



May 17, 2011

In Reply Refer To:
HSST/B-221

Mr. Robert Bielenberg
Midwest Roadside Safety Facility
527 Nebraska Hall
P. O. Box 880529
Lincoln, NE 68588-0529

Dear Mr. Bielenberg:

This letter is in response to your request for Federal Highway Administration's (FHWA) acceptance of a roadside safety system for use on the National Highway System (NHS).

Name of system: TL-3 Upstream Anchorage for F-shape Temporary Concrete Barrier
Type of system: Portable Longitudinal concrete Barrier End Anchorage
Test Level: AASHTO Manual for Assessing Safety Hardware
TL-3
Testing conducted by: Midwest Roadside Safety Facility
Date of request: December 20, 2010
Date initially acknowledged: December 22, 2010
Task Force 13 Designator: SWC17

You requested that we find this system acceptable for use on the NHS under the provisions of the American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH).

Requirements

Roadside safety devices should meet the guidelines contained in the MASH.

Decision

The following devices are found acceptable, with details provided below:

- Upstream Anchorage for F-shape Temporary Concrete Barrier



Description

The as tested barrier consisted of 156.5 feet (47.7 meter) long test installation consisting of the following two major components:

- I. 12 reinforced concrete segments of 32 inches (813 millimeters) high F-shape, temporary barrier installed on a concrete surface.
- II. 1 anchorage system composed of two 3/4-inch (19 millimeters) diameter wire cables and 2 anchor posts assemblies.

The concrete barrier utilized Iowa's Concrete Barrier Mix, which was configured with a minimum 28 day concrete compressive strength of 5,000 psi (34.5 MPa). A minimum concrete cover varied at different rebar positions within the barrier. A minimum concrete cover of 2 inches (51 millimeters) was used along the top of the vertical stirrup rebar and at the bottom of the longitudinal rebar. Minimum concrete cover of 1-3/4 inches (44 millimeters) and 1 inch (25 millimeters) were used along the sides of the vertical stirrup rebar and at the rebar around the anchor bolt block, respectively. All steel reinforcement in the barrier conformed to ASTM A615 Grade 60 rebar, except for the loop bars which were ASTM A706 Grade 60 rebar. Barrier reinforcement consisted of three Number 5 and two Number 4 longitudinal bars, twelve Number 4 bars for the vertical stirrups, and six Number 6 bars for the anchor bolt block reinforcement loops. Each of the 5 longitudinal rebars was 12 feet 2 inches (3.71 meters) long. The vertical spacing of the lower, middle, and upper longitudinal bars were 6-1/2 inches (165 millimeters), 14-1/2 inches (368 millimeters), and 29-1/8 inches (780 millimeters) from the ground to their centers, respectively. The vertical stirrups were 72 inches (1,829 millimeters) long and were bent into the shape of the barrier and the spacing is varied longitudinally. The reinforcing steel loops used around the tie-down anchor holes in the barrier were 35 inches (889 millimeters) long, were bent into a U-shape, and were used to reinforce the anchor bolt area.

The barriers used a pin and loop type connection comprised of two sets of three rebar loops on each barrier interconnection. Each loop assembly was configured with three ASTM A706 Grade sixty Number 6 bars that were bent into a loop shape. The vertical pin used in the connection consisted of a 1-1/4 inches (32 millimeter) diameter x 28 inches (711 millimeter) long round bar comprised of ASTM A36 steel. The pin was held in place using one 2-1/2 inches wide x 4 inches long x 1/2 inch thick (64 millimeters x 102 millimeters x 13 millimeters) ASTM A36 steel plate with a 1-3/8 inches (35 millimeters) diameter hole centered on it. The plate was welded 2-1/2 inches (64 millimeters) below the top of the pin. A gap of 3-5/8 inches (92 millimeters) between the ends of two consecutive barriers was formed from the result of pulling the connection taut.

The upstream-most barrier segment was installed with 36 inches of the downstream end placed on the concrete surface and the remainder of the barrier segment resting on soil. This end barrier was anchored by two cable assemblies that connected the end connector pin to two driven, steel pile, anchor posts. Each of the two anchor posts was a 8 feet (2,438 millimeters) long, W6 x 25 (W152 x 37.2) steel section with a 24 inches x 24 inches x 1/2 inch thick (610 millimeters x 610 millimeters x 13 millimeters) soil plate welded to the front flange and a 1/2 inch (13 millimeters) thick plate welded to the top of the post. The anchor posts were placed in soil

with an embedment depth of 8 feet (2,438 millimeters). One post was located along the longitudinal axis of the system, 45-3/8 inches (1,153 millimeters) upstream of the edge of the first barrier. The second post was located 29-3/8 inches (746 millimeters) upstream of the first barrier and offset 11-1/2 inches (292 millimeters) laterally from the traffic side face of the barrier.

The soil pit underneath the asphalt surface was comprised of a crushed limestone aggregate soil satisfying the standard soil requirements of MASH. Cable brackets were bolted to the top of the anchor posts.

The cable brackets were assembled using multiple 1/2 inch (13 millimeters) thick A36 steel plates welded together. The cable assemblies were comprised of a 3/4 inch (19 millimeters) diameter, 7 x 19 wire rope, BCT cable end fitting, a Crosby heavy-duty HT thimble, and a 115-HT mechanical splice. It should be noted that the wire ropes were ordered as 6 x 19 IWRC IPS wire ropes in order to be consistent with the wire rope specifications for W-beam guardrail cable anchorages. However, the manufacturer substituted the 7 x 19 wire rope as an equivalent to the 6 x 19 IWRC IPS. The substitution was not determined until the wire ropes were disassembled after the full-scale crash test. One 54-3/4 inches (1,391 millimeters) long cable assembly was aligned with the longitudinal axis of the barrier system. This cable assembly was attached with one end fixed between the lower barrier loops on an additional connection pin on the upstream end of the barrier and the other end attached to the anchor post. The end connector pin utilized a second 2-1/2 inches wide x 4 inches long x 1/2 inch thick (64 millimeters x 102 millimeters x 13 millimeters) ASTM A36 steel plate and a 1/2 inch diameter x 10 inches long (13 millimeters diameter x 254 millimeters long) Grade 8 hex bolt and nut at the bottom of the pin to prevent the pin from pulling out of the barrier loops when the anchorage was loaded.

The second cable assembly measured 48 3/8 inches (1,229 millimeters) long, and it was attached from just below the top barrier loop on the connector pin on the end of the barrier to the offset anchor post. A pin sleeve, made from 1-1/2 inches (38 millimeters) Schedule 40 pipe, was used to keep the anchor cables in the correct vertical positions. The use of the pin sleeve also allowed the cable anchorages to be attached at the same vertical position on the end pin regardless of which end of the F-shape barrier was used. Thus, if the barrier ends were reversed, the offset cable would attach to the connection pin between the top two barrier loops, and the in-line cable would attach to the connection pin between the pin sleeve and lower barrier loop.

However the as-built physically crash tested system details as described herein slightly vary from the following Test House recommended variances.

- A. The Test House indicated the anchor posts used in the physical crash test were placed before the entire system was configured and were not in an optimal position. Therefore the anchor post positions are moved slightly from those evaluated by physical crash test as follows.

The anchor posts were placed in soil with an embedment depth of 8 feet (2,438 millimeters). The first post is located along the longitudinal axis of the system, 41-1/4 inches (1,048 millimeters) upstream the edge of the first barrier. The

second post is located 23-1/4 inches (591 millimeters) upstream of the first barrier and offset 7-1/4 inches (184 millimeters) laterally from the traffic side face of the barrier.

The Test House indicated this change in anchor positions is not believed to negatively affect the system's safety performance.

