SAFETY PERFORMANCE EVALUATION OF MISSOURI'S GROUND-MOUNTED TEMPORARY SIGN STANDS – PHASE II

Submitted by

Karla A. Polivka, M.S.M.E., E.I.T.
Research Associate Engineer

Ronald K. Faller, Ph.D., P.E.
Research Assistant Professor

John R. Rohde, Ph.D., P.E.
Associate Professor

James C. Holloway, M.S.C.E., E.I.T.
Research Manager

Dean L. Sicking, Ph.D., P.E.
Professor and MwRSF Director

MIDWEST ROADSIDE SAFETY FACILITY
University of Nebraska-Lincoln
527 Nebraska Hall
Lincoln, Nebraska 68588-0529
(402) 472-6864

Submitted to

MISSOURI DEPARTMENT OF TRANSPORTATION
105 West Capitol Avenue
P.O. Box 270
Jefferson City, MO 65102

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16. Abstract (Limit: 200 words)

A wide variety of traffic controlling devices are used in work zones, some of which are not normally found on the roadside nor in the traveled way outside of the work zones. These devices are used to enhance the safety of the work zones by controlling the traffic through these areas. Due to the placement of the traffic control devices, the devices themselves may be potentially hazardous to both workers and errant vehicles. The impact performance of many unique work-zone traffic control devices is mainly unknown and to date limited crash testing has been conducted, under the criteria of National Cooperative Highway Research Program (NCHRP) Report No. 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*.

The objective of the study was to evaluate the safety performance of a portable sign support through full-scale crash testing. One full-scale crash test was conducted on a ground-mounted, single-post portable sign support to determine its safety performance according to the Test Level 3 (TL-3) criteria set forth in the NCHRP Report No. 350. The impact on the portable sign support resulted in unacceptable safety performance. Following the unacceptable performance of the sign support, developmental and compliant bogie tests were conducted on a modified design. The bogie test impacts resulted in acceptable safety performance according to the TL-3 criteria. The result of the crash tests were documented, and conclusions and recommendations pertaining to the safety performance of the work-zone traffic control device were made.

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K.L. Krenk, B.S.M.A., Field Operations Manager
Undergraduate and Graduate Assistants

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James Dunlap, President and Owner

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1 INTRODUCTION

1.1 Problem Statement

A wide variety of traffic controlling devices are used in work zones, some of which are not normally found on the roadside nor in the traveled way outside of the work zones. These devices are used to enhance the safety of the work zones by controlling the traffic through these areas. Due to the placement of the traffic control devices, the devices themselves may be potentially hazardous to both workers (or bystanders) and errant vehicles. Thus, the Federal Highway Administration (FHWA) and the *Manual on Uniform Traffic Control Devices (MUTCD)* (1) require that work-zone traffic control devices must demonstrate acceptable crashworthy performance in order to be used within the roadway on the National Highway System (NHS).

The impact performance of many unique work-zone traffic control devices is mainly unknown and limited crash testing has been conducted in accordance with the guidelines set forth in National Cooperative Highway Research Program (NCHRP) Report No. 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features* (2). The Texas Department of Transportation (TxDOT) has sponsored a number of studies at the Texas Transportation Institute (TTI) to assess the impact performance of various work-zone traffic control devices, including plastic drums, sign substrates, barricades, and temporary sign supports (3-7). Full-scale crash testing on plastic drums, barricades, portable sign supports, and tall-mounted, rigid panel sign supports has also been previously conducted at the University of Nebraska-Lincoln (8-26). These previous studies have provided some useful information. However, there remains unanswered questions regarding the performances of many work-zone traffic control devices, which vary from those crash tested previously.

1.2 Objective

The objective of the research project was to evaluate the safety performance of Missouri's redesigned ground-mounted temporary sign supports through full-scale crash testing. The safety performance evaluations were conducted according to the Test Level 3 (TL-3) criteria set forth in the NCHRP Report No. 350 (2).

1.3 Scope

The research objective was achieved by performing several tasks. First, one full-scale vehicle crash test was performed on one work-zone traffic control device. The crash test was completed in one run with a centerline point impact. The full-scale test was performed using a small car, weighing approximately 820 kg (1,808 lbs), with target impact speed and angle of 100.0 km/h (62.1 mph) and 0 degrees, respectively. Next, one research and development bogie test and two compliant bogie tests were performed on a retrofit design. These crash tests were performed using a bogie vehicle, weighing approximately 1,119 kg (2,467 lbs), with target impact speeds of 100 km/h (62.1 mph) and angles of either 0 or 90 degrees. Finally, the test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made that pertain to the safety performance of the redesigned portable sign supports.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Work-zone traffic control devices, such as portable sign supports, must satisfy the requirements provided in NCHRP Report No. 350 to be accepted by FHWA for use on NHS construction projects or as a replacement for existing designs not meeting current safety standards. According to FHWA's Submission Guidelines attached to the July 1997 memorandum, *Action: Identifying Acceptable Highway Safety Features* (27), work-zone traffic control devices are Category 2 devices, which are not expected to produce significant change in vehicular velocity, but may penetrate a windshield, injure a worker, or cause vehicle instability when driven over or lodged under a vehicle.

According to TL-3 of NCHRP Report No. 350 and FHWA's Submission Guidelines for acceptable Category 2 devices, work-zone traffic control devices must be subjected to two full-scale vehicle crash tests:(1) an 820-kg (1,808-lb) small car impacting at a speed of 35.0 km/h (21.7 mph) and at an angle of 0 degrees; and (2) an 820-kg (1,808-lb) small car impacting at a speed of 100.0 km/h (62.1 mph) and at an angle of 0 degrees. The low-speed test is intended to evaluate the breakaway, fracture, or yielding mechanism of the device and occupant risk factors whereas the high-speed test is intended to evaluate vehicular stability, test article trajectory, and occupant risk factors. Since most work-zone traffic control devices have a relatively small mass (less than 45 kg or 99.2 lbs), the high-speed crash test is more critical due to the propensity of the test article to penetrate into the occupant compartment. Therefore, the 820-kg (1,808-lb) small car crash test, impacting at a speed of 35.0 km/h (21.7 mph) and at an angle of 0 degrees, was deemed unnecessary for this project. However, these devices are often situated on the roadway where an impact could occur at other angle orientations, such as at 90 degrees at an intersecting roadway. Thus, it has become generally recognized and endorsed by the FHWA as described in "Questions and Answers about Crash Testing of Work-Zone Safety Appurtenances" that an additional test should be performed on such devices at the target speed of 100 km/h (62.1 mph) and at a target impact angle of 90 degrees (28).

2.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the work-zone traffic control device to break away, fracture, or yield in a predictable manner. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle, including windshield damage. Vehicle trajectory after collision is a measure of the potential for the post-impact trajectory of the vehicle to cause subsequent multi-vehicle accidents. This criterion also indicated the potential safety hazard for the occupants of other vehicles or the occupants of the impacting vehicle when subjected to secondary collisions with other fixed objects. These three evaluation criteria are defined in Table 1. The full-scale vehicle crash tests were conducted and reported in accordance with the procedures provided in NCHRP Report No. 350 and for Category 2 devices.

Windshield damage is a major area of concern when evaluating the safety performance of a work-zone traffic control device. The windshield should not be shattered nor damaged in a way that visibility is significantly obstructed. Minor chipping and cracking of the windshield is acceptable. Significant loss of visibility due to extensive "spider web" cracking at key regions of the windshield would deem the performance of the device unsatisfactory. Both layers of glass should not be fractured nor indented with the potential for the test article to penetrate the windshield. The five main failure criteria are defined in Table 2.

Table 1. NCHRP Report No. 350 Evaluation Criteria for 820C Small Car Crash Test (2)

Structural Adequacy	B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.
Occupant Risk	D.	Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.
	E.	Detached elements, fragments or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.
	F.	The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.
	H.	Longitudinal occupant impact velocities should fall below the preferred value of 3 m/s (9.8 ft/s), or at least below the maximum allowable value of 5 m/s (16.4 ft/s).
	I.	Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15 G's, or at least below the maximum allowable value of 20 G's.
Vehicle Trajectory	K.	After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.
	N.	Vehicle trajectory behind the test article is acceptable.

Table 2. Failure Criteria

METHOD OF FAILURE	
1	Severe windshield cracking and fracture
2	Windshield indentation
3	Obstruction of driver visibility
4	Windshield penetration
5	Occupant compartment penetration other than windshield penetration
6	Roof deformations greater than 127 mm (5 in.)

3 WORK-ZONE PORTABLE SIGN SUPPORTS

3.1 General Descriptions

One work-zone traffic control devices were crash tested under this study, as described below. The crash test was conducted on a ground-mounted portable sign support. The material for the traffic control devices were supplied by the sponsor.

The ground-mounted portable sign support tested was a single-post sign support with a 1,219-mm x 1,219-mm (48-in. x 48-in.) vinyl flexible roll-up sign mounted at a height of 457 mm (18 in.) from the ground to the bottom of the sign panel and with the top of the sign panel at a height of 2,172 mm (85 ½ in.) from the ground to the top of the system. The crash test is summarized in Table 3.

Table 3. List of Crash Test Conducted

WORK-ZONE TRAFFIC CONTROL DEVICE		
PORTABLE SIGN SUPPORT		
Test M-3	System No. 3	Ground-Mounted, Single-Post Sign Support, Vinyl Sign Panel, Head-on Impact (0 degrees)

3.2 Portable Sign Support

The details of the portable sign support system are shown in Figures 1 through 3. The corresponding English-unit drawings are shown in Appendix A. The dimensional measurements of the portable sign support system are found in Appendix B.

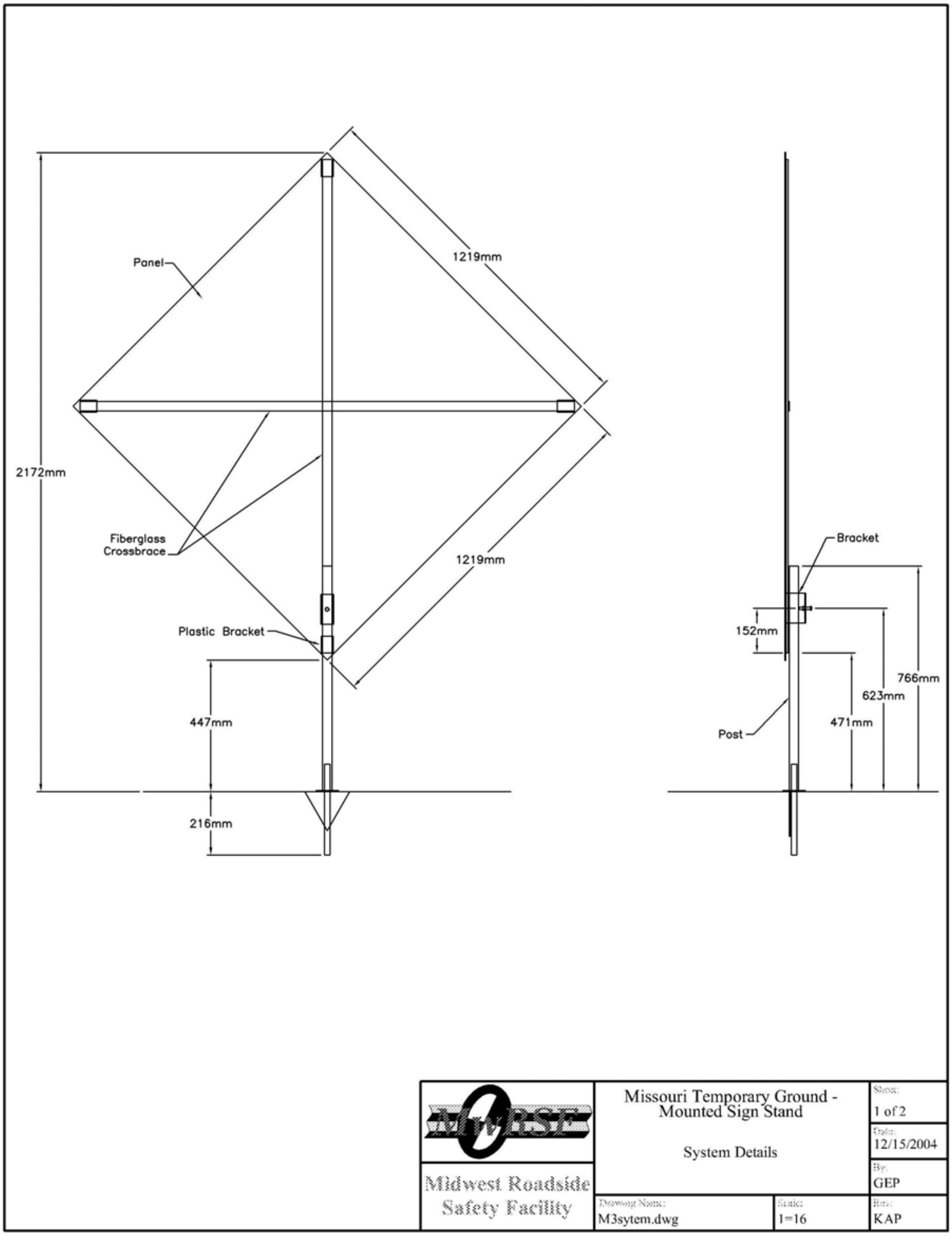


Figure 1. System No. 3 Sign Support Details, Test M-3

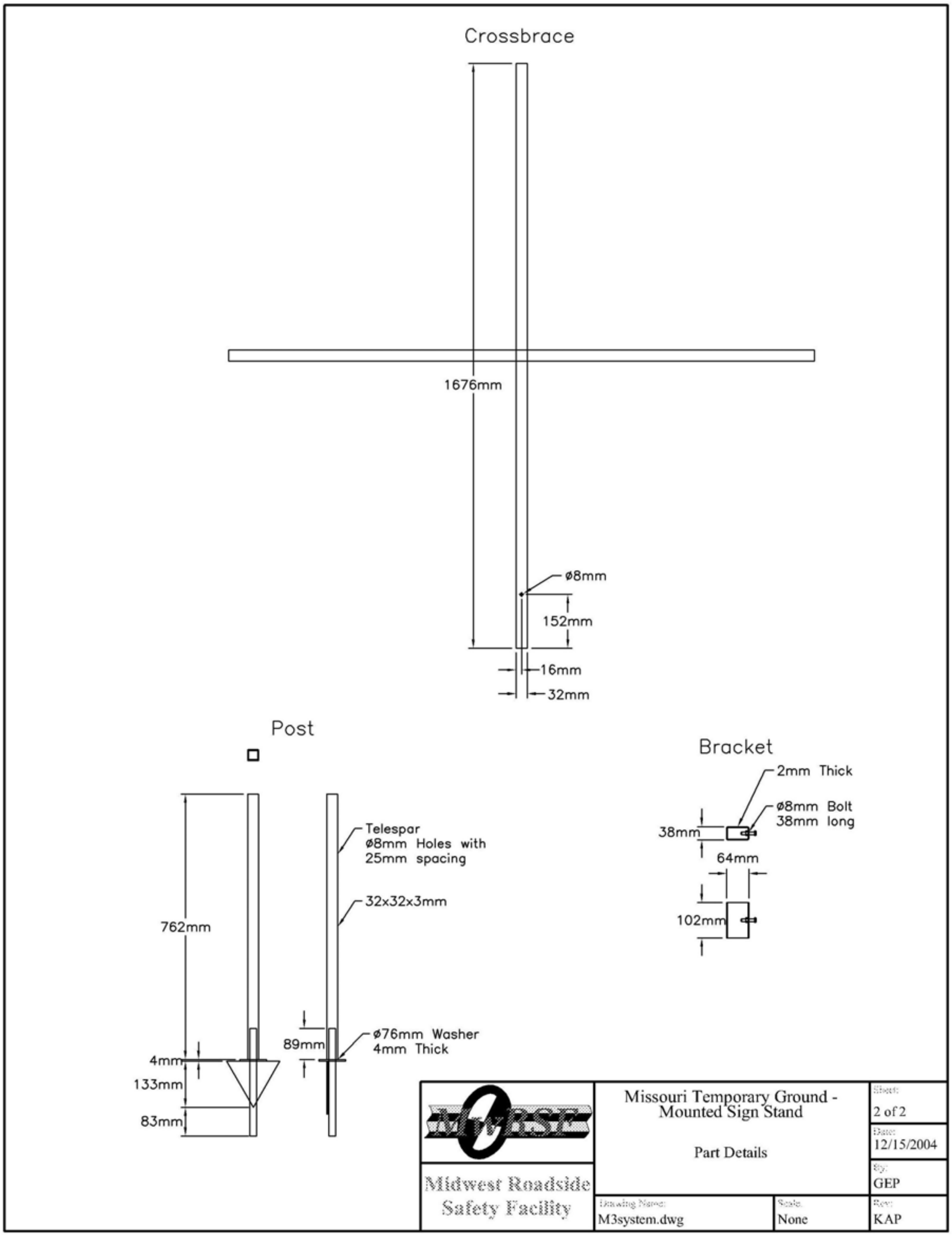


Figure 2. System No. 3 Sign Support Details, Test M-3

Figure 3. System No. 3 Sign, Test M-3

4 TEST CONDITIONS - FULL-SCALE TESTING

4.1 Test Facility

The testing facility is located at the Lincoln Air-Park on the northwest (NW) side of the Lincoln Municipal Airport and is approximately 8.0 km (5 mi.) NW of the University of Nebraska-Lincoln.

