



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

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

June 10, 2011

In Reply Refer To:  
HSST/B-211

Ms. Karla A. Lechtenberg, MSME, EIT  
Research Associate Engineer  
Midwest Roadside Safety Facility  
130 Whittier Research Center  
2200 Vine Street  
Lincoln, NE 68583-0853

Dear Ms. Lechtenberg:

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

Name of system: Midwest Guardrail System placed adjacent to 2:1 Fill Slope

Type of system: Steel Post and W-beam roadside barrier

Test Level: AASHTO Manual for Assessing Safety Hardware  
Test Level 3

Testing conducted by: Midwest Roadside Safety Facility

Date of request: December 18, 2010

Date initially acknowledged: December 18, 2010

Task Force 13 Designator: SGR38

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 device was found acceptable, with details provided below:

- Midwest Guardrail System (MGS) placed adjacent to 2:1 Fill Slope

### **Description**

An MGS guardrail system was developed for installation at the slope break point of a 2:1 fore slope which utilizes the benefits of the recently developed MGS guardrail. The MGS on a 2:1 fill slope system was designed to meet the Test Level 3 (TL-3) safety performance criteria set



FHWA:HSST:WLongstreet:ms:x60087:6/1/11

File: h://directory folder/HSST/ B211\_053111.docx

cc: HSST Will Longstreet

forth in the MASH. The new design of this stiffened version of the MGS incorporates 2,743 millimeters (9 feet) long posts on a 1,905 millimeters (75 inches) spacing. With the top of the W-beam mounted at a height of 787 millimeters (31 inches), this stiffened MGS guardrail design with full post spacing is acceptable for use on the NHS. This new guardrail design will provide a safe and economical alternative for use along highways with steep slopes very close to the roadway.

The test installation consisted of 53.3 meters (175 feet) of standard 2.66 millimeters thick (12-gauge) W-beam guardrail supported by steel posts. The W-beam guardrail height was 787 millimeters (31 inches) with a 632 millimeter (24-7/8 inches) center mounting height. Anchorage systems similar to those used on tangent guardrail terminals were utilized on both the upstream and downstream ends of the guardrail system. The entire system was constructed with 29 guardrail posts. Post numbers 3 through 8 and 21 through 27 were galvanized ASTM A36 steel W152 x 13.4 (W6 x 9) sections measuring 1,829 millimeters (6 feet) long. Post numbers 9 through 20 were also ASTM A36 steel W152 x 13.4 (W6 x 9) sections, but measured 2,743 millimeters (9 feet) long. Post no. 1, 2, 28, and 29 were timber posts measuring 140-mm wide x 190 millimeters deep x 1,080 millimeters long (5-1/2 inches x 7-1/2 inches x 42-1/2 inches) and were placed in 1,829 millimeters (6 feet) long steel foundation tubes. The timber posts and foundation tubes were part of anchor systems designed to replicate the capacity of a tangent guardrail terminal. Post numbers 1 through 29 were spaced 1,905 millimeters (75 inches) on center and were embedded to a depth of 1,930 millimeters (76 inches). For post numbers 3 through 27, 152 millimeters wide x 305 millimeters deep x 362 millimeters long (6 inches x 12 inches x 14-1/4 inches) wood spacer blockouts were used to block the rail away from the front face of the steel posts. Standard 2.66 millimeters thick (12-gauge) W-beam rails with additional post bolt slots at half-post spacing intervals were placed between post numbers 1 and 29. The rail splices have been moved to the center of the span location. All lap-splice connections between the rail sections were configured to reduce vehicle snag at the splice during the crash test. A 2:1 fore slope excavation was located behind post numbers 9 through 20. The maximum excavation dimensions were 3.0 meters (10 feet) wide and 1.5 meters (5 feet) deep. The length of the excavation was 22.9 meters (75 feet), spanning from the mid-span between post numbers 8 and 9 to the mid-span between post numbers 20 and 21. Design details are provided as enclosure to this correspondence.

### **Crash Testing**

The recommended post configuration was evaluated using computer simulation modeling. Dynamic component impact testing was conducted on W152 x 13.4 (W6 x 9) steel posts placed at the break point of a 2:1 fill slope was performed to evaluate the post-soil behavior for various embedment depths as well as to select a steel post alternative for use in the BARRIER VII numerical analyses. Additional details related to the dynamic post testing are provided in the referenced Midwest Roadside Safety Facility research report. A total of seventeen bogie crash tests were performed with post lengths varying from 1,829 millimeters (6 feet) through 2,743 millimeters (9 feet) and with embedment depths ranging between 1,016 millimeters (40 inches) and 1,930 millimeters (76 inches). For each bogie test, raw acceleration data was acquired and filtered, and then force-displacement and energy-displacement graphs were plotted. From the energy-displacement graphs, the average post-soil forces were calculated for a 381 millimeters (15 inches) displacement at the center rail height. Average post-soil forces were then compared to the baseline average post capacity of 28kN (6 kips), which representative of

steel posts is found in the MGS placed on a level terrain. From these comparisons, a recommended post length was selected for the 1,905 millimeters (75 inches) standard post spacing. A 2,743 millimeters (9 feet) long post with a 1,930 millimeters (76 inches) embedment depth was found to best meet the post requirements, while providing an average force of 28.43 kN (6.39 kips), determined from results of two tests as enclosed in this correspondence.