- B. The repositioning of the anchor posts resulted in the following modification of the as tested lengths of the cable assemblies.
1. One 51-1/4 inches (1,302 millimeters) long cable assembly was aligned with the longitudinal axis of the barrier system. This cable assembly was attached with one end fixed between the lower barrier loops on an additional connection pin on the upstream end of the barrier and the other end attached to the anchor post.
 2. The second cable assembly measured 44 inches (1,118 millimeters) long, and it was attached from just below the top barrier loop on the connector pin on the end of the barrier to the offset anchor post.
 3. The barrier system was installed at an angle to one of the Test House's existing soil test pits in order to provide an achievable tow distance and impact angle for use in the crash test. As such, the end barrier in this test installation was placed with approximately three quarters of the barrier resting on the same soil foundation that surrounded the anchor posts. Actual field installations of the termination and anchorage system would not require the same soil area for use in placing the first barrier segment nor the anchorage posts. It is therefore recommended the anchor posts be installed in a soil foundation. However, the required size of the soil area must be sufficient for the anchors to be embedded in the soil and resist the dynamic loads imparted through the cable assemblies. The maximum longitudinal overlap of end barrier on soil is 112-1/2 inches (2,858 millimeters), while the minimum lateral distance between the top plate of the anchor post and the pavement edge is 10-3/4 inches (273 millimeters). Larger lateral offsets are allowed. The minimum longitudinal length of the soil leave out for the anchor posts is a length defined by the upstream end of the first barrier segment and 12 inches (305 millimeters) upstream of the in-line anchor post.

Crash Testing

The barrier was crash tested at the test facilities at the Midwest Roadside Safety Facility. Terminals and crash cushions, such as temporary concrete barrier terminations, must satisfy impact safety standards provided in the MASH, in order to be accepted by the FHWA for use on the NHS for new construction projects or as a replacement for existing designs not meeting current safety standards. According to Test Level 3 of MASH, non-gating terminals and crash cushions must be subjected to the following 9 full-scale vehicle crash tests:

1. Test Designation 3-30 consists of a 2,425 pounds (1,100 kilograms) passenger car impacting the terminal at a 1/4-point offset, head-on manner at a nominal speed and angle of 62 mph (100 km/h) and 0 degrees, respectively.

2. Test Designation 3-31 consists of a 5,004-lb (2,270 kg) pickup truck impacting the terminal head-on at a nominal speed and angle of 62 mph (100 km/h) and 0 degrees, respectively.
3. Test Designation 3-32 consists of a 2,425-lb (1,100-kg) passenger car impacting the terminal head-on at a nominal speed and angle of 62 mph (100 km/h) and 5-15 degrees, respectively.
4. Test Designation 3-33 consists of a 5,004-lb (2,270-kg) pickup truck impacting the terminal head at a nominal speed and angle of 62 mph (100 km/h) and 5-15 degrees, respectively.
5. Test Designation 3-34 consists of a 2,425-lb (1,100-kg) passenger car impacting the terminal at the critical impact point (CIP) location transitioning between gating or capturing and redirection at a nominal speed and angle of 62 mph (100 km/h) and 15 degrees, respectively.
6. Test Designation 3-35 consists of a 5,004-lb (2,270-kg) pickup truck impacting the terminal at the beginning of the length of need at a nominal speed and angle of 62 mph (100 km/h) and 25 degrees, respectively.
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8. Test Designation 3-37 consists of a 5,004-lb (2,270-kg) pickup truck impacting the terminal at the CIP for the reverse direction at a nominal speed and angle of 62 mph (100 km/h) and 25 degrees, respectively.
9. Test Designation 3-38 consists of a 3,307-lb (1,500-kg) intermediate car impacting the terminal head-on at a nominal speed and angle of 62 mph (100 km/h) and 0 degrees, respectively.

The temporary concrete barrier termination and anchorage system, as described herein was designed with the intention of either placing an approved impact attenuator, such as sand barrels, in front of the anchorage posts or placing the anchorage system outside of the clear zone. However, most of the crash tests for terminals and crash cushions that are required in the MASH test matrix do not need to be conducted because they have been previously addressed in the prior successful compliance testing programs. Placement of the termination and anchorage system outside of the clear zone would also negate the need for the majority of the required terminal and crash cushion tests. Tests 3-30 through 3-33 and 3-38 are used to evaluate vehicle stability and containment issues related to impacts at the head of a crash cushion. Tests 3-34 and 3-36 evaluate the front end of crash cushions for either their behavior when impacted at a critical impact point or for transitioning to rigid barriers, respectively. Thus, both tests are not intended to evaluate the safety performance of the concrete barrier or termination anchor system.

Therefore, Test 3-35 is only crash test recommended for this test with further recommendation to waive the remaining tests.

Findings

The analysis of the test results showed that the temporary concrete barrier termination and anchorage system adequately contained and redirected the vehicle. There were no detached elements or fragments which neither showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. The deformation of, or intrusion into, the occupant compartment was minimal and did not pose a threat to cause serious injury. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were within tolerable limits of the MASH. The occupant impact velocities and ridedown accelerations were within the recommended limits for the impacting vehicle. There was no significant deformation of the roof, windshield or occupant compartment. After impact, the vehicle exited the barrier at an angle of 15.9 degrees and did not intrude into adjacent traffic lanes.

The system described in the request above and detailed in the enclosed drawings is acceptable for use on the NHS under the range of conditions tested, when such use is acceptable to a highway agency.

Crash Test Summary details of this system are provided as enclosures to this correspondence.

Please note the following standard provisions that apply to FHWA letters of acceptance:

- This acceptance provides a AASHTO/ARTBA/AGC Task Force 13 designator that should be used for the purpose of the creation of a new and/or the update of an existing Task Force 13 drawing. The drawing should emphasize to designers the requirement of placing an approved impact attenuator, such as sand barrels, in front of the anchorage posts or placing the anchorage system outside of the clear zone.
- This acceptance is limited to the crashworthiness characteristics of the systems and does not cover its structural features, nor conformity with the Manual on Uniform Traffic Control Devices.
- Any changes that may adversely influence the crashworthiness of the system will require a new acceptance letter.
- Should the FHWA discover that the qualification testing was flawed, that in-service performance reveals unacceptable safety problems, or that the system being marketed is significantly different from the version that was crash tested, we reserve the right to modify or revoke our acceptance.
- You will be expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.
- You will be expected to certify to potential users that the hardware furnished has essentially the same chemistry, mechanical properties, and geometry as that submitted for acceptance, and that it will meet the crashworthiness requirements of the FHWA and the AASHTO MASH.

- To prevent misunderstanding by others, this letter of acceptance is designated as number B-221 and shall not be reproduced except in full. This letter and the test documentation upon which it is based are public information. All such letters and documentation may be reviewed at our office upon request.
- This acceptance letter shall not be construed as authorization or consent by the FHWA to use, manufacture, or sell any patented system for which the applicant is not the patent holder. The acceptance letter is limited to the crashworthiness characteristics of the candidate system, and the FHWA is neither prepared nor required to become involved in issues concerning patent law. Patent issues, if any, are to be resolved by the applicant.

Sincerely yours,

Michael S. Griffith
Director, Office of Safety Technologies
Office of Safety

Enclosures



U.S. Department
of Transportation
**Federal Highway
Administration**

1200 New Jersey Ave., SE
Washington, D.C. 20590

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second post is located 23-1/4 inches (591 millimeters) upstream of the first barrier and offset 7-1/4 inches (184 millimeters) laterally from the traffic side face of the barrier.