4.2 Vehicle Tow and Guidance System

A reverse cable tow system with a 1:2 mechanical advantage was used to propel the test vehicle. The distance traveled and the speed of the tow vehicle were one-half that of the test vehicle. The test vehicle was released from the tow cable before impact with the work-zone traffic control device. A digital speedometer was located on the tow vehicle to increase the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch (29) was used to steer the test vehicle. A guide-flag, attached to the front-left wheel and the guide cable, was sheared off before impact with the work-zone traffic control device. The 9.5-mm (0.375-in.) diameter guide cable was tensioned to approximately 13.3 kN, (3,000 lbf) and supported laterally and vertically every 30.48 m (100 ft) by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide-flag struck and knocked each stanchion to the ground. The vehicle guidance system was approximately 305-m (1,000-ft) long.

4.3 Test Vehicles

For test M-3, a 1996 Geo Metro was used as the test vehicle. The test inertial and gross static weights were 815 kg (1,797 lbs) and 890 kg (1,963 lbs), respectively. The test vehicle is shown in Figure 4, and vehicle dimensions are shown in Figure 5.

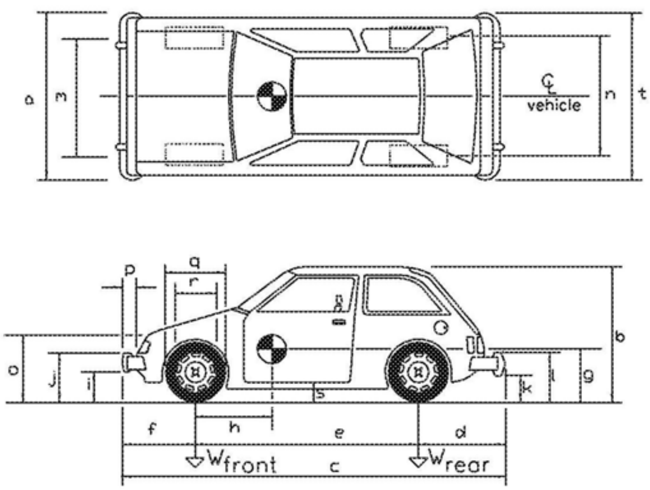
Figure 4. Test Vehicle, Test M-3

Date: 11/11/03 Test Number: M-3 Model: Metro

Make: Geo Vehicle I.D.#: 2C1MR229XT6786381

Tire Size: 155/80 R13 Year: 1996 Odometer: 78039

*(All Measurements Refer to Impacting Side)



Vehicle Geometry – mm (in.)

a	1562 (61.5)	b	1426 (56.125)
c	3778 (148.75)	d	635 (25.0)
e	2362 (93.0)	f	781 (30.75)
g	546 (21.5)	h	835 (32.875)
i	241 (9.5)	j	533 (21.0)
k	343 (13.5)	l	660 (26.0)
m	1365 (53.75)	n	1327 (52.25)
o	578 (22.75)	p	108 (4.25)
q	565 (22.25)	r	365 (14.375)
s	324 (12.75)	t	1549 (61.0)

Wheel Center Height 260 (10.25)

Engine Type Gas

Engine Size 4 cyl.

Transmission Type:

(Automatic) or Manual

(FWD) or RWD or 4WD

Weights kg (lbs)	Curb	Test Inertial	Gross Static
W_{front}	513 (1132)	528 (1163)	564 (1243)
W_{rear}	278 (613)	288 (634)	327 (720)
W_{total}	792 (1745)	815 (1797)	890 (1963)

Note any damage prior to test: NONE: Broken Driver Side Taillight

Figure 5. Vehicle Dimensions, Test M-3

The longitudinal component of the center of gravity was determined using the measured axle weights. The location of the final centers of gravity are shown in Figure 4.

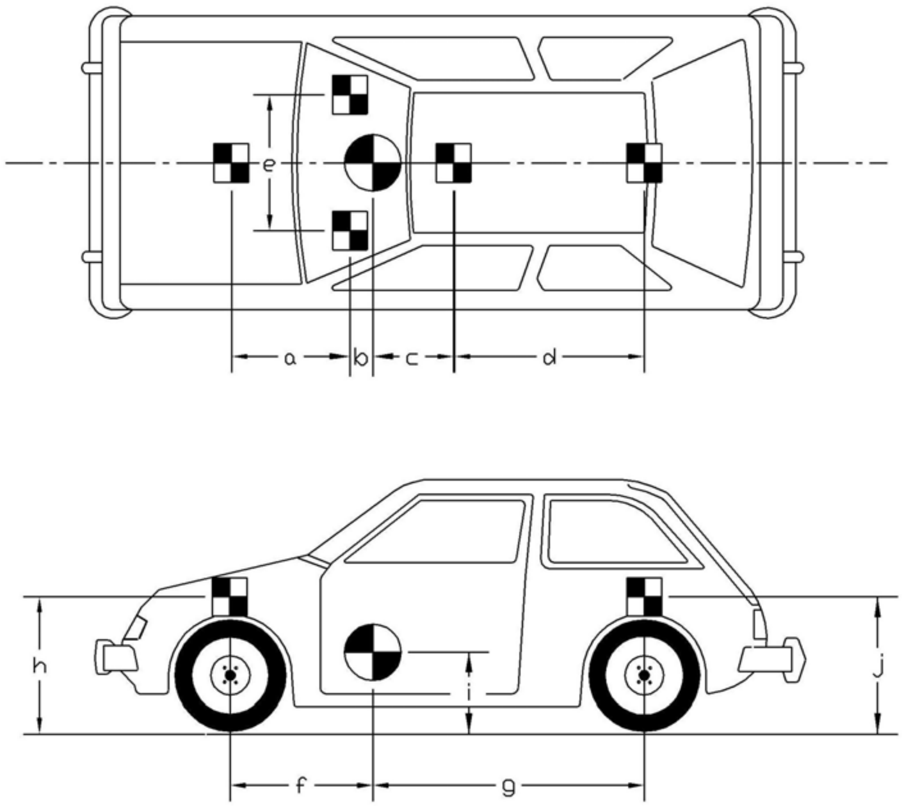
Square, black and white-checkered targets were placed on the vehicle to aid in the analysis of the high-speed film, as shown in Figure 6. One target was place directly above each of the wheels on the driver and passenger sides.

The front wheels of the test vehicle were aligned for camber, caster, and toe-in values of zero so that the vehicle would track properly along the guide cable. Two 5B flash bulbs were mounted on the right-quarter point of the vehicle's roof to pinpoint the time of impact with the work-zone traffic control device on the high-speed film. The flash bulbs were fired by a pressure tape switch mounted at the centerline point on the front face of the bumper. A remote controlled brake system was installed in the test vehicle so the vehicle could be brought safely to a stop after the test.

4.4 Data Acquisition Systems

4.4.1 High-Speed Photography

For test M-3, one high-speed 16-mm Red Lake Locam camera, with operating speed of approximately 500 frames/sec, was used to film the crash test. Two high-speed Red Lake E/cam video cameras, with operating speeds of 500 frames/sec, were also used to film the crash test. Two Canon digital video cameras, with a standard operating speed of 29.97 frames/sec, were also used to film the crash test. A Locam, two Red Lake E/cam high-speed video cameras, and a Canon digital video camera were placed on the right-side of the impact orientation and had a field of view perpendicular to the impact of the device. A Canon digital video camera was placed downstream and offset to the right from the impact point and had a panning view of the impact. A schematic of all five camera locations for test M-3 is shown in Figure 7. The film was analyzed using the Vanguard



TEST #: M-3

TARGET GEOMETRY -- mm (in.)

a	----	b	----	c	----	d	----
e	----	f	835 (32.875)	g	1527 (60.125)	h	737 (29.0)
		i	546 (21.5)	j	781 (30.75)		

Figure 6. Vehicle Target Locations, Test M-3

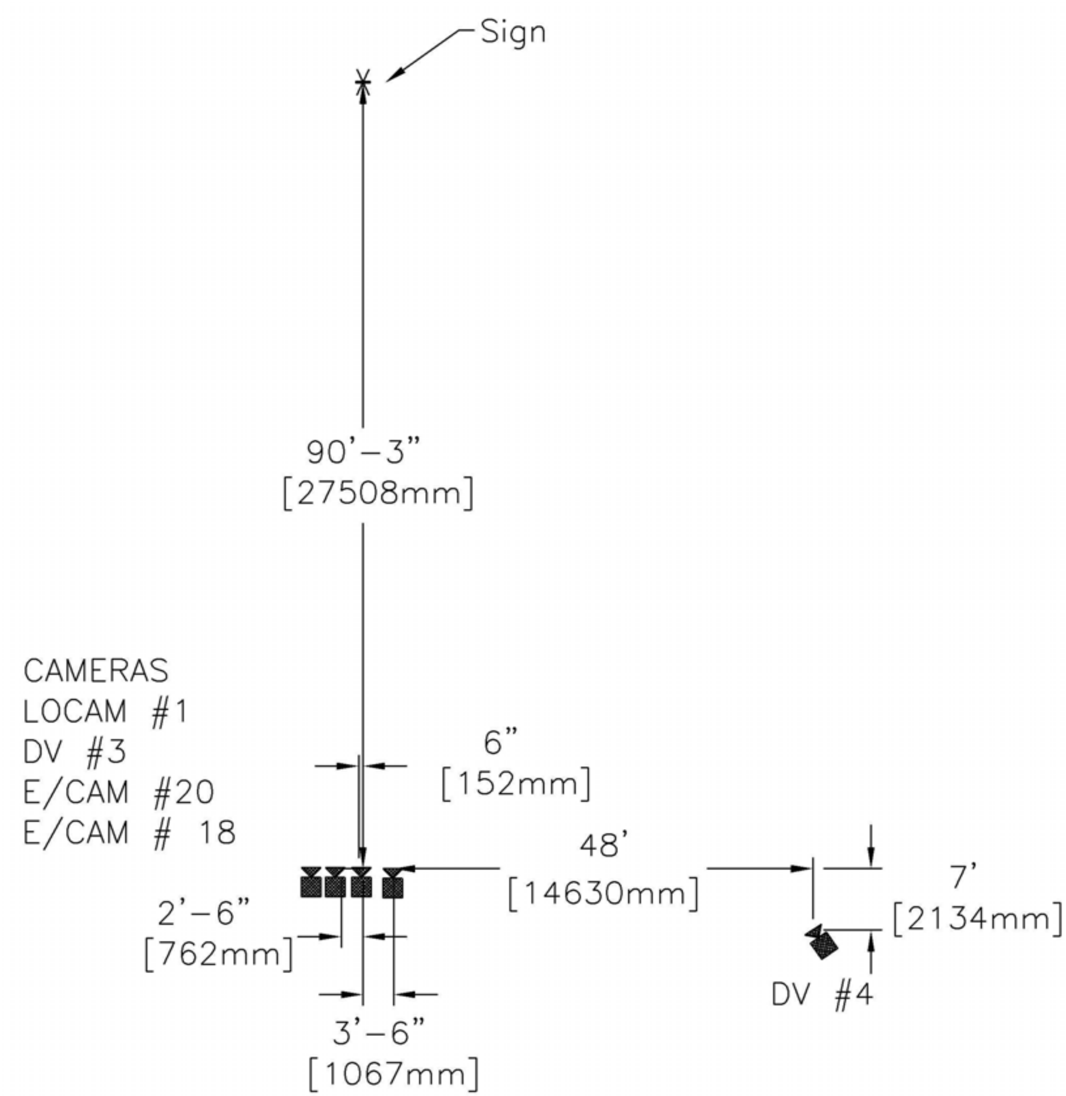


Figure 7. Location of High-Speed Cameras, Test M-3

Motion Analyzer. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed film.

4.4.2 Pressure Tape Switches

For test M-3, five pressure-activated tape switches, spaced at 2-m (6.56-ft) intervals, were used to determine the speed of the vehicle before impact with the device. Each tape switch fired a strobe light which sent an electronic timing signal to the data acquisition system as the left-front tire of the test vehicle passed over the tape switches. Test vehicle speed was determined from electronic timing mark data recorded using the "Test Point" software. Strobe lights and high-speed film analysis are used only as a backup in the event that vehicle speed cannot be determined from the electronic data.

5 CRASH TEST NO. 3 (SYSTEM NO. 3)

5.1 Test M-3

The 890-kg (1,963-lb) small car impacted System No. 3, a sign support oriented head-on to the vehicle (perpendicular to the vehicle's path), at a speed of 99.8 km/h (62.0 mph) and at an angle of 0 degrees. A summary of the test results and the sequential photographs are shown in Figure 8. The summary of the test results and sequential photographs in English units are shown in Appendix C. Additional sequential photographs are shown in Figure 9.

5.2 Test Description

The test vehicle impacted System No. 3 with the centerline point of the vehicle's bumper aligned with the centerline of the sign support, as shown in Figure 10. At 0.006 sec after initial impact, the sign post deflected away from the front of the vehicle and the sign panel's bottom corner. At 0.014 sec, the bottom third of the sign panel flexed around the front of the vehicle and pulled the top of the sign panel downward. At this same time, the sign post continued to deflect away from the vehicle and sliced through the soil. At 0.016 sec, the ends of the horizontal crossbrace flexed toward the vehicle. At 0.018 sec, the anchor pulled completely out of the ground and the vertical crossbrace encountered extensive flex toward the vehicle. At 0.022 sec, the vertical crossbrace member disengaged from the panel clip and sign post. At 0.034 sec, the horizontal crossbrace disengaged from the sign panel vinyl which was in contact with the hood. At this same time, the sign panel continued to rotate toward the vehicle. At 0.048 sec, the top of the sign panel vinyl contacted the windshield. At this same time, the sign post was airborne under the front of the vehicle. At 0.052 sec, the top of the vertical crossbrace contacted the central region of the windshield. At 0.060 sec, the middle hub connecting the two crossbraces contacted the hood, and the top of the vertical crossbrace remained in contact with the windshield. At 0.096 sec, the sign panel vinyl and top of the vertical crossbrace were in contact with the top half of the windshield. At this same time, the sign post rotated upward, lodged between the ground and the front bumper, and was drug along with the vehicle. At 0.112 sec, the vertical crossbrace rebounded off of the vehicle, and the lower portion of the sign panel began to rise into the air. At 0.158 sec, the sign panel vinyl was deformed up toward the top of the vertical crossbrace. At 0.168 sec, the bottom of the vertical crossbrace contacted the front of the vehicle with the remainder of the crossbraces and sign panel vinyl airborne above the front of the vehicle. At 0.206 sec, the sign panel vinyl and crossbraces were completely airborne above the vehicle, and the sign post remained under the front end of the vehicle. At 0.256 sec, the sign panel vinyl disengaged from the crossbraces. The sign panel vinyl was located 11.89-m (39-ft) downstream and 0.46-m (1-ft 6-in.) left from the initial position. The bottom plastic crossbrace bracket was located 34.24-m (112-ft 4-in.) downstream and 2.69-m (8-ft 10-in.) left from the original position. The crossbraces were located 47.09-m (154-ft 6-in.) downstream and 0.36-m (1-ft 2-in.) left from the initial position. The sign post support came to rest 71.32-m (234-ft) downstream and 0.46-m (1-ft 6-in.) left from the original position. The vehicle subsequently came to rest 141.43-m (464-ft) downstream from the midpoint of the impact point and 0.61-m (2-ft) right from the centerline of the vehicle's original path. The final positions of the vehicle and the sign support are shown in Figure 8.

5.3 System and Component Damage

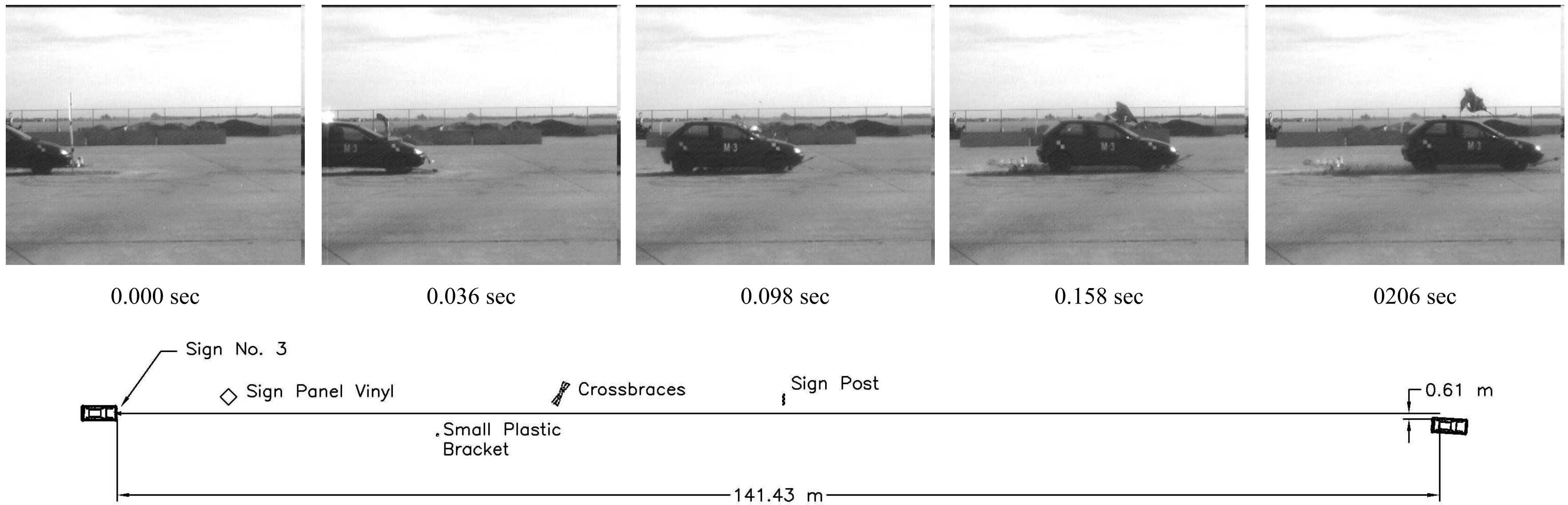
The moderate damage to System No. 3 is shown in Figure 11. The sign panel vinyl was removed from the horizontal and vertical crossbraces. The bottom crossbrace bracket was removed from the sign panel vinyl. Glass was embedded in the sign panel vinyl along the locations of the vertical and horizontal crossbraces. The bottom of the vertical crossbrace was splintered. The sign panel bracket remained loosely attached to the sign post. The sign panel bracket was deformed on the bolt side. The soil plate on the sign post was deformed at the top. The sign post was pulled completely out of the ground.

