research was to crash test a transition from the pinned-down F-shape temporary concrete barrier placed on asphalt to a permanent single-slope concrete barrier. The test performed was Test 3-21 of the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*4*). The design of the transition was kept the same as the previous design developed for temporary barriers pinned on concrete, with the exception that the pinned barrier was placed on 4-inch thick asphalt, and was pinned using 3 pins per barrier segment.

This report provides details of the concrete barriers tested, anchorage of the temporary concrete barrier pinned on asphalt, and the transition from pinned temporary concrete barrier to the rigid concrete barrier. Also presented in this report are the detailed documentation of the crash test results and an assessment of the performance of the transition as tested according to *MASH* Test 3-21 specifications.

2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

2.1.1 General Test Configuration

The overall length of the test installation was 104 ft-5½ inches. The installation was comprised of seven 12 ft-6 inch long, 32-inch tall precast concrete F-shape barrier segments connected end-to-end, with the last downstream segment abutting a 16-ft long, 42-inch tall permanent single-slope concrete barrier (SSCB). The precast concrete barrier segments had the standard “F” profile and were anchored to 4–inch thick × 10-ft wide asphalt pavement using three 1½-inch diameter steel pins per barrier segment. The asphalt pad was constructed on top of 1-ft deep crushed limestone base. The SSCB had a nominal slope of 11-degrees on both the traffic side and the field side faces. It was constructed on top of an 8-inch thick × 5-ft wide concrete base. The F-shape barrier segments were placed such that their uppermost slope point was flush with the face of the SSCB. The transition elements encompassed a transition cap, a nested thrie beam guardrail section with end shoes, and a field-side strap.

2.1.2 Temporary Precast “F” Shape Segments

The precast concrete barrier F-shape segments were 32 inches tall, 24 inches wide at the base, and 9½ inches wide at the top. The end of each barrier segment had a ½-inch horizontal taper from center to outside. The top, bottom, and end edges were chamfered ¾-inch. Horizontal barrier reinforcement consisted of eight #4 bars (½-inch nominal diameter) spaced along the height of the barrier within the vertical reinforcement. Vertical barrier reinforcement consisted of 10 rebar stirrups of #4 bars. These vertical bars were bent to conform to the F-shape barrier profile and to provide sufficient concrete cover for the faces of the barrier and the drainage scupper at the base of the barrier. The inner most six vertical bars were spaced at 18 inches on centers. For the last two vertical stirrup bars closest to the ends of the barrier segments, the spacing was reduced to 17⅞ inches and 7⅞ inches, respectively.

Adjacent precast barrier segments were connected using a pin-and-loop type connection. The loops were made of ¾-inch diameter ASTM A36 round stock steel and were 41 inches long with the final 6 inches bent at 45 degrees for anchorage. The outer diameter of each loop was 3½ inches, and these extended 2 inches outside the end of the barrier segment. The barrier connection was comprised of two sets of three loops. A 1-inch diameter, 30-inch long connecting pin of ASTM A449 material was inserted between the loops to establish the connection. A 2-inch diameter × ¼-inch thick washer was welded 1¾ inches down from the top of the connecting pin. The pin was held in place by resting the washer on insets built into the faces of adjacent barriers. When installed, the distance between the end faces of adjacent barrier segments was about 2 inches. Each barrier segment contained two drainage/forklift slots, each 3 inches high × 11 inches wide and located at the quarter points at 37½ inches from the ends of the segment.

Three 1⅞-inch wide × 4-inch long slotted holes, inclined 40 degrees from horizontal, were cast into the toe of each precast barrier segment. These slotted holes originated on the traffic face of the barrier and exited near its bottom centerline. Two of the slotted holes were positioned 16 inches away from each end of the barrier segment and the third slotted hole was positioned in the middle of the barrier segment. All three slotted holes were used for anchoring the barrier to the underlying asphalt overlay.

Inside the F-shape barrier segments, each slotted hole was reinforced with a U-shaped "403 Bar" #4 bar (½-inch nominal diameter) measuring 22 inches long and 6⅜ inches wide. This U-shaped bar surrounded the slot to reinforce the concrete around it and resist pullout of the anchoring pin in the event of concrete failure in the vicinity of the slotted hole.

The F-shape barrier segments were placed on a foundation comprised of a 4-inch thick × 10-ft wide × 103-ft long asphalt pad constructed on top of a 12-inch thick layer of crushed limestone road base (Type A, Grade 1), which was compacted to 95% of standard proctor density. The 4-inch thick asphalt was constructed by adding a 1-inch thick lift on top of an existing 3-inch thick asphalt foundation atop the road base. A layer of asphalt binder (CSS-1H tack coat binder) was sprayed at the interface between the asphalt layers, as was previously done between the underlying road base and the initial 3 inches of asphalt. Both asphalts used were hot mixed Type D with reclaimed asphalt pavement (RAP).

Once the precast barrier segments were positioned, the three slotted holes in each concrete barrier segment were used as guides to create holes in the underlying asphalt overlay and base. These holes were percussion drilled using a 1¾-inch diameter masonry drill bit. After the holes were drilled, a 1½-inch diameter × 48-inch long ASTM A36 anchoring pin (with a 2¾-inch long conical taper on the end) was passed through each of the slotted holes in the barrier and into the asphalt and base. Thus, each barrier segment was anchored to the ground with three pins. The top of each anchoring pin had a ½-inch thick × 4-inch square ASTM A36 steel plate washer welded to it. The plate washers were welded at a 5-degree angle offset such that they closely matched the profile of the barrier's toe when installed.

2.1.3 Permanent Single-Slope Concrete Barrier

The 42-inch tall permanent single slope concrete barrier (SSCB) was 16 ft long, 24 inches wide at the base, and 8 inches wide at the top. The barrier had a nominal slope of 11 degrees on both the traffic side (impact side) and the field side faces. The barrier was reinforced using 16 #4 (½-inch nominal diameter) lateral stirrup bars that were bent to conform to the profile of the barrier and provide a minimum 1½-inch concrete cover. The lateral stirrups were spaced 12 inches apart along the length of the SSCB. The longitudinal reinforcement of the SSCB was comprised of 10 #5 bars (⅝-inch nominal diameter), each 15 ft-9 inches long, that were placed inside the lateral stirrups and spaced vertically on approximately 8-inch centers along the sloped faces of the barrier. At the location of each of the 16 lateral stirrups in the single slope barrier, a10-inch × 21-inch L-shaped #6 bar (¾-inch nominal diameter) was placed inside the concrete foundation with the 21-inch long leg raised upwards into the single slope barrier. The shorter 10-inch leg of each L-shaped bar was placed 2¼ inches above the bottom of the concrete foundation.

The barrier was cast over a reinforced concrete foundation that measured 16 ft long × 5 ft wide × 8 inches thick. At the location of each of the 16 aforementioned L-shaped bars, a 56-inch long #4 bar was placed laterally in the foundation. These 56-inch long bars were also placed 2¼ inches above the bottom of the concrete foundation. The longitudinal reinforcement of the concrete foundation was comprised of five #4 bars that were each 15 ft-9 inches long and were laterally spaced 12 inches apart. The concrete foundation was secured to the adjacent unreinforced concrete apron using five #5 bars that were each 12 inches long. These #5 bars were installed horizontally in the face of the apron, in drilled holes 3 inches from the top, with a minimum of 5½-inches embedment, and were secured in place with Hilti RE500 epoxy in accordance with manufacturer's instructions.

2.1.4 Transition Components

The exposed connection loops on the downstream end of the F-shape barrier segment (No. 7) placed adjacent to the permanent SSCB were removed. This allowed placing the pinned-down F-shape barrier segment flush to the SSCB.

The connection between the last F-shape barrier (No. 7) and the SSCB was accomplished using two nested 12-gauge thrie beam guardrails. The top of the thrie-beam was 31 inches above grade. The thrie-beam guardrails were longitudinally centered at the junction of the F-shape barrier (No. 7) and the SSCB. At the upstream end, the nested thrie beam guardrails were connected to the traffic-side face of the F-shape barrier segment via a 10 gauge thrie beam end-shoe (RTE01b) positioned on top of the guardrails, and at the downstream end, the nested guardrails were connected to the traffic-side face of the SSCB via 10 gauge thrie beam end-shoe beneath the guardrails. Each thrie beam end-shoe was connected to its respective end of the guardrail using twelve ⅝-inch diameter × 2-inch long ASTM A307 guardrail bolts (FBB02), recessed guardrail nuts, and rectangular guardrail washers (FWR03). The washers were under the bolt head on the upstream end, and under the nut on the downstream end. Each thrie beam end-shoe was connected to its respective barrier using five ⅞-inch diameter SAE Grade 5 bolts that passed through horizontally core drilled holes in the cross-section of the respective barrier and were fastened on the field side of the barriers using heavy hex nuts and SAE hardened washers.

On the field side of the barriers, a ¼-inch thick × 8-inch wide × 16-ft-4-inch long ASTM A36 steel strap was fastened to the barriers using the top two through-bolts used to connect the thrie beam end-shoes. An 8-inch × 8-inch × 2½-inch thick wooden block spacer was attached to this steel strap near the end of the pinned-down F-shape segment placed adjacent to the SSCB. The wood block spacer was attached to the steel strap using a ⅝-inch diameter × 4-inch long carriage bolt, and secured with a hex nut on the field side of the strap. The strap and the wooden spacer were used to reduce slack near the top of the F-shape and the SSCB profiles, thus providing additional resistance to the lateral roll of the pinned-down F-shape barrier during vehicle redirection.

A transition cap fabricated from ⅛-inch thick ASTM A36 steel plate was attached to the top of the last F-shape barrier (No. 7) and the SSCB. The transition cap tapered 10 inches vertically over a length of 48 inches to transition from the 32-inch tall F-shape barrier to the 42-inch tall SSCB. The transition cap had a 4-inch long skirt that fit over the upper slope of the the F-shape barrier. The transition cap was reinforced using five stiffener plate ribs, also ⅛ inch thick, equally spaced on 9-inch centers along the length of the cap, and secured with ⅛-inch fillet welds. The cap was bolted to the top of the F-shape barrier and the single slope barrier via a 9-inch long tab on each end of the cap with two ½-inch diameter × 6½-inch long Hilti HAS-E adhesive anchors through each tab. The adhesive anchors had a 5-inch minimum embedment and were installed in core drilled holes using Hilti RE500 epoxy in accordance with manufacturer's instructions.

Figure 2.1 presents the general layout of the transition from temporary concrete barrier pinned on asphalt to rigid concrete barrier, and Figure 2.2 provides photographs of the installation. Appendix A provides further details of the installation.

2.2. MATERIAL SPECIFICATIONS

All reinforcing steel rebar was ASTM A615 grade 60 material. The loops for the connecting pin, the anchor pins, and the anchor pin plate washers were ASTM A36 steel. The connecting pin between adjacent barrier segments was ASTM A449 steel. The washer on each connecting pin met ASTM A572 grade 50 standards. Certifications for different materials used are included in Appendix B.

The compressive strength of the concrete for the single slope barrier and the concrete foundation was specified as 3600 psi. The compressive strength on the day of the test was 4669 psi for the foundation at 49 days of age (cast on September 2, 2015), and 4155 psi for the single slope barrier at 48 days of age (cast on September 3, 2015). Results of the tests performed to determine the compressive strength are shown in Appendix B. The compressive strength of the concrete for the precast F-shape barrier segments was specified as 5000 psi. The compressive strength on core samples on the day of testing was 5520 psi.

The precast F-shape concrete barrier segments used in the test installation were donated for this research by WASKEY.

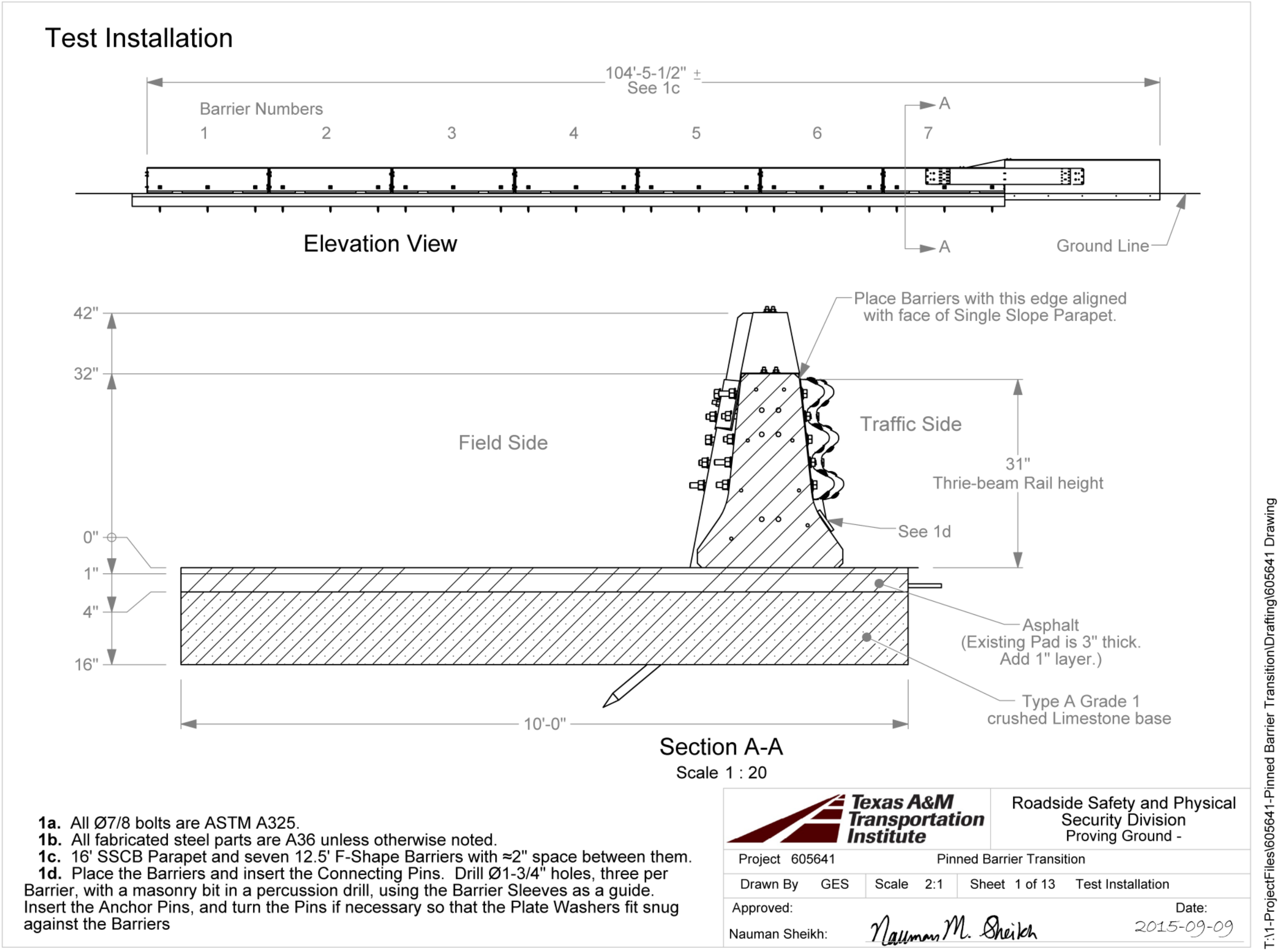


Figure 2.1. General Layout of the Transition from Temporary Concrete Barrier Pinned on Asphalt to Rigid Concrete Barrier.

Figure 2.2. Transition Installation prior to Testing.

3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1. CRASH TEST MATRIX

According to *MASH*, two tests are recommended to evaluate transitions to Test Level Three (TL-3) and are as described below.

- ***MASH* Test 3-20**: A 2420-lb vehicle impacting the critical impact point (CIP) of the transition at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This test investigates a barrier's ability to successfully contain and redirect a small passenger vehicle and evaluate the risk to the occupants.
- ***MASH* Test 3-21**: A 5000-lb pickup truck impacting the CIP of the transition at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This test investigates a barrier's ability to successfully contain and redirect light trucks and sport utility vehicles, as well as risk to occupants.

The test reported herein corresponds to *MASH* test 3-21. This test was deemed sufficient to evaluate the impact performance of the transition. It is argued that the test with the smaller 2425-lb is not needed. Due to higher impact energy and a higher vehicle center of gravity (CG), the test with the 5000-lb pickup truck would result in greater potential for snagging and vehicular instability. The transition design is not expected to cause any underride when impacted by the small passenger car. Similarly, the lighter passenger car is not expected to cause any significant movement of the pinned-down barriers that can increase the potential for vehicle snagging or pocketing. Thus, only test 3-21 was conducted.

The target CIP for test 3-21 was determined to be 4.3 ft upstream of the joint between the pinned-down F-shape concrete barrier and the permanent single slope barrier. This impact point was selected based on guidance provided in Table 2.6 of *MASH*. *MASH* recommends this distance for testing upstream of the joint in a rigid barrier system that has the highest potential for vehicle snagging. Since the greatest variation in the stiffness of the tested barrier exists at the joint between the pinned-down F-shape and the permanent single-slope barrier, along with the change in barrier profiles and heights, it is believed that the recommended 4.3 ft upstream of this joint is the appropriate CIP for this design.

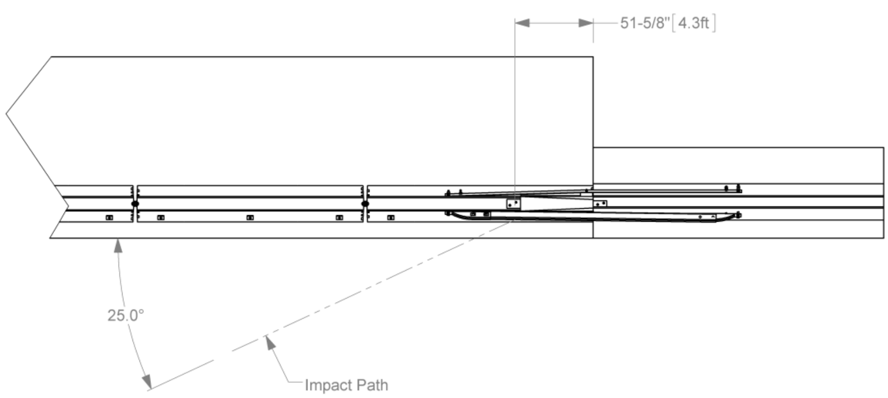


Figure 3.1. CIP for Transition from Temporary Concrete Barrier Pinned on Asphalt to Rigid Concrete Barrier.

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

3.2. EVALUATION CRITERIA

The researchers evaluated the crash test in accordance with the criteria presented in *MASH*. The performance of the transition was judged based on three factors:

- Structural adequacy, which is judged on the ability of the transition to contain and redirect the vehicle, or bring the vehicle to a controlled stop in a predictable manner.
- Occupant risk criteria evaluate the potential risk of hazard to occupants in the impacting vehicle, and, to some extent, other traffic, pedestrians, or workers in construction zones, if applicable.
- Post-impact vehicle trajectory is assessed to determine potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles.

The appropriate safety evaluation criteria from Table 5-1 of *MASH* were used to evaluate the crash test reported here, and are listed in further detail under the assessment of the crash test.

4. TEST CONDITIONS

4.1. TEST FACILITY

The full-scale crash test reported here was performed at Texas A&M Transportation Institute (TTI) Proving Ground, an International Standards Organization (ISO) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing certificate 2821.01. The full-scale crash test was performed according to TTI Proving Ground quality procedures, and according to the *MASH* guidelines and standards.

The TTI Proving Ground is a 2000-acre complex of research and training facilities located 10 miles northwest of the main 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 that are well-suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for construction and testing of the transition 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.

4.2 VEHICLE TOW AND GUIDANCE SYSTEM

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, 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 (no sooner than 2 s after impact), after which the brakes can be activated, if needed, to bring the test vehicle to a safe and controlled stop.

