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PERFORMANCE EVALUATION OF TYPE II AND TYPE IIA BOX BEAM END TERMINALS – VOLUME I: RESEARCH RESULTS AND DISCUSSION

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16. Abstract (Limit: 200 words)

Two types of guide rail end terminals were constructed and evaluated according to the American Association of State Highway Transportation Officials' (AASHTO's)*Manual for Assessing Safety Hardware* (MASH). The guide rail end terminals are used with weak-post, box beam guide rail systems by the New York State Department of Transportation (NYSDOT).

Nine full-scale vehicle crash tests were performed in accordance with either Test Level 3 (TL-3) or Test Level 2 (TL-2) requirements using both standard and modified impact locations and test conditions for the 1100C [1,100-kg (2,425-lb)] passenger car and the 2270P [2,268-kg (5,000-lb)] pickup truck. One test was run on the Type II box beam end terminal, six tests were performed on the Type IIA end terminal on flat ground, and two tests were performed on the Type IIA end terminal installed in a ditch. The Volume I report contains the research results and discussion. The Volume II report contains the appendices.

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UNCERTAINTY OF MEASUREMENT STATEMENT

The Midwest Roadside Safety Facility (MwRSF) has determined the uncertainty of measurements for several parameters involved in standard full-scale crash testing and non-standard testing of roadside safety features. Information regarding the uncertainty of measurements for critical parameters is available upon request by the sponsor and the Federal Highway Administration.

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1 INTRODUCTION

1.1 Background

In the 1960s through 1970s, several research studies were conducted and/or devoted to the research and development of box beam guide rail and median barrier systems [1-5]. From the research performed by the New York State Department of Transportation (NYSDOT), the standard roadside box beam guide rail system used in New York was configured with a 152-mm x 152-mm x 4.8-mm (6-in. x 6-in. x 3/16-in.) structural steel tube rail supported by S76x8.5 (S3x5.7) steel I-beam posts and with the top of the box beam positioned 685 mm (27 in.) above the soil grade.

For these box beam guide rail systems, standard and special end treatments were designed (1) to prevent vehicles from exiting the roadway in advance of the point of need of the barrier and striking the hazard, (2) to prevent spearing of vehicles at the ends of the rail, and (3) to allow the rail to develop its full strength downstream of the ends. Standard end treatments were typically long and flared, thus minimizing the probability of an end-on impact. Special end treatments were configured for situations where long, flared rail ends could not be used, such as near driveways or intersections. For these situations, special end treatments were designed to develop the full rail capacity over a shorter length and tapered to the ground at a greater slope than standard ends, while retaining many of the safety advantages of standard end treatments.

In the 1970s, NYSDOT researchers conducted three full-scale vehicle crash tests on special box beam end treatments for box beam guide rail and median barrier systems using sedans and a compact wagon and oriented end-on to the barrier ends [5]. For these tests, the results demonstrated that vehicles would ride up the ramped ends, become airborne, and cause severe front-end vehicle damage but prevent vehicle spearing. The sloped rail ends also were found to not drop when impacted. In addition, rail ends positioned too far above grade resulted in increased vehicle snag on sloped rail ends. Lowering the box beam rail end to be flush with the ground was found to eliminate the vehicle snag hazard.

In the 1980s, NYSDOT personnel continued to perform the research and development on several box beam end terminals used under restricted conditions [6]. A total of seventeen full-scale vehicle crash tests and safety performance evaluations were conducted according to the criteria published in the National Cooperative Highway Research Program (NCHRP) Report No. 230, *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances* [7].

1.2 Problem Statement

The Type II (driveway opening) box beam end terminal was intended to be a turned-down terminal that would minimize the potential for ramping vehicles and the resulting rollover-type accidents. Since this terminal is used exclusively by the State of New York, the terminal system was not included in the nationally-sponsored crash testing programs that more common terminals were given when NCHRP Report No. 350 went into effect [8]. As such, the NYSDOT and the Federal Highway Administration (FHWA) have been concerned that the system may not pass the relevant safety performance criteria when subjected to impact testing. The outcome of the crash testing to the current criteria could have significant repercussions since the terminal is presently in place in many locations throughout the New York State. As a result of the failures and marginal passes observed in prior crash testing performed in the 1970s and 1980s [5-6], it is unlikely that any modification to the sloped end of the Type II terminal will eliminate the ramping problem, if such is identified, in the current testing program. Consequently, in the event the existing terminal did not pass at Test Level 3 (TL-3), a tightly-curved, Type I (now referred to as Type IIA) end terminal design was to be tested as the alternative.

1.3 Research Objectives

The objectives of this research were to evaluate the safety performance of the NYSDOT box beam Type II end terminal through full-scale vehicle crash testing. If the Type II end terminal was not found to meet current impact safety standards, then researchers were to perform safety performance evaluations on the tightly-curved Type I (now referred to as Type IIA) end terminal design with the hope that the Type IIA end terminal would meet the TL-3 safety guidelines. Once an end terminal system was deemed acceptable according to the full-scale crash testing criteria, the system was to be tested adjacent to a ditch as found in real-world situations. The safety performance evaluations were conducted according to the TL-3 and TL-2 criteria provided in the *Manual for Assessing Safety Hardware* (MASH) [9].

1.4 Scope

The research objective was achieved through the completion of several tasks. First, a literature review on previous crash testing of relevant box beam guide rails, box beam median barriers, and box beam end terminals was undertaken. Emphasis was placed on R&D efforts involving Type II and Type IIA end terminals. Next, a series of nine full-scale vehicle crash tests were performed on the two types of box beam end terminal systems. The tests were conducted according to MASH criteria with either a passenger car, weighing approximately 1,100 kg (2,425 lb) or a pickup truck, weighing approximately 2,268 kg (5,000 lb). The target impact conditions varied according to the test designation criteria specified in MASH. The test results were analyzed, evaluated, and documented. Finally, conclusions and recommendations were made that pertain to the safety performance of the Type II and Type IIA box beam end terminal systems relative to the tests performed. The research results and discussion are presented in the Volume I report, and the appendices are presented in the Volume II report.

2 LITERATURE REVIEW

2.1 Introduction

In the 1980s, the Engineering Research and Development Bureau of the NYSDOT conducted seventeen full-scale crash tests to evaluate the performance of NYSDOT's box beam guide rail terminals [6]. Ten out of the seventeen tests were performed on versions of the Type II end terminal, which were referred to in the 1988 report [6] as the Type I, II, III, and IV end terminals. In addition, seven tests were performed on the Type I end terminal, which was referred to in the 1988 report as the Type V end terminal. All tests were conducted and reported in accordance with the safety performance criteria presented in NCHRP Report No. 230 [7].

2.2 Type II

Test 79 evaluated the strength of the Type I (1988) terminal. A 2,018-kg (4,450-lb) Ford station wagon impacted the barrier 7.6 m (25 ft) downstream from the end at a speed of 100 km/h (62 mph) and at an angle of 25 degrees. The vehicle was safely redirected and was determined to be successful according to the criteria presented in NCHRP Report No. 230.

Test 80 evaluated the strength of the Type II (1988) end terminal. A 2,041-kg (4,500-lb) Chrysler sedan impacted the system 6.5 m (21.2 ft) downstream from the end at 93.5 km/h (58.1 mph) and 23 degrees. The vehicle was safely redirected and was determined to be successful according to the criteria presented in NCHRP Report No. 230. During the test, the barrier experienced 1.4 m (4.5 ft) of dynamic deflection. The Type II (1988) terminal developed the standard 1.5 m (5 ft) deflection for impacts within 6.1 m (20 ft) from the end of the rail.

Test 81 evaluated the terminal release for departing impacts by a small sedan on the Type I (1988) terminal. A 794-kg (1,750-lb) Honda impacted the system 2.7 m (9 ft) from the departure end at 92.7 km/h (57.6 mph) and 15 degrees. Upon impact, the rail lifted, shearing the bolt used to secure the rail to the anchor posts, allowing the vehicle to pass under the end. This test confirmed that the Type I (1988) terminal rail released from the anchor posts without snagging the vehicle and was determined to be successful according to the criteria presented in NCHRP Report No. 230.

Test 82 evaluated the terminal release for the Type II (1988) terminal. A 735-kg (1,620-lb) Honda impacted the terminal 3.0 m (10 ft) downstream from the end at 98.3 km/h (61.1 mph) and 16 degrees. Upon impact, the rail lifted with the shearing of the anchor attachment bolt, thus allowing the vehicle to pass under the end. This test confirmed that the Type II (1988) terminal rail released from the anchor posts without snagging the vehicle, and thus it was determined to be successful according to the criteria presented in NCHRP Report No. 230.

Test 83 evaluated the Type II (1988) terminal for ramping during an end-on impact. An 862-kg (1,900-lb) Subaru sedan impacted the barrier end at 99.5 km/h (61.8 mph) and 17 degrees. On impact, the vehicle rode up the turned-down end, became airborne, and rolled. The turned-down barrier end withstood the impact without separation of the weld, but the rail did not drop down, thus providing a ramp to launch the vehicle. Thus, this test was unacceptable according to the NCHRP Report No. 230 criteria.

Although the Types I (1988) and II (1988) end terminals performed well in terms of developing rail strength and preventing snagging on departure impacts, modifications were needed to eliminate the severe ramping. Thus, the Type III (1988) end terminal was developed with a triangular notch cut in the underside of the beam to reduce the vertical strength, and a splice plate was bolted to the inside of the box beam as a stiffener to provide lateral support. Meanwhile, the terminal height was also lowered with the intent of reducing the potential for ramping.

Test 84 evaluated the Type III (1988) terminal for ramping during an end-on impact. A 748-kg (1,650-lb) Honda sedan impacted the ramped section of the terminal at a speed of 98.2 km/h (61.0 mph) and at an angle of 17 degrees. The vehicle pitched upward, became airborne, yawed to the left, and rolled laterally 4.5 times after impact. Occupant risk factors exceeded NCHRP Report No. 230 recommended values. In addition, this test was considered a failure because of the severe rollover.

The Type IV (1988) end terminal was developed based on the Type III (1988) end terminal for low-speed impact. The modifications included: (1) the box-beam hinge was not tack-welded; (2) post no. 1 was removed; (3) the support angle was removed from post no. 2; and (4) a 6.4-mm (1/4-in.) bolt was substituted for the 15.9-mm (5/8-in.) bolt used to attach the support angle to post no. 3.

Test 85 evaluated the Type IV (1988) end terminal for ramping during an end-on impact. An 816-kg (1,800-lb) Honda sedan impacted the Type IV (1988) end terminal at a speed of 83.0 km/h (51.6 mph) and at an angle of 0 degrees, with impact occurring just inside the right-front wheel. The vehicle ramped up the terminal, became partially airborne, and exited on the right side of the barrier with slight roll. This test indicated that the Type IV (1988) end terminal would perform adequately up to 80.5 km/h (50.0 mph) for similar impact conditions.

Test 86 evaluated the Type IV (1988) end terminal at a higher speed. An 816-kg (1,800-lb) Honda sedan impacted the end of the Type IV (1988) end terminal at a speed of 98.0 km/h (60.9 mph) and at an angle of 17 degrees, with impact centered on the front of the car. Upon impact, the vehicle ramped up the terminal, yawed slightly to the left, and rolled over laterally several times. The test was deemed a failure due to the severe damage of the vehicle.

Test 87 evaluated the Type IV (1988) end terminal's angled impact at low speed. An 816-kg (1,800-lb) Honda sedan impacted the end of the Type IV (1988) end terminal at a speed of 67.3 km/h (41.8 mph) and at an angle of 18 degrees. The vehicle rode up and exited behind the barrier. Occupant risk factors were very mild, and the vehicle proceeded behind the barrier at an exit speed of 62.8 km/h (39.0 mph) and at an angle of 6 degrees to the back side of the barrier. The vehicle suffered only superficial damage.

Test 94 evaluated the Type IV (1988) end terminal's performance with large vehicles. A 2,168-kg (4,780-lb) Chevrolet station wagon impacted the Type IV (1988) end terminal 6.7 m (22 ft) downstream from the end at a speed of 68.9 km/h (42.8 mph) and at an angle of 25 degrees. The vehicle was redirected smoothly, and the test was determined to be acceptable.

Tests 85 and 87 showed that the Type IV (1988) end terminal appeared to perform acceptably for end-on impacts at speeds up to 72.4 km/h (45.0 mph). However, for 96.6-km/h (60-mph) impacts, the Type IV (1988) did not eliminate vehicle vaulting and rollover.

A Type V (1988) end terminal was developed in an attempt to accommodate higher-speed impacts. Test 88 evaluated the Type V (1988) end terminal at higher speeds. An 816-kg (1,800-lb) Honda sedan impacted the center of the 45-degree turned-down end at a speed of 98.7 km/h (61.3 mph) and at an angle of 0 degrees, with impact occurring just inside the right-front wheel. The vehicle immediately vaulted up the end ramp, became airborne, and yawed 90 degrees to the left. The vehicle landed on its right side and rolled laterally. The test was deemed a failure because of high occupant risk values and severe rollover. However, this test confirmed that the terminal and rail splice has adequate strength in order to prevent rail fracture and rail penetration into the vehicle.

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

Historically, guide rail end terminal systems have been required to satisfy impact safety standards in order to be accepted by FHWA for use on National Highway System (NHS) construction projects or as a replacement for existing designs not meeting current safety standards. According to TL-3 of MASH, gating end terminals must be subjected to nine full-scale vehicle crash tests. The nine full-scale crash tests are as follows:

1. Test Designation 3-30 consisting of an 1,100-kg (2,425-lb) passenger car impacting at a nominal speed and angle of 100 km/h (62 mph) and 0 degrees, respectively, on the nose of the end terminal with a ¼-point offset.

2. Test Designation 3-31 consisting of a 2,268-kg (5,000-lb) pickup truck impacting at a nominal speed and angle of 100 km/h (62 mph) and 0 degrees, respectively, on the nose of the end terminal.

3. Test Designation 3-32 consisting of an 1,100-kg (2,425-lb) passenger car impacting at a nominal speed and angle of 100 km/h (62 mph) and 5 to 15 degrees, respectively, on the nose of the end terminal.

4. Test Designation 3-33 consisting of a 2,268-kg (5,000-lb) pickup truck impacting at a nominal speed and angle of 100 km/h (62 mph) and 5 to 15 degrees, respectively, on the nose of the end terminal.

5. Test Designation 3-34 consisting of an 1,100-kg (2,425-lb) passenger car impacting at a nominal speed and angle of 100 km/h (62 mph) and 15 degrees, respectively, and at the Critical Impact Point (CIP) on the end terminal.

6. Test Designation 3-35 consisting of a 2,268-kg (5,000-lb) pickup truck impacting at a nominal speed and angle of 100 km/h (62 mph) and 25 degrees, respectively, and at the beginning of the Length-of-Need (LON) on the end terminal.

7. Test Designation 3-36 consisting of a 2,268-kg (5,000-lb) pickup truck impacting at a nominal speed and angle of 100 km/h (62 mph) and 25 degrees, respectively, and at the CIP with respect to the transition to the backup structure.

8. Test Designation 3-37 consisting of a 2,268-kg (5,000-lb) pickup truck impacting at a nominal speed and angle of 100 km/h (62 mph) and 25 degrees, respectively, and at the CIP for reverse direction impacts on the end terminal.

9. Test Designation 3-38 consisting of a 1,500-kg (3,307-lb) intermediate car impacting at a nominal speed and angle of 100 km/h (62 mph) and 0 degrees, respectively, on the nose of the end terminal, if it is demonstrated to be necessary following an analysis of selected test results.