In addition, BARRIER VII computer simulations were also performed in order to evaluate barrier alternatives for the MGS installed on a 2:1 fill slope and to determine the CIP for the proposed crash test planned for the final as-built barrier configuration. Computer modeling was therefore used to analyze and evaluate the MGS placed on a 2:1 fill slope when installed at both the 787 millimeters (31 inches) and 706 millimeters (27-3/4 inches) top mounting heights. From eight design variations that were evaluated, it was determined that the most valid model was the MGS with minimum 706 millimeters (27-3/4 inches) top mounting height on a 2:1 fill slope. This was based on the fact that the maximum wheel snag occurred with the design variation utilizing a 10 percent reduction in the strong-axis bending moment. This also verified that it was appropriate to include the slope effects, i.e., the associated minor increase in impact velocity. The CIP was selected to occur at 238 millimeters (9-3/8 inches) upstream from the centerline of post number 13, or 595 millimeters (23-7/16 inches) downstream from the centerline of the splice between post numbers 12 and 13.

Physical crash test for TL-3 as per MASH requires that longitudinal barrier systems be subjected to the following two full-scale vehicle crash tests:

1. Test Designation 3-10. A 1,100-kg (2,425-lb.) small car impacting the W-beam system at a nominal speed and angle of 100 km/h (62 mph) and 25 degrees, respectively.
2. Test Designation 3-11. A 2,268-kg (5,000-lb.) pickup truck impacting the W-beam system at a nominal speed and angle of 100 km/h (62 mph) and 25 degrees, respectively.

Since Test Designation 3-10 was previously and successfully conducted on MGS with maximum height tolerance, the 1,100-kg (2,425-lb.) passenger car crash test was deemed unnecessary for this project.

### **Findings**

The analysis of the Test Designation 3-11 test results showed that the MGS, with a 787 millimeters (31 inches) top mounting height and installed adjacent to a 2:1 fill slope, adequately contained and redirected the 2270P vehicle. There were no detached elements nor fragments which neither showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusion into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the guardrail system and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were noted, but they were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After collision, the vehicle's trajectory revealed minimum intrusion into adjacent traffic lanes. In addition, the vehicle exited the barrier within the exit box. Therefore, Test Designation 3-11 was determined to be acceptable according to the TL-3 safety performance criteria as per MASH.

All physical crash test summaries are included as enclosure to this correspondence. We concur in consideration of previous successfully conducted Test Designation 3-10 on MGS with maximum height tolerance, the 1,100-kg (2,425-lb.) passenger car crash test and is therefore deemed unnecessary for this project.

Therefore, the system described in the requests 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.

