

TECHNICAL MEMORANDUM

Contract No.: T4541 Task Order BD
Test Report No.: TM 405160-30-1
Project Name: Washington State Department of Transportation Pin and Loop Barrier with Drainage Slots
Sponsor: Roadside Safety Research Program Pooled Fund Study

DATE: January 13, 2012

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Washington State Department of Transportation

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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 Washington State Department of Transportation, the Roadside Safety Research Program Pooled Fund Study, The Texas A&M University System, or Texas Transportation Institute. This report does not constitute a standard, specification, or regulation. In addition, the above listed 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 American Association of State Highways and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware (MASH)*.

TEST ARTICLE DESIGN AND CONSTRUCTION

The Washington Pin and Loop Barrier system tested for this project consisted of precast concrete barrier segments that were 12 ft-6 inches in length and 34 inches in height. The barrier segment was 8 inches wide at the top and 21 inches wide at the base with a uniform single slope surface on each side face of the barrier. A 4-inch high by 15-inch wide “V” shaped cutout was centered in the base of the barrier and continuous along the entire length of the barrier segment. In addition to this longitudinal drainage slot, a drainage scupper opening was located at the center of the barrier segment. The drainage scupper opening was 9-inch high by 28 inches in width. This drainage scupper opening would permit drainage from the roadway through the barrier segment or along the barrier through the “V” shape drainage slot located in the base of the barrier. Three ¾-inch diameter steel loops were constructed on the ends of the barrier segments. These loops overlay three loops on the end of the adjacent barrier segment. The segments are connected together by inserting a 1¼-inch diameter steel rods. The ¾-inch steel loops were fabricated using A36 material. The 1¼-inch diameter steel rods were fabricated from ASTM F1554 grade 105 material and were 31 inches in length.

Vertical reinforcement (stirrups) in each barrier segment consisted of #4 rebar stirrups spaced as close as 4 inches on the ends to 11½ inches toward the center of the barrier segment . The stirrups were spaced on 7-inch centers (3 spaces) immediately above the drainage scupper located in the center of the segment. Longitudinal reinforcement in the barrier segment consisted of twelve #5 bars. The bars located in the bottom of the barrier segment were bent to accommodate the drainage scupper opening located in the center of the barrier segment.

The test installation for this project consisted of 16 barrier segments connected together using the 1¼-inch diameter ASTM F1554 grade 105 rods. The total length of the test installation was approximately 200 ft. The minimum compressive strength of the concrete used to construct the units was specified to be 4000 psi. All reinforcing steel used to construct the barrier units was specified to be grade 60 material. For additional information, please refer to the drawings shown as Attachment A and figure 1 in this report.



Figure 1. WSDOT pin and loop barrier with drainage slots before test 405160-30-1.



Figure 1. WSDOT pin and loop barrier with drainage slots before test 405160-30-1 (continued).

TEST DESIGNATION AND ACTUAL TEST CONDITIONS

MASH test 3-11 involves a 2270P vehicle weighing 5000 lb \pm 100 lb impacting the WSDOT pin and loop barrier with drainage slots at an impact speed of 62.2 mi/h \pm 2.5 mi/h and an angle of 25 degrees \pm 1.5 degrees. The target impact point was 4.3 ft upstream of the joint between segments 6 and 7. The 2003 Dodge Ram 1500 pickup truck used in the test weighed 5008 lb and the actual impact speed and angle were 62.0 mi/h and 26.1 degrees, respectively. The actual impact point was 3.3 ft upstream of the joint between segments 6 and 7.

TEST VEHICLE

The 2003 Dodge Ram 1500 pickup truck, shown in figures 5.1 and 5.2, was used for the crash test. Test inertia weight of the vehicle was 5008 lb, and its gross static weight was 5008 lb. The height to the lower edge of the vehicle front bumper was 13.5 inches, and the height to the upper edge of the front bumper was 26.0 inches. The height to the center of gravity was 28.3 inches.

SOIL AND/OR WEATHER CONDITIONS

The crash test was performed the afternoon of September 27, 2011. Weather conditions at the time of testing were: Wind speed: 5 mi/h; wind direction: 146 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 92 °F; relative humidity: 51 percent.

BRIEF TEST DESCRIPTION

The 2003 Dodge Ram 1500 pickup truck, traveling at an impact speed of 62.0 mi/h, impacted the WSDOT pin and loop barrier with drainage slots 3.3 ft upstream of the joint between segments 6 and 7 at an impact angle of 26.1 degrees. At approximately 0.023 s, the vehicle began to redirect, and at 0.032 s, segments 6 and 7 began to deflect toward the field side. A crack appeared in segment 7 near the joint between segments 6 and 7 at 0.070 s. The truck began to roll counterclockwise at 0.184 s. At 0.201 s, the vehicle was traveling parallel with the

barrier at a speed of 53.2 mi/h. As the vehicle exited the barrier, it continued to roll counterclockwise and came to rest on its left side 202 ft downstream of impact and 31 ft toward traffic lanes.

TEST ARTICLE/COMPONENT DAMAGE

Damage to the WSDOT pin and loop barrier with drainage slots is shown in figure 2. There was no visible damage to the pins. Spalling of the concrete at the joints and gouging of the traffic face of the barrier segments in the impact area was evident. Movement of the barriers is recorded in table 1. Working width was 6.0 ft. Maximum dynamic deflection and maximum permanent deformation of the barrier was 5.4 ft.



Figure 2. Damage to WSDOT pin and loop barrier with drainage slots after test 405160-30-1.

Table 1. Barrier segment movements.

Segment Joint	Space before	Space after		Longitudinal Movement	Lateral Movement
		Traffic side	Field side		
1 end				4 inches dwnstrm	0
1-2	1 inch	1-1/4 inches	1-1/4 inches	4 inches dwnstrm	0
2-3	9/10 inch	1-1/8 inches	1/1/2 inches	5 inches dwnstrm	1 inch back
3-4	1/2 inch	1-1/2 inches	1-1/8 inches	5-1/2 inches dwn	6-1/4 inches fwd
4-5	7/8 inch	2 inches	3/4 inches	7-1/2 inches dwn	1-1/2 inches fwd
5-6	3/4 inch	1-1/2 inches	1-3/8 inches	6 inches dwnstrm	30 inches back
6-7	3/4 inch	1-1/4 inches	3-1/8 inches	0	64-1/2 inches back
7-8	1/2 inch	1-1/4 inches	1-7/8 inches	0	58 inches back
8-9	7/16 inch	1-1/4 inches	1-3/4 inches	0	34-1/2 inches
9-10	7/8 inch	2 inches	3/4 inches	4 inches upstrm	0
10-11	7/8 inch	1-5/8 inches	1 inch	2 inches upstrm	8-1/2 inches fwd
11-12	7/8 inch	1 inch	1-3/8 inches	2 inches upstrm	0
12-13	3/4 inch	1-1/8 inches	1-1/8 inches	1-1/2 inches up	0
13-14	11/16 inch	1-1/4 inches	1-1/4 inches	1 inch upstrm	0
14-15	5/8 inch	1-1/4 inches	1-1/4 inches	1/2 inch upstrm	0
15-16	11/16 inch	3/4 inch	3/4 inch	0	0
16 end				0	0

