WYOMING DEPARTMENT OF TRANSPORTATION

QUARTERLY PROGRESS REPORT

Project title: Pooled Fund for the Development of Approach Guardrail Transitions for Box Beam and MGS

Project Number: TPF-5(393)

Progress period: 2/1/2022 – 4/30/2022

Principal Investigator and all others who have worked on the project (provide name and ORCID number): Roger Bligh (#0000-0001-5699-070X), Nauman Sheikh (#0000-0003-1718-4881), Nathan Schulz (#0000-0002-7527-9419), James Kovar (#0000-0002-1542-7010)

1. Please state whether the project is ahead of schedule, on time, or behind schedule:

The design of the box beam transition to concrete parapet took longer than expected to complete due to design challenges associated with the stability of the pickup truck. At the same time, the approval of Amendment #3 to the contract was delayed due to delays in WyDOT receiving federal funds. These time periods overlapped and were not additive, but did result in a delay to the overall project schedule.

2. Percentage of overall work completed.

93% (Note that this percentage reflects completion of work currently under contract. Once Amendment #3 is approved, the percentage will be adjusted to reflect the additional scope of work being added to the project).

3. Activities and Accomplishments:

a. What are the major goals and objectives of the project?

The research objective is to develop non-proprietary approach guardrail transition systems from box beam and MGS guardrail to the Texas Department of Transportation (TxDOT) Type C2P bridge rail system that are MASH Test Level 3 (TL-3) compliant. An additional objective added to the scope of the project is to develop a box beam guardrail transition to a vertical concrete parapet. Shape transitions will be designed to transition the vertical concrete parapet to both a single slope barrier and a New Jersey profile barrier. The work plan for the project is divided into ten tasks. These include:

Task 1: Engineering Design and Drawing Development
Task 2: Finite Element Modeling & Simulation
Task 3: Test Installation Construction
Task 4: Crash Testing of the Box Beam Transition

Task 5: Crash Testing of the MGS Transition
Task 6: Concrete Transition Parapet Design and Analysis
Task 7: Development of Box Beam Transition to Concrete Parapet
Task 8: Full-Scale Crash Testing – Box Beam Transition to Concrete Parapet
Task 9: Final Report
Task 10: FHWA Eligibility Letter

b. Describe what was accomplished under these goals.

Task 1: Engineering Design and Drawing Development (previously completed)

Task 2: Finite Element Modeling & Simulation (previously completed)

Task 3: Test Installation Construction (previously completed)

Task 4: Crash Testing of the Box Beam Transition (previously completed)

Task 5: Crash Testing of the MGS Transition (previously completed)

Task 6: Concrete Transition Parapet Design and Analysis (completed)

Researchers completed the structural analysis and reinforcement design for the concrete shape transitions from a vertical concrete parapet to both single slope and New Jersey profile concrete barriers. The recommended geometry, reinforcement, and anchorage details for the concrete shape transitions were incorporated into CAD drawings that were submitted to WYDOT for review and approval.

Task 7: Development of Box Beam Transition to Concrete Parapet (completed)

The research team is currently investigating additional modifications to the box beam transition to reduce the roll of the pickup truck. This will consist of changing the rub rail to an HSS4x3x1/4 rail element. Figure 7 shows the box beam transition system with the updated rub rail. Once satisfactory performance is achieved, additional simulations will be performed at different impact locations to select the critical impact points for both the pickup truck in Test 3-21 and the small passenger car in Test 3-20. Drawings for the design of the box beam transition to vertical concrete parapet will then be developed and submitted to WYDOT for review and approval along with any recommendations for full-scale crash testing needed to confirm MASH compliance of the transition.

The research team utilized finite element computer simulations to further investigate the performance of the Wyoming box beam transition to a vertical concrete parapet. Various modifications to the transition system were evaluated to mitigate instability of the pickup truck observed during simulations of MASH Test 3-21.

As previously presented, the initial transition concept incorporated details similar to the successfully crash tested box beam transition to C2P bridge rail. Figure 1 shows the finite element model of this initial design concept. A MASH Test 3-21 simulation of this design resulted in a very high roll angle for the pickup truck.

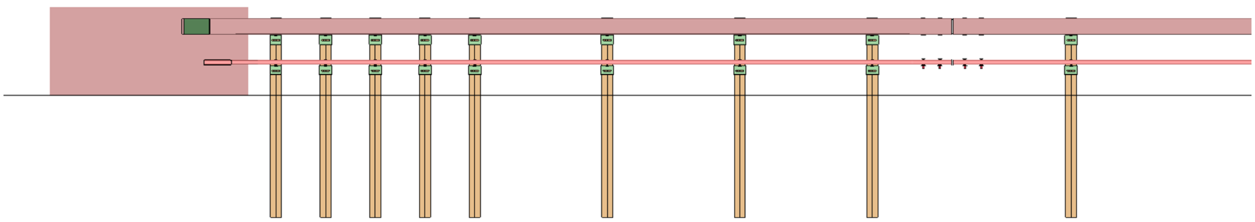


Figure 1. Box Beam Transition to Concrete Parapet.

To improve stability of the pickup truck, the lower rubrail element was changed from an HSS 6x2 section to an HSS 4x3 rail. Figure 2 shows the updated finite element model with the modified rubrail.

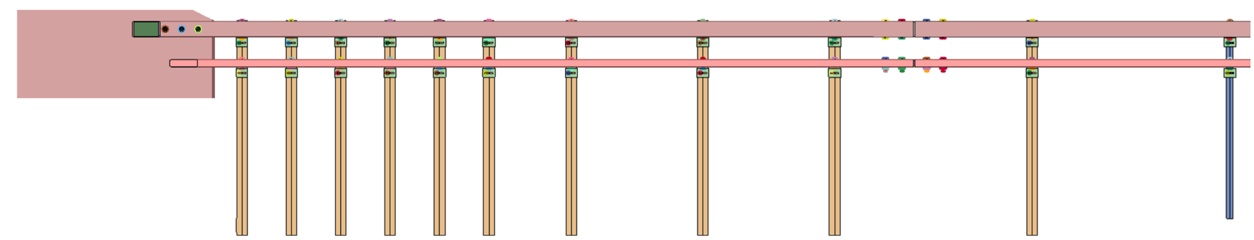


Figure 2. Box Beam Transition with HSS 4x3 Rubrail.

The stability of the pickup truck was improved in the MASH Test 3-21 simulation with the HSS 4x3 rubrail. Figure 3 shows a comparison of the pickup truck roll for the original HSS 6x2 rubrail and HSS 4x3 rubrail.

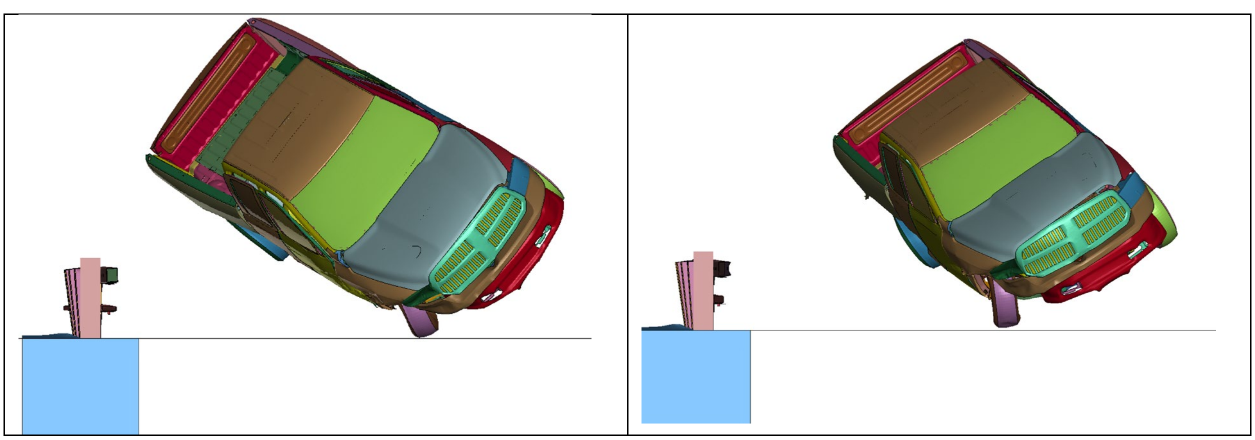


Figure 3. HSS 6x2 (left) and HSS 4x3 (right) Pickup Truck at Maximum Roll Angle.

Additional impact simulations were then performed on this modified design following MASH Test 3-20 and Test 3-21 impact conditions to determine critical impact locations for full-scale crash testing. The two primary MASH evaluation factors are structural adequacy and occupant risk. In all simulations, the vehicle was successfully contained and redirected. Table 1 and Table 2 show the occupant risk values and vehicle angular displacements for MASH Tests 3-20 and 3-21, respectively.

Table 1. MASH Test 3-20 Occupant Risk Results for Downstream Transition.

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

Table 2. MASH Test 3-21 Occupant Risk Results for Downstream Transition.

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

For MASH Test 3-20 with the 1100C passenger car, the CIP was determined to be 5 ft upstream of the parapet end. This simulation resulted in one of the higher OIV and RDA metrics. The 6 ft upstream also had high OIV and RDA metrics but there was less potential for vehicle snagging interaction with the parapet. For MASH Test 3-21 with the 2270P pickup truck, the CIP was determined to be 7 ft upstream of the parapet end. This simulation resulted in the highest OIV and highest pitch angle.

Overall, the box beam transition simulations indicated satisfactory performance for MASH evaluation criteria.

Upstream Transition

The upstream end of the box beam transition to C2P bridge rail was previously evaluated through computer simulation and full-scale crash testing. However, with the change in rubrail element, it was necessary to evaluate the effect of the HSS 4x3 rubrail modification to the impact performance of the upstream transition from box beam guardrail to the transition section. MASH Test 3-20 and Test 3-21 simulations were performed on the upstream transition system with the HSS 4x3 rubrail. Critical impact points previously identified for the upstream box beam transition system with HSS 6x2 rubrail were used in this evaluation.

For both simulations, the MASH occupant risk values were below the required limits. The MASH Test 3-21 simulation was very similar to the behavior observed with the previously tested HSS 6x2 rubrail system. In the MASH Test 3-20 simulation, the vehicle interacted longer with the transition system compared to the behavior seen with the HSS 6x2 rubrail system. However, since this interaction did not result in any excessive occupant risk or instability of the vehicle, the research team considered the performance of the upstream transition system with an HSS4x3 rubrail to be acceptable.

The recommended details of the modified box beam transition to vertical concrete parapet were incorporated into CAD drawings and submitted to WYDOT for review and approval.

Task 8: Full-Scale Crash Testing – Box Beam Transition to Concrete Parapet

Details of the concrete shape transitions developed under Task 6 and the box beam transition to vertical concrete parapet developed under Task 7 were incorporated into detailed construction drawings for the test installation. The drawings were submitted to WYDOT for review and approval on April 1, 2022. These drawings are presented in Appendix A to this report.

The research team met with representatives of WYDOT on April 14, 2022 to review the recommended design details. WYDOT approval of the test installation details for both the concrete shape transitions box beam transition was received on the same day.

After receiving approval of the test installation drawings, a bid package was prepared and submitted through the state procurement process for purposes of selecting a construction contractor for the test installation.

Task 9: Final Report

A draft interim report that documents the full-scale crash testing of the box beam and MGS transitions to the C2P bridge rail was completed and submitted to WyDOT for review and approval on March 24, 2022. The interim report fully documents the research effort for the two transitions, including transition design, transition modeling and simulation, full-scale crash testing, and assessment of MASH compliance. The interim report was prepared to be publication ready as a 508 compliant report. In fact, it could be published as a separate report, with the final report documenting the design, development, full-scale crash testing, and MASH compliance of the box beam transition to vertical concrete barrier and associated concrete shape transition to both single slope and New Jersey profile concrete barriers.

Technical comments on the report were received on April 7, 2022. The comments have been addressed in the revised report and a response to comments was transmitted to WYDOT. Members of the research team met with the WYDOT Research Manager and WYDOT Project Champion to discuss the formatting and 508 compliance of the report on April 14, 2022. The report is being revised to address the identified issues.

Task 10: FHWA Eligibility Letter

The research team prepared a request for FHWA funding eligibility package for the C2P bridge rail for submittal to FHWA by the Texas Department of Transportation (TxDOT). The FHWA eligibility request package for the C2P bridge rail included FHWA Office of Safety Form to Request Federal Aid Reimbursement Eligibility of Safety Hardware Devices (version 10.0), drawings of the test installation, test summary pages, high-speed and real-time video of the crash tests performed, and photographs of the test installation and test vehicle before and after each test. The eligibility package was submitted to FHWA by TTI on behalf of TxDOT on April 4, 2002.

A draft eligibility request form for the box beam transition to C2P bridge rail was developed and submitted to WYDOT for review and approval. Review comments were received and addressed. A draft eligibility request form for the MGS transition to C2P bridge rail was developed and submitted to WYDOT for review and approval.

c. What opportunities for training and professional development has the project provided? If the research is not intended to provide training and professional development, state "Nothing to Report". Otherwise, describe opportunities for training and professional development, training activities, and professional development.

Nothing to report.

d. How have the results been disseminated to communities of interest? Describe what results have been disseminated and in what manner, including publications, conference papers, and presentation. Please list ALL derivative reports/publications which were generated from this project, and provide an electronic copy of the report/publication.

Nothing to report.

e. What do you plan to do during the next reporting period to accomplish the goals and objectives? Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.

Task 8: Full-Scale Crash Testing – Box Beam Transition to Concrete Parapet

A construction contractor will be selected for construction of the test installation for full-scale crash testing and evaluation of the box beam transition to vertical concrete parapet and associated concrete shape transition to New Jersey profile barrier. The test installation will be constructed in accordance with the approved drawings. Preparations for the MASH crash testing will proceed, and the tests of the box beam transition to vertical concrete parapet and concrete shape transition from vertical concrete parapet to New Jersey profile concrete barrier will be scheduled on the TTI Proving Ground test calendar.

Task 9: Final Report

A revised draft interim report that documents the full-scale crash testing of the box beam and MGS transitions to the C2P bridge rail will be submitted to WyDOT for further review and approval. The interim report fully documents the research effort for the two transitions, including transition design, transition modeling and simulation, full-scale crash testing, and assessment of MASH compliance. The revised interim report will address technical comments received as well as comments received on 508 compliance. The approved interim report will be used as part of the FHWA eligibility request packages for the box beam and MGS transitions to C2P bridge rail.

Task 10: FHWA Eligibility Letter

The FHWA funding eligibility packages for the box beam and MGS transitions to C2P bridge rail will be submitted upon WYDOT approval of the interim report documenting the full-scale crash testing of these systems. In addition to the interim report, the FHWA eligibility request package for the transition systems will include FHWA Office of Safety Form to Request Federal Aid Reimbursement Eligibility of Safety Hardware Devices (version 10.0), drawings of the test installations, high-speed and real-time video of the crash tests performed, and photographs of the test installation and test vehicle before and after each test.

f. List any products resulting from the project during the reporting period. Include in this list:

1. Publications, conference papers, and presentations.
2. Website(s) or other internet sites (List the URL).
3. Technologies or techniques.
4. Inventions, patent applications, and/or licenses.
5. Other products, such as data or databases, physical collections, audio or video products, software or NetWare, models, educational aids or curricula, instruments or equipment.

Nothing to report.

g. Impact:

1. How will this project impact WYDOT?
2. How will this project impact other agencies?

WYDOT's Mission Statement is to "provide a safe, high quality and efficient transportation system." One of the goals within the mission statement is to "improve safety on the state transportation system." Successful implementation of the transitions developed under this project into WYDOT's standard plans will provide an improved level of safety. The transitions will provide continuity of motorist safety from MASH guardrail systems to MASH bridge rail systems. Full implementation of MASH compliant roadside safety devices, including transition systems, will provide an enhanced level of safety that will help reduce the severity of lane departure crashes that represent over 75% of highway fatalities in Wyoming. Additionally, the AASHTO/FHWA MASH Implementation Agreement requires state DOTs to provide MASH compliant roadside safety features to obtain federal funding reimbursement on projects. The results of this research will be useful to other agencies. This project is being funded as a pooled fund effort between WYDOT and Montana DOT. It will provide transition details that will be immediately implementable by both of these agencies as well as other agencies that use similar guardrail and bridge rail systems.