5.4 Vehicle Damage

Exterior vehicle damage is shown in Figures 12 through 14. The front bumper and lower plastic shield encountered light contact marks near the center. Contact and scrape marks were also found on the hood and roof. Two small dents were found near the top portion of the hood. The center of the windshield sustained extensive "spider web" cracking of both layers of the glass, causing weak spots. This region of the windshield was also deformed toward the interior of the vehicle with a concentrated indentation. A 32-mm (1 ¼-in) concentrated indentation occurred 89 mm (3 ½ in.) from the top of the windshield. Concentrated indentations were also found at both outer edges of the windshield. A significant amount of windshield glass had fractured off and was found in the interior of the vehicle. No damage was found to have occurred to the parking lights, headlights, and fog lights.

5.5 Discussion

Following test M-3, a safety performance evaluation was conducted, and the work-zone traffic control device, System No. 3, was determined to be unacceptable according to the NCHRP Report No. 350 criteria. It was deemed unacceptable due to the extensive "spider web" cracking and indentation in the windshield which resulted in obstructed driver visibility and loss of structure of both glass layers. Detached elements and debris from System No. 3 did not penetrate, but showed potential of windshield penetration. Deformations of, or intrusion into, the occupant compartment did occur. The vehicle's trajectory did not intrude into adjacent traffic lanes.



- Test Number M-3
- System Number 3
- Date 11/11/03
- Test Article
  - Type . . . . Traffic Control Device – Ground-Mounted, Single-Post, Sign Support System
  - Stand Name . . . . Modified SH-96-2
  - Sign Panel Name . . . . Flexible Panel
  - Key Elements
    - Size and/or dimension . 2.2 m high after installation
    - Material . . . . ASTM Steel Grade A36 Telespar Tubing
  - Orientation . . . . Head-on with centerline point
- Soil Type . . . . Grading B - AASHTO M 147-65 (1990)
- Vehicle Model . . . . 1996 Geo Metro
  - Curb . . . . 792 kg
  - Test Inertial . . . . 815 kg
  - Gross Static . . . . 890 kg
- Vehicle Speed
  - Impact . . . . 99.8 km/h
  - Exit . . . . NA
- Vehicle Angle
  - Impact . . . . 0 deg
  - Exit . . . . 0 deg
- Vehicle Stability . . . . Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal . . . . NA
  - Lateral (not required) . . . . NA
- Occupant Impact Velocity (Normalized)
  - Longitudinal . . . . NA
  - Lateral (not required) . . . . NA
- Vehicle Damage . . . . Severe windshield cracking and indentation
  - TAD[30] 12-FC-1
  - SAE[31] 12-FCAW6
- Vehicle Stopping Distance . . . . 141.43 m downstream 0.61 m right
- Test Article Damage . . . . Moderate – Broke apart

Figure 8. Summary of Test Results and Sequential Photographs, Test M-3

0.000 sec

0.000 sec

0.000 sec

0.014 sec

0.100 sec

0.067 sec

0.022 sec

0.167 sec

0.200 sec

0.034 sec

0.234 sec

0.400 sec

0052 sec

0.334 sec

0.634 sec

0060 sec

0.400 sec

0.968 sec

Figure 9. Additional Sequential Photographs, Test M-3

Figure 10. Impact Locations, Test M-3

Figure 11. System No. 3 Damage, Test M-3

Figure 12. Vehicle Damage, Test M-3

Figure 13. Windshield Damage, Test M-3

Figure 14. Windshield Damage, Test M-3

6 DISCUSSION AND DESIGN MODIFICATION

6.1 Discussion

Following test M-3, a safety performance evaluation was conducted, and the work-zone safety device system was determined to be unacceptable according to the NCHRP Report No. 350 criteria. Due to the unsuccessful crash test of the system, it was necessary to determine the cause of the temporary sign support's poor performance so that design modifications potentially could be incorporated into the sign support system. Although these temporary sign support systems could remain in use through their normal service life, the Missouri Department of Transportation (MoDOT) wished to utilize these devices with modifications.

Following an analysis of the test results, the researchers determined that the quick release of the vertical crossbrace from the panel-to-post bracket led to the system failure. The sign panel had developed significant flex toward the vehicle prior to its release from the bracket. This downward panel movement toward the windshield, followed by the panel release, caused the concentrated impacts on the windshield.

Following this investigation, Midwest Roadside Safety Facility (MwRSF) researchers determined that there was an opportunity to improve the safety performance of the ground-mounted, single-post support system. The modification included redesigning the panel-to-post bracket to allow the bolt to pass completely through the vertical fiberglass crossbrace and the sign post. This modification would provide improved attachment between the sign panel and the sign post, thus keeping the sign panel's downward motion and vehicle contact in the hood region away from the windshield. It was believed that this modification would reduce the potential for severe windshield contact and fracture. The improvement in the safety performance due to this modification was believed to be dependent on how the sign post rotated in the soil.

6.2 Design Modifications

The modification to the sign post system involved redesigning the panel-to-post connection mechanism. The clamp consisted of a U-shaped piece of steel with a single bolt welded to it. The clamp was placed through a holed drilled in the vertical fiberglass crossbrace and the sign post, and secured with a nut on the backside of the sign post. The top of this new clamp was positioned flush with the top of the sign post. These modifications would help to keep the sign panel attached to the sign post. The modified sign support system is shown in Figure 15.

Prior to performing a compliant crash test on the modified ground-mounted, single-post sign system, MwRSF researchers deemed it necessary to conduct a preliminary evaluation using a bogie vehicle test. Therefore, one bogie test on the modified sign post was conducted. This assessment would be based on sign panel contact relative to the simulated windshield located on the bogie vehicle.

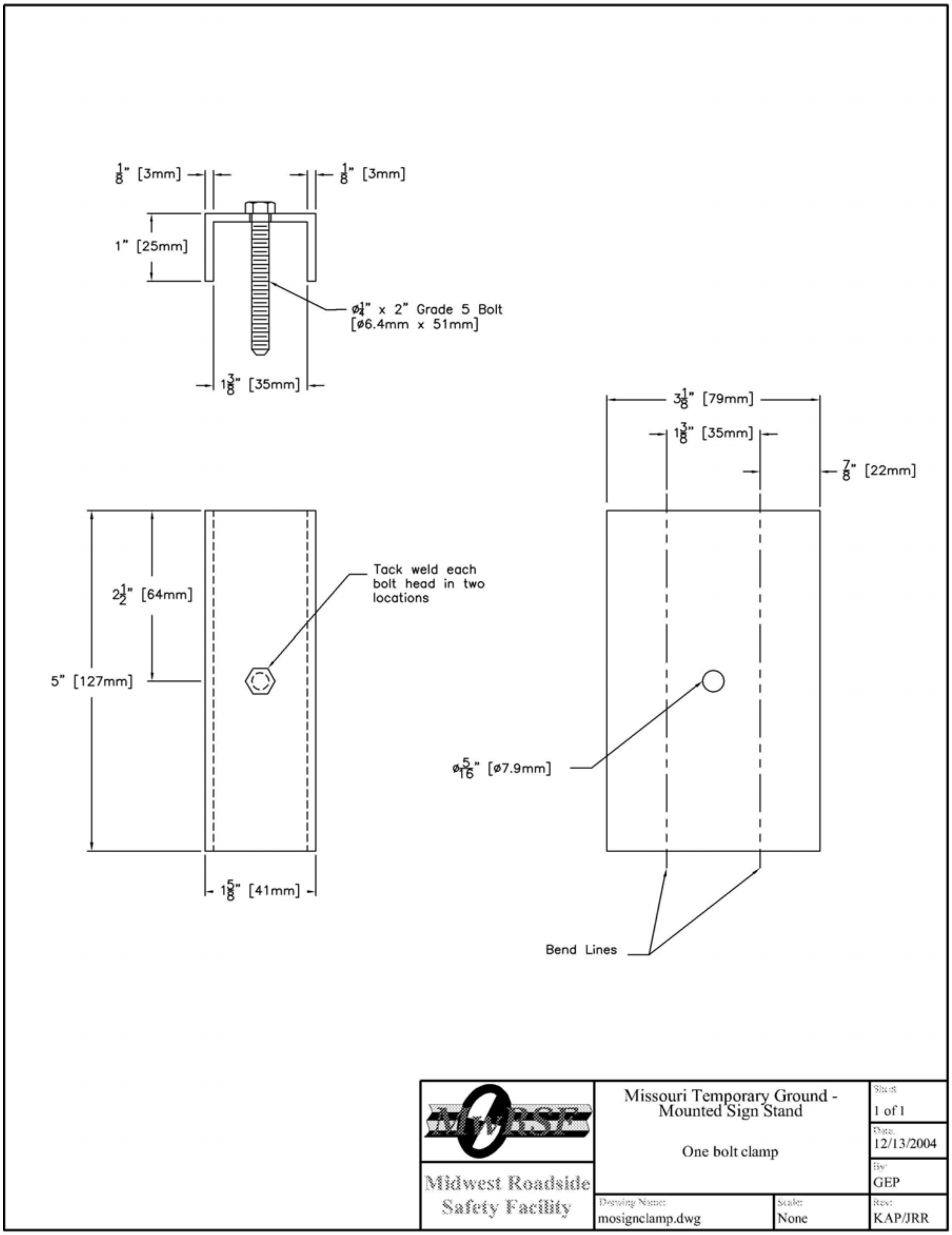


Figure 15. System Design Modifications

7 TEST CONDITIONS - BOGIE TESTING

7.1 Bogie Vehicle

A rigid frame bogie, constructed from FHWA specifications (32), was used to impact the retrofitted design. The bogie was modified by adding a combination HDPE and steel tube frame which simulated the bumper, front clip, hood, windshield, A-pillars, and roof of a 1994 Geo Metro, as shown in Figures 16 and 17.

7.2 Bogie Tow and Guidance System

A reverse cable tow system with a 1:2 mechanical advantage was used to propel the bogie vehicle. The distance traveled and the speed of the tow vehicle were one-half that of the bogie vehicle. For bogie test nos. MOSBOG-10, MOSBOG-11, and MOSBOG-12, the bogie guide track length was 150.9 m (495 ft), 189.0 m (620 ft), and 182.9 m (600 ft), respectively. The guide track was constructed with 57-mm (2 ¼-in.) diameter steel pipes, with wall thicknesses and lengths of 4.76 mm (3/16 in.) and 2,965 mm (116 ft-9 in.), respectively. The pipes were supported every 3,048 mm (10 ft) by steel stanchions. The bogie vehicle was released from the tow cable and the bogie guide track before impact with the work-zone traffic control device, allowing the bogie to become a free projectile as it came off the bogie guide track.

7.3 System Installation

The system was installed in a compacted course, crushed limestone material that met Grading B of AASHTO M147-65 (1990) as found in NCHRP Report No. 350. The system installation would be representative of its in-service installation, as shown in Figure 18.

Figure 16. Modified Bogie Vehicle

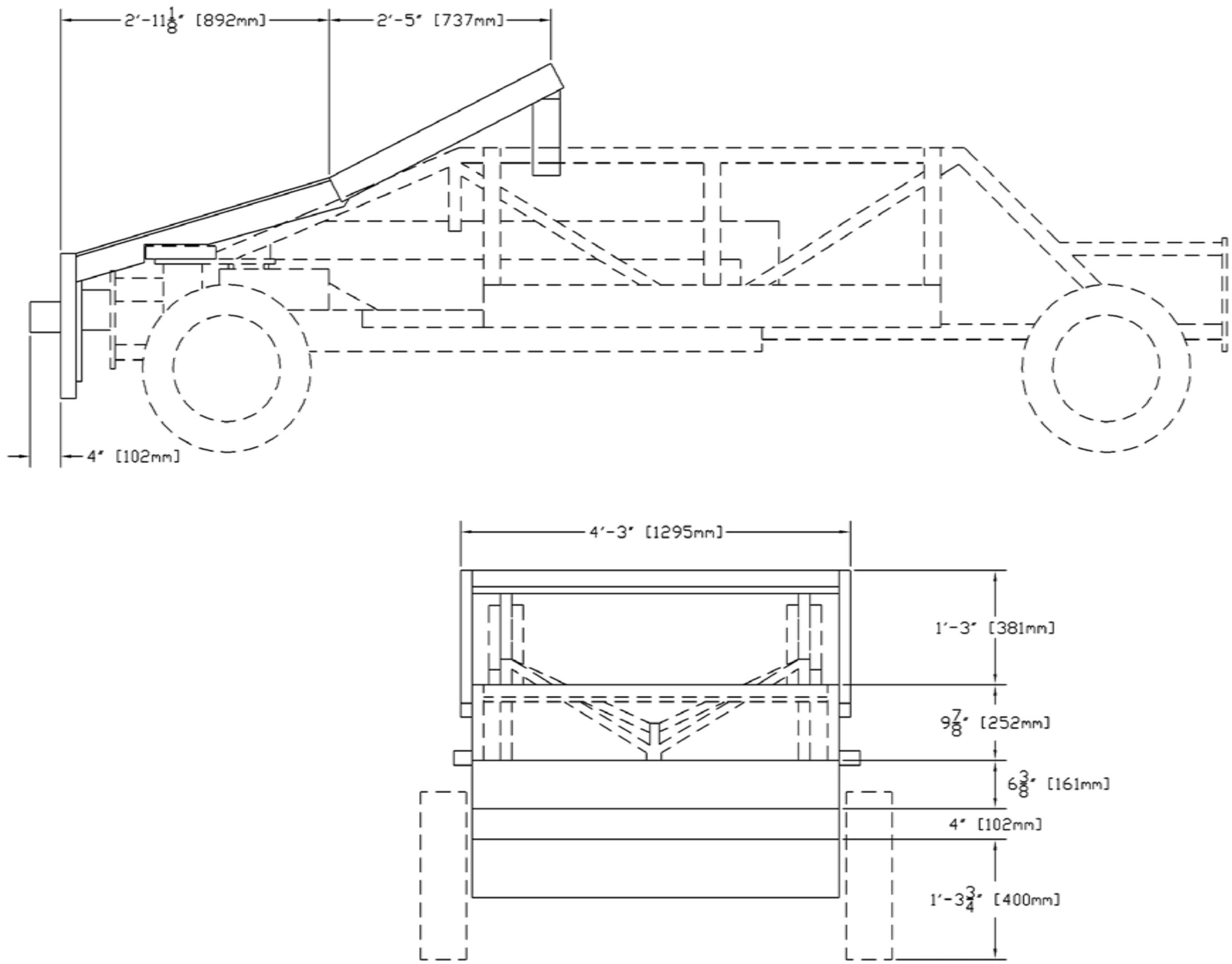


Figure 17. Modified Bogie Vehicle Dimensions

Figure 18. System Installation for Bogie Testing

7.4 Data Acquisition Systems

7.4.1 High-Speed Photography

For bogie test MOSBOG-10, two high-speed Red Lake E/cam video cameras, with operating speeds of 500 frames/sec, were placed on the left side of the impact orientation and had a field of view perpendicular to the impact. A Canon digital video camera was also placed on the left side of the system and had a slightly angled view of the system and impact.

For bogie tests MOSBOG-11 and MOSBOG-12, two high-speed Photron video cameras, with operating speeds of 500 frames/sec, were placed on the left side of the impact orientation and had a field of view perpendicular to the impact. A Canon digital video camera was also placed on the left side of the system and had a slightly angled view of the system and impact.

7.4.2 Pressure Tape Switches

One set of three pressure-activated tape switches, spaced at 2-m (6.56-ft) intervals, were used to determine the speed of the bogie vehicle before impact with the device. Each tape switch fired a strobe light which sent an electronic timing signal to the data acquisition system as the left-front tire of the bogie vehicle passed over the set of tape switches. Test bogie vehicle speed was determined from electronic timing mark data recorded using the "Test Point" software.