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 existing Task Force 13 drawing for posting on the on-line 'Guide to Standardized Highway Barrier Hardware' currently referenced in AASHTO 'Roadside Design Guide'.
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- 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-211 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  
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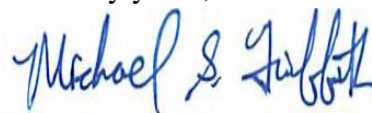
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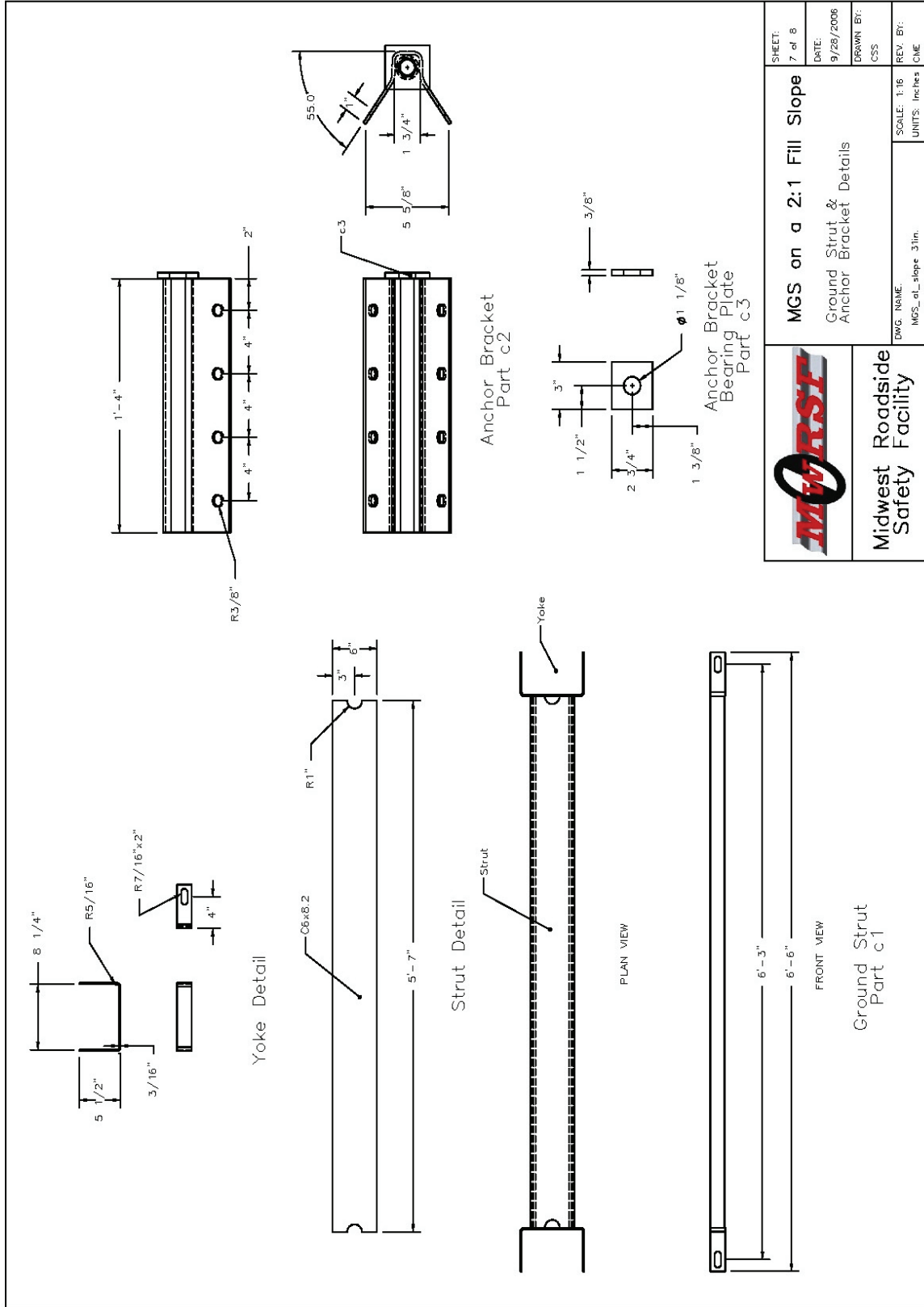
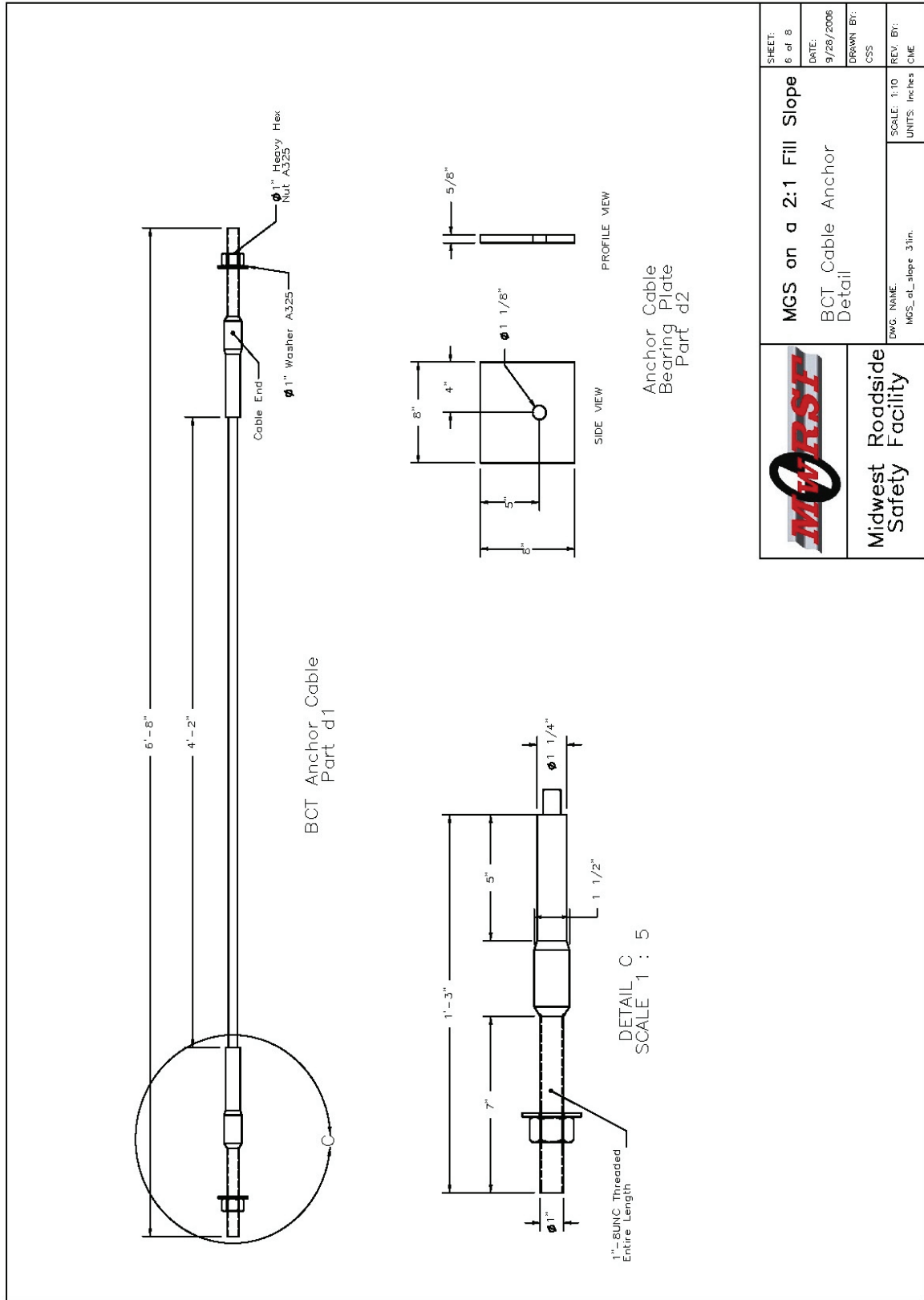


