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TECHNICAL MEMORANDUM

Contract No.: **T4541-CC**
Test Report No.: **604581-1**
Project Name: **Full-Scale MASH Crash Testing of Stacked W-Beam Transition for 31-inch Guardrail**
Sponsor: **Roadside Safety Research Program Pooled Fund**

DATE: **May 11, 2016**

TO: **John P. Donahue, P.E.**
Pooled Fund Technical Representative

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SUMMARY REPORT:

DISCLAIMER:

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the data, findings and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Roadside Safety Research Program Pooled Fund, Texas A&M University, or Texas A&M Transportation Institute (TTI). This report does not constitute a standard, specification, or regulation. In addition, the above listed company/agencies assume no liability for its contents or use thereof. The names of specific products or manufacturers listed herein do not imply endorsement of those products or manufacturers. The results reported herein apply only to the article being tested. The test was performed according to TTI Proving Ground quality procedures and according to quality system procedures and the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*).

INTRODUCTION

The objective of this study was to investigate the crashworthiness of a stacked W-beam guardrail transition design for use with a 31-inch guardrail system. The transition's crashworthiness was evaluated according to *MASH* criteria. The full-scale crash test was conducted according to *MASH* Test 3-21. The test employed a 2270P vehicle (pickup truck) impacting the test article at the critical impact point (CIP) at an impact speed of 62 mi/h and 25-degree impact angle.

TEST ARTICLE DESIGN AND CONSTRUCTION

General Test Configuration

The overall length of the test installation was 100 ft-8 inches. The installation was comprised of a 31-inch tall 12 gauge W-beam guardrail attached to a 32-inch tall, 16 ft long cast-in-place concrete bridge deck parapet wall on the downstream end, and a Trinity SoftStop® guardrail terminal on the upstream end (posts A, 1, and 2). Measuring from the upstream end of the test installation, the post centerline spacing was as follows: 4 ft-7 inches from terminal anchor post A to post 1; 5 ft-8 inches from post 1 to post 2; 6 ft-3 inches for each of posts 3 through 11, for a total of 56 ft-3 inches; 3 ft-1½ inches for each of posts 12 through 15 for a total of 12 ft-6 inches; 1 ft-6¾ inches for each of posts 16, 17, and 18, for a total of 4 ft-8¼ inches; and 7 inches from the centerline of post 18 to the end face of the concrete parapet. Additionally, a nested 12 gauge W-beam rub rail was installed between grade and the upper W-beam from post 13 to the concrete parapet. The system was installed just off the edge of an out of service runway at an angle of approximately 10 degrees from the edge to allow for sufficient lateral width for the tow system. Overall installation details are shown in Sheets 1 and 2 of 10 in Attachment A Figure A.1.

Bridge Deck Parapet with F-Shape on Downstream End

The reinforced concrete bridge deck F-shape parapet was 32 inches tall, 15½ inches wide at the base, and 8 inches wide at the top. The parapet had an F-shape profile on the traffic side over the most downstream 5 ft-6 inches. The upper slope was 6½ degrees from vertical; the lower slope was 35½ degrees from vertical, and it had a 3-inch high vertical toe at the base. The most upstream 3 ft section of the parapet, onto which the W-beam guardrail and rub rail were attached was 32 inches tall and 8 inches thick with a flat vertical face on both the traffic and field sides. The upstream, traffic side corner was chamfered at 45-degrees over a 3-inch length. The middle 7 ft-6 inch section of the parapet contained a linear transition on the traffic side from the upstream vertical flat face to the downstream F-shape face. The field side was a vertical flat surface for the length of the parapet. The field side of the parapet was located 6 inches inward from the field side edge of the foundation. The traffic side face at the top of the parapet measured approximately 24 inches from the edge of the runway at the downstream end, and 58 inches at the upstream end.

Parapet reinforcement consisted of six longitudinal #5 bars (⅝-inch nominal diameter) spaced in pairs at 11 inches along the height of the parapet within the vertical reinforcement. Vertical parapet reinforcement consisted of eight #5 rebar "T" stirrups spaced at 8 inches along the length of the F-shape section. In the transition section, eleven #5 rebar "U" stirrups were evenly spaced at 8 inches. In the upstream vertical section, nine #5 rebar "U" stirrups were evenly spaced at 4 inches. The parapet was secured to the foundation with 32 #4 (½-inch nominal diameter) rebar "L" bent-leg stirrups equally spaced at 6 inches along the length of the parapet. Each bent-leg was secured to the bottom mat of the foundation reinforcement.

Concrete cover was approximately 1½ inches on the top and sides of the parapet. See Sheets 5-9 of 10 in Attachment A for details.

To accommodate the W-beam terminal connector end shoes (type RWE02b, shown in Attachment A Figure A.2), eight lengths of 1-inch schedule 40 PVC pipe were cast into the upstream end of the vertical parapet section. Two sets of the four-pipe arrays were horizontally located 24 inches from the end of the parapet, and vertically located at 10⅞ inches and 24⅞ inches above grade/top of the foundation. The fifth hole on each end shoe was not utilized. See Sheet 4 of 10 in Attachment A Figure A.1 for details.

Bridge Deck and Parapet Foundation

The parapet was cast over a reinforced concrete foundation that measured 16 ft long × 18 inches thick, and tapered from 6 ft wide on the upstream end to 3 ft-2⅛ inches wide on the downstream end to achieve the 10 degree offset from the runway. Longitudinal reinforcement of the concrete foundation in the top mat was comprised of seven #4 bars laterally spaced 9 inches apart. Longitudinal reinforcement in the bottom mat consisted of six #5 bars laterally spaced 12 inches apart. Lateral reinforcement (perpendicular to the parapet) consisted of 32 #5 bars spaced on 6-inch centers in the top mat and 12 #5 bars spaced on 18-inch centers in the bottom mat. The top and bottom mats were vertically spaced approximately 13 inches apart. Concrete cover was approximately 1½ inches on the top of the foundation and 3 inches on the bottom and sides.

The concrete foundation was secured to the adjacent unreinforced concrete runway using eleven #5 bars that were each 24 inches long. These #5 bars were spaced on approximately 18-inch centers and were installed horizontally in, and perpendicular to, the face of the runway edge. These dowel bars were secured in drilled holes located 3 inches from the top surface of the runway with a minimum 6 inches embedment using Hilti HT200 epoxy in accordance with manufacturer's instructions. See Sheets 5-9 of 10 in Attachment A Figure A.1.

W-Beam Guardrail

The top of the W-beam was 31 inches above grade, and guardrail splices were located mid-span between every other post with the exception of a bolted splice being located at post 13 due to the reduced post spacing. Standard 12-gauge W-beam guardrail (type RWM04a, shown in Attachment A Figure A.3) in 12 ft-6 inch long spans was used in the system with the exception of a 9 ft-4½ inch span installed from the midspan of posts 10 and 11 to post 13, and at the end terminal as noted below. The downstream end of the guardrail was secured to the parapet via a W-beam terminal connector shoe (RWE02b 10-gauge, shown in Attachment A Figure A.2) with four ⅞-inch diameter × 10-inch long ASTM A325 bolts through the aforementioned 1-inch diameter schedule 40 PVC pipes that were cast into the concrete parapet. Two SAE hardened washers and a heavy hex nut was used on the end of each bolt to complete the connection. The RWE02b shoe was connected to the end of the W-beam guardrail using eight ⅝-inch diameter × 2-inch long ASTM A307 guardrail bolts (FBB02, shown in Attachment A Figure A.4), recessed guardrail nuts, and rectangular guardrail washers (FWR03, shown in Attachment A Figure A.5).

Posts 2 to 11 were equally spaced at 6 ft-3 inches, posts 11 to 15 were spaced at 3 ft-1½ inches, and posts 15 to 18 were spaced at 18¾ inches each.

Posts 3 through 14 were 72-inch long W6×8.5 wide flange guardrail posts (PWE01, shown in Attachment A Figure A.6). Posts 15 and 16 were modified PWE01 posts in that there was one additional $^{13}/_{16}$-inch diameter hole located 21 inches from the top and offset 1⅛ inches from the web centerline in one traffic side flange to accommodate the rubrail. Posts 17 and 18 were special transition posts made from 90-inch long W8×13 steel sections with two sets of $^{13}/_{16}$-inch diameter holes located 7 inches and 21 inches from the top, and offset 1⅛ inches from the web centerline in the traffic side flanges. All posts were installed in 2-ft diameter holes drilled into native soil, and backfilled with Type A grade 1 crushed limestone road base. See Sheet 3 of 10 in Attachment A Figure A.1 for details.

Guardrail offset for posts 2 to 18 was accomplished by use of 14-inch tall × 6-inch wide × 7⅞-inch deep (nominal) wood offset blocks (type PDB01a, shown in Attachment A Figure A.7) attached with standard 10-inch long FBB03 guardrail bolts and recessed nuts. See Sheets 1-3 of 10 in Attachment A Figure A.1 for details.

W-Beam Rubrail

A nested W-beam rubrail consisting of a single 4-space RWM04a rail section backed with a partial RWM04a section was installed on posts 13 through 18 and terminated on the parapet. The nested rubrail was positioned between the 31-inch high guardrail and grade at a centerline elevation of 10⅞ inches above grade. The nested partial rail section on the field side extended from the parapet to the mid-point between post 14 and 15 for a fabricated overall end-to-end length of 8 ft-4 inches. The downstream end of the rubrail and field side nested partial rail were attached to the parapet with a single W-beam terminal connector shoe (RWE02b) in a similar manner as that of the W-beam guardrail above. The upstream end of the rubrail was installed on the field side of post 13 and secured with one ⅝-inch × 6-inch long carriage bolt and a FBB02 recessed guardrail nut through a hole in the post flange. Modified 14-inch tall × 6-inch wide type PDB01a wood offset blocks of varying depth were attached to posts 15 through 18 (see Sheet 3 of 10 in Attachment A). Each of these blocks were attached to their respective post with a ⅝-inch × 5-inch, 7-inch, or 8-inch long (as appropriate) carriage bolt and a FBB recessed guardrail nut. Post 14 did not have an offset block for the nested rubrail. The carriage bolts did not attach the nested rubrail to the offset blocks and posts at posts 16, 17, and 18. However, the nested rubrail was secured to post 15 with the aforementioned carriage bolt and nut. See Sheets 1-3 of 10 in Attachment A Figure A.1 for rubrail details.

End Terminal

The upstream end of the installation was comprised of a Trinity SoftStop® guardrail end terminal. The upstream end point of this installation was considered to be at the W-beam splice between posts 2 and 3. This point corresponded to a distance of 13 ft 4½ inches from the centerline of end terminal anchor post A. The spacing between end terminal anchor post A and post 1 was 55 inches, and the post 1 to post 2 spacing was 68 inches. Refer to Sheet 10 of 10 in Attachment A Figure A.1 for details of the end terminal.

Figure 1 shows the transition installation before the full-scale crash test. Detailed drawings are included in Attachment A.

MATERIAL SPECIFICATIONS

The minimum compressive strength of the concrete for the concrete parapet and foundation was specified as 5000 psi. The compressive strength for the foundation slab on the day of the test was 6147 psi at 43 days of age (cast on December 16, 2015), and compressive strength for the parapet was 6739 psi at 41 days of age (cast on December 18, 2015).