The test conditions for TL-3 guide rail end terminals are summarized in Table 1. It should be noted that the only difference between the test conditions for TL-2 guide rail end terminals and the TL-3 test conditions is the target impact speed. For the TL-2 and TL-3 tests, the target impact speed is 70 km/h and 100 km/h (44 mph and 62 mph), respectively.

Table 1. MASH Test Level 3 Crash Test Conditions

Test Article	Test Designation [1]	Test Vehicle	Impact Conditions			Evaluation Criteria [2]
			Speed		Angle (degrees)	
			(km/h)	(mph)		
Terminals	3-30	1100C	100	62	0	C,D,F,H,I,N
	3-31	2270P	100	62	0	C,D,F,H,I,N
	3-32	1100C	100	62	5 to 15	C,D,F,H,I,N
	3-33	2270P	100	62	5 to 15	C,D,F,H,I,N
	3-34	1100C	100	62	15	C,D,F,H,I,N
	3-35	2270P	100	62	25	A,D,F,H,I
	3-36	2270P	100	62	25	A,D,F,H,I
	3-37	2270P	100	62	25	C,D,F,H,I,N
	3-38	1500A	100	62	0	C,D,F,H,I,N

[1] The impact speed for TL-2 tests is 70 km/h (44 mph) as compared to 100 km/h (62 mph) for TL-3 tests.

[2] Evaluation criteria explained in Table 3.

According to the request of the NYSDOT, the Type II box beam end terminal was to be impacted according to a modified test designation 3-32 versus using test designation 3-30. For gating terminals, test designation 3-32 is to be performed at an angle ranging between 5 and 15 degrees with the vehicle’s centerline impacting the nose of the end terminal. Instead, NYSDOT personnel believed that a more critical test would occur when the right-side tires just missed the end terminal, while (1) the left-side tires were lifted by the ramped end, inducing vehicle roll and vehicle yaw, and (2) the left-front tire engages the face of the barrier, also inducing vehicle yaw. It was also believed that the combined yaw and roll motions would produce vehicle rollover during the test. Finally, NYSDOT personnel deemed the 10-degree impact angle more critical than the 5- or 15-degree limits.

For the Type I, now referred to as Type IIA, end terminal, NYSDOT personnel requested that the first crash on this terminal be performed according to a modified test designation 3-30. For gating terminals, test designation 3-30 is to be performed at an angle of 0 degrees with the vehicle's right-side quarter point aligned with the nose of the end terminal. Instead, NYSDOT personnel requested that the left-side quarter point aligned with the centerline of the box beam rail in the tangent region of the barrier system. For this impact condition, it was believed that the vehicle would cause the end rail to release and push away from the vehicle, thus causing a bend in the rail downstream and a greater propensity for rail impalement into the vehicle.

The second test requested on the Type IIA end terminal was to be performed according to test designation 3-34 where the right-front corner of the vehicle would be positioned at the CIP of the terminal device.

For the modified Type IIA end terminal, the first test requested was to be performed according to test designation 3-35 where the right-front corner of the vehicle would be positioned at the beginning of the LON of the terminal device. The second test performed on a further modified Type IIA end terminal was to be test designation 3-35 where the right-front corner of the vehicle would be positioned at the beginning of the LON of the terminal device.

At the request of the NYSDOT, the third test requested on the latest modified Type IIA end terminal was to be conducted with the modified Type IIA end terminal installed in a ditch section. In addition, NYSDOT personnel requested that this crash test on the end terminal be performed according to a modified test designation 2-34. For gating terminals, test designation 2-34 is to be performed at an angle of 15 degrees with the vehicle's right-front corner aligned with the CIP of the terminal where the behavior of the terminal changed from gating to redirection. However, in order to evaluate the potential mitigating effects of the terminal on the crash performance as well as the potential vehicle underride, NYSDOT personnel requested the impact angle to be reduced to 7.5 degrees. Evaluating potential vehicle underride was also the basis for reducing the test conditions to TL-2 from TL-3.

Similarly and at the request of the NYSDOT, the fourth test performed on the latest modified Type IIA end terminal was to be conducted with the modified Type IIA end terminal installed in a ditch section. In addition, NYSDOT personnel requested that this crash test on the end terminal be performed according to a modified test designation 3-35. For gating terminals, test designation 3-35 is to be performed at an angle of 25 degrees with the vehicle's right-front corner aligned with the beginning of the LON of the terminal in order to examine the capacity of the terminal for containing and redirecting heavy passenger vehicles. The intent of this test was to determine the degree of impact attenuation that the end terminal could provide for a vehicle headed toward the back of a non-traversable ditch rather than obtaining a passing test. Therefore, NYSDOT personnel requested that the impact point be moved to the center of the curved nose piece as opposed to the beginning of the LON.

For the latest modified Type IIA end terminal, the next test requested was to be performed according to test designation 3-34 where the right-front corner of the vehicle would be positioned at the CIP of the terminal device. The final test requested on the latest modified Type IIA end terminal was to be performed according to a modified test designation 3-35. The intent of this test was to determine the performance of the end terminal when impacted at a critical impact point where both gating and redirection could occur. Thus, this point was determined to be the center of the vertical bolt on post no. 5 as opposed to the beginning of the LON. A summary of the nine tests is shown in Table 2.

3.2 Evaluation Criteria

According to MASH, the 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 barrier to contain, redirect, or allow controlled vehicle penetration in a predictable manner. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Vehicle trajectory after collision is a measure of the potential for the post-impact trajectory of the vehicle to result in secondary collisions with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and other vehicles. These evaluation criteria are summarized in Table 3 and defined in greater detail in MASH [9]. The full-scale vehicle crash tests were conducted and reported in accordance with the procedures provided in MASH.

In addition to the standard occupant risk measures, the Post Impact Head Deceleration (PHD), the Theoretical Head Impact Velocity (THIV), and the Acceleration Severity Index (ASI) were determined and reported. Additional discussion on PHD, THIV, and ASI is provided in Reference 9.

Table 2. Summary of Crash Tests and Impact Conditions

Test No.	System	Test Designation	MASH Target Impact Conditions
NYBBT-1	Type II	Modified 3-32	1100C - 100 km/h @ 5-15 deg w/ centerline on nose of terminal
NYBBT-2	Type IIA	Modified 3-30	1100C - 100 km/h @ 0 deg @ ¼-pt offset on nose toward front of system (right-side ¼-pt)
NYBBT-3	Type IIA	3-34	1100C - 100 km/h @ 15 deg @ CIP of terminal
NYBBT-4	Modified Type IIA (longer posts 1-3 and moved to front side, shelf angles added to top @ posts 2-3 w/ 13 mm (1/2 in.) dia. connecting bolts)	3-35	2270P - 100 km/h @ 25 deg @ beginning of LON of terminal
NYBBT-5	Modified Type IIA (3 intermediate posts added between posts 2-5 and placed on back side, new post 3 not connected to box beam)	3-35	2270P - 100 km/h @ 25 deg @ beginning of LON of terminal
NYBBT-6	Modified Type IIA in 2:1 Ditch (Same system as in NYBBT-5)	Modified 2-34	1100C - 70 km/h @ 15 deg @ CIP of terminal
NYBBT-7	Modified Type IIA in 2:1 Ditch (Same system as in NYBBT-5)	Modified 3-35	2270P - 100 km/h @ 25 deg @ beginning of LON of terminal
NYBBT-8	Modified Type IIA (posts 1, 2, and 4 moved to back side)	3-34	1100C - 100 km/h @ 15 deg @ CIP of terminal
NYBBT-9	Modified Type IIA (Same system as in NYBBT-8)	Modified 3-35	2270P - 100 km/h @ 25 deg @ beginning of LON of terminal

Table 3. MASH Evaluation Criteria for Crash Tests

Structural Adequacy	A.	Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.
	C.	Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle.
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 undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.
	F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.
	H.	Longitudinal and lateral occupant impact velocities should fall below the preferred value of 9.1 m/s (30 ft/s), or at least below the maximum allowable value of 12.2 m/s (40 ft/s).
	I.	Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g's, or at least below the maximum allowable value of 20.49 g's.
Vehicle Trajectory	N.	Vehicle trajectory behind the test article is acceptable.

3.3 Soil Strength Requirements

In order to limit the variation of soil strength among testing agencies, the foundation soil must satisfy the recommended performance characteristics set forth in Chapter 3 and Appendix B of MASH. Testing facilities must first subject their soil to a dynamic post test to demonstrate a minimum dynamic load of 33.4 kN (7.5 kips) at deflections between 127 and 508 mm (5 and 20 in.). If satisfactory results are observed, a static test is conducted using an identical test installation. The results of this static test become the baseline requirement for soil strength in future full-scale testing. On full-scale test day, an additional post installed near the impact point is statically tested in the same manner as the baseline test. If the static test results provide a resistance equal to 90 percent or greater of the baseline test at deflections of 127, 254, and 381 mm (5, 10, and 15 in.), then the full-scale test can be conducted. Otherwise, testing must be postponed until the soil demonstrates adequate strength.

4 TEST CONDITIONS

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 miles) 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 barrier system. A digital speedometer on the tow vehicle increased the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch [10] was used to steer the test vehicle. A guide-flag was attached to the guide cable as well as to the right-front wheel for test nos. NYBBT-1, NYBBT-8, and NYBBT-9 and the left-front wheel for test nos. NYBBT-2 through NYBBT-7. The guide flag was sheared off before impact with the barrier system. The 9.5-mm (3/8-in.) diameter guide cable was tensioned to approximately 15.6 kN (3,500 lbf), and supported laterally and vertically every 30.5 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. For test nos. NYBBT-1, NYBBT-2, NYBBT-3, and NYBBT-6, the vehicle guidance system was 166 m (546 ft) long. For test nos. NYBBT-4, NYBBT-5, and NYBBT-7, the vehicle guidance system was 227 m (746 ft) long. For test no. NYBBT-8, the vehicle guidance system was 242 m (795 ft) long. For test no. NYBBT-9, the vehicle guidance system was 302 m (991 ft) long.

4.3 Test Vehicles

For test no. NYBBT-1, a 2002 Kia Rio passenger car was used as the test vehicle. The test inertial and gross static weights were 1,087 kg (2,397 lb) and 1,173 kg (2,586 lb), respectively. The test vehicle is shown in Figure 1, and vehicle dimensions are shown in Figure 2.

For test no. NYBBT-2, a 2003 Kia Rio passenger car was used as the test vehicle. The test inertial and gross static weights were 1,086 kg (2,395 lb) and 1,158 kg (2,553 lb), respectively. The test vehicle is shown in Figure 3, and vehicle dimensions are shown in Figure 4.

For test no. NYBBT-3, a 2003 Kia Rio passenger car was used as the test vehicle. The test inertial and gross static weights were 1,101 kg (2,428 lb) and 1,176 kg (2,594 lb), respectively. The test vehicle is shown in Figure 5, and vehicle dimensions are shown in Figure 6.

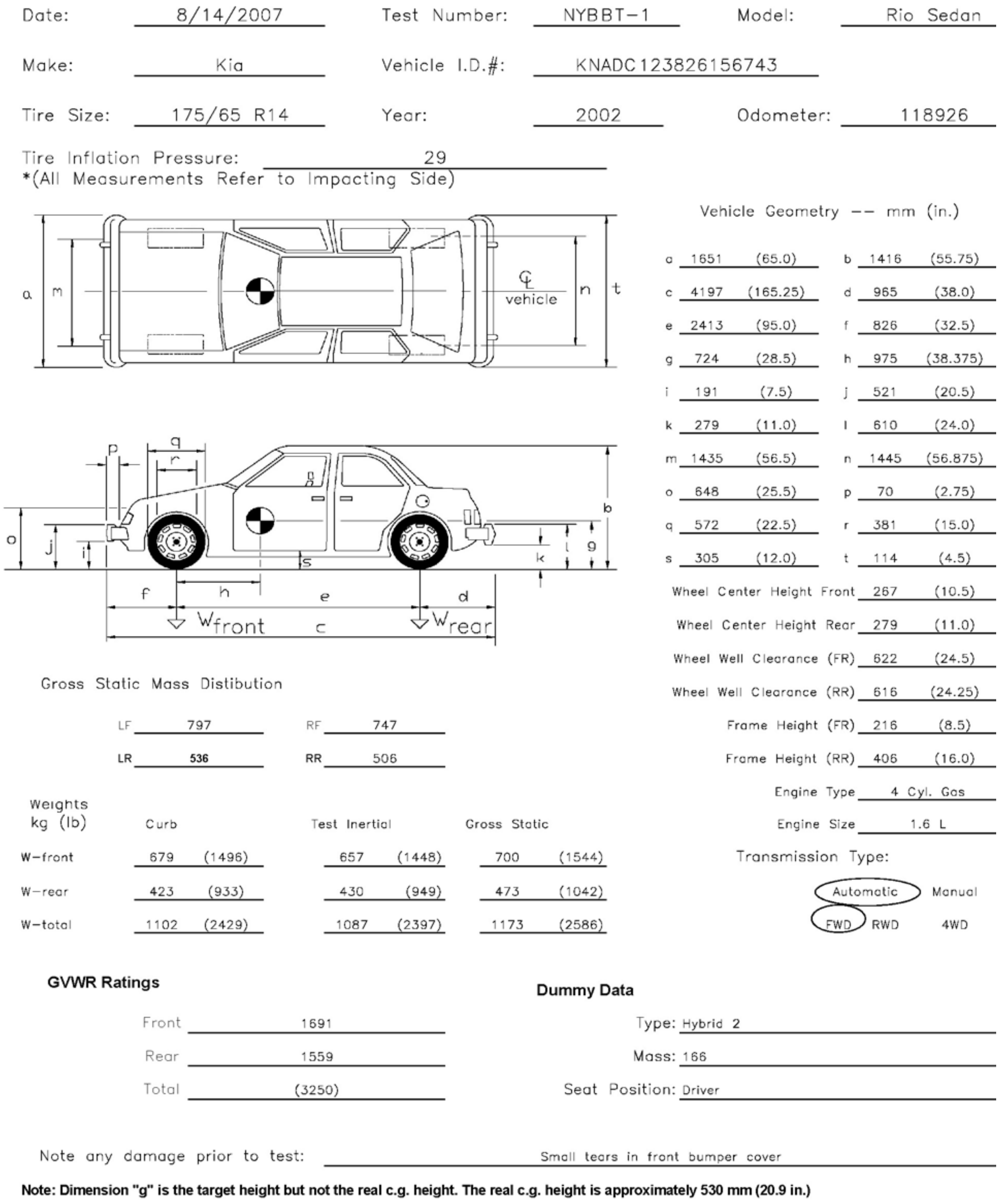
For test no. NYBBT-4, a 2002 Dodge Ram 1500 Quad Cab pickup truck was used as the test vehicle. The test inertial and gross static weights were 2,270 kg (5,004 lb) and 2,348 kg (5,176 lb), respectively. The test vehicle is shown in Figure 7, and vehicle dimensions are shown in Figure 8.

For test no. NYBBT-5, a 2002 Dodge Ram 1500 Quad Cab pickup truck was used as the test vehicle. The test inertial and gross static weights were 2,276 kg (5,018 lb) and 2,354 kg (5,190 lb), respectively. The test vehicle is shown in Figure 9, and vehicle dimensions are shown in Figure 10.

For test no. NYBBT-6, a 2002 Kia Rio passenger car was used as the test vehicle. The test inertial and gross static weights were 1,100 kg (2,424 lb) and 1,176 kg (2,593 lb), respectively. The test vehicle is shown in Figure 11, and the vehicle dimensions are shown in Figure 12.