Figure G-15. Ground Strut and Anchor Bracket Details, Test No. MGS221-2 (English)




	<b>MGs on a 2:1 Fill Slope</b> BCT Cable Anchor Detail	SHEET: 6 of 8 DATE: 9/28/2006 DRAWN BY: CSS REV. BY: CME
	Midwest Roadside Safety Facility	SCALE: 1:10 UNITS: Inches

Figure G-14. Anchor Cable Details, Test No. MGS221-2 (English)

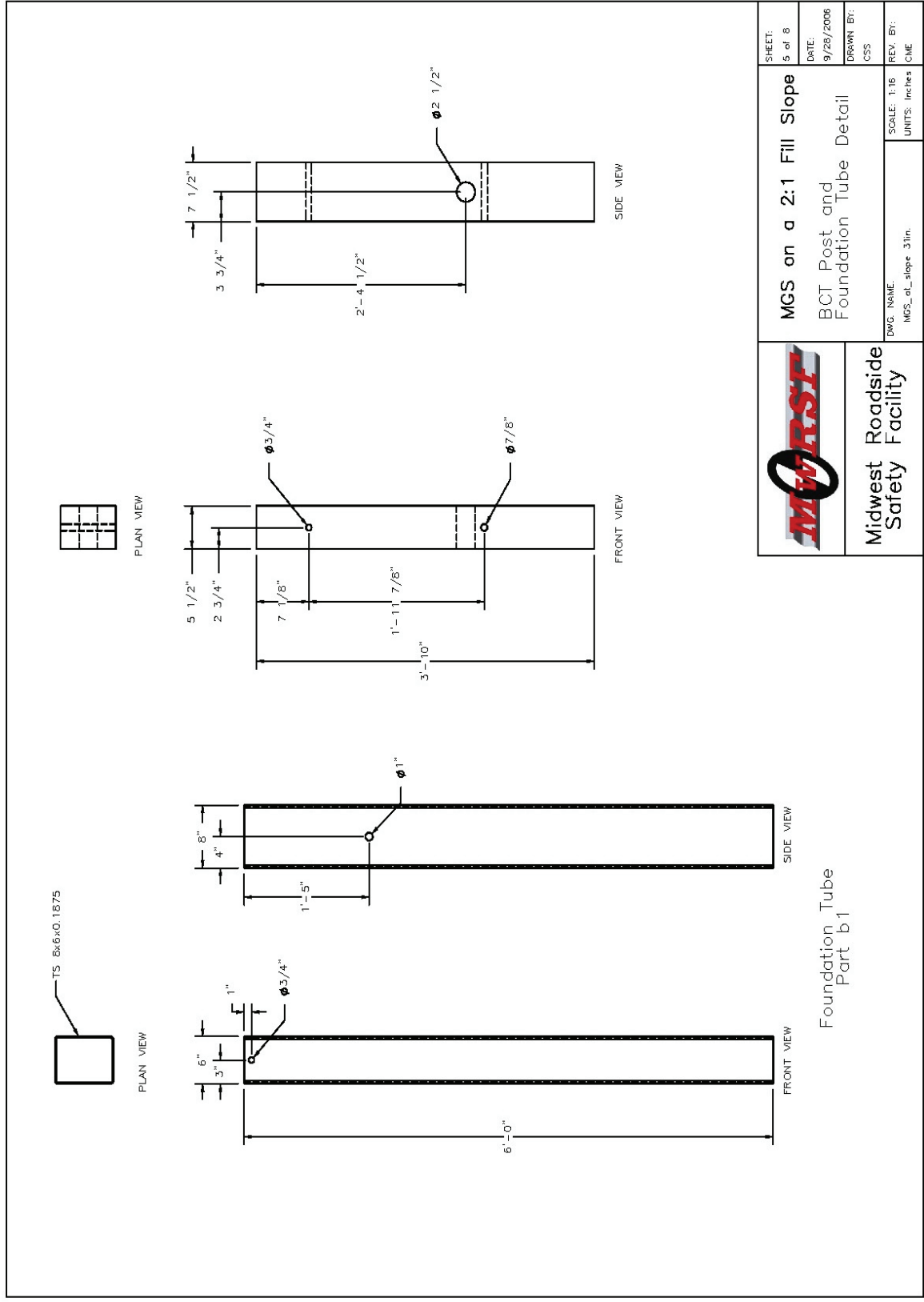


Figure G-13. Post and Foundation Tube Details, Test No. MGS221-2 (English)