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro that Diversified Technical Systems, Inc. produced. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as 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. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology. All accelerometers are calibrated annually according to SAE J211 *4.6.1* by means of an ENDEVCO® 2901, precision primary vibration standard. This device and its support instruments are returned to the factory annually for a National Institute of Standards Technology (NIST) traceable calibration. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel, per SAE J211. Calibrations and evaluations are also made any time data are suspect. Acceleration data is measured with an expanded uncertainty of ±1.7% at a confidence factor of 95 percent (k=2).

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the 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 a 60-Hz 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, 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 of the vehicle-fixed coordinate systems 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).

4.3.2 Anthropomorphic Dummy Instrumentation

Use of a dummy in the 2270P vehicle is optional according to *MASH*, and a dummy was not used in the tests with the 2270P vehicle.

4.3.3 Photographic Instrumentation Data Processing

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

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

A flashbulb was positioned on the impacting vehicle, which was activated by pressure-sensitive tape switches when contact was made with the transition, to indicate the instant of contact with the installation. The flashbulb was visible from each camera. The video from these high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A mini-digital video camera and still cameras recorded and documented conditions of the test vehicle and installation before and after the test.

5. CRASH TEST NO. 605641-1 (*MASH* TEST 3-21)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-21 involves a 2270P vehicle weighing 5000 lb ±110 lb and impacting the CIP of the transition at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The CIP for *MASH* Test 3-21 on the transition was 4.3 ft upstream of the joint between the pinned-down temporary concrete barrier and the rigid concrete barrier. The 2010 Dodge Ram 1500 pickup truck used in the test weighed 5064 lb. The actual impact speed and angle were 62.5 mi/h and 25.1 degrees, respectively. The actual impact point was 4.3 ft upstream of the joint between the pinned-down temporary concrete barrier and the rigid concrete barrier. Minimum impact severity (IS) for *MASH* Test 3-21 is 106 kip-ft, and actual IS was 119 kip-ft.

5.2 WEATHER CONDITIONS

The test was performed on the morning of October 21, 2015. Weather conditions at the time of testing were as follows: wind speed: 8 mi/h; wind direction: 134 degrees with respect to the vehicle (vehicle was traveling in a northwesterly direction); temperature: 84°F; relative humidity: 65 percent.

5.3 TEST VEHICLE

The 2010 Dodge Ram 1500 pickup truck, shown in Figure 5.1 and Figure 5.2, was used for the crash test. The vehicle's test inertia weight was 5064 lb, and its gross static weight was 5064 lb. The height to the lower edge of the vehicle bumper was 11.75 inches and 27.0 inches to the upper edge. The height to the vehicle's center of gravity was 28.6 inches. Tables C.1 and C.2 in Appendix C1 provide additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 5.1. Transition/Test Vehicle Geometrics for Test No. 605641-1.

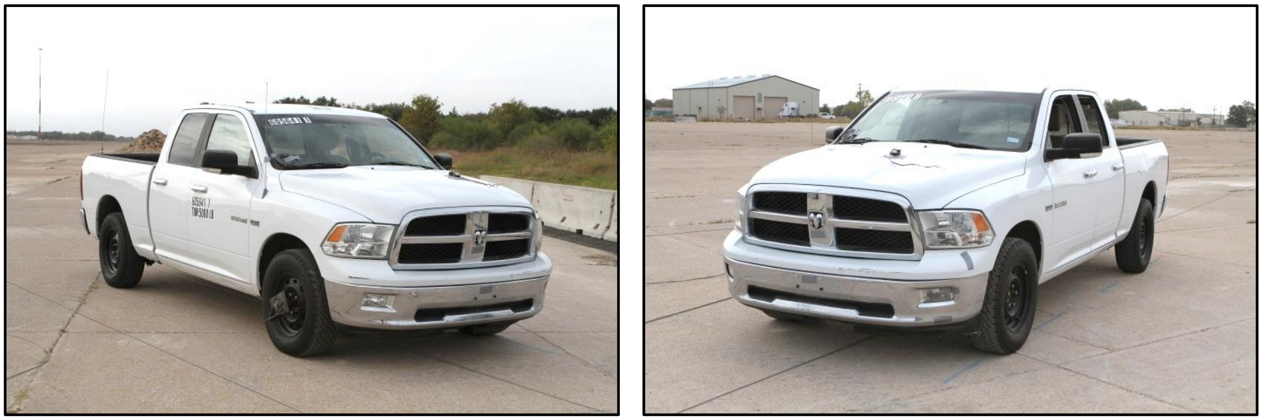


Figure 5.2. Test Vehicle before Test No. 605641-1.

5.4 TEST DESCRIPTION

The 2010 Dodge Ram 1500 pickup truck, traveling at an impact speed of 62.5 mi/h, contacted the transition 4.3 ft upstream of the joint between the anchored temporary barrier on asphalt and rigid concrete barrier at an impact angle of 25.1 degrees. At 0.007 s after impact, the left front tire contacted the F-shape concrete barrier. At 0.021 s, the hood reached the top of the transition taper. The left front corner of the hood reached the rigid concrete barrier at 0.026 s, and the vehicle began to redirect at 0.040 s. At 0.049 s, the left front door contacted the thrie beam. The left front tire blew out at 0.076 s. At 0.078 s, the right front tire began to rise upward and to the right, and at 0.112 s, the tire lost contact with the pavement. The right rear tire lost contact with the pavement at 0.155 s, and the vehicle was parallel with the barrier at 0.184 s. At 0.198 s, the rear of the vehicle contacted the barrier, and at 0.213 s, the left rear tire blew out. At 0.350 s after impact, the vehicle lost contact with the installation and was traveling at an exit speed and angle of 47.6 mi/h and 5.7 degrees, respectively. The 2270P vehicle exited within the exit box criteria. Brakes on the vehicle were applied at 2.4 s, and the vehicle subsequently came to rest 200 ft downstream of impact and 77 ft toward traffic. In Appendix D2, Figures D.1 and D.2 present sequential photographs during the test.

5.5 DAMAGE TO TEST INSTALLATION

Figure 5.3 shows the damage to the transition. The concrete on the downstream end of barrier segment 7 was cracked around the pin location. The downstream end was also displaced toward the field side 1.75 inches. The vehicle was in contact with the installation for 11.5 ft, leaving scrapes and tire marks along the traffic face of the barriers. The top of the metal transition piece on top of barrier segment 7 was slightly scraped and the thrie beam metal rail on the traffic side of the barriers was deformed. Working width was 25.8 inches. Maximum dynamic deflection during the test was 4.0 inches, and maximum permanent deformation was 1.5 inches.

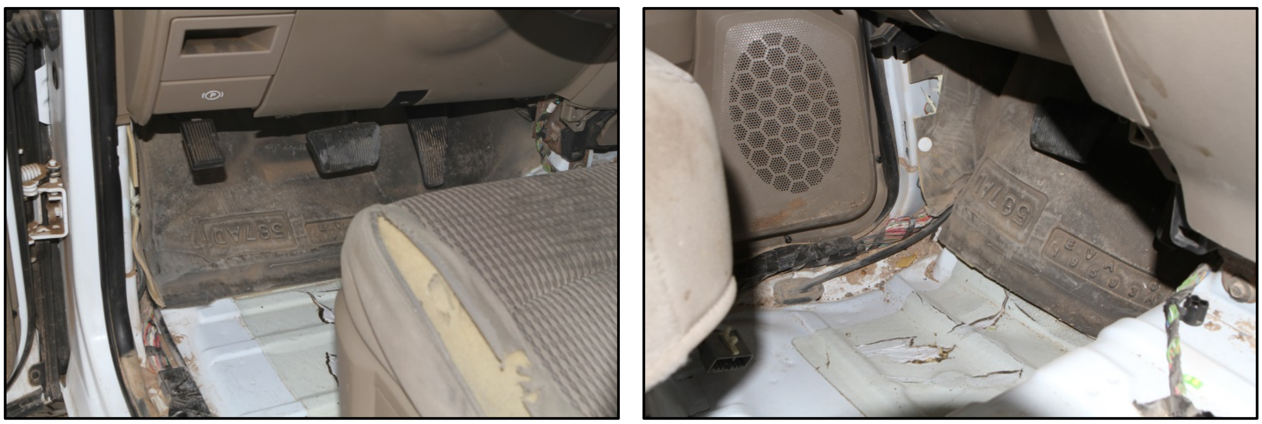
Figure 5.3. Transition after Test No. 605641-1.

5.6 VEHICLE DAMAGE

Figure 5.4 shows the damage sustained by the vehicle. The left front upper and lower A-arms and the left frame rail were deformed. The front bumper, hood, grill, radiator, left front fender, left tire and rim, left front and rear doors, left exterior bed, left rear tire and rim, and rear bumper were damaged. Maximum exterior crush to the vehicle was 17.0 inches in the front plane at the left front corner at bumper height. Maximum occupant compartment deformation was 4.0 inches in the kickpanel on the driver's side. Figure 5.5 shows the interior of the vehicle.

Tables D.3 and D.4 in Appendix D1 provide exterior crush and occupant compartment measurements, respectively.

Figure 5.4. Test Vehicle after Test No. 605641-1.

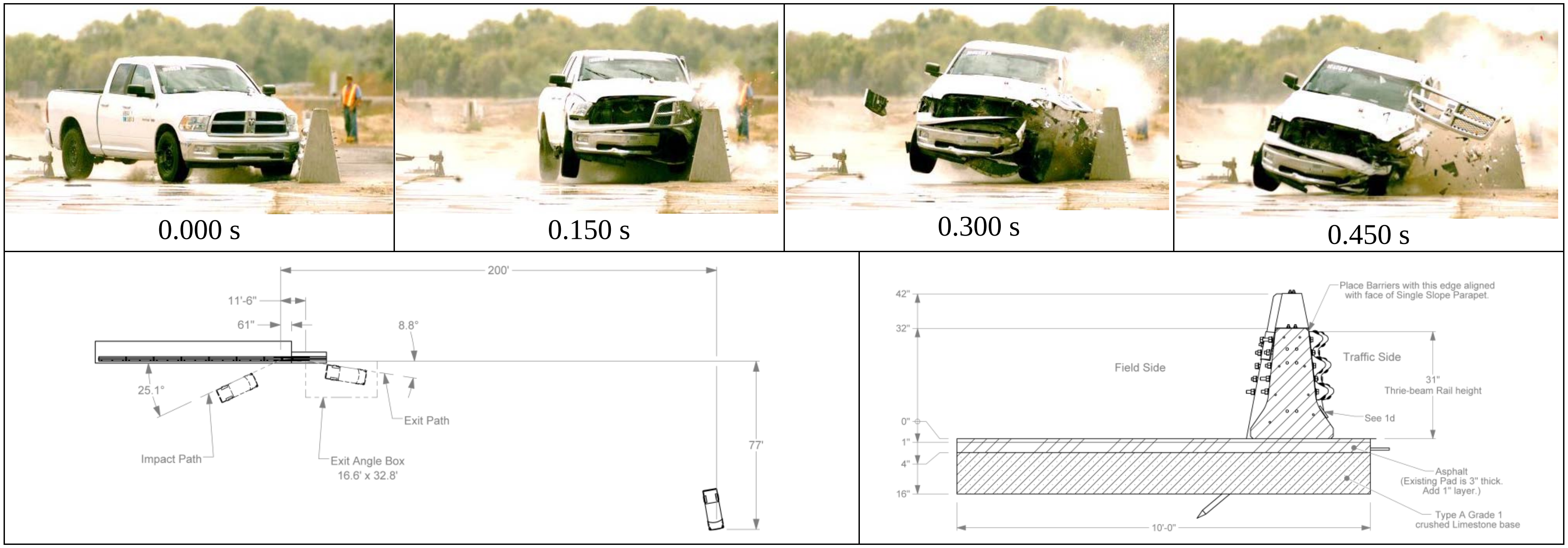


Before Test After Test

Figure 5.5. Interior of Test Vehicle for Test No. 605641-1.

5.7 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity (OIV) was 22.6 ft/s at 0.094 s, the highest 0.010-s occupant ridedown acceleration was 6.2 g from 0.212 to 0.222 s, and the maximum 0.050-s average acceleration was –10.5 g between 0.048 and 0.098 s. In the lateral direction, the OIV was 29.8 ft/s at 0.094 s, the highest 0.010-s occupant ridedown acceleration was 10.8 g from 0.211 to 0.221 s, and the maximum 0.050-s average was 15.3 g between 0.040 and 0.090 s. Theoretical Head Impact Velocity (THIV) was 40.6 km/h or 11.3 m/s at 0.092 s; Post-Impact Head Decelerations (PHD) was 12.3 g between 0.211 and 0.221 s; and Acceleration Severity Index (ASI) was 2.02 between 0.066 and 0.116 s. Figure 5.6 summarizes these data and other pertinent information from the test. In Appendix D3, Figure D.3 shows the vehicle angular displacements, and Figures D.4 through D.9 in Appendix D4 show acceleration versus time traces.



General Information
Test Agency........................ Texas A&M Transportation Institute (TTI)
Test Standard Test No. .... MASH Test 3-21
TTI Test No. 605641-1
Test Date 2015-10-21
Test Article
Type .... Transition
Name.................................. Pinned Barrier Transition
Installation Length............... 104 ft-5½ inches
Material or Key Elements .... Seven 12 ft-6 inch long, 32-inch tall precast concrete F-shape barriers pinned to asphalt abutting a 16-ft long, 42-inch tall permanent SSCB
Soil Type and Condition ...... 4-inch asphalt pad on top of 1-ft deep crushed limestone base
Test Vehicle
Type/Designation................ 2270P
Make and Model .... 2010 Dodge Ram 1500 Pickup
Curb................................... 5122 lb
Test Inertial .... 5064 lb
Dummy .... No dummy
Gross Static .... 5064 lb

Impact Conditions
Speed ....62.5 mi/h
Angle ....25.1 degrees
Location/Orientation ....4.3 ft upstream of joint
Impact Severity....................119 kip-ft
Exit Conditions
Speed ....47.6 mi/h
Angle ....5.7 degrees
Occupant Risk Values
Longitudinal OIV ....22.6 ft/s
Lateral OIV.........................29.8 ft/s
Longitudinal Ridedown ....6.2 g
Lateral Ridedown ....10.8 g
THIV ....40.6 km/h
PHD ....12.3 g
ASI.....................................2.02
Max. 0.050-s Average
Longitudinal ....–10.5 g
Lateral.............................15.3 g
Vertical............................−5.0 g

Post-Impact Trajectory
Stopping Distance.....................200 ft dwnstrm
77 ft twd traffic
Vehicle Stability
Maximum Yaw Angle ....49 degrees
Maximum Pitch Angle ....5 degrees
Maximum Roll Angle ....13 degrees
Vehicle Snagging......................No
Vehicle Pocketing ....No
Test Article Deflections
Dynamic....................................4.0 inches
Permanent ....1.5 inches
Working Width...........................25.8 inches
Vehicle Damage
VDS 11LFQ4
CDC..11FLEW4
Max. Exterior Deformation..........17.0 inches
OCDI...LF0010000
Max. Occupant Compartment Deformation ....4.0 inches

Figure 5.6. Summary of Results for *MASH* Test 3-21 on the Transition from Temporary Concrete Barrier Pinned on Asphalt to Rigid Concrete Barrier.

6. SUMMARY AND CONCLUSIONS

6.1. ASSESSMENT OF TEST RESULTS

An assessment of the test based on the applicable *MASH* safety evaluation criteria for *MASH* test 3-21 is provided below.

6.1.1 Structural Adequacy

A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.

Results: The transition contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 4.0 inches. (PASS)

6.1.2 Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.

Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/ transmission tunnel area ≤12.0 inches).

Results: No detached elements, fragments, or other debris from the transition were present to penetrate or show potential for penetrating or present undue hazard to others in the area. (PASS)

Maximum occupant compartment deformation was 4.0 inches in the front plane at the left front corner at bumper height. (PASS)

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

Results: The 2270P vehicle remained upright during and after the collision. Maximum roll and pitch angles were 13 degrees and 5 degrees, respectively. (PASS)

H. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
30 ft/s	*40 ft/s*

Results: Longitudinal occupant impact velocity was 22.6 ft/s, and lateral occupant impact velocity was 29.8 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15 g	*20.49 g*

Results: Maximum longitudinal ridedown acceleration was 6.2 g, and maximum lateral ridedown acceleration was 10.8 g. (PASS)

6.2 CONCLUSIONS

Table 6.1 shows that the transition from temporary concrete barrier pinned on asphalt to rigid concrete barrier performed acceptably according to the evaluation criteria for *MASH* Test 3-21.

Table 6.1. Performance Evaluation Summary for *MASH* Test 3-21 on the Temporary Concrete Barrier Pinned on Asphalt to Rigid Concrete Barrier.

Test Agency: Texas A&M Transportation Institute | Test No.: 605641-1 | Test Date: 2015-10-21

***MASH* Test 3-21 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> *A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*	The transition contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 4.0 inches.	Pass
<u>Occupant Risk</u> *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris from the transition were present to penetrate or show potential for penetrating or present undue hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 4.0 inches in the front plane at the left front corner at bumper height.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision. Maximum roll and pitch angles were 13 degrees and 5 degrees, respectively.	Pass
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.	Longitudinal occupant impact velocity was 22.6 ft/s, and lateral occupant impact velocity was 29.8 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.	Maximum longitudinal ridedown acceleration was 6.2 g, and maximum lateral ridedown acceleration was 10.8 g.	Pass

7. REFERENCES

1. N.M. Sheikh, R.P. Bligh, and W.L. Menges, *Crash Testing and Evaluation of the 12-ft Pinned F-Shaped Temporary Barrier*. Test Report No. 405160-3-1, Texas A&M Transportation Institute, College Station, TX, 2008.

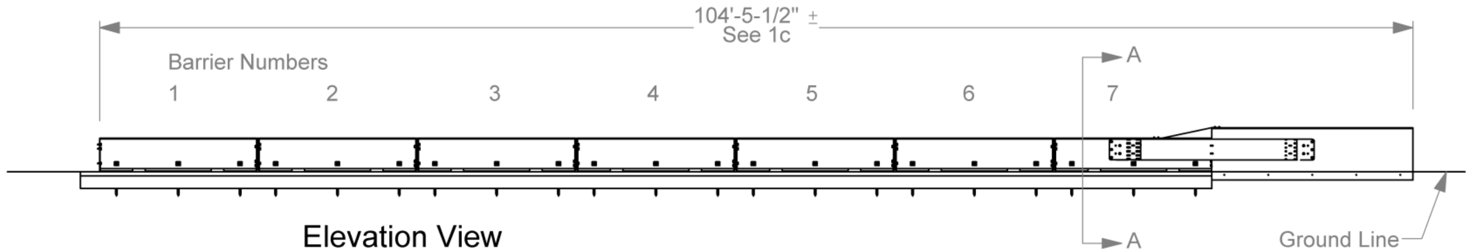
2. N.M. Sheikh and W.L. Menges, *Development and Testing of Anchored Temporary Concrete Barrier for Use on Asphalt*. Test Report No. 405160-25-1, Texas A&M Transportation Institute, College Station, TX, 2011.

3. N.M. Sheikh and W.L. Menges, *Transition Design for Pinned-Down Anchored Temporary Barrier to Rigid Barrier*. Test Report No. 405160-34-1, Texas A&M Transportation Institute, College Station, TX, 2012.