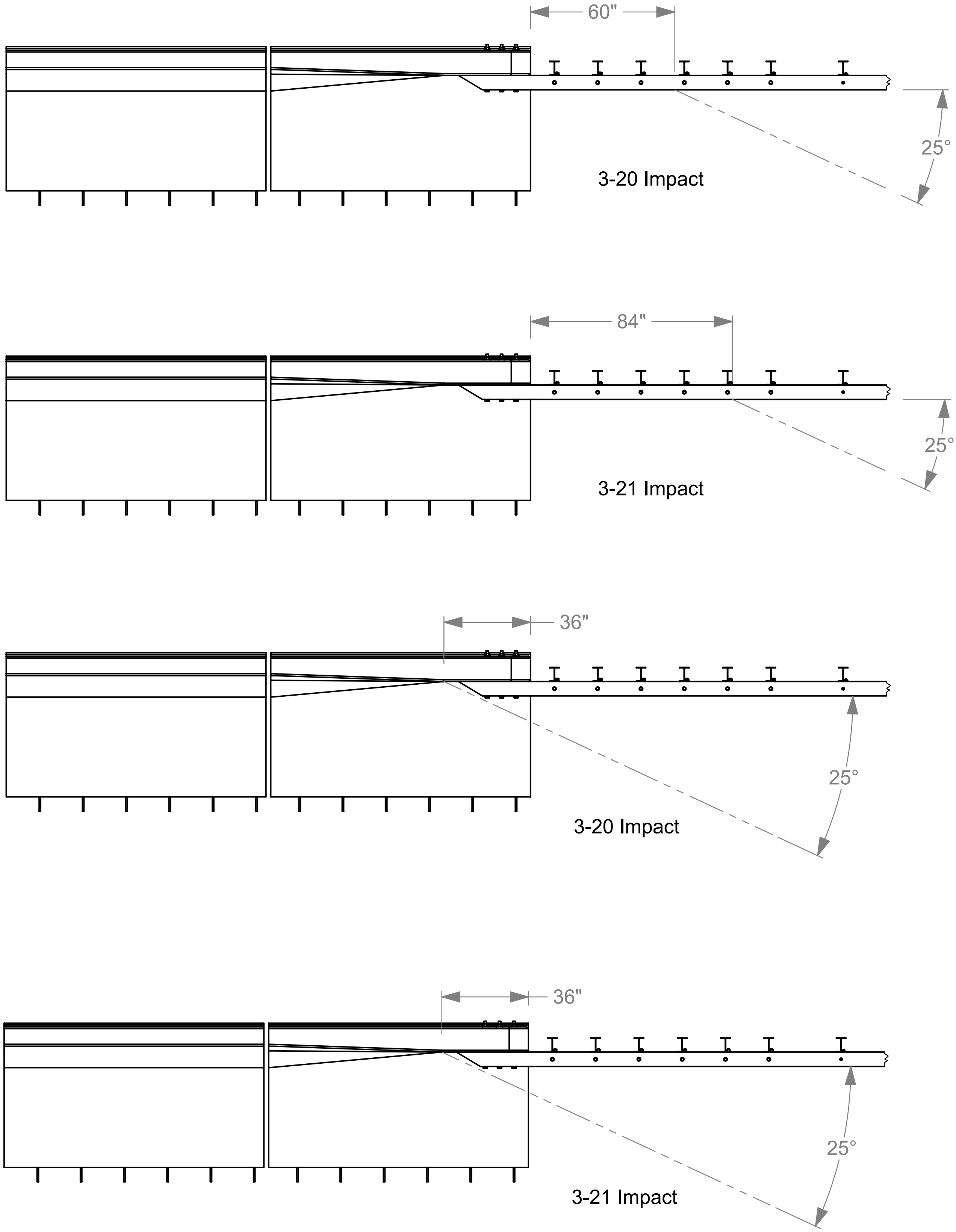
h. Changes to Scope of Work. Provide the following changes, if applicable:

1. Scope of work or objectives of the project.
2. Changes in key persons.
3. Disengagement from the project for more than three (3) months, or a twenty five (25) percent reduction in time devoted to the project.
4. The inclusion of costs that require prior approval.
5. The transfer of funds between line items in the budget.
6. The subawarding, transferring or contracting of work.
7. Changes in the approved cost-sharing or match.

At the request of Wyoming DOT, a modification to the current project agreement was prepared and submitted. The modification adds additional crash testing to the project scope to enable evaluation of the impact performance and MASH compliance of the box beam transition to concrete parapet and the concrete shape transitions from vertical concrete parapet to both New Jersey and single slope profile concrete barriers. The modification includes additional scope, time, and budget to accomplish the proposed work. The modification request was submitted to WyDOT on September 27, 2021 and was considered during an October 20, 2021 RAC meeting. The RAC chose to table making a final determination on funding the modification until funding/obligation approval is secured from FHWA.

APPENDIX A

Recommended Design of Box Beam Transition to Vertical Concrete Parapet and Associated Concrete Shape Transitions to Single Slope and New Jersey Profile Concrete Barriers



Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #611801-03 Project Name		0000-00-00
Drawn by GES	Scale 1:500	Sheet 1 of 1 / Impact

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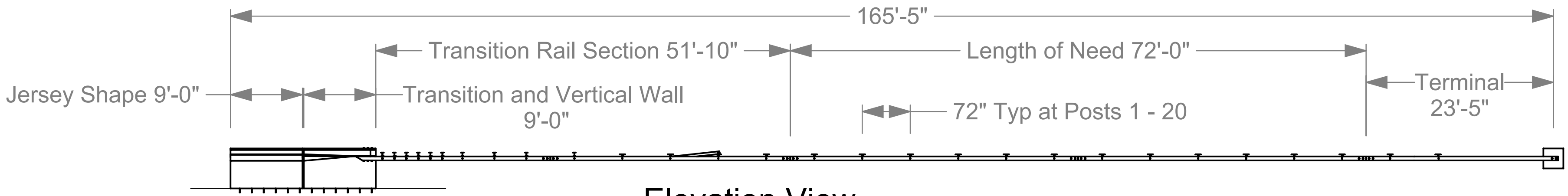
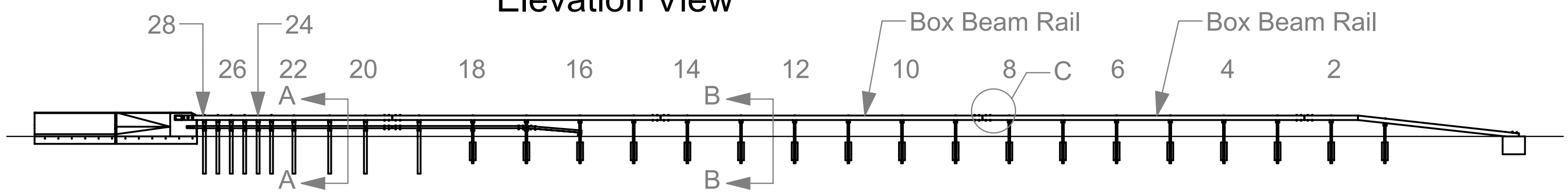
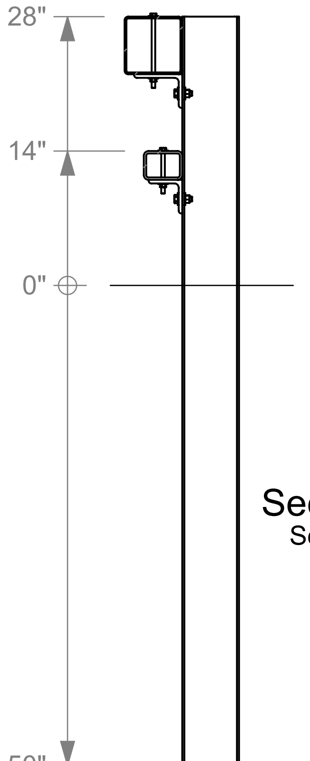
Test Installation



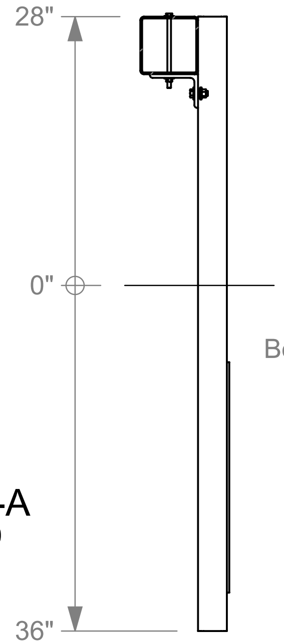
Elevation View



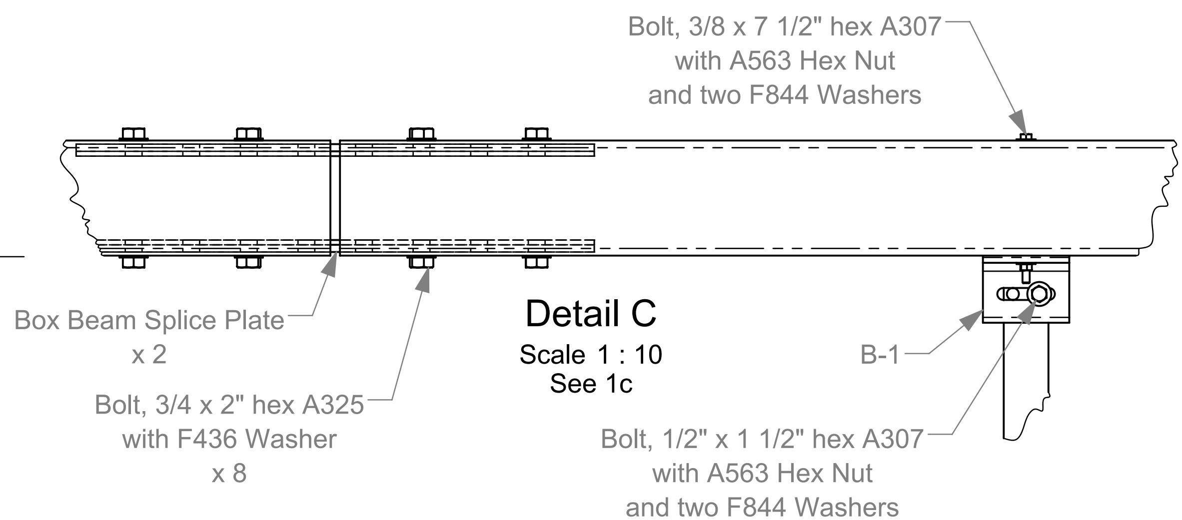
Plan View



Section A-A
Scale 1 : 20



Section B-B
Scale 1 : 20
Typ @ Posts 2 - 15



Detail C
Scale 1 : 10
See 1c

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

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

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

1b. Threads not shown on Bolts for clarity.

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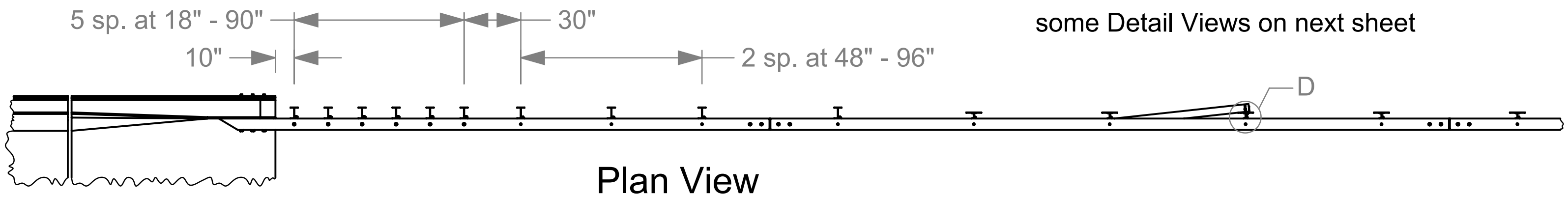
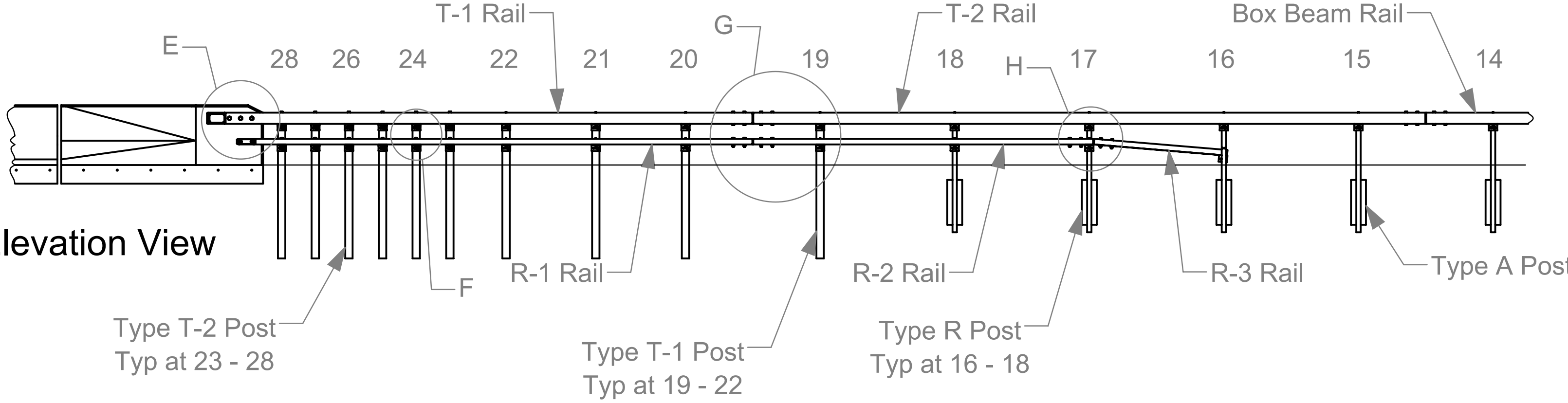
Drawn by GES	Scale 1:250	Sheet 1 of 21 Test Installation	