TEST VEHICLE DAMAGE

Damage to the vehicle is shown in figure 3. Damage was imparted to the front bumper, grill, left front fender, left tire and wheel rim, left upper and lower A-arms, left front door and glass, left rear door, left rear exterior bed, left rear wheel rim and the rear bumper. The windshield sustained stress cracks near the left A-pillar. Maximum exterior crush to the vehicle was 11.0 inches at the left front corner at bumper height. The floor pan sustained a small dent measuring 4 inches \times 6 inches \times 0.5 inch deep. Maximum occupant compartment deformation was 1.0 inch in the rear passenger compartment near hip height.



Figure 3. Vehicle after test 405160-30-1.

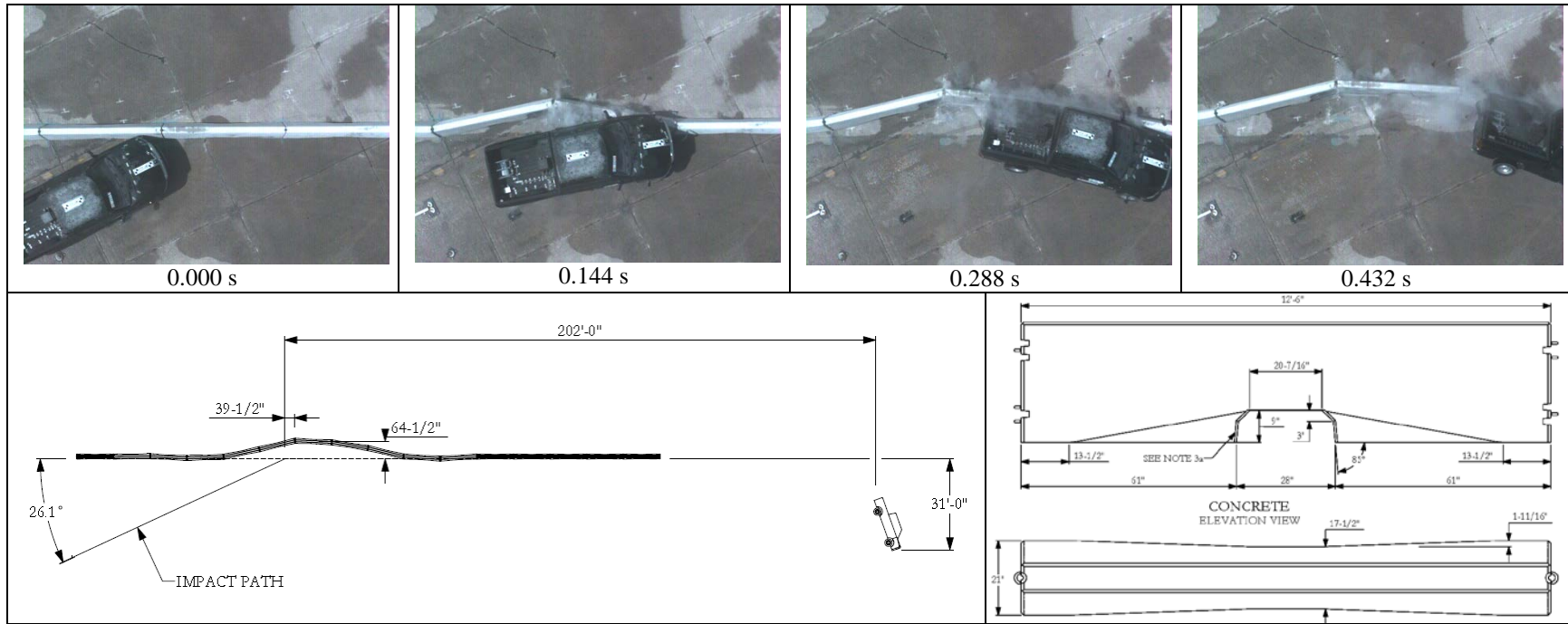
OCCUPANT RISK VALUES

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 was 14.4 ft/s at 0.100 s, the highest 0.010-s occupant ridedown acceleration was 5.9 Gs from 0.266 to 0.276 s, and the maximum 0.050-s average acceleration was -6.7 Gs between 0.020 and 0.070 s. In the lateral direction, the occupant impact velocity was 22.3 ft/s at 0.100 s, the highest 0.010-s occupant ridedown acceleration was 10.4 Gs from 0.279 to 0.289 s, and the maximum 0.050-s average was 10.2 Gs between 0.032 and 0.082 s. Theoretical Head Impact Velocity (THIV) was 29.2 km/h or 8.1 m/s at 0.097 s; Post-Impact Head Decelerations (PHD) was 10.4 Gs between 0.280 and 0.290 s; and Acceleration Severity Index (ASI) was 1.24 between 0.032 and 0.082 s. These data and other pertinent information from the test are summarized in figure 4.

SUMMARY AND CONCLUSIONS

The WSDOT pin and loop barrier with drainage slots contained and redirected the 2270P vehicle. Maximum deflection of the barrier during the test was 5.4 ft. No detached elements, fragments or other debris were present to penetrate the occupant compartment, show potential for penetrating the occupant compartment or to present undue hazard to others in the area. Maximum occupant compartment deformation was 1.0 inch in the rear passenger area near the hip level. After loss of contact with the barrier, the 2270P vehicle rolled counterclockwise 121 degrees and came to rest on its left side. Occupant risk factors were within the limits specified in *MASH*. The 2270P vehicle exited within the exit box.

According to criteria for *MASH* test 3-11 shown in table 2, the WSDOT pin and loop barrier with drainage slots did not perform acceptably due to rollover of the test vehicle.