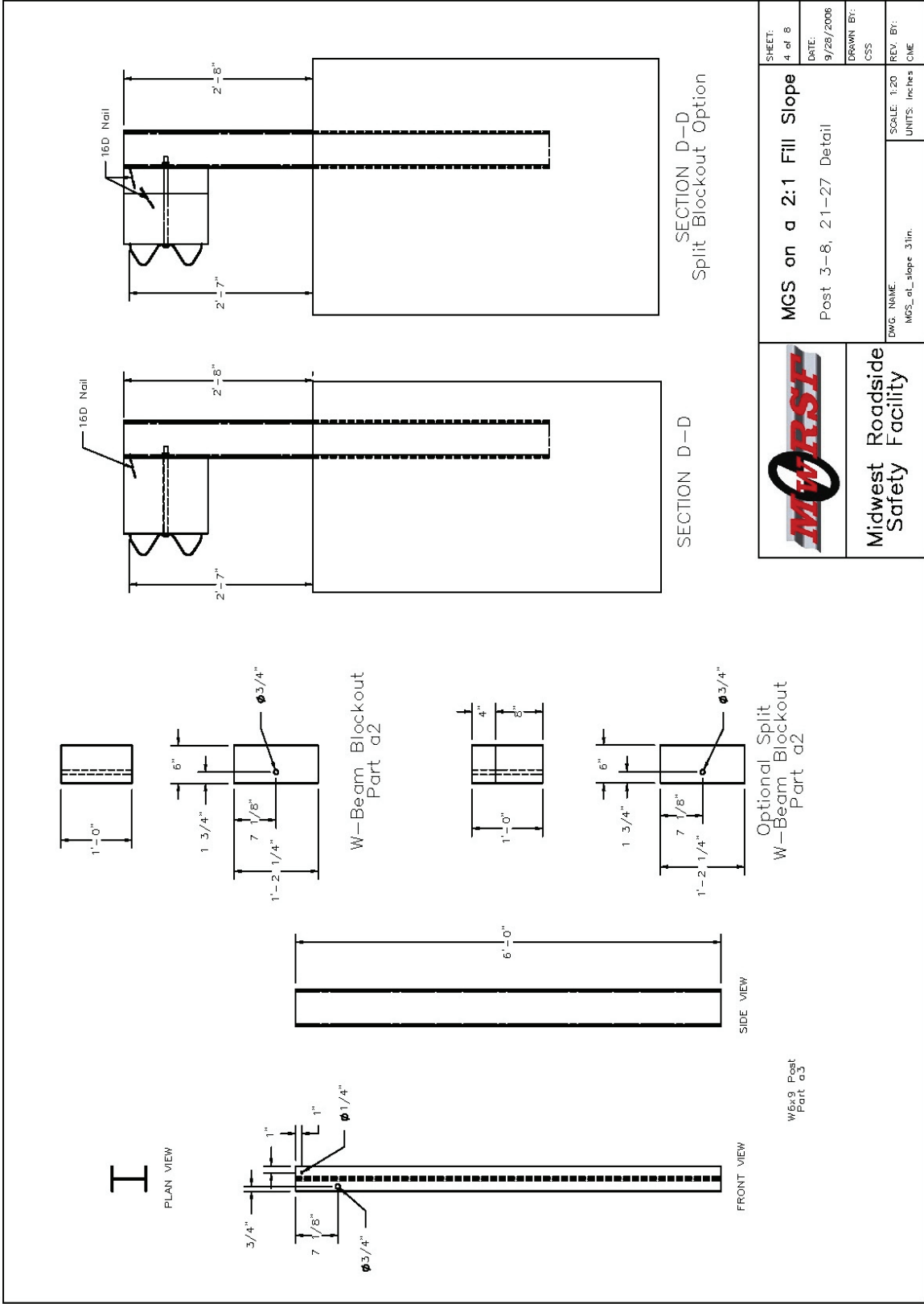


Figure G-12. Post Details, Test No. MGS221-2 (English)