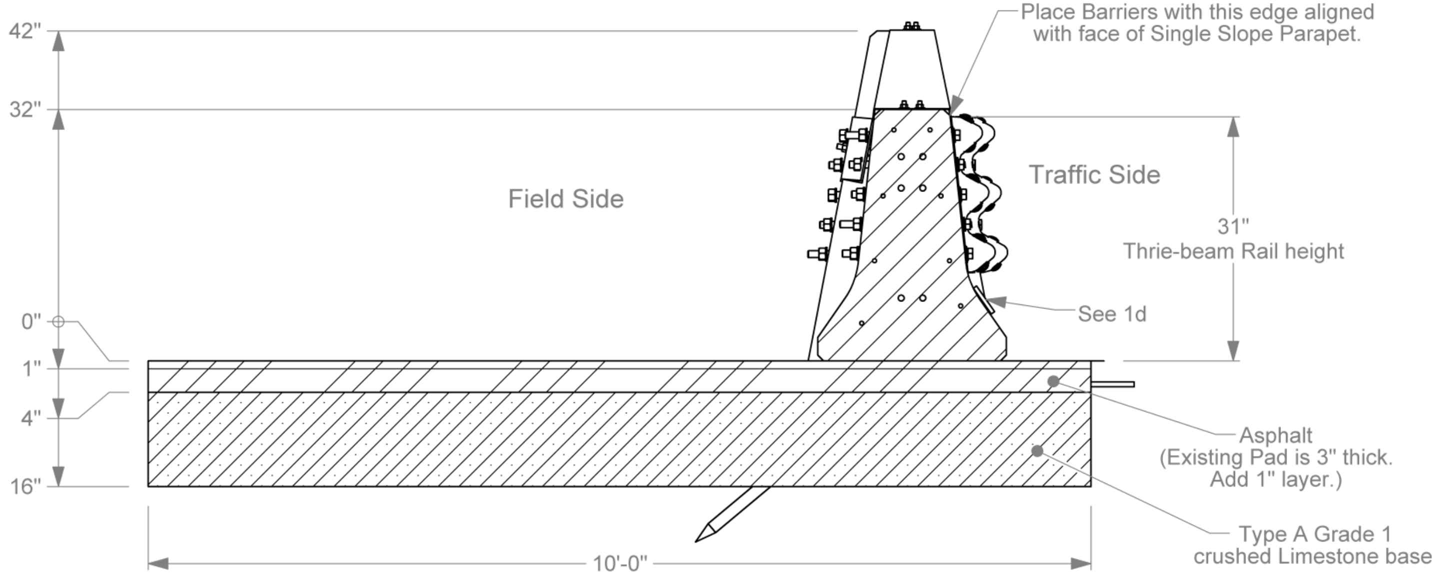
4. AASHTO. *Manual for Assessing Roadside Safety Hardware.* 2009, American Association of State Highway and Transportation Officials: Washington, DC.

APPENDIX A. DETAILS OF THE TRANSITION

Test Installation



Elevation View



Section A-A
Scale 1 : 20

1a. All Ø7/8 bolts are ASTM A325.
1b. All fabricated steel parts are A36 unless otherwise noted.
1c. 16' SSCB Parapet and seven 12.5' F-Shape Barriers with ≈2" space between them.
1d. Place the Barriers and insert the Connecting Pins. Drill Ø1-3/4" holes, three per Barrier, with a masonry bit in a percussion drill, using the Barrier Sleeves as a guide. Insert the Anchor Pins, and turn the Pins if necessary so that the Plate Washers fit snug against the Barriers

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division Proving Ground -
Project 605641	Pinned Barrier Transition
Drawn By GES / Scale 2:1 / Sheet 1 of 13	Test Installation
Approved: Nauman Sheikh: Nauman M. Sheikh	Date: 2015-09-09

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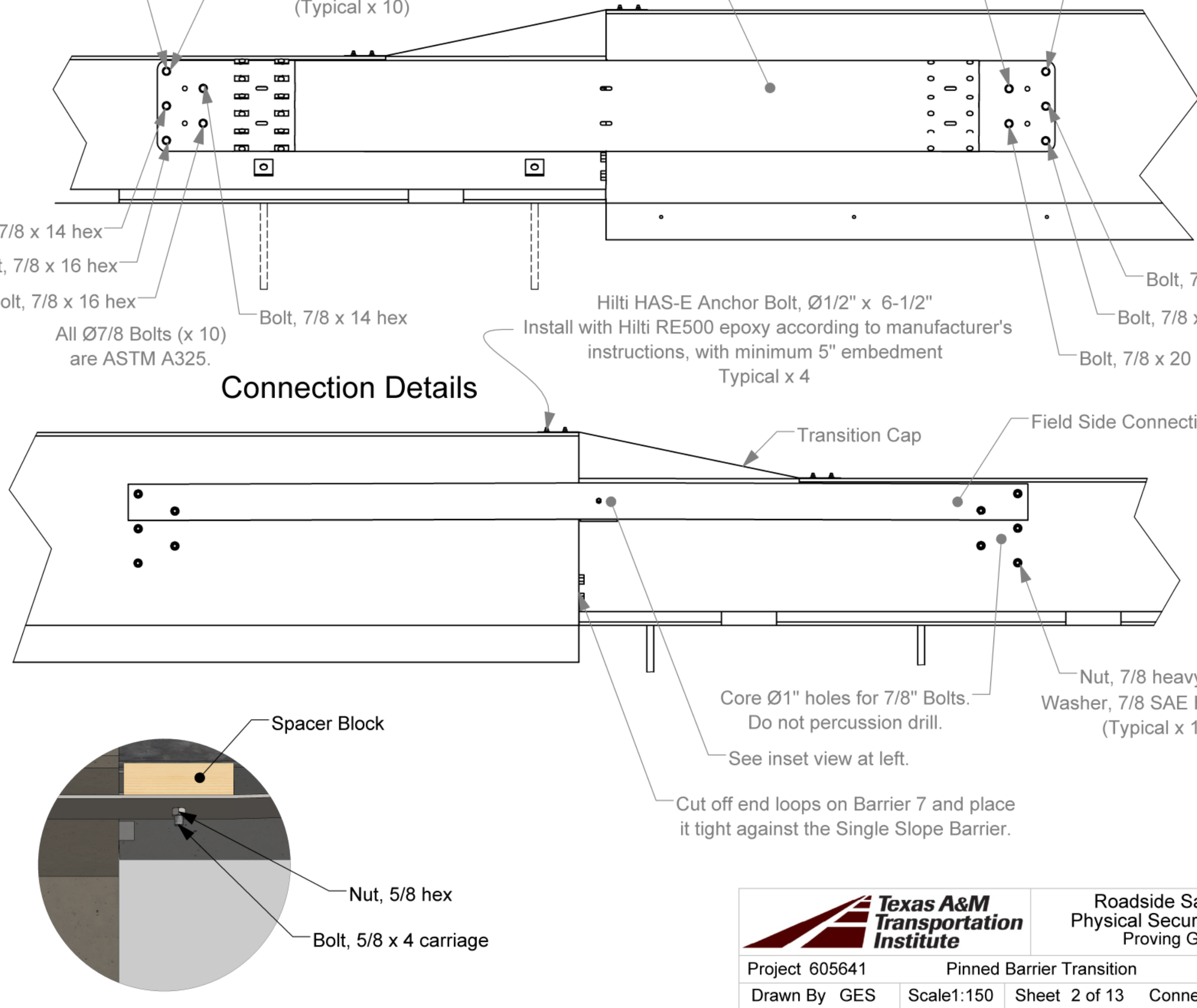
Connection Details



Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 605641	Pinned Barrier Transition		2015-09-09
Drawn By GES	Scale1:150	Sheet 2 of 13	Connection Details

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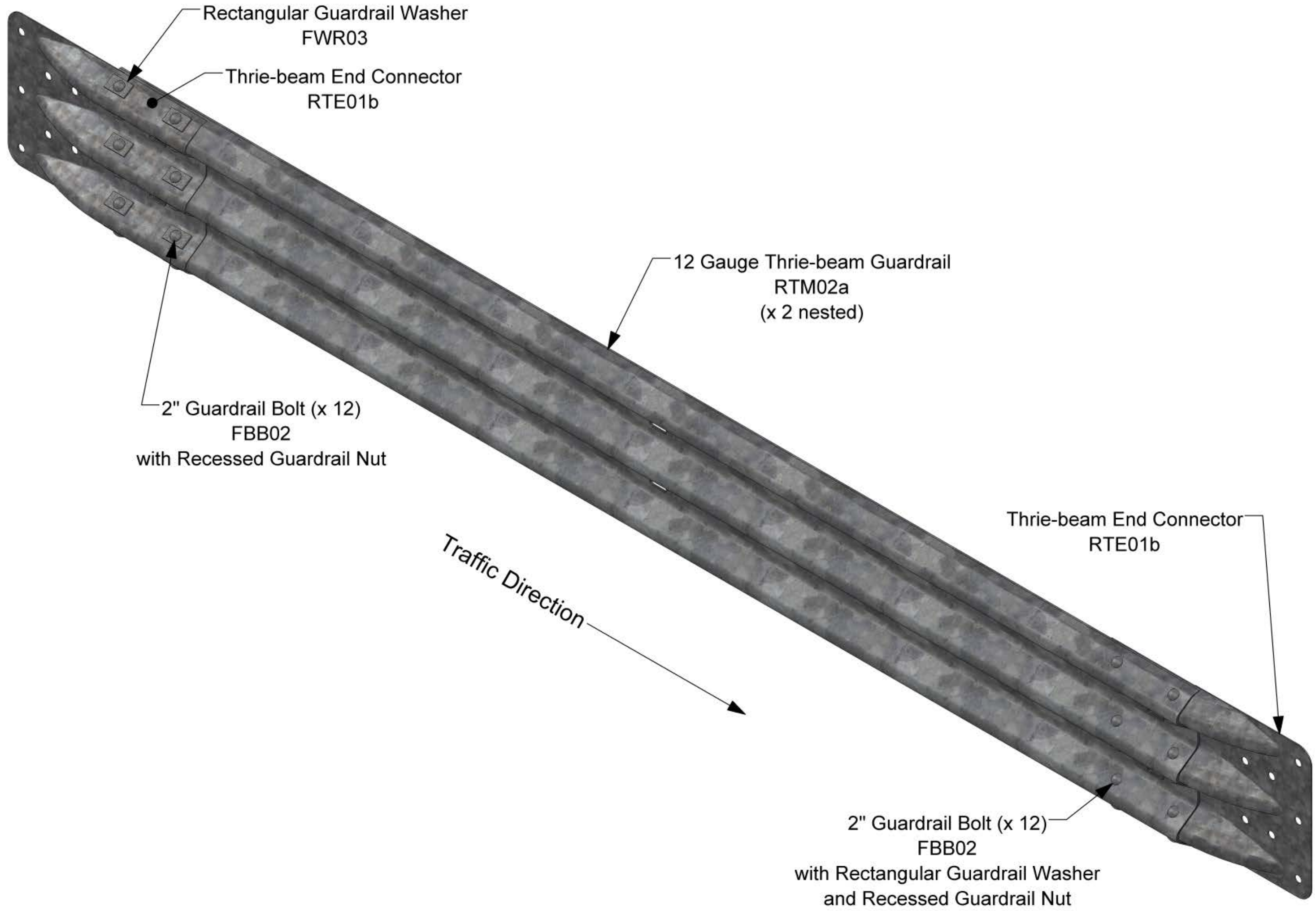

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 605641	Pinned Barrier Transition		2015-09-09
Drawn By GES	Scale 1:15	Sheet 3 of 13	Thrie-beam Assembly

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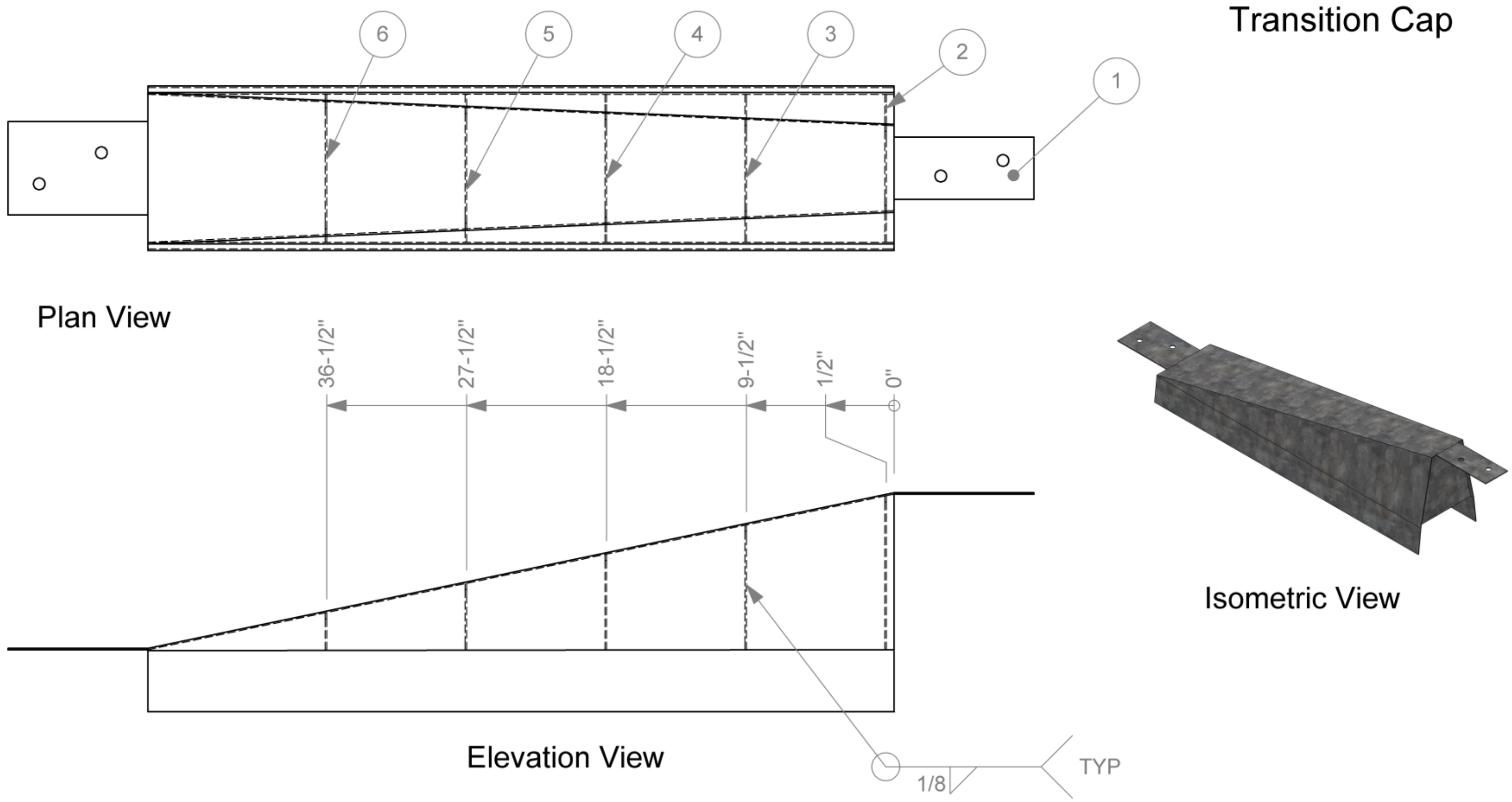
Transition Cap



Transition Cap Cut List		
#	Part Name	Qty.
1	Box	1
2	Rib 1	1
3	Rib 2	1
4	Rib 3	1
5	Rib 4	1
6	Rib 5	1

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project 605641	Pinned Barrier Transition		2015-09-09
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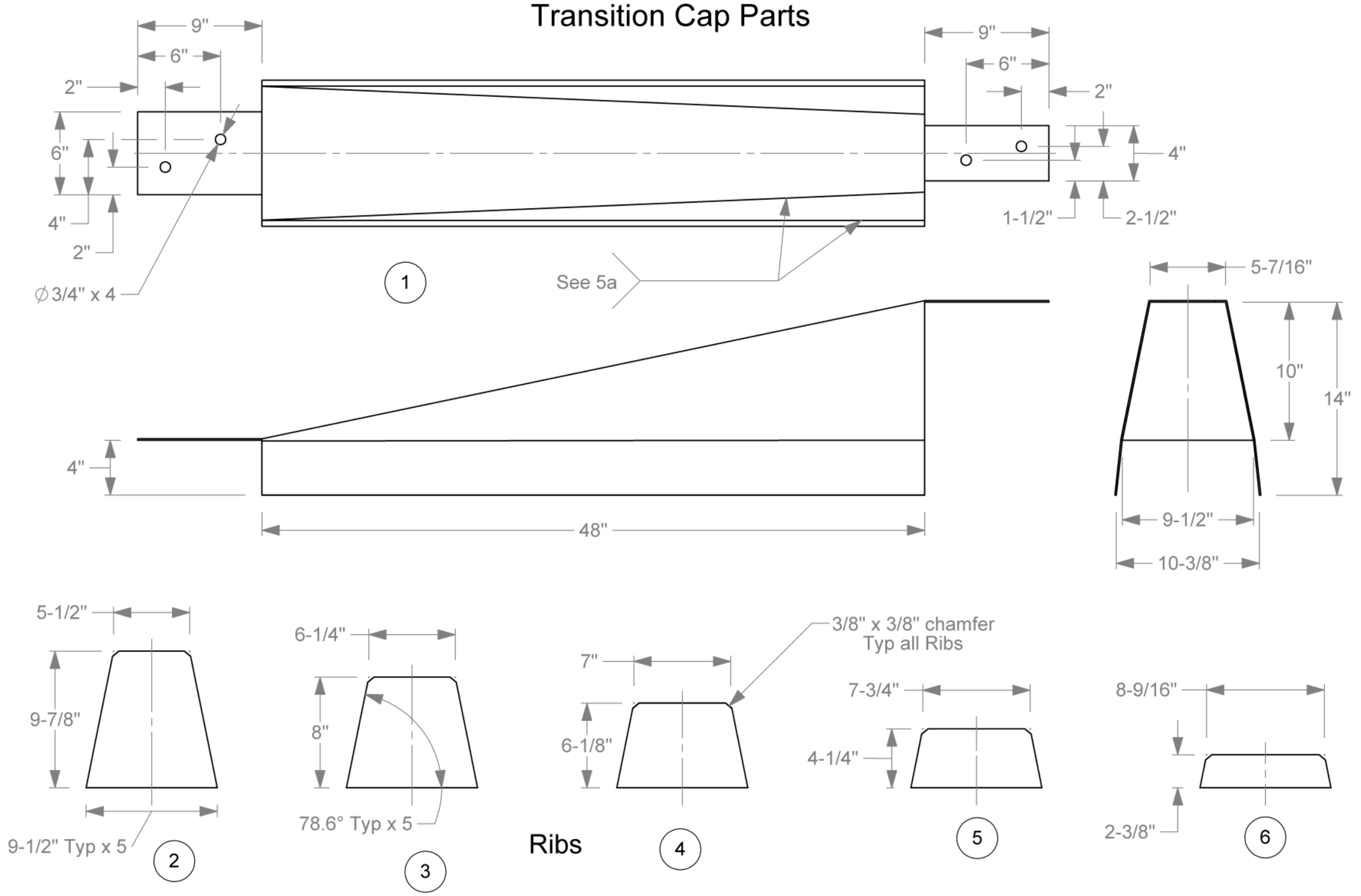
Transition Cap Parts



5a. This Part (Cap and Ribs) is to be fabricated from 1/8" thick ASTM A36 steel. It may be fabricated from seperate plates welded together at the joints, bent plate (with bend radii no greater than 1/4"), or any combination of the two, at the fabricator's discretion.
5b. The width dimensions for the Rib pieces are to intersection of side and top (corner before chamfer).