Transition Details

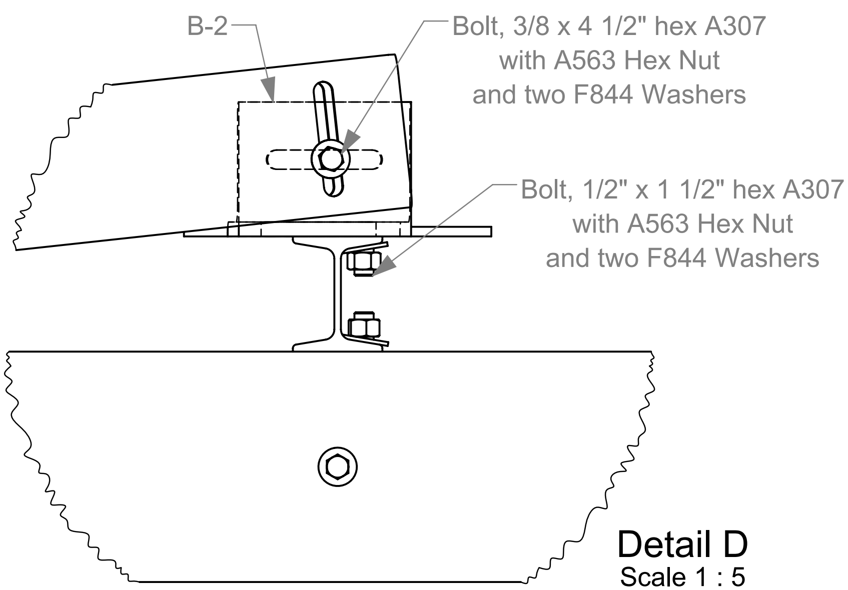
some Detail Views on next sheet



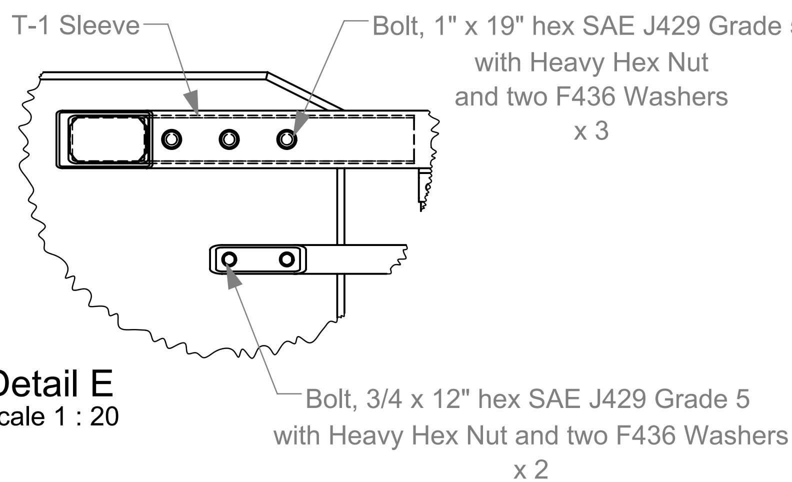
Plan View



Elevation View



Detail D
Scale 1 : 5



Detail E
Scale 1 : 20

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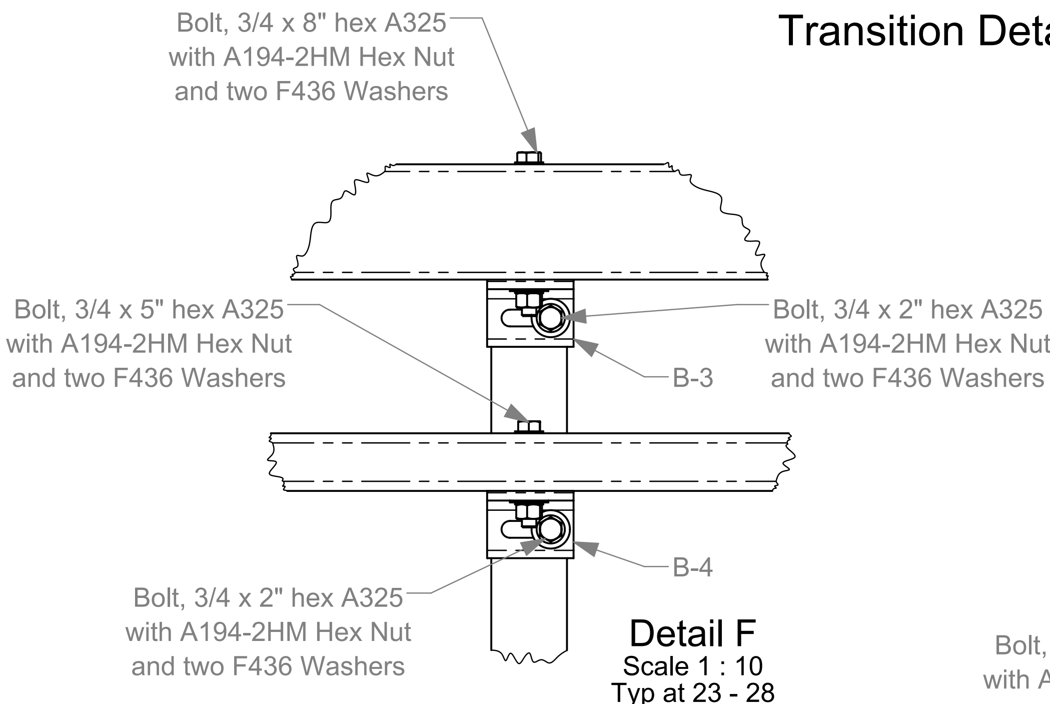
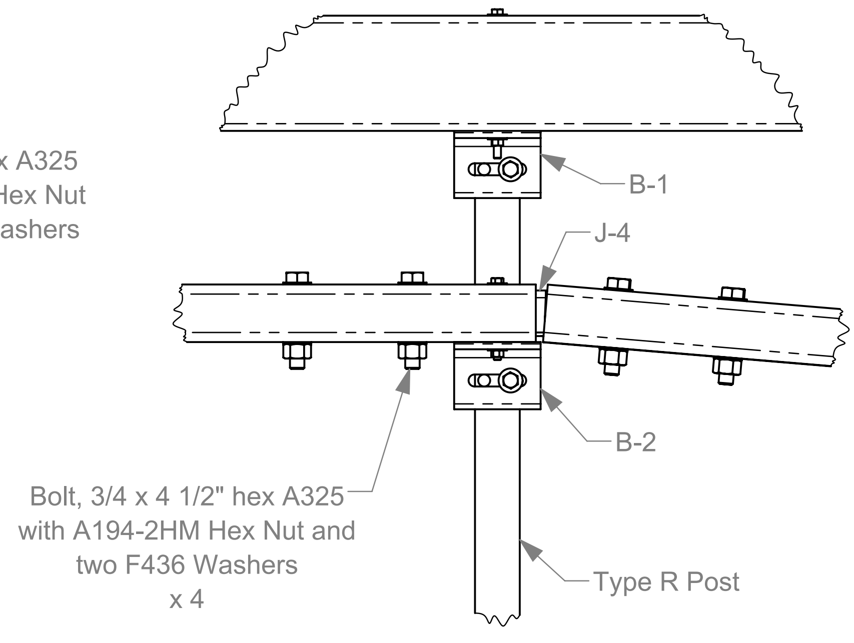
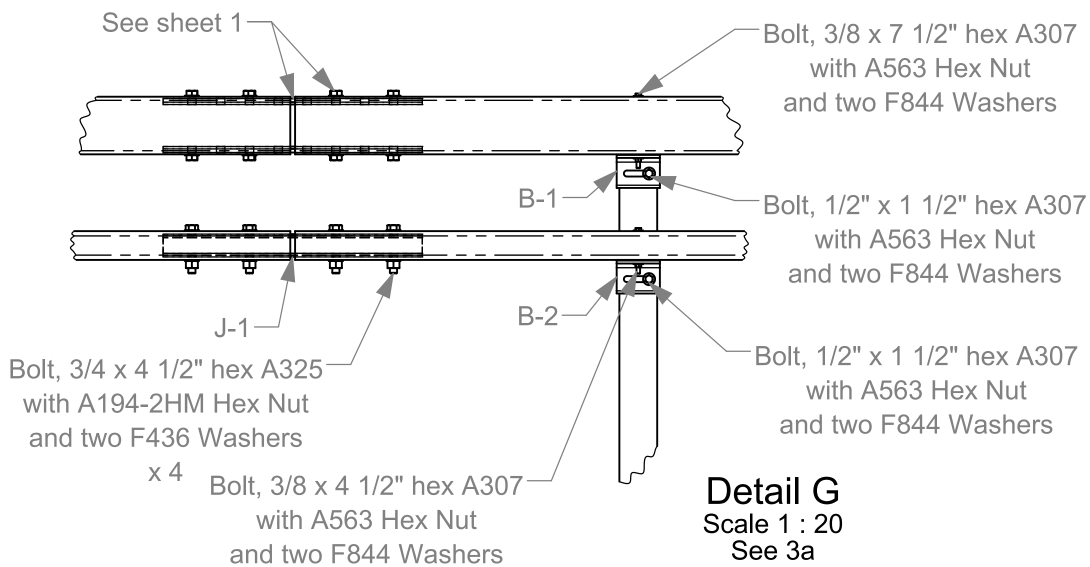
Transition Detail Views



Detail F
Scale 1 : 10
Typ at 23 - 28



Detail H
Scale 1 : 10



Detail G
Scale 1 : 20
See 3a

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

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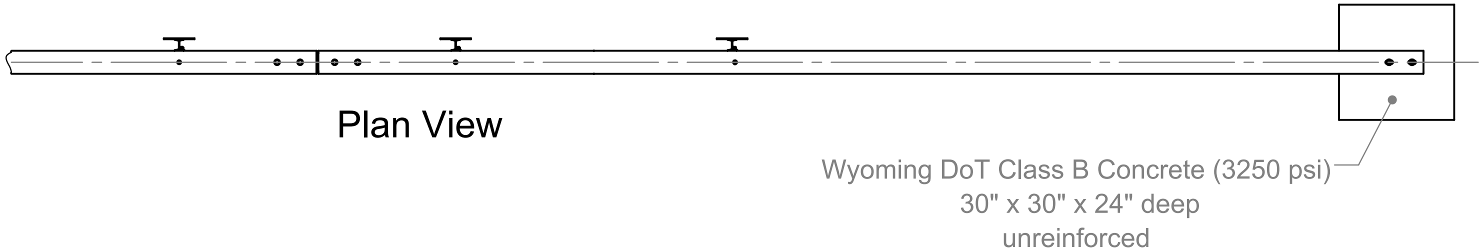
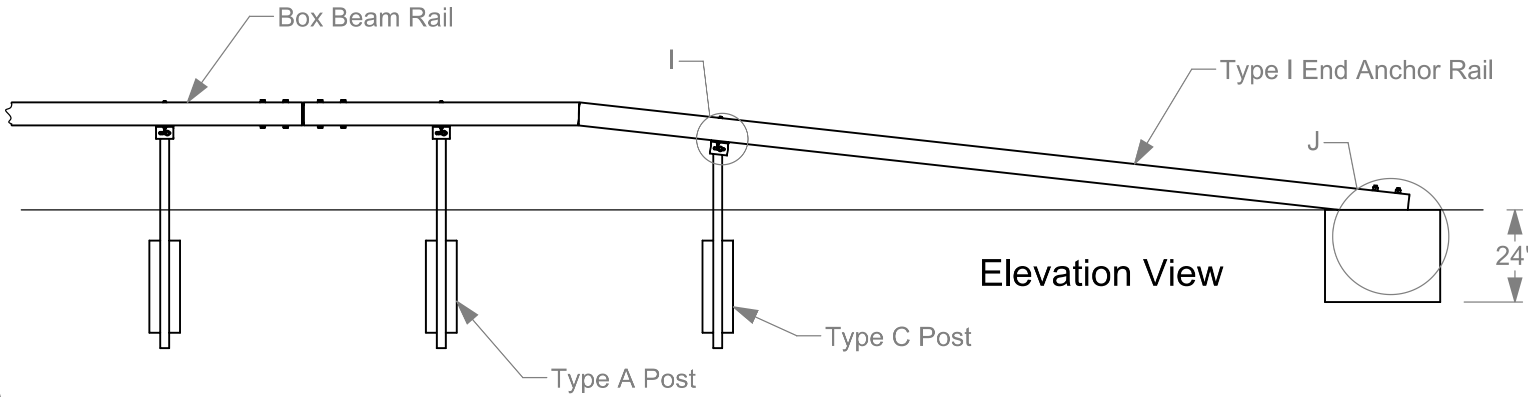
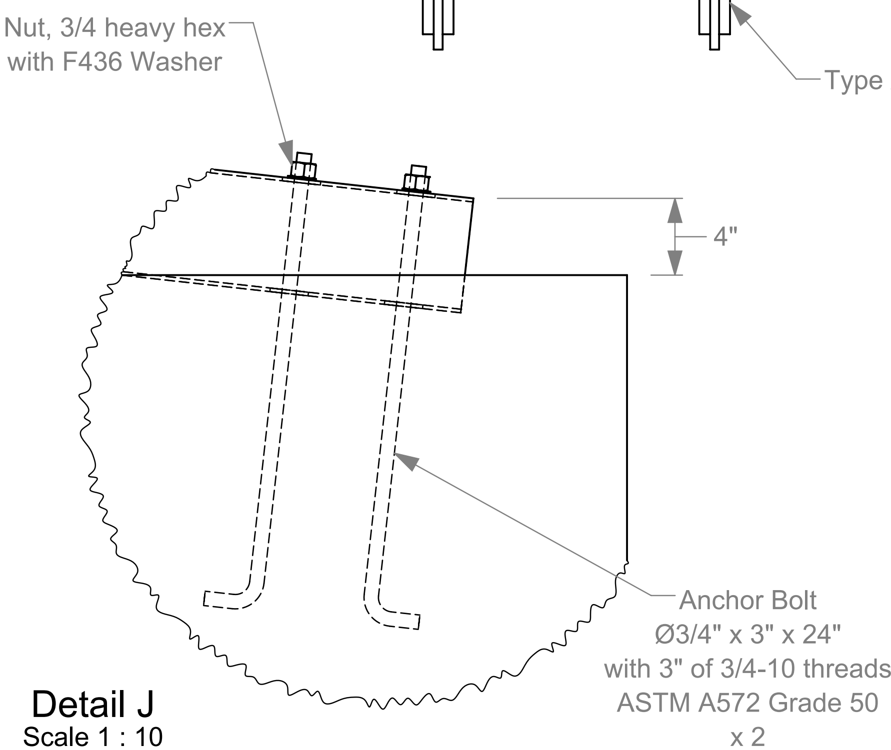
Terminal Details



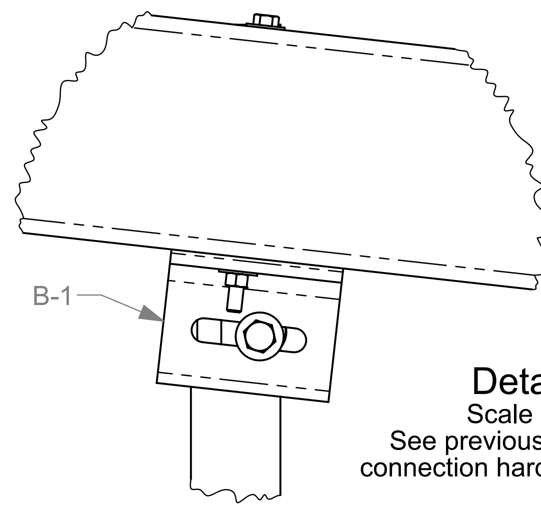
Plan View



Elevation View



Detail J
Scale 1 : 10



Detail I
Scale 1 : 5
See previous sheets for
connection hardware details.