For test no. NYBBT-7, a 2002 Dodge Ram 1500 Quad Cab pickup truck was used as the test vehicle. The test inertial and gross static weights were 2,273 kg (5,012 lb) and 2,351 kg (5,184 lb), respectively. The test vehicle is shown in Figure 13, and the vehicle dimensions are shown in Figure 14.

Figure 1. Test Vehicle, Test No. NYBBT-1



Date: 8/14/2007
Test Number: NYBBT-1
Model: Rio Sedan
Make: Kia
Vehicle I.D.#: KNADC123826156743
Tire Size: 175/65 R14
Year: 2002
Odometer: 118926
Tire Inflation Pressure: 29
*(All Measurements Refer to Impacting Side)

Vehicle Geometry -- mm (in.)

a	1651	(65.0)	b	1416	(55.75)
c	4197	(165.25)	d	965	(38.0)
e	2413	(95.0)	f	826	(32.5)
g	724	(28.5)	h	975	(38.375)
i	191	(7.5)	j	521	(20.5)
k	279	(11.0)	l	610	(24.0)
m	1435	(56.5)	n	1445	(56.875)
o	648	(25.5)	p	70	(2.75)
q	572	(22.5)	r	381	(15.0)
s	305	(12.0)	t	114	(4.5)

Wheel Center Height Front	267	(10.5)
Wheel Center Height Rear	279	(11.0)
Wheel Well Clearance (FR)	622	(24.5)
Wheel Well Clearance (RR)	616	(24.25)
Frame Height (FR)	216	(8.5)
Frame Height (RR)	406	(16.0)
Engine Type	4 Cyl. Gas	
Engine Size	1.6 L	

Transmission Type: [✓ Automatic] Manual
[✓ FWD] RWD 4WD

Gross Static Mass Distibution

LF 797 RF 747
LR 536 RR 506

Weights kg (lb)	Curb		Test Inertial		Gross Static	
W-front	679	(1496)	657	(1448)	700	(1544)
W-rear	423	(933)	430	(949)	473	(1042)
W-total	1102	(2429)	1087	(2397)	1173	(2586)

GVWR Ratings

Front 1691
Rear 1559
Total (3250)

Dummy Data

Type: Hybrid 2
Mass: 166
Seat Position: Driver

Note any damage prior to test: Small tears in front bumper cover

Note: Dimension "g" is the target height but not the real c.g. height. The real c.g. height is approximately 530 mm (20.9 in.)

Figure 2. Test Vehicle Dimension, Test No. NYBBT-1

Figure 3. Test Vehicle, Test No. NYBBT-2

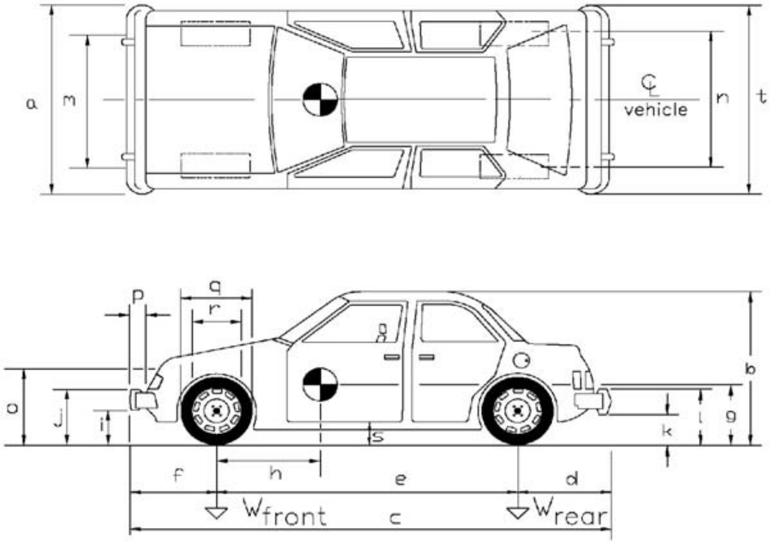
Date: 8/15/2007 Test Number: NYBBT-2 Model: Rio Sedan

Make: Kia Vehicle I.D.#: KNADC125936252061

Tire Size: 175/65 R14 Year: 2003 Odometer: 60366

Tire Inflation Pressure: 30

*(All Measurements Refer to Impacting Side)



Vehicle Geometry -- mm (in.)

a	1638	(64.5)	b	1435	(56.5)
c	4232	(166.625)	d	965	(38.0)
e	2413	(95.0)	f	851	(33.5)
g	470	(18.5)	h	968	(38.125)
i	241	(9.5)	j	616	(24.25)
k	279	(11.0)	l	584	(23.0)
m	1435	(56.5)	n	1441	(56.75)
o	718	(28.25)	p	76	(3.0)
q	572	(22.5)	r	381	(15.0)
s	305	(12.0)	t	1626	(64.0)

Wheel Center Height Front 273 (10.75)

Wheel Center Height Rear 279 (11.0)

Wheel Well Clearance (FR) 635 (25.0)

Wheel Well Clearance (RR) 622 (24.5)

Frame Height (FR) 222 (8.75)

Frame Height (RR) 425 (16.75)

Engine Type 4 Cyl. Gas

Engine Size 1.6 L

Transmission Type:

Automatic [✓ Manual]

[✓ FWD] RWD 4WD

Gross Static Mass Distibution

LF 705 RF 784

LR 504 RR 560

Weights kg (lb)	Curb	Test Inertial	Gross Static
W-front	663 (1461)	6451 (14223)	675 (1489)
W-rear	400 (882)	441 (973)	483 (1064)
W-total	1063 (2343)	1086 (2395)	1158 (2553)

GVWR Ratings

Front 1691

Rear 1559

Total (3250)

Dummy Data

Type: Hybrid 2

Mass: 166

Seat Position: Driver

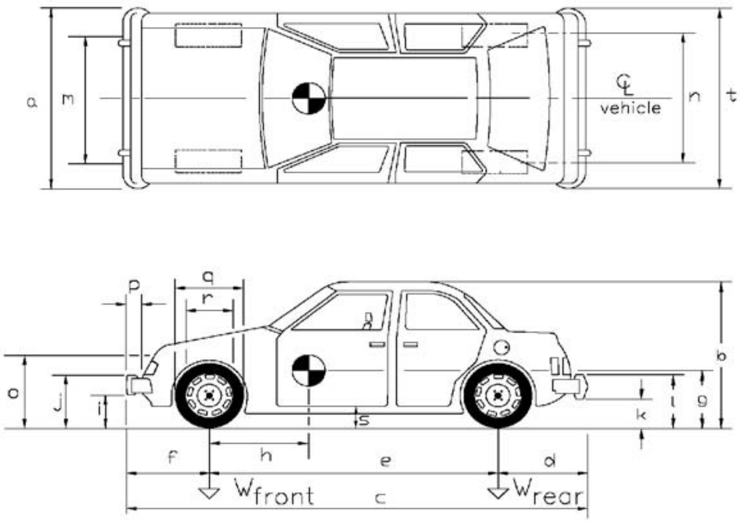
Note any damage prior to test: light hail damage

Note: Dimension "g "is the target height but not the real c.g. height. The real c.g. height is approximately 530 mm (20.9 in.)

Figure 4. Test Vehicle Dimension, Test No. NYBBT-2

Figure 5. Test Vehicle, Test No. NYBBT-3

Date: 9/7/2007
Test Number: NYBBT-3
Model: Rio Sedan
Make: Kia
Vehicle I.D.#: KNADC125836222971
Tire Size: P175/65R14 81T
Year: 2003
Odometer: 39195
Tire Inflation Pressure: 30 psi
*(All Measurements Refer to Impacting Side)



Vehicle Geometry -- mm (in.)

a	1657	(65.25)	b	1432	(56.375)
c	4232	(166.625)	d	975	(38.375)
e	2419	(95.25)	f	838	(33.0)
g	695	(27.375)	h	972	(38.25)
i	216	(8.5)	j	565	(22.25)
k	279	(11.0)	l	584	(23.0)
m	1422	(56.0)	n	1441	(56.75)
o	686	(27.0)	p	83	(3.25)
q	559	(22.0)	r	394	(15.5)
s	337	(13.25)	t	1638	(64.5)

Wheel Center Height Front 267 (10.5)
Wheel Center Height Rear 283 (11.125)
Wheel Well Clearance (FR) 635 (25.0)
Wheel Well Clearance (RR) 635 (25.0)
Frame Height (FR) 191 (7.5)
Frame Height (RR) 419 (16.5)
Engine Type
Engine Size
Transmition Type:
[✓ Automatic] Manual
[✓ FWD] RWD 4WD

Mass Distribution

LF	758	RF	767
LR	503	RR	565

Weights kg (lbs)	Curb		Test Inertial		Gross Static	
W-front	671	(1480)	693	(1528)	693	(1528)
W-rear	398	(878)	693	(1528)	693	(1528)
W-total	1070	(2358)	1177	(2594)	1177	(2594)

GVWR Ratings

Front 1808
Rear 1742
Total (3315)

Dummy Data

Type: Hybrid 2
Mass: 166lbs
Seat Position: Full Rearward

Note any damage prior to test: Hail Damage

Note: Dimension "g" is the target height but not the real c.g. height. The real c.g. height is approximately 530 mm (20.9 in.)

Figure 6. Test Vehicle Dimension, Test No. NYBBT-3

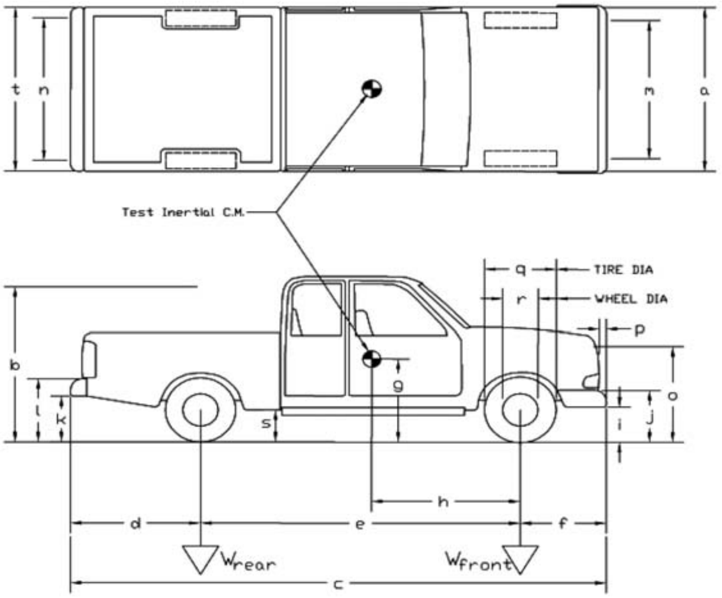
Figure 7. Test Vehicle, Test No. NYBBT-4

Date: 7/11/2008 Test Number: NYBBT-4 Model: Ram 1500 Q.C.

Make: Dodge Vehicle I.D.#: 3D7HA18N22G111286

Tire Size: 265/70 R17 Year: 2002 Odometer: 104412

*(All Measurements Refer to Impacting Side)



Vehicle Geometry -- mm (in.)

a	1969 (77.5)	b	1873 (73.75)
c	5775 (227.375)	d	1137 (44.75)
e	3562 (140.25)	f	1076 (42.375)
g	733 (28.875)	h	1559 (61.375)
i	406 (16.0)	j	692 (27.25)
k	508 (20.0)	l	718 (28.25)
m	1727 (68.0)	n	1683 (66.25)
o	1168 (46.0)	p	89 (3.5)
q	787 (31.0)	r	470 (18.5)
s	394 (15.5)	t	1918 (75.5)

Wheel Center Height Front 387 (15.25)

Wheel Center Height Rear 381 (15.0)

Wheel Well Clearance (FR) 908 (35.75)

Wheel Well Clearance (RR) 965 (38.0)

Frame Height (FR) 438 (17.25)

Frame Height (RR) 584 (23.0)

Engine Type 8cyl. Gas

Engine Size 4.7L

Transmission Type:

Automatic

RWD

Weights kg (lb)	Curb	Test Inertial	Gross Static
W-front	1291 (2846)	1259 (2775)	1307 (2882)
W-rear	1021 (2251)	1011 (2229)	1040 (2293)
W-total	2312 (5097)	2270 (5004)	2348 (5176)

Front GVWR	3650
Rear GVWR	3900
Total GVWR	6650

Note any damage prior to test: none

Figure 8. Test Vehicle Dimension, Test No. NYBBT-4

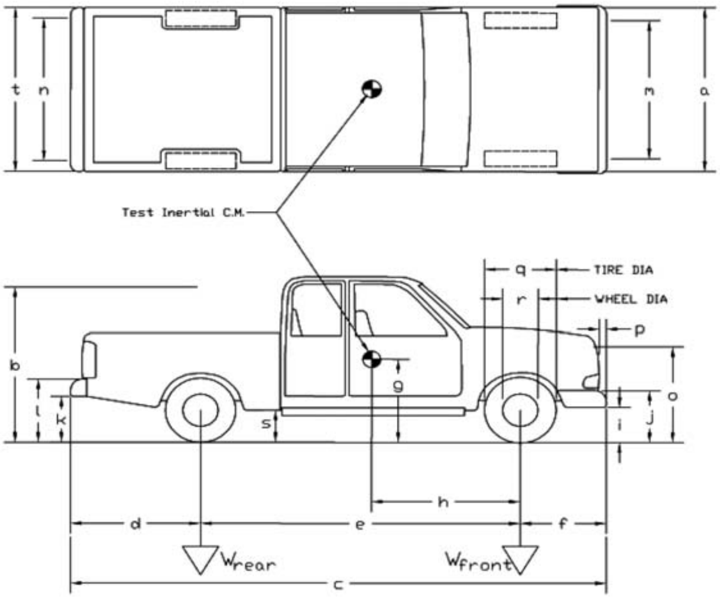
Figure 9. Test Vehicle, Test No. NYBBT-5

Date: 7/31/2008 Test Number: NYBBT-5 Model: Ram 1500 Q.C.