TEST DESIGNATION AND ACTUAL TEST CONDITIONS

MASH test 3-21 involves a 2270P vehicle weighing 5000 lb ±100 lb and impacting the guardrail at an impact speed of 62.2 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees.

Parametric finite element computer simulations were developed to investigate the critical impact point based on occupant risk and vehicle snagging probability against the vertical parapet. The target impact point was 5 ft-7 inches from end of concrete parapet. The 2010 Dodge Ram 1500 pickup truck used in the test weighed 5005 lb and the actual impact speed and angle were 64.0 mi/h and 25.0 degrees, respectively. The actual impact point was 6 ft-4 inches. Target impact severity (IS) was 106 kip-ft, and actual IS was 122 kip-ft.

Figure 1. Stacked W-Beam Transition before Test No. 604581-1.

SOIL AND/OR WEATHER CONDITIONS

The crash test was performed the morning of January 18, 2016. Weather conditions at the time of testing were: Wind speed: 6 mi/h; wind direction: 207 degrees with respect to the vehicle (vehicle was traveling in a northwest direction); temperature: 57°F; relative humidity: 47 percent.

TEST VEHICLE

A 2010 Dodge Ram 1500 pickup truck was used for the crash test. Test inertia weight of the vehicle was 5005 lb, and its gross static weight was 5005 lb. The height to the lower edge of the vehicle front bumper was 10.75 inches, and the height to the upper edge of the front bumper was 27.5 inches. The height to the center of gravity was 28.25 inches. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

BRIEF TEST DESCRIPTION

The 2010 Dodge Ram 1500 pickup truck, traveling at an impact speed of 64.0 mi/h, impacted the transition 6 ft-4 inches upstream of the end of the concrete parapet at an impact angle of 25.0 degrees. At 0.002 s, post 15 began to deflect toward the field side, and at 0.008 s, post 16 began to deflect toward the field side. Posts 17 and 18 began to deflect toward the field side at 0.016 s and 0.021 s, respectively. At 0.024 s, post 14 began to deflect toward the field side, and at 0.036 s, the vehicle began to redirect. The right front corner of the bumper reached the end of the concrete parapet at 0.049 s, and the right front door of the vehicle dislodged and began to open at 0.054 s. The vehicle began to travel parallel with the installation at 0.176 s, and the rear of the vehicle contacted the installation at 0.192 s. At 0.373 s, the vehicle lost contact with the installation and was traveling at an exit speed and angle of 52.4 mi/h and 5.2 degrees, respectively. Brakes on the vehicle were not applied, the vehicle rolled clockwise 90 degrees, and subsequently came to rest on its right side 215 ft downstream of impact and 40 ft toward traffic lanes.

TEST ARTICLE/COMPONENT DAMAGE

The stacked W-beam transition received minimal damage, as shown in Figure 2. The W-beam guardrail and rubrail were deformed in the impact area. Posts 15 and 16 were leaning towards the field side 2 degrees and 3 degrees off vertical, respectively, and posts 17 and 18 were leaning towards the field side 2 degrees and 1 degree off vertical, respectively. No movement was noted in the upstream anchor. Working width was 24.3 inches. Maximum permanent deformation of the W-beam guardrail was 2.5 inches at post 16. Maximum dynamic deflection during the test was 4.0 inches.

TEST VEHICLE DAMAGE

Figure 3 shows the vehicle after Test No. 604581-1. The vehicle rolled onto its right side after loss of contact with the installation. The right frame rail was deformed and the right upper ball joint broke. The front bumper, grill, hood, right front fender, right front tire and rim, right front door and glass, right rear door, right rear cab corner, right exterior bed, right rear rim, and rear bumper were also damaged. Maximum exterior crush was 17.0 inches in the side plane at the right front corner at bumper height. Maximum occupant compartment deformation was 5.0 inches in the right firewall area near the toe pan.

OCCUPANT RISK VALUES

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 19.4 ft/s at 0.098 s, the highest 0.010-s occupant ridedown acceleration (RDA) was 5.6 g from 0.098 to 0.108 s, and the maximum 0.050-s average acceleration was −10.0 g between 0.040 and 0.090 s. In the lateral direction, the OIV was 29.9 ft/s at 0.098 s, the highest 0.010-s occupant RDA was 15.0 g from 0.225 to 0.235 s, and the maximum 0.050-s average was −15.4 g between 0.042 and 0.092 s. Theoretical Head Impact Velocity (THIV) was 24.1 mi/h or 35.4 ft/s (38.8 km/h or 10.8 m/s) at 0.096 s; Post-Impact Head Decelerations (PHD) was 15.0 g between 0.225 and 0.235 s; and Acceleration Severity Index (ASI) was 1.98 between 0.065 and 0.115 s. These data and other pertinent information from the test are summarized in Figure 4.

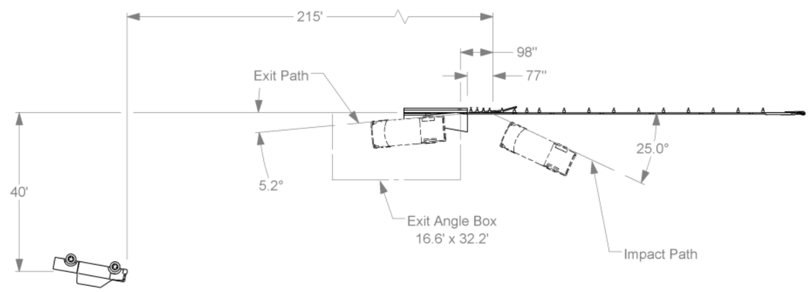
Figure 2. Stacked W-Beam Transition after Test No. 604581-1.

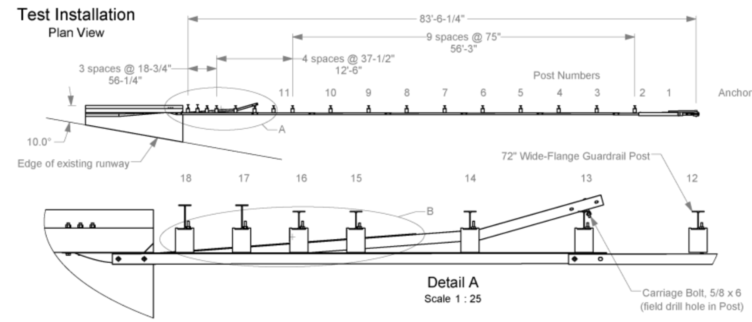
Final Rest

After Being Uprighted

Figure 3. Vehicle after Test No. 604581-1.

0.000 s | 0.120 s | 0.240 s | 0.360 s





General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-21
TTI Test No.	604581-1
Date	2016-01-28

Test Article

Type	Transition
Name	Stacked W-Beam Transition
Installation Length	100 ft-8 inches
Material or Key Elements	31-inch tall stacked W-beam transition to 32-inch tall concrete parapet wall
Soil Type and Condition	Standard AASHTO M147-65(2004) Grade B Soil, Dry

Test Vehicle

Type/Designation	2270P
Make and Model	2010 Dodge Ram 1500 Pickup Truck
Curb	4962 lb
Test Inertial	5005 lb
Dummy	No dummy
Gross Static	5005 lb

Impact Conditions

Speed	64.0 mi/h
Angle	25.0 degrees
Location/Orientation	CIP
Impact Severity	122 kip-ft

Exit Conditions

Speed	52.4 mi/h
Angle	5.2 degrees

Occupant Risk Values

Longitudinal OIV	19.4 ft/s
Lateral OIV	29.9 ft/s
Longitudinal RDA	5.6 g
Lateral RDA	15.0 g
THIV	24.1 mi/h
PHD	15.0 g
ASI	1.98
Max. 0.050-s Average	
Longitudinal	−10.0 g
Lateral	−15.4 g
Vertical	−3.9 g

Post-Impact Trajectory

Stopping Distance	215 ft dwnstrm 40 ft twd traffic

Vehicle Stability

Maximum Yaw Angle	85 degrees
Maximum Pitch Angle	5 degrees
Maximum Roll Angle	90 degrees
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	4.0 inches
Permanent	2.5 inches
Working Width	24.3 inches

Vehicle Damage

VDS	01RD4
CDC	01FROA3
Max. Exterior Deformation	17.0 inches
OCDI	RF0020000
Max. Occupant Compartment Deformation	5.0 inches

Figure 4. Summary of Results for *MASH* Test 3-21 on the Stacked W-Beam Transition.

SUMMARY AND CONCLUSIONS

The stacked W-beam 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. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present an undue hazard to others in the area. Maximum deformation of the occupant compartment was 5.0 inches in the right firewall area near the toe pan. As consequence of the impact and interaction with the test article, the roll angle of the 2270P vehicle started increasing to the point that the vehicle rolled 90 degrees onto its right side after loss of contact with the installation. Occupant risk factors were within the preferred limits specified in *MASH*.

Due to vehicle rollover, the stacked W-beam transition did not meet specifications for *MASH* Test 3-21, as shown in Table 1.

Table 1. Performance Evaluation Summary for *MASH* Test 3-21 on the Stacked W-Beam Transition.

Test Agency: Texas A&M Transportation Institute | Test No.: 604581-1 | Test Date: 2016-01-28

***MASH* Test 3-21 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy A. *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable*	The stacked W-beam 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
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.*	No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present an 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 deformation of the occupant compartment was 5.0 inches in the right firewall area near the toe pan.	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 contact with the installation; however, the vehicle rolled 90 degrees onto its right side after loss of contact with the installation.	Fail
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 OIV was 19.4 ft/s, and lateral OIV was 29.9 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 Gs, or at least below the maximum allowable value of 20.49 Gs.*	Maximum longitudinal ridedown acceleration was 5.6 g, and maximum lateral ridedown acceleration was 15.0 g.	Pass

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ATTACHMENT A: TEST ARTICLE DETAILS