8 DEVELOPMENTAL TESTING – BOGIE TEST NO. MOSBOG-10

8.1 System Description

Ground-Mounted, Single-Post Sign Stand

- Vertical Tubing – 32-mm (1.25-in.) square galvanized telespar steel tubing with 3.2-mm (0.125 in.) wall thickness and a length of 762 mm (30 in.).
- Anchor – 19-mm (0.75-in.) diameter by 305-mm (12-in.) long steel rod with a 152-mm (6-in.) wide x 133-mm (5.25-in.) high x 3.2-mm (0.125-in.) thick triangle soil plate. A 76-mm (3-in.) diameter washer with a 4.0-mm (0.156-in.) thickness was welded to the steel rod at the top of the attached soil plate. The material in the anchor is ASTM Grade A-513 steel.
- The vertical tubing welded to the top of the washer on the anchor.
- Panel-to-Post Clamp – 41-mm (1.625-in.) wide x 127-mm (5-in.) long, U-shaped with 25-mm (1-in.) long legs and a 3.2-mm (0.125-in.) thickness. The material for the clamp is ASTM A-36 steel. A 6.4-mm (0.25-in.) diameter by 57-mm (2.25-in.) long ASTM A-307 Grade 3 bolt with nut was inserted through a hole in the center of the U-shaped clamp and tack welded around the bolt head.

Flexible Sign

- Panel – Fold & Roll style, reflective vinyl, 1,219 mm x 1,219 mm (48 in. x 48 in.).
- Crossbrace, Vertical Member – 6.4-mm (0.25-in.) thick x 32-mm (1.25-in.) wide x 1,676-mm (66-in.) long fiberglass. A 7.9-mm (0.3125-in.) diameter hole was drilled at 210 mm (8.25 in.) from the bottom of the vertical crossbrace.
- Crossbrace, Horizontal Member – 4.8-mm (0.1875-in.) thick x 32-mm (1.25-in.) wide x 1,676-mm (66-in.) long fiberglass.

Height to Bottom of Sign:	457 mm (18 in.)
Height to Center of Clamp:	702 mm (27.625 in.)
Height to Top of Sign Post:	765 mm (30.125 in.)
Height to Top of Sign Panel:	2,181 mm (85.875 in.)

Weights of Sign System:

Sign Post:	2.722 kg (6.0 lbs)
Clamp and Bolt:	0.244 kg (0.5 lbs)
Panel and Crossbraces:	2.854 kg (6.3 lbs)
Total Weight:	5.820 kg (12.8 lbs)

Details of the portable sign support system are shown in Figures 19 and 20. The corresponding English-unit drawings are shown in Appendix A. Photographs of the portable sign support system are shown in Figure 21.

8.2 Test MOSBOG-10

The 1,119-kg (2,467-lb) bogie vehicle impacted the modified sign support system oriented head-on to the vehicle at a speed of 99.3 km/h (61.7 mph) and at an angle of 0 degrees. Sequential photographs are shown in Figure 22. The bogie vehicle experienced a velocity change of approximately 3.5 km/h (2.2 mph).

8.3 System Performance

Damage to the modified system is shown in Figure 23. The system encountered moderate damage. The sign post deformed at the area of bumper impact. The sign panel vinyl was removed from the horizontal and vertical crossbraces. The vertical crossbrace remained attached to the sign post but encountered extensive splintering at the top of the sign post. The horizontal crossbrace disengaged from the vertical crossbrace, and the middle of the crossbrace encountered extensive fiberglass splintering. The soil plate on the sign post was deformed at the top. The sign post was pulled completely out of the ground. Both fiberglass crossbraces contacted the hood region, but no contact nor damage to the windshield area was observed. Furthermore, the system traveled along with the bogie. Subsequently, the bogie vehicle traversed over the deformed system in a stable manner.

8.6 Discussion

Following the developmental bogie test MOSBOG-10, an evaluation was conducted, and the modified work-zone traffic control device performed acceptably in the bogie crash test. The modified system performed as expected, with the vertical crossbrace remaining attached to the sign post. If a small car would have been used in place of the bogie vehicle, the system would have deformed around the bumper at the front of the small car. Along with the deformation around the front of the small car, the sign panel and crossbraces would have impacted the hood region of the vehicle. With this, it is believed that the system would not have become a potential hazard to the vehicle nor the occupant compartment. Therefore, the system's performance was acceptable in the 0 degree orientation.

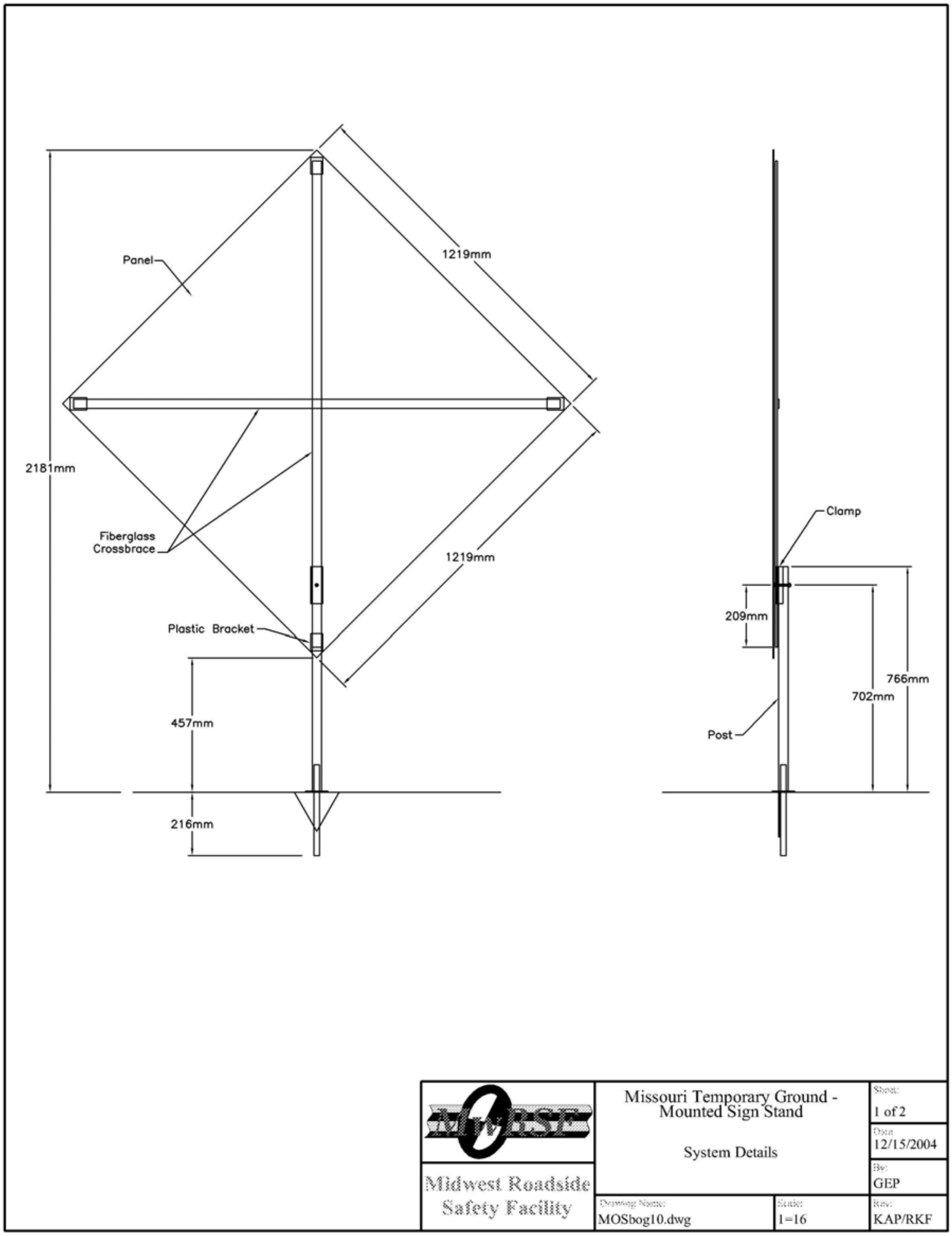


Figure 19. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-10

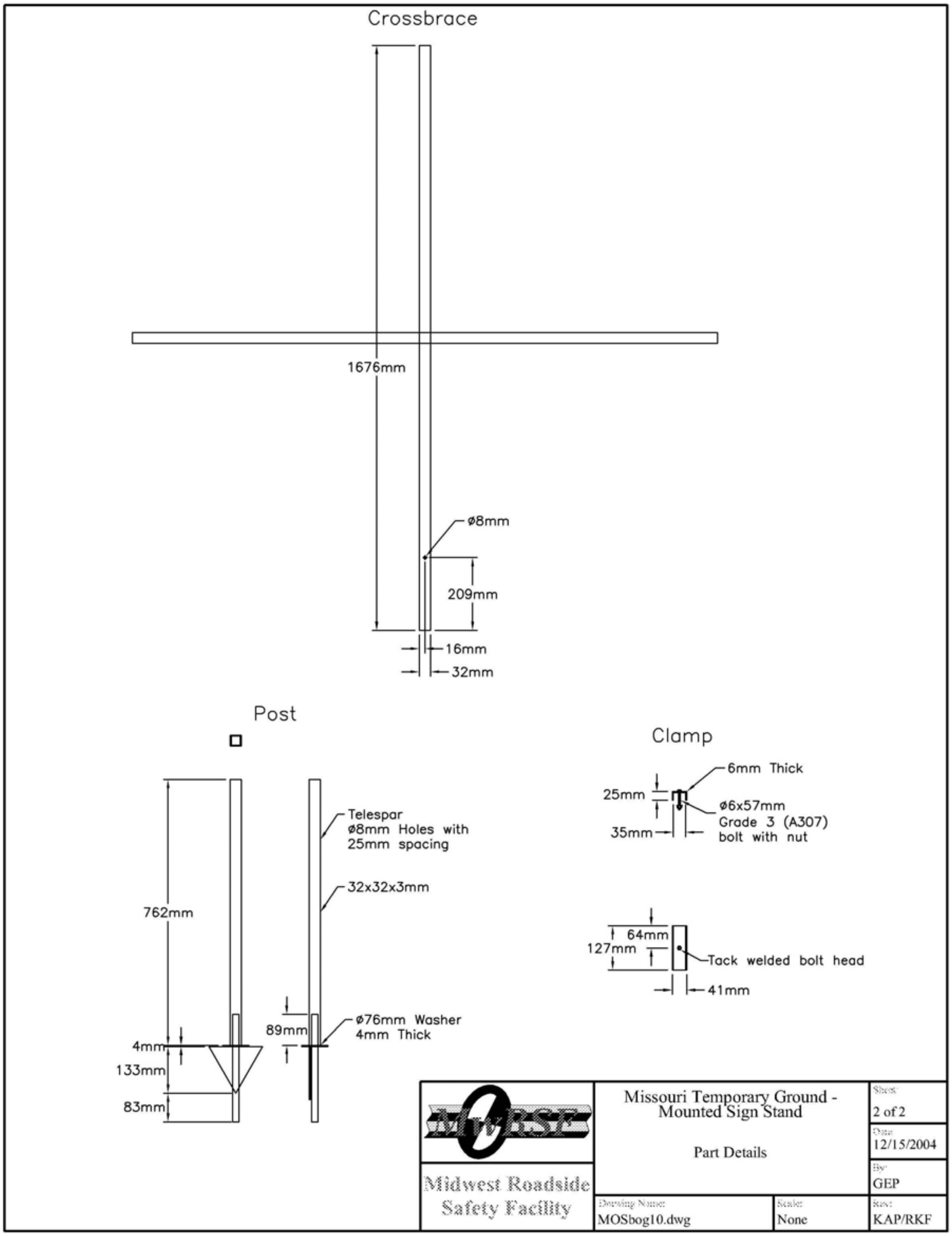


Figure 20. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-10

Figure 21. Ground-Mounted, Single-Post Sign System, Bogie Test MOSBOG-10

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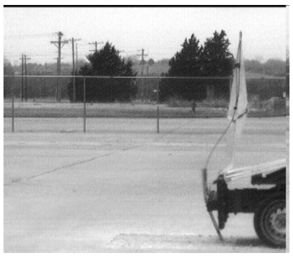

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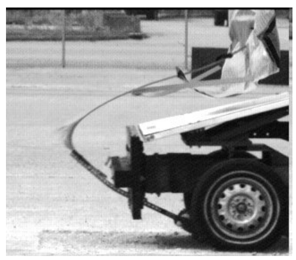

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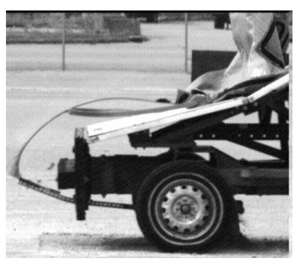

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0.054 sec

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Figure 22. Sequential Photographs, Bogie Test MOSBOG-10

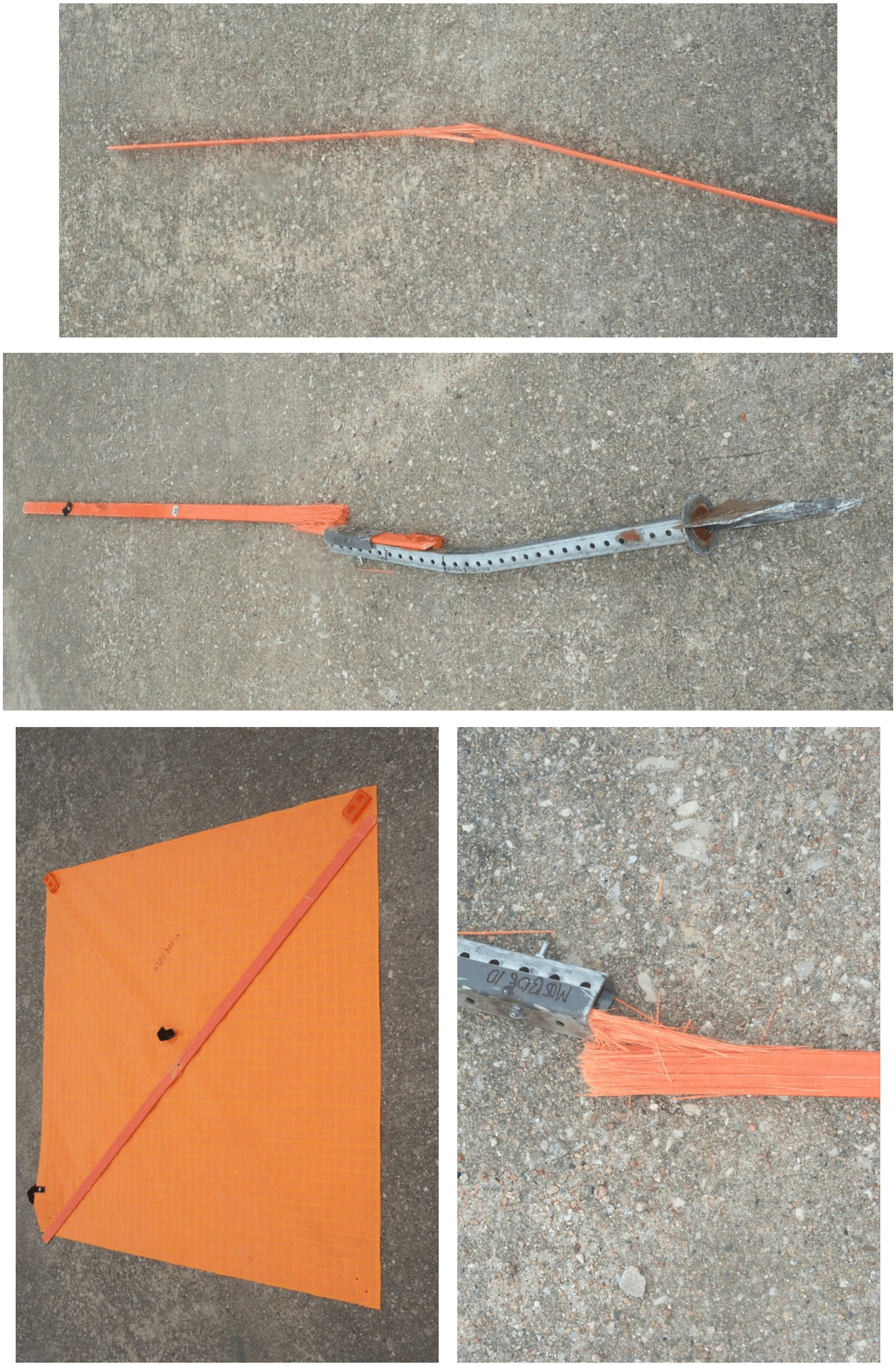

Figure 23. System Damage, Bogie Test MOSBOG-10

9 COMPLIANT BOGIE TESTING – BOGIE TEST NO. MOSBOG-11

9.1 System Description

Ground-Mounted, Single-Post Sign Stand

- Vertical Tubing – 32-mm (1.25-in.) square galvanized telespar steel tubing with 3.2-mm (0.125 in.) wall thickness and a length of 762 mm (30 in.).
- Anchor – 19-mm (0.75-in.) diameter by 305-mm (12-in.) long steel rod with a 152-mm (6-in.) wide x 133-mm (5.25-in.) high x 3.2-mm (0.125-in.) thick triangle soil plate. A 76-mm (3-in.) diameter washer with a 4.0-mm (0.156-in.) thickness was welded to the steel rod at the top of the attached soil plate. The material in the anchor is ASTM Grade A-513 steel.
- The vertical tubing welded to the top of the washer on the anchor.
- Panel-to-Post Clamp – 41-mm (1.625-in.) wide x 127-mm (5-in.) long, U-shaped with 25-mm (1-in.) long legs and a 3.2-mm (0.125-in.) thickness. The material for the clamp is ASTM A-36 steel. A 6.4-mm (0.25-in.) diameter by 57-mm (2.25-in.) long ASTM A-307 Grade 3 bolt with nut was inserted through a hole in the center of the U-shaped clamp and tack welded around the bolt head.