Make: Dodge Vehicle I.D.#: 1D7HA18Z42J195287

Tire Size: 265/70 R17 Year: 2002 Odometer: 82947

*(All Measurements Refer to Impacting Side)



Vehicle Geometry -- mm (in.)

a	1981	(78.0)	b	1911	(75.25)
c	5782	(227.625)	d	1213	(47.75)
e	3562	(140.25)	f	1006	(39.625)
g	718	(28.25)	h	1540	(60.625)
i	362	(14.25)	j	616	(24.25)
k	546	(21.5)	l	743	(29.25)
m	1746	(68.75)	n	1724	(67.875)
o	1073	(42.25)	p	89	(3.5)
q	787	(31.0)	r	470	(18.5)
s	387	(15.25)	t	1924	(75.75)

Wheel Center Height Front	375	(14.75)
Wheel Center Height Rear	384	(15.125)
Wheel Well Clearance (FR)	876	(34.5)
Wheel Well Clearance (RR)	965	(38.0)
Frame Height (FR)	422	(16.625)
Frame Height (RR)	641	(25.25)
Engine Type	8cyl. Gas	
Engine Size	5.9L 360CI	

Transmission Type:

Automatic

RWD

Weights kg (lb)	Curb	Test Inertial	Gross Static
W-front	1332 (2937)	1283 (2828)	1330 (2933)
W-rear	994 (2191)	993 (2190)	1024 (2257)
W-total	2326 (5128)	2276 (5018)	2354 (5190)

Front GVWR	3650
Rear GVWR	3900
Total GVWR	6650

Note any damage prior to test: none

Figure 10. Test Vehicle Dimension, Test No. NYBBT-5



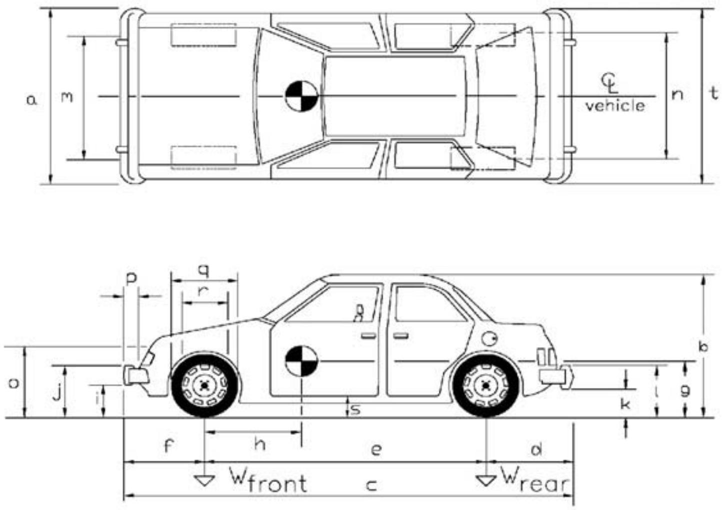
Figure 11. Test Vehicle, Test No. NYBBT-6

Date: 10/3/2008 Test Number: NYBBT-6 Model: Rio Sedan

Make: Kia Vehicle I.D.#: KNADC123026175982

Tire Size: P175/65R14 Year: 2002 Odometer: 93313

Tire Inflation Pressure: 30 psi
*(All Measurements Refer to Impacting Side)



Vehicle Geometry -- mm (in.)

a	1619	(63.75)	b	1416	(55.75)
c	4216	(166.0)	d	965	(38.0)
e	2419	(95.25)	f	832	(32.75)
g	457	(18.0)	h	943	(37.125)
i	229	(9.0)	j	521	(20.5)
k	311	(12.25)	l	540	(21.25)
m	1416	(55.75)	n	1441	(56.75)
o	648	(25.5)	p	76	(3.0)
q	572	(22.5)	r	391	(15.375)
s	210	(8.25)	t	1651	(65.0)

Wheel Center Height Front 267 (10.5)

Wheel Center Height Rear 273 (10.75)

Wheel Well Clearance (FR) 625 (24.625)

Wheel Well Clearance (RR) 603 (23.75)

Frame Height (FR) 178 (7.0)

Frame Height (RR) 410 (16.125)

Engine Type 4 Cyl Gas

Engine Size 1.4l

Transmition Type:

[✓ Automatic] Manual

[✓ FWD] RWD 4WD

Mass Distribution

Gross Static	LF	762	RF	786
	LR	514	RR	531

Weights kg (lb)	Curb	Test Inertial	Gross Static
W-front	684 (1509)	664 (1463)	702 (1548)
W-rear	399 (879)	436 (961)	474 (1045)
W-total	1082 (2386)	1100 (2424)	1176 (2593)

GVWR Ratings

Front 1808

Rear 1742

Total **(3315)**

Dummy Data

Type: Hybrid 2

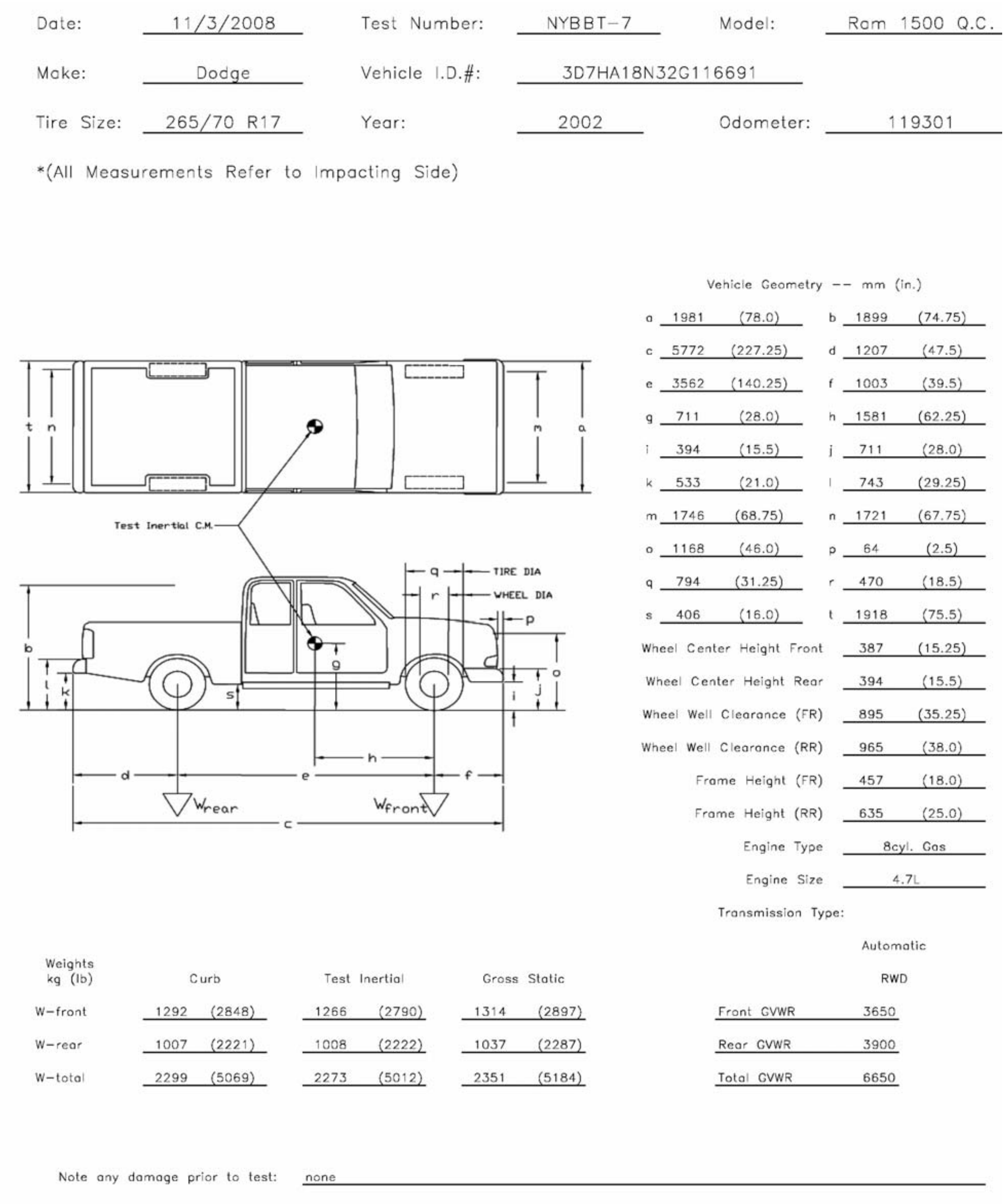
Mass: 166lbs

Seat Position: Passenger

Note any damage prior to test: none

Figure 12. Test Vehicle Dimension, Test No. NYBBT-6

Figure 13. Test Vehicle, Test No. NYBBT-7



Date: 11/3/2008 Test Number: NYBBT-7 Model: Ram 1500 Q.C.

Make: Dodge Vehicle I.D.#: 3D7HA18N32G116691

Tire Size: 265/70 R17 Year: 2002 Odometer: 119301

*(All Measurements Refer to Impacting Side)

Vehicle Geometry -- mm (in.)

a	1981	(78.0)	b	1899	(74.75)
c	5772	(227.25)	d	1207	(47.5)
e	3562	(140.25)	f	1003	(39.5)
g	711	(28.0)	h	1581	(62.25)
i	394	(15.5)	j	711	(28.0)
k	533	(21.0)	l	743	(29.25)
m	1746	(68.75)	n	1721	(67.75)
o	1168	(46.0)	p	64	(2.5)
q	794	(31.25)	r	470	(18.5)
s	406	(16.0)	t	1918	(75.5)

Wheel Center Height Front	387	(15.25)
Wheel Center Height Rear	394	(15.5)
Wheel Well Clearance (FR)	895	(35.25)
Wheel Well Clearance (RR)	965	(38.0)
Frame Height (FR)	457	(18.0)
Frame Height (RR)	635	(25.0)
Engine Type	8cyl. Gas	
Engine Size	4.7L	

Transmission Type:

Automatic

RWD

Weights kg (lb)	Curb		Test Inertial		Gross Static	
W-front	1292	(2848)	1266	(2790)	1314	(2897)
W-rear	1007	(2221)	1008	(2222)	1037	(2287)
W-total	2299	(5069)	2273	(5012)	2351	(5184)

Front GVWR	3650
Rear GVWR	3900
Total GVWR	6650

Note any damage prior to test: none

Figure 14. Test Vehicle Dimension, Test No. NYBBT-7

For test no. NYBBT-8, a 2003 Kia Rio passenger car was used as the test vehicle. The test inertial and gross static weights were 1,106 kg (2,438 lb) and 1,183 kg (2,608 lb), respectively. The test vehicle is shown in Figure 15, and the vehicle dimensions are shown in Figure 16.

For test no. NYBBT-9, a 2003 Dodge Ram 1500 Quad Cab pickup truck was used as the test vehicle. The test inertial and gross static weights were 2,263 kg (4,989 lb) and 2,340 kg (5,159 lb), respectively. The test vehicle is shown in Figure 17, and the vehicle dimensions are shown in Figure 18.

The Suspension Method [11] was used to determine the vertical component of the center of gravity (c.g.) for the pickup trucks. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicles were suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the c.g. location. The longitudinal component of the c.g. was determined using the measured axle weights. The locations of the final c.g. are shown in Figures 2, 4, 6, 8, 10, 12, 14, 16, and 18 through 27. The data used for the c.g. calculations and ballast information are shown in Appendix A.

Square black and white, checkered targets were placed on the vehicle to aid in the analysis of the high-speed digital video, as shown in Figures 19 through 27. Round, checkered targets were placed at the vehicle's center of gravity on the left-side door, right-side door, and the roof of the vehicle. The remaining targets were located for reference so that they could be viewed from the high-speed cameras for video analysis.

The front wheels of the test vehicle were aligned for camber, caster, and toe-in values of zero so the vehicle would track properly along the guide cable. A 5B flash bulb was mounted on

Figure 15. Test Vehicle, Test No. NYBBT-8

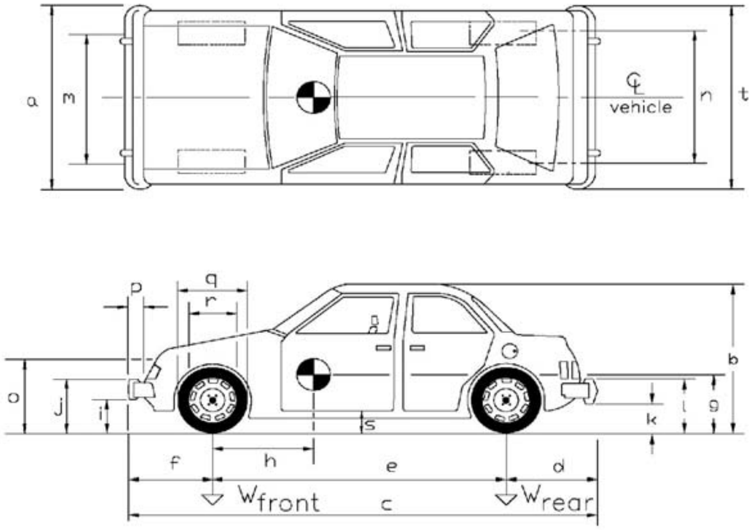
Date: 7/15/2009 **Test Number:** NYBBT-8 **Model:** Rio Sedan (1100C)

Make: Kia **Vehicle I.D.#:** KNADC125936246549

Tire Size: 175/65 R14 **Year:** 2003 **Odometer:** 126385

Tire Inflation Pressure: 30 Psi

***(All Measurements Refer to Impacting Side)**



Vehicle Geometry -- mm (in.)

a	1651	(65.0)	b	1410	(55.5)
c	4229	(166.5)	d	997	(39.25)
e	2419	(95.25)	f	813	(32.0)
g	457	(18.0)	h	917	(36.12)
i	222	(8.75)	j	584	(23.0)
k	286	(11.25)	l	610	(24.0)
m	1426	(56.125)	n	1448	(57.0)
o	711	(28.0)	p	83	(3.25)
q	591	(23.25)	r	394	(15.5)
s	292	(11.5)	t	1613	(63.5)

Wheel Center Height Front	270	(10.625)
Wheel Center Height Rear	273	(10.75)
Wheel Well Clearance (F)	622	(24.5)
Wheel Well Clearance (R)	616	(24.25)
Frame Height (F)	229	(9.0)
Frame Height (R)	419	(16.5)

Engine Type 4cyl. Gas

Engine Size 1.4L

Transmition Type:

[✓ Automatic] Manual

[✓ FWD] RWD 4WD

Mass Distribution

Gross Static	LF	816	RF	787
	LR	526	RR	491

Weights kg (lb)	Curb	Test Inertial	Gross Static
W-front	700 (1543)	682 (1503)	727 (1603)
W-rear	404 (891)	424 (935)	461 (1017)
W-total	1104 (2434)	1106 (2438)	1183 (2608)

GVWR Ratings

Front 1808

Rear 1742

Total 3379

Dummy Data

Type: Hybrid 1

Mass: 170 lbs.