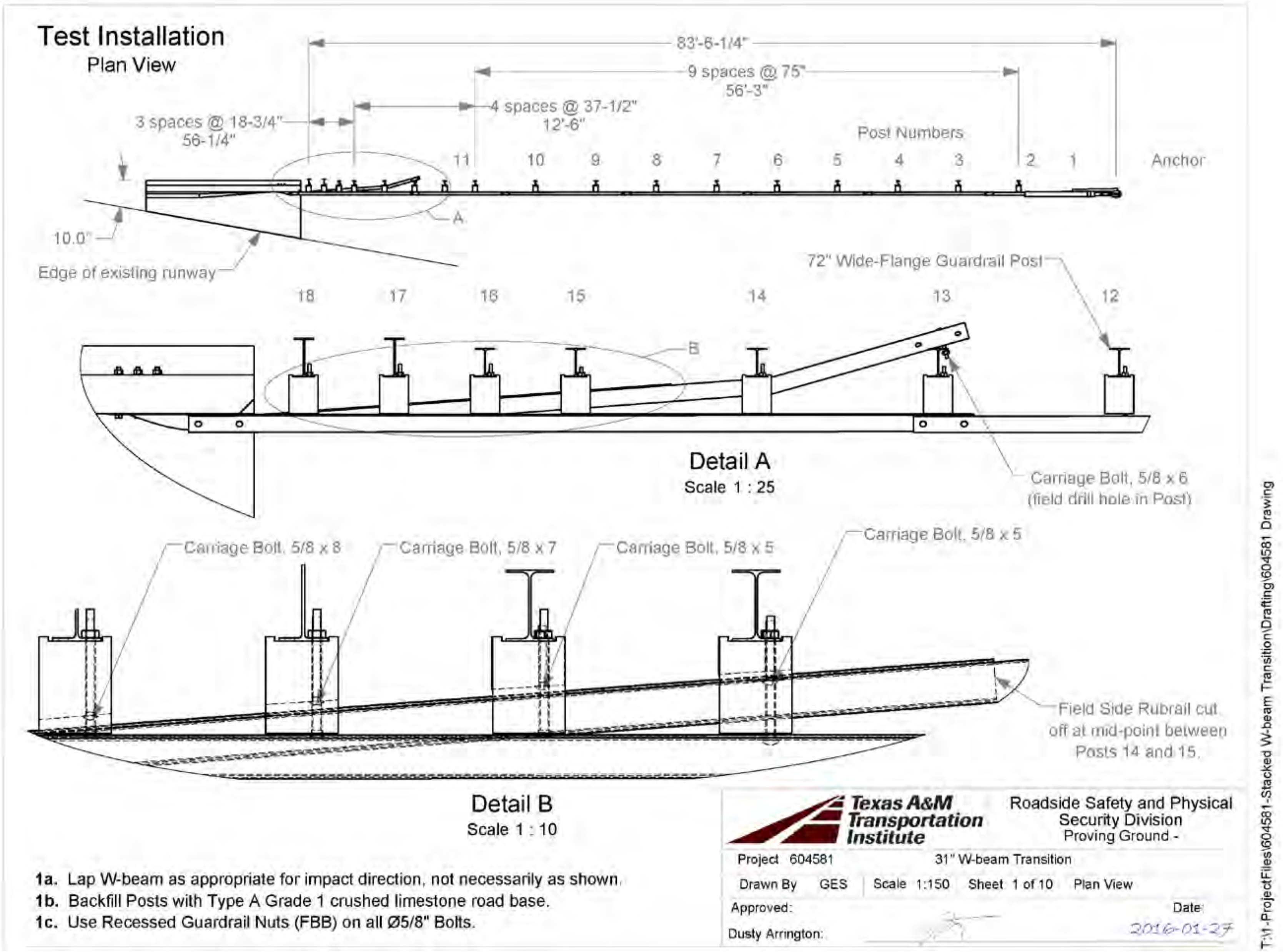


Figure A.1. Details of the 31-inch W-Beam Transition.

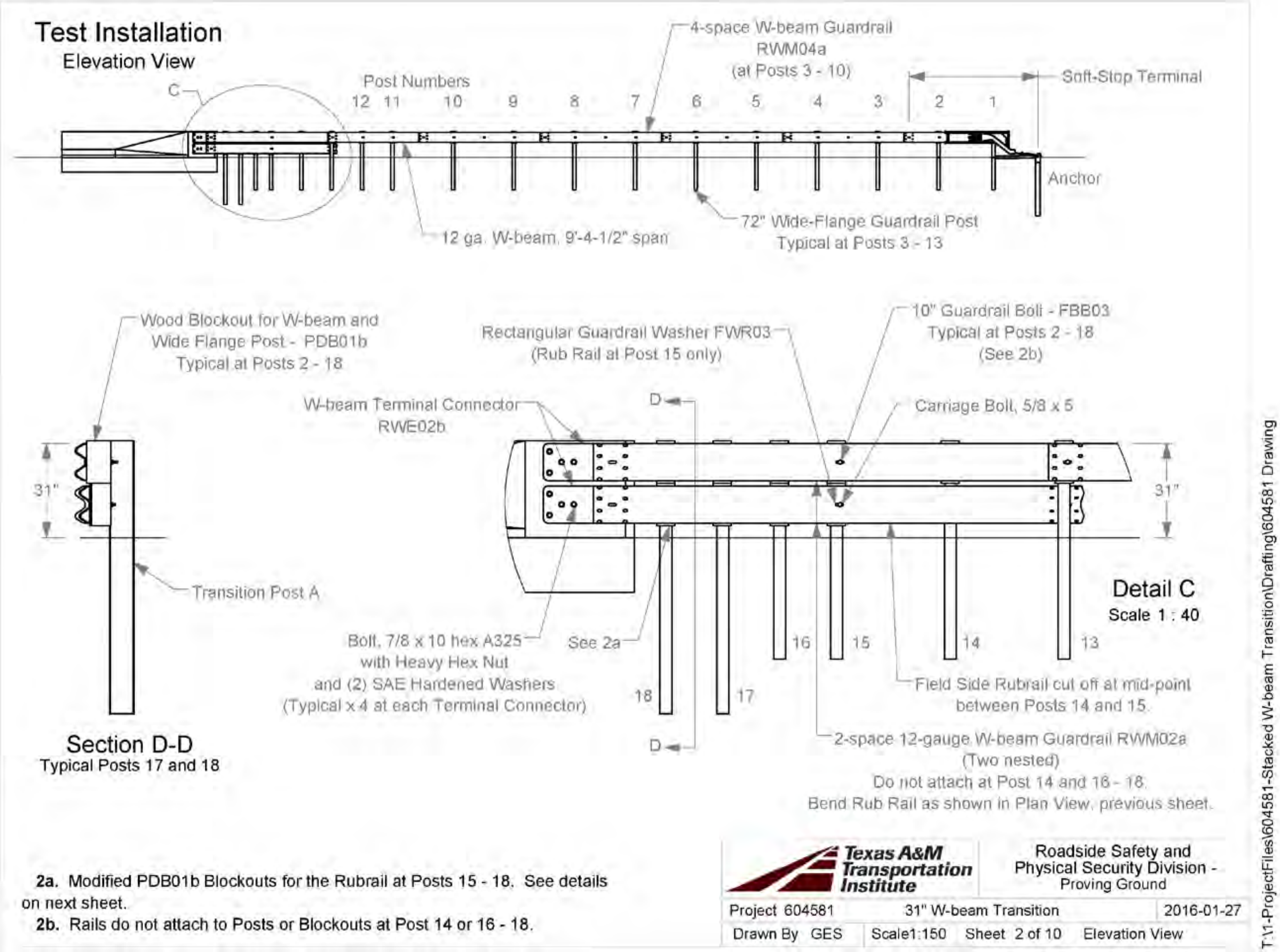


Figure A.1. Details of the 31-inch W-Beam Transition (Continued).

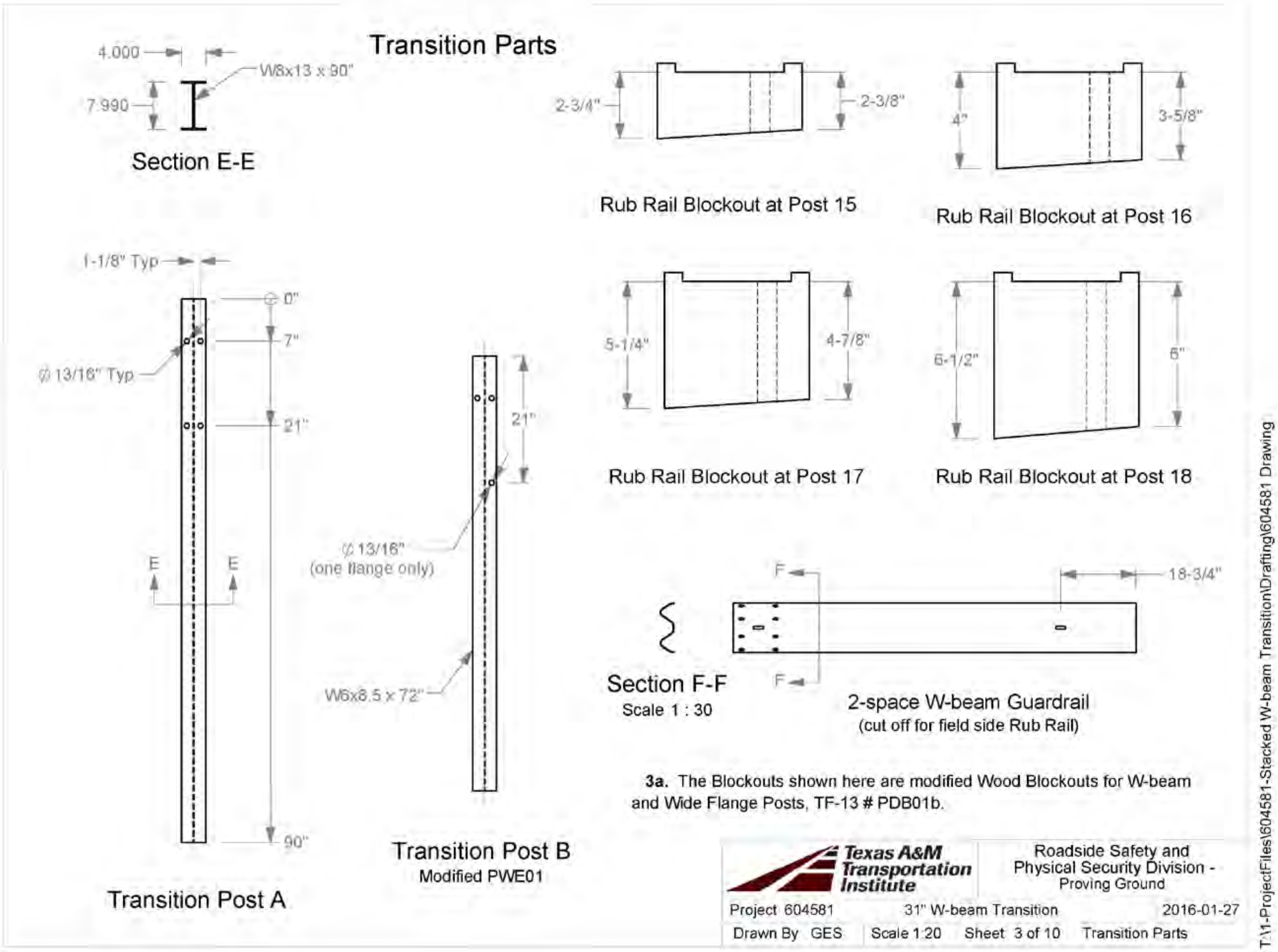


Figure A.1. Details of the 31-inch W-Beam Transition (Continued).