General Information

Test Agency Texas Transportation Institute
 Test Standard Test No. MASH Test 3-11
 Test Agency Test No. 405160-30-1
 Test Date 2011-09-27

Test Article

Type Portable Concrete Median Barrier
 Name WSDOT pin & loop barrier with drainage slots
 Installation Length 201.25 ft
 Material or Key Elements Precast concrete barrier segments
 12 ft-6 inches long 34 inches in height

Soil Type and Condition

Placed on concrete surface, dry

Test Vehicle

Designation 2270P
 Model 2003 Dodge 1500 Ram pickup truck
 Mass
 Curb 4874 lb
 Test Inertial 5008 lb
 Dummy No dummy
 Gross Static 5008 lb

Impact Conditions

Speed 62.0 mi/h
 Angle 26.1 degrees

Exit Conditions

Speed 53.2 mi/h
 Angle Out of View

Occupant Risk Values

Impact Velocity
 Longitudinal 14.4 ft/s
 Lateral 22.3 ft/s
 THIV 29.2 km/h
 Ridedown Accelerations
 Longitudinal 5.9 G
 Lateral 10.4 G
 PHD 10.4 G
 ASI 1.24
 Max. 0.050-s Average
 Longitudinal -6.7 G
 Lateral 10.2 G
 Vertical -3.6 G

Test Article Deflections

Dynamic 5.4 ft
 Permanent 5.4 ft
 Working Width 6.0 ft

Vehicle Damage

Exterior
 VDS 11LFQ5
 CDC 11FLEW4
 Max. Exterior
 Vehicle Crush 11.0 inches
 Interior
 OCDI LS00000100
 Max. Occupant Compartment
 Deformation 1.0 inch

Post-Impact Behavior

(during 1.0 sec after impact)
 Max. Yaw Angle -121 degrees
 Max. Pitch Angle 10.2 degrees
 Max. Roll Angle -3.6 degrees

Figure 4. Summary of results for MASH test 3-11 on the WSDOT pin and loop barrier with drainage slots.

Table 2. Performance evaluation summary for *MASH* test 3-11 on the WSDOT pin and loop barrier with drainage slots.

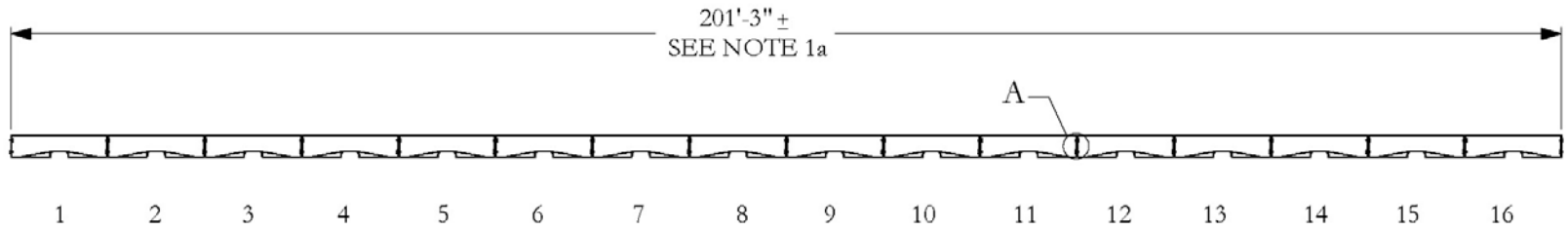
Test Agency: Texas Transportation Institute

Test No.: 405160-30-1

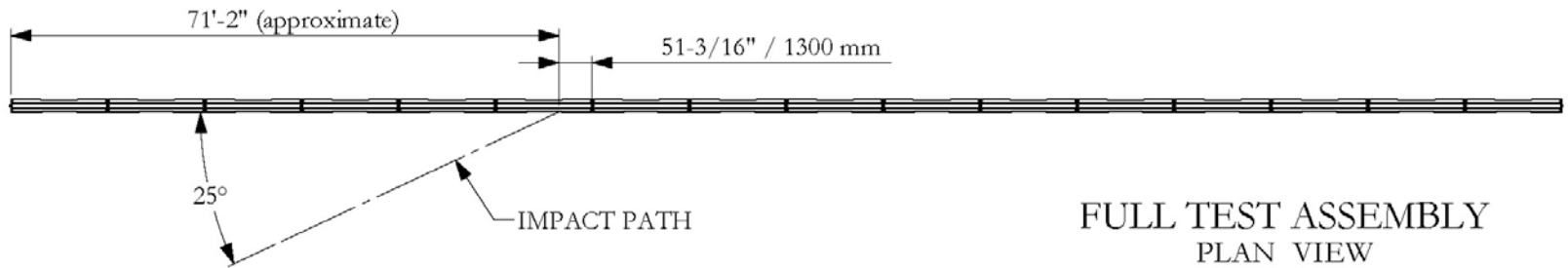
Test Date: 2011-09-27

NCHRP MASH 3-11 Evaluation Criteria	Test Results	Assessment
Structural Adequacy		
<i>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.</i>	The WSDOT pin and loop barrier with drainage slots contained and redirected the 2270P vehicle. Maximum deflection of the barrier during the test was 5.4 ft.	Pass
Occupant Risk		
<i>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. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH08.</i>	No detached elements, fragments or other debris were present to penetrate the occupant compartment, show potential for penetrating the occupant compartment or to present undue hazard to others in the area. Maximum occupant compartment deformation was 1.0 inch in the rear passenger area near the hip level.	Pass Pass
<i>F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</i>	After loss of contact with the barrier, the 2270P vehicle rolled counterclockwise 121 degrees and came to rest on its left side.	Fail
<i>H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 9.0 m/s (29.5ft/s), or at least below the maximum allowable value of 12.0 m/s (39.4 ft/s).</i>	Longitudinal occupant impact velocity was 14.4 ft/s, and lateral occupant impact velocity was 22.3 ft/s.	Pass
<i>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 20.0 Gs.</i>	Longitudinal ridedown acceleration was 5.9 G, and lateral ridedown acceleration was 10.4 G.	Pass
Vehicle Trajectory		
<i>Vehicle should exit with the exit box.</i>	The vehicle exited within the exit box.	Pass