Seat Position: Driver

Note any damage prior to test: Cometic right rear quarter panel

Figure 16. Test Vehicle Dimension, Test No. NYBBT-8

Figure 17. Test Vehicle, Test No. NYBBT-9

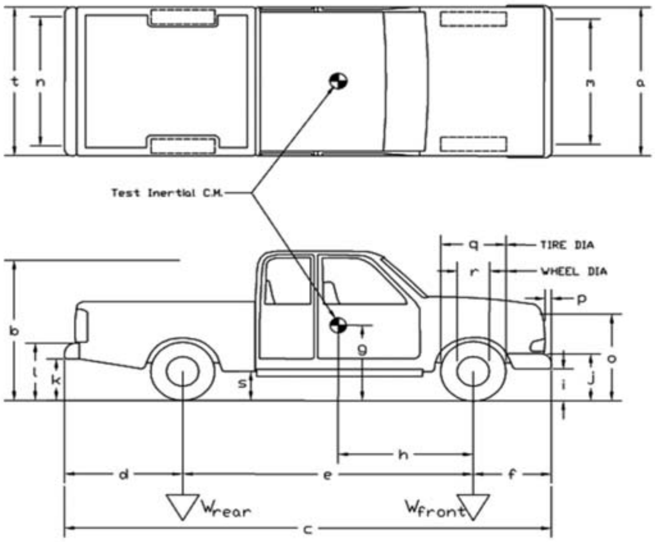
Date: 8/6/2009 **Test Number:** NYBBT-9 **Model:** Ram 1500 (2270P)

Make: Dodge **Vehicle I.D.#:** 1D7HA18N93J508963

Tire Size: 275/55-R20 **Year:** 2003 **Odometer:** 193804

Tire Inflation Pressure: 35psi

***(All Measurements Refer to Impacting Side)**



Vehicle Geometry -- mm (in.)

a	1969	(77.5)	b	1899	(74.75)
c	5779	(227.5)	d	1232	(48.5)
e	3569	(140.5)	f	978	(38.5)
g	729	(28.72)	h	1606	(63.23)
i	368	(14.5)	j	584	(23.0)
k	546	(21.5)	l	756	(29.75)
m	1734	(68.25)	n	1721	(67.75)
o	1156	(45.5)	p	102	(4.0)
q	800	(31.5)	r	552	(21.75)
s	387	(15.25)	t	1918	(75.5)

Wheel Center Height Front	375	(14.75)
Wheel Center Height Rear	375	(14.75)
Wheel Well Clearance (F)	889	(35.0)
Wheel Well Clearance (R)	972	(38.25)
Frame Height (F)	451	(17.75)
Frame Height (R)	654	(25.75)
Engine Type	V8 Gas	
Engine Size	4.7L	

Transmition Type:

[✓ Automatic] Manual

FWD [✓ RWD] 4WD

Mass Distribution

Gross Static	LF	1461	RF	1396
	LR	1146	RR	1156

Weights kg (lb)	Curb	Test Inertial	Gross Static
W-front	1276 (2812)	1249 (2753)	1296 (2857)
W-rear	1007 (2221)	1014 (2236)	1044 (2302)
W-total	2283 (5033)	2263 (4989)	2340 (5159)

GVWR Ratings

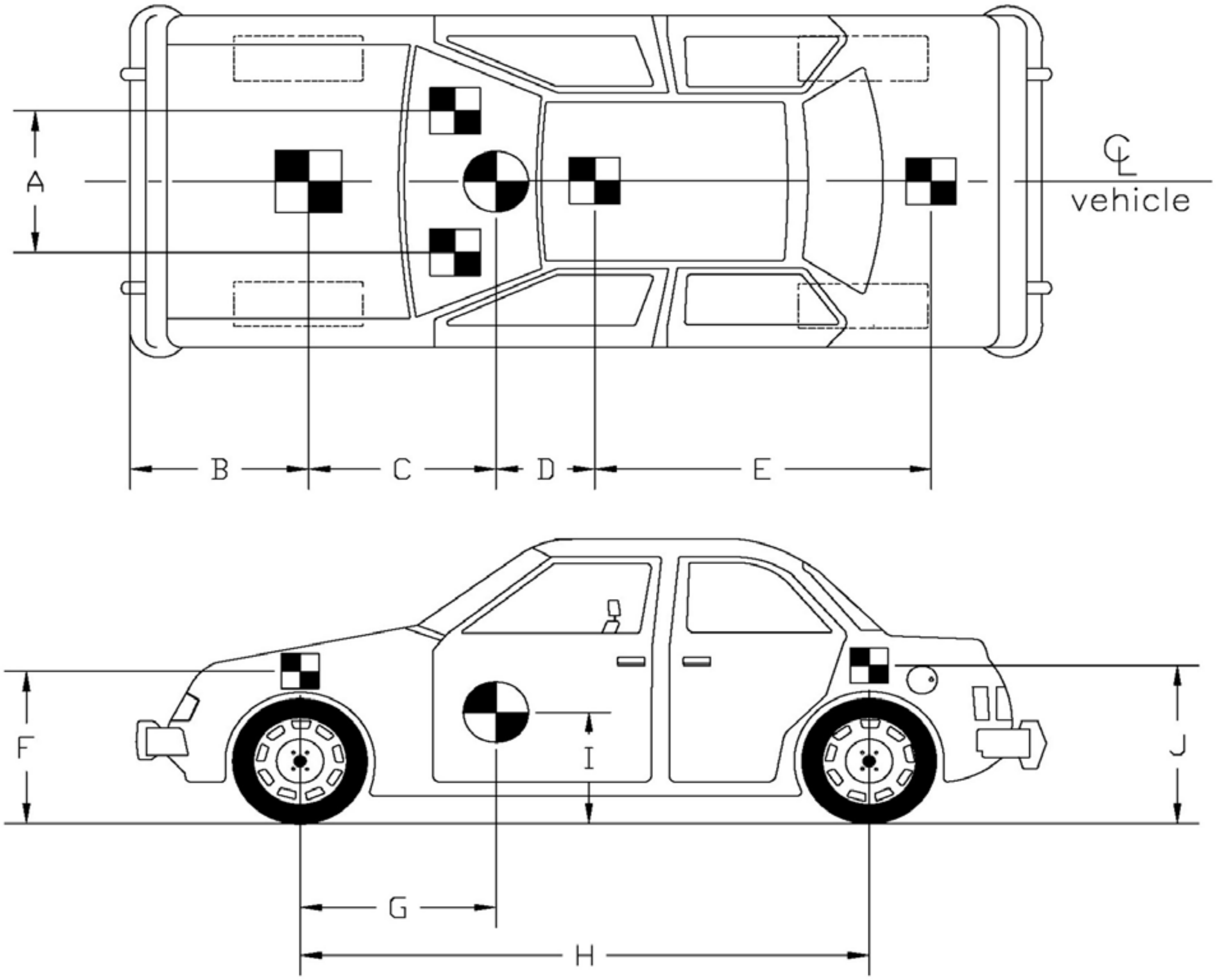
Front 3650
Rear 3900
Total 6650

Dummy Data

Type: Hybrid II
Mass: 170 lbs
Seat Position: Driver

Note any damage prior to test: None

Figure 18. Test Vehicle Dimension, Test No. NYBBT-9

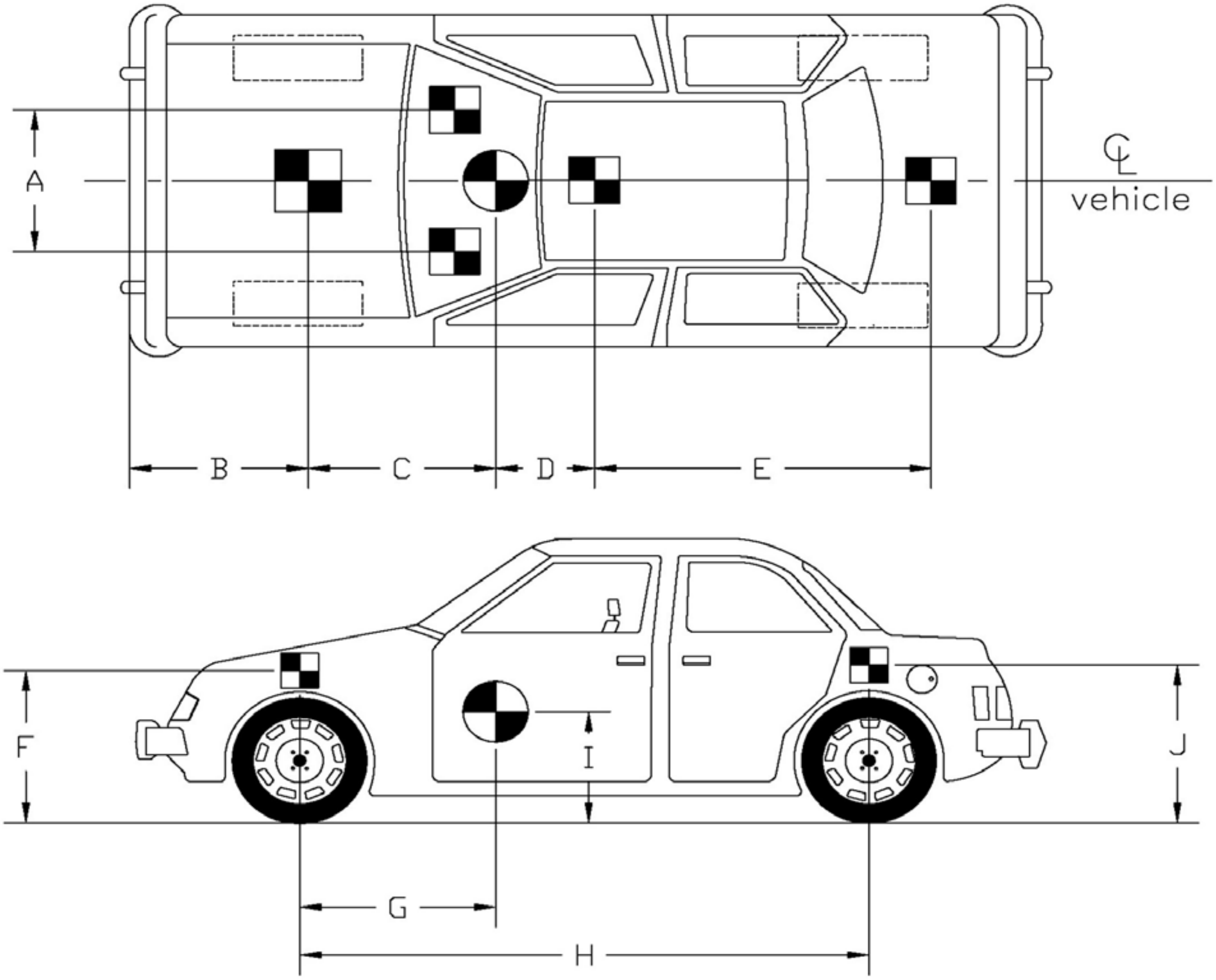


TEST #: NYBBT-1
TARGET GEOMETRY-- mm (in.)

A	851	(33.5)	E	1975	(77.75)	I	724	(28.5)
B	743	(29.25)	F	724	(28.5)	J	721	(28.375)
C	1003	(39.5)	G	975	(38.375)			
D	219	(8.625)	H	2419	(95.25)			

Note: Dimension "I" is the target height but not the real c.g. height.

Figure 19. Vehicle Target Locations, Test No. NYBBT-1



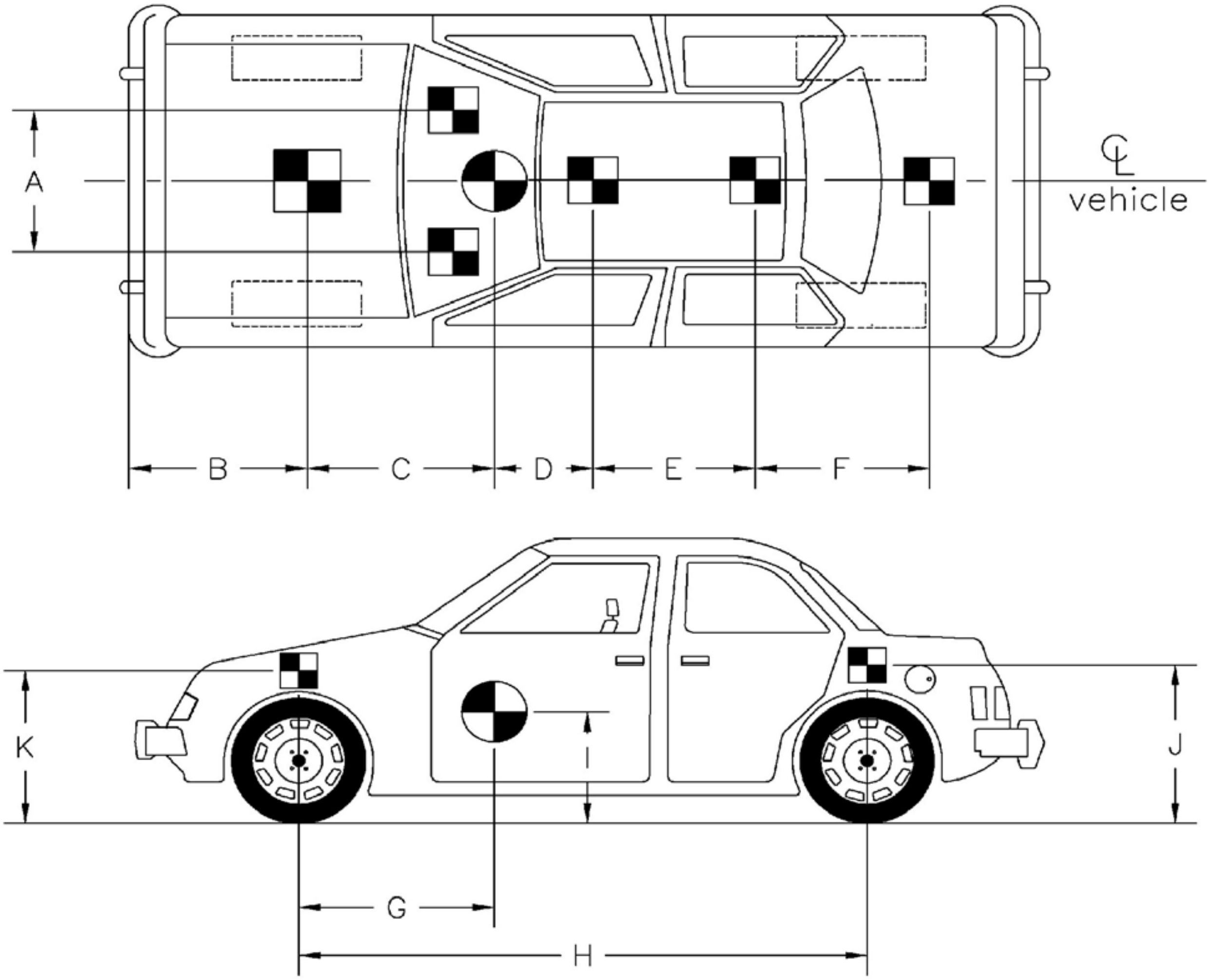
TEST #: NYBBT-2

TARGET GEOMETRY-- mm (in.)

A	876	(34.5)	E	1810	(71.25)	I	470	(18.5)
B	629	(24.75)	F	737	(29.0)	J	737	(29.0)
C	1156	(45.5)	G	965	(38.0)			
D	387	(15.25)	H	2407	(94.75)			

Note: I is the target height but not the real c.g. height.

Figure 20. Vehicle Target Locations, Test No. NYBBT-2

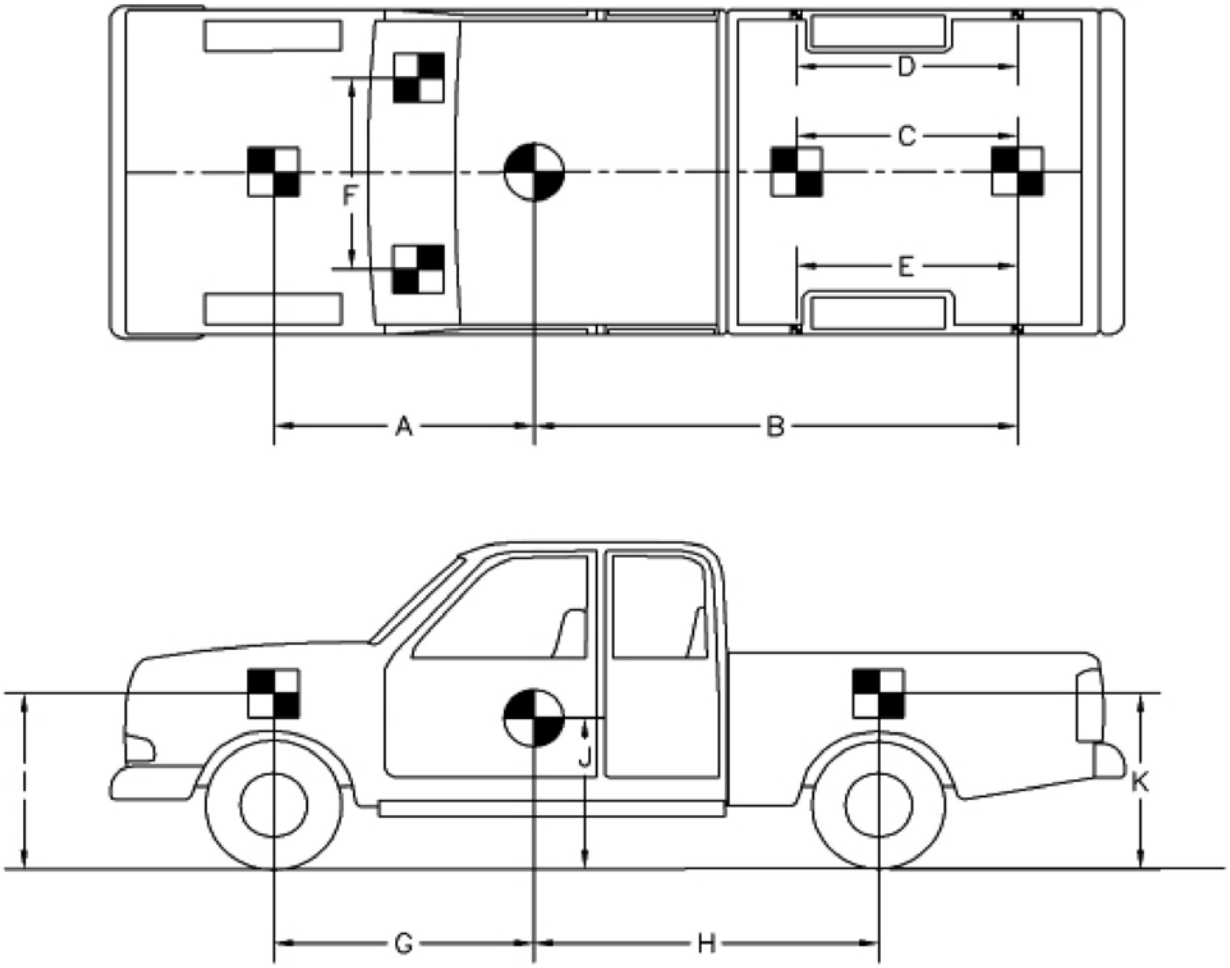


TEST #: NYBBT-3
TARGET GEOMETRY-- mm (in.)