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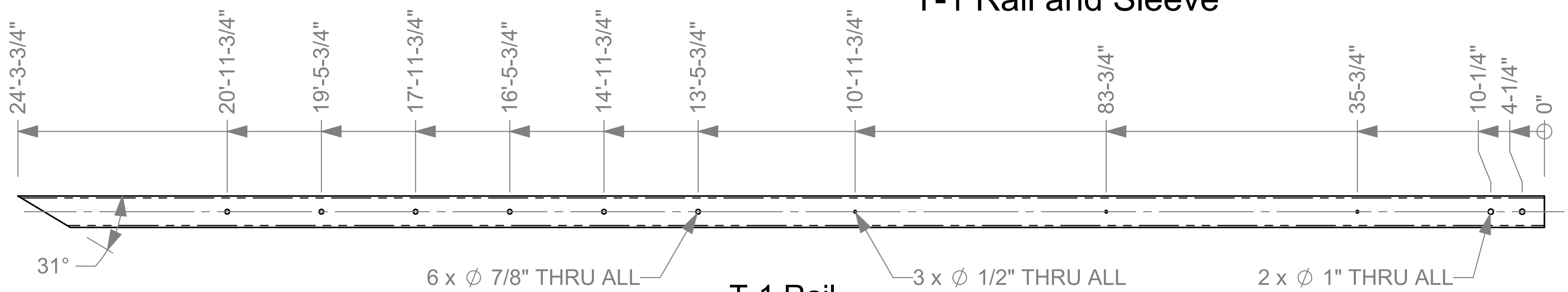
Roadside Safety and Physical Security Division - Proving Ground

Project #611801-03 Wyoming Box Beam Transition	2022-03-24

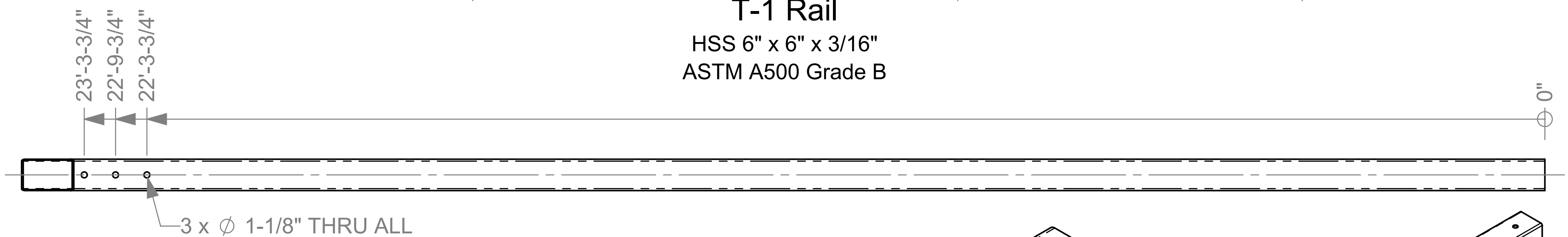
Drawn by GES	Scale 1:50	Sheet 4 of 21 Terminal Details

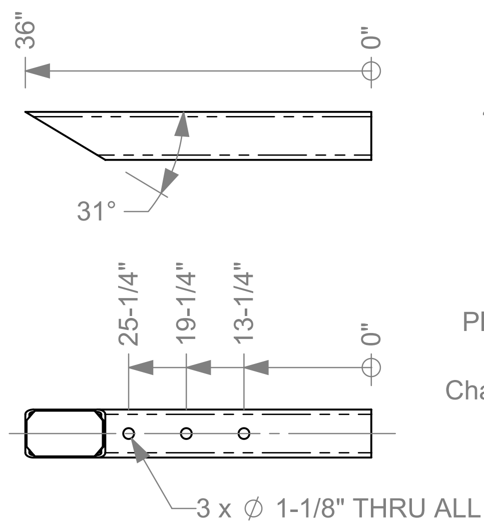
T-1 Rail and Sleeve

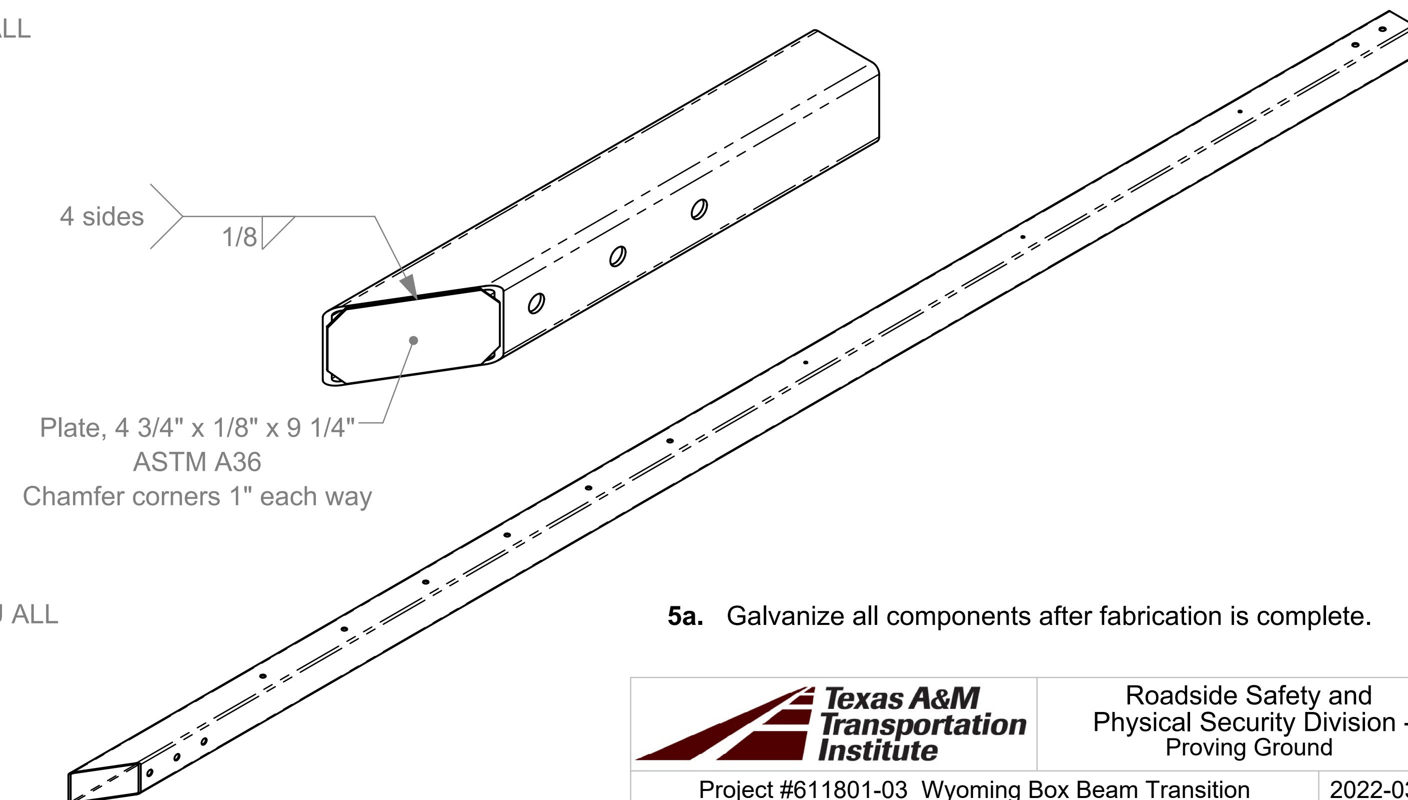


T-1 Rail

HSS 6" x 6" x 3/16"
ASTM A500 Grade B







T-1 Sleeve

HSS 5" x 5" x 1/4"
ASTM A500 Grade B

5a. Galvanize all components after fabrication is complete.

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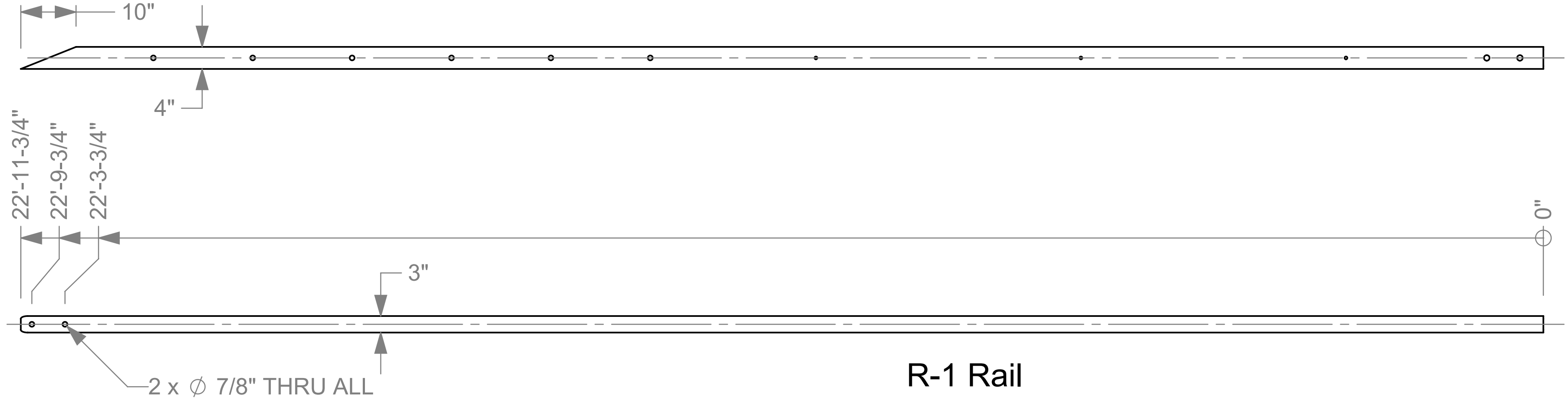
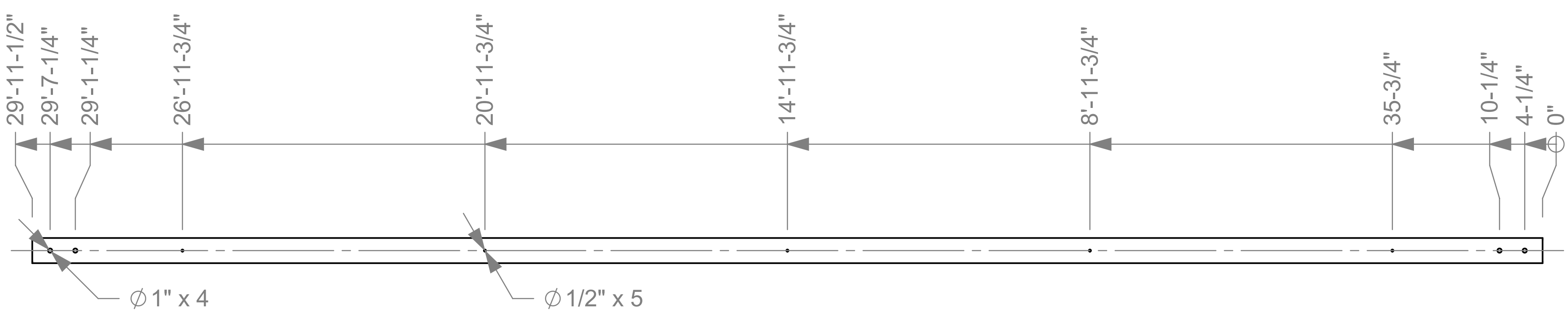
Drawn by GES	Scale 1:30	Sheet 5 of 21 T-1 Rail and Sleeve

R-1 and T-2 Rails



R-1 Rail

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



T-2 Rail

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

6a. Galvanize all components after fabrication is complete.

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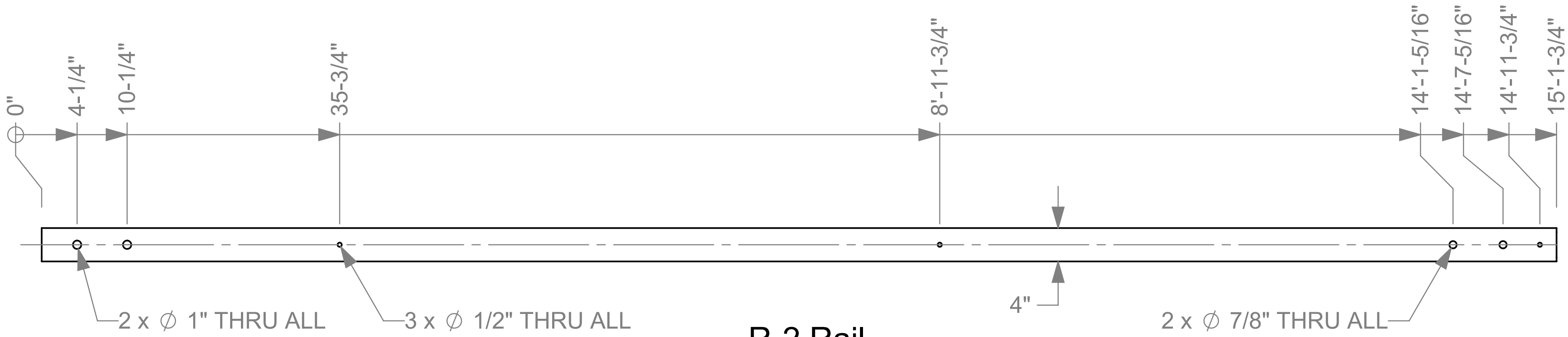
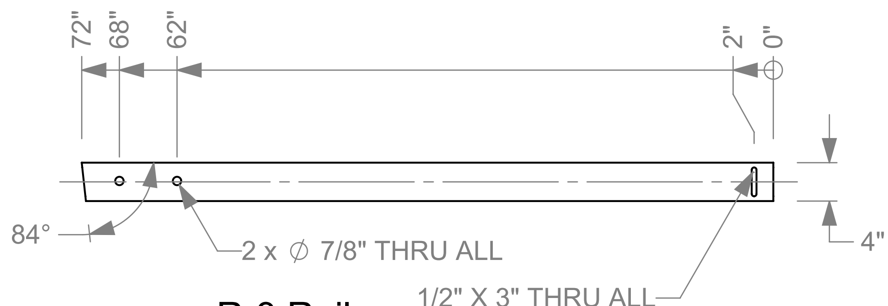
Rub Rails



R-2 Rail

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



R-3 Rail

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

7a. Galvanize all components after fabrication is complete.

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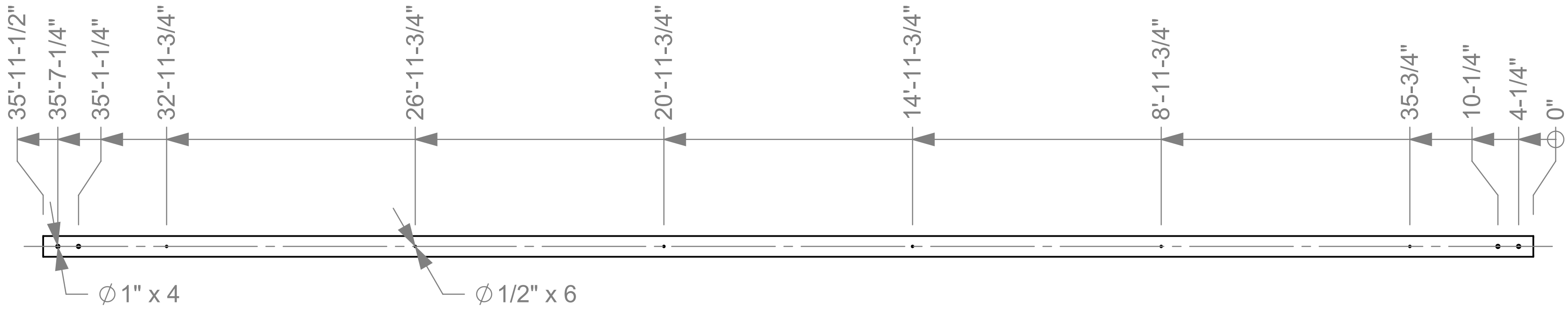
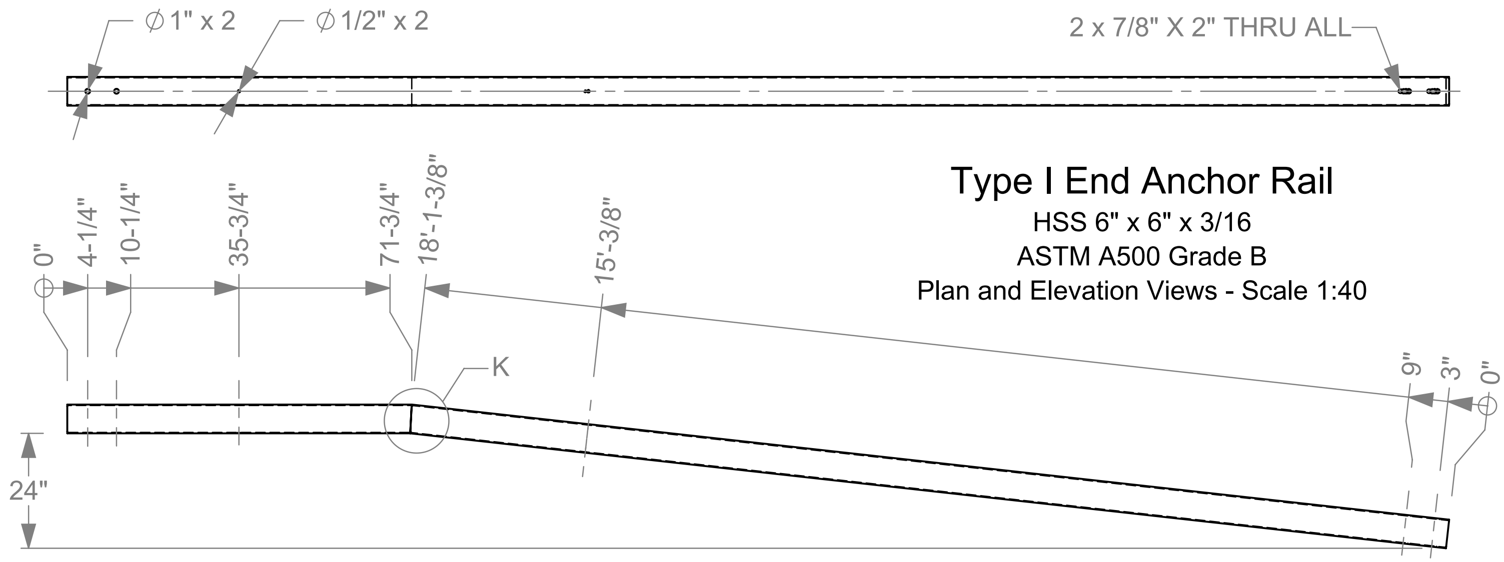
Drawn by GES	Scale 1:20	Sheet 7 of 21 Rub Rails	