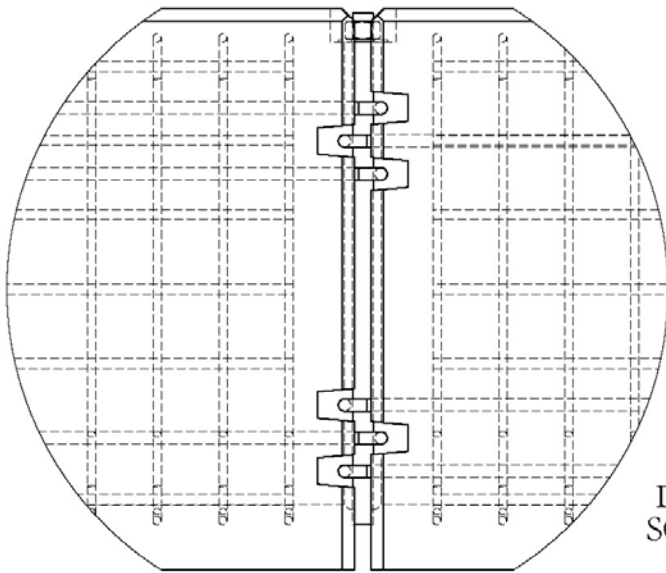
**ATTACHMENT A: DETAILS OF THE WSDOT PIN AND LOOP
BARRIER WITH DRAINAGE SLOTS**



FULL TEST ASSEMBLY
ELEVATION VIEW



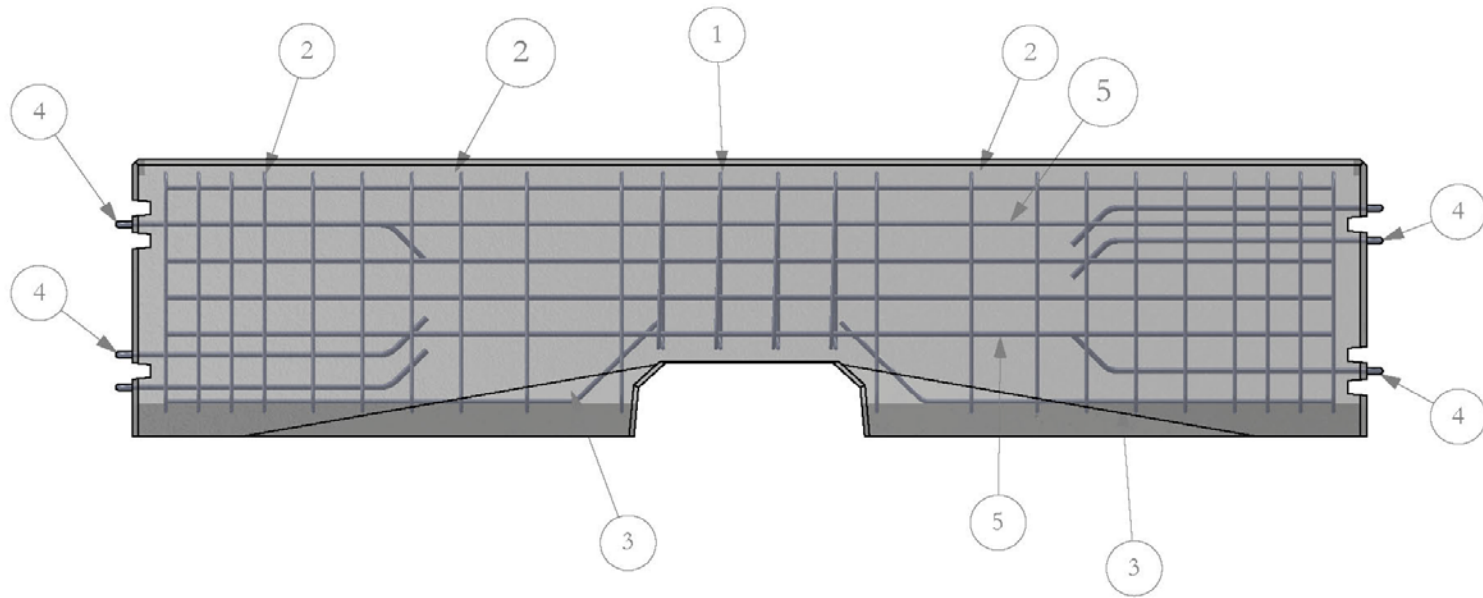
FULL TEST ASSEMBLY
PLAN VIEW



DETAIL A
SCALE 1 : 10

1a. 16 barriers @ 12'-6" with ≈1" space between barriers.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project	405160-30	Wash DOT Pin and Loop Barriers	
Drawn By	GES	Scale 1:250	Sheet 1 of 8 200' Installation
Approved:	Signature:		Date:
William Williams:	<i>William Williams</i>		2011-09-08

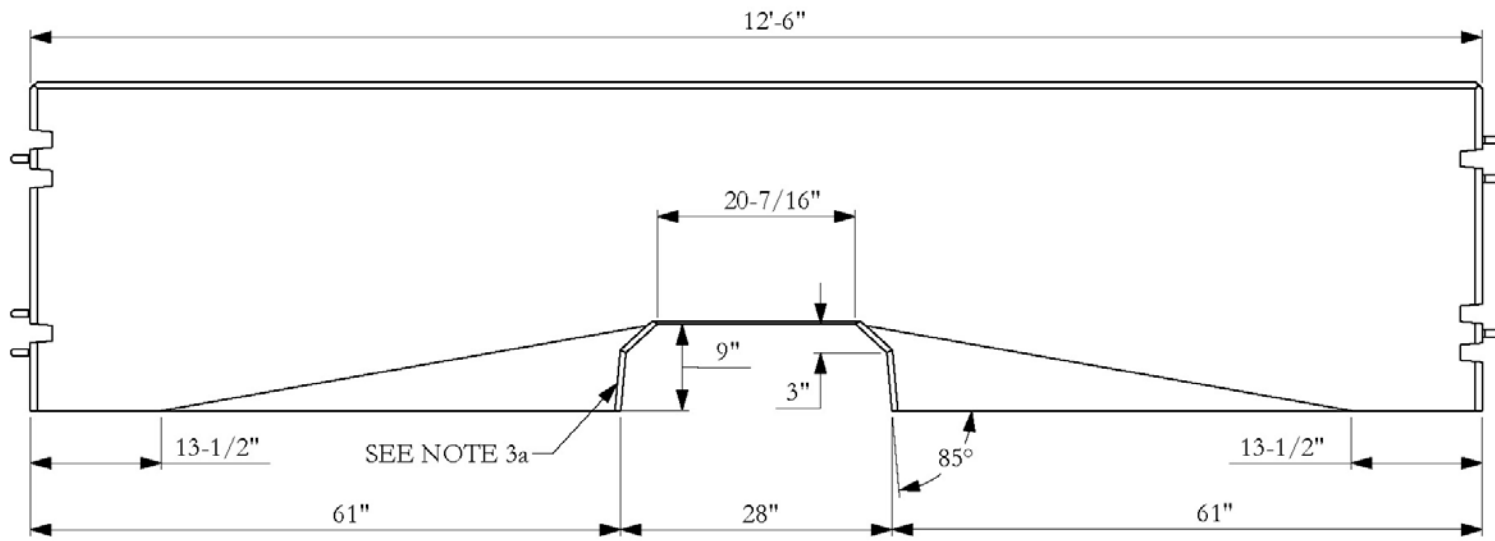


#	PART	QTY.
1	Rebar Stirrup, #4 center	4
2	Rebar Stirrup, #4 ends	20
3	Rebar, #5 Bent	4
4	End Loop, A36 3/4" Rod	6
5	Rebar, #5 - 11' 10 1/2"	10