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Project 605641	Pinned Barrier Transition	2015-09-09
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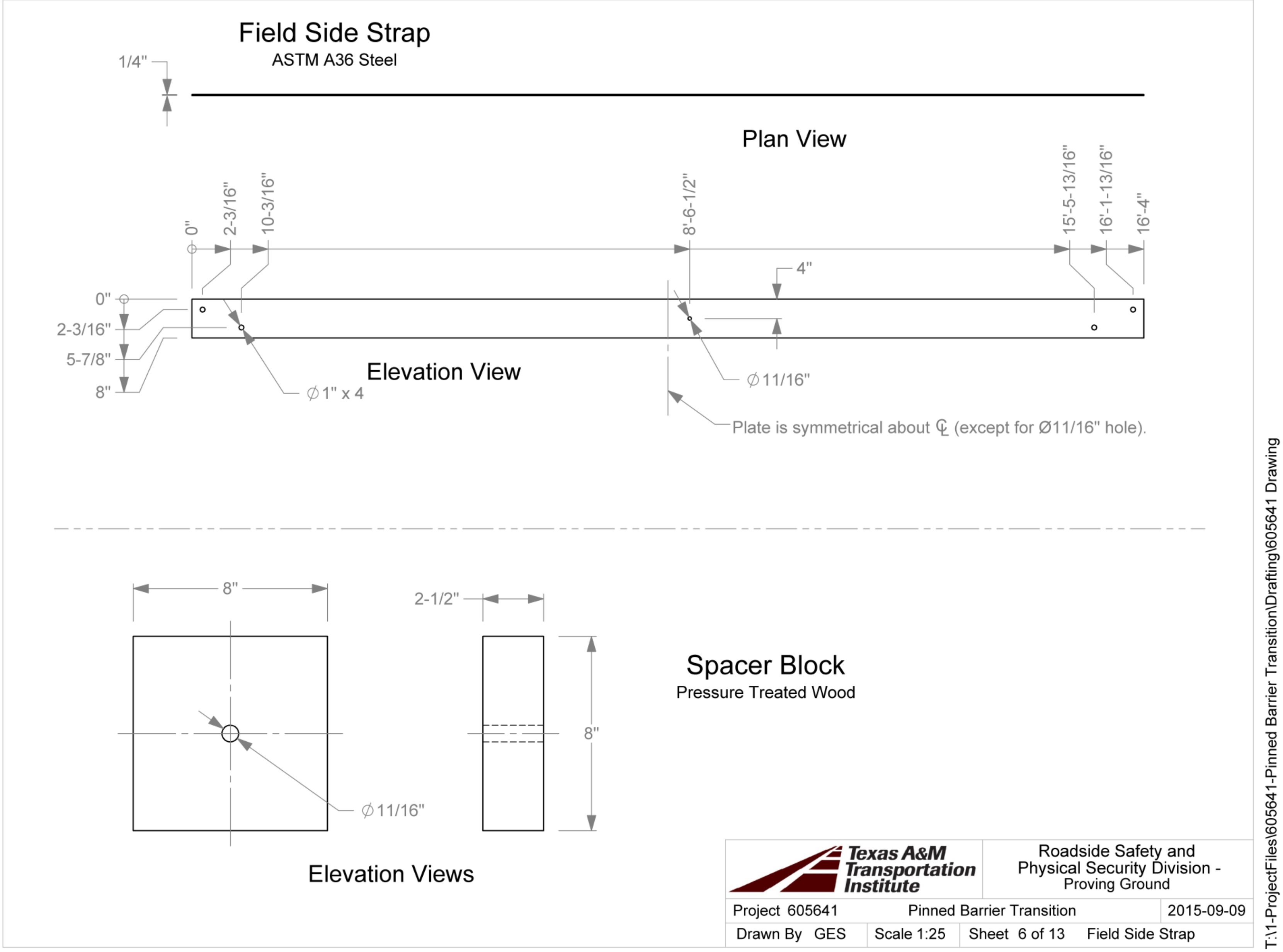
Field Side Strap
ASTM A36 Steel
1/4"
Plan View
0"
2-3/16"
10-3/16"
8'-6-1/2"
15'-5-13/16"
16'-1-13/16"
16'-4"
4"
0"
2-3/16"
5-7/8"
8"
Elevation View
∅1" x 4
∅11/16"
Plate is symmetrical about ℄ (except for Ø11/16" hole).
8"
2-1/2"
8"
∅11/16"
Spacer Block
Pressure Treated Wood
Elevation Views
Texas A&M Transportation Institute
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Drawn By GES
Scale 1:25
Sheet 6 of 13
Field Side Strap
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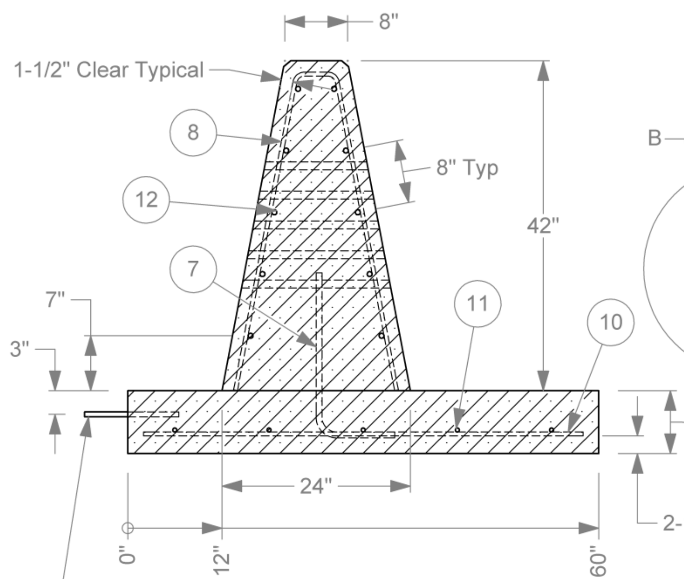
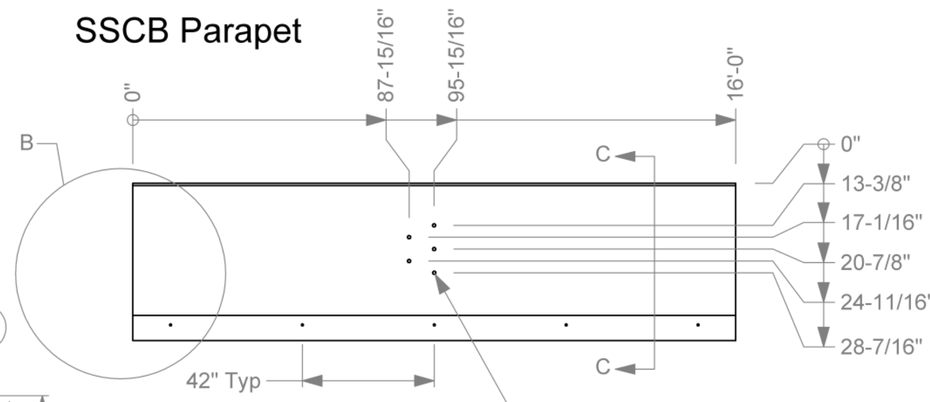
SSCB Parapet

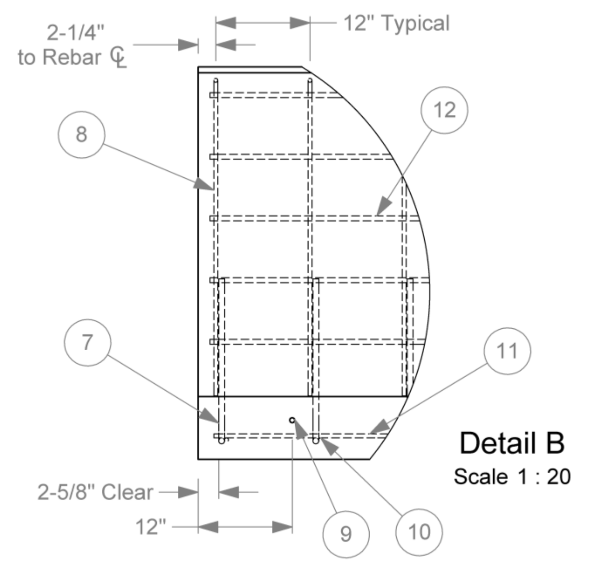


Section C-C
Scale 1 : 20

9 Install in existing concrete with Hilti RE500 epoxy according to manufacturer's instructions, with minimum 5-1/2" embedment.



Elevation View



Detail B
Scale 1 : 20

#	Part Name	Qty.
7	L-bar for SSCB	16
8	Stirrup, V1	16
9	Rebar, #5 x 12"	5
10	Rebar, #4 x 56"	16
11	Rebar, #4 x 15'9"	5
12	Rebar, #5 x 15'9"	10

7a. Minimum concrete strength is 3600 psi.
7b. All rebar is grade 60.

Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project 605641	Pinned Barrier Transition		2015-09-09
Drawn By GES	Scale 1:50	Sheet 7 of 13	SSCB Parapet

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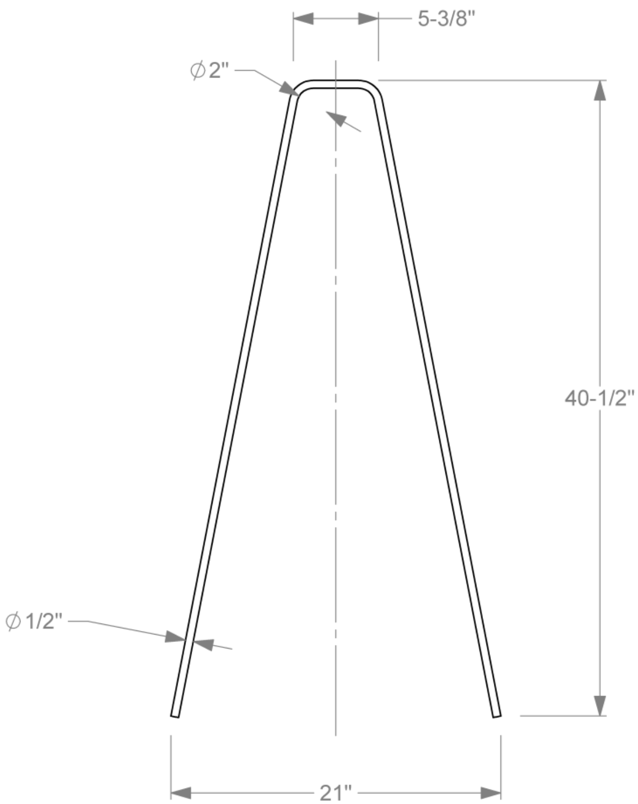
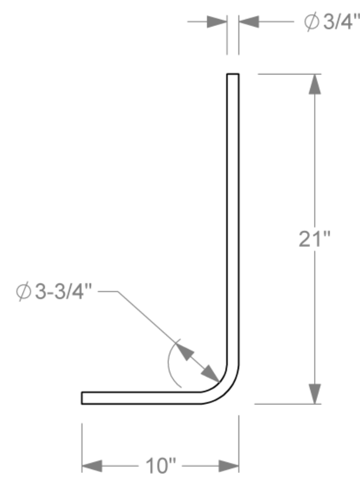


8 V1 Stirrup

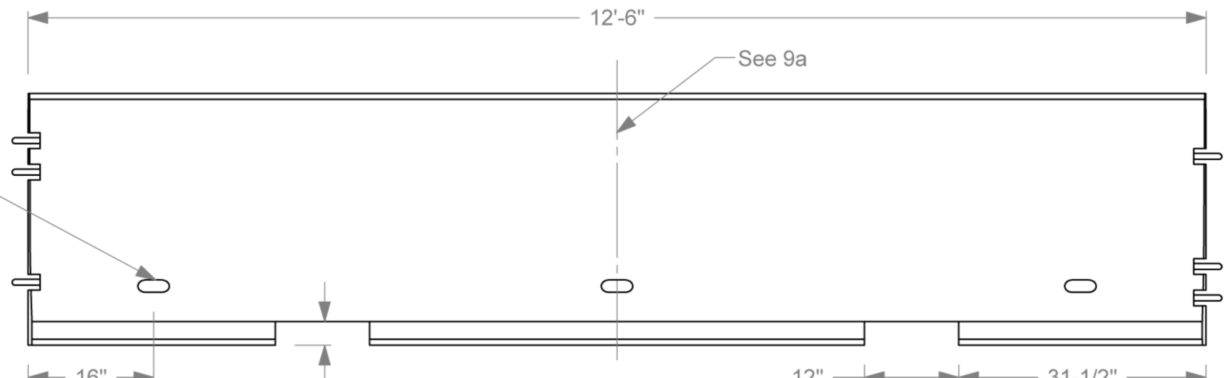


7 L-Bar

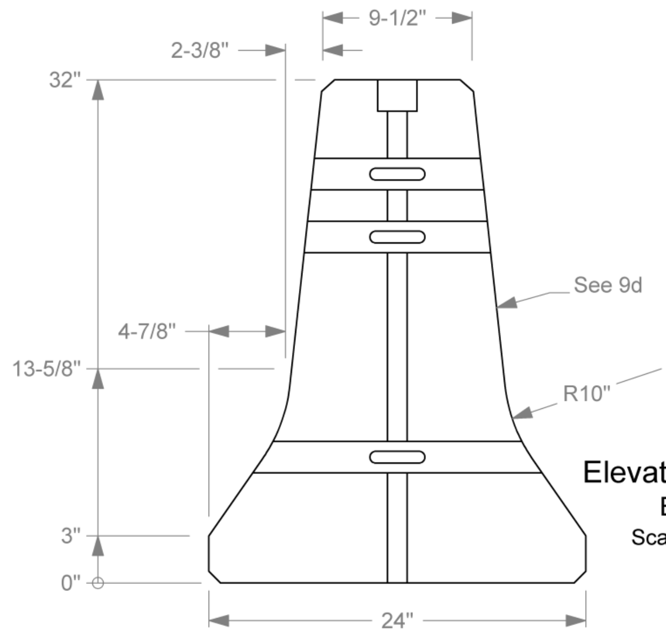
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project 605641	Pinned Barrier Transition	2015-09-09
Drawn By GES	Scale 1:10	Sheet 8 of 13 SSCB Stirrups

T:\1-ProjectFiles\605641-Pinned Barrier Transition\Drafting\605641 Drawing

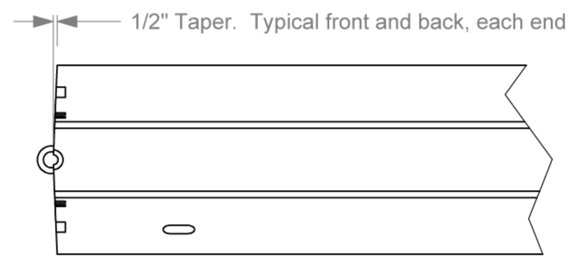
Pin-Down Barrier



Elevation View



Elevation View
End
Scale 1:10

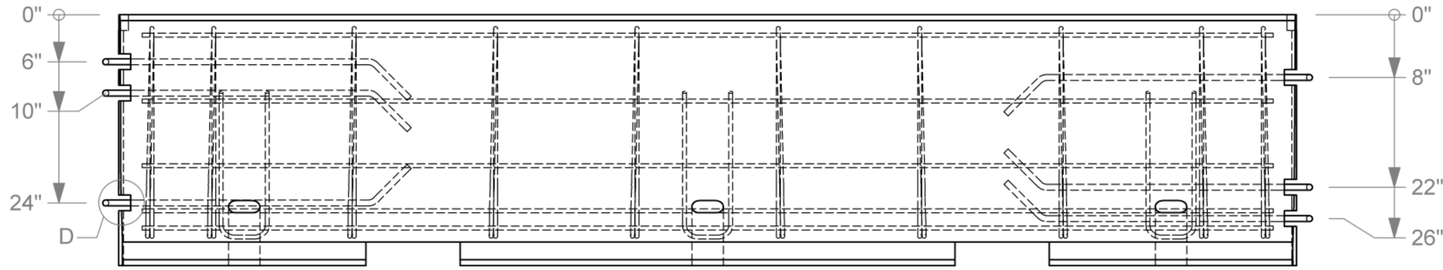


Plan View

9a. Barriers are symmetric about ℄'s, except for end loops. See next sheet for end loop and cut-out details.
9b. All rebar is grade 60.
9c. Concrete shall be 5000 psi.
9d. Chamfer top, bottom, and ends 3/4". End chamfers not shown for clarity.

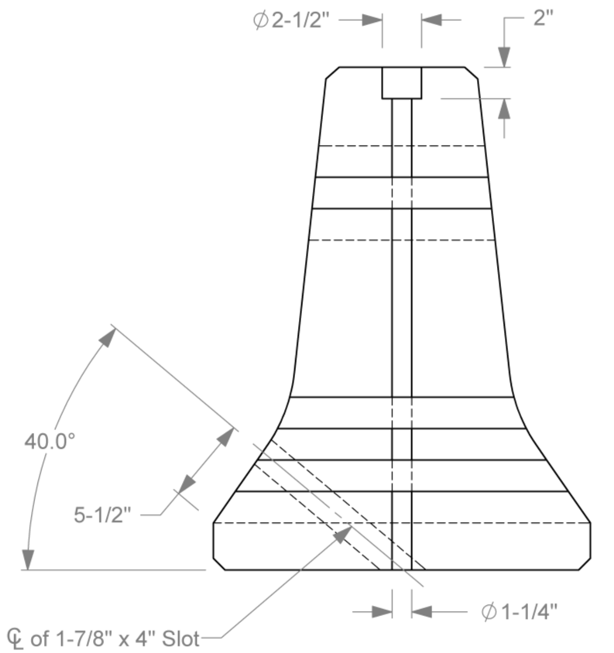
Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project 605641	Pinned Barrier Transition		2015-09-09
Drawn By GES	Scale 1:20	Sheet 9 of 13	Barrier Details a

T:\1-ProjectFiles\605641-Pinned Barrier Transition\Drafting\605641 Drawing



Pin-Down Barrier

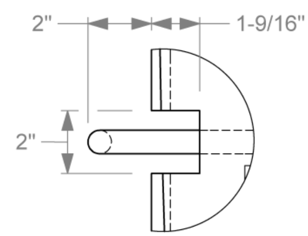
End Loop Details



End View

Scale 1:10

(Rebar and End Loops not shown for clarity.)