Flexible Sign

- Panel – Fold & Roll style, reflective vinyl, 1,219 mm x 1,219 mm (48 in. x 48 in.).
- Crossbrace, Vertical Member – 6.4-mm (0.25-in.) thick x 32-mm (1.25-in.) wide x 1,676-mm (66-in.) long fiberglass. A 7.9-mm (0.3125-in.) diameter hole was drilled at 210 mm (8.25 in.) from the bottom of the vertical crossbrace.
- Crossbrace, Horizontal Member – 4.8-mm (0.1875-in.) thick x 32-mm (1.25-in.) wide x 1,676-mm (66-in.) long fiberglass.

Height to Bottom of Sign:	457 mm (18 in.)
Height to Center of Clamp:	702 mm (27.625 in.)
Height to Top of Sign Post:	765 mm (30.125 in.)
Height to Top of Sign Panel:	2,181 mm (85.875 in.)

Weights of Sign System:

Sign Post:	2.722 kg (6.0 lbs)
Clamp and Bolt:	0.244 kg (0.5 lbs)
Panel and Crossbraces:	2.854 kg (6.3 lbs)
Total Weight:	5.820 kg (12.8 lbs)

Details of the portable sign support system are shown in Figures 24 and 25. The corresponding English-unit drawings are shown in Appendix A. Photographs of the portable sign support system are shown in Figure 26.

9.2 Test MOSBOG-11

The 1,119-kg (2,467-lb) bogie vehicle impacted the modified sign support system oriented end-on to the vehicle at a speed of 104.4 km/h (64.9 mph) and at an angle of 90 degrees. Sequential photographs are shown in Figure 27. The bogie vehicle experienced a velocity change of approximately 5.4 km/h (3.4 mph).

9.3 System Performance

Damage to the modified system is shown in Figure 28. The system encountered moderate damage. The sign post deformed at the area of bumper impact. The sign panel vinyl was removed from the horizontal and vertical crossbraces. The vertical crossbrace fractured at the top of the sign post and encountered extensive fiberglass splintering at the fracture point. The bottom crossbrace bracket was removed from the sign panel vinyl and remained attached to the bottom of the vertical crossbrace. The soil plate on the sign post was slightly deformed. The sign post was pulled completely out of the ground. Both fiberglass crossbraces contacted the hood region, but no contact nor damage to the windshield area was observed. Furthermore, the system traveled along with the bogie. Subsequently, the bogie vehicle traversed over the deformed system in a stable manner.

9.6 Discussion

Following the compliant bogie test MOSBOG-11, an evaluation was conducted, and the modified work-zone traffic control device performed acceptably in the bogie crash test. The modified system performed as expected, with the vertical crossbrace remaining attached to the sign post until the vehicle passed over the system. If a small car would have been used in place of the bogie vehicle, the system would have deformed around the bumper at the front of the small car. Along with the deformation around the front of the small car, the sign panel and crossbraces would have impacted the hood region of the vehicle. With this, it is believed that the system would not have become a potential hazard to the vehicle nor the occupant compartment. Therefore, the system's performance was acceptable in the 90 degree orientation.

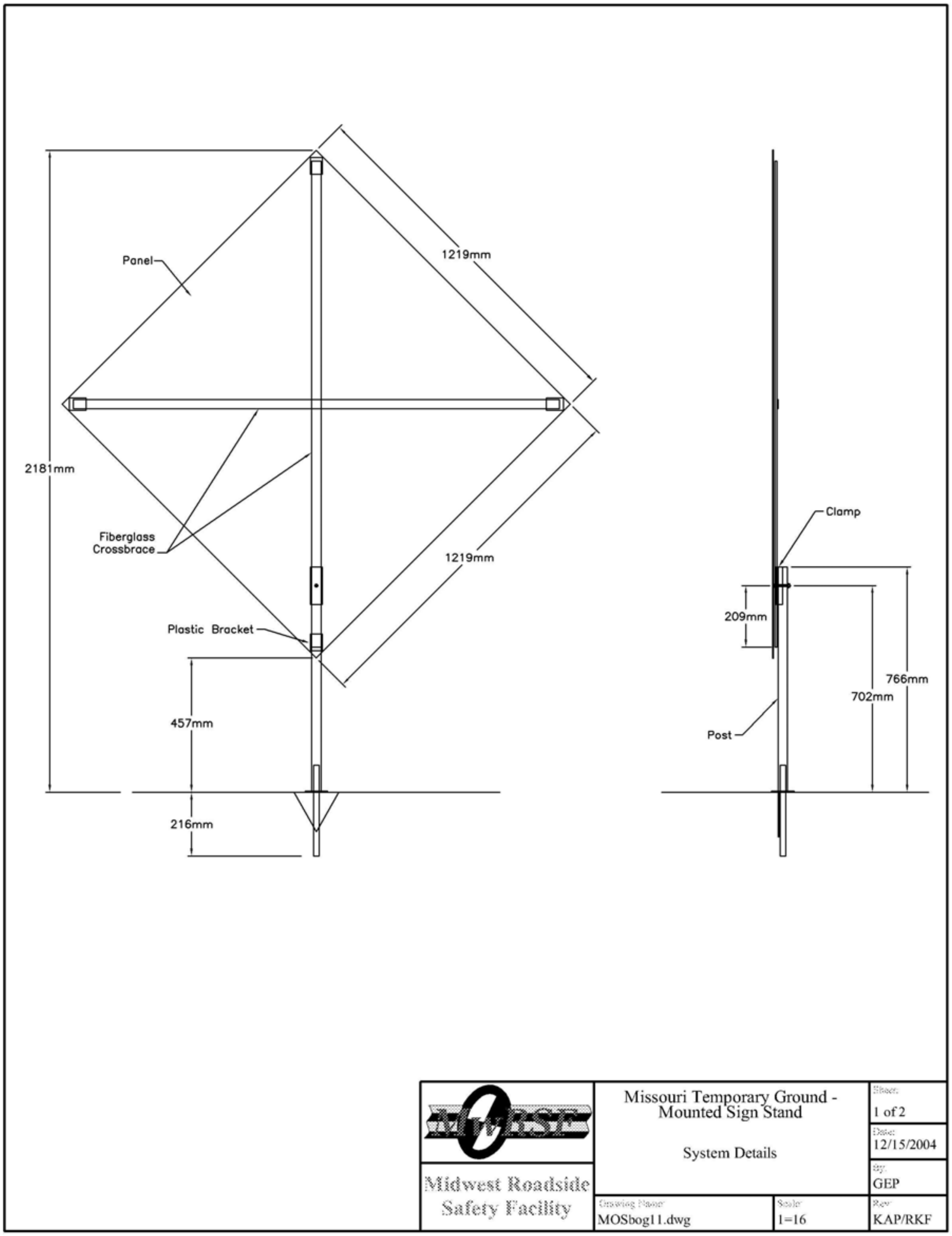

Figure 24. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-11

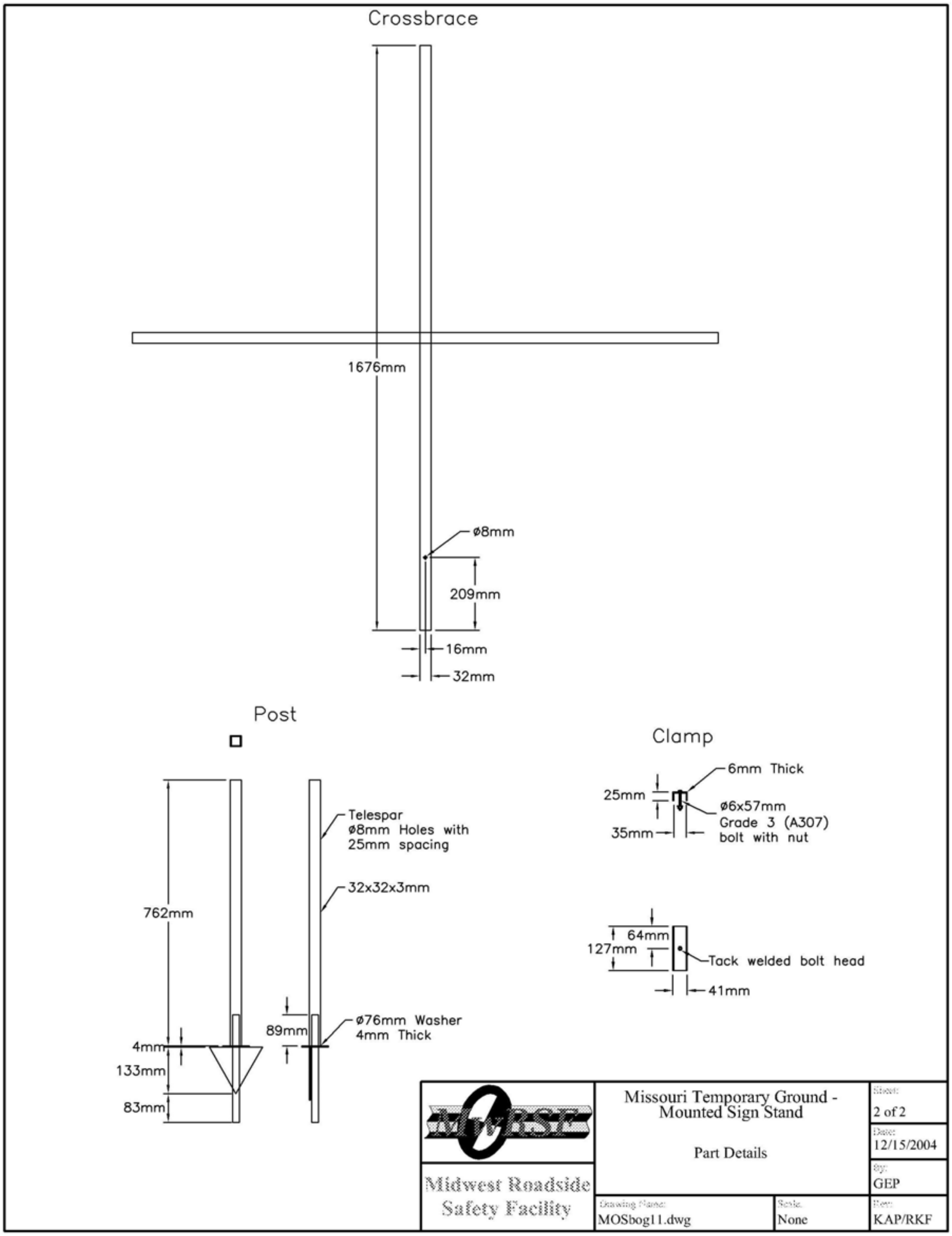

Figure 25. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-11

Figure 26. Ground-Mounted, Single-Post Sign System, Bogie Test MOSBOG-11

0.000 sec

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0.012 sec

0.028 sec

0.028 sec

0.054 sec

0.042 sec

0.130 sec

0.068 sec

0.222 sec

Figure 27. Sequential Photographs, Bogie Test MOSBOG-11 (90 degrees)

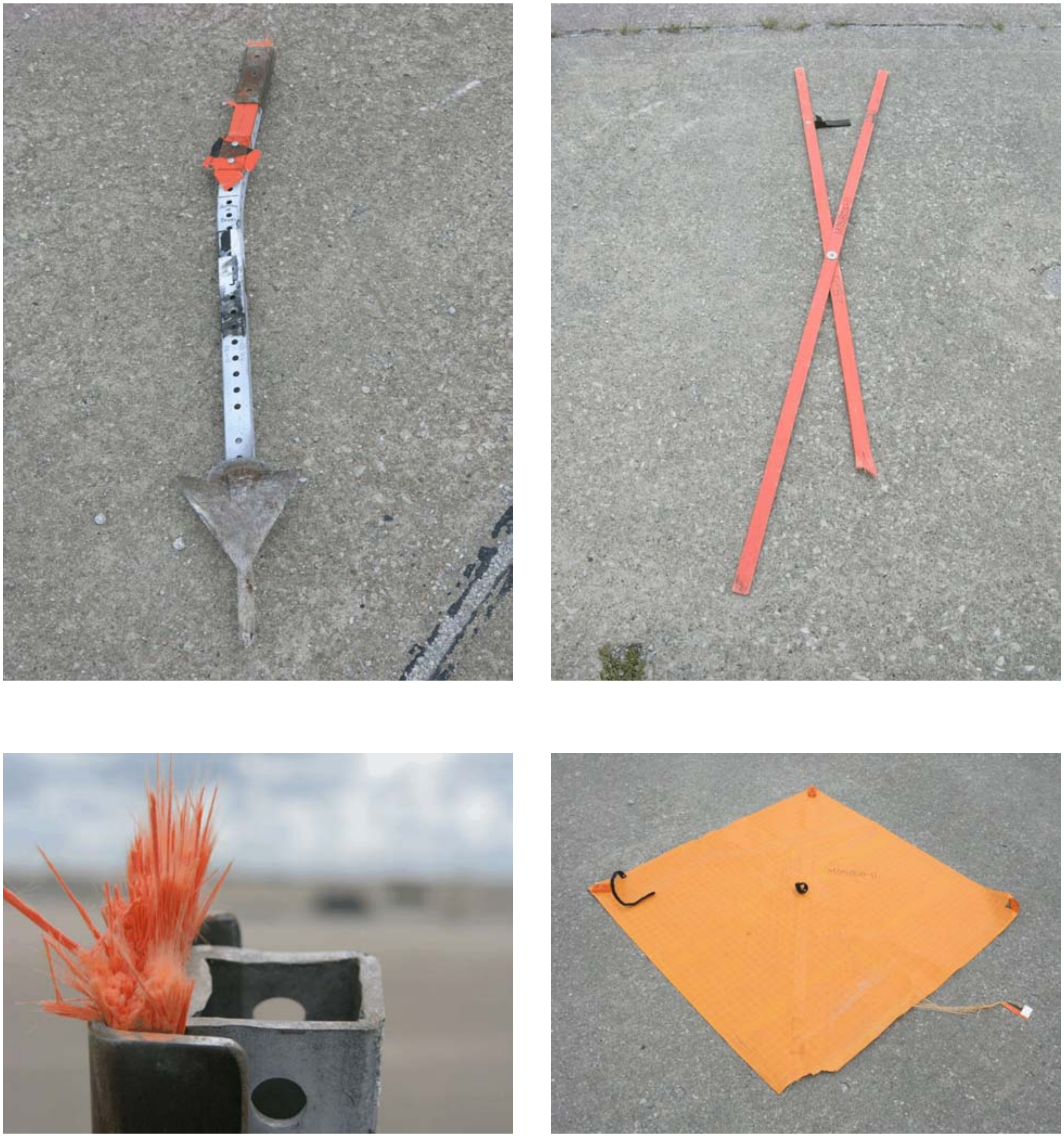

Figure 28. System Damage, Bogie Test MOSBOG-11 (90 degrees)

10 COMPLIANT BOGIE TESTING – BOGIE TEST NO. MOSBOG-12

10.1 System Description

Ground-Mounted, Single-Post Sign Stand

- Vertical Tubing – 32-mm (1.25-in.) square galvanized telespar steel tubing with 3.2-mm (0.125 in.) wall thickness and a length of 762 mm (30 in.).
- Anchor – 19-mm (0.75-in.) diameter by 305-mm (12-in.) long steel rod with a 152-mm (6-in.) wide x 133-mm (5.25-in.) high x 3.2-mm (0.125-in.) thick triangle soil plate. A 76-mm (3-in.) diameter washer with a 4.0-mm (0.156-in.) thickness was welded to the steel rod at the top of the attached soil plate. The material in the anchor is ASTM Grade A-513 steel.
- The vertical tubing welded to the top of the washer on the anchor.
- Panel-to-Post Clamp – 41-mm (1.625-in.) wide x 127-mm (5-in.) long, U-shaped with 25-mm (1-in.) long legs and a 3.2-mm (0.125-in.) thickness. The material for the clamp is ASTM A-36 steel. A 6.4-mm (0.25-in.) diameter by 57-mm (2.25-in.) long ASTM A-307 Grade 3 bolt with wing nut was inserted through a hole in the center of the U-shaped clamp and tack welded around the bolt head.

Flexible Sign

- Panel – Fold & Roll style, reflective vinyl, 1,219 mm x 1,219 mm (48 in. x 48 in.)
- Crossbrace, Vertical Member – 6.4-mm (0.25-in.) thick x 32-mm (1.25-in.) wide x 1,676-mm (66-in.) long fiberglass. A 7.9-mm (0.3125-in.) diameter hole was drilled at 210 mm (8.25 in.) from the bottom of the vertical crossbrace.
- Crossbrace, Horizontal Member – 4.8-mm (0.1875-in.) thick x 32-mm (1.25-in.) wide x 1,676-mm (66-in.) long fiberglass.

Height to Bottom of Sign:	457 mm (18 in.)
Height to Center of Clamp:	702 mm (27.625 in.)
Height to Top of Sign Post:	765 mm (30.125 in.)
Height to Top of Sign Panel:	2,181 mm (85.875 in.)