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Findings

The analysis of the test results showed that the temporary concrete barrier termination and anchorage system adequately contained and redirected the vehicle. There were no detached elements or fragments which neither showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. The deformation of, or intrusion into, the occupant compartment was minimal and did not pose a threat to cause serious injury. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were within tolerable limits of the MASH. The occupant impact velocities and ridedown accelerations were within the recommended limits for the impacting vehicle. There was no significant deformation of the roof, windshield or occupant compartment. After impact, the vehicle exited the barrier at an angle of 15.9 degrees and did not intrude into adjacent traffic lanes.

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- You will be expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.
- You will be expected to certify to potential users that the hardware furnished has essentially the same chemistry, mechanical properties, and geometry as that submitted for acceptance, and that it will meet the crashworthiness requirements of the FHWA and the AASHTO MASH.

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Sincerely yours,



 Michael S. Griffith
Director, Office of Safety Technologies
Office of Safety

Enclosures

9 RECOMENDATIONS

As presented herein, the new termination and anchorage system provides users with increased safety and flexibility during placement of temporary concrete barrier systems. The termination and anchorage system should result in shorter installation lengths for temporary concrete barrier, fewer vehicle impacts into the barrier, and an overall reduction in the cost of the installation. While this research and development effort was successful, there are some comments that need to be made regarding implementation of the new system.

The system details, as shown in previous sections of this report, represented the as-built, as-tested system. These details differ slightly from the final recommended details shown in Figure 46 through Figure 57. Metric details are shown in Appendix A. First, the final system details were configured with slightly different anchor post positions than those evaluated by the full-scale test. The anchor posts used in the full-scale crash test were placed before the entire system was configured and were not in an optimal position. For the final design, the anchor posts were moved slightly, but the change in position is not believed to negatively affect the system's safety performance. Second, a repositioning of the anchor posts also resulted in the need to modify the lengths of the cable assemblies. Finally, the barrier system was installed at an angle to one of MwRSF's soil test pits in order to provide an achievable tow distance and impact angle for use in the crash test. The end barrier in this test installation was placed with approximately three quarters of the barrier resting on the same soil foundation that surrounded the anchor posts. Actual field installations of the termination and anchorage system would not require the same soil area for use in placing the first barrier segment nor the anchorage posts. It is recommended that the anchor posts be installed in a soil foundation. However, the required size of the soil area must be sufficient for the anchors to be embedded in the soil and resist the dynamic loads

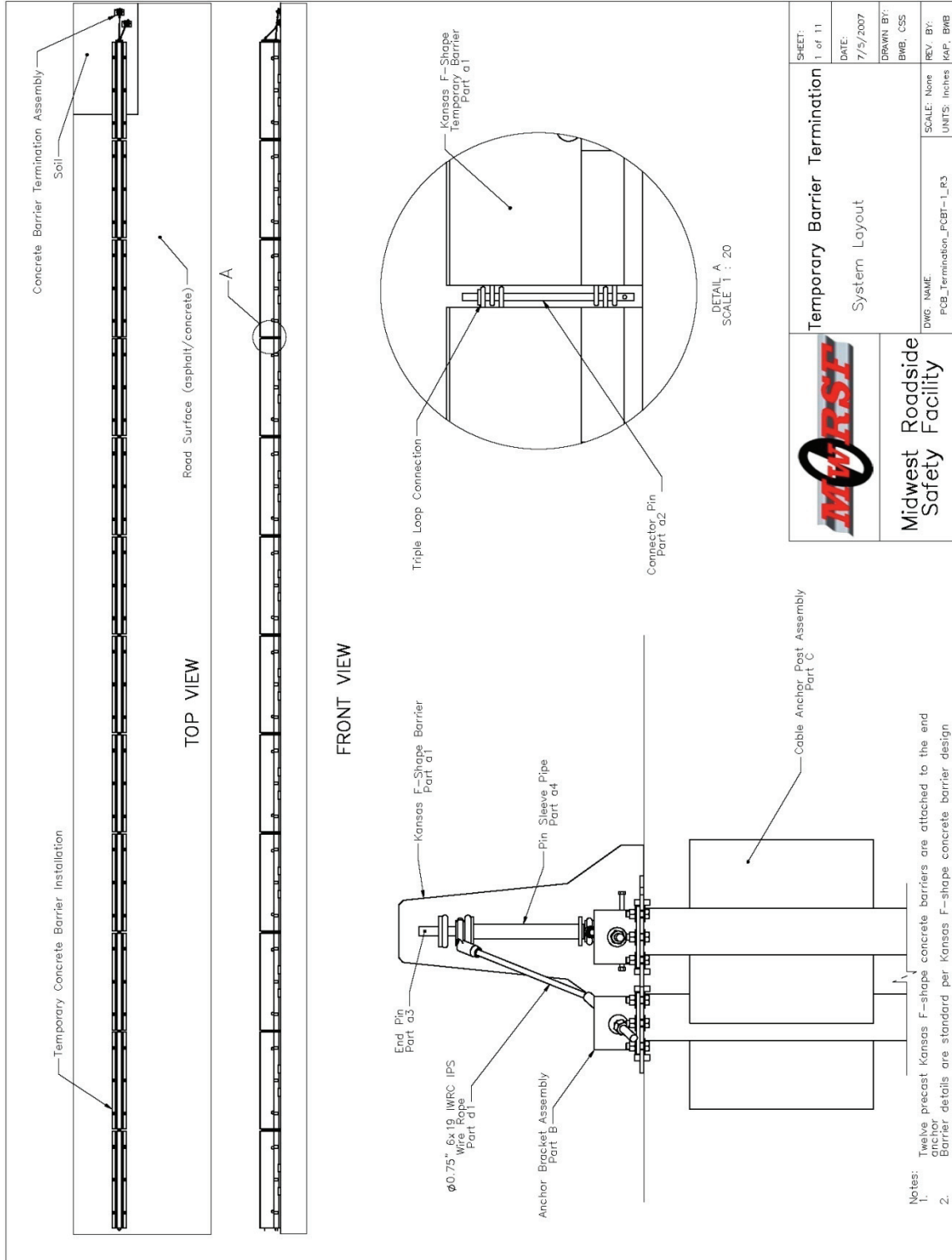
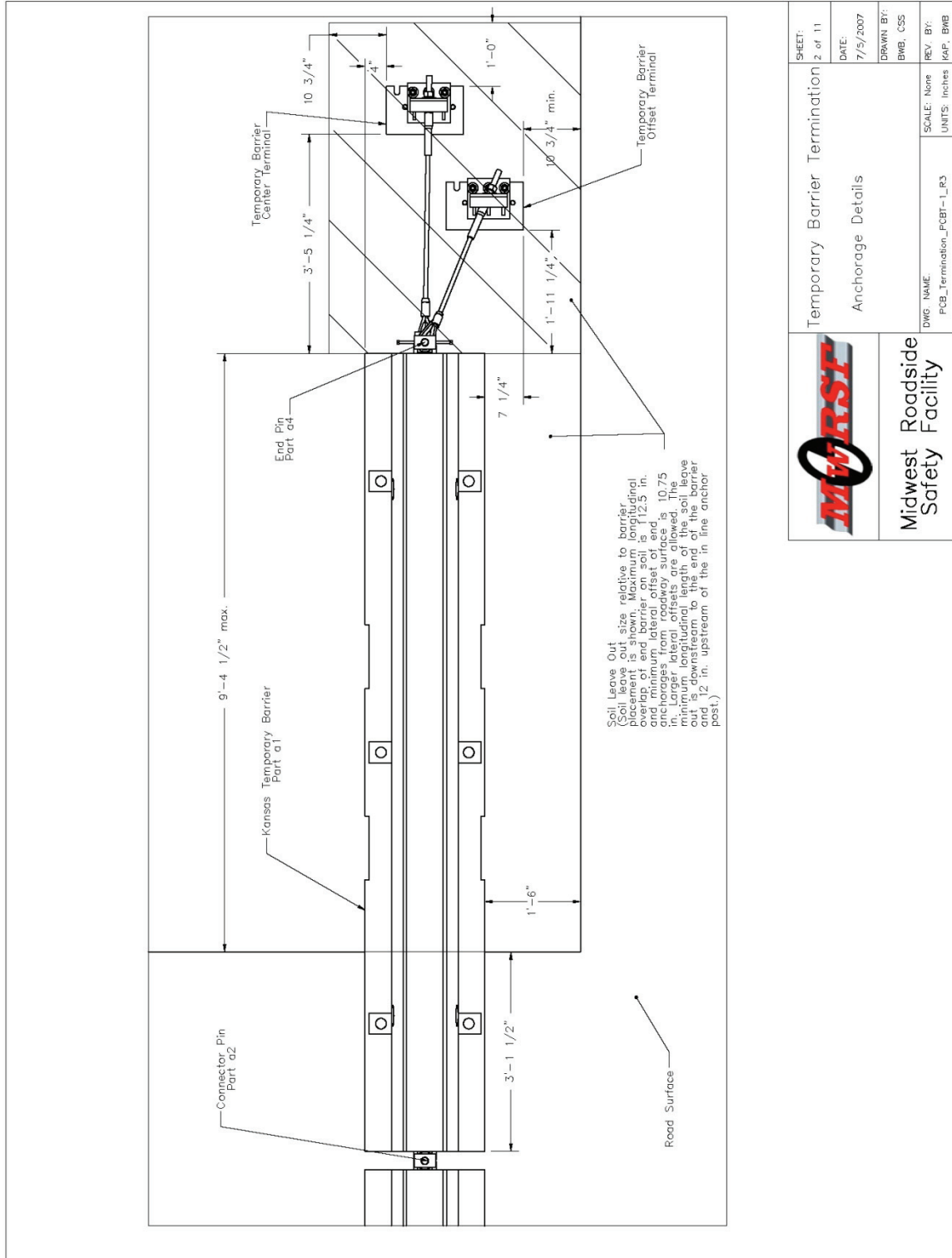