Detail D

Scale 1 : 5

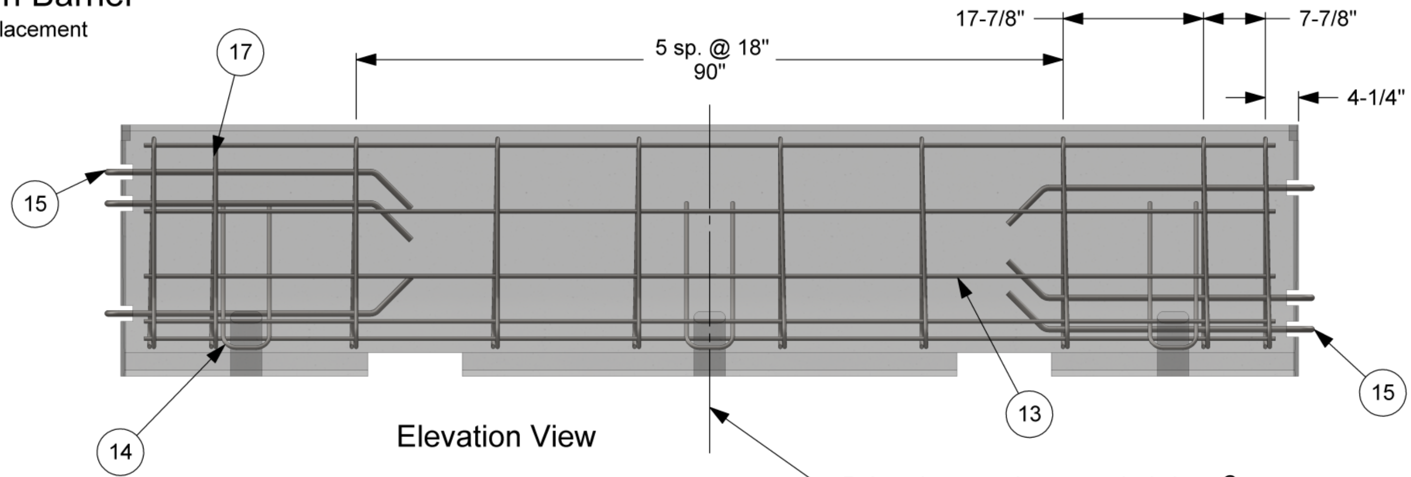
Typical x 6

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project 605641	Pinned Barrier Transition	2015-09-09
Drawn By GES	Scale 1:20	Sheet 10 of 13 Barrier Details b

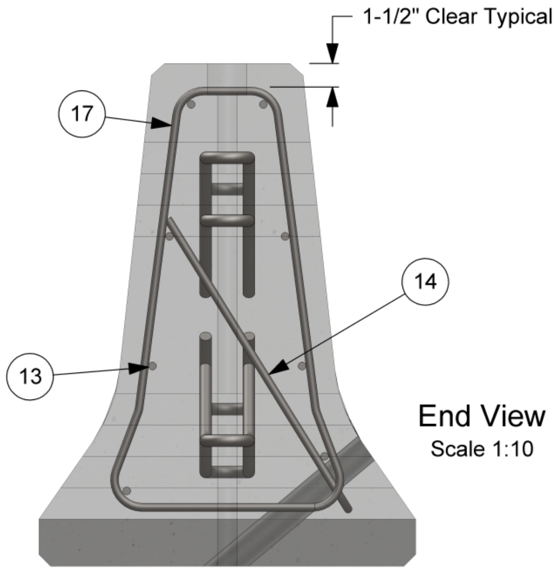
T:\1-ProjectFiles\605641-Pinned Barrier Transition\Drafting\605641 Drawing

Pin-Down Barrier

Rebar Placement



Elevation View

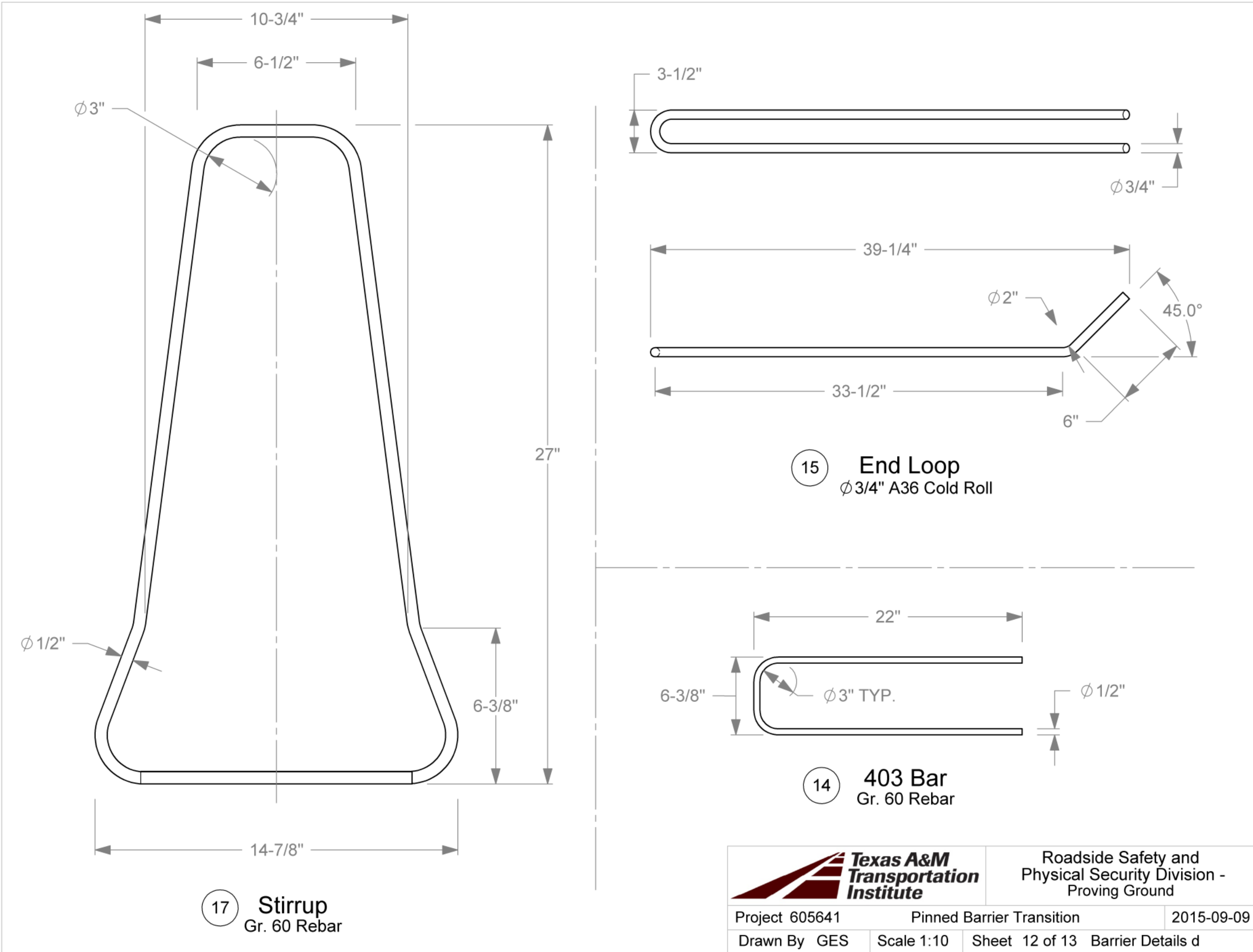


End View
Scale 1:10

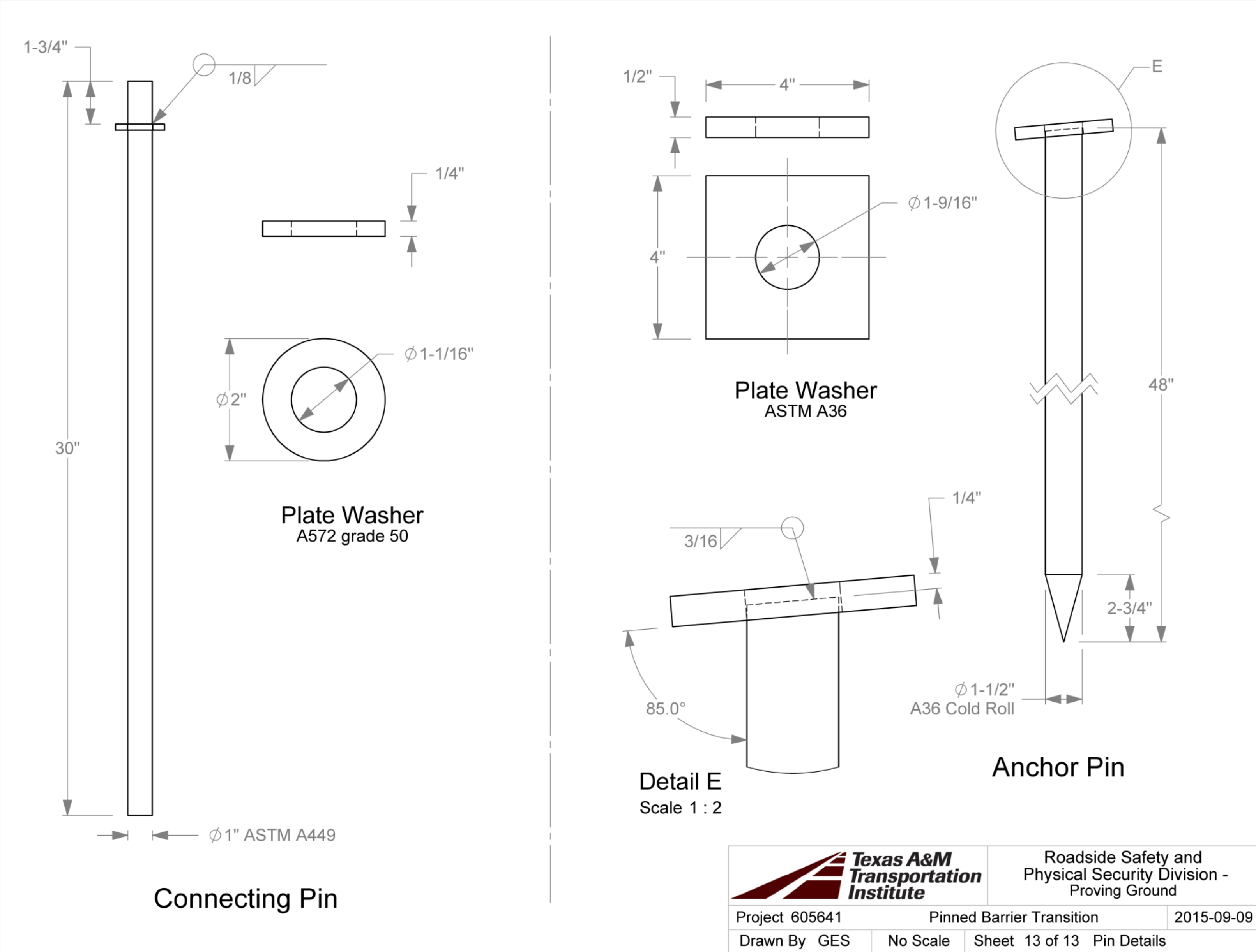
#	Part Name	Qty.
13	Rebar, Ø1/2" x 144"	8
14	Stirrup A	3
15	End Loops	6
17	403 Bar	10

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project 605641	Pinned Barrier Transition	2015-09-09
Drawn By GES	Scale 1:20	Sheet 11 of 13 Barrier Details c

T:\1-ProjectFiles\605641-Pinned Barrier Transition\Drafting\605641 Drawing



T:\1-ProjectFiles\605641-Pinned Barrier Transition\Drafting\605641 Drawing



T:\1-ProjectFiles\605641-Pinned Barrier Transition\Drafting\605641 Drawing

MATERIAL USED

TEST NUMBER: 605641-1

TEST NAME: Transition from Temporary Concrete Barrier Pinned on Asphalt to Rigid Concrete Barrier

TEST DATE: 2015-10-21

#	DATE RECEIVED	DESCRIPTION	GRADE	YIELD	TENSILE	SUPPLIER
15-001	2015-09-04	Cold Roll, 1-1/2"	1018	269	448	Mack Bolt & Steel
15-002	2015-09-04	Plate, 4" x 1/2"	A36	285	475	Mack Bolt & Steel
15-003	2015-09-04	Plate, 8" x 1/4"		no information		Mack Bolt & Steel
15-005	2015-09-08	Guardrail Parts		see attached		Trinity Industries
15-008	2015-09-28	Hardware		see attached		Mack Bolt & Steel

Concrete documents at end of this appendix.

15-001

Vulcan THREADED PRODUCTS, INC.

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

Material Certification

Customer:	**Triple-S Steel**
Ship To:	**Houston**
Customer PO No:	**HOU-164525**
Vulcan Order No:	**250758**
Order Line:	**3**
Shipped Qty:	**2055**
Vulcan Part No:	**CDR 1018 1.5000x240**
Customer Part No:	**CDR 1018 1.5000x240**
Customer Part Description:	
Reference No:	
Melted and Manufactured in:	**USA**
Rolled Mill:	**AltSte**
Melted Mill:	**AltSte**
Grade:	**1018**
Heat:	**145068**
Note:	**(1.5625 - 25.57:1)(1.8125 - 19:1)**
Spec No:	**AISI 1018**
Spec Note:	
Spec No:	**ASTM A108**
Spec Note:	

Material Specification Type	Material Specification	Actual
Chemistry	Carbon (C)	0.200 %
	Manganese (Mn)	0.78 %
	Phosphorus (P)	0.007 %
	Sulfur (S)	0.029 %
	Silicon (Si)	0.19 %
	Copper (Cu)	0.18 %
	Nickel (Ni)	0.07 %
	Chromium (Cr)	0.12 %
	Molybdenum (Mo)	0.02 %
	Vanadium (V)	0.037 %
	Tin (Sn)	0.010 %
	Columbium (Cb)	0.002 %
	Aluminum (Al)	0.002 %
	Nitrogen (N)	0.0103 %
	Boron (B)	0.0003 %
	Reduction Ratio	25.57:1

This document certifies that the foregoing data is furnished by the producing mill and test lab.

Plex 3/20/15 9:34 AM vulc.roal Page 1

Metals 2 Go
Customer PO. 73621

Heat 52070
Shipment: 0000596978

CAG CELIK
DEMIR VE CELIK END.A.S.

CAG CELIK DEMIR VE CELIK END.A.S.
CAG CELIK PLAZA, ESENSEHIR EMEK MAH ESKI NATO YOLU NO 288
SANCAKTEPE ISTANBUL, TURKEY
REGISTRATION NO : 341798/289380

MILL TEST CERTIFICATE

Date.28.11.2014
Ref:2014-222

Customer: Metals 2 Go 254-235-7700

Description of Goods: MATERIAL · PRIME QUALITY HOT ROLLED FLAT BARS, ROUND BARS AND SQUARE BARS PRODUCED N ACCORDANCE TO ASTM A36 DIMENSIONAL TOLERANCES TO ASTM A6 LATEST REVISION (ACTUAL REVISION DATE 2009) LENGTH TOLERANCE PLUS 2/MINUS 0 INCHES

Manufacturer: CAG CELIK DEMIR VE CELIK END. A.S.

MECHANICAL PROPERTIES / CHEMICAL ANALYSIS (%)

LOT 4
FLAT BARS

SIZE (inch)	QUALITY	LENGTH (feet)	Heat No	Yield Point N/MM2	Tensile Strength N/MM2	Elong %	Bend Test	C	Mn	Si	S	P	N m	Cu
5/16" X 2"	ASTM A 36/A6	20	52071	268	481	36	OK	0.13	0.68	0.18	0.019	0.020	64	0.054
3/8" X 1 1/2"	ASTM A 36/A6	20	51807	272	457	35	OK	0.15	0.61	0.20	0.021	0.017	62	0.051
3/8" X 2"	ASTM A 36/A6	20	51750	284	476	32	OK	0.16	0.70	0.16	0.019	0.020	63	0.053
3/8" X 2 1/4"	ASTM A 36/A6	20	51887	272	457	34	OK	0.14	0.65	0.16	0.020	0.018	64	0.054
3/8" X 2 1/2"	ASTM A 36/A6	20	51688	263	448	32	OK	0.13	0.62	0.18	0.021	0.017	63	0.051
3/8" X 3	ASTM A 36/A6	20	52065	281	462	34	OK	0.16	0.62	0.19	0.022	0.020	62	0.052
1/2" X 1 1/2"	ASTM A 36/A6	20	51681	268	453	34	OK	0.12	0.66	0.18	0.022	0.019	62	0.054
1/2" X 2"	ASTM A 36/A6	20	51705	279	468	38	OK	0.15	0.67	0.18	0.019	0.020	61	0.054
1/2" X 2 1/2"	ASTM A 36/A6	20	51699	270	458	35	OK	0.12	0.69	0.17	0.020	0.018	64	0.054
5/8" x 2"	ASTM A 36/A6	20	52363	269	468	35	OK	0.16	0.66	0.16	0.020	0.017	60	0.053
3/4" X 3"	ASTM A 36/A6	20	52304	282	459	33	OK	0.14	0.66	0.16	0.022	0.017	59	0.054
3/8 x 5"	ASTM A 36/A6	20	52365	280	459	34	OK	0.12	0.68	0.20	0.022	0.017	59	0.051
3/8 x 6"	ASTM A 36/A6	20	52365	277	468	34	OK	0.14	0.70	0.18	0.022	0.019	63	0.054
1/2 x 4"	ASTM A 36/A6	20	52070	285	475	37	OK	0.15	0.71	0.17	0.021	0.020	64	0.052
1/2 x 5"	ASTM A 36/A6	20	52367	289	470	38	OK	0.15	0.68	0.18	0.020	0.019	63	0.053
3/4 x 4"	ASTM A 36/A6	20	52368	272	486	33	OK	0.14	0.69	0.18	0.019	0.019	59	0.054
3/4 x 5"	ASTM A 36/A6	20	52368	276	467	32	OK	0.16	0.64	0.19	0.019	0.019	63	0.054
						( )							(pp)	
SIZE (inch)	QUALITY	LENGTH (feet)												
1/2"	ASTM A 36/A6	20	51910											
3/4"	ASTM A 36/A6	20	51405	288	466	36	OK	0.14	0.89	0.16	0.019	0.018	64	0.052
1"	ASTM A 36/A6	20	51765	272	460	34	OK	0.14	0.65	0.19	0.020	0.019	64	0.051
1 1/4"	ASTM A 36/A6	20	51379	265	453	36	OK	0.12	0.65	0.20	0.019	0.017	64	0.052
1 1/2"	ASTM A 36/A6	20	52207	289	448	38	OK	0.14	0.61	0.16	0.021	0.019	64	0.051
				282	481	34	OK	0.18	0.61	0.20	0.019	0.019	60	0.053
SQUARE BARS SIZE (inch)	QUALITY	LENGTH (feet)												
1" x 1	ASTM A 36/A6	20	52366											
1 1/2" x 1 1/2	ASTM A 36/A6	20	52124	270	466	33	OK	0.14	0.64	0.17	0.021	0.018	60	0.053
ROUND BARS				275										
					468	33	OK	0.15	0.66	0.18	0.020	0.020	59	0.053

ISSUED BY CAG CELIK DEMIR VE CELIK END A.S.

Metals 2 Go
Customer PO. 73621

4/30/2015 - 1:05 AM

Heat 52070
Shipment: 0000596978

CAG CELIK
DEMIR VE CELIK END.A.S.

CAG CELIK DEMIR VE CELIK END.A.S.
CAG CELIK PLAZA, ESENSEHIR EMEK MAH ESKI NATO YOLU NO 288
SANCAKTEPE ISTANBUL, TURKEY
REGISTRATION NO : 341798/289380

MILL TEST CERTIFICATE

Date,28.11.2014
Ref:2014-222

Customer: Metals 2 Go 254-235-7700

Description of Goods: MATERIAL · PRIME QUALITY HOT ROLLED FLAT BARS, ROUND BARS AND SQUARE BARS PRODUCED IN ACCORDANCE TO ASTM A36 DIMENSIONAL TOLERANCES TO ASTM A6 LATEST REVISION (ACTUAL REVISION DATE 2009) LENGTH TOLERANCE PLUS 2/MINUS 0 INCHES

Manufacturer: CAG CELIK DEMIR VE CELIK END. A.S.