A	667	(26.25)	E	813	(32.0)	I	695	(27.375)
B	749	(29.5)	F	1003	(39.5)	J	752	(29.625)
C	1041	(41.0)	G	972	(38.25)	K	756	(29.75)
D	292	(11.5)	H	2419	(95.25)			

Note: Dimension "I" is the target height but not the real c.g. height.

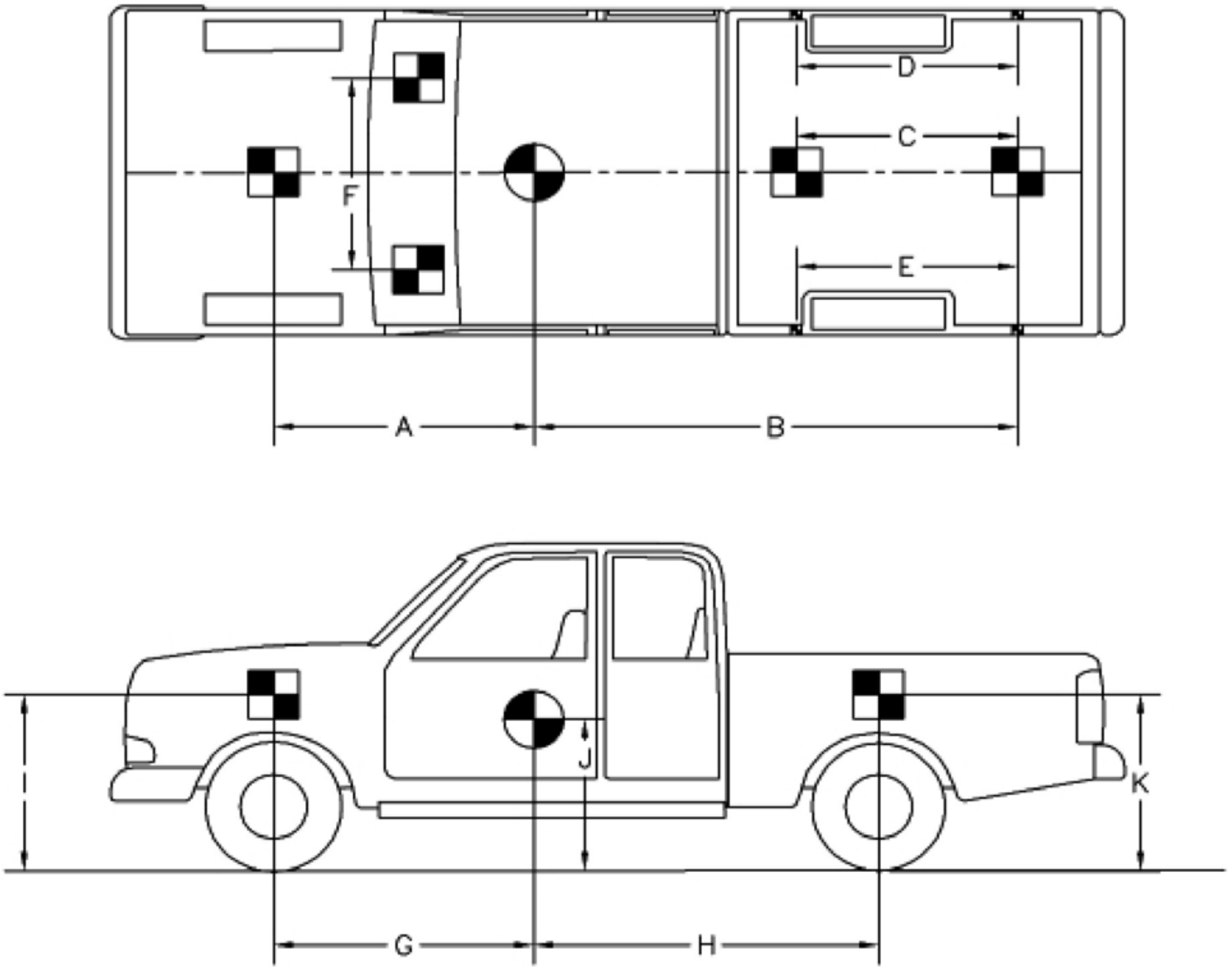
Figure 21. Vehicle Target Locations, Test No. NYBBT-3



TEST #: NYBBT-4
TARGET GEOMETRY-- mm (in.)

A 1880 (74.0)	E 1753 (69.0)	I 1026 (40.375)
B 2800 (110.25)	F 1035 (40.75)	J 733 (28.875)
C 1219 (48.0)	G 1559 (61.375)	K 1073 (42.25)
D 1753 (69.0)	H 2003 (78.875)	

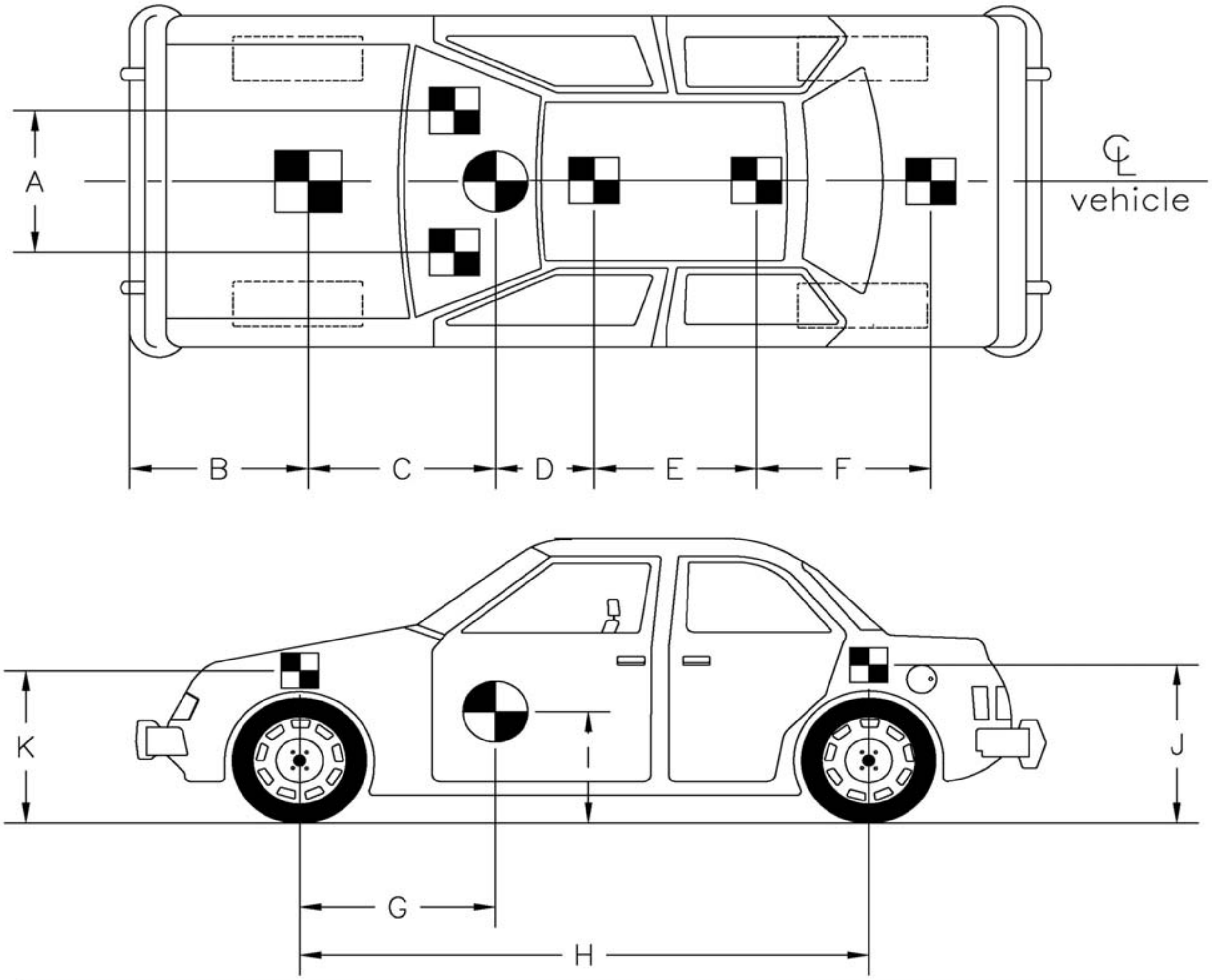
Figure 22. Vehicle Target Locations, Test No. NYBBT-4



TEST #: NYBBT-5
TARGET GEOMETRY-- mm (in.)

A 1880 (74.0)	E 1622 (63.875)	I 984 (38.75)
B 2661 (104.75)	F 1165 (45.875)	J 718 (28.25)
C 1133 (44.625)	G 1540 (60.625)	K 1073 (42.25)
D 1622 (63.875)	H 2022 (79.625)	

Figure 23. Vehicle Target Locations, Test No. NYBBT-5



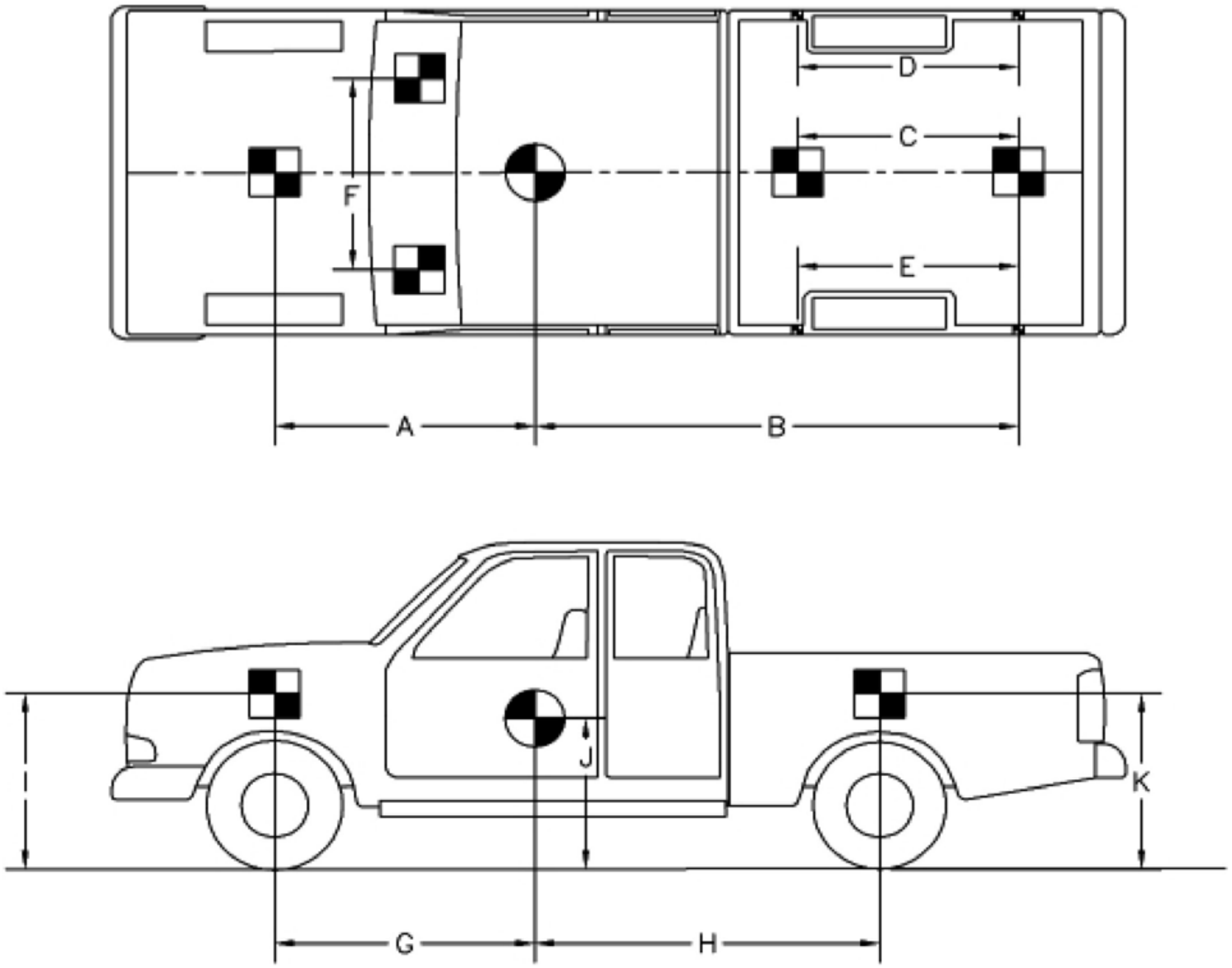
TEST #: NYBBT-6

TARGET GEOMETRY-- mm (in.)