LON and Terminal Rails



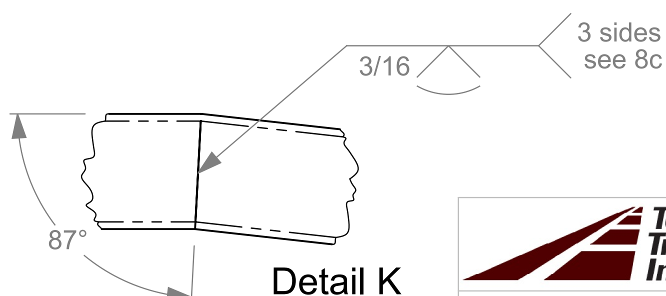
Box Beam Rail

HSS 6" x 6" x 3/16"
ASTM A500 Grade B
Plan View



Type I End Anchor Rail

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



Detail K

Scale 1 : 10

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

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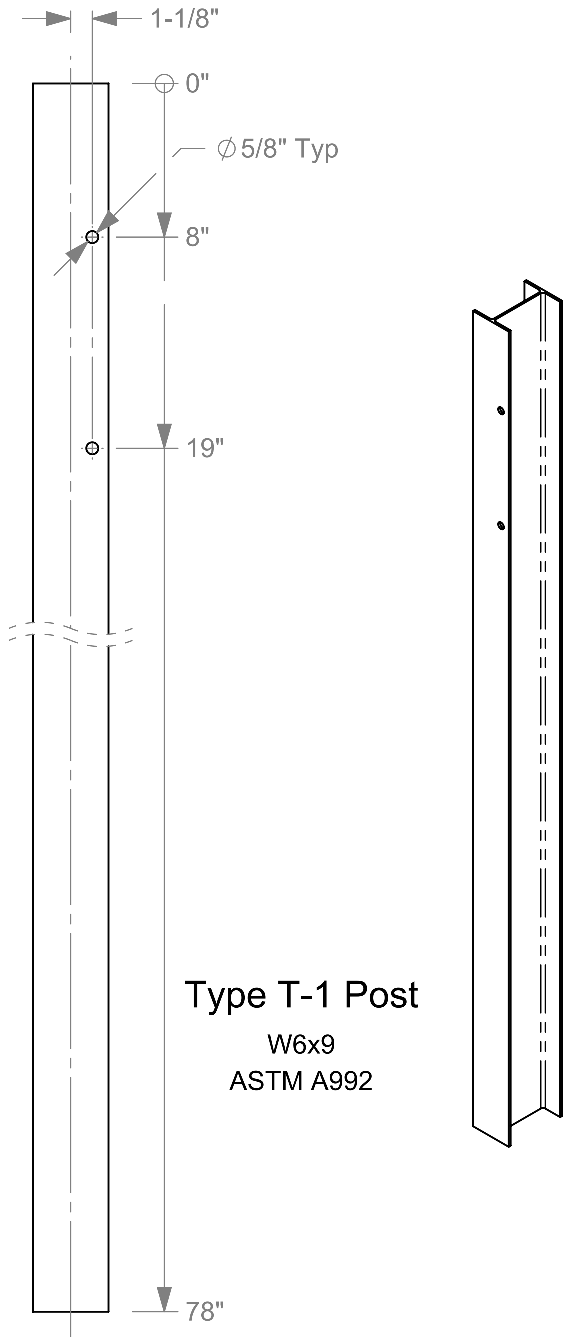
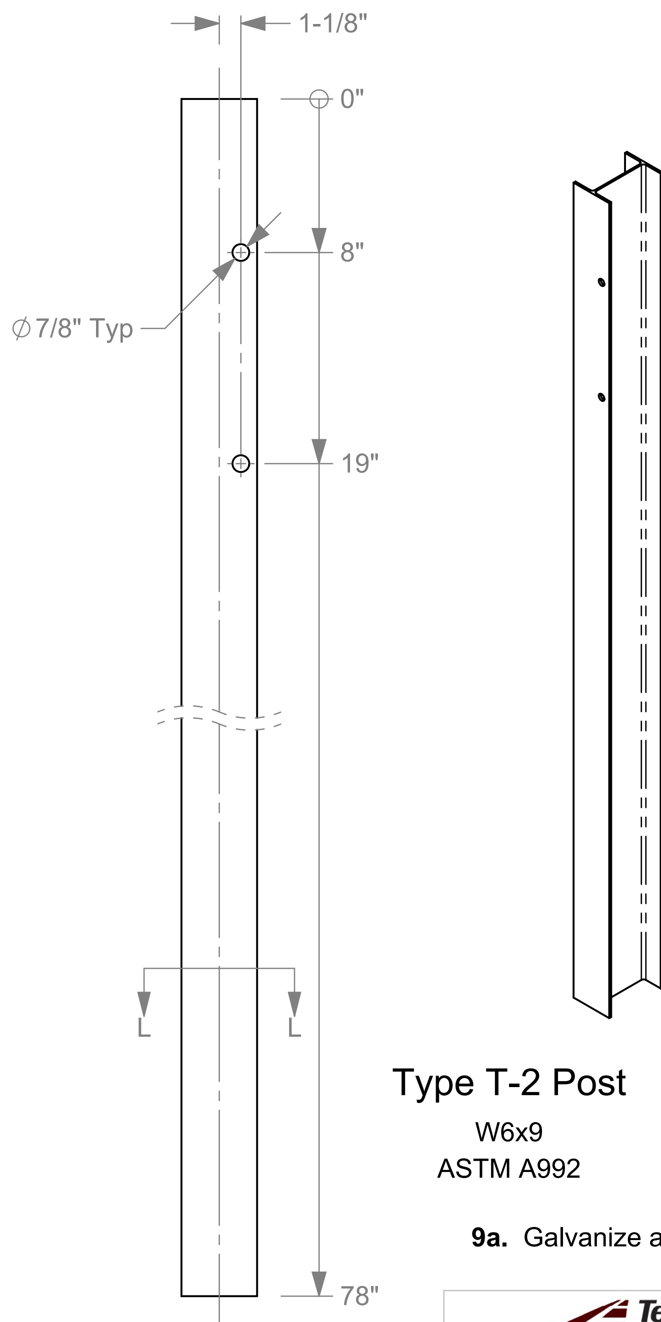
Drawn by GES	Scale 1:50	Sheet 8 of 21 LON and Terminal Rails



Type T-1 Post

W6x9

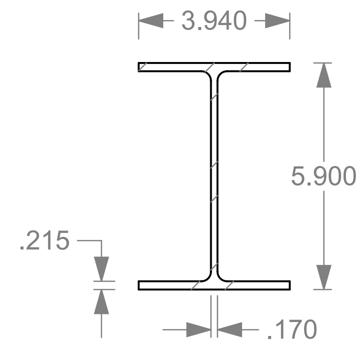
ASTM A992



Type T-2 Post

W6x9

ASTM A992



Section L-L

Scale 1:5

9a. Galvanize all components after fabrication is complete.

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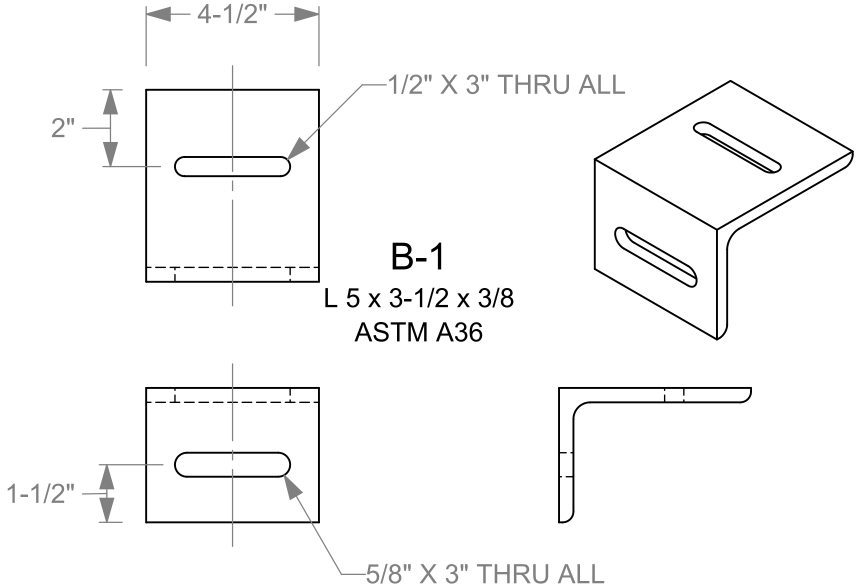

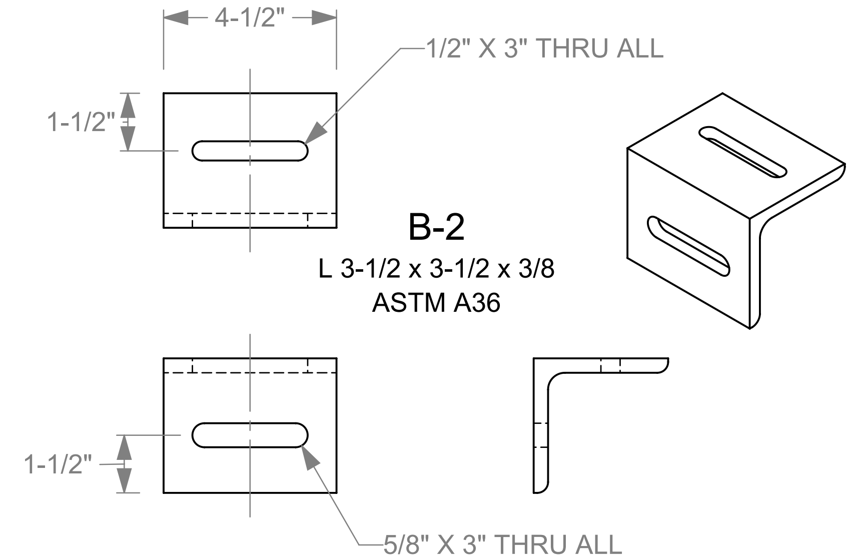

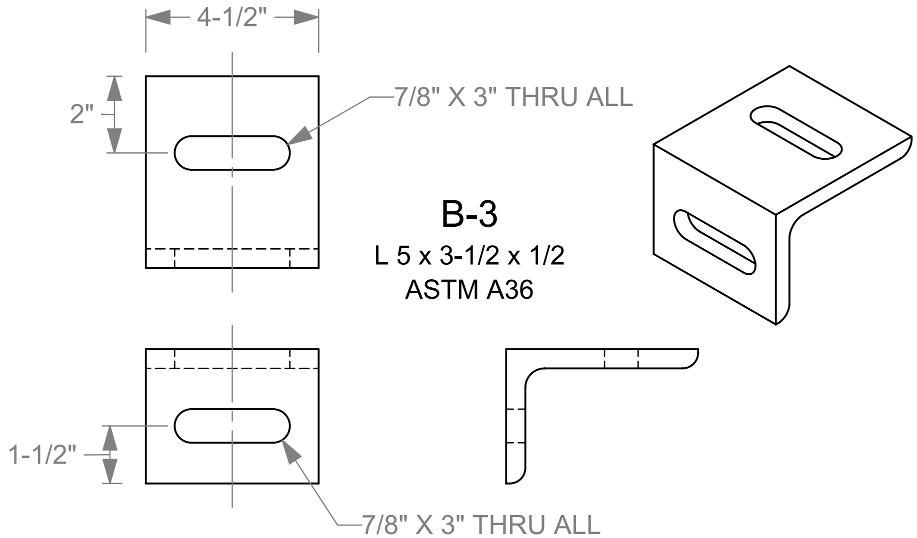

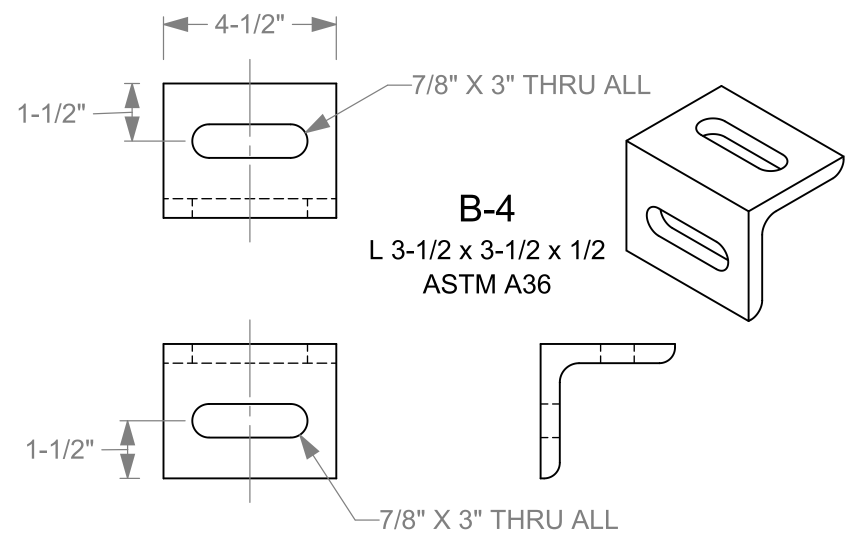

10a. Galvanize all components after fabrication is complete.