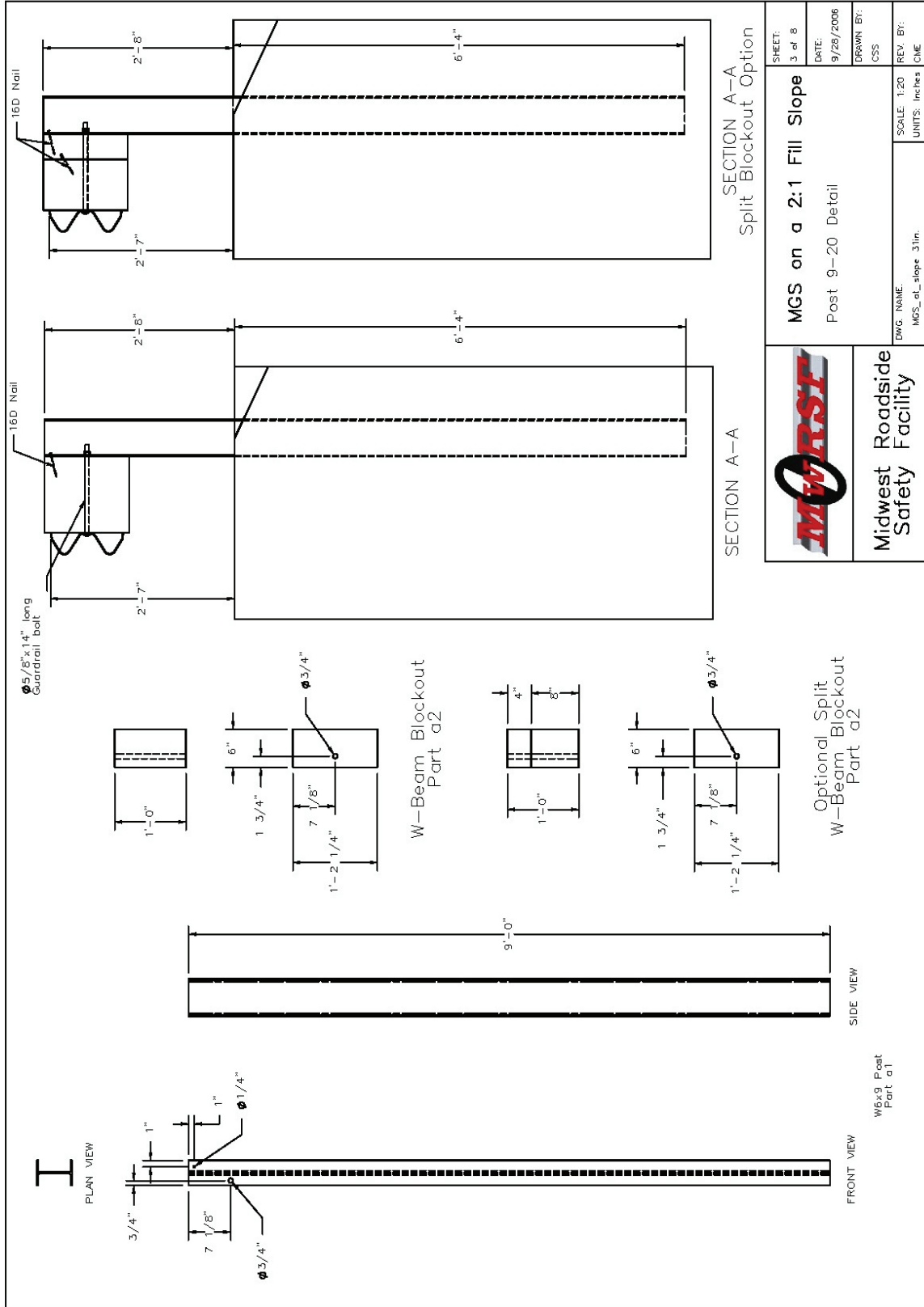


Figure G-11. Post Details, Test No. MGS221-2 (English)