Figure 46. Termination of Temporary Concrete Barrier, Final Design Details



 Midwest Roadside Safety Facility	SHEET: 2 of 11 DATE: 7/5/2007 DRAWN BY: BMB, CCS DWG. NAME: PCB_Termination_PCBT-L_R3 SCALE: None UNITS: Inches	Temporary Barrier Termination Anchorage Details
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Figure 47. Termination of Temporary Concrete Barrier, Final Design Details

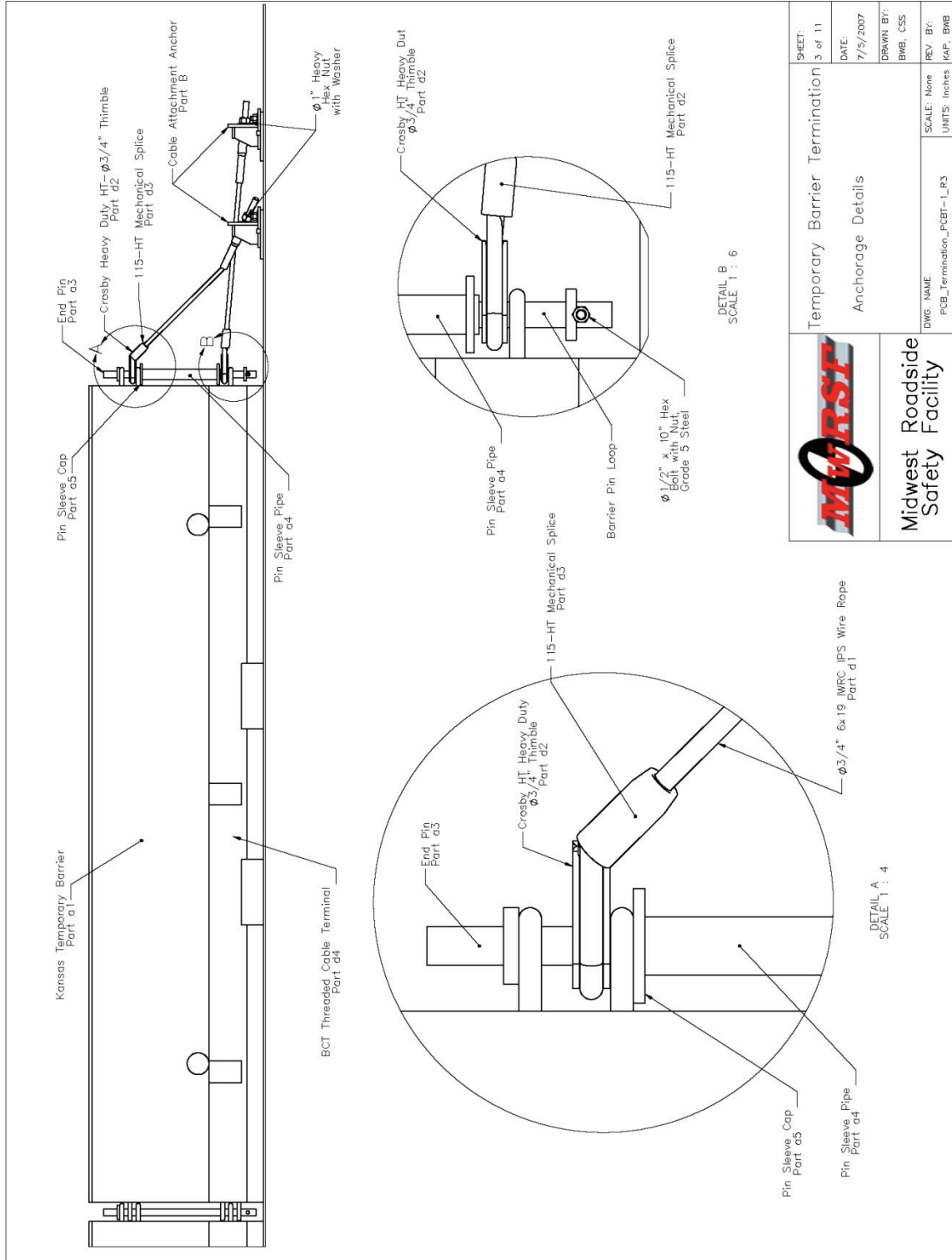


Figure 48. Termination of Temporary Concrete Barrier, Final Design Details

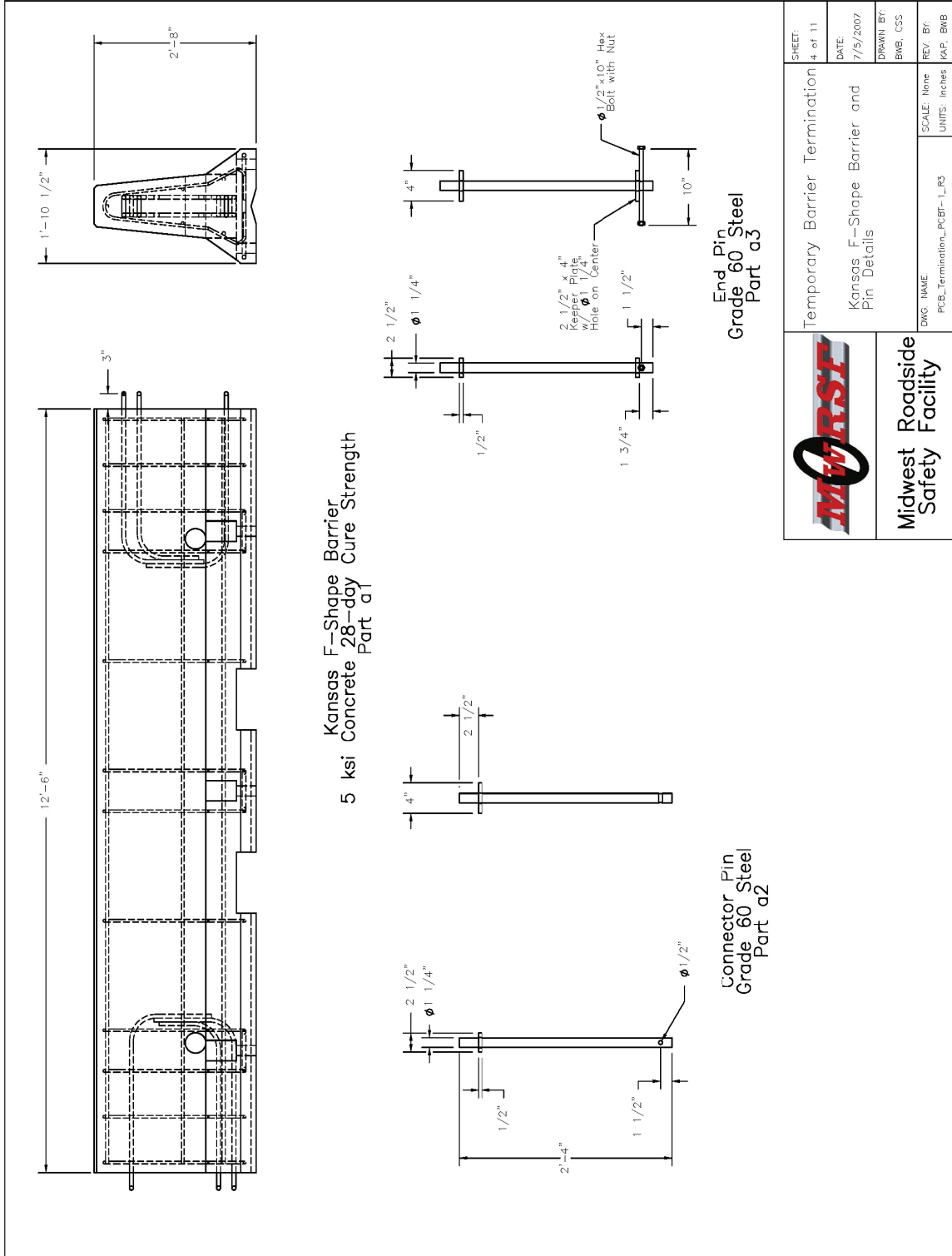


Figure 49. Termination of Temporary Concrete Barrier, Final Design Details