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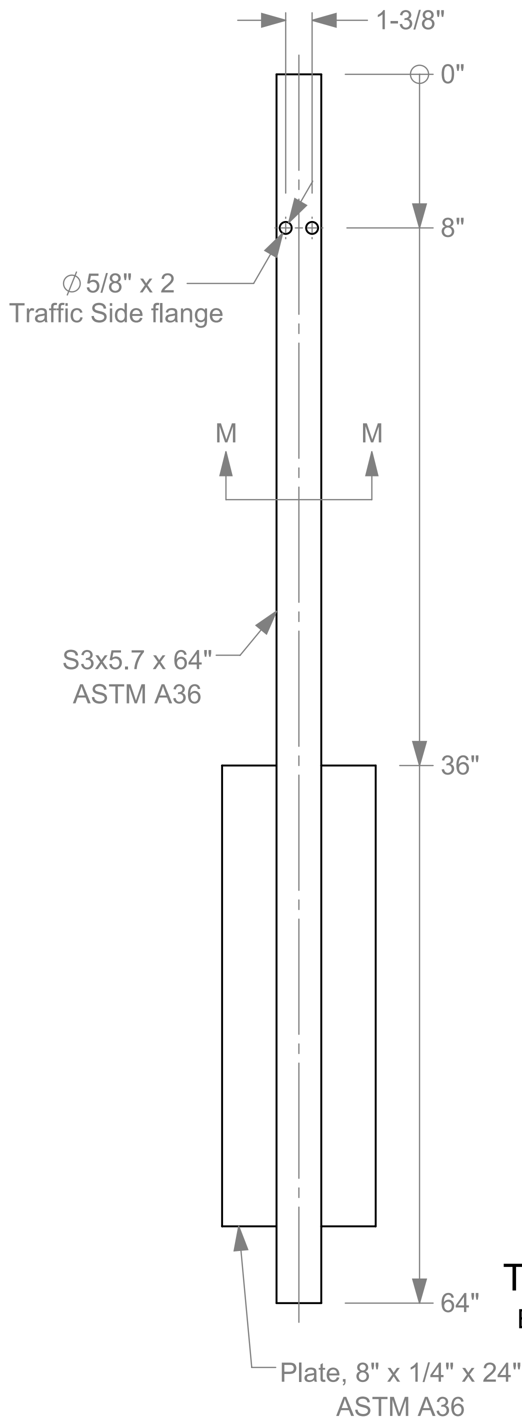
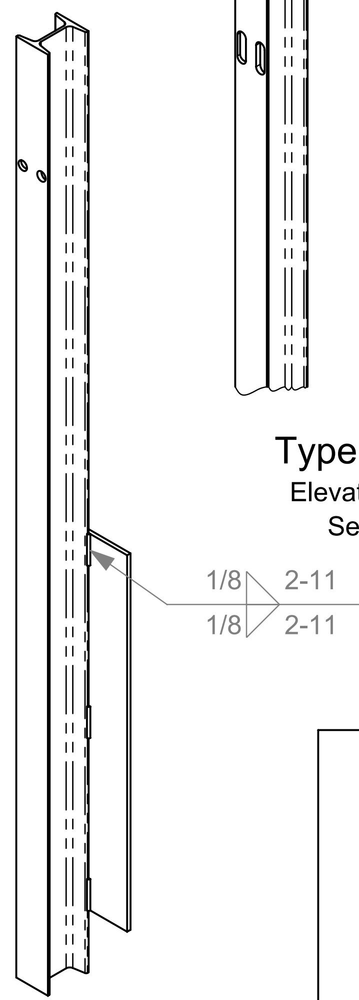
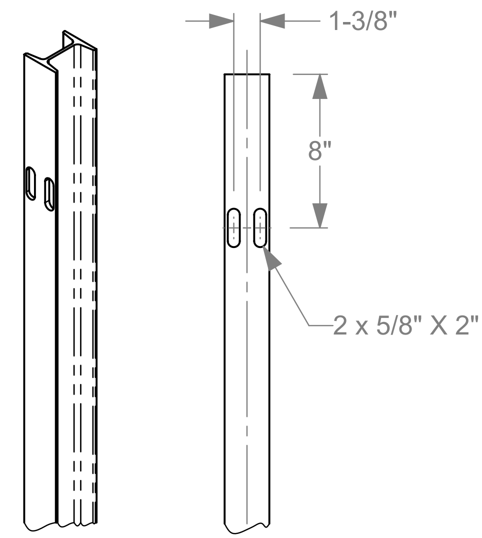
Drawn by GES	Scale 1:5	Sheet 10 of 21 Brackets

S3x5.7 Posts

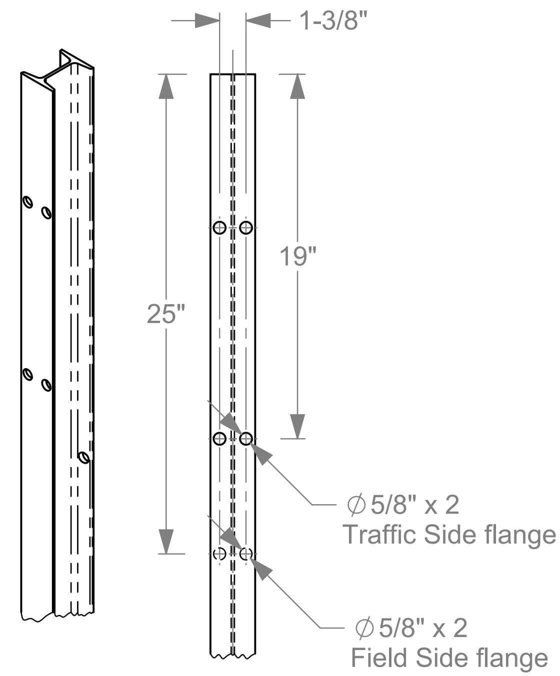




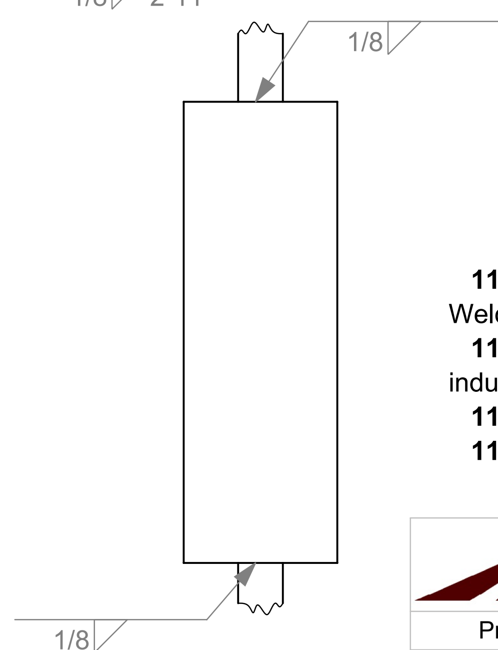
Type A Post
Elevation View



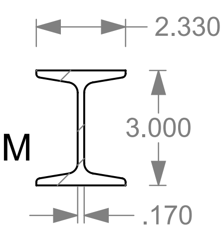
Type C Post
Elevation View
See 11d



Type R Post
Elevation View
See 11d



Section M-M
Scale 1 : 5



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

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

11c. Galvanize all components after fabrication is complete.

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

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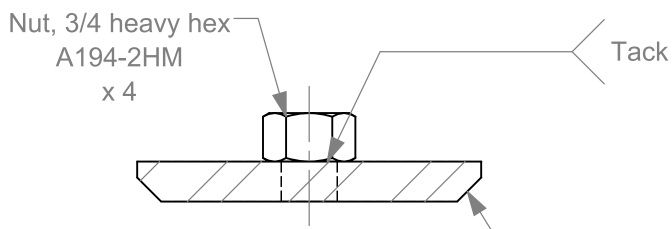
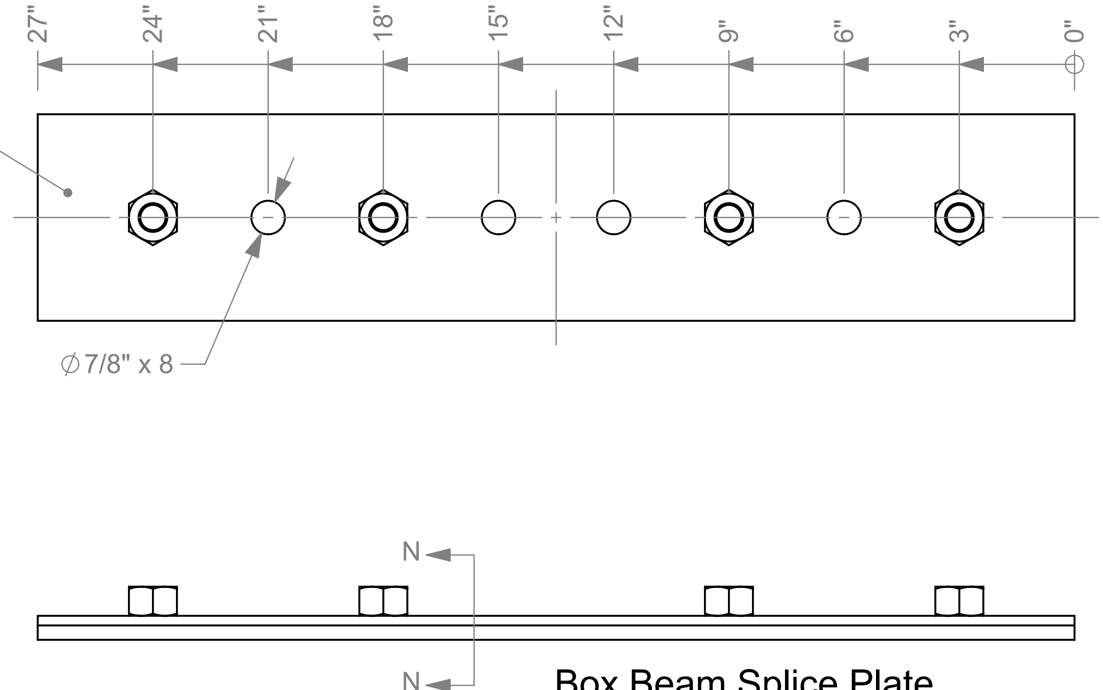
Drawn by GES	Scale 1:10	Sheet 11 of 21 S3x5.7 Posts

Box Beam Splice Plate



Section N-N

Scale 1 : 3



Box Beam Splice Plate

Plan and Elevation Views

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

12b. Galvanize all components after fabrication is complete.

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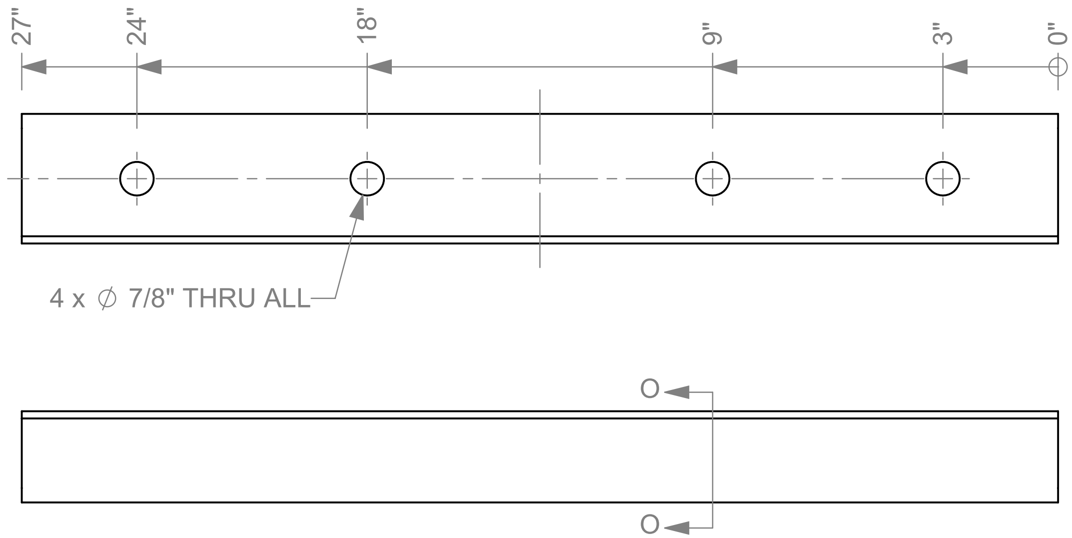
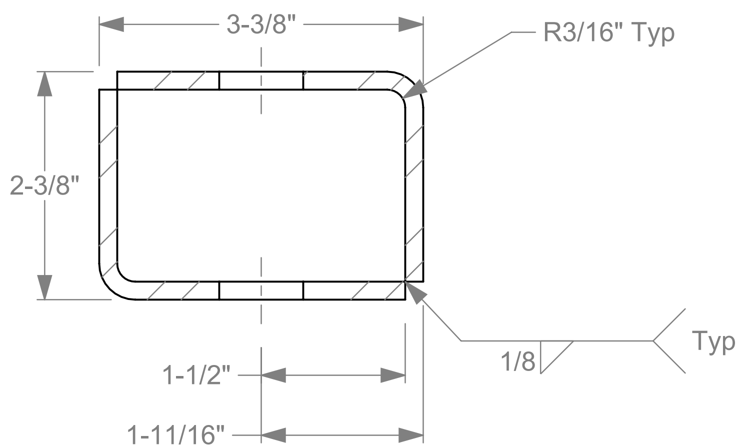
Drawn by GES	Scale 1:5	Sheet 12 of 21 Box Beam Splice Plate



J-1

ASTM A36 Plate, 27" x 3/16"

Plan and Elevation Views



Section O-O

Scale 1 : 2

13a. All welding must be performed by certified welders using industry standard practices.

13b. Galvanize all components after fabrication is complete.

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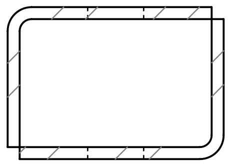
Drawn by GES	Scale 1:5	Sheet 13 of 21 J-1

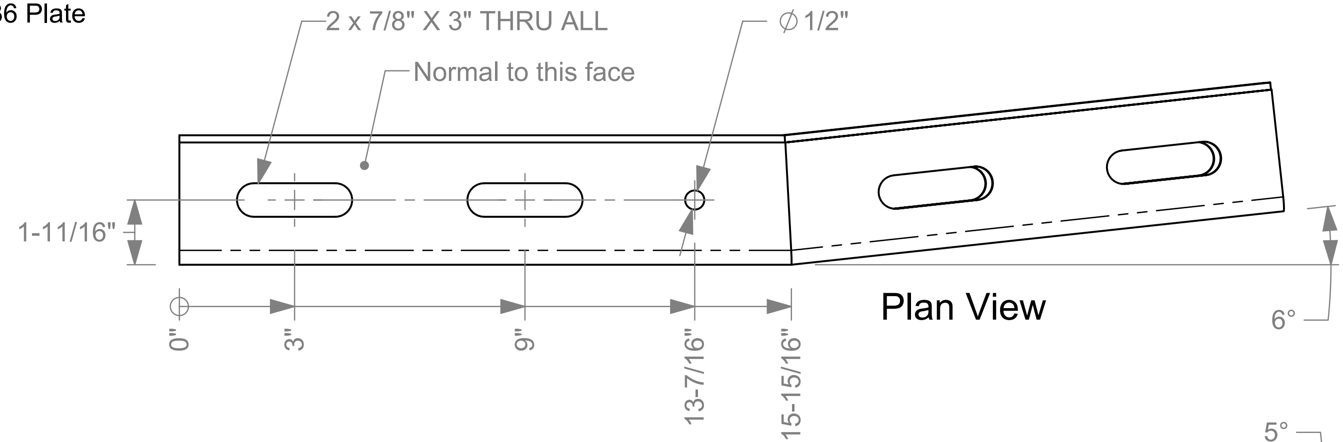
J-4

3/16" ASTM A36 Plate
See 14a

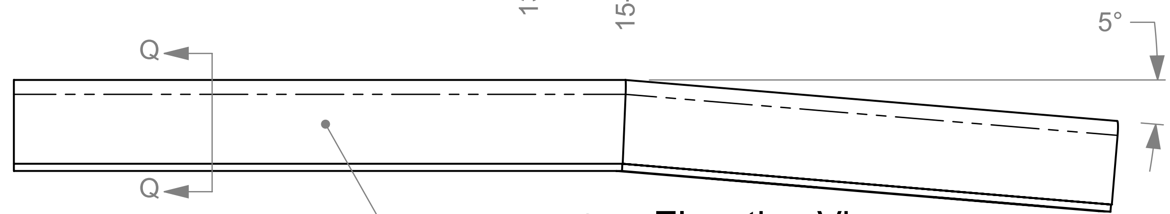


Section Q-Q

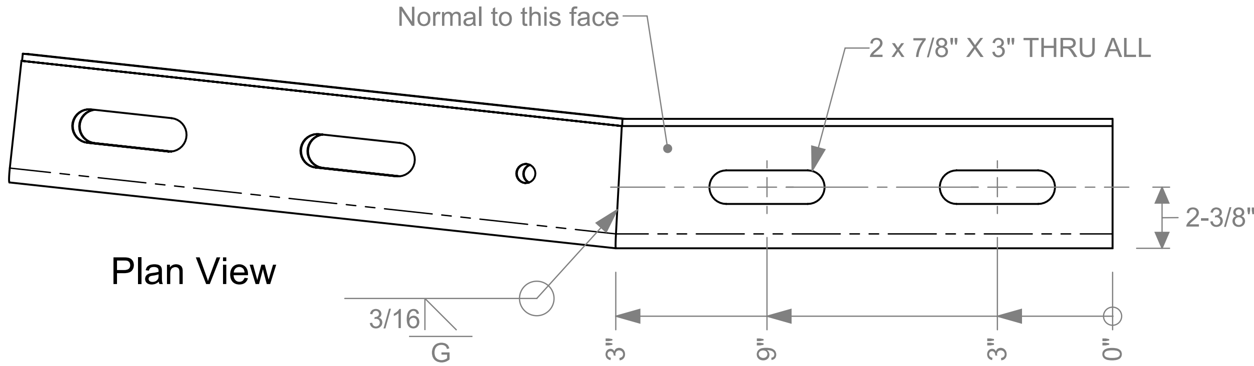
Scale 1 : 3
See J-1 Section View on previous sheet.