Weights of Sign System:

Sign Post:	2.722 kg (6.0 lbs)
Clamp and Bolt:	0.248 kg (0.5 lbs)
Panel and Crossbraces:	2.892 kg (6.4 lbs)
Total Weight:	5.862 kg (12.9 lbs)

Details of the portable sign support system are shown in Figures 29 and 30. The corresponding English-unit drawings are shown in Appendix A. Photographs of the portable sign support system are shown in Figure 31.

10.2 Test MOSBOG-12

The 1,119-kg (2,467-lb) bogie vehicle impacted the modified sign support system oriented head-on to the vehicle at a speed of 100.7 km/h (62.6 mph) and at an angle of 0 degrees. Sequential photographs are shown in Figure 32. The bogie vehicle experienced a velocity change of approximately 4.2 km/h (2.6 mph).

10.3 System Performance

Damage to the modified system is shown in Figure 33. The system encountered moderate damage. The sign post deformed at the area of bumper impact. The sign panel vinyl was removed from the horizontal and vertical crossbraces. The vertical crossbrace fractured at the top of the sign post and encountered extensive fiberglass splintering at the fracture point. The bottom crossbrace bracket was removed from the sign panel vinyl and remained attached to the bottom of the vertical crossbrace. The soil plate on the sign post was deformed at the top. The sign post was pulled completely out of the ground. Both fiberglass crossbraces contacted the hood region, but no contact nor damage to the windshield area was observed. Furthermore, the system traveled along with the bogie. Subsequently, the bogie vehicle traversed over the deformed system in a stable manner.

10.6 Discussion

Following the compliant bogie test MOSBOG-12, an evaluation was conducted, and the modified work-zone traffic control device performed acceptably in the bogie crash test. The modified system performed as expected, neither the sign panel nor crossbraces contacted the windshield region. If a small car would have been used in place of the bogie vehicle, the system would have deformed around the bumper at the front of the small car. Along with the deformation around the front of the small car, the sign panel and crossbraces would have impacted the hood region of the vehicle. Due to fracturing of the vertical crossbrace, the crossbraces traveled toward the vehicle after contact with the hood. However, it is believed that contact with the windshield never occurred. Therefore, the system's performance was acceptable in the 0 degree orientation.

It should be noted that there was an extra hole drilled in the vertical fiberglass crossbrace near the top of the sign post. It is believed that this caused a stress concentration point and caused the vertical crossbrace to fracture completely. When compared to the results of the developmental bogie test MOSBOG-10 on an identical system, without an extra hole in the crossbrace, the vertical crossbrace did not fracture completely. It is believed that the system's performance would be similar to that of bogie test MOSBOG-10 without the extra hole as it was designed. Thus, the system performed in an acceptable manner with and without a hole drilled in the vertical fiberglass crossbrace slightly above the top of the sign post.

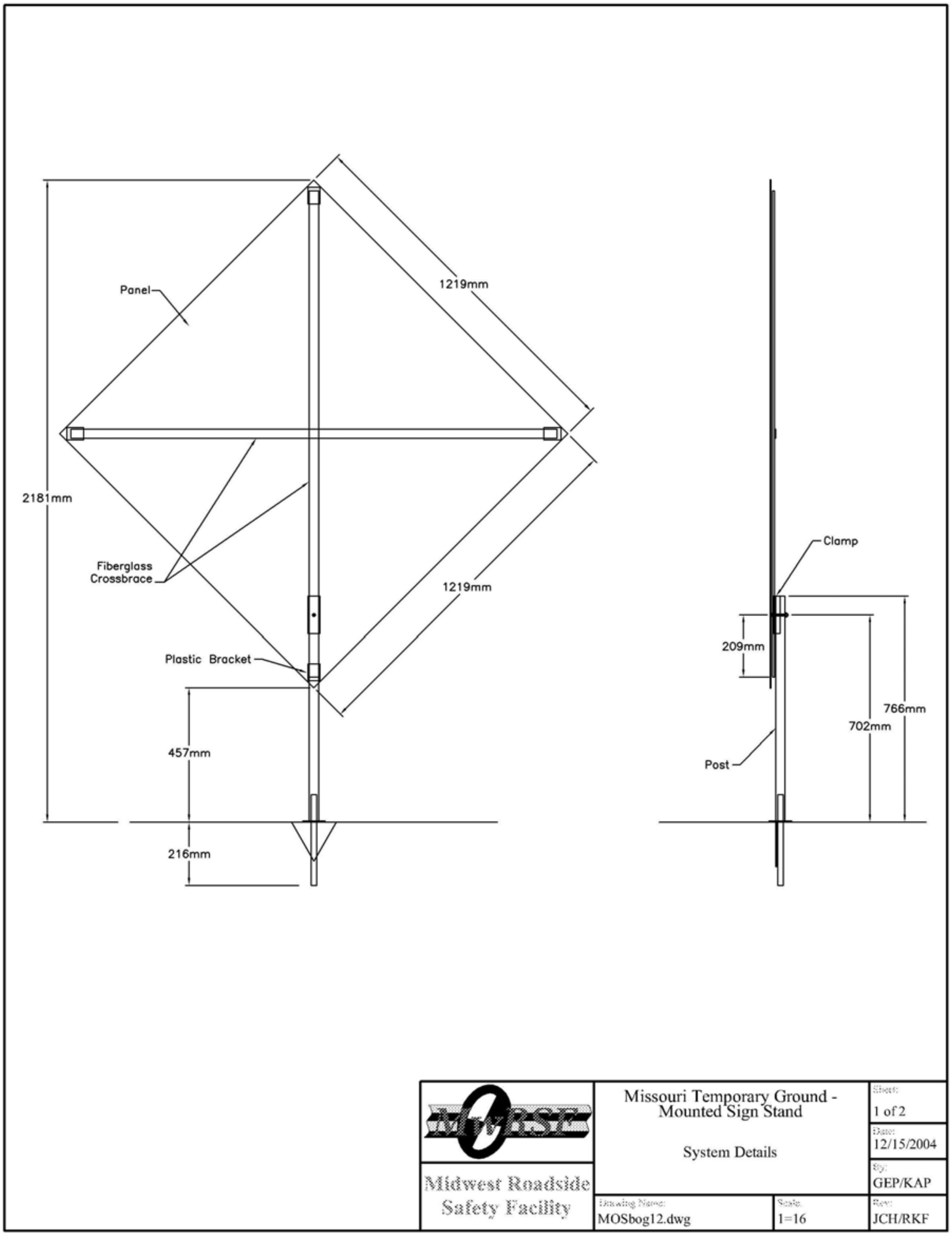

Figure 29. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-12

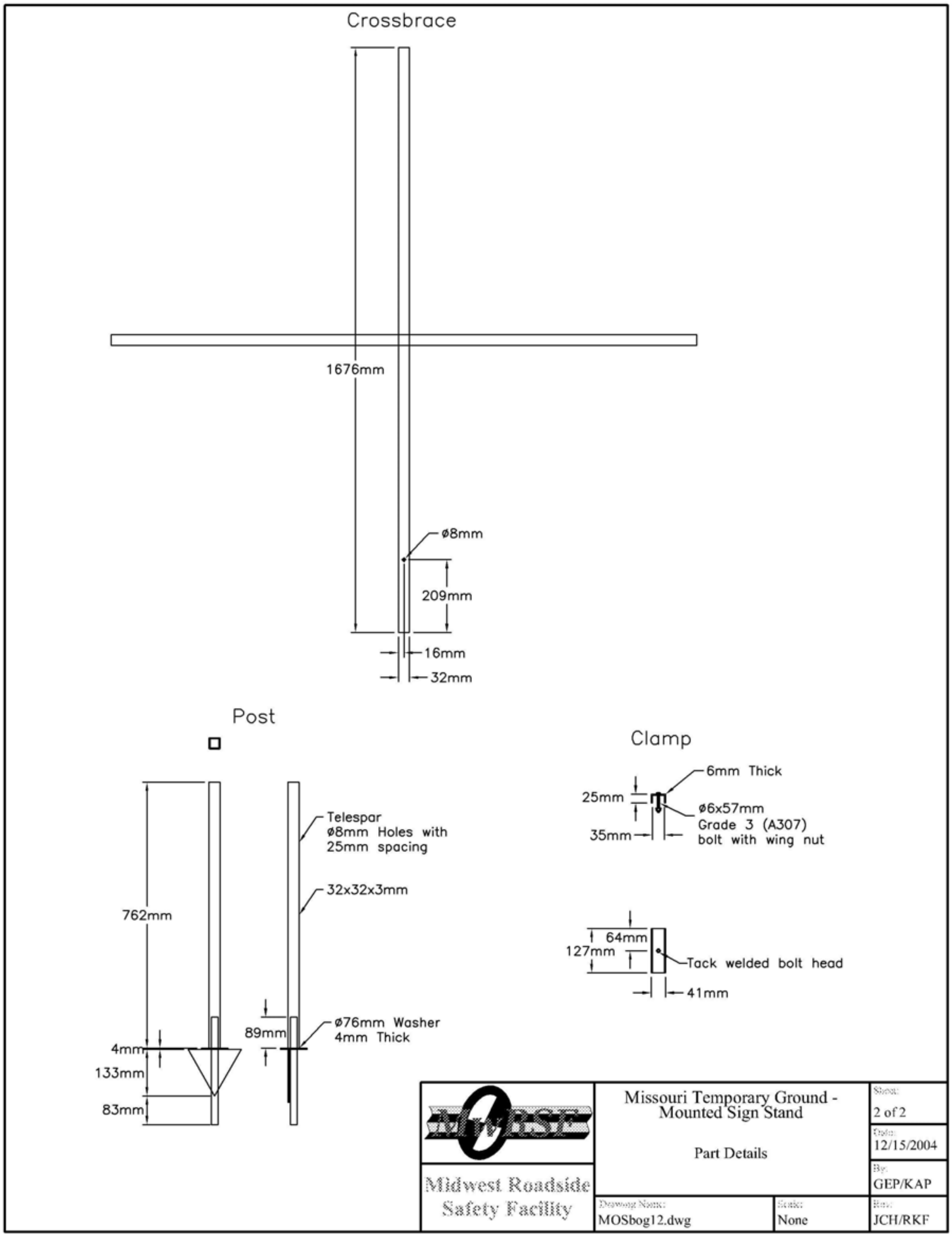

Figure 30. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-12

Figure 31. Ground-Mounted, Single-Post Sign System, Bogie Test MOSBOG-12

0.000 sec | 0.000 sec | 0.017 sec

0.024 sec | 0.024 sec | 0.050 sec

0.042 sec | 0.042 sec | 0.083 sec

0.084 sec | 0.050 sec | 0.117 sec

0.170 sec | 0.080 sec | 0.150 sec

Figure 32. Sequential Photographs, Bogie Test MOSBOG-12 (0 degrees)

Figure 33. System Damage, Bogie Test MOSBOG-12 (0 degrees)

11 SUMMARY AND CONCLUSIONS

A total of one full-scale crash test and three bogie vehicle tests were conducted on the portable sign supports. The full-scale crash test on the work-zone traffic control device failed to satisfactorily meet the TL-3 evaluation criteria set forth in NCHRP Report No. 350. The developmental bogie vehicle test on the modified sign support system exhibited satisfactory system performance. The two compliant bogie vehicle tests on the modified sign support system satisfactorily met the TL-3 evaluation criteria set forth in NCHRP Report No. 350. A summary of the safety performance evaluation of each system is provided in Table 4.

For portable sign supports, the performance of these sign supports is based on the behavior of many sign features, such as the vertical distribution of the system's mass, stiffness and strength of the mast and stand, crossbrace member sizes and strength, and sign material. Consequently, slight differences in system design details can potentially lead to very different results.

Table 4. Summary of Safety Performance Evaluation Results

Evaluation Factors	Evaluation Criteria	Full-Scale Test	R&D Bogie Test	Compliant Bogie Test	
		M-3	MOSBOG-10	MOSBOG-11	MOSBOG-12
		PS[1]	PS[1]	PS[1]	PS[1]
		0 degrees	0 degrees	90 degrees	0 degrees
Structural Adequacy	B	S	S	S	S
Occupant Risk	D	U	S	S	S
	E	U	S	S	S
	F	S	S	S	S
	H	NA	NA	NA	NA
	I	NA	NA	NA	NA
Vehicle Trajectory	K	S	S	S	S
	N	S	S	S	S
NCHRP Test Level		TL-3	TL-3	TL-3	TL-3
Method of Failure[2]		1,2,3	NA	NA	NA
Pass/Fail		Fail	Pass	Pass	Pass

[1] Hardware Type: PS – Portable Sign

[2] Method of Failure:
1 - Severe windshield cracking and fracture
2 - Windshield indentation
3 - Obstruction of driver visibility
4 - Windshield penetration
5 - Occupant compartment penetration other than windshield penetration
6 - Roof deformations greater than 127 mm (5 in.)

S - Satisfactory
M - Marginal
U - Unsatisfactory
NA - Not Available

12 RECOMMENDATIONS

One work-zone traffic control device satisfactorily met the evaluation criteria set forth in NCHRP Report No. 350 and is recommended for field implementations. This work-zone traffic control device includes:

- Compliant Bogie Test Nos. MOSBOG-11 and MOSBOG-12 – A modified ground-mounted, single-post, sign support stand with a vinyl flexible sign panel and a panel-to-post connection clamp oriented end-on and head-on, respectively.

One work-zone traffic control device performed unsatisfactorily according to the test evaluation criteria set forth in NCHRP Report No. 350 in the direction the system was oriented and is not recommended for field applications. This work-zone traffic control device includes:

- Test No. M-3, System No. 3 – Ground-mounted, single-post, sign support SH-96-2 stand with a vinyl flexible sign panel and a panel-to-post connection bracket oriented head-on.

For work-zone traffic control devices, such as those presented herein, similar devices may be capable of meeting the performance requirements from NCHRP Report No. 350. However, it is noted that slight differences in design details can potentially lead to very different results. Therefore, it is suggested that the impact performance of ground-mounted, single-post sign supports can only be verified through the use of full-scale vehicle or compliant bogie crash testing.

13 REFERENCES

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3. Mak, K. K. and Zimmer, R. A., *Evaluation of Plastic Drum Specification*, Research Report No. 2924-2F, Texas Transportation Institution, Texas A&M University, College Station, Texas, September 1995.

4. Mak, K. K., Bligh, R. P., and Menges, W. L., *Evaluation of Sign Substrates for Use with Plastic Drums*, Research Report No. 2924-3F, Texas Transportation Institute, Texas A&M University, College Station, Texas, December 1996.

5. Mak, K. K., Bligh, R. P., and Menges, W. L., *Evaluation of Work Zone Barricades and Temporary Sign Supports*, Research Report No. 5388-1F, Texas Transportation Institute, Texas A&M University, College Station, Texas, February 1996.

6. Bligh, R. P., Mak, K. K., and Rhodes, Jr., L. R., *Crash Testing and Evaluation of Work Zone Barricades*, Texas Transportation Institute, Texas A&M University, Paper No. 980625, 77th Annual Meeting of the Transportation Research Board, Washington, D.C., January 1998.