			MECHANICAL PROPERTIES					CHEMICAL ANALYSIS (%)						
			Heat No	Yield Point N/MM2	Tensile Strength N/MM2	Elong %	Bend Test	C	Mn	Si	S	P	N m	Cv
LOT 4 FLAT BARS SIZE (inch)	QUALITY	LENGTH (feet)												
5/16" X 2"	ASTM A 36/A6	20	52071	288	481	36	OK	0.13	0.68	0.18	0.019	0.020	64	0.054
3/8" X 1 1/2"	ASTM A 36/A6	20	51807	272	457	35	OK	0.15	0.61	0.20	0.021	0.017	62	0.051
3/8" X 2"	ASTM A 36/A6	20	51750	284	476	32	OK	0.18	0.70	0.16	0.019	0.020	63	0.053
3/8" X 2 1/4"	ASTM A 36/A6	20	51887	272	457	34	OK	0.14	0.65	0.10	0.020	0.018	64	0.054
3/8" X 2 1/2"	ASTM A 36/A6	20	51688	263	448	32	OK	0.13	0.62	0.18	0.021	0.017	63	0.051
3/8" X 3	ASTM A 36/A6	20	52065	281	462	34	OK	0.16	0.62	0.19	0.022	0.020	62	0.052
1/2" X 1 1/2"	ASTM A 36/A6	20	51681	268	453	34	OK	0.12	0.68	0.18	0.022	0.019	62	0.054
1/2" X 2"	ASTM A 36/A6	20	51705	279	468	38	OK	0.15	0.67	0.18	0.019	0.020	61	0.054
1/2" X 2 1/2"	ASTM A 36/A6	20	51690	270	458	35	OK	0.12	0.69	0.17	0.020	0.018	64	0.054
5/8" x 2"	ASTM A 36/A6	20	52363	269	468	35	OK	0.16	0.66	0.16	0.020	0.017	60	0.053
3/4" X 3"	ASTM A 36/A6	20	52304	262	459	33	OK	0.14	0.66	0.16	0.022	0.017	59	0.054
3/8 x 5"	ASTM A 36/A6	20	52305	260	459	34	OK	0.12	0.66	0.20	0.022	0.017	59	0.051
3/8 x 6"	ASTM A 36/A6	20	52365	277	468	34	OK	0.14	0.70	0.16	0.022	0.019	63	0.054
1/2 x 4"	ASTM A 36/A6	20	52070	285	475	37	OK	0.15	0.71	0.17	0.021	0.020	64	0.052
1/2 x 5"	ASTM A 36/A6	20	52367	289	470	36	OK	0.15	0.68	0.18	0.020	0.019	63	0.053
3/4 x 4"	ASTM A 36/A6	20	52368	272	466	33	OK	0.14	0.69	0.16	0.019	0.019	59	0.054
3/4 x 5"	ASTM A 36/A6	20	52366	276	467	32	OK	0.16	0.64	0.19	0.019	0.019	63	0.054
						( )							(pp)	

SIZE (inch)	QUALITY	LENGTH (feet)	Heat No	Yield Point N/MM2	Tensile Strength N/MM2	Elong %	Bend Test	C	Mn	Si	S	P	N m	Cv
1/2"	ASTM A 36/A6	20	51910											
3/4"	ASTM A 36/A6	20	51405	288	466	36	OK	0.14	0.69	0.16	0.019	0.018	64	0.052
1"	ASTM A 36/A6	20	51765	272	460	34	OK	0.14	0.65	0.19	0.020	0.019	64	0.051
1 1/4"	ASTM A 36/A6	20	51379	265	453	38	OK	0.12	0.65	0.20	0.019	0.017	64	0.052
1 1/2"	ASTM A 36/A6	20	52207	289	448	36	OK	0.14	0.61	0.16	0.021	0.019	64	0.051
				282	481	34	OK	0.18	0.61	0.20	0.019	0.019	60	0.053
SQUARE BARS SIZE (inch)	QUALITY	LENGTH (feet)												
1" x 1	ASTM A 36/A6	20	52366											
1 1/2" x 1 1/2	ASTM A 36/A6	20	52124	270	456	33	OK	0.14	0.64	0.17	0.021	0.018	60	0.053
ROUND BARS				275										

ISSUED BY CAG CELIK DEMIR VE CELIK END A.S.

466	33	OK	0.15	0.66	0.16	0.020	0.020	59	0.053

15-005

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX 76111 Phn:(817) 665-1499

Customer: TEXAS A&M TRANS INSTITUTE
ROADSIDE SAFETY & PHYSICA
BUSINESS OFFICE
3135 TAMU
COLLEGE STATION, TX 77843-3135

Order Number: 1248341 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: POOLED FUND T
BOL Number: 58809 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 9/4/15

Project: POOLED FUND TEST THRIE BEAM

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
3	209G	T12/12'6/6'3/S	RHC			L34214													4
			M-180	A		182997	58,340	76,890	26.9	0.180	0.730	0.014	0.004	0.010	0.130	0.000	0.060	0.001	4
			M-180	A		182998	60,310	78,910	25.4	0.200	0.730	0.012	0.006	0.010	0.140	0.000	0.050	0.001	4
			M-180	A		182999	61,100	80,000	26.1	0.190	0.740	0.013	0.003	0.020	0.130	0.000	0.070	0.001	4
			M-180	A		183107	57,060	76,210	29.1	0.200	0.720	0.012	0.004	0.010	0.120	0.000	0.050	0.000	4
			M-180	A		183930	63,240	81,490	26.1	0.180	0.720	0.011	0.003	0.020	0.100	0.000	0.060	0.001	4
			M-180	A		183931 15-005	59,180	80,750	27.9	0.170	0.720	0.013	0.003	0.020	0.120	0.000	0.070	0.000	4
			M-180	A		183932	63,930	82,010	26.7	0.190	0.730	0.012	0.004	0.020	0.110	0.000	0.070	0.001	4
2	975G	T10/END SHOE	A-1011			N65303	42,000	56,200	37.4	0.070	0.390	0.005	0.009	0.008	0.000	0.000	0.000	0.000	4
15	3320G	3/16"X1.75"X3" WASHER	HW			P36081													
15	3400G	5/8"X2" GR BOLT	HW			140411B													

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT , 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B,P, OR S, ARE UNCOATED

15-005

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX 76111 Phn:(817) 665-1499
Customer: TEXAS A&M TRANS INSTITUTE
ROADSIDE SAFETY & PHYSICA
BUSINESS OFFICE
3135 TAMU
COLLEGE STATION, TX 77843-3135

Order Number: 1248341 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: POOLED FUND T
BOL Number: 58809 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 9/4/15

Project: POOLED FUND TEST THRIE BEAM

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 4th day of September, 2015 .

Notary Public:
Commission Expires

JOMARY LUGINSLAND
Notary Public, State of Texas
My Commission Expires
May 28, 2019

Trinity Highway Products , LLC
Certified By:
Quality Assurance

15-008

Mack Bolt and Steel
5875 East State Highway 21
Bryan, TX 77808
979-778-8088 Fax 979-778-8310

Invoice

DATE	INVOICE #
9/29/2015	6838535

BILL TO

Texas Transportation Institute
Texas A&M University
3135 TAMU
College Station, TX 77843-3135
Must have PO# or Name

P.O. NO.	TERMS	REP	BRANCH
605641	PO--Net 30	DT	Gary Gerke

QTY	DESCRIPTION	RATE	AMOUNT
3	7/8-9 x 14" Galvanized A325 Hex Bolt	23.15	69.45
3	7/8-9 x 16" Galvanized A325 Hex Bolt	103.70	311.10
2	7/8-9 x 18" Galvanized A325 Hex Bolt	46.25	92.50
1	7/8-9 x 20" Galvanized A325 Hex Bolt	126.75	126.75
1	7/8-9 x 22" Galvanized A325 Hex Bolt	127.75	127.75
20	7/8" Galvanized SAE Flat Washer	0.30	6.00
10	7/8-9 2H Galvanized Nut	0.96	9.60
20	1/4 x 8 Flat Bar	4.39	87.80

Total $830.95

Thank you for your business.

Rec'd By:________________Inside Sales ID:__________Delivered by____Date 9-29-15
Paid: Check__________Cash_________Charge__________
Due and Payable in Brazos County, TX. No returns after 30 days. Must have receipt. Subject to 10% restocking fee. NO RETURNS ON SPECIAL ORDERS (Includes Anything Cut or Machined).

15-008

171208

K-T Bolt Manufacturing Company, Inc.®
1150 Katy Fort-Bend Road
Katy, Texas 77494
Ph.: 281-391-2196 Fax: 281-391-2673

C & I Testing Labs, Inc.
1170 Katy Fort-Bend Road
Katy, Texas 77494
Ph. 281-391-2197 Fax: 281-391-2044
E-Mail: certs@k-tbolt.com

July 28, 2014

Material Test Report

Customer / Company: Gulf Coast Fasteners

Part Description: 200pcs 7/8 – 9 X 14 Heavy Hex Bolts

K-T A-325

Material Specification: ASTM A325 – '10 Type I

Coating Specification: None

Purchase Order Number: H4142

Lot Number: 24328-01

Comments: None

Material Heat Number: 3046575

Tensile Test Results

Lab Reference Number: 171208
Lab ID: Y183

Test Specification: ASTM F606-'00a
Sampling: ASTM F1470

Property	#1 lbf	#2 lbf
Tensile	64800	-
Yield / Proof	42100	-
Elongation %	-	-
ROA %	-	-

Coating Thickness Evaluation

Sample	Average	Weight oz./ft²	Sample	Average	Weight oz./ft²
1.			6.		
2.			7.		
3.			8.		
4.			9.		
5.			10.		

Hardness Testing

	Hardness-HRC
1.	32
2.	32

Chemical Analysis

C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb	Sn	Al	N
0.45	0.74	0.010	0.027	0.21	0.21	0.07	0.08	0.019	0.000	0.000	0.011	0.001	0.0094

100% Melted and Manufactured in the USA

Comments

All tests are in accordance with the latest revisions of the methods prescribed in the applicable SAE and ASTM specifications. The samples tested conform to the specifications listed above and were manufactured free of mercury contamination. No heats to which Bismuth, Selenium, Tellurium or Lead was intentionally added to produce the products. The steels were melted and manufactured in the U.S.A. and the product manufactured and tested in the U.S.A. We certify that this data is a true representation of the information provided by the material supplier and our testing laboratory. The above tested sample has been inspected for Visual Discontinuities and found Acceptable. They comply in all respects with the following ASTM A325 Type I or Type 3 and ASME B18.2.6. Threads are per ANSI B1 Class 2A.

C&I Testing Labs, Inc.
Quality Assurance Manager

ISO 9001

ANAB

15-008

184071

K-T Bolt Manufacturing Company, Inc.®
1150 Katy Fort-Bend Road
Katy, Texas 77494
Ph.: 281-391-2196 Fax: 281-391-2673

C & I Testing Labs, Inc.
1170 Katy Fort-Bend Road
Katy, Texas 77494
Ph. 281-391-2197 Fax: 281-391-2044
E-Mail: ccrts@k-tbolt.com

September 28, 2015

Material Test Report

Customer / Company: Mack Bolt & Steel

Part Description: 3 pcs. 7/8" (9p) x 16" Heavy Hex Head Bolts

K-T A-325

Material Specification: ASTM A325 – '10 Type 1

Coating Specification: Galvanized per ASTM F2329 / A153

Purchase Order Number: 29794

Lot Number: 43819-2

Comments: None

Material Heat Number: 3056102

Tensile Test Results

Lab Reference Number: 184071
Lab ID: 15ST217

Test Specification: ASTM F606-'00a
Sampling: ASTM F1470

Property	#1 lbf	#2 lbf
Tensile:	69400	-
Yield / Proof:	40400	-
Elongation %	-	-
ROA %	-	-

Coating Thickness Evaluation

Sample	Average	Weight oz./ft²	Sample	Average	Weight oz./ft²
1.	4.50	2.64	6.		
2.	4.26	2.50	7.		
3.			8.		
4.			9.		
5.			10.		

Hardness Testing

	Hardness-HRC
1.	32
2.	-
3.	-

Chemical Analysis

C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb	Sn	Al	N
.44%	.78%	.015%	.027%	.21%	.23%	.11%	.09%	.029%	.004%	.001%	.010%	.002%	.0057%

100% Melted and Manufactured in the USA

Comments

All tests are in accordance with the latest revisions of the methods prescribed in the applicable SAE and ASTM specifications. The samples tested conform to the specifications listed above and were manufactured free of mercury contamination. No heats to which Bismuth, Selenium, Tellurium or Lead was intentionally added to produce the products. The steels were melted and manufactured in the U.S.A. and the product manufactured and tested in the U.S.A. We certify that this data is a true representation of the information provided by the material supplier and our testing laboratory. The above tested sample has been inspected for Visual Discontinuities and found Acceptable. They comply in all respects with the following ASTM A325 Type I and ASME B18.2.6. Threads are per ANSI B1 Class 2A.

C&I Testing Labs, Inc.

Sarah Holland

Sarah Holland
Data Entry Clerk

ISO 9001

ANAB ACCREDITED

15-008

K-T Bolt Manufacturing Company, Inc.®
1150 Katy Fort-Bend Road
Katy, Texas 77494
Ph: 281-391-2196 Fax: 281-391-2673

Material Test Report

Company:	**Gulf Coast Fasteners**
Part Description:	**34 pcs ⅞ X 18" Heavy Hex Bolts**
Material Specification:	**ASTM A325-'01a Type 1**
Coating Specification	**None**
Purchase Order Number:	**H3159**
Lot Number:	**01232-1**
Comments:	**None**
Material Heat Number:	**3019444**

Chemical Analysis – Weight Percent

C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb	Sn	Al	B	Ti	N
.41	.80	.008	.011	.22	.23	.85	.09	.208	.027	.001	.011	.002	-	-	-

100% Melted & Manufactured in the USA. Values reflect originating Steel Mill

C&I Testing Labs, Inc.®
1170 Katy Fort-Bend Road
Katy, Texas 77494
Ph: 281-391-2197 Fax: 281-391-2044
E-Mail: shirley.tkboltbolt@yahoo.com

Tensile and Hardness Test Results

Lab Reference Number:	**154834**
Lab ID:	**J 95**
Date Tested:	**November 10, 2010**
Test Specification:	**ASTM F606-'00a**
Sampling:	**Per customer**

Property	**#1 lbf**
Tensile:	**68.600**
Proof/Yield	**39.250**
Elongation	**-**
ROA	**-**
Hardness	**34 HRC**

Comments

Test results meet tensile/hardness requirements of specification.

15-008

184070

K-T Bolt Manufacturing Company, Inc.®
1150 Katy Fort-Bend Road
Katy, Texas 77494
Ph.: 281-391-2196 Fax: 281-391-2673

C & I Testing Labs, Inc.
1170 Katy Fort-Bend Road
Katy, Texas 77494
Ph. 281-391-2197 Fax: 281-391-2044
E-Mail: certs@k-tbolt.com

September 28, 2015
Material Test Report

Customer / Company: Mack Bolt & Steel

Part Description: 1 pcs. 7/8" (9p) x 20" Heavy Hex Head Bolts

K-T A-325

Material Specification: ASTM A325 – '10 Type 1

Coating Specification: Galvanized per ASTM F2329 / A153

Purchase Order Number: 43819-3

Lot Number: 29794

Comments: None

Material Heat Number: 3056102

Tensile Test Results

Lab Reference Number: 184070
Lab ID: 15ST218

Test Specification: ASTM F606-'00a
Sampling: ASTM F1470

Property	#1 lbf	#2 lbf
Tensile:	71800	-
Yield / Proof:	41600	-
Elongation %	-	-
ROA %	-	-

Coating Thickness Evaluation

Sample	Average	Weight oz./ft²	Sample	Average	Weight oz./ft²
1.	4.58	2.69	6.		
2.			7.		
3.			8.		
4.			9.		
5.			10.		

Hardness Testing

	Hardness-HRC
1.	32
2.	-
3.	-

Chemical Analysis

C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb	Sn	Al	N
.44%	.78%	.015%	.027%	.21%	.23%	.11%	.09%	.029%	.004%	.001%	.010%	.002%	.0057%

100% Melted and Manufactured in the USA

Comments

All tests are in accordance with the latest revisions of the methods prescribed in the applicable SAE and ASTM specifications. The samples tested conform to the specifications listed above and were manufactured free of mercury contamination. No heats to which Bismuth, Selenium, Tellurium or Lead was intentionally added to produce the products. The steels were melted and manufactured in the U.S.A. and the product manufactured and tested in the U.S.A. We certify that this data is a true representation of the information provided by the material supplier and our testing laboratory. The above tested sample has been inspected for Visual Discontinuities and found Acceptable. They comply in all respects with the following ASTM A325 Type 1 and ASME B18.2.6. Threads are per ANSI B1 Class 2A.

C&I Testing Labs, Inc.

Sarah Holland

Sarah Holland
Data Entry Clerk

ANAB ACCREDITED

ISO 9001

15-008

184072

K-T Bolt Manufacturing Company, Inc.®
1150 Katy Fort-Bend Road
Katy, Texas 77494
Ph.: 281-391-2196 Fax: 281-391-2673

C & I Testing Labs, Inc.
1170 Katy Fort-Bend Road
Katy, Texas 77494
Ph. 281-391-2197 Fax: 281-391-2044
E-Mail: certs@k-tbolt.com

September 28, 2015

Material Test Report

Customer / Company: Mack Bolt & Steel

Part Description: 1 pc. 7/8" (9p) x 22" Heavy Hex Head Bolts

K-T A-325

Material Specification: ASTM A325 – '10 Type I

Coating Specification: Galvanized per ASTM F2329 / A153

Purchase Order Number: 29794

Lot Number: 43819-4

Comments: None

Material Heat Number: 3056102

Tensile Test Results

Lab Reference Number: 184072
Lab ID: 15ST219

Test Specification: ASTM F606-'00a
Sampling: ASTM F1470

Property	#1 lbf	#2 lbf
Tensile:	71900	-
Yield / Proof:	40600	-
Elongation %	-	-
ROA %	-	-

Coating Thickness Evaluation

Sample	Average	Weight oz./ft²	Sample	Average	Weight oz./ft²
1.	4.34	2.55	6.		
2.			7.		
3.			8.		
4.			9.		
5.			10.		

Hardness Testing

	Hardness-HRC
1.	32
2.	-
3.	-

Chemical Analysis

C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb	Sn	Al	N
.44%	.78%	.015%	.027%	.21%	.23%	.11%	.09%	.029%	.004%	.001%	.010%	.002%	.0057%

100% Melted and Manufactured in the USA

Comments

All tests are in accordance with the latest revisions of the methods prescribed in the applicable SAE and ASTM specifications. The samples tested conform to the specifications listed above and were manufactured free of mercury contamination. No heats to which Bismuth, Selenium, Tellurium or Lead was intentionally added to produce the products. The steels were melted and manufactured in the U.S.A. and the product manufactured and tested in the U.S.A. We certify that this data is a true representation of the information provided by the material supplier and our testing laboratory. The above tested sample has been inspected for Visual Discontinuities and found Acceptable. They comply in all respects with the following ASTM A325 Type 1 and ASME B18.2.6. Threads are per ANSI B1 Class 2A.

C&I Testing Labs, Inc.

Sarah Holland

Sarah Holland
Data Entry Clerk

ISO 9001

ANAB ACCREDITED

15-008

Stelfast Inc.

22979 Stelfast Parkway
Strongsville, Ohio

44149

Report of Chemical and Physical Properties

Issued To: Mack Bolt, Steel & Machine
5875 Hwy 21 East
BRYAN, TX
77808

Purchase Order: 28577
Stelfast Order: SO 124478
Certificate #: 498,082

Quantity: 750
Part #: DHWGA08750
Description: 7/8 Hardened Washer F436 HDG

Lot Number: GBR13538445-013
Heat Number: D113000218
Country of Origin: CN

Chemical Analysis

C	Mn	P	S	Si	Cr	Mo	V	B	Ni	Cu
0.46	0.56	0.019	0.016	0.21						

Mechanical Properties

Hardness (Core)	29 - 34 HRC

We hereby certify that the above data is a true copy of the data furnished to us by the producing mill or the data resulting from tests performed in approved laboratories.

This certificate applies to the product shown on this document, as supplied by Stelfast Inc. Alterations to the product by our customer or a third party will render this certificate void.

ROBERT D. MEAGHER
QUALITY MANAGER

February 06, 2015

Page 1 of 1

Stelfast Inc. 15-008

22979 Stelfast Parkway
Strongsville, Ohio

44149

Report of Chemical and Physical Properties

Issued To: Mack Bolt, Steel & Machine
5875 Hwy 21 East
BRYAN, TX
77808

Purchase Order: 28577
Stelfast Order: SO 124478
Certificate #: 520,511

Quantity: 200
Part #: A2HHG0875C
Description: 7/8-9 Hvy Hx Nut 2H HDG/TOS 0.022

Lot Number: 5073290011
Heat Number: 331312398
Country of Origin: CN

Chemical Analysis

C	Mn	P	S	Si	Cr	Mo	V	B	Ni	Cu
0.45	0.74	0.025	0.005	0.17						

Mechanical Properties

Minimum Tempering Temp.	520 C
Result of 24 Hr. Temper Test	94 - 96 HRB
Hardness (Core)	30 - 32 HRC
Proof Load	80850 LBF MIN.
Macro Etch Test	S2,R2,C2
Grade Markings	ASTM A194(13a)-2H

We hereby certify that the above data is a true copy of the data furnished to us by the producing mill or the data resulting from tests performed in approved laboratories.

This certificate applies to the product shown on this document, as supplied by Stelfast Inc. Alterations to the product by our customer or a third party will render this certificate void.