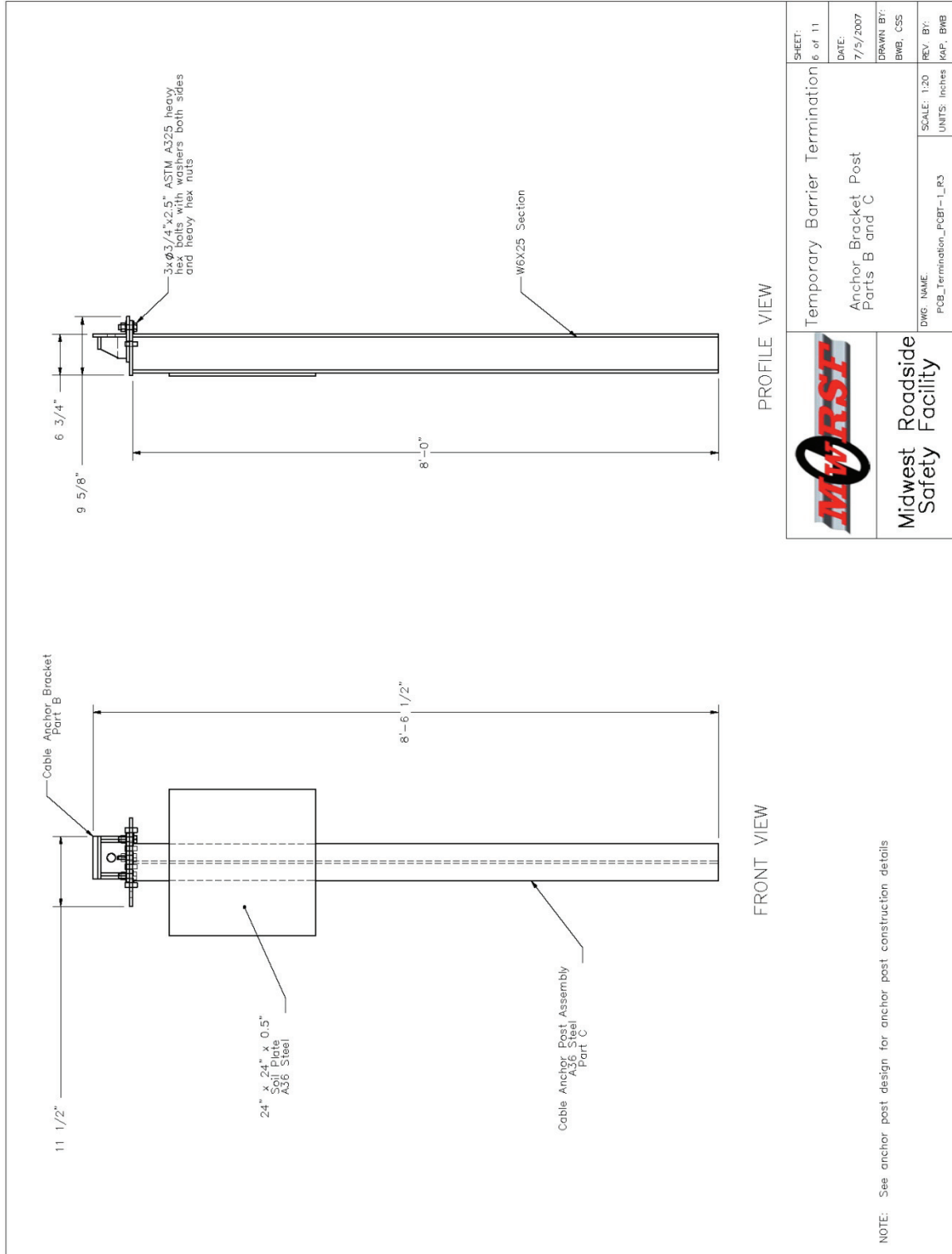


Figure 51. Termination of Temporary Concrete Barrier, Final Design Details

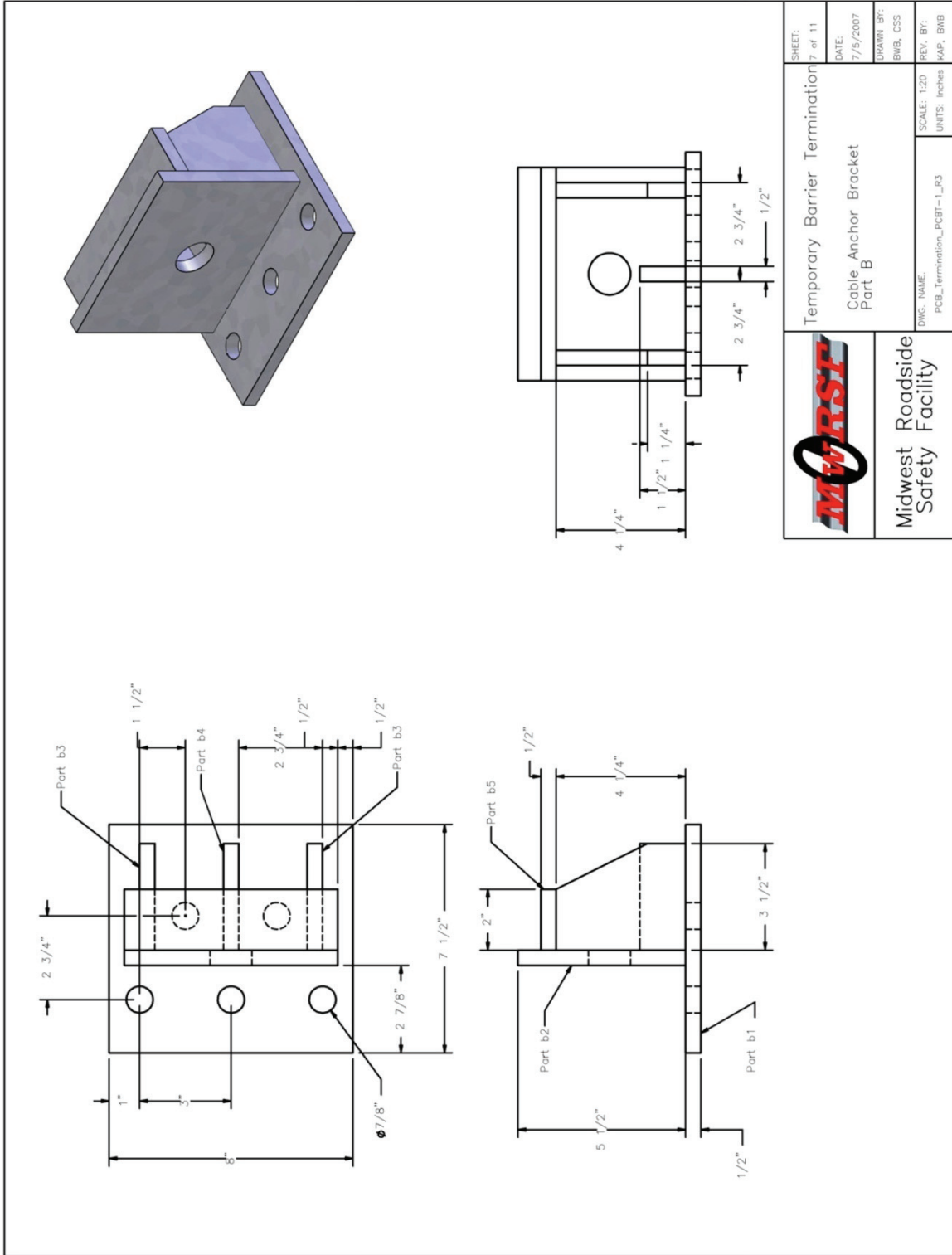


Figure 52. Termination of Temporary Concrete Barrier, Final Design Details

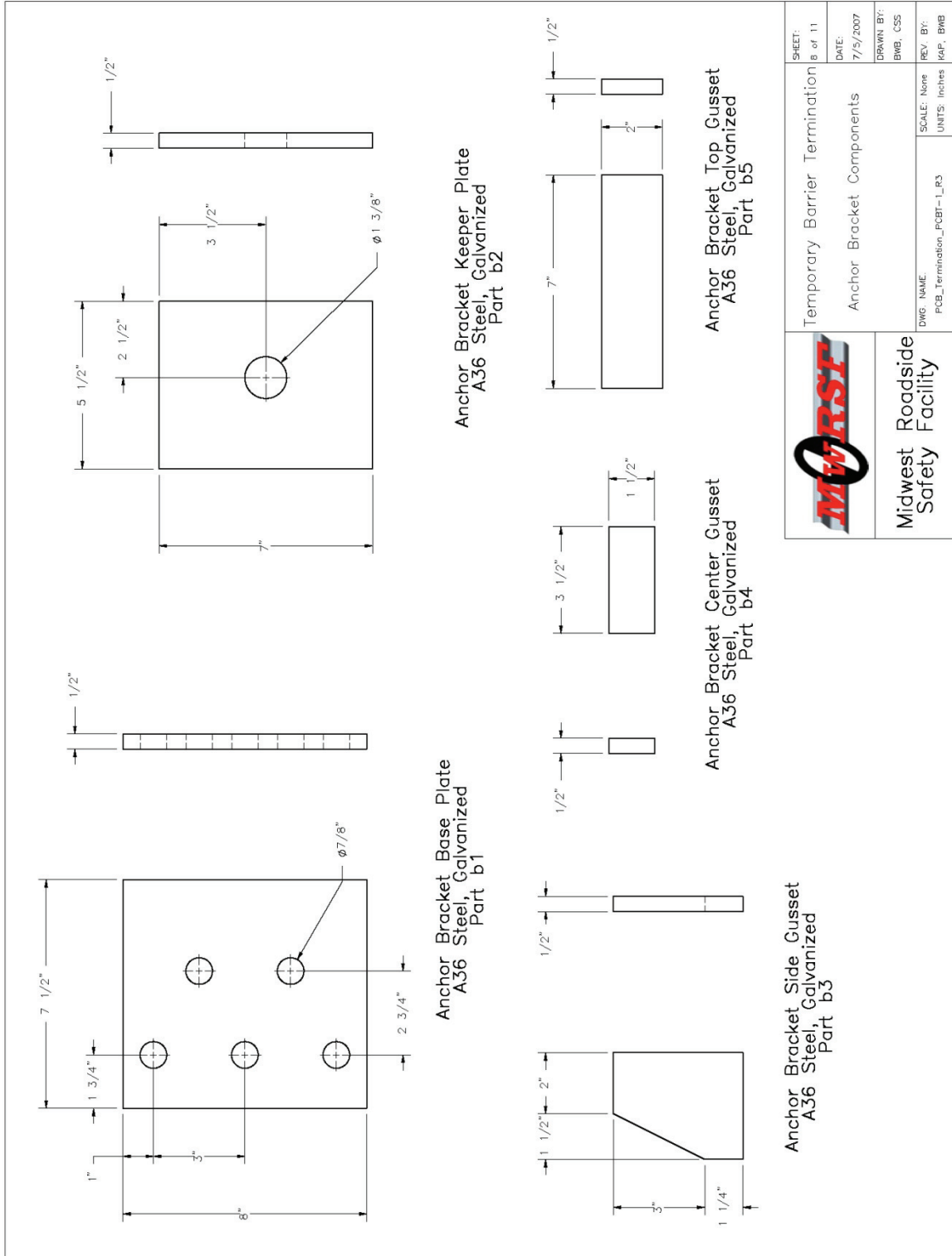


Figure 53. Termination of Temporary Concrete Barrier, Final Design Details

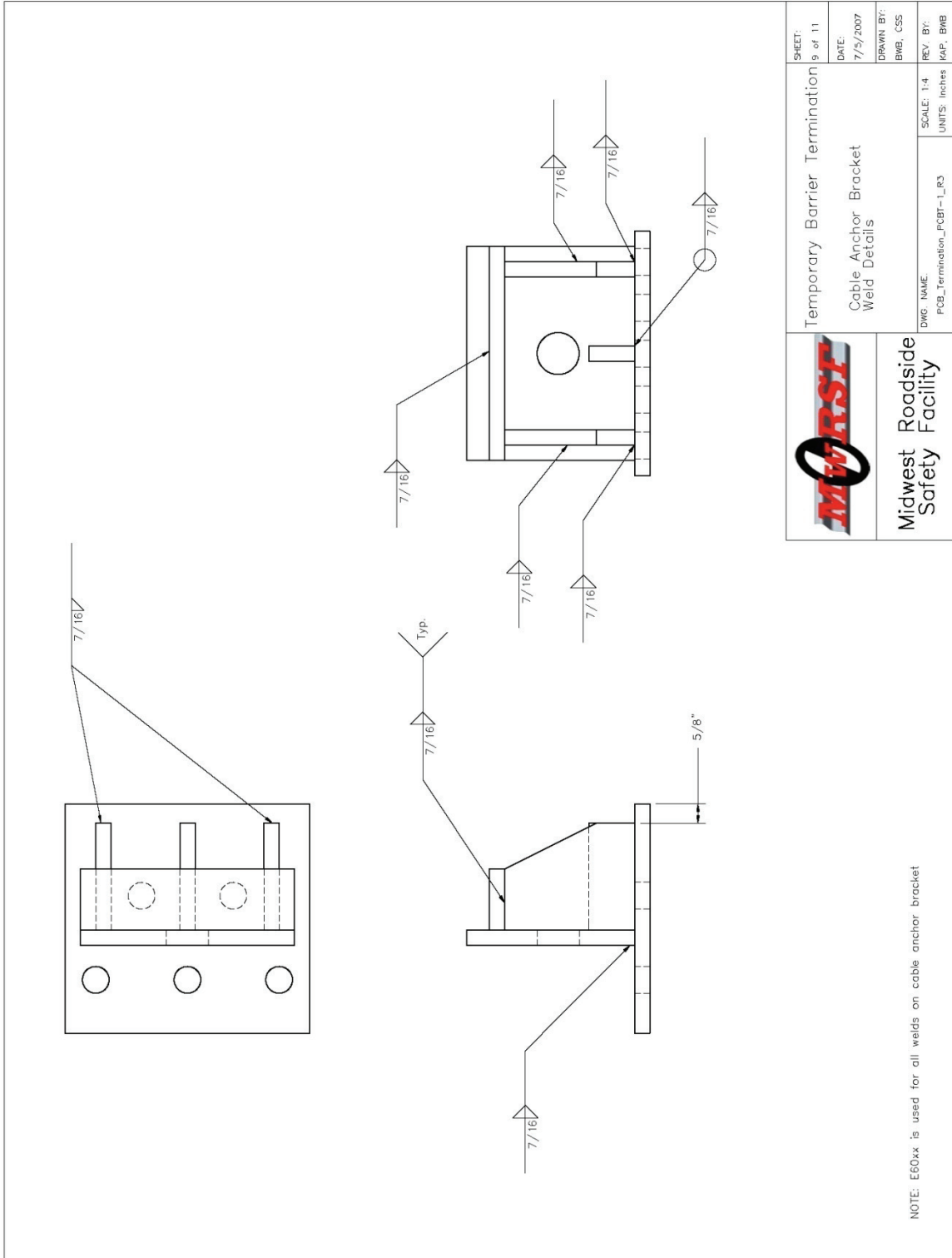


Figure 54. Termination of Temporary Concrete Barrier, Final Design Details

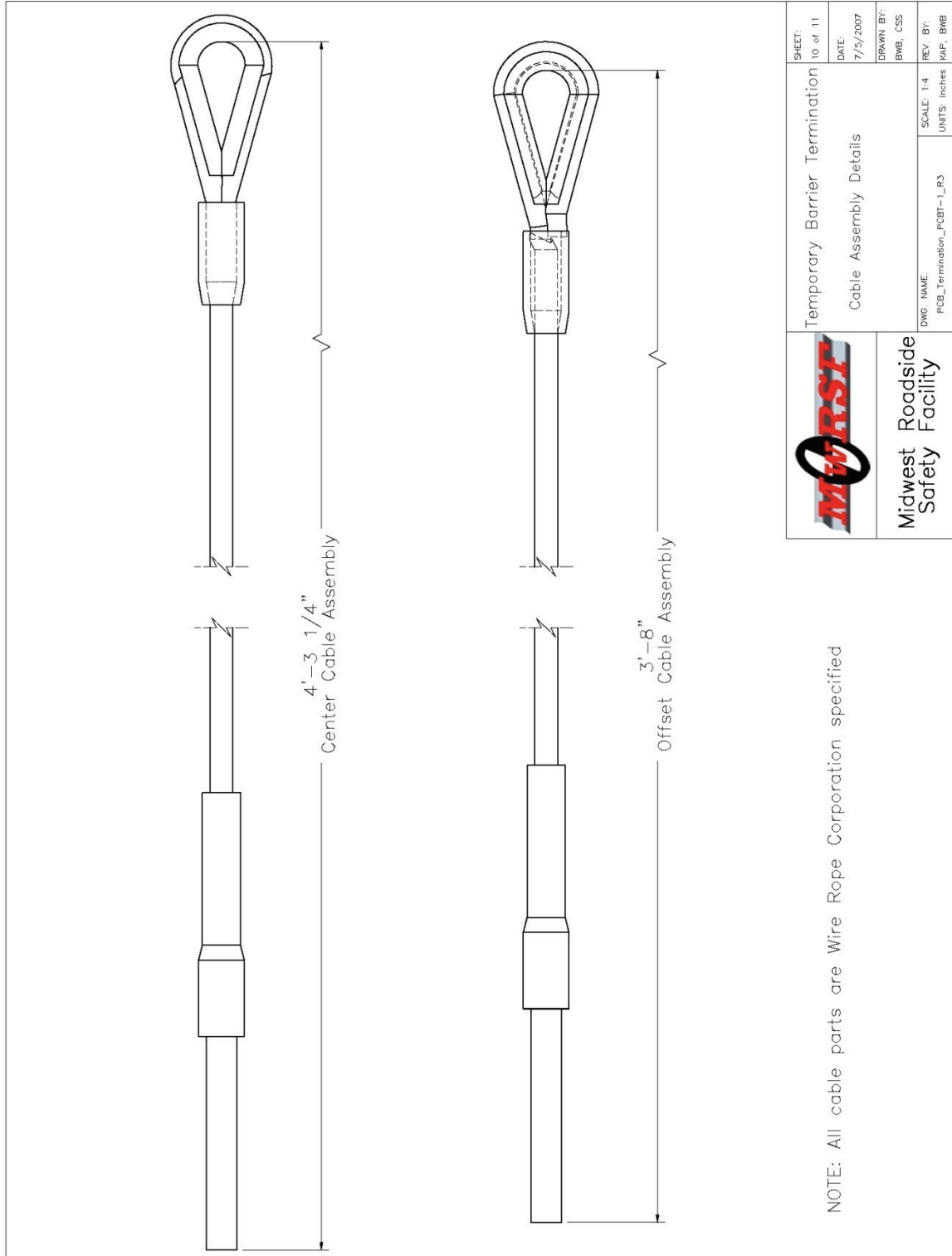


Figure 55. Termination of Temporary Concrete Barrier, Final Design Details

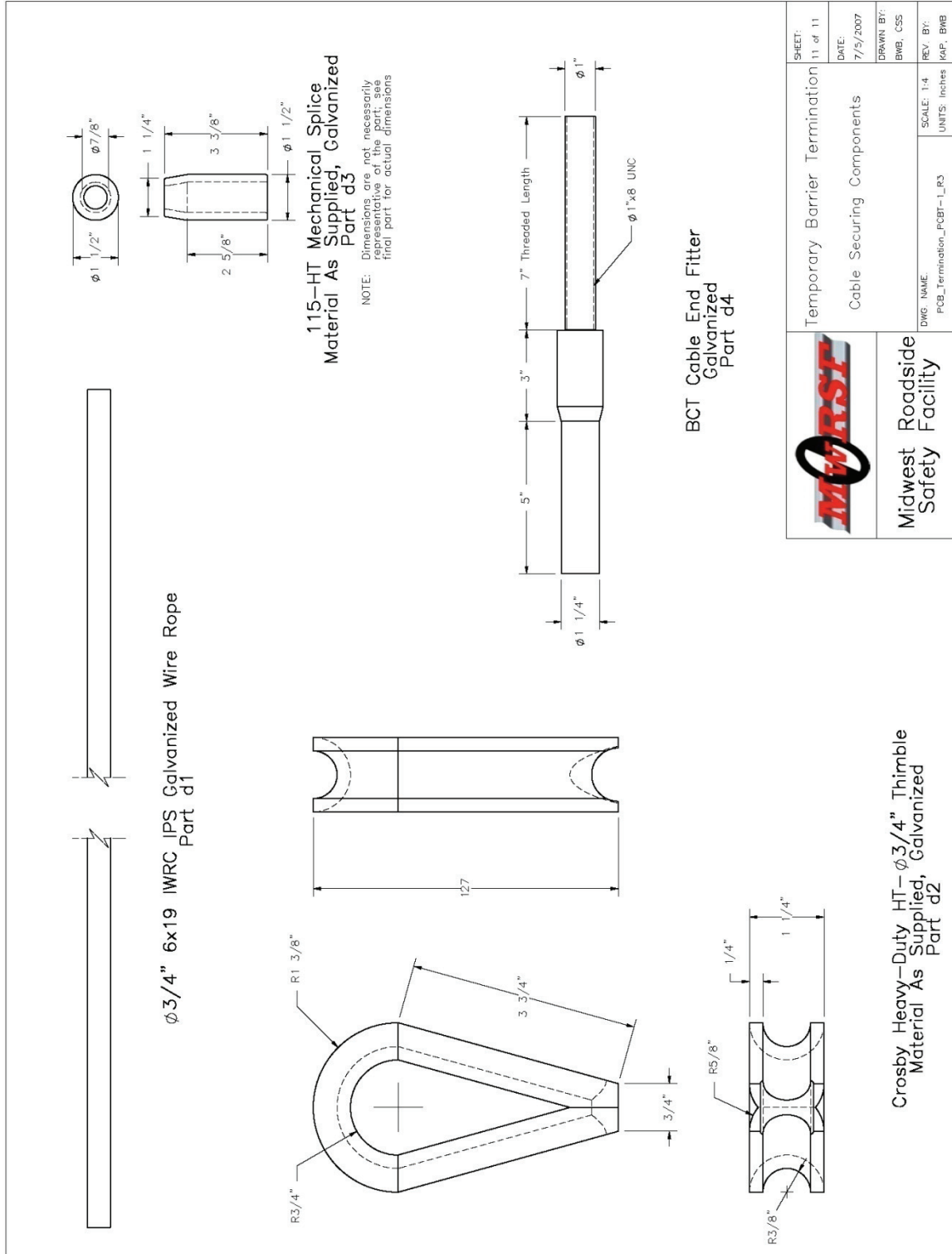
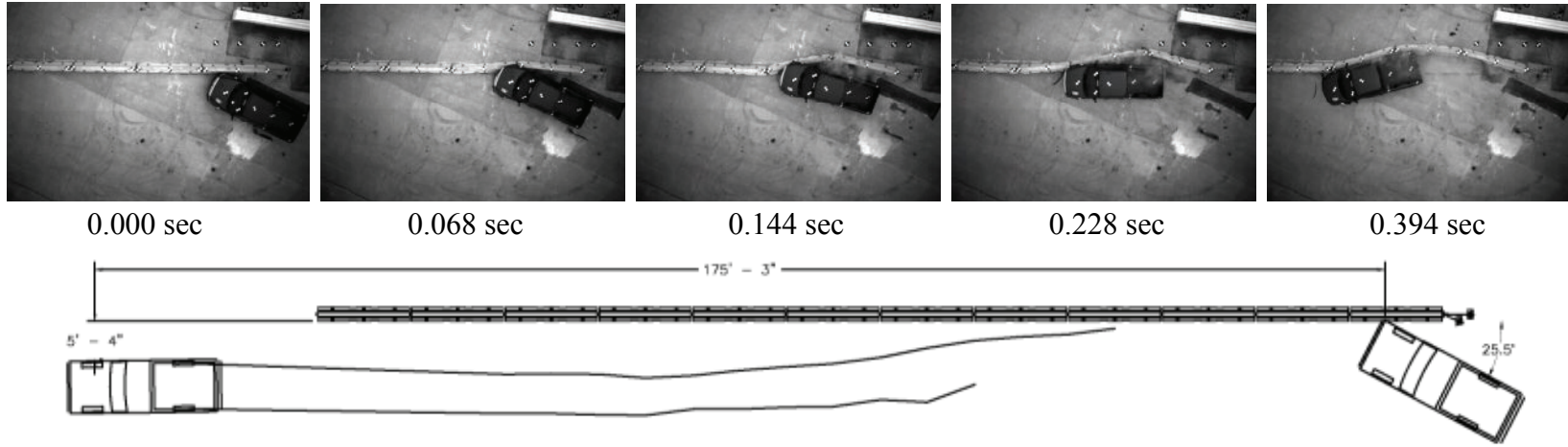