A	670	(26.375)	E	1045	(41.125)	I	457	(18.0)
B	721	(28.375)	F	911	(35.875)	J	705	(27.75)
C	1041	(41.0)	G	943	(37.125)	K	724	(28.5)
D	232	(9.125)	H	2419	(95.25)			

Note: Dimension "I" is the target height but not the real c.g. height

Figure 24. Vehicle Target Locations, Test No. NYBBT-6

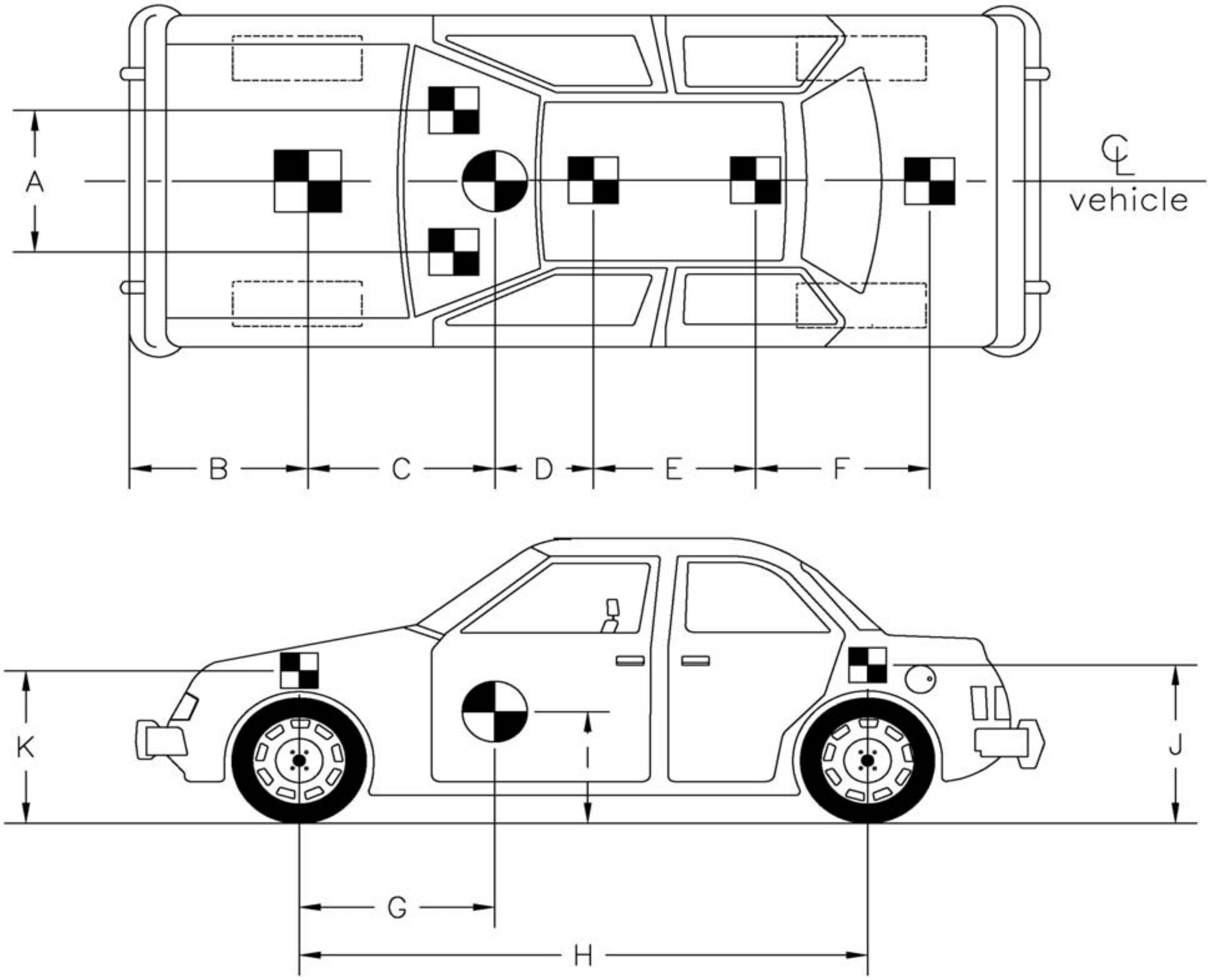


TEST #: NYBBT-7

TARGET GEOMETRY-- mm (in.)

A 1778 (70.0)
B 2540 (100.0)
C 1219 (48.0)
D 1626 (64.0)
E 1626 (64.0)
F 959 (37.75)
G 1581 (62.25)
H 2896 (114.0)
I 997 (39.25)
J 711 (28.0)
K 1067 (42.0)

Figure 25. Vehicle Target Locations, Test No. NYBBT-7



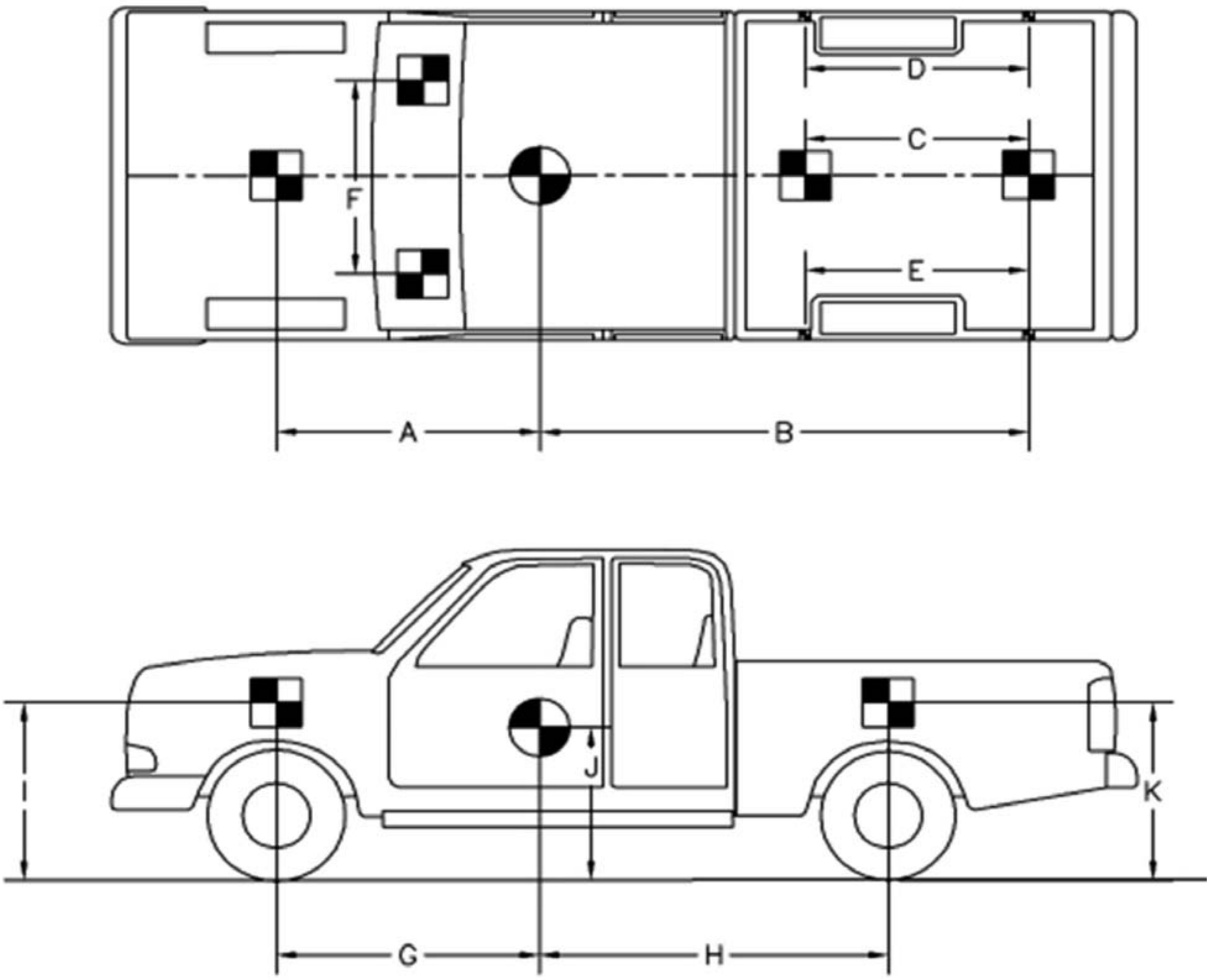
TEST #: NYBBT-8

TARGET GEOMETRY-- mm (in.)

A	**660**	**(26.0)**	**E**	**800**	**(31.5)**	**I**	**457**	**(18.0)**
B	**552**	**(21.75)**	**F**	**984**	**(38.75)**	**J**	**718**	**(28.25)**
C	**1575**	**(62.0)**	**G**	**918**	**(36.125)**	**K**	**724**	**(28.5)**
D	**394**	**(15.5)**	**H**	**2419**	**(95.25)**	**L**	**1041**	**(41.0)**

*Notes: L is distance from windshield target to ground
Dimension "I" is the target height but not the real c.g. height

Figure 26. Vehicle Target Locations, Test No. NYBBT-8



TEST #: NYBBT-9

TARGET GEOMETRY-- mm (in.)

A	**1867**	**(73.5)**	**E**	**1753**	**(69.0)**	**I**	**1010**	**(39.75)**
B	**2534**	**(99.75)**	**F**	**978**	**(38.5)**	**J**	**729**	**(28.72)**
C	**1219**	**(48.0)**	**G**	**1606**	**(63.23)**	**K**	**1086**	**(42.75)**
D	**1746**	**(68.75)**	**H**	**1963**	**(77.27)**			

Figure 27. Vehicle Target Locations, Test No. NYBBT-9

the right side of the vehicle's dash to pinpoint the time of impact with the barrier on the high-speed video footage, except for test no. NYBBT-2, in which it was mounted on the left side of the vehicle's dash. The flash bulb was fired by a pressure tape switch mounted at the impact corner 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 Simulated Occupant

A Hybrid II 50th Percentile Adult Male Dummy was used during the crash tests. For test nos. NYBBT-1, NYBBT-8, and NYBBT-9, the dummy was placed in the left-front seat of the test vehicle with the seat belt fastened. For test nos. NYBBT-2 through NYBBT-7, the dummy was placed in the right-front seat of the test vehicle with the seat belt fastened. The dummy was equipped with clothing and footwear and had a final weight of 77 kg (170 lb). The dummy was manufactured by Android Systems of Carson, California under model no. 572 and serial no. 451. As recommended by MASH, the dummy was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

Three environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. All of the accelerometers were mounted near the center of gravity of the test vehicles.

One triaxial piezoresistive accelerometer system, Model EDR-4M6, developed and manufactured by Instrumented Sensor Technology (IST) of Okemos, Michigan and includes three differential channels as well as three single-ended channels. The EDR-4 was configured with 6 MB of RAM memory, a range of ± 200 g's, a sample rate of 10,000 Hz, and a 1,500 Hz lowpass filter. “DynaMax 1 (DM-1)” and “DADiSP” computer software programs were used to analyze and plot the accelerometer data.

The second system was a two-arm piezoresistive accelerometer developed by Endevco of San Juan Capistrano, California. Three accelerometers were used to measure each of the longitudinal, lateral, and vertical accelerations independently at a sample rate of 10,000 Hz. The accelerometers were configured and controlled using a system developed and manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. More specifically, data was collected using a DTS Sensor Input Module (SIM), Model TDAS3-SIM-16M. The SIM was configured with 16 MB SRAM memory and 8 sensor input channels with 250 kB SRAM/channel. The SIM was mounted on a TDAS3-R4 module rack. The module rack was configured with isolated power/event/communications, 10BaseT Ethernet and RS232 communication, and an internal backup battery. Both the SIM and module rack were crashworthy. The computer software program “DTS TDAS Control” and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

The third system, Model EDR-3, was a triaxial piezoresistive accelerometer system developed and manufactured by IST of Okemos, Michigan. The EDR-3 was configured with 256 kB of RAM memory, a range of ± 200 g’s, a sample rate of 3,200Hz, and a 1,120 Hz lowpass filter. “DynaMax 1 (DM-1)” and “DADiSP” computer software programs and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

As a replacement for the triaxial piezoresistive accelerometer system used in test nos. NYBBT-1 through NYBBT-6, a different triaxial piezoresistive accelerometer system was used for test nos. NYBBT-7 and NYBBT-8. The triaxial piezoresistive accelerometer system, Model EDR-4-6DOF-500/1200, was developed and manufactured by IST of Okemos, Michigan and includes three differential channels as well as three single-ended channels. The EDR-4-6DOF-500/1200 was configured with 24 MB of RAM memory, a range of ± 500 g's, a sample rate of 10,000 Hz, and a 1,667 Hz anti-aliasing filter. "EDR4COM" and "DynaMax Suite" computer software programs and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

4.5.2 Rate Transducers

An Analog System 3-axis rate transducer with a range of 1,200 degrees/sec in each of the three directions (roll, pitch, and yaw) was used to measure the rates of motion of the test vehicle. The rate transducer was mounted inside the body of the EDR-4M6. Data was recorded at 10,000 Hz to a second data acquisition board inside the EDR-4M6 housing. The raw data measurements were then downloaded, converted to the appropriate Euler angles for analysis, and plotted. "DynaMax 1 (DM-1)" and "DADiSP" computer software programs and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

An additional angular rate sensor, the ARS-1500, with a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw) was used to measure the rates of rotation of the test vehicle. The angular rate sensor was mounted on an aluminum block inside the test vehicle near the center of gravity. Data was recorded at 10,000 Hz to the SIM unit. The raw data measurements were then downloaded, converted to the proper Euler angles for analysis, and plotted. The computer softward program "DTS TDAS Control" and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

As a replacement for the Analog Systems 3-axis rate transducer used in test nos. NYBBT-1 through NYBBT-6, a different Analog Systems 3-axis rate transducer was used for test nos. NYBBT-7 and NYBBT-8. The Analog Systems 3-axis rate transducer with a range of

1,200 degrees/sec in each of the three directions (roll, pitch, and yaw) was used to measure the rates of motion of the test vehicles. The rate transducer was mounted inside the body of the EDR-4-6DOF-500/1200 housing. Data was recorded at 10,000 Hz to a second data acquisition board inside the EDR-4-6DOF-500/1200 housing. The raw data measurements were then downloaded, converted to the appropriate Euler angles for analysis, and plotted. “EDR4COM” and “DynaMax Suite” computer software programs and a customized Microsoft Excel worksheet were used to analyze and plot the rate transducer data.

4.5.3 Pressure Tape Switches

For all nine tests, five pressure-activated tape switches, spaced at 2-m (6.6-ft) intervals, were used to determine the speed of the vehicle before impact. 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 it for test nos. NYBBT-1, NYBBT-3, and NYBBT-7 through NYBBT-9 and the right-front tire for test nos. NYBBT-2 and NYBBT-4 through NYBBT-6. Test vehicle speeds were determined from the electronic timing mark data recorded using TestPoint computer software program. Strobe lights and high-speed video analysis provided a backup method of determining the vehicle speed in the event that it could not be determined from the electronic data.

4.5.4 High-Speed Photography

Five AOS VITcam high-speed digital video cameras, four JVC digital video cameras, and two Canon digital video cameras were used to film crash test no. NYBBT-1. Five AOS VITcam high-speed digital video cameras, five JVC digital video cameras, and two Canon digital video cameras were used to film crash test no. NYBBT-2. Four AOS VITcam high-speed digital video cameras, one AOS miniVIS high-speed digital video camera, five JVC digital video cameras, and two Canon digital video cameras were used to film crash test no. NYBBT-3. Three AOS VITcam high-speed digital video cameras, one AOS X-PRI high-speed digital video camera, five JVC digital video cameras, and two Canon digital video cameras were used to film crash test nos. NYBBT-4, NYBBT-5, NYBBT-6, and NYBBT-7. Two AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and two Canon digital cameras were used to film crash test no. NYBBT-8. Three AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and two Canon digital cameras were used to film crash test no. NYBBT-9.

Camera details, camera operating speed, lens information, and a schematic of the camera locations relative to the system for test nos. NYBBT-1 through NYBBT-9 are shown in Figures 28 through 36, respectively. The high-speed videos were analyzed using ImageExpress MotionPlus and Redlake Motion Scope computer software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos.