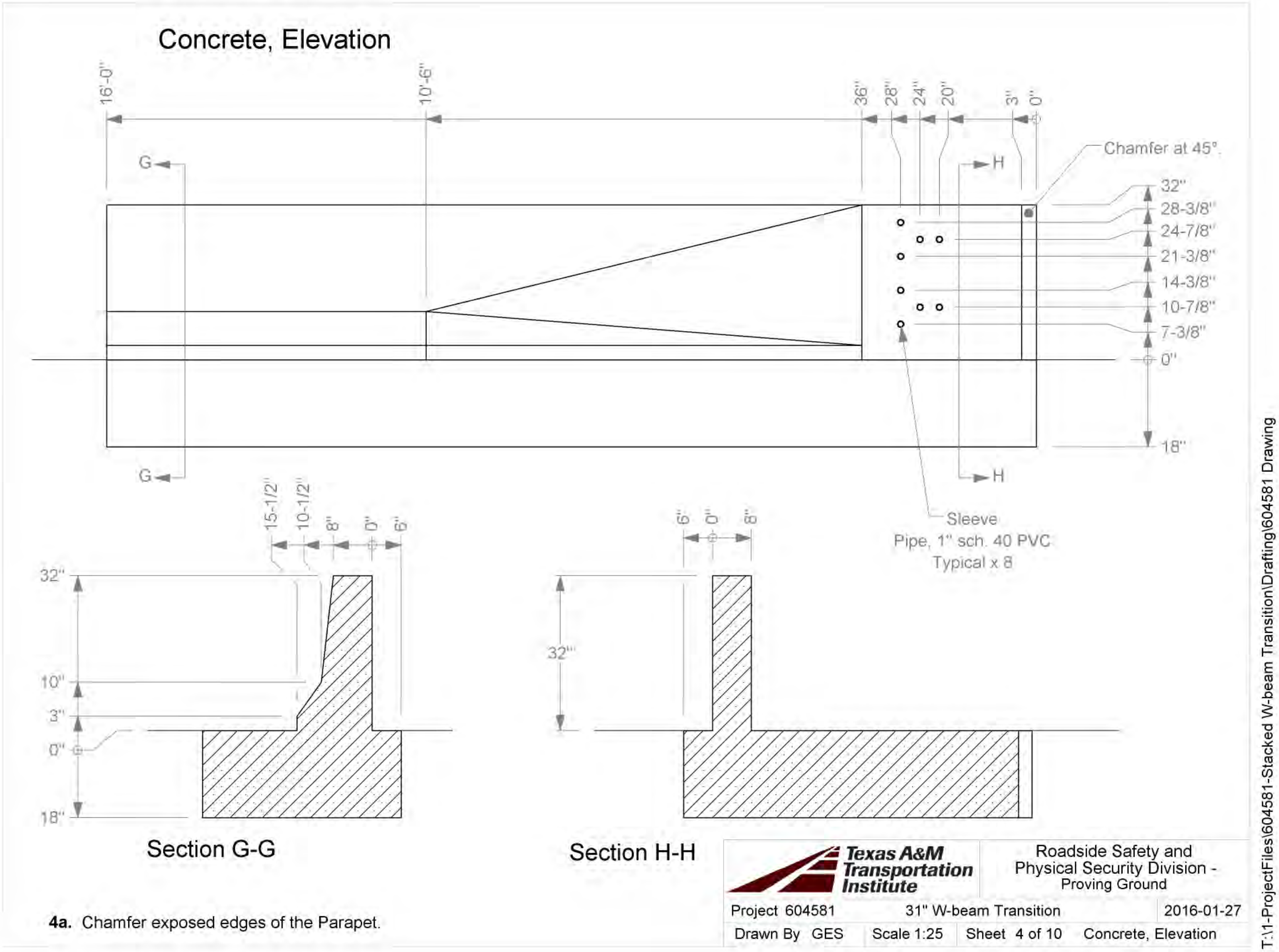


Figure A.1. Details of the 31-inch W-Beam Transition (Continued).

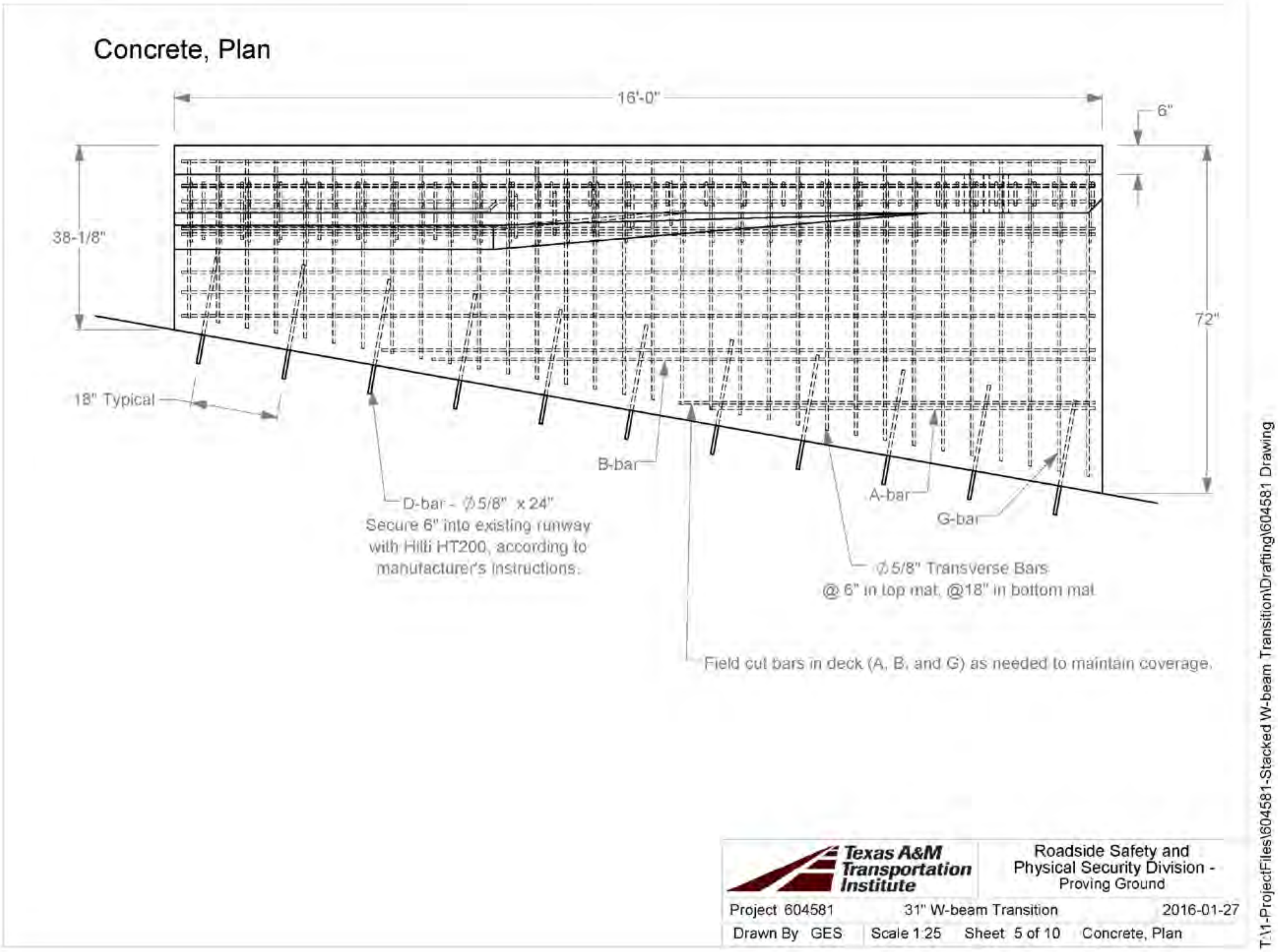


Figure A.1. Details of the 31-inch W-Beam Transition (Continued).

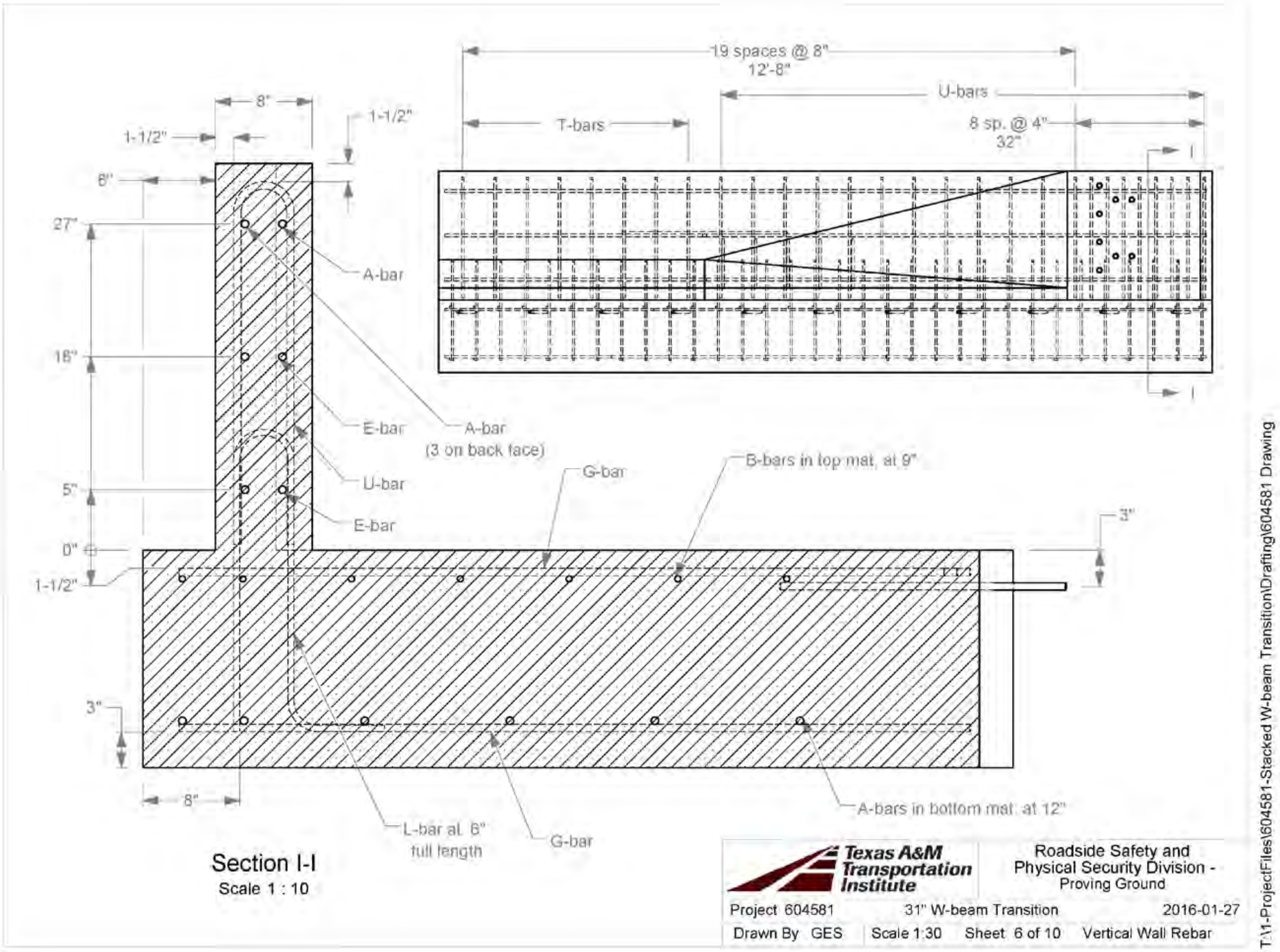


Figure A.1. Details of the 31-inch W-Beam Transition (Continued).