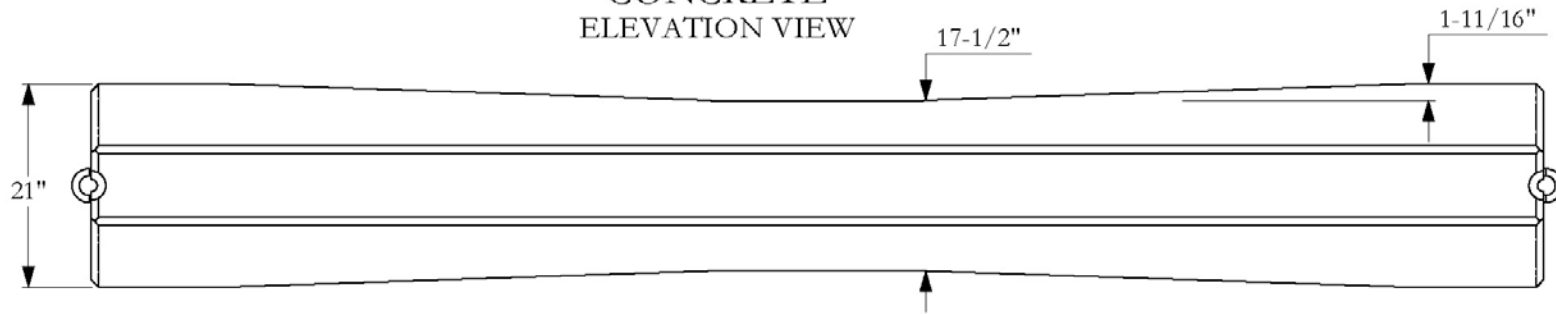
- 2a. All rebar is grade 60.
- 2b. Concrete strength is 4000 psi.
- 2c. Rebar stirrups are detailed on page 7.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project	405160-30	Wash DOT Pin and Loop Barriers	
Drawn By	GES	Scale	1:20
Sheet		2 of 8	Parts List

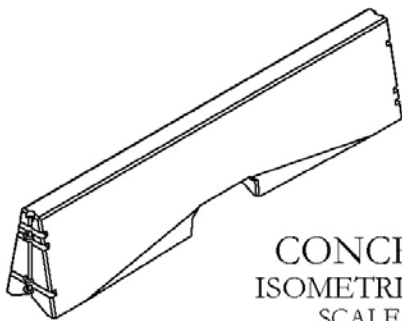
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CONCRETE ELEVATION VIEW



CONCRETE PLAN VIEW

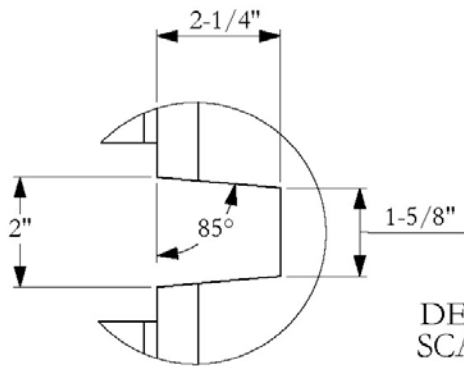
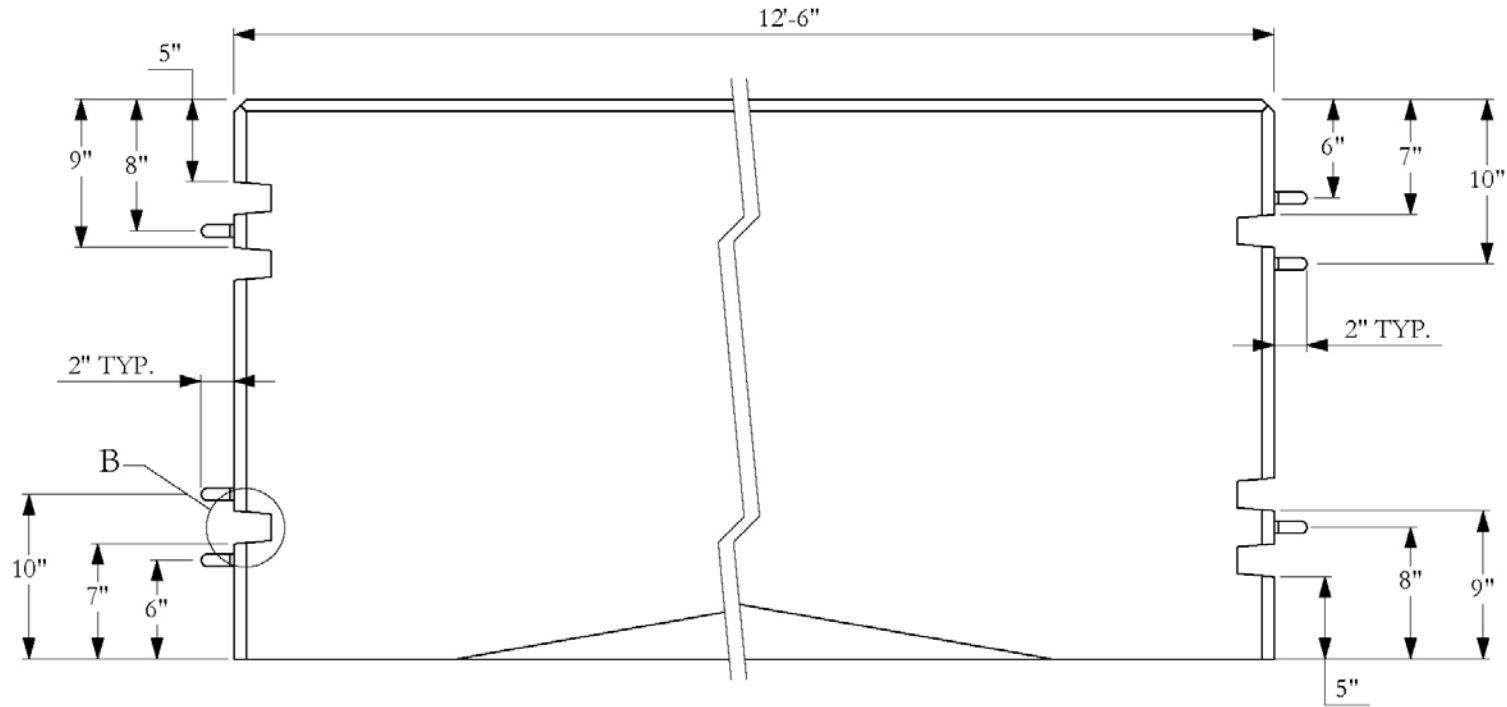