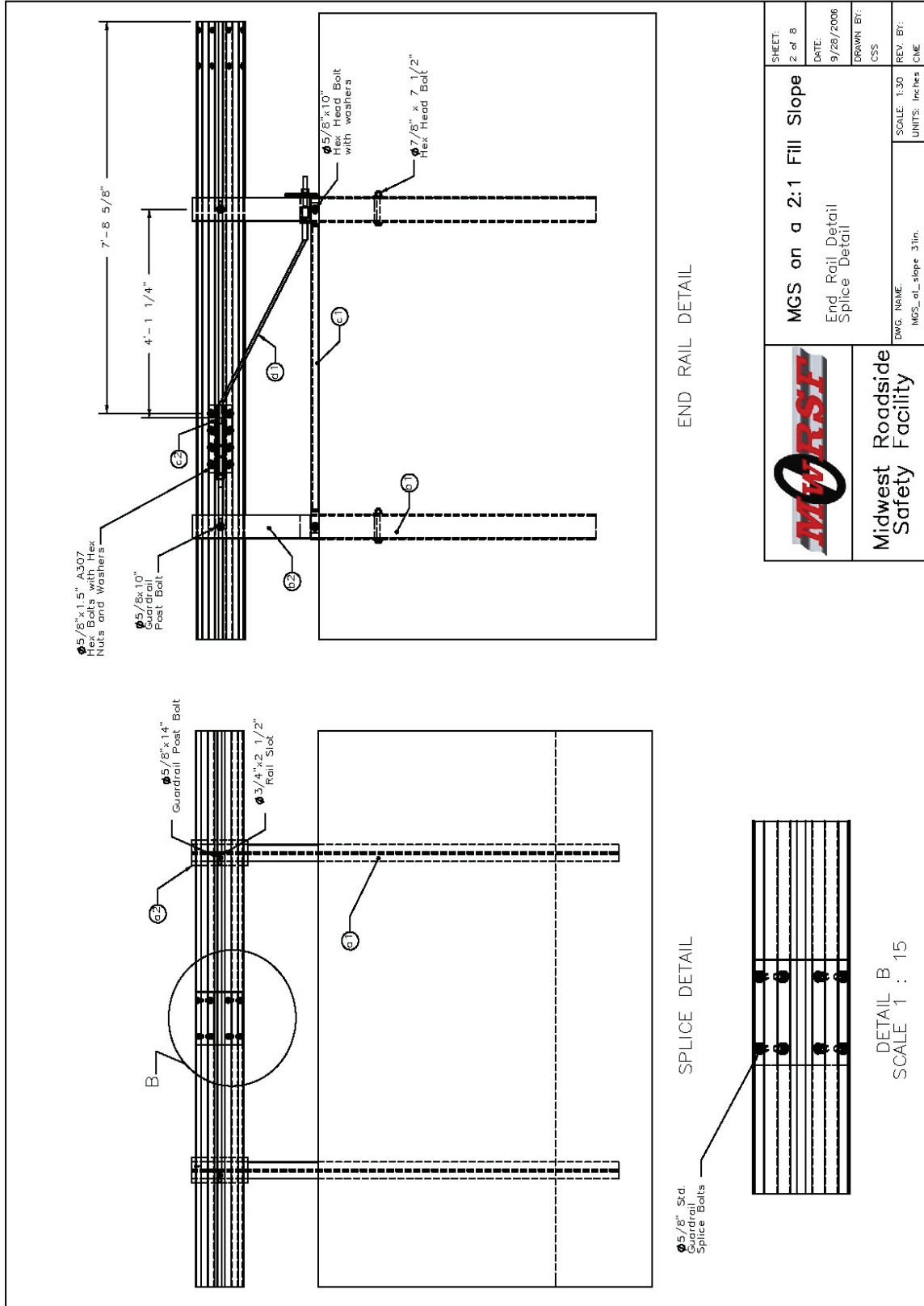
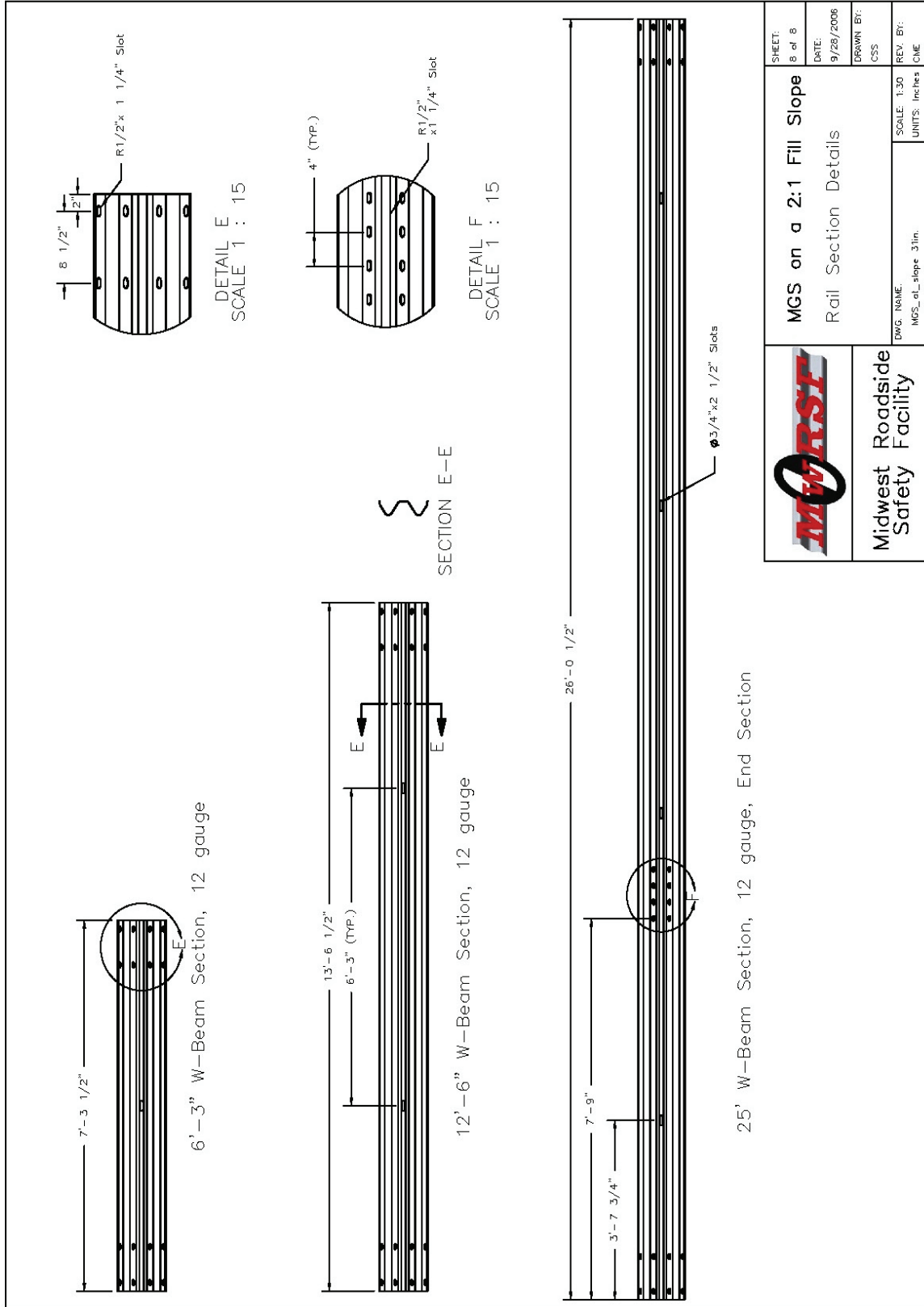


Figure G-10. Rail Detail, Test No. MGS221-2 (English)