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14 APPENDICES

APPENDIX A

English-Unit System Drawings

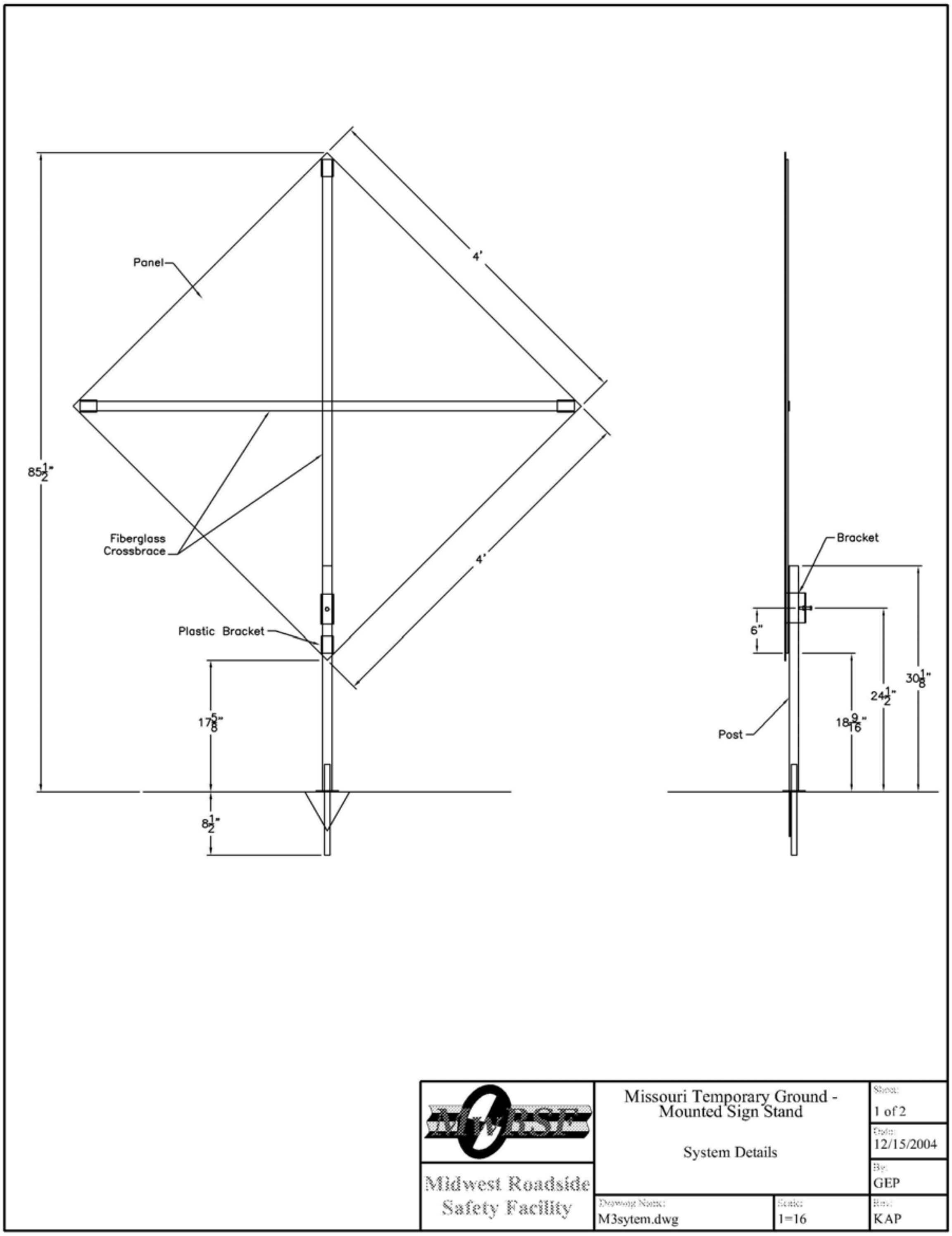


Figure A-1. System No. 3 Sign Support Details, Test M-3 (English)

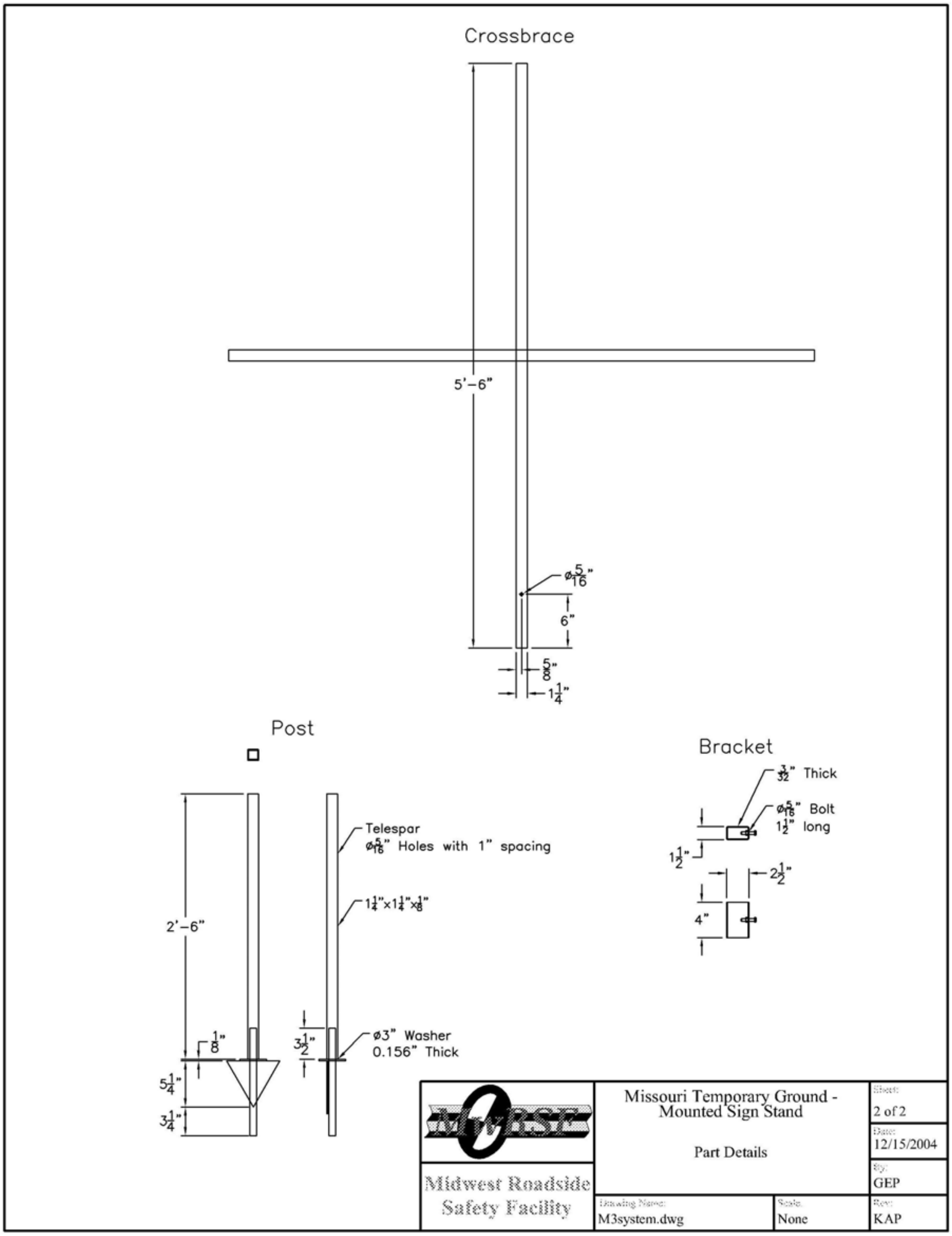


Figure A-2. System No. 3 Sign Support Details, Test M-3 (English)

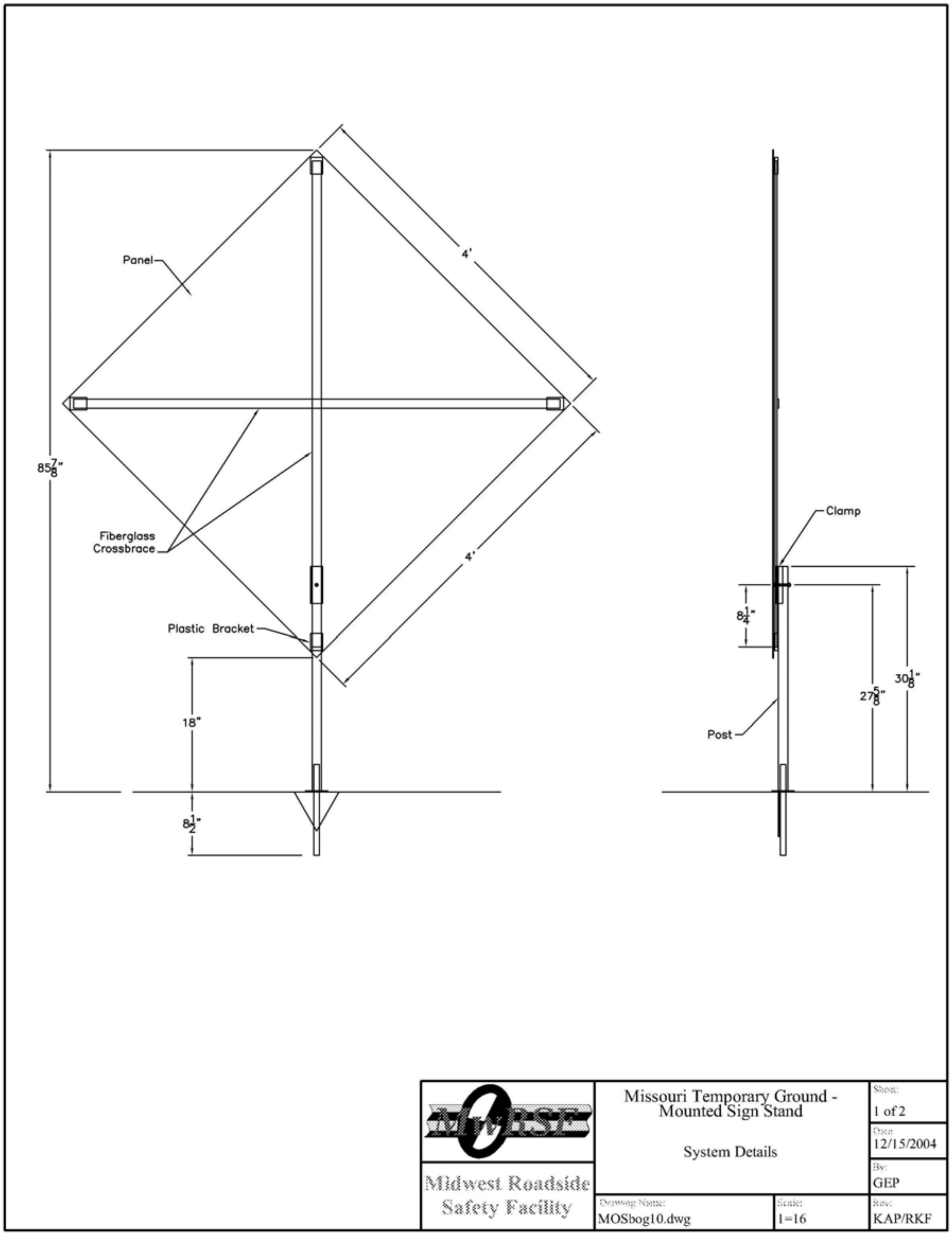


Figure A-3. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-10 (English)

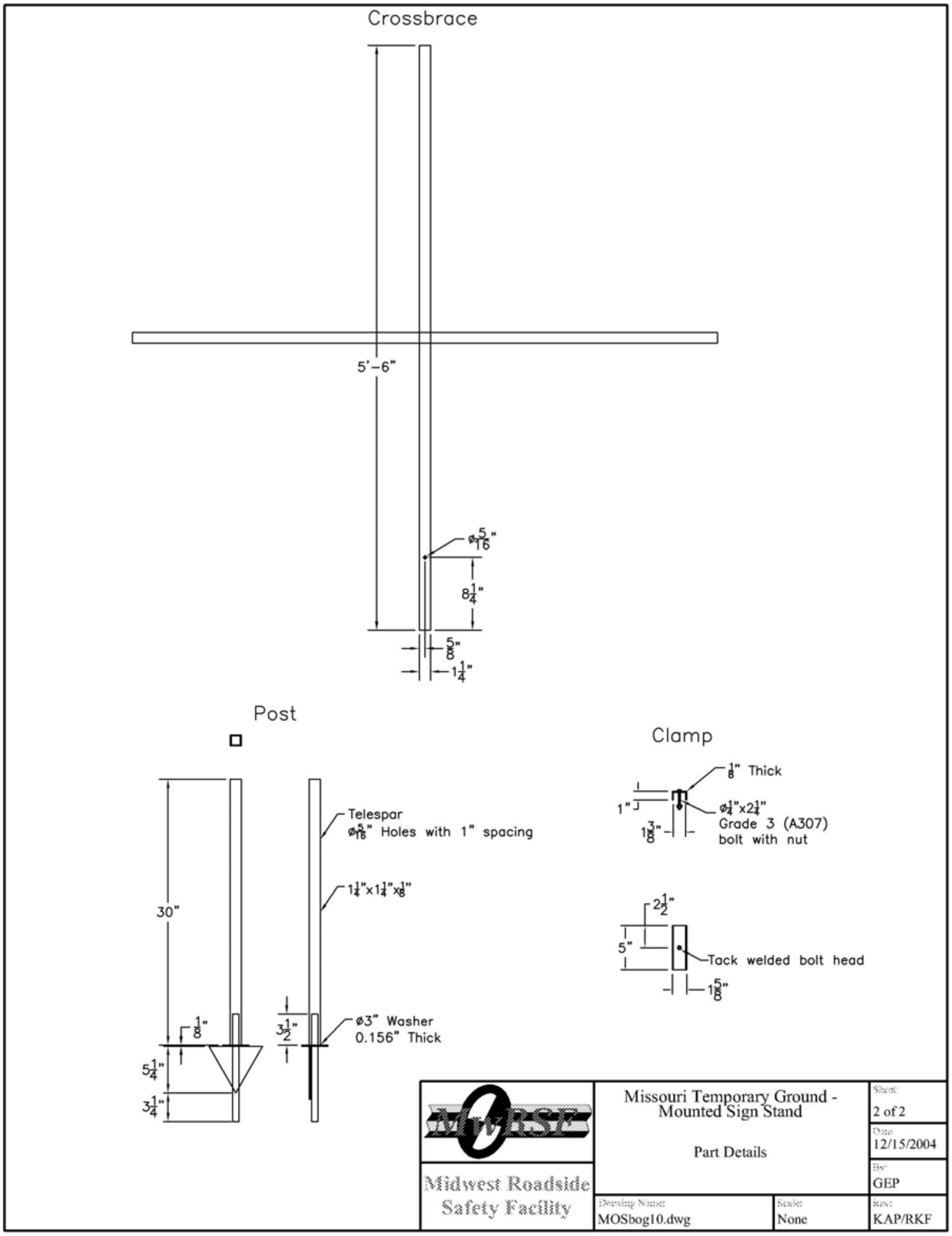


Figure A-4. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-10 (English)

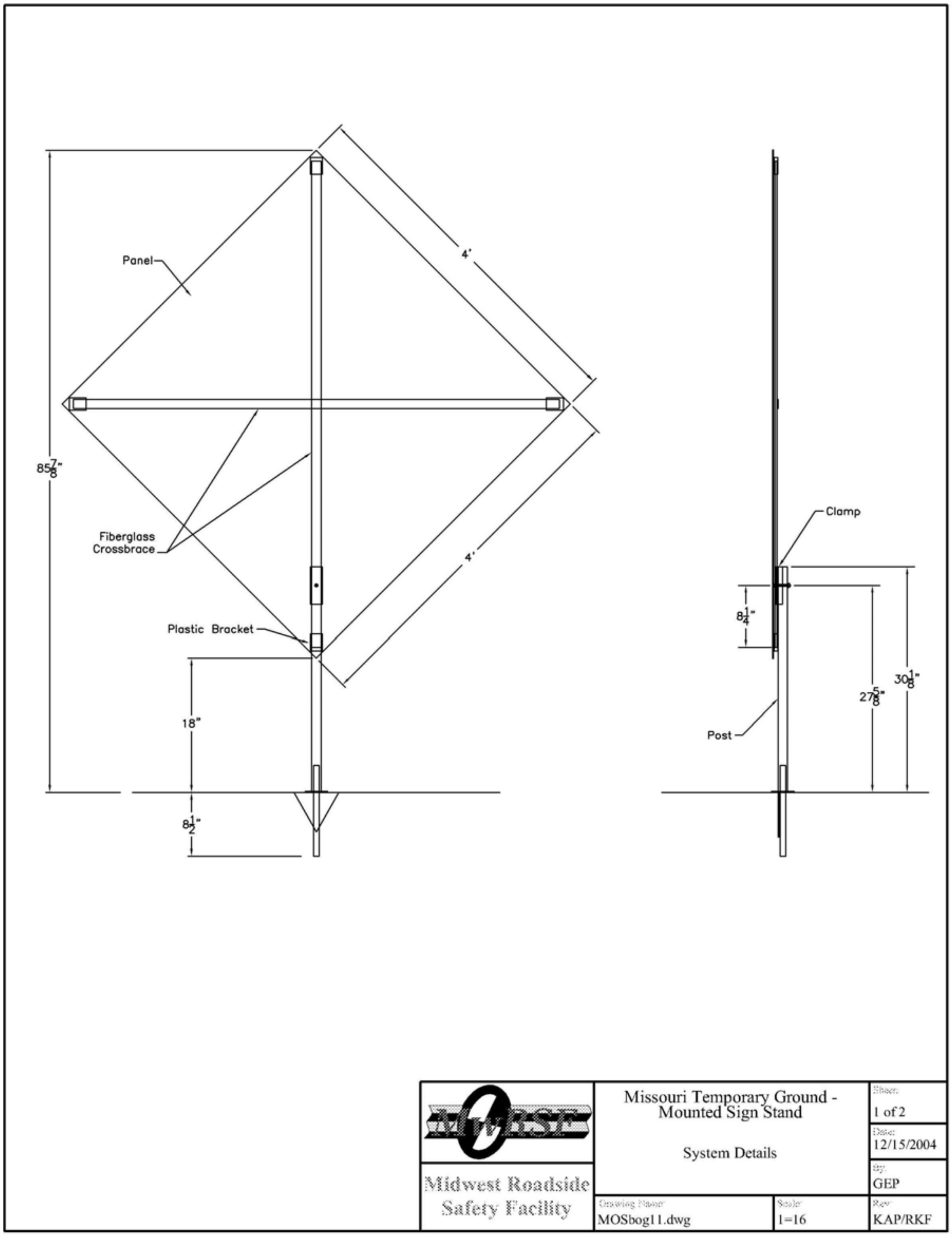


Figure A-5. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-11 (English)