ROBERT D. MEAGHER
QUALITY MANAGER

February 06, 2015

Page 1 of 1

NUCOR
NUCOR CORPORATION
NUCOR STEEL TEXAS

Mill Certification
4/7/2015

MTR #: 0000092343
8812 Hwy 79 W
Jewett, TX 75846
(903) 626-4461
Fax: (903) 626-6290

Sold To: KLOECKNER METALS CORP
500 COLONIAL CENTER PARKWAY
SUITE 500
ROSWELL, GA 30076-0000
(678) 259-8817
Fax: (678) 259-8894

Ship To: KLOECKNER METALS
2560 SOUTH LOOP 4
BUDA, TX 78610
(512) 472-5533

Customer P.O.	6914092	Sales Order	217107.31
Product Group	Merchant Bar Quality	Part Number	532508002405300
Grade	ASTM A529/A529M-05 GR 55	Lot #	JW1510042151
Size	1/4x8" Flat	Heat #	JW15100421
Product	1/4x8" Flat 20' A529 Gr55	B.L. Number	J1-701760
Description	A529 Gr55	Load Number	J1-305306
Customer Spec		Customer Part #	MB148WFLTM5290240

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

Roll Date: 1/23/2015 Melt Date: 1/16/2015 Qty Shipped LBS: 9,800 Qty Shipped Pcs: 72

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Cb	CEA529
0.14%	1.03%	0.011%	0.030%	0.20%	0.31%	0.15%	0.14%	0.055%	0.0042%	0.033%	0.42%
CBV	MN/C										
0.040%	07.36%										

CEA529: A529 CARBON EQUIVALENT
CBV: CB+V
MN/C: MN / C

Yield 1: 69,400psi Tensile 1: 84,000psi Elongation: 20% in 8"(% in 203.3mm)
Yield 2: 68,600psi Tensile 2: 83,700psi Elongation 24% in 8"(% in 203.3mm)

Specification Comments: COMPLIES WITH DIN 50049 PARA 3.1B & EN 10204-3.1

Comments: E-mail: websales@nstexas.com

1. All manufacturing processes of the steel, including melting, have been performed in the U.S.A.
2. Mercury in any form has not been used in the production or testing of this product.
3. Welding or weld repair was not perfomed on this material.
4. This material conforms to the specifications described on this document and may not be reproduced, except in full, without written approval of Nucor Corporation.
5. Results reported for ASTM E45 (Inclusion content) and ASTM E381 (Macro-etch) are provided as interpretation of ASTM procedures.

Bhargava R Vantari
Division Metallurgist

NBMG-10 January 1, 2012

Texas A&M Transportation Institute Proving Ground, 3100 SH 47, Bldg 7091, Bryan, TX 77807 Texas A&M University, College Station, TX 77843, Phone 979-845-6375	5.7.2 Concrete Break	Doc. No. QPF 5.7.2	Revision Date: 2012-09-17
Quality Policy Form	Revised by: G. E. Schroeder Approved by: C. E. Buth	Revision: 5	Page: 1 of 1

Project No.: 605641 **Casting Date:** 2015-09-02

Placement: SLAB **Mix Design P.S.I.:** 4000

Truck No.	Batch Ticket	Yards

Printed name of Technician taking sample: EDWIN HANG

Signature of Technician taking sample:

Printed name of Technician breaking sample: EDWIN HANG

Signature of Technician breaking sample:

Break Date	Cylinder Age	Truck No.	Total Load (Pounds)	PSI Break	Average
2015-10-21	49 DAYS		132,000	4669	4669
			129,000	4563	
			135,000	4775	

Texas A&M Transportation Institute Proving Ground, 3100 SH 47, Bldg 7091, Bryan, TX 77807 Texas A&M University, College Station, TX 77843, Phone 979-845-6375	5.7.2 Concrete Break	Doc. No. QPF 5.7.2	Revision Date: 2012-09-17
Quality Policy Form	Revised by: G. E. Schroeder Approved by: C. E. But	Revision: 5	Page: 1 of 1

Project No.: 605641 **Casting Date:** 2015-09-03

Placement: PARAPET **Mix Design P.S.I.:** 4000

Truck No.	Batch Ticket	Yards

Printed name of Technician taking sample: EDWIN HANG

Signature of Technician taking sample: [signature]

Printed name of Technician breaking sample: EDWIN HANG

Signature of Technician breaking sample: [signature]

Break Date	Cylinder Age	Truck No.	Total Load (Pounds)	PSI Break	Average
2015-10-21	48 DAYS		116,500	4120	4155
			115,000	4067	
			121,000	4280	

APPENIDX C. CRASH TEST NO. 605641-1 (*MASH* TEST 3-21)

C.1 VEHICLE PROPERTIES AND INFORMATION

Table C.1. Vehicle Properties for Test No. 605641-1.

Date: 2015-10-21 Test No.: 605641-1 VIN No.: 1D7RB16T4AS206652

Year: 2010 Make: Dodge Model: Ram 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 197278

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

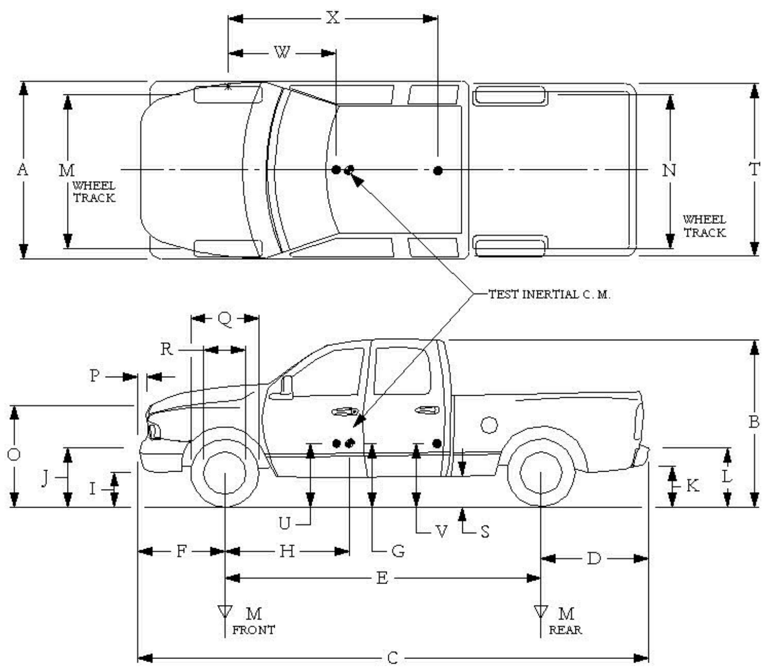
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
x Auto or ____ Manual
____ FWD x RWD ____ 4WD

Optional Equipment:
None

Dummy Data:
Type: No dummy used
Mass: NA
Seat Position: NA



Geometry: inches

A	78.50	F	40.00	K	19.75	P	3.00	U	28.50
B	74.25	G	28.60	L	29.00	Q	30.50	V	29.50
C	227.50	H	60.54	M	68.50	R	18.00	W	60.50
D	47.00	I	11.75	N	68.00	S	13.25	X	77.00
E	140.50	J	27.00	O	46.25	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	18.25
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.10

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2971	2882	----
Back	3900	M_{rear}	2151	2182	----
Total	6700	M_{Total}	5172	5064	----

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

Mass Distribution:
lb LF: 1422 RF: 1460 LR: 1114 RR: 1068

Table C.2. Measurements of Vehicle Vertical CG for Test No. 605641-1.

Date: 2015-10-21 Test No.: 605641-1 VIN: 1D7RB16T4AS206652

Year: 2010 Make: Dodge Model: Ram 1500

Body Style: Quad Cab Mileage: 197278

Engine: V-8 5.7 liter Transmission: Automatic

Fuel Level: Empty Ballast: 76 lb (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)									
LF:	1422		RF:	1460			Front Axle:	2882	
LR:	1114		RR:	1068			Rear Axle:	2182	
Left:	2536		Right:	2528			Total:	5064	
							5000 ±110 lb allowed		
Wheel Base:		140.5	inches	Track: F:	68.5	inches	R:	68	inches
	148 ±12 inches allowed				Track = (F+R)/2 = 67 ±1.5 inches allowed				
Center of Gravity, SAE J874 Suspension Method									
X:	60.54	inches	Rear of Front Axle		(63 ±4 inches allowed)				
Y:	-0.05	inches	Left -	Right +	of Vehicle Centerline				
Z:	28.6	inches	Above Ground		(minumum 28.0 inches allowed)				

Hood Height: 46.25 inches
43 ±4 inches allowed

Front Bumper Height: 27.00 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

Rear Bumper Height: 29.00 inches

Overall Length: 227.50 inches
237 ±13 inches allowed

Table C.3. Exterior Crush Measurements for Test No. 605641-1.

Date: 2015-10-21 Test No.: 605641-1 VIN No.: 1D7RB16T4AS206652

Year: 2010 Make: Dodge Model: Ram 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front plane at bumper ht	20	14	36	14	12	10	9	6	2	-12
2	Side plane at bumper ht	20	17	30	3	3.5	--	--	16	17	+76
	Measurements recorded										
	in inches										

[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).

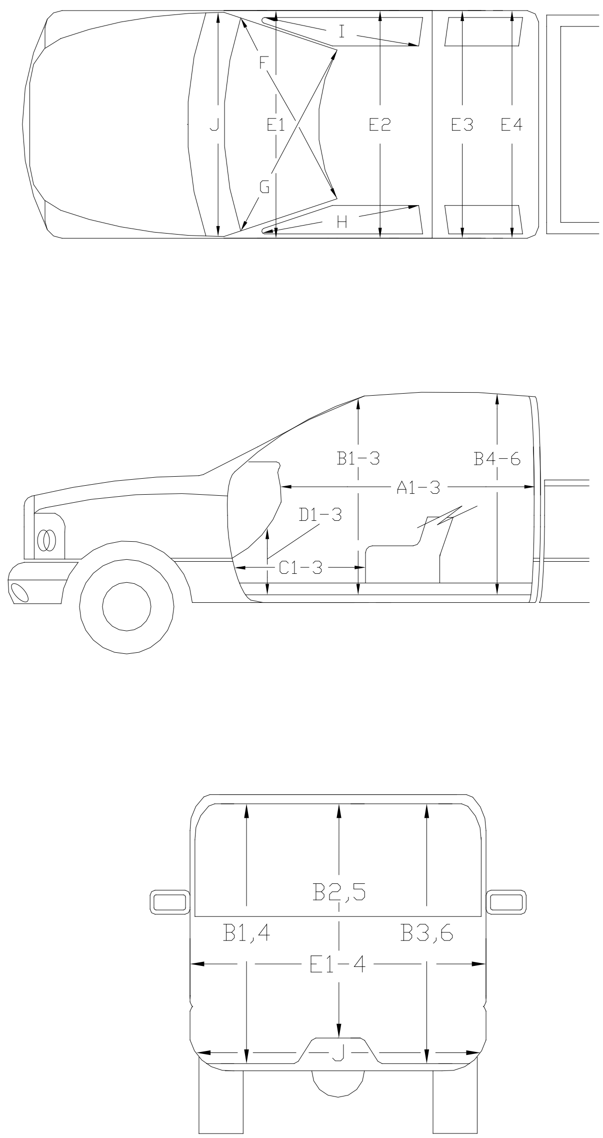
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Table C.4. Occupant Compartment Measurements for Test No. 605641-1.

Date: 2015-10-21 Test No.: 605641-1 VIN No.: 1D7RB16T4AS206652

Year: 2010 Make: Dodge Model: Ram 1500



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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	65.25	65.00
A2	62.50	62.50
A3	65.50	65.50
B1	44.75	46.00
B2	37.75	37.75
B3	44.75	44.75
B4	39.50	39.50
B5	43.25	43.25
B6	39.50	39.50
C1	27.50	24.50
C2	-----	-----
C3	26.50	26.50
D1	11.25	12.50
D2	-----	-----
D3	11.25	11.25
E1	58.50	58.25
E2	63.50	64.00
E3	63.25	63.25
E4	63.25	63.25
F	58.50	58.50
G	58.50	58.50
H	37.25	37.25
I	37.25	37.25
J*	23.50	19.50

C.2 SEQUENTIAL PHOTOGRAPHS

Figure C.1. Sequential Photographs for Test No. 605641-1 (Overhead and Frontal Views).


0.300 s



0.375 s



0.450 s



0.525 s


Figure C.1. Sequential Photographs for Test No. 605641-1 (Overhead and Frontal Views) (Continued).

Figure C.2. Sequential Photographs for Test No. 605641-1 (Rear View).

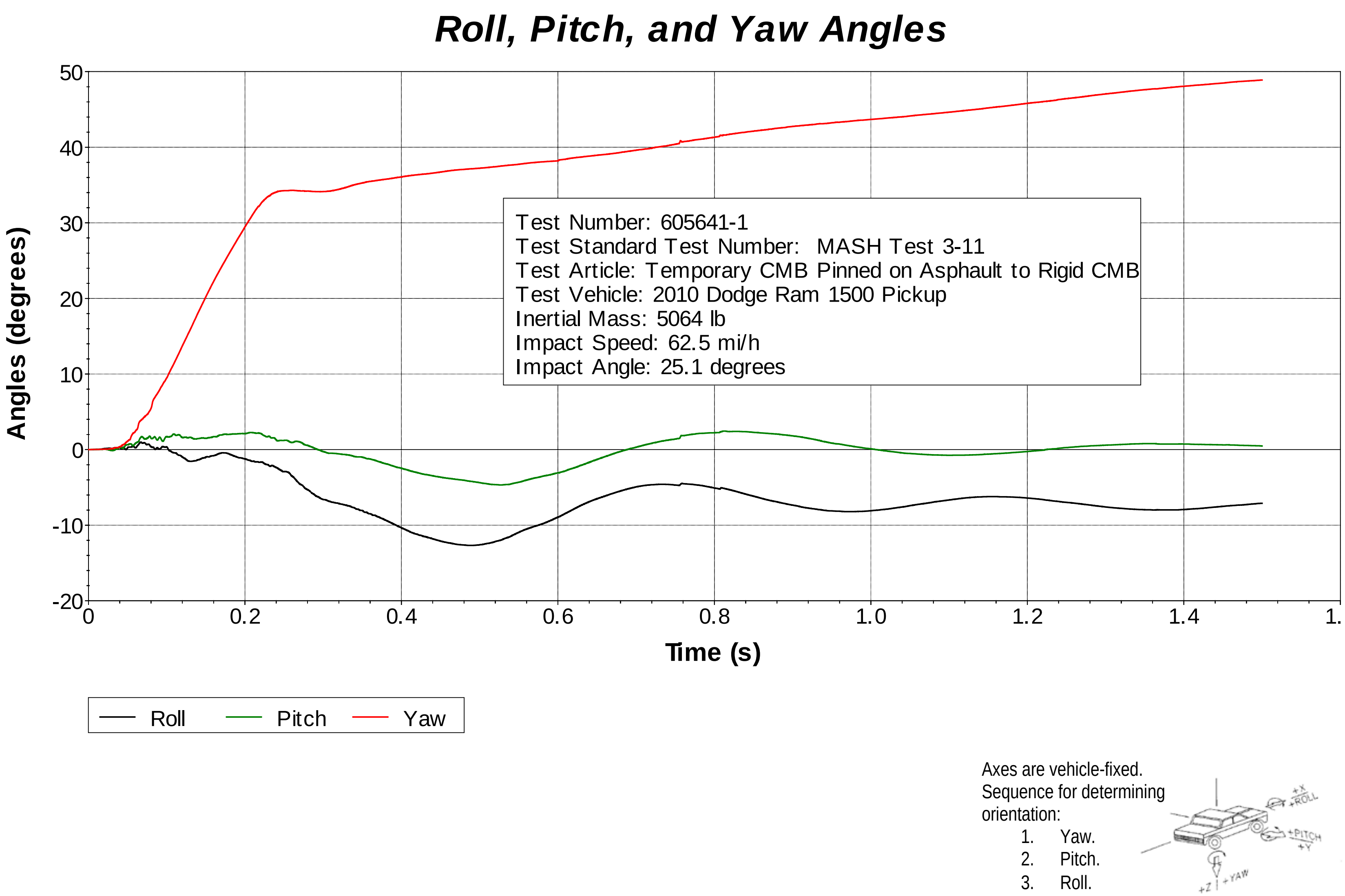


Figure C.3. Vehicle Angular Displacements for Test No. 605641-1.

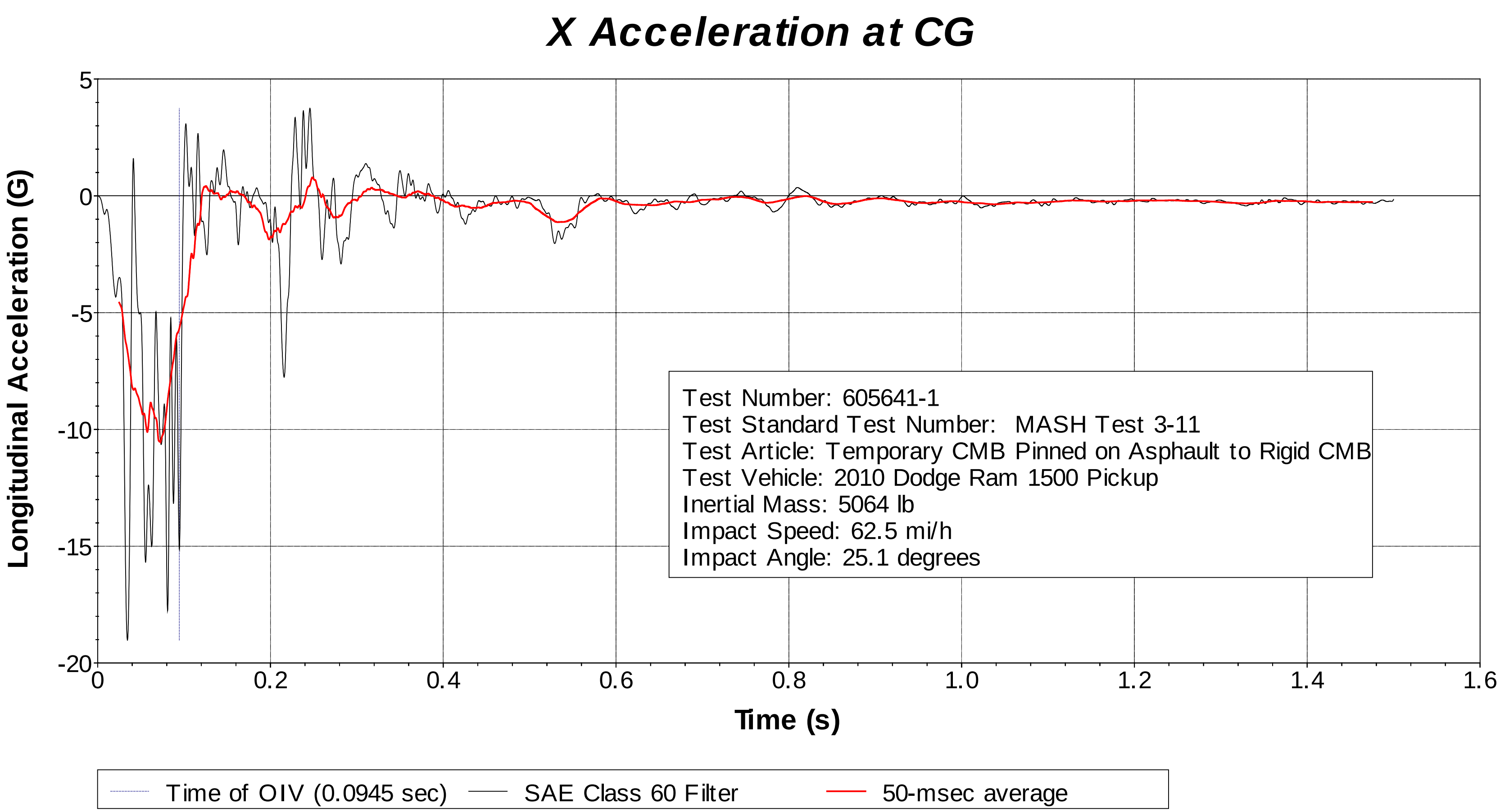


Figure C.4. Vehicle Longitudinal Accelerometer Trace for Test No. 605641-1 (Accelerometer Located at Center of Gravity).