Plan View



Elevation View



Plan View

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
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Drawn by GES	Scale 1:5	Sheet 14 of 21 J-4

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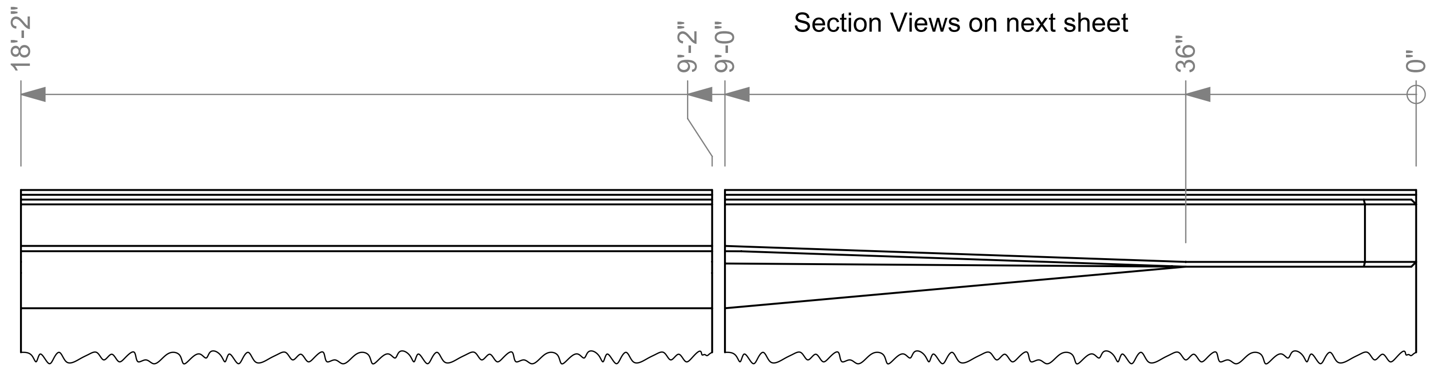
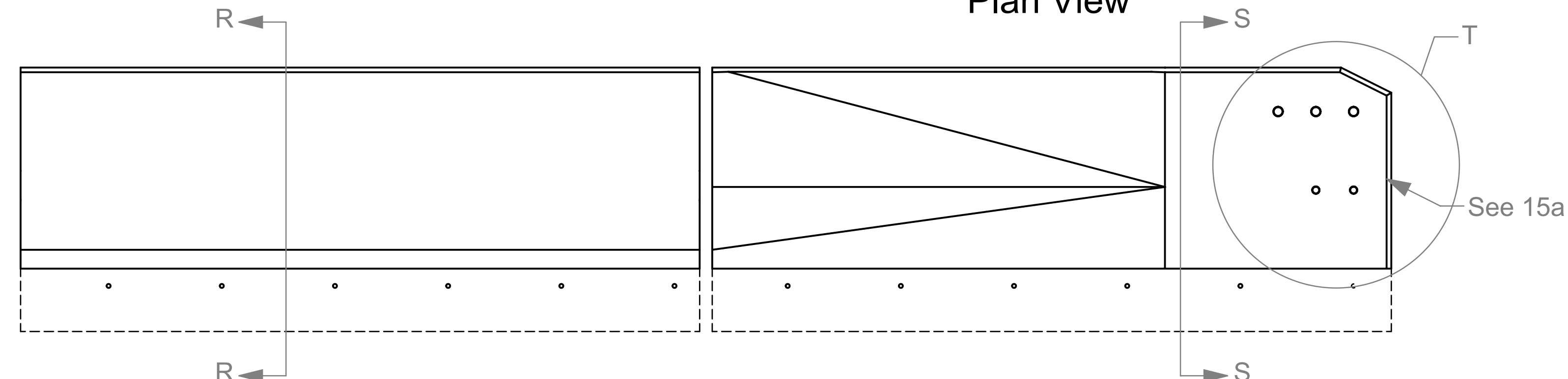
Concrete Details

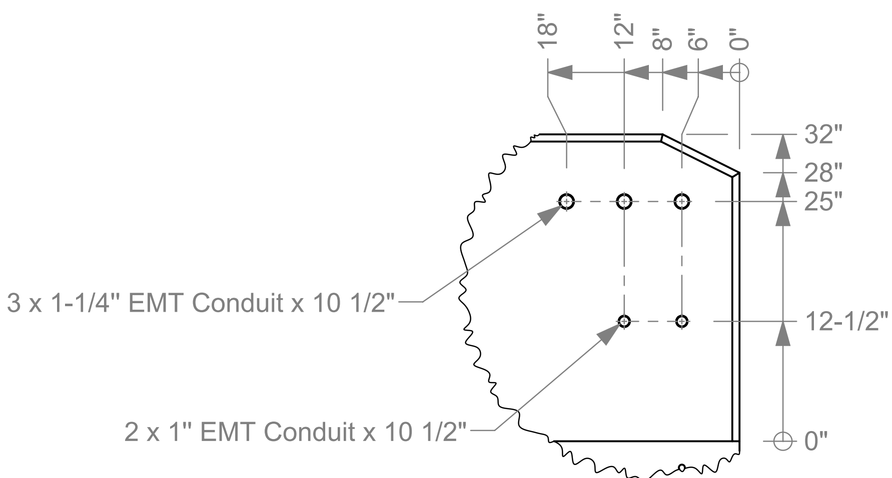
Section Views on next sheet



Plan View



Elevation View



Detail T
Scale 1 : 20

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

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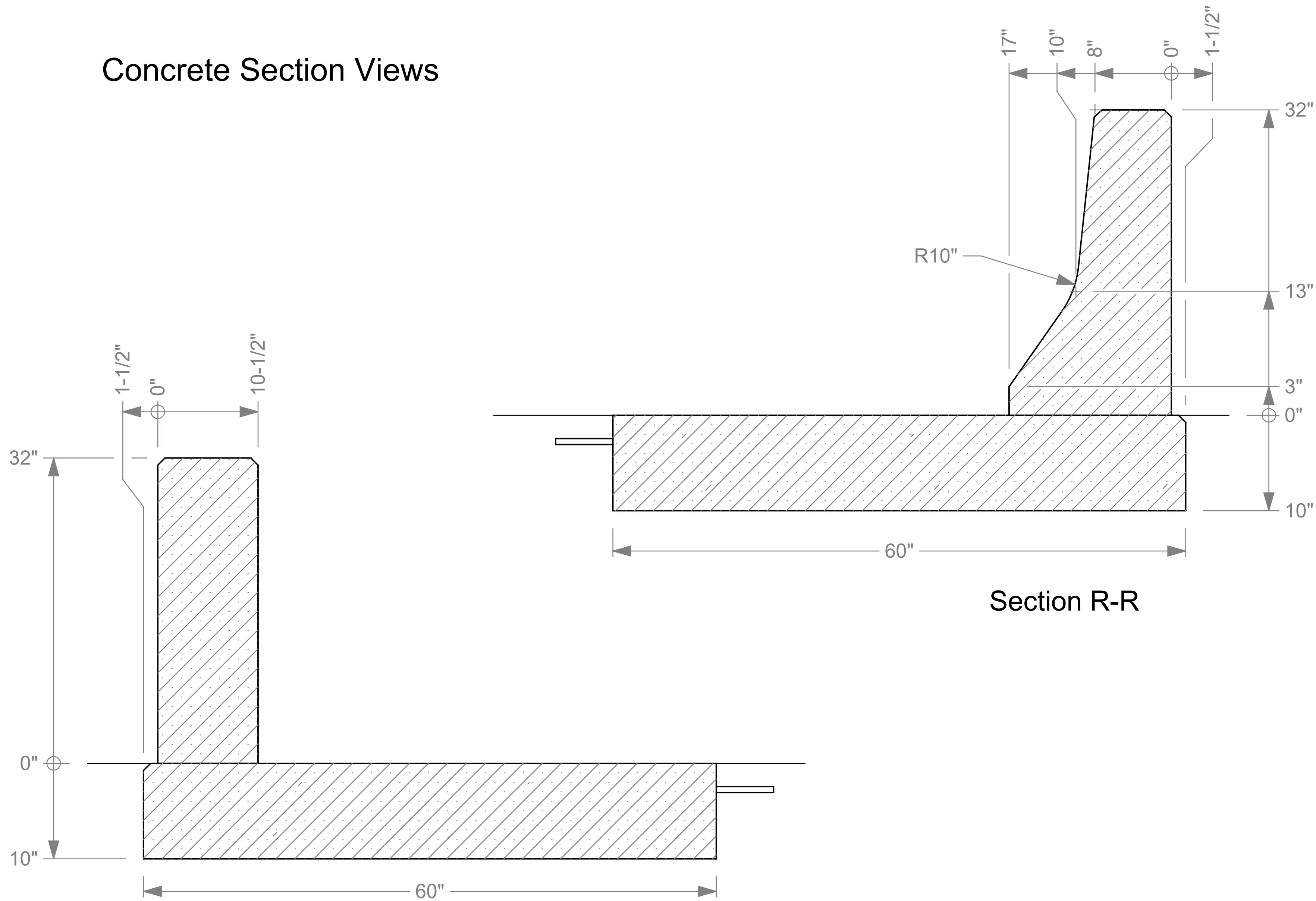
Drawn by GES	Scale 1:30	Sheet 15 of 21 Concrete Details

Concrete Section Views



Section R-R

Section S-S

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

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
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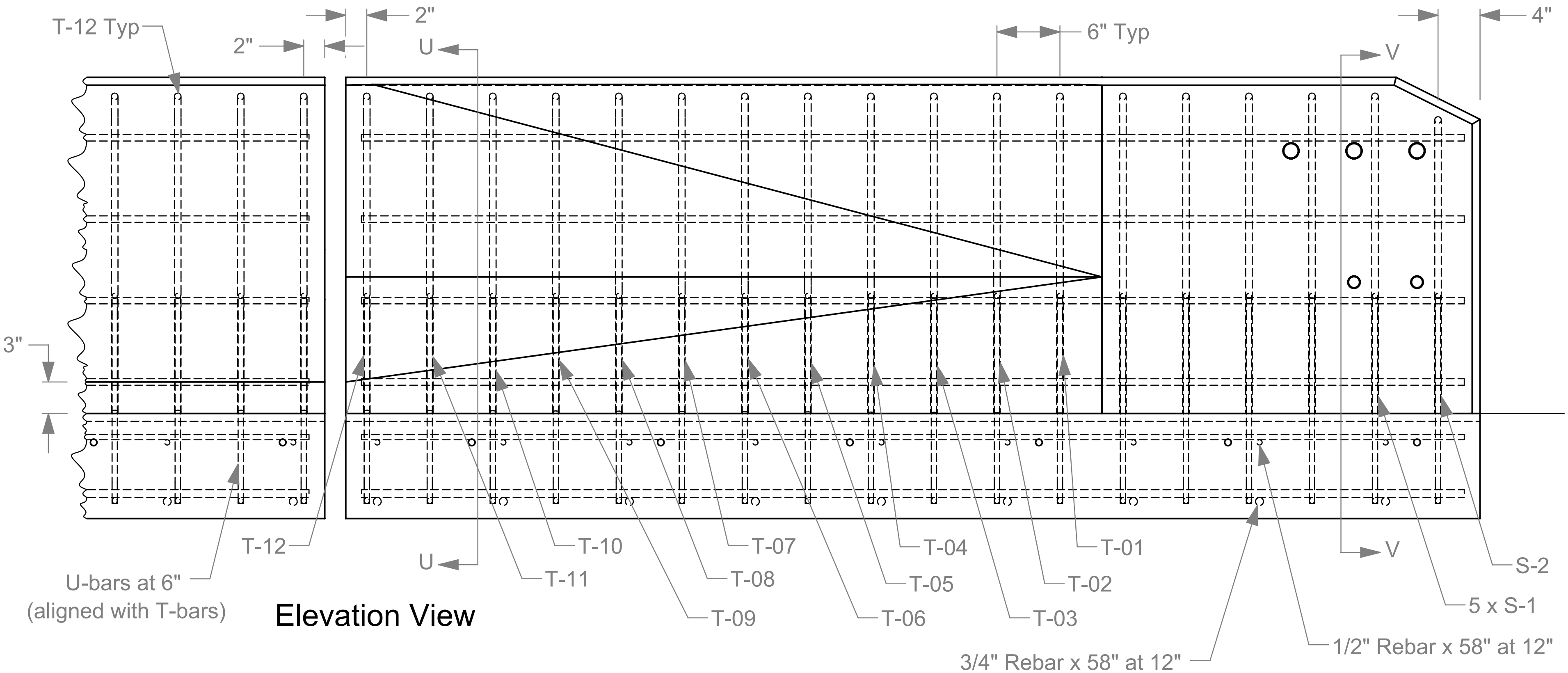
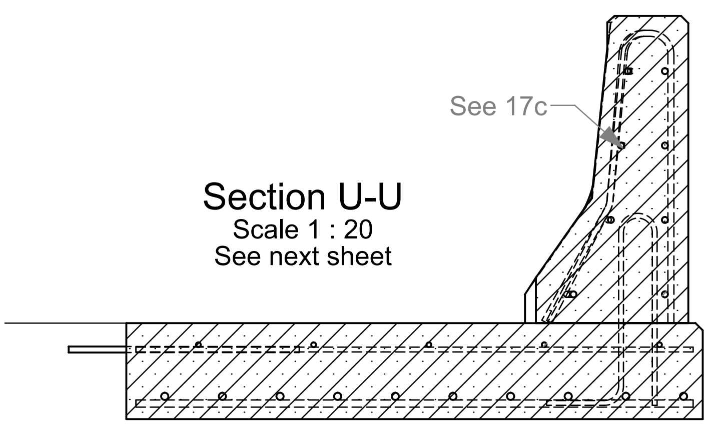
Drawn by GES	Scale 1:15	Sheet 16 of 21 Concrete Section Views

Rebar Details

Section V-V on next sheet



Elevation View



Section U-U
Scale 1 : 20
See next sheet

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

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

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

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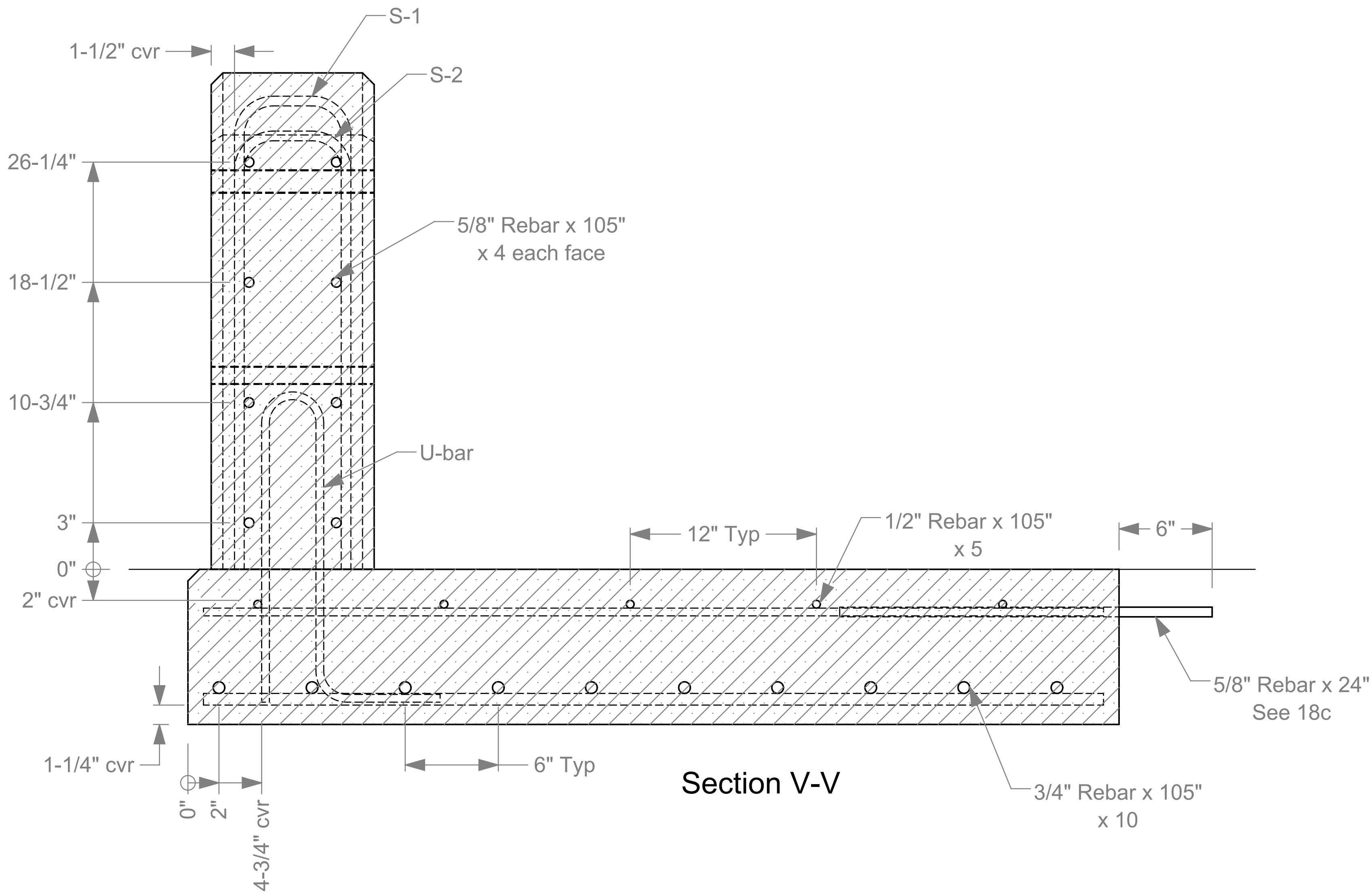
Drawn by GES	Scale 1:15	Sheet 17 of 21 Rebar Details



Section V-V

18a. Concrete is 4,000 psi. Rebar is Grade 60.