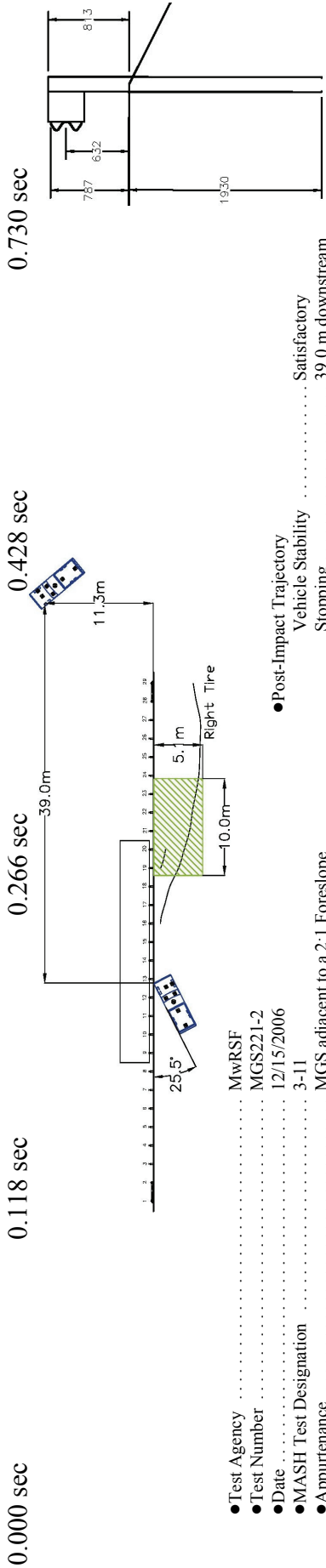
 Midwest Roadside Safety Facility	<b>MGS on a 2:1 Fill Slope</b> Rail Section Details	SHEET: 8 of 8 DATE: 9/28/2006 DRAWN BY: CSS REV. BY: CME
	DWG. NAME: MGS_of_slope_3lin.	SCALE: 1:30 UNITS: Inches

Figure G-16. Rail Details, Test No. MGS221-2 (English)





- Test Agency ..... MwRSF
- Test Number ..... MGS221-2
- Date ..... 12/15/2006
- MASH Test Designation ..... 3-11
- Appearance ..... MGS adjacent to a 2:1 Foreslope
- Total Length ..... 53.34 m
- Key Elements - Steel W-beam
  - Thickness ..... 2.66 mm
  - Top Mounting Height ..... 787 mm
- Key Elements - Steel Posts
  - Post Nos. 3-8, 21-27 ..... W152x13.4 by 1,829 mm long
  - Post Nos. 9-20 ..... W152x13.4 by 2,743 mm long
  - Post Location ..... Centerline of posts at slope break point
  - Spacing ..... 1,905 mm
- Key Elements - Wood Posts
  - Post Nos. 1-2, 28-29 ..... 140 mm x 190 mm by 1,080 mm long
- Key Elements - Foundation Tube ..... 1,829 mm long
- Wood Spacer Blocks
  - Post Nos. 3-27 ..... 152 mm x 305 mm x 362 mm long
- Type of Soil ..... Grading B-AASHTO M 147-65 (1990)
- Test Vehicle
  - Type/Designation ..... 2270P
  - Make and Model ..... 2004 Dodge Ram 1500 Quad Cab
  - Curb ..... 2,327 kg
  - Test Inertia ..... 2,274 kg
  - Gross Static ..... 2,274 kg
- Impact Conditions
  - Speed ..... 101.5 km/h
  - Angle ..... 25.5 degrees
  - Impact Location ..... 394 mm upstream of centerline of post 13
- Exit Conditions
  - Speed ..... 62.1 km/h
  - Angle ..... 17.4 degrees
  - Exit Box Criterion ..... Pass
- Post-Impact Trajectory
  - Vehicle Stability ..... Satisfactory
  - Stopping ..... 39.0 m downstream
  - ..... 11.3 m laterally behind
- Occupant Impact Velocity (EDR-3)
  - Longitudinal ..... -4.24 m/s < 12.2 m/s
  - Lateral ..... 4.15 m/s < 12.2 m/s
- Occupant Ride Down Deceleration (EDR-3)
  - Longitudinal ..... -5.36 g's < 20.49 g's
  - Lateral ..... 5.28 g's < 20.49 g's
- Occupant Impact Velocity (EDR-4)
  - Longitudinal ..... -4.10 m/s < 12.2 m/s
  - Lateral ..... 4.06 m/s < 12.2 m/s
- Occupant Ride Down Deceleration (EDR-4)
  - Longitudinal ..... -5.13 g's < 20.49 g's
  - Lateral ..... 5.73 g's < 20.49 g's
- THIV (EDR-4 - not required) ..... 6.26 m/s
- PHD (EDR-4 - not required) ..... 6.93 g's
- Test Article Damage ..... Moderate
- Test Article Deflections
  - Permanent Set ..... 1,067 mm
  - Dynamic ..... 1,463 mm
  - Working Width ..... 1,631 mm
  - Vehicle Damage ..... Minimal
  - VDS<sup>26</sup> ..... 11-LFQ-3
  - CDC<sup>27</sup> ..... 11-LFEN3
  - Maximum Deformation ..... 13 mm front-center of the left-side floor pan
- Angular Displacements (Estimated from Video)
  - Roll ..... 6 degrees
  - Pitch ..... 5 degrees
  - Yaw ..... 45 degrees

Figure 50. Summary of Test Results and Sequential Photographs, Test No. MGS221-2