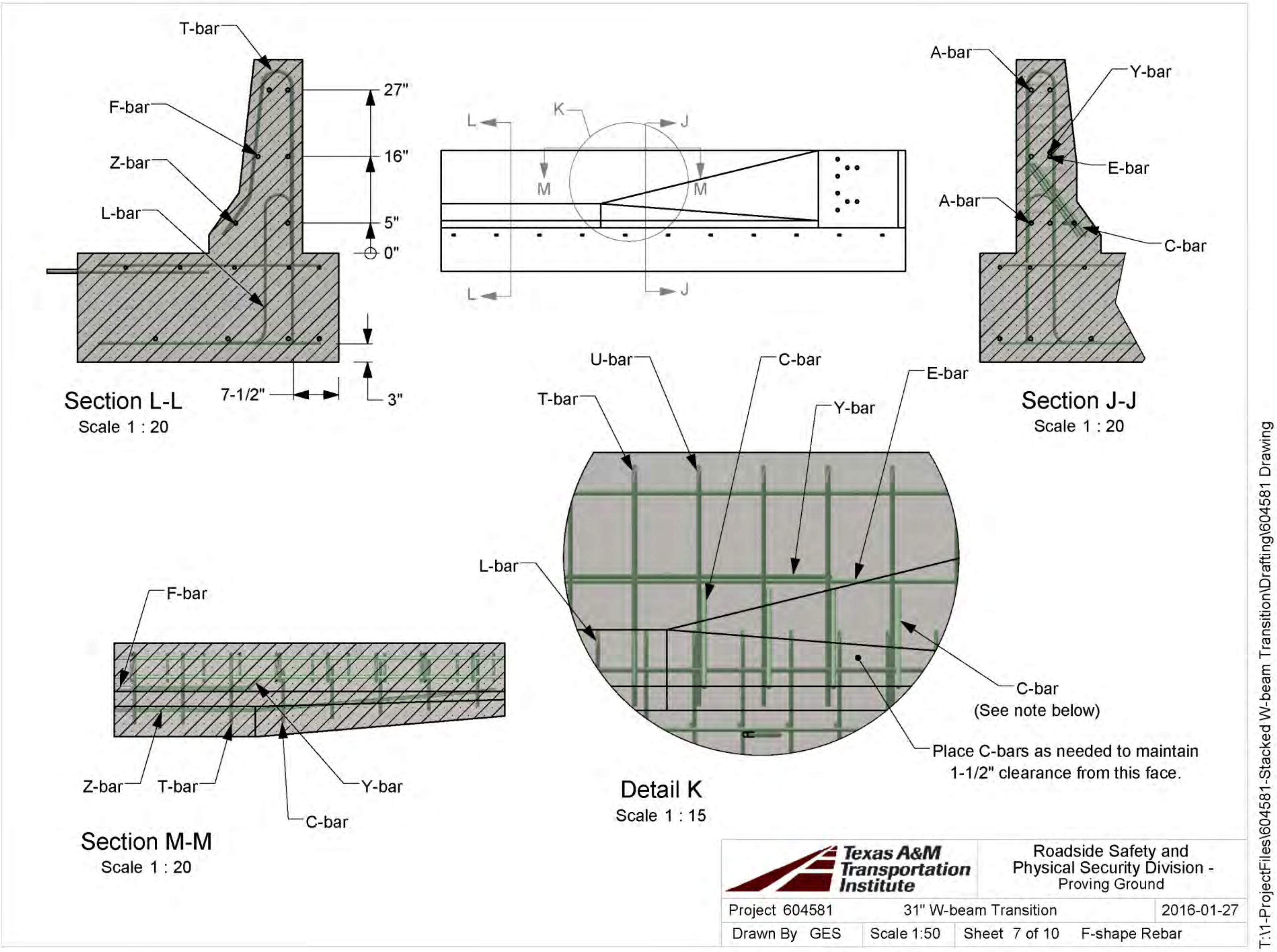
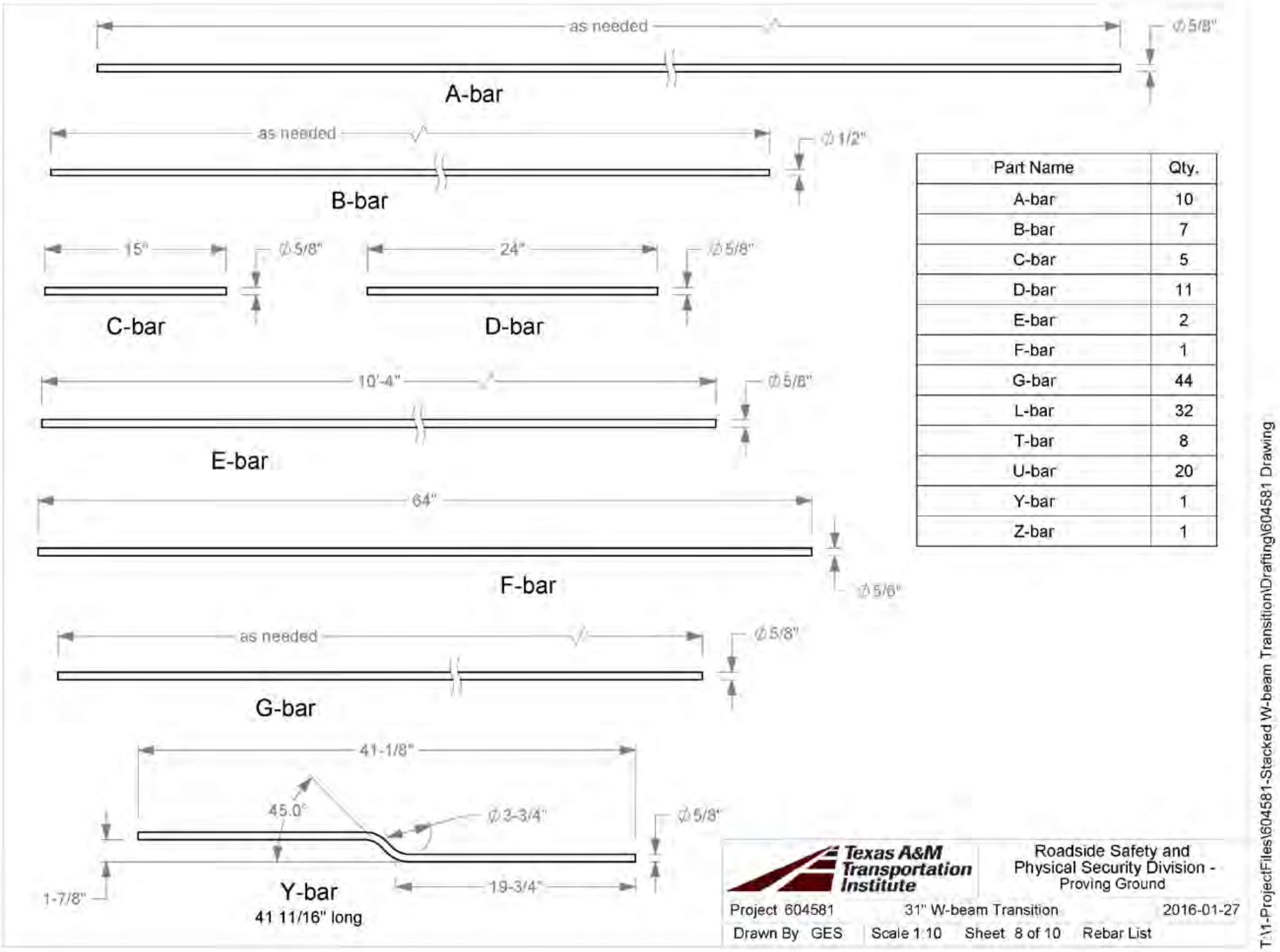


Figure A.1. Details of the 31-inch W-Beam Transition (Continued).



Part Name	Qty.
A-bar	10
B-bar	7
C-bar	5
D-bar	11
E-bar	2
F-bar	1
G-bar	44
L-bar	32
T-bar	8
U-bar	20
Y-bar	1
Z-bar	1

Figure A.1. Details of the 31-inch W-Beam Transition (Continued).

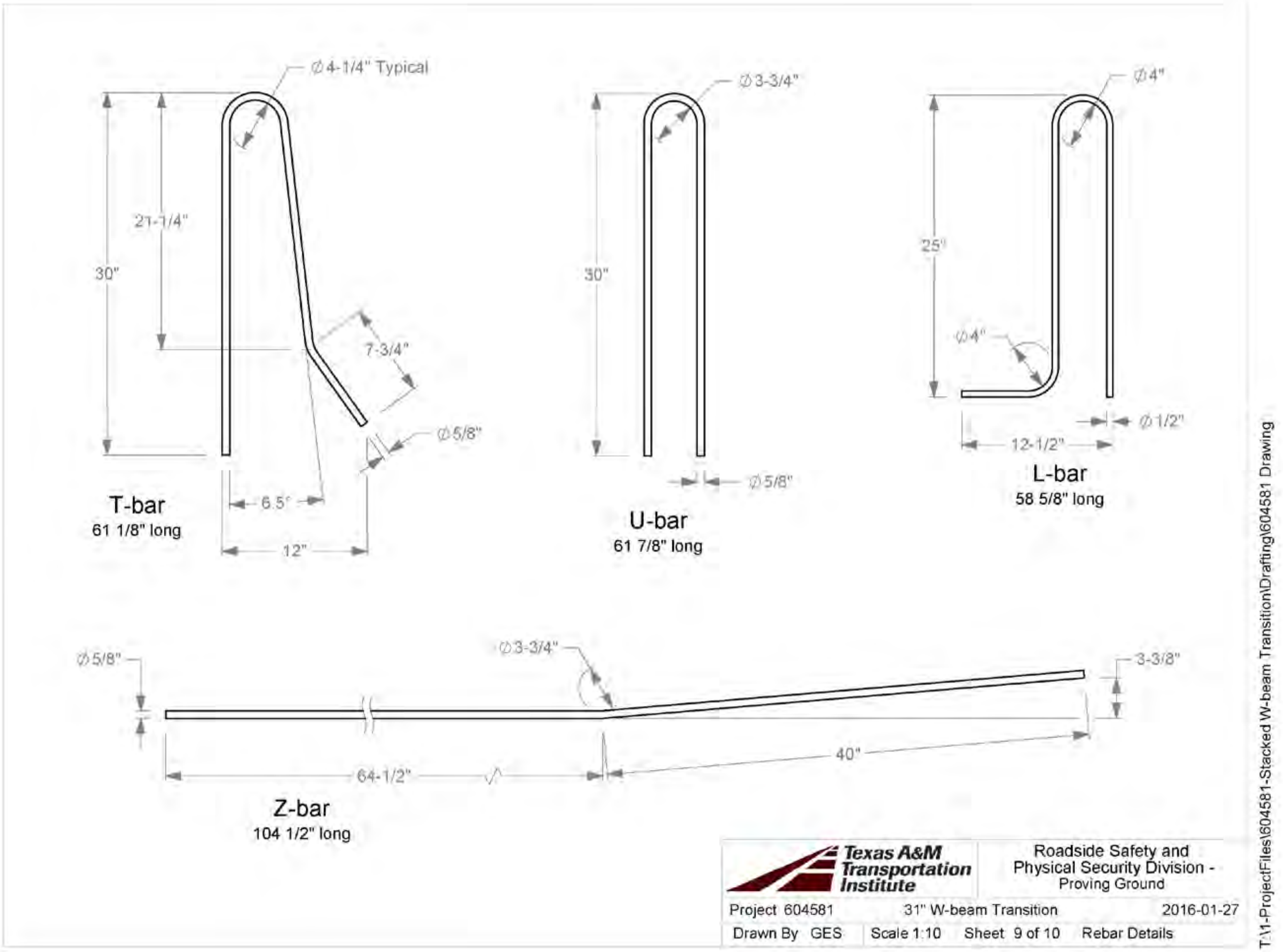


Figure A.1. Details of the 31-inch W-Beam Transition (Continued).