CONCRETE ISOMETRIC VIEW
SCALE 1:50

3a. 3/4" chamfer scupper edges.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project	405160-30	Wash DOT Pin and Loop Barriers	
Drawn By	GES	Scale	1:17
Sheet		3 of 8	Concrete

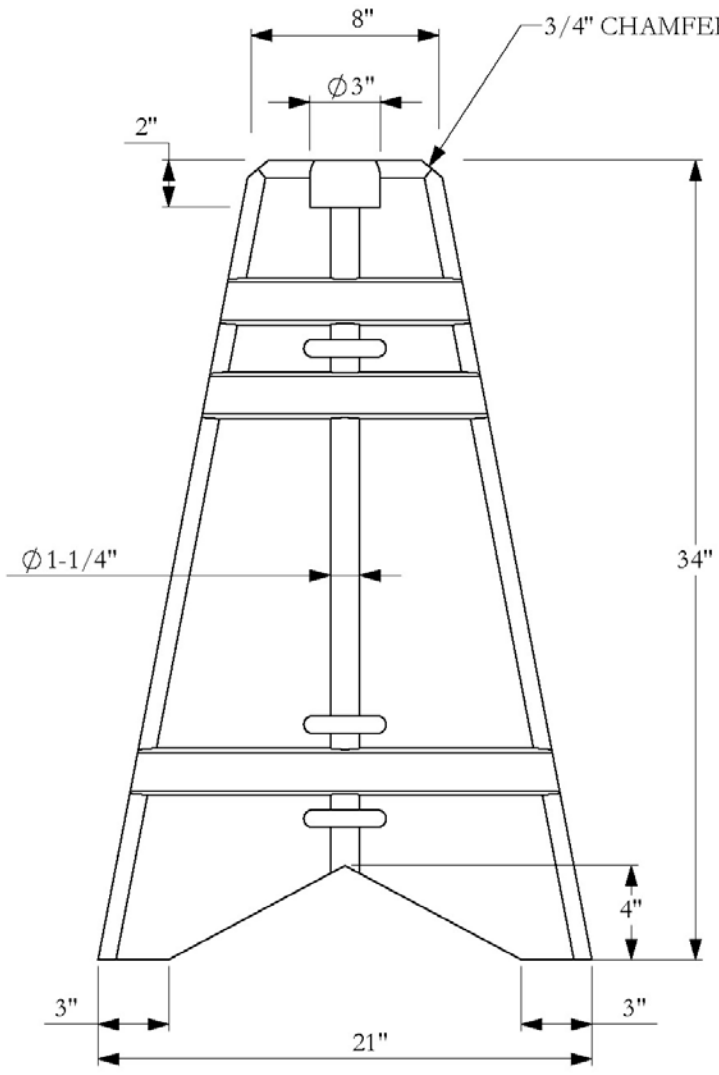
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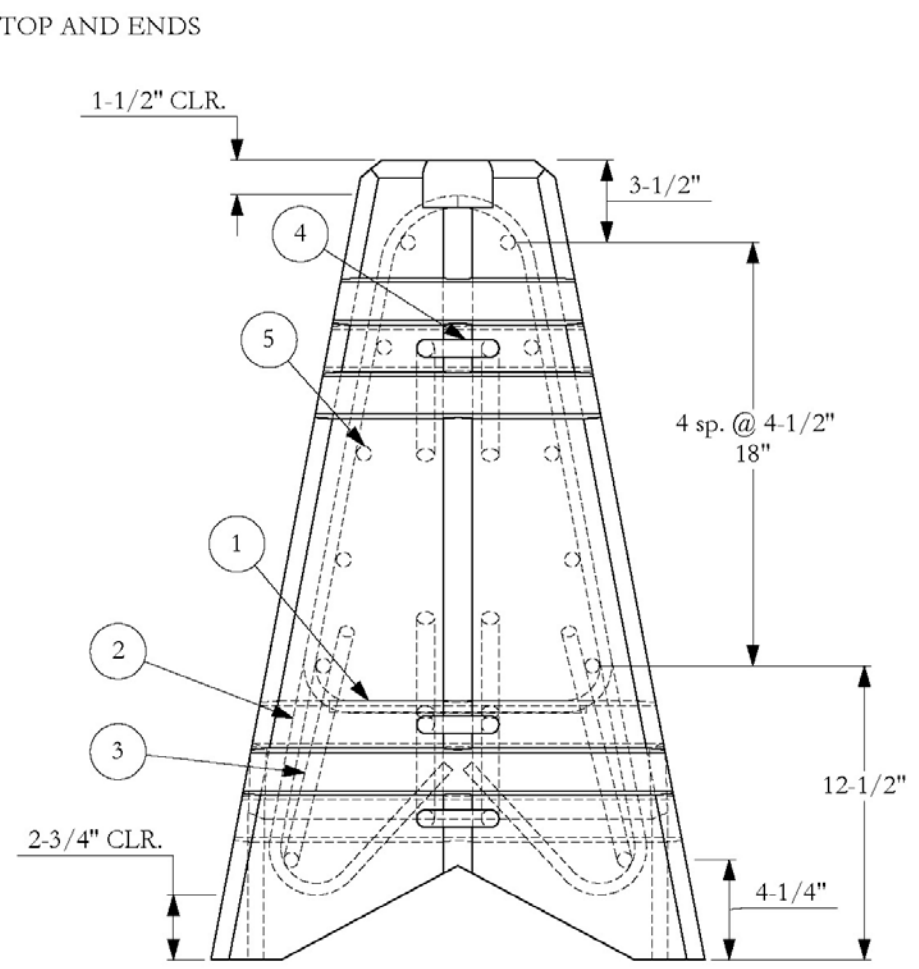
DETAIL B
SCALE 1 : 3
TYPICAL 6 SLOTS