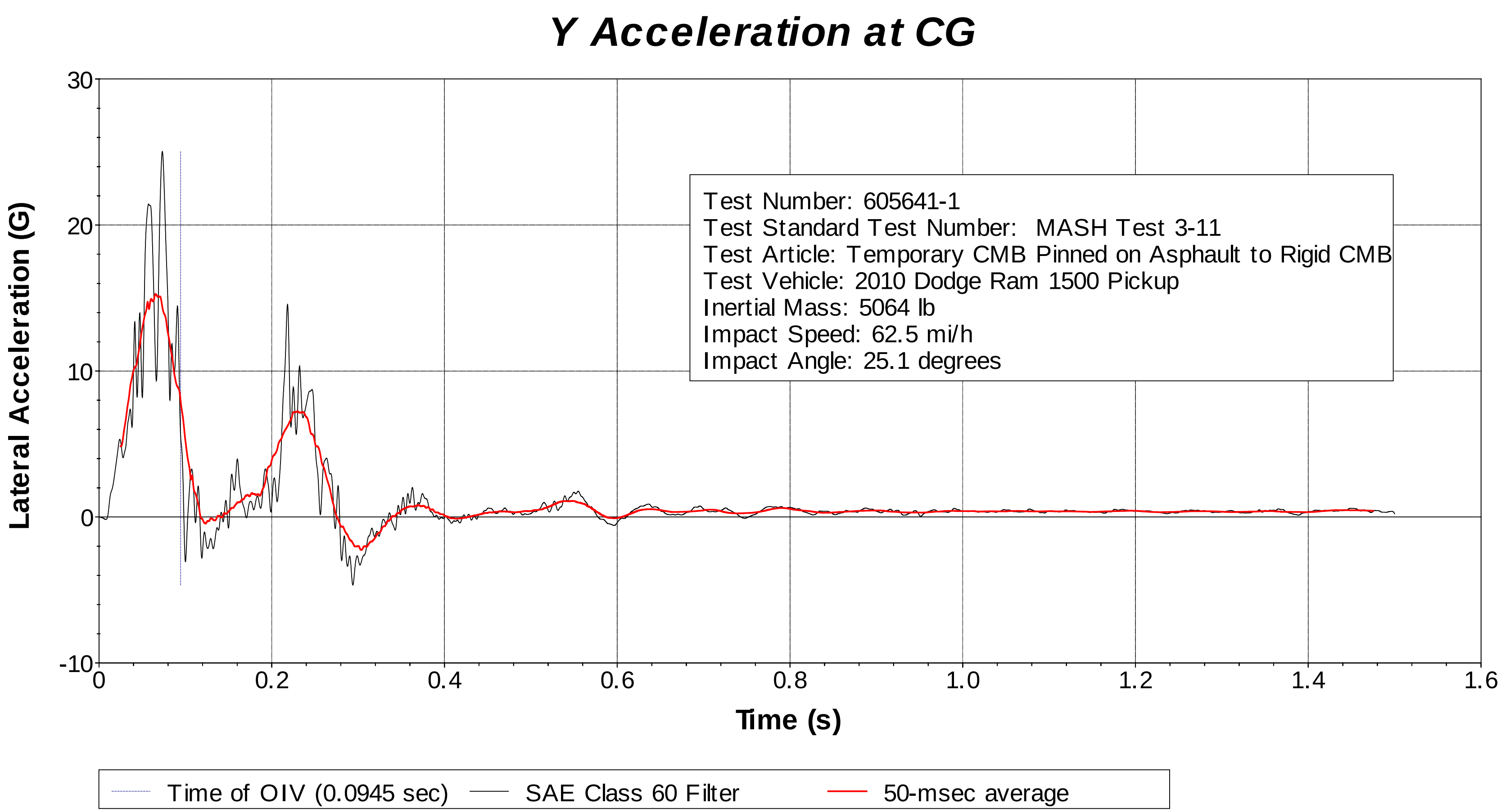


Figure C.5. Vehicle Lateral Accelerometer Trace for Test No. 605641-1 (Accelerometer Located at Center of Gravity).

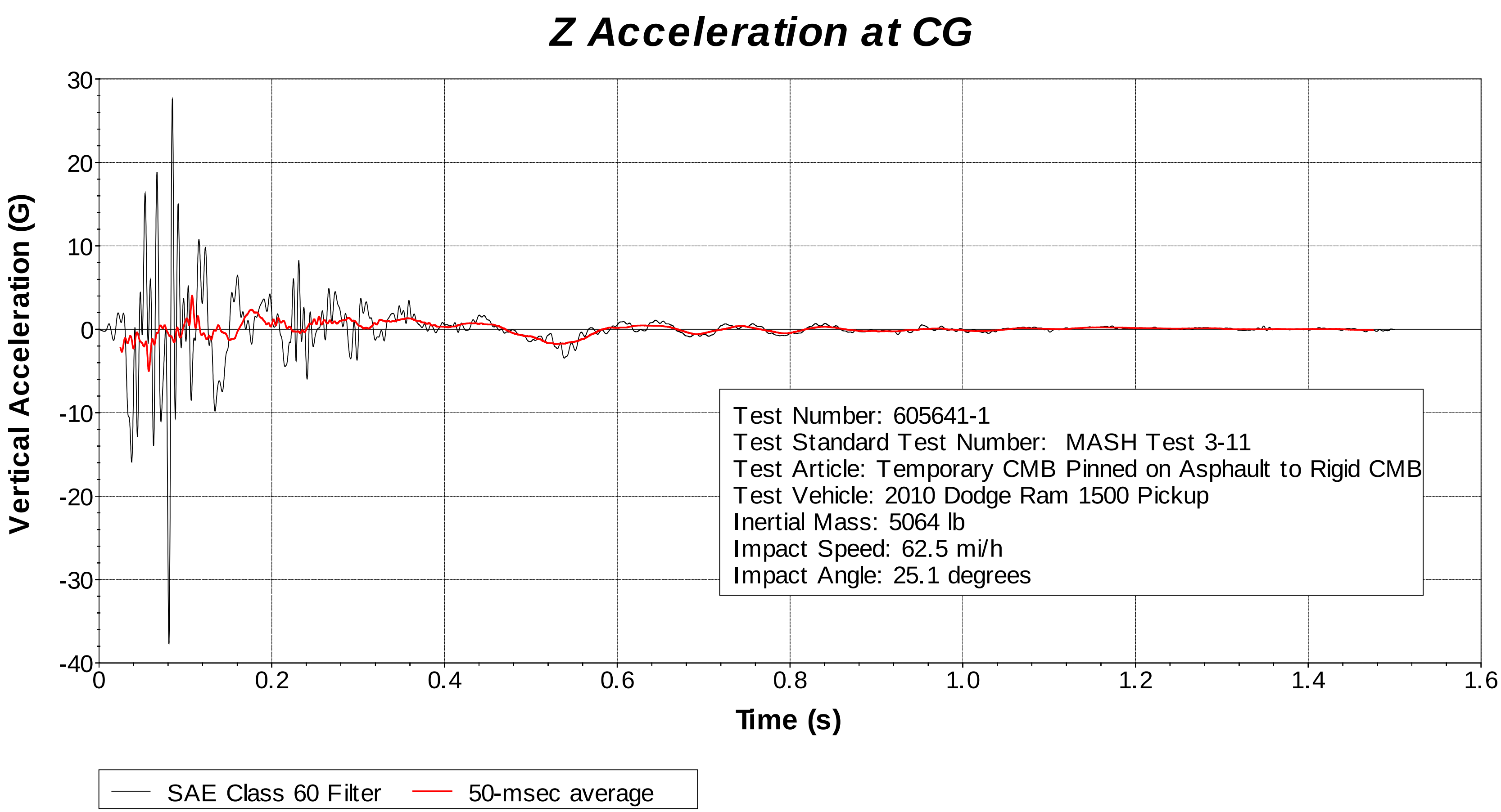


Figure C.6. Vehicle Vertical Accelerometer Trace for Test No. 605641-1 (Accelerometer Located at Center of Gravity).

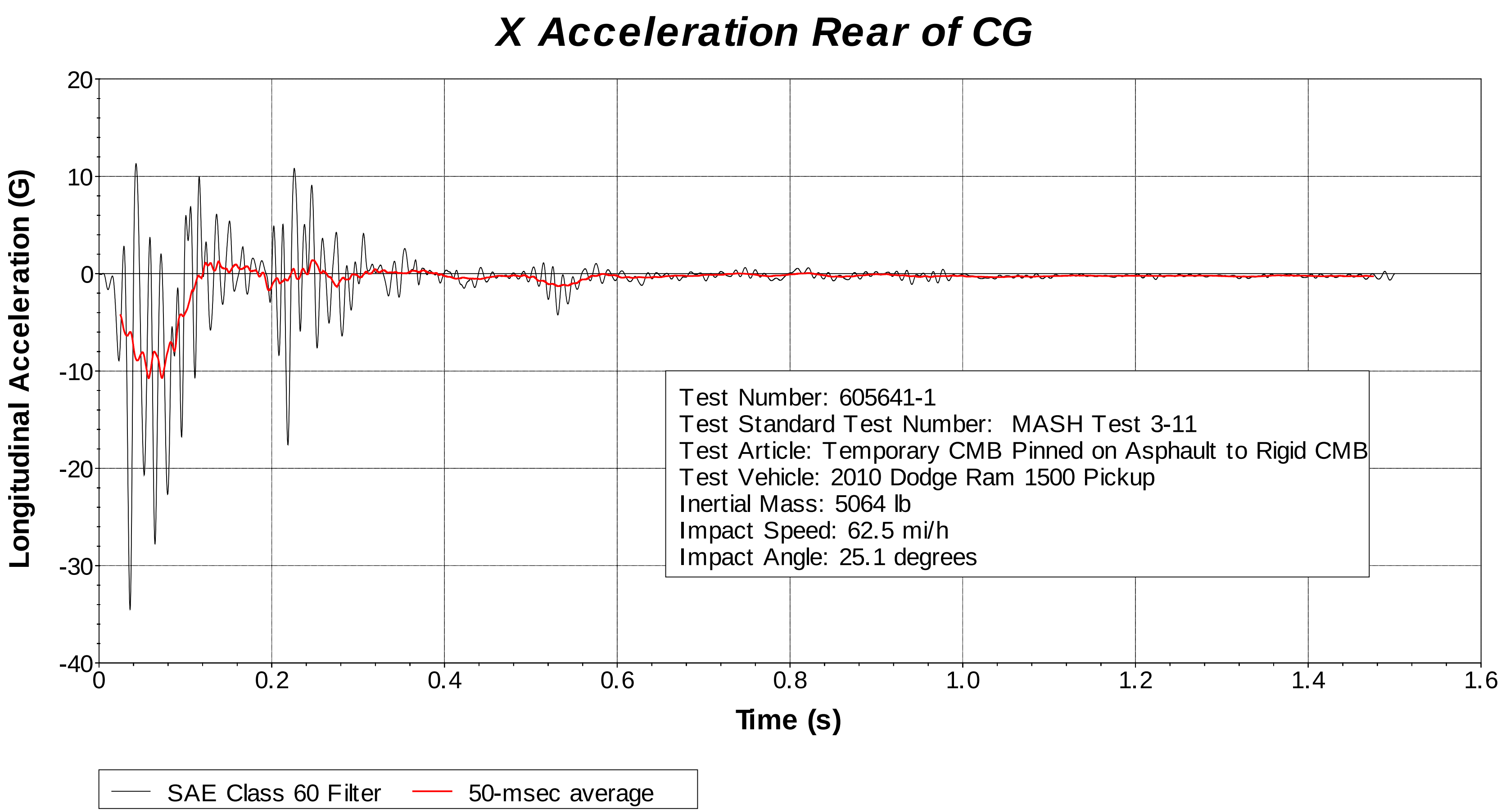


Figure C.7. Vehicle Longitudinal Accelerometer Trace for Test No. 605641-1 (Accelerometer Located Rear of Center of Gravity).

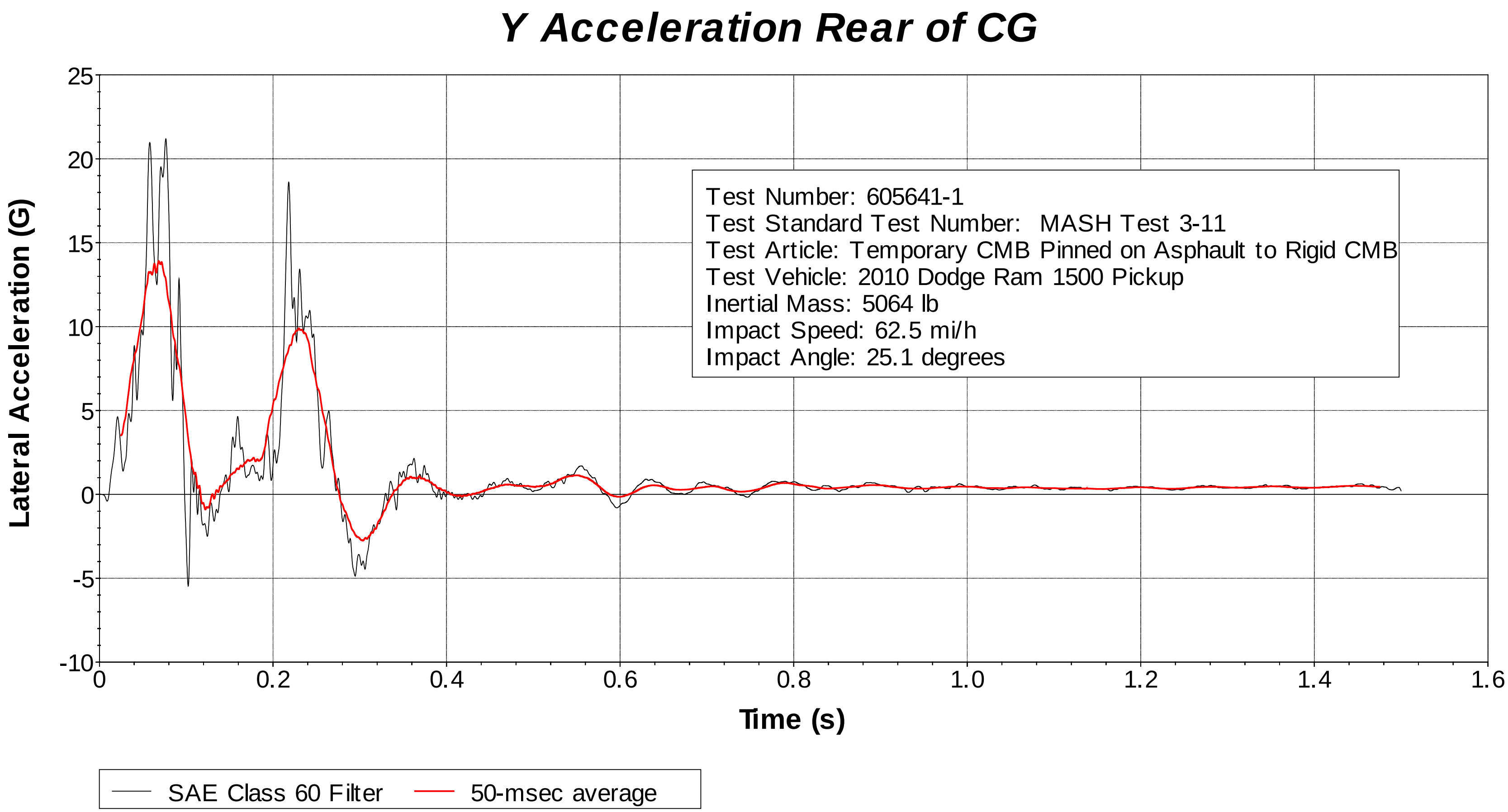


Figure C.8. Vehicle Lateral Accelerometer Trace for Test No. 605641-1 (Accelerometer Located Rear of Center of Gravity).

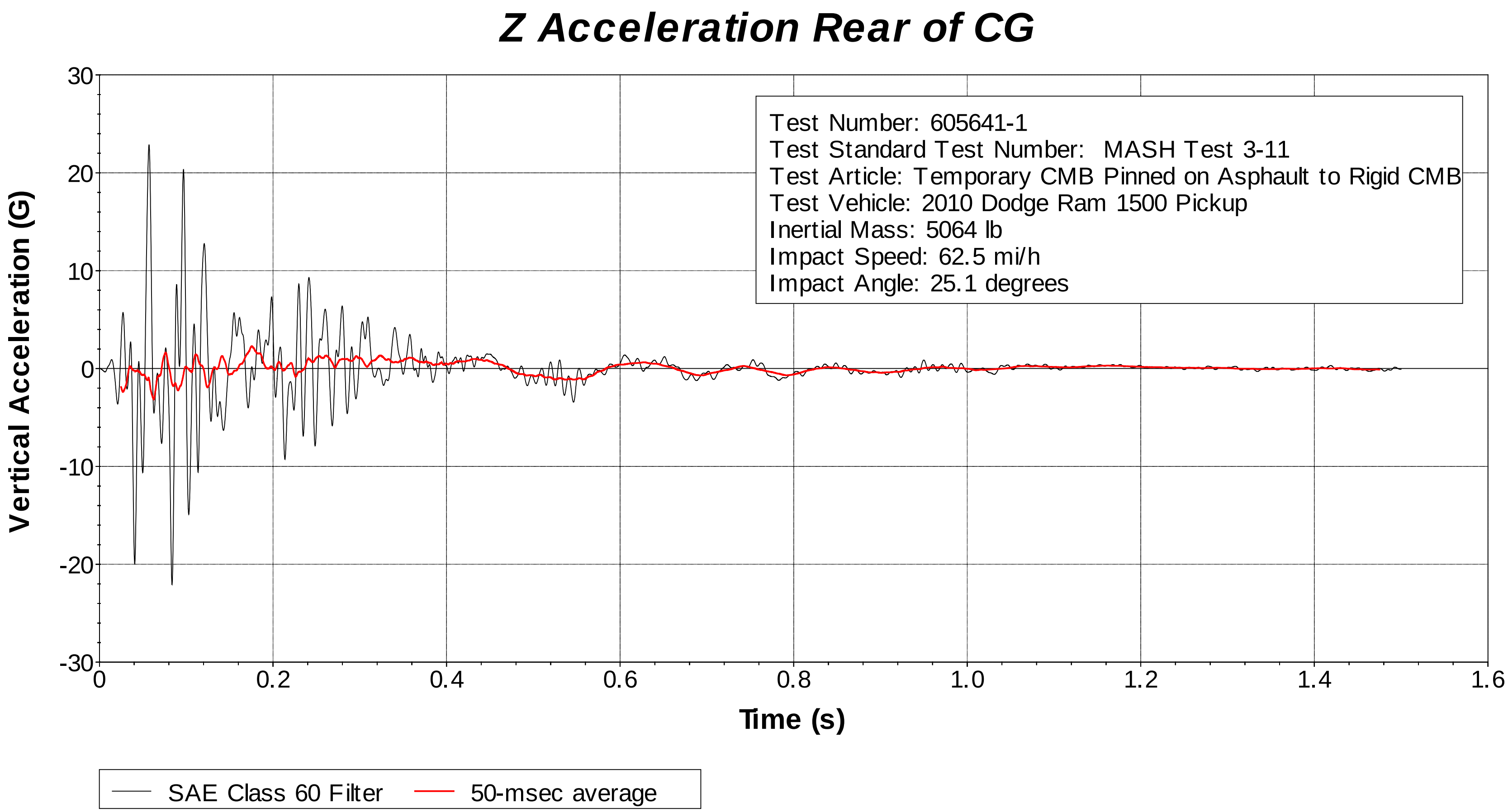


Figure C.9. Vehicle Vertical Accelerometer Trace for Test No. 605641-1 (Accelerometer Located Rear of Center of Gravity).