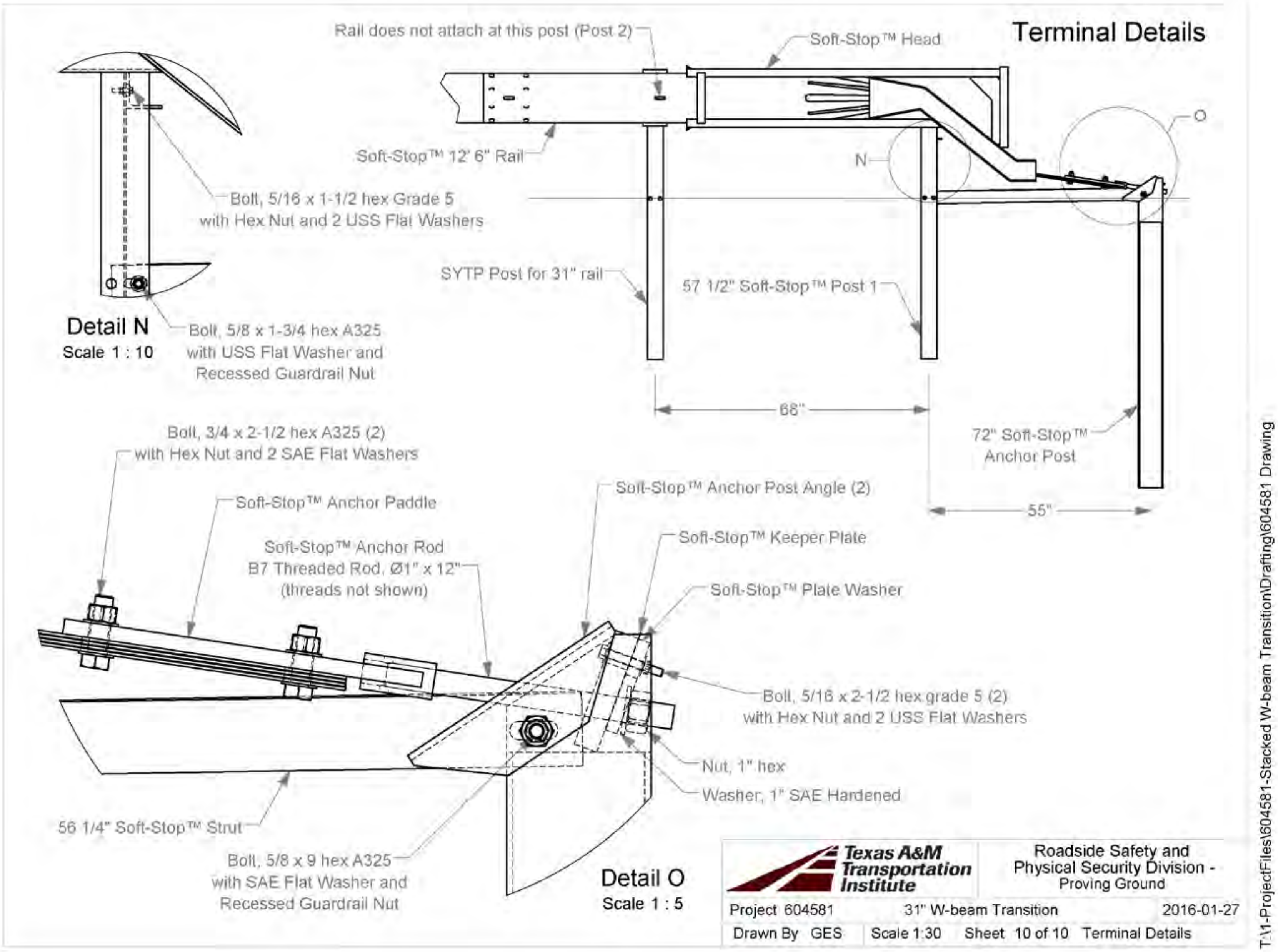


Figure A.1. Details of the 31-inch W-Beam Transition (Continued).

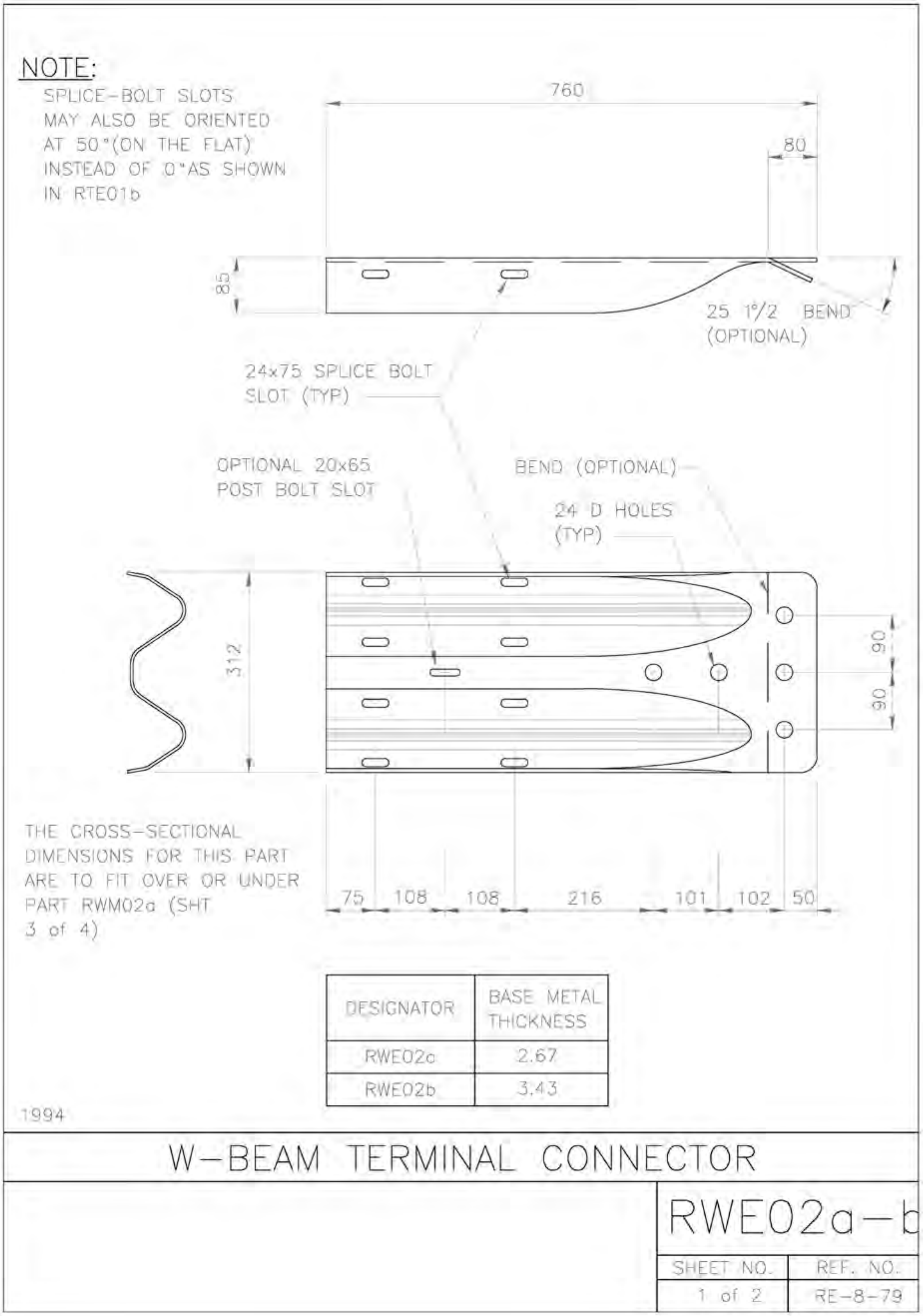


Figure A.2. TF13 Drawing RWE02a-b.