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project	405160-30	Wash DOT Pin and Loop Barriers	
Drawn By	GES	Scale	1:10
Sheet	4 of 8	Loops	

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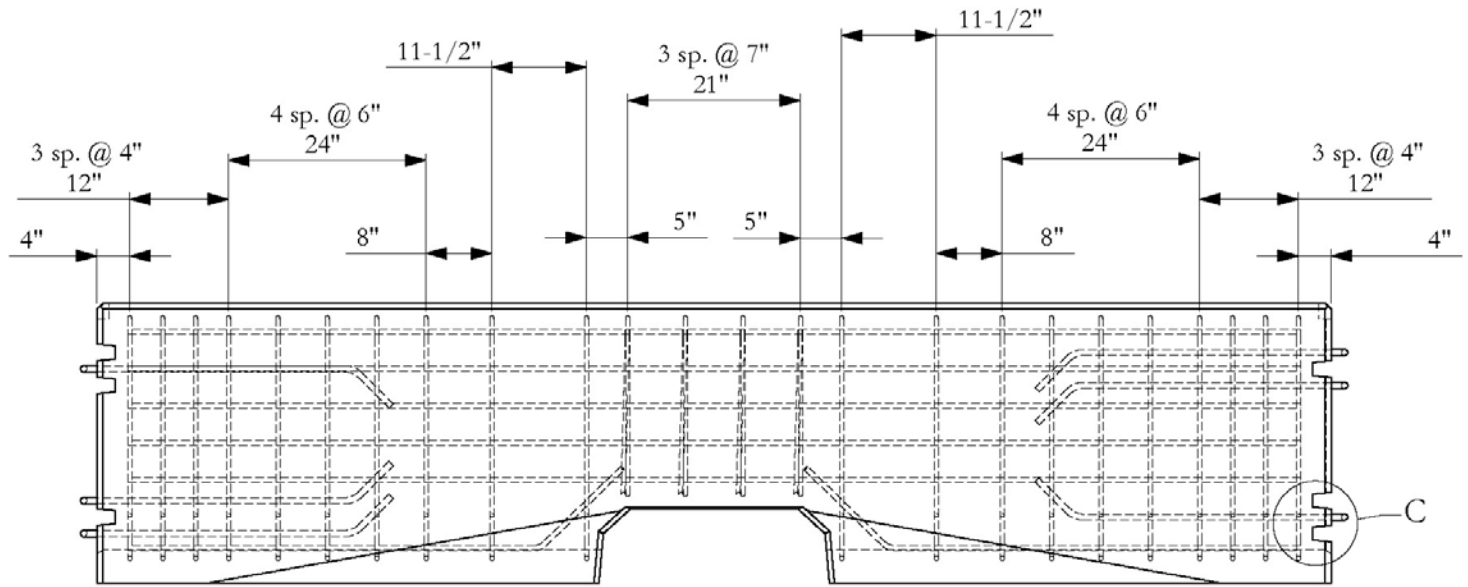
CONCRETE
ELEVATION VIEW - END



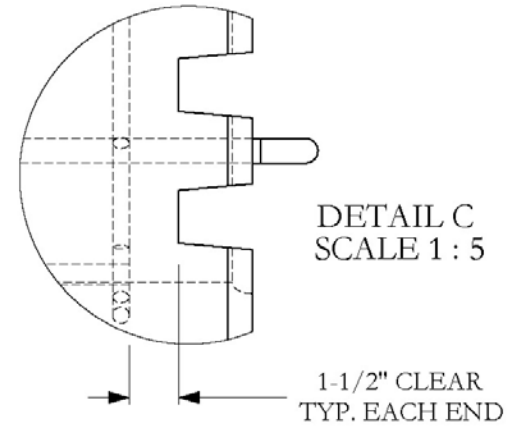
REBAR
ELEVATION VIEW - END

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project	405160-30	Wash DOT Pin and Loop Barriers	
Drawn By	GES	Scale	1:7
		Sheet	5 of 8
		End Views	

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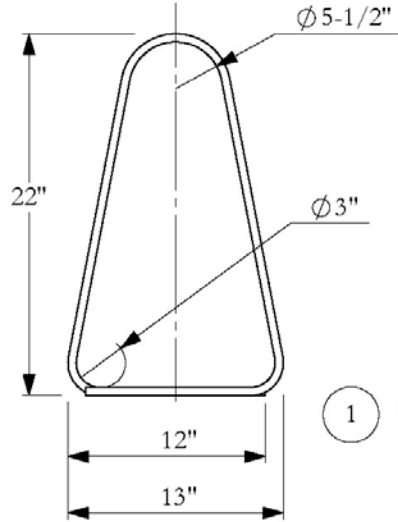
REBAR
ELEVATION VIEW



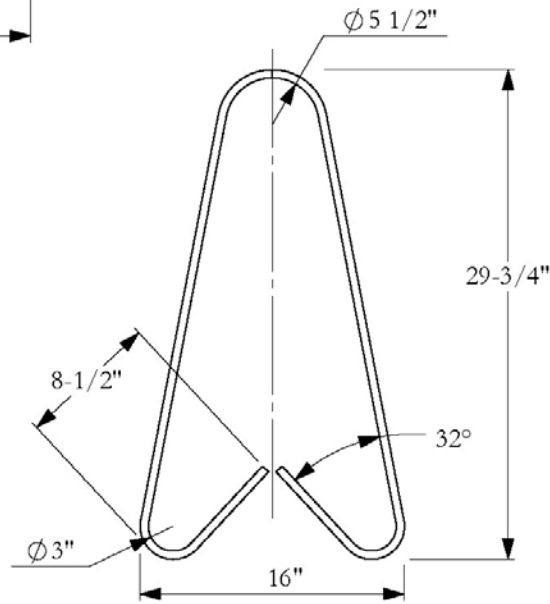
6a. All rebar spacing dimensions are to \varnothing unless otherwise noted.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project	405160-30	Wash DOT Pin and Loop Barriers	
Drawn By	GES	Scale 1:20	Sheet 6 of 8 Rebar - Elevation