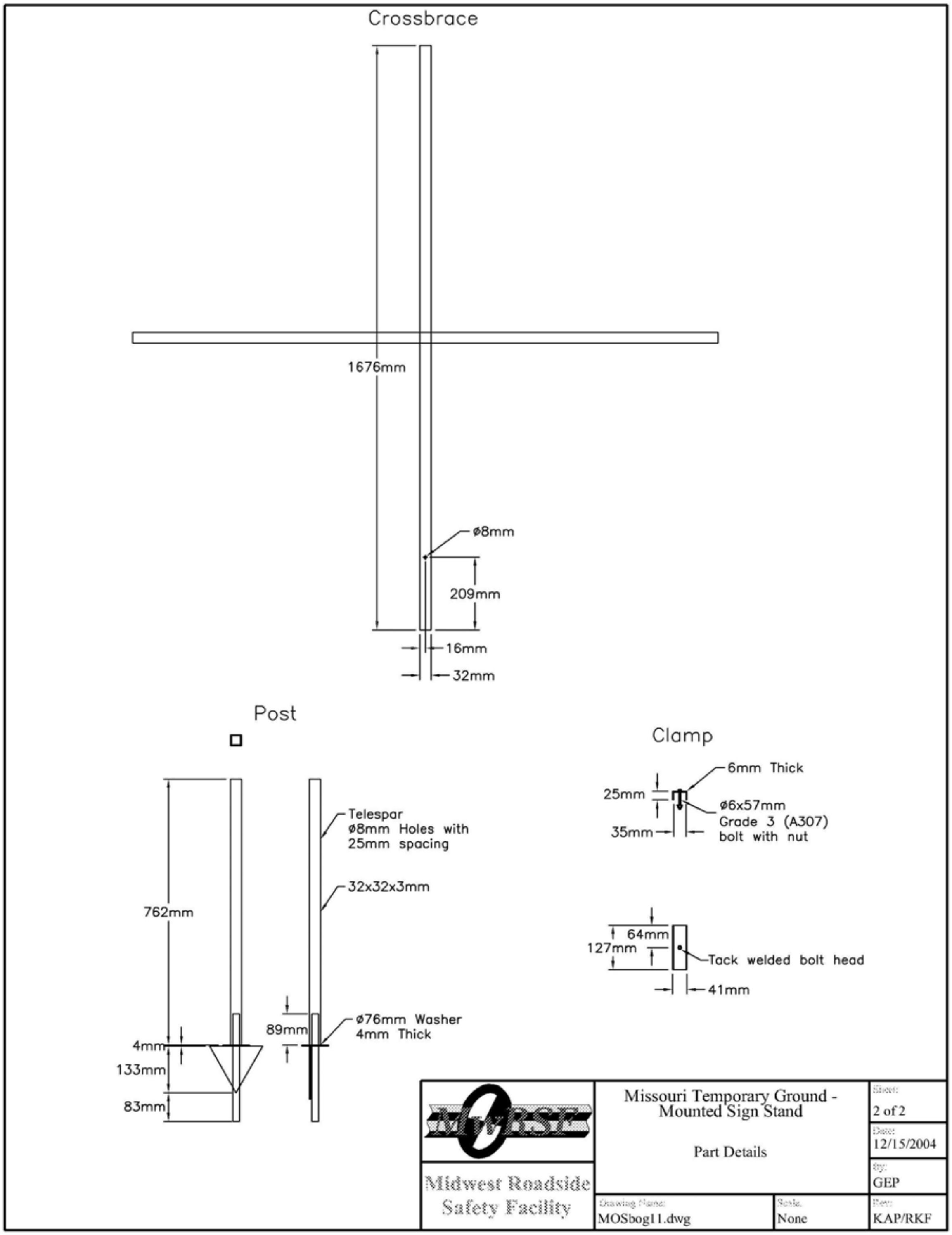


Figure A-6. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-11 (English)

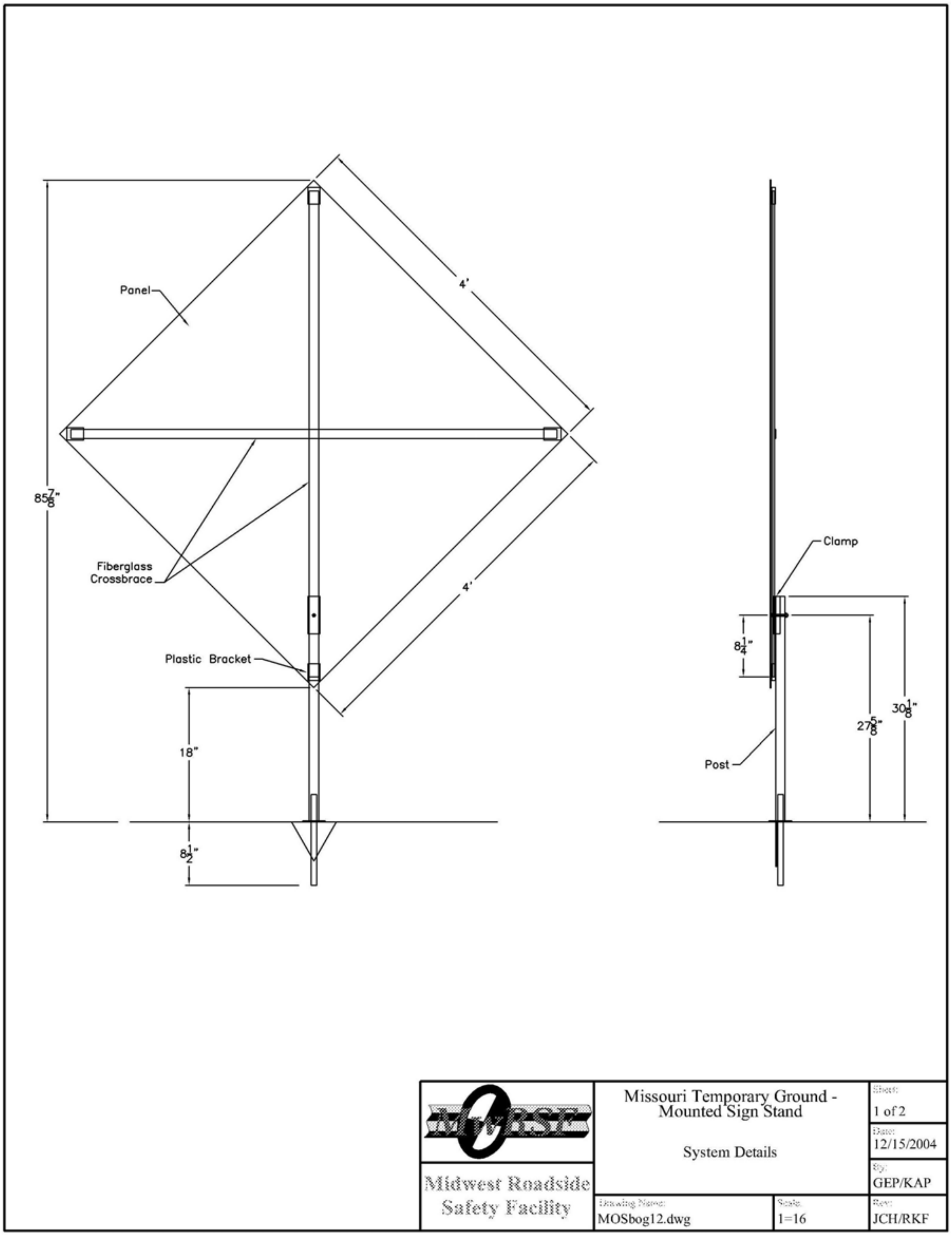


Figure A-7. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-12 (English)

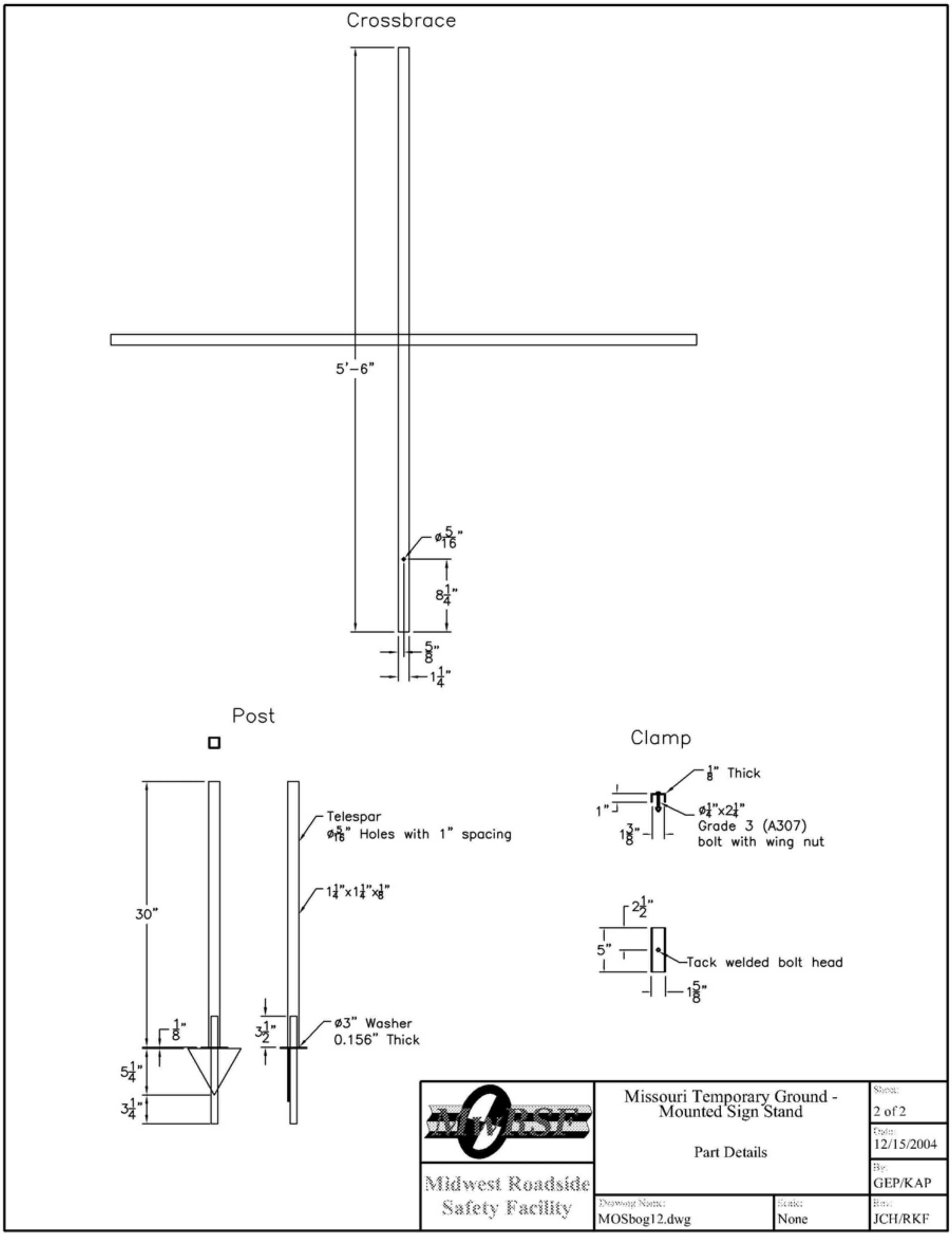


Figure A-8. Ground-Mounted, Single-Post Sign System Design Details, Bogie Test MOSBOG-12 (English)

APPENDIX B

Dimensional Measurements of Portable Sign Support System, Test M-3

Table B-1. Portable Sign Support System Dimensional Measurements, Test M-3

System Number	Test Number	STAND			SIGN			
		Type [1]	Weight		Type [2]	Material [3]	Weight	
			(kg)	(lbs)			(kg)	(lbs)
3	M-3	Ground-Mounted with Bracket	3.260	7.2	Flexible	1	2.874	6.3

[1] When more than one stand type is listed, they are different reference names for the same stand.
[2] When more than one sign type is listed, they are different reference names for the same sign.
[3] Description of material types: 1 - (Reflexite Superbright)
2 - (3M RS34)
3 - (3M Diamond Grade RS24)
4 - (Non-reflective Mesh)
5 - (Reflexite Non-reflective)
6 - (Aluminum)

Table B-2. Portable Sign Support System Dimensional Measurements, Test M-3

System Number	HEIGHTS TO					
	Bottom of Sign Panel		Top of Sign Post		Top of Sign Panel	
	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)
3	447	17.625	766	30.125	2172	85.5

Table B-3. Portable Sign Support System Dimensional Measurements, Test M-3

Stand Type	VERTICAL TUBING								
	Material	Dimension #1		Dimension #2		Length		Thickness	
		(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)
Ground-Mounted	Galvanized Telespar Steel Tubing	32	1.25	32	1.25	762	30	3.2	0.125

Table B-4. Portable Sign Support System Dimensional Measurements, Test M-3

Stand Type	ANCHOR								
	ROD					WASHER			
	Material	Diameter		Length		Diameter		Thickness	
		(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)
Ground-Mounted	ASTM Steel Grade A513	19	0.75	305	12	76	3	4	0.156

Table B-5. Portable Sign Support System Dimensional Measurements, Test M-3

Stand Type	ANCHOR												
	TRIANGLE SOIL PLATE							DISTANCES					
	Material	Diameter		Length		Thickness		Anchor end to bottom of soil plate		Anchor end to top of soil plate		Anchor end to top of sign post	
		(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)
Ground-Mounted	ASTM Steel Grade A513	152	6	133	5.25	3.2	0.125	83	3.25	216	8.5	982	38.625

Table B-6. Portable Sign Support System Dimensional Measurements, Test M-3

Stand Type	PANEL-TO-POST BRACKET									BOLT			
	Material	Width		Depth		Height		Thickness		Diameter		Length	
		(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)
Ground-Mounted	ASTM A-36 Steel	38	1.5	64	2.5	102	4	2.4	0.094	7.9	0.313	38	1.5

Table B-7. Portable Sign Support System Dimensional Measurements, Test M-3

Sign Type	CROSSBRACE – VERTICAL MEMBER							BOLT HOLE			
	Material	Thickness		Width		Length		Diameter		Distance from Bottom of Vertical Crossbrace	
		(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)
Flexible	Fiberglass	6.4	0.25	32	1.25	1676	66	7.9	0.3125	152	6

Table B-8. Portable Sign Support System Dimensional Measurements, Test M-3

Sign Type	CROSSBRACE – HORIZONTAL MEMBER						
	Material	Thickness		Width		Length	
		(mm)	(in.)	(mm)	(in.)	(mm)	(in.)
Flexible	Fiberglass	4.8	0.1875	32	1.25	1676	66

Table B-9. Portable Sign Support System Dimensional Measurements, Test M-3

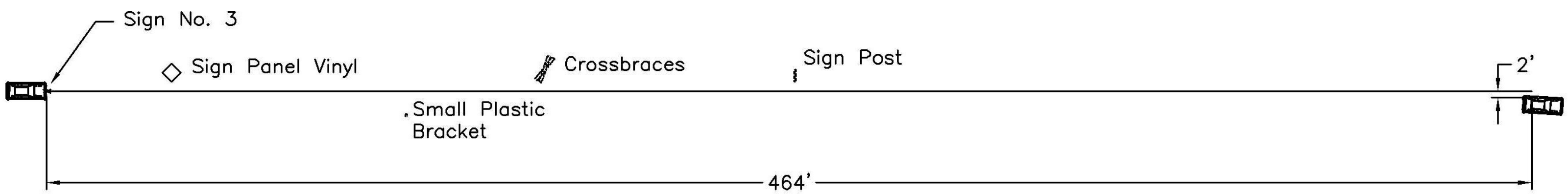
Sign Type	SIGN PANEL								
	Material	Thickness				Length		Width	
		Across Seam		At Seam					
		(mm)	(in.)	(mm)	(in.)	(mm)	(in.)	(mm)	(in.)
Flexible	Reflective Vinyl	0.85	0.03	0.65	0.03	1219	48	1219	48

APPENDIX C

Test Summary Sheet in English Units, Test M-3

Figure C-1. Summary of Test Results and Sequential Photographs (English), Test M-3

0.000 sec | 0.036 sec | 0.098 sec | 0.158 sec | 0206 sec



- Test Number M-3
- System Number 3
- Date 11/11/03
- Test Article
  - Type . . . . Traffic Control Device – Ground-Mounted, Single-Post, Sign Support System
  - Stand Name . . . . Modified SH-96-2
  - Sign Panel Name . . . . Flexible Panel
  - Key Elements
    - Size and/or dimension . 85.5 in. high after installation
    - Material . . . . ASTM Steel Grade A36 Telespar Tubing
  - Orientation . . . . Head-on with centerline point
- Soil Type . . . . Grading B - AASHTO M 147-65 (1990)
- Vehicle Model . . . . 1996 Geo Metro
  - Curb . . . . 1,745 lbs
  - Test Inertial . . . . 1,797 lbs
  - Gross Static . . . . 1,963 lbs
- Vehicle Speed
  - Impact . . . . 62.0 mph
  - Exit . . . . NA
- Vehicle Angle
  - Impact . . . . 0 deg
  - Exit . . . . 0 deg
- Vehicle Stability . . . . Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal . . . . NA
  - Lateral (not required) . . . . NA
- Occupant Impact Velocity (Normalized)
  - Longitudinal . . . . NA
  - Lateral (not required) . . . . NA
- Vehicle Damage . . . . Severe windshield cracking, and indentation
  - TAD[30] 12-FC-1
  - SAE[31] 12-FCAW6
- Vehicle Stopping Distance . . . . 464 ft downstream, 2 ft right
- Test Article Damage . . . . Moderate – Broke apart

Figure C-1. Summary of Test Results and Sequential Photographs (English), Test M-3