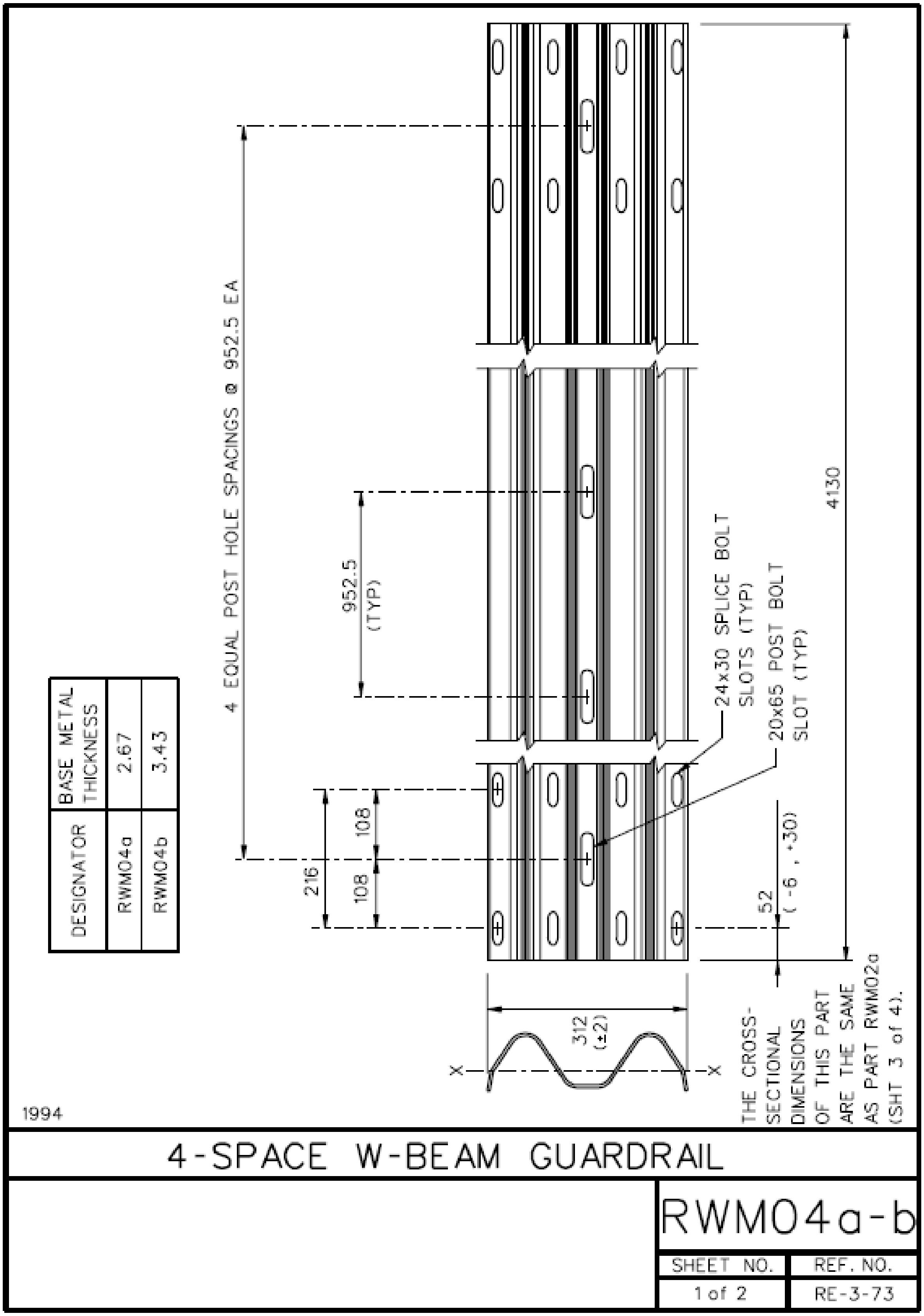
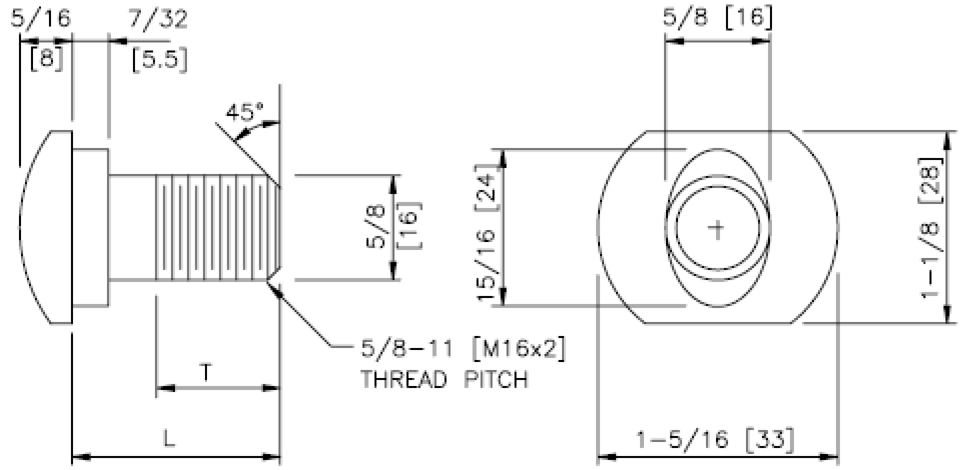
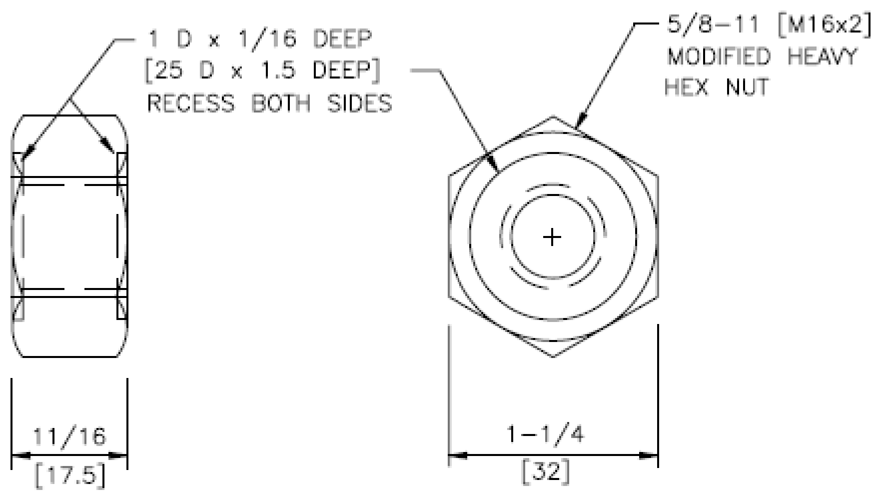


Figure A.3. TF13 Drawing RWM04a-b.

NOTES: 1. ALL FILLETS SHALL HAVE A MINIMUM RADIUS OF 1/16 [2].
2. IF THE BOLT EXTENDS MORE THAN 1/4 [6] FROM THE NUT THE BOLT SHOULD BE TRIMMED BACK.



DESIGNATOR	L	T (MIN)
FBB01	1–1/4 [35]	1–1/8 [30]
FBB02	2 [50]	1–3/4 [45]
FBB03	10 [255]	4 [100]
FBB04	18 [460]	4 [100]
FBB05	25 [640]	4 [100]



1976

GUARDRAIL BOLT AND RECESSED NUT

FBB01–05

SHEET NO.	DATE:
1 of 2	6/30/2005

Figure A.4. TF13 Drawing FBB02.

SPECIFICATIONS

The geometry and material specifications for this oval shoulder button-headed bolt and hex nut are found in AASHTO M 180. The bolt shall have 5/8-11 [M16x2] threads as defined in ANSI B1.1 [ANSI B1.13M] for Class 2A [6g] tolerances. Bolt material shall conform to ASTM A307 Grade A [ASTM F 568M Class 4.6], with a tensile strength of 60 ksi [400 MPa] and yield strength of 36 ksi [240 MPa]. Material for corrosion-resistant bolts shall conform to ASTM A325 Type 3 [ASTM F 568M Class 8.8.3], with tensile strength of 120 ksi [830 MPa] and yield strength of 92 ksi [660 MPa]. This bolt material has corrosion resistance comparable to ASTM A588 steels. Metric zinc-coated bolt heads shall be marked as specified in ASTM F 568 Section 9 with the symbol "4.6."

Nuts shall have ANSI B1.1 Class 2B [ANSI B1.13M Class 6h] 5/8-11 [M16x2] threads. The geometry of the nuts, with the exception of the recess shown in the drawing, shall conform to ANSI B18.2.2 [ANSI B18.2.4.1M Style 1] for zinc-coated hex nuts (shown in drawing) and ANSI B18.2.2 [ANSI B18.2.4.6M] for heavy hex corrosion-resistant nuts (not shown in drawing). Material for zinc-coated nuts shall conform to the requirements of AASHTO M 291 (ASTM A 563) Grade A [AASHTO M 291M (ASTM A 563M) Class 5], and material for corrosion-resistant nuts shall conform to the requirements of AASHTO M 291 (ASTM A 563) Grade C3 [AASHTO M 291M (ASTM A 563M) Class 8S3].

When zinc-coated bolts and nuts are required, the coating shall conform to either AASHTO M 232 (ASTM A 153/A 153M) for Class C or AASHTO M 298 (ASTM B 695) for Class 50. Zinc-coated nuts shall be tapped over-size as specified in AASHTO M 291 (ASTM A 563) [AASHTO M 291M (ASTM A 563M)], except that a diametrical allowance of 0.020 inch [0.510 mm] shall be used instead of 0.016 inches [0.420 mm].

Designator	Stress Area of Threaded Bolt Shank (in^2 [mm^2])	Min. Bolt Tensile Strength (kips [kN])
FBB01-05	0.226 [157.0]	13.6 [62.8]

Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

INTENDED USE

These bolts and nuts are used in numerous guardrail and median barrier designs.

GUARDRAIL BOLT AND RECESSED NUT

FBB01-05	
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Figure A.4. TF13 Drawing FBB02 (Continued).

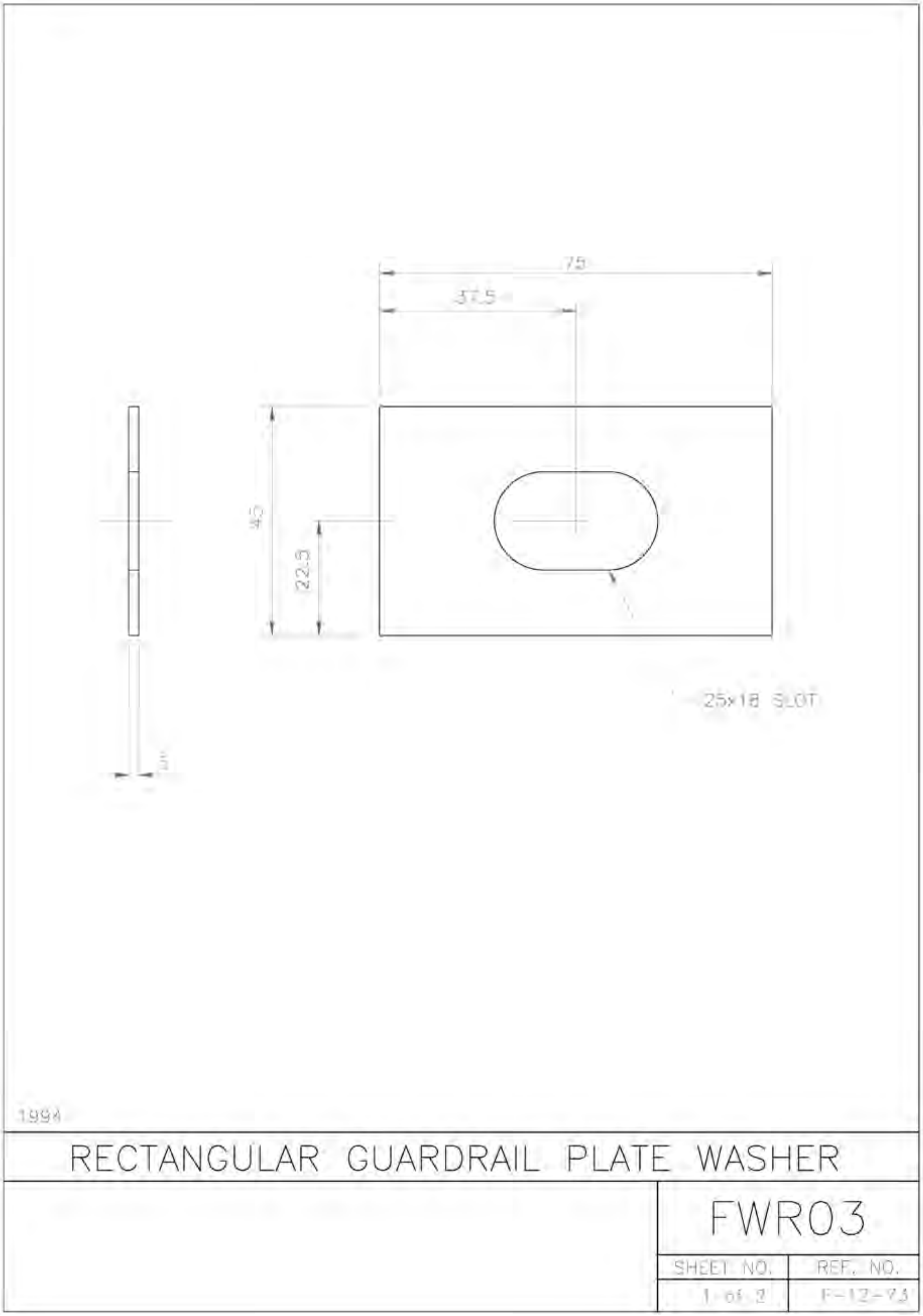
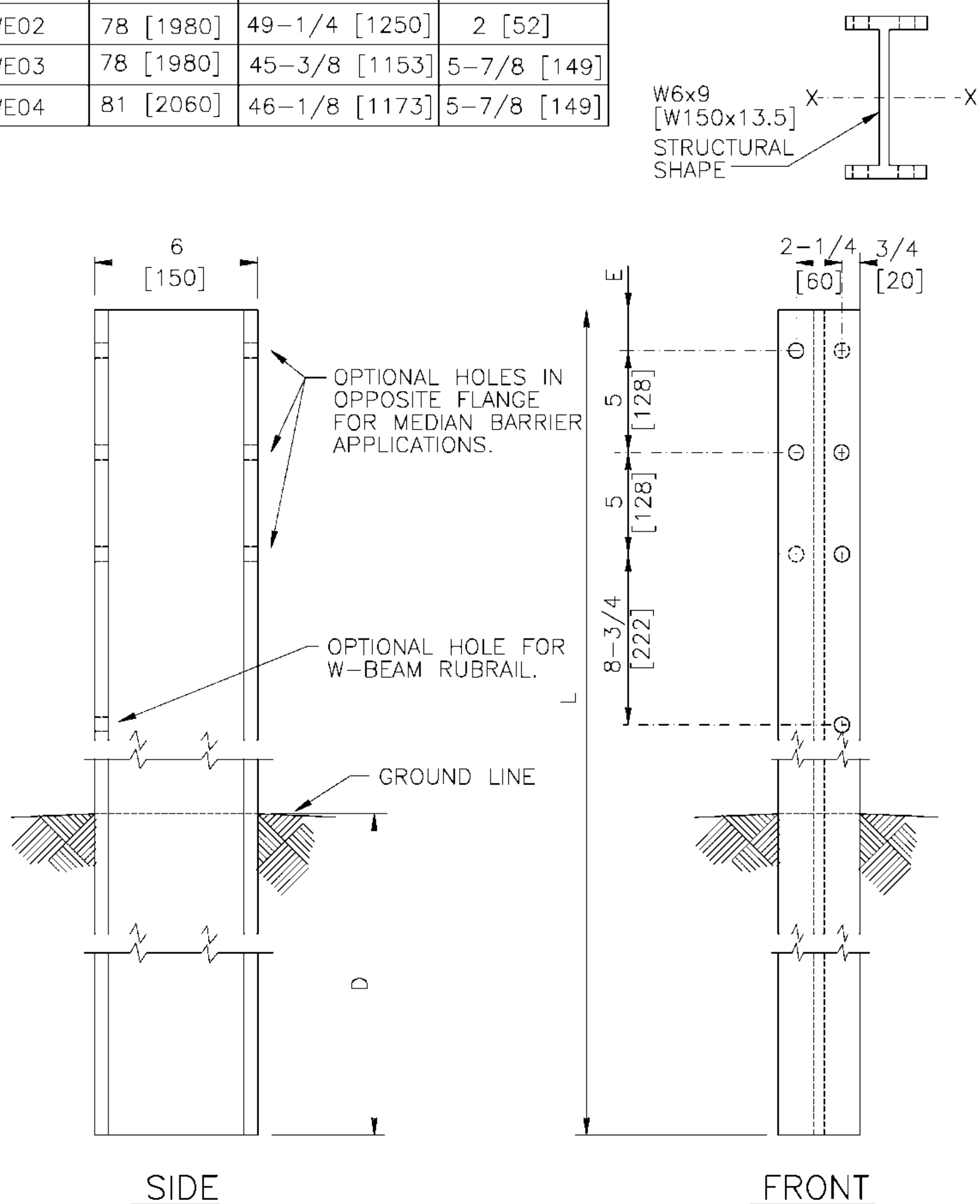