18b. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

18c. Field bend traffic side bars as needed.

18c. Secure in existing concrete with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment. Space at 18".

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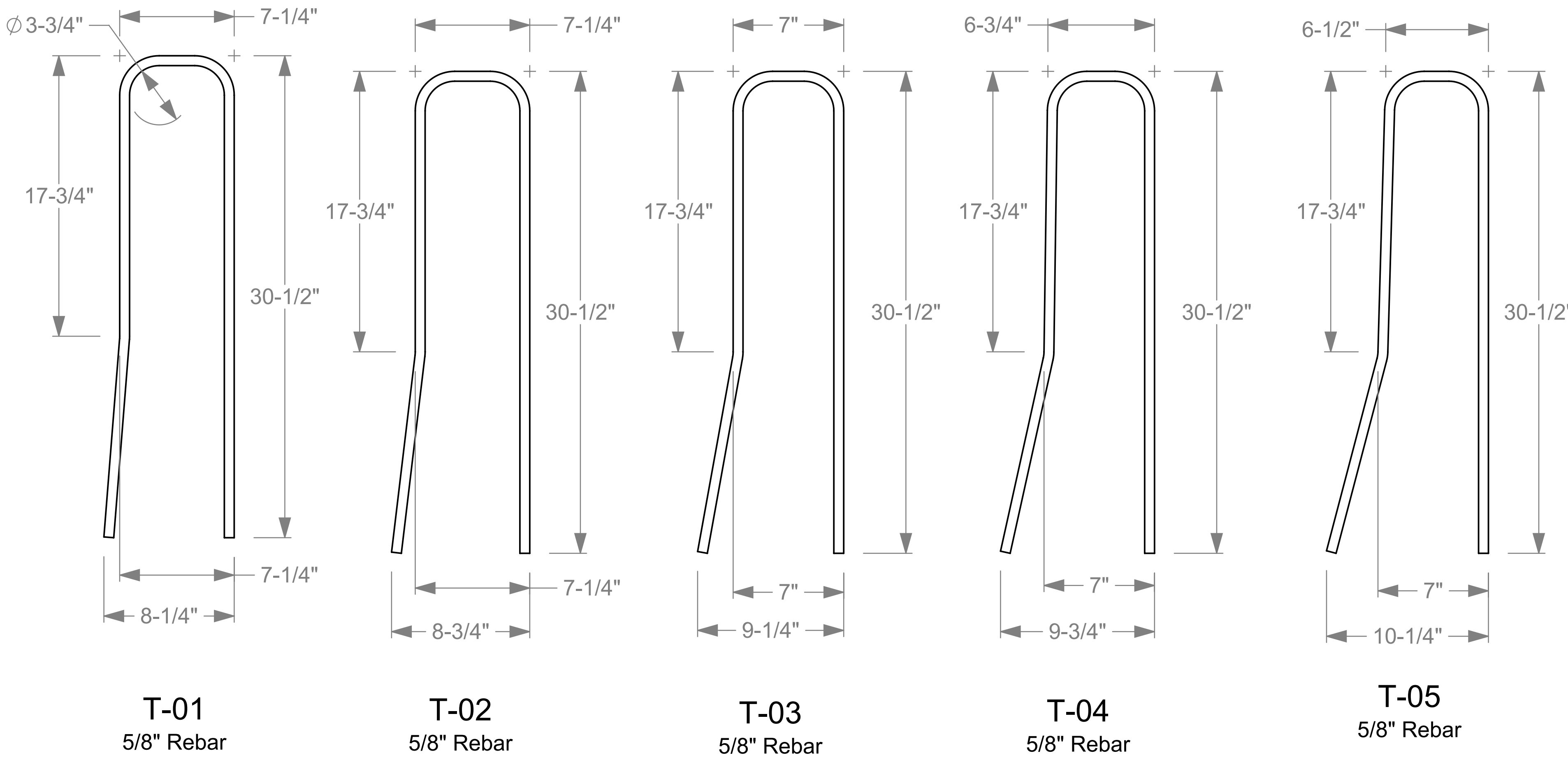
Drawn by GES	Scale 1:10	Sheet 18 of 21 Rebar Section View

T-1 to T-5



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

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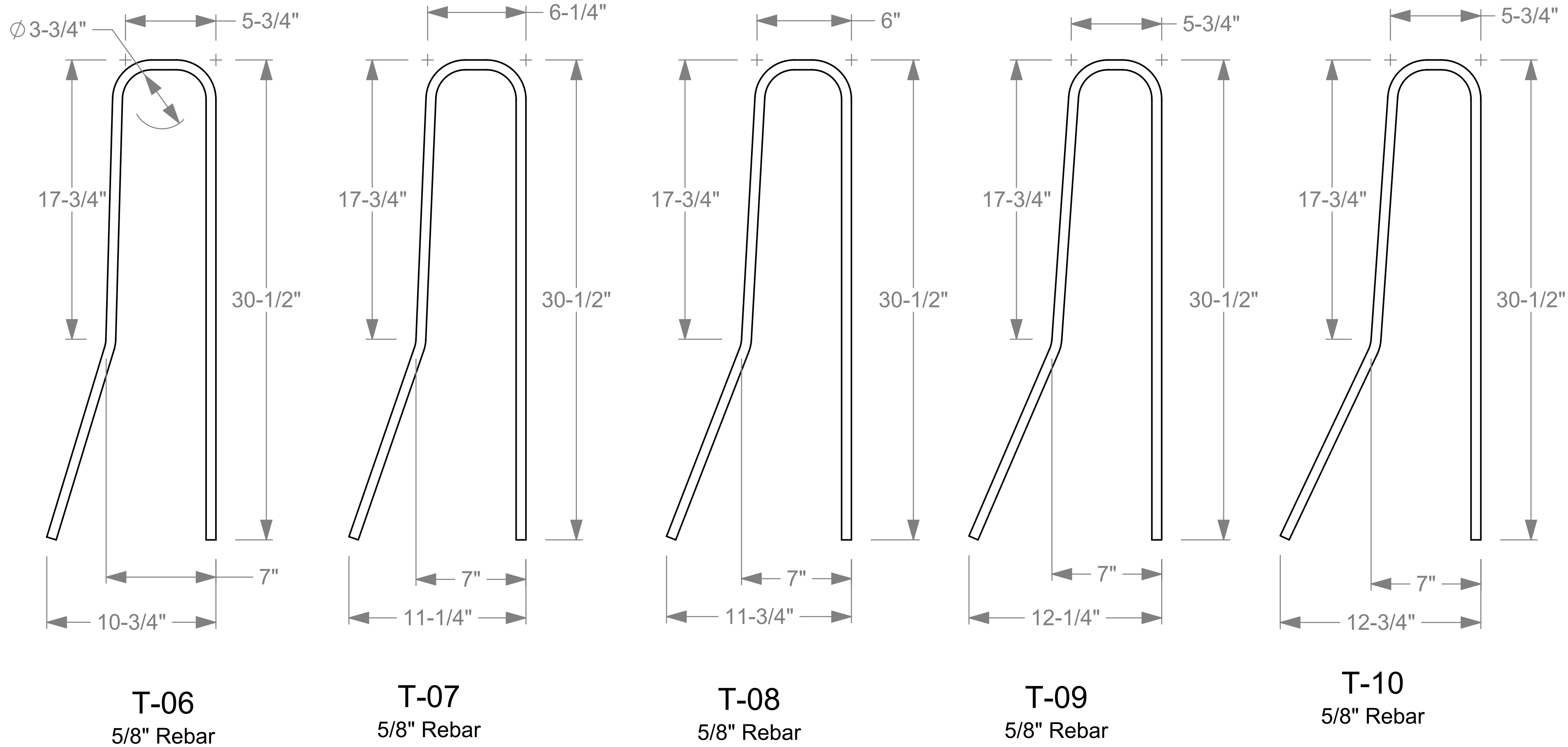
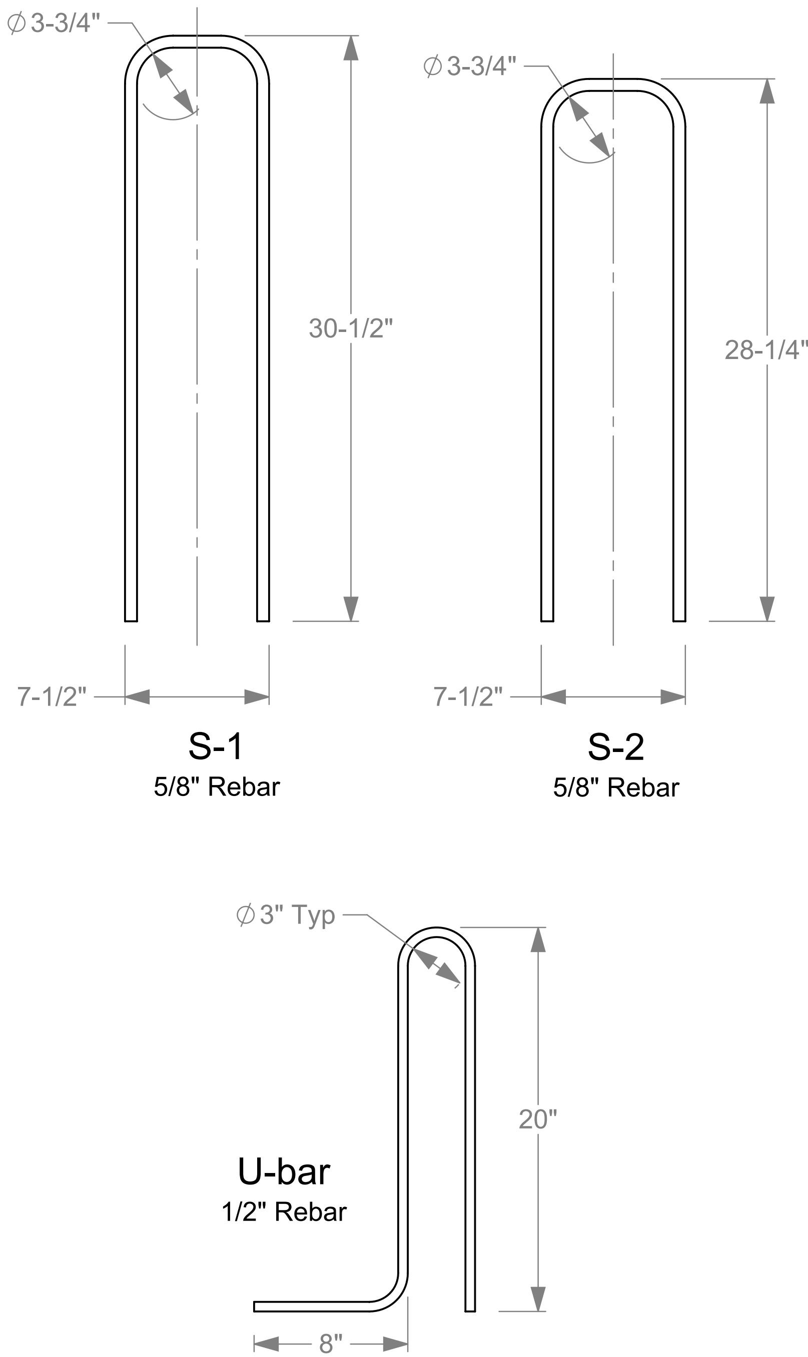
Drawn by GES	Scale 1:10	Sheet 19 of 21 T-1 to T-5	

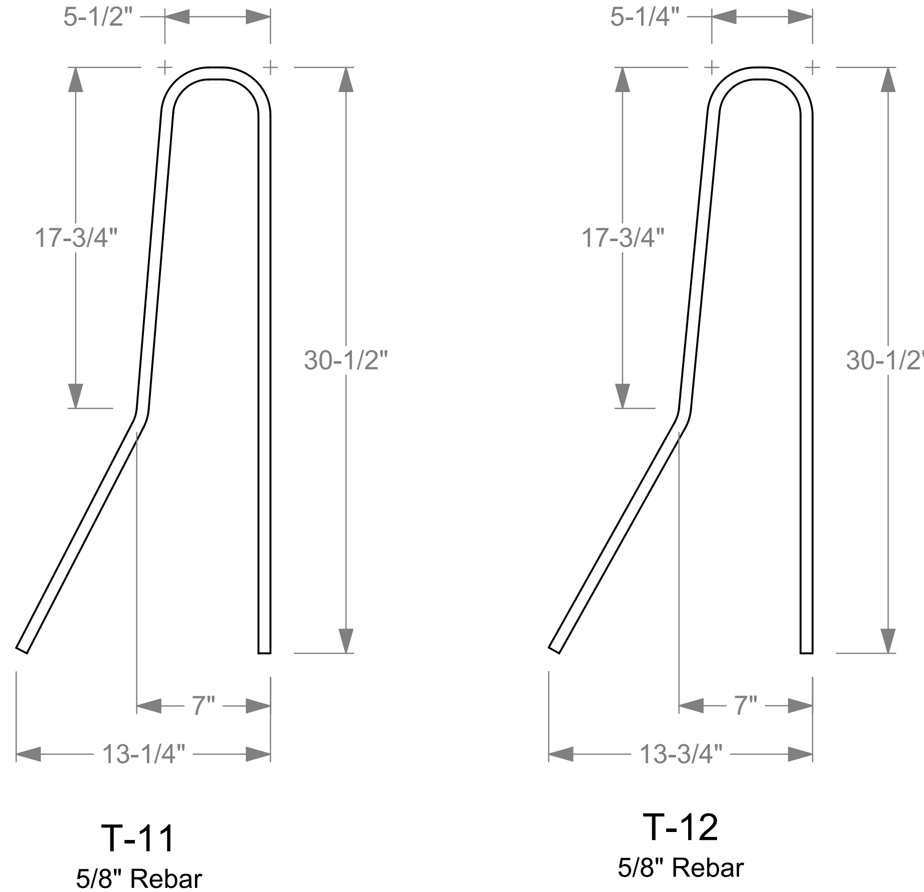
T-6 to T-10



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

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition			2022-03-24
Drawn by GES	Scale 1:10	Sheet 20 of 21 T-6 to T-10	





Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #611801-03 Wyoming Box Beam Transition			2022-03-24
Drawn by GES	Scale 1:10	Sheet 21 of 21 U-, S-, T-11, and T -12 bars	

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