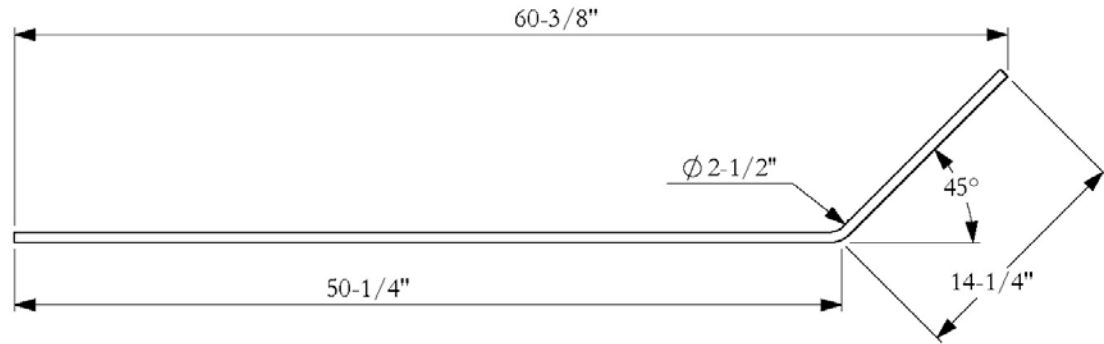
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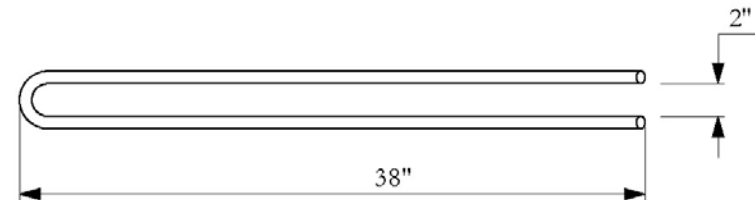
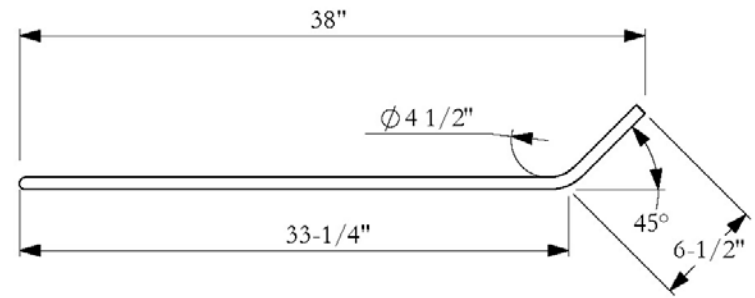
① #4 CENTER STIRRUP



② #4 END STIRRUP



③ #5 BENT REBAR

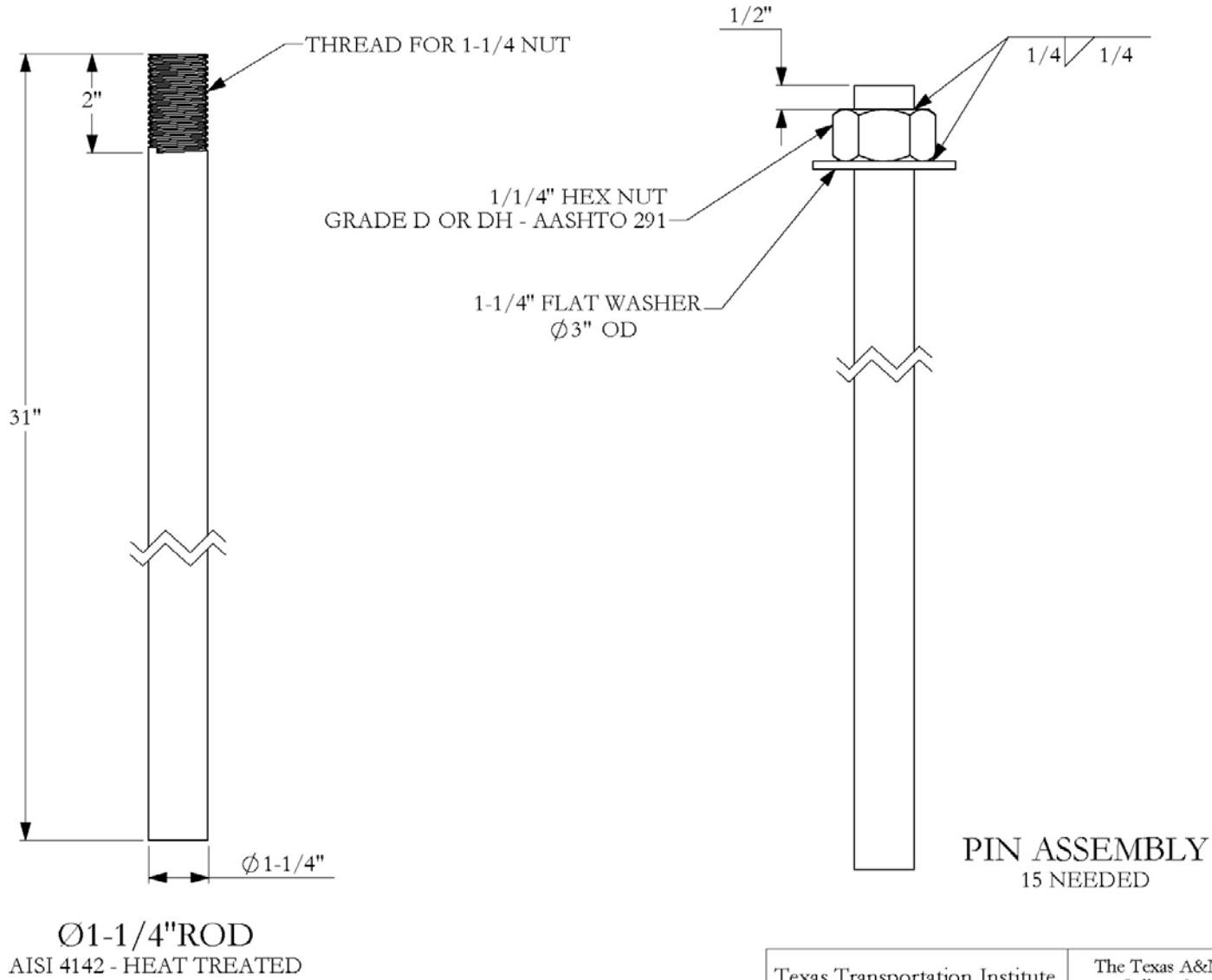


④ END LOOP
Ø3/4" A36 ROD

7a. Stirrups (1) and (2) are symmetrical about \bar{C} 's.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project	405160-30	Wash DOT Pin and Loop Barriers	
Drawn By	GES	Scale	1:10
Sheet		7 of 8	Rebar Details

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Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project	405160-30	Wash DOT Pin and Loop Barriers	
Drawn By	GES	Scale	1:3
Sheet	8 of 8	Pins	

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