Figure A.5. TF13 Drawing FWR03.

NOTE: ALL HOLES ARE 3/4 [20] D.

DESIGNATOR	L	D	E
PWE01	72 [1830]	43-1/4 [1100]	2 [52]
PWE02	78 [1980]	49-1/4 [1250]	2 [52]
PWE03	78 [1980]	45-3/8 [1153]	5-7/8 [149]
PWE04	81 [2060]	46-1/8 [1173]	5-7/8 [149]



1994

WIDE-FLANGE GUARDRAIL POST

PWE01-04

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Figure A.6. TF13 Drawing PWE01.

SPECIFICATIONS

W-beam and thrie-beam guardrail posts shall be manufactured using AASHTO M 270 / M 270M (ASTM A 709 / A 709M) Grade 36 [250] steel unless corrosion-resistant steel is required, in which case the post shall be manufactured from AASHTO M 270 / M 270M (ASTM A 709 / A 709M) Grade 50W [345W] steel. The dimensions of the cross-section shall conform to a W6x9 [W150x13.5] section as defined in AASHTO M 160 / M 160M (ASTM A 6 / A 6M). [W150x12.6] wide flange posts are an acceptable alternative that is considered equivalent to the [W150x13.5].

After the section is cut and all holes are drilled or punched, the component should be zinc-coated according to AASHTO M 111 (ASTM A 123) unless corrosion-resistant steel is used. When corrosion-resistant steel is used, the portion of the post to be embedded in soil shall be zinc-coated according to AASHTO M 111 (ASTM A 123) and the portion above the soil shall not be zinc-coated, painted or otherwise treated.

Designator	Area in^2 [10^3 mm^2]	I_x in^4 [10^6 mm^4]	I_y in^4 [10^6 mm^4]	S_x in^3 [10^3 mm^3]	S_y in^3 [10^3 mm^3]
PWE01-04	2.63 [1.7]	16.43 [6.84]	2.19 [0.91]	5.57 [91.2]	1.11 [18.2]

Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

INTENDED USE

Posts PWE01 and PWE02 are used with the SGR04a and SGR04c guardrails and the SGM04a median barrier. Blockouts like PWB01 (steel) or PDB01 (wood) are attached to each post.

Post PWE03 is used with the SGR09a guardrail and the SGM09a median barrier. Wood or plastic blockouts like the PWB02 are attached to each post with FBB03 bolts and FWC16a washers under the nuts.

Post PWE04 is used with the SGR09b guardrail and the SGM09b median barrier. A modified steel blockout PWB03 is attached to each post with at least two 1.5-inch [40 mm] long FBX16a bolts and nuts.

WIDE-FLANGE GUARDRAIL POST

PWE01-04	
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Figure A.6. TF13 Drawing PWE01 (Continued).

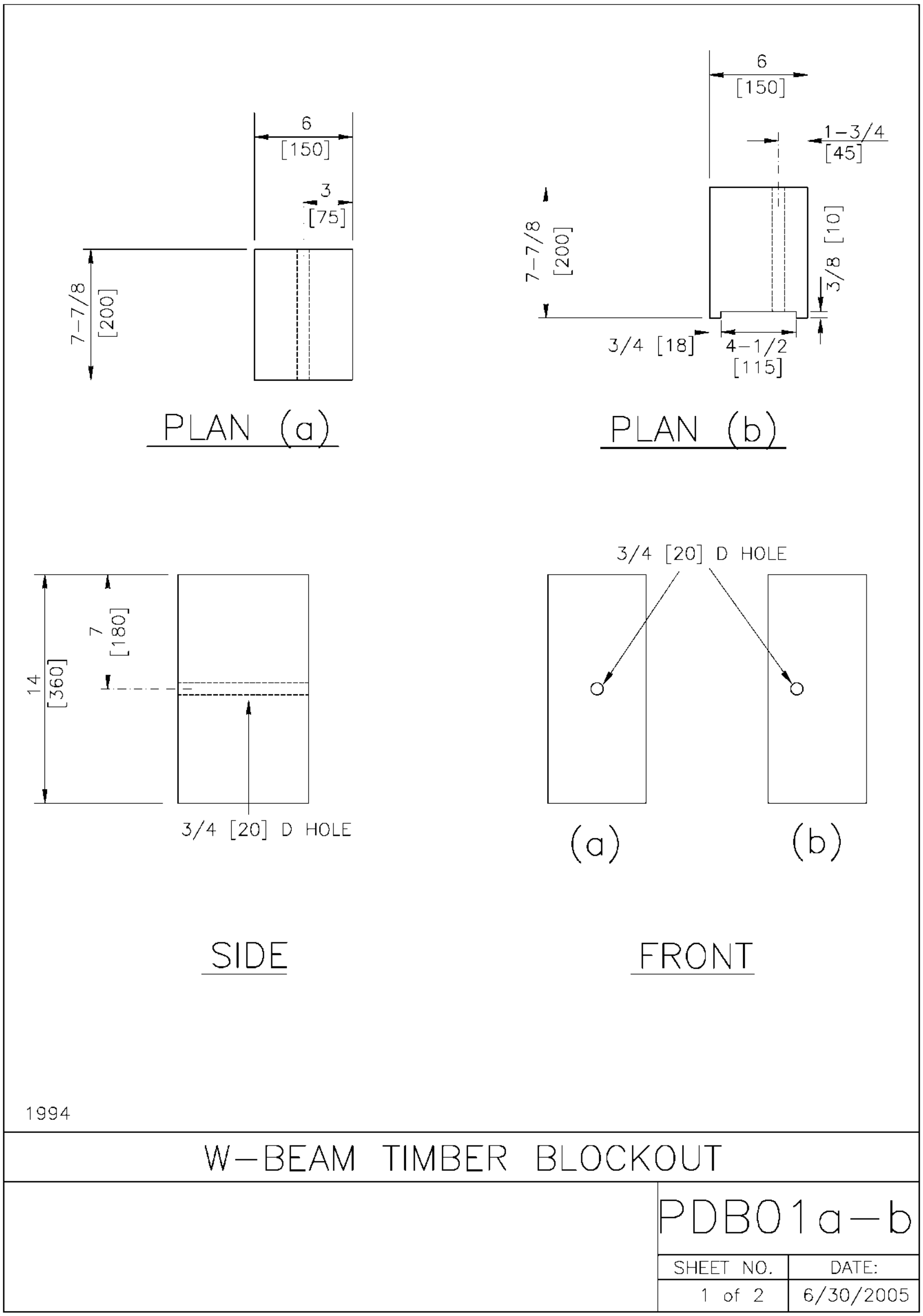

Figure A.7. TF13 Drawing PDB01a-b.

SPECIFICATIONS

Blockouts shall be made of timber with a stress grade of at least 1160 psi [8 MPa]. Grading shall be in accordance with the rules of the West Coast Lumber Inspection Bureau, Southern Pine Inspection Bureau, or other appropriate timber association. Timber for blockouts shall be either rough-sawn (unplaned) or S4S (surfaced four sides) with nominal dimensions indicated. The variation in size of blockouts in the direction parallel to the axis of the bolt holes shall not be more than ± ¼ inch [6 mm]. Only one type of surface finish shall be used for posts and blockouts in any one continuous length of guardrail.

All timber shall receive a preservation treatment in accordance with AASHTO M 133 after all end cuts are made and holes are drilled.

Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

INTENDED USE

Blockout PDB01a is used with wood post PDE01 or PDE02 in the SGR04b strong-post W-beam guardrail and the SGM04b median barrier. Blockout PDB01b is routed to be used with steel post PWE01 or PWE02 in the SGR04c guardrail and the SGM04a median barrier.

W-BEAM TIMBER BLOCKOUT

PDB01a-b		
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Figure A.7. TF13 Drawing PDB01a-b (Continued).