Figure 56. Termination of Temporary Concrete Barrier, Final Design Details



- Test Agency MwRSF
- Test Number TTCB-1
- Date 6/27/07
- MASH Test Designation 3-35
- Test Article Termination of Temporary Concrete Barrier
- System Length 156 ft – 6 in.
- Temporary Concrete Barriers
 - Type Precast Kansas F-Shape
 - Quantity 12
 - Length 12 ft – 6 in.
 - Base Width 22.5 in.
 - Height 32 in.
- Anchorage Components
 - Cables 0.75 in. Diameter 6x19 IWRC Wire Rope
 - Cable Assembly Lengths 51 & 46 in.
 - Post Type W6x25
 - Post Length (Embedment) 8 ft
- Vehicle Make and Model 2003 Dodge Ram 1500 Quad Cab.
 - Curb 4,988 lbs
 - Test Inertial 4,991 lbs
 - Gross Static 4,991 lbs
- Impact Conditions
 - Speed 62.9 mph
 - Angle 25.5 deg
 - Impact Location 108 5/8 in. DS from US End of Barrier 1
- Exit Conditions
 - Speed 36.1 mph
 - Angle 15.9 deg
- Vehicle Stability Satisfactory
- Occupant Ridedown Acceleration (10 msec avg.) (EDR-3)
 - Longitudinal -16.47 g's < 20.49 g's
 - Lateral -8.00 g's < 20.49 g's
- Occupant Impact Velocity (EDR-3)
 - Longitudinal -13.41 ft/s < 40 ft/s
 - Lateral -17.15 ft/s < 40 ft/s
- Occupant Ridedown Acceleration (10 msec avg.) (EDR-4)
 - Longitudinal -10.36 g's < 20.49 g's
 - Lateral -8.04 g's < 20.49 g's
- Occupant Impact Velocity (EDR-4)
 - Longitudinal -14.04 ft/s < 40 ft/s
 - Lateral -16.02 ft/s < 40 ft/s
- THIV (not required) 21.74 ft/s
- PHD (not required) 16.78 g's
- Vehicle Damage Moderate
 - VDS^[15] 1-FR-6 and 1-RD-3
 - CDC^[16] 01-FREN2 and 01-RDES2
 - Maximum Interior Deformation 4.25 in. near RF corner of the floorboard
- Vehicle Stopping Distance 175.25 ft DS of impact, 5.3 ft laterally
- Test Article Damage Moderate
- Test Article Deflections
 - Permanent Set 66.5 in.
 - Dynamic NA
 - Working Width 89.0 in.
- Maximum Roll Angle 14.75 deg @ 0.693 sec

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Figure 26. Summary of Test Results and Sequential Photographs, Test No. TTCB-1