	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	1	AOS VITcam CTM	500	12.5 mm fixed	- -
	2	AOS VITcam CTM	500	NIKKOR 20 mm fixed	- -
	3	AOS VITcam CTM	500	Sigma 24-70	24
	4	AOS VITcam CTM	500	Sigma 70-200	70
		AOS DEMO	500	FUJINON 50 mm fixed	- -
Digital Video	2	JVC - GZ-MC40u(Everio)	29.97		
	3	JVC - GZ-MC40u(Everio)	29.97		
	4	JVC - GZ-MC40u(Everio)	29.97		
	5	JVC - GZ-MC27u(Everio)	29.97		
	7	Canon - ZR90	29.97		
	8	Canon - ZR90	29.97		

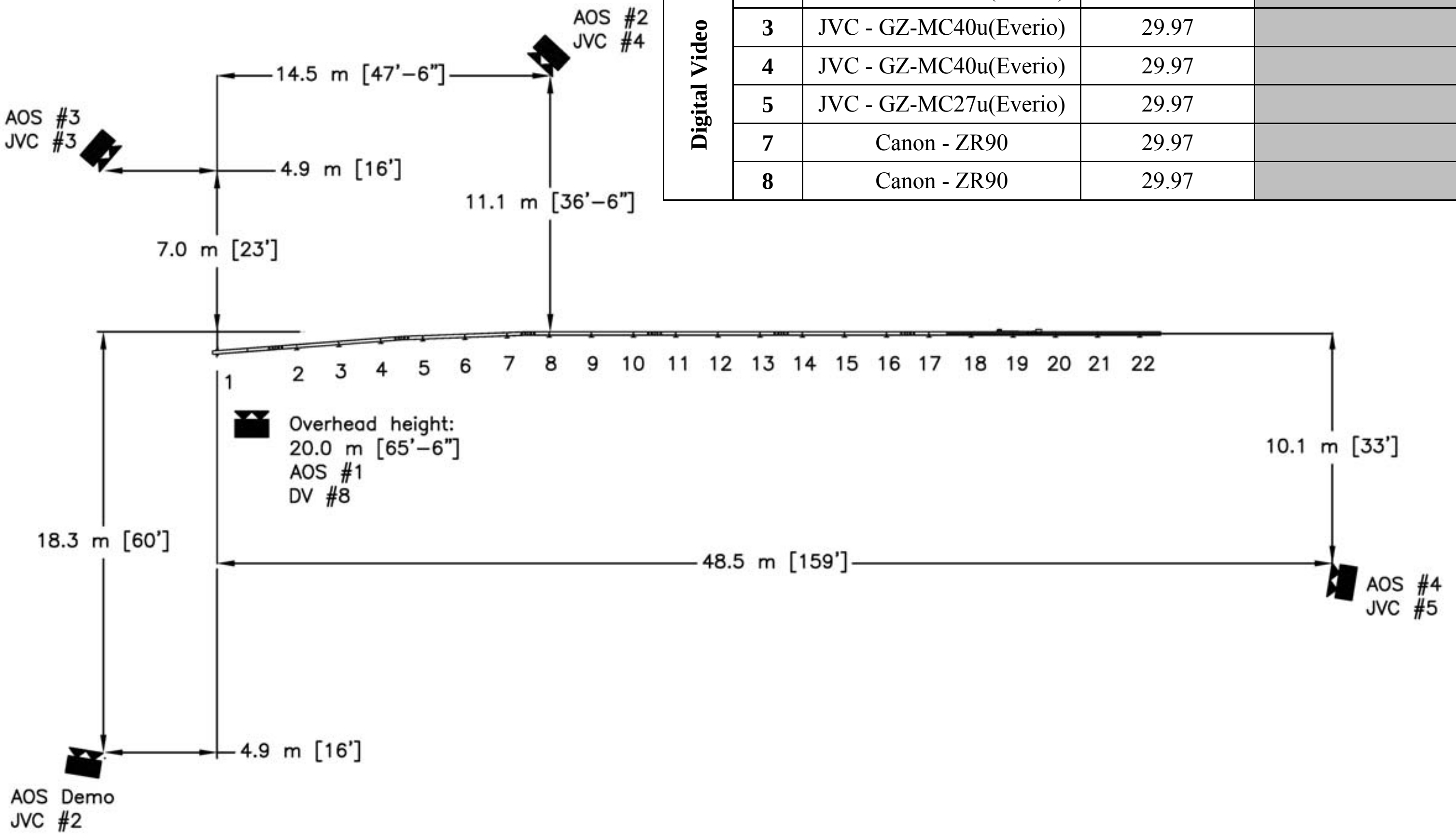


Figure 28. Location of Cameras, Test No. NYBBT-1

	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	**1**	AOS VITcam CTM	500	12.5 mm fixed	- -
	2	AOS VITcam CTM	500	50 mm fixed	- -
	3	AOS VITcam CTM	500	Sigma 24-70	24
	4	AOS VITcam CTM	500	Sigma 70-200	135
	DEMO	AOS VITcam CTM	500	20 mm fixed	- -
Digital Video	**1**	JVC - GZ-MC500(Everio)	29.97		
	2	JVC - GZ-MC40u(Everio)	29.97		
	3	JVC - GZ-MC40u(Everio)	29.97		
	4	JVC - GZ-MC40u(Everio)	29.97		
	5	JVC - GZ-MC27u(Everio)	29.97		
	7	Canon - ZR90	29.97		
	8	Canon - ZR90	29.97		

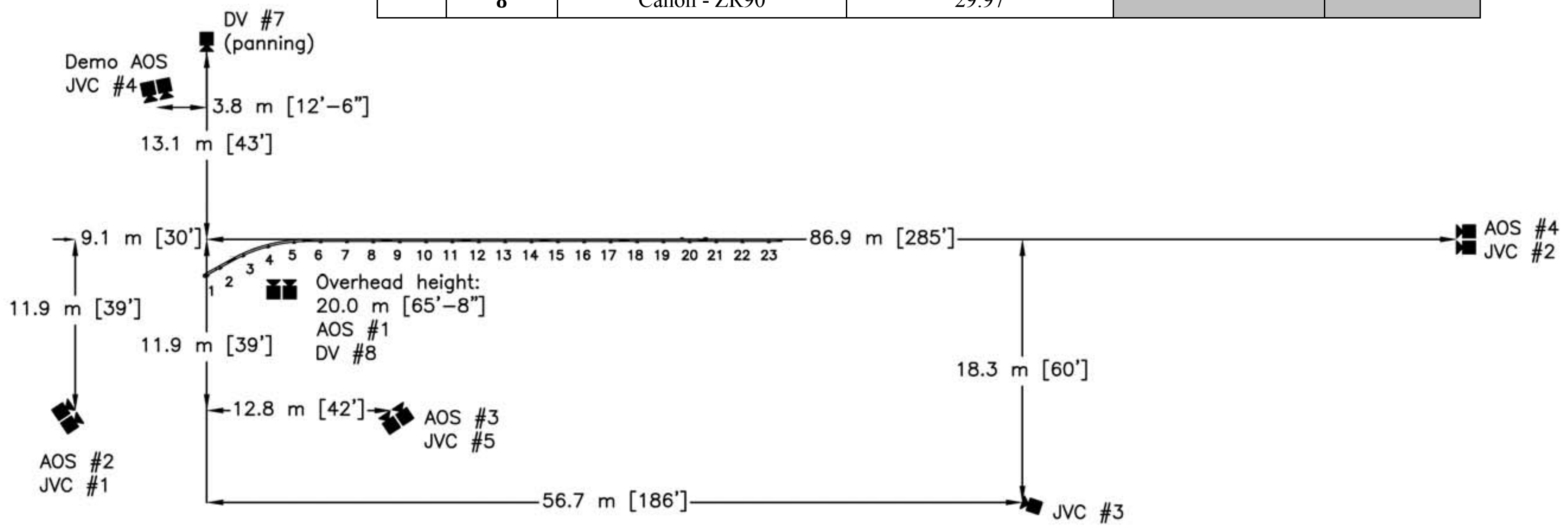


Figure 29. Location of Cameras, Test No. NYBBT-2

	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	**1**	AOS VITcam CTM	500	12.5 mm fixed	- -
	2	AOS VITcam CTM	500	Sigma 50 mm fixed	- -
	3	AOS VITcam CTM	500	Sigma 24-70	50
	4	AOS VITcam CTM	500	Sigma 70-200	135
		AOS Mini Vis	500	Cosmicar 12.5mm fixed	- -
Digital Video	**1**	JVC - GZ-MC500(Everio)	29.97		
	2	JVC - GZ-MC40u(Everio)	29.97		
	3	JVC - GZ-MC40u(Everio)	29.97		
	4	JVC - GZ-MC40u(Everio)	29.97		
	5	JVC - GZ-MC27u(Everio)	29.97		
	7	Canon - ZR90	29.97		
	8	Canon - ZR90	29.97		

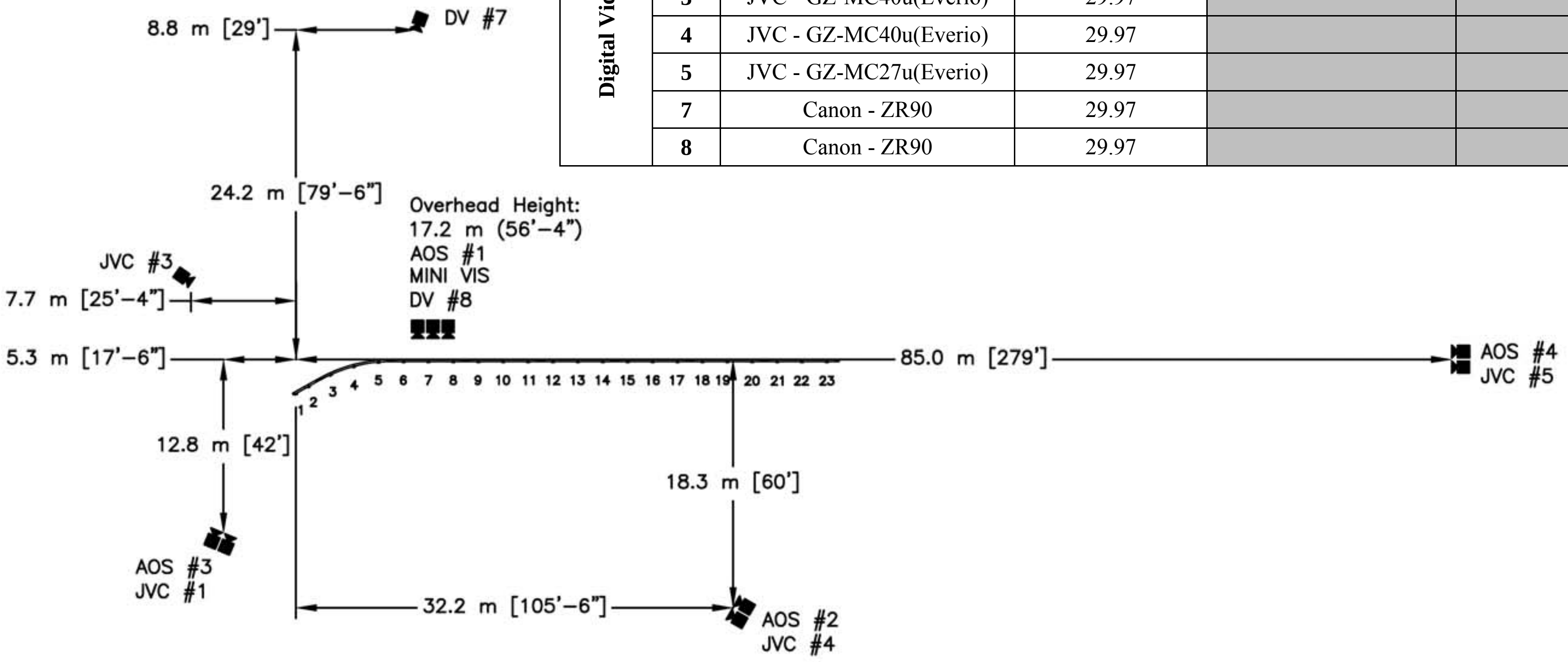


Figure 30. Location of Cameras, Test No. NYBBT-3

	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	2	AOS VITcam CTM	500	12.5 mm fixed	- -
	3	AOS VITcam CTM	500	Sigma 55 mm	- -
	4	AOS VITcam CTM	500	Sigma 70-200	Unknown
	5	AOS X-PRI Gigabit	500	Sigma 24-70	24
Digital Video	1	JVC - GZ-MC500 (Everio)	29.97		
	2	JVC - GZ-MC40u(Everio)	29.97		
	3	JVC - GZ-MC40u(Everio)	29.97		
	4	JVC - GZ-MC40u(Everio)	29.97		
	5	JVC - GZ-MC27u(Everio)	29.97		
	7	Canon - ZR90	29.97		
	8	Canon - ZR90	29.97		

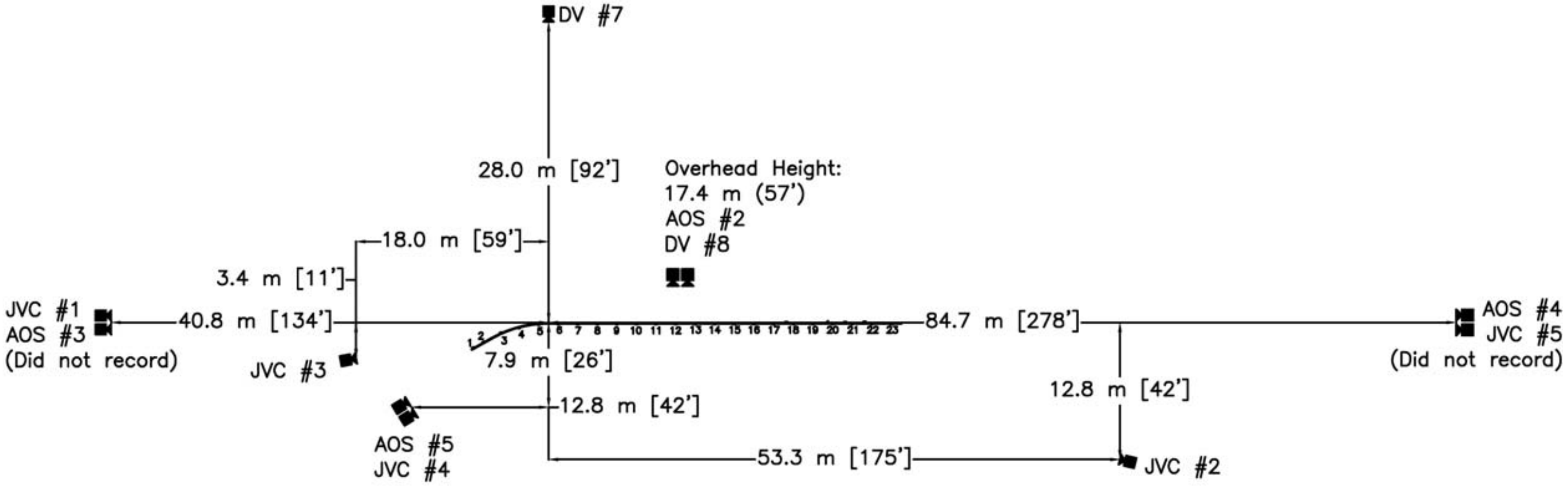


Figure 31. Location of Cameras, Test No. NYBBT-4

	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	**2**	AOS VITcam CTM	500	12.5 mm fixed	- -
	3	AOS VITcam CTM	500	Fixed 50 mm	- -
	4	AOS VITcam CTM	500	Sigma 24-70	28
	5	AOS X-PRI Gigabit	500	Sigma 70-200	135
Digital Video	**1**	JVC - GZ-MC500 (Everio)	29.97		
	2	JVC - GZ-MC40u(Everio)	29.97		
	3	JVC - GZ-MC40u(Everio)	29.97		
	4	JVC - GZ-MC40u(Everio)	29.97		
	5	JVC - GZ-MC27u(Everio)	29.97		
	7	Canon - ZR90	29.97		
	8	Canon - ZR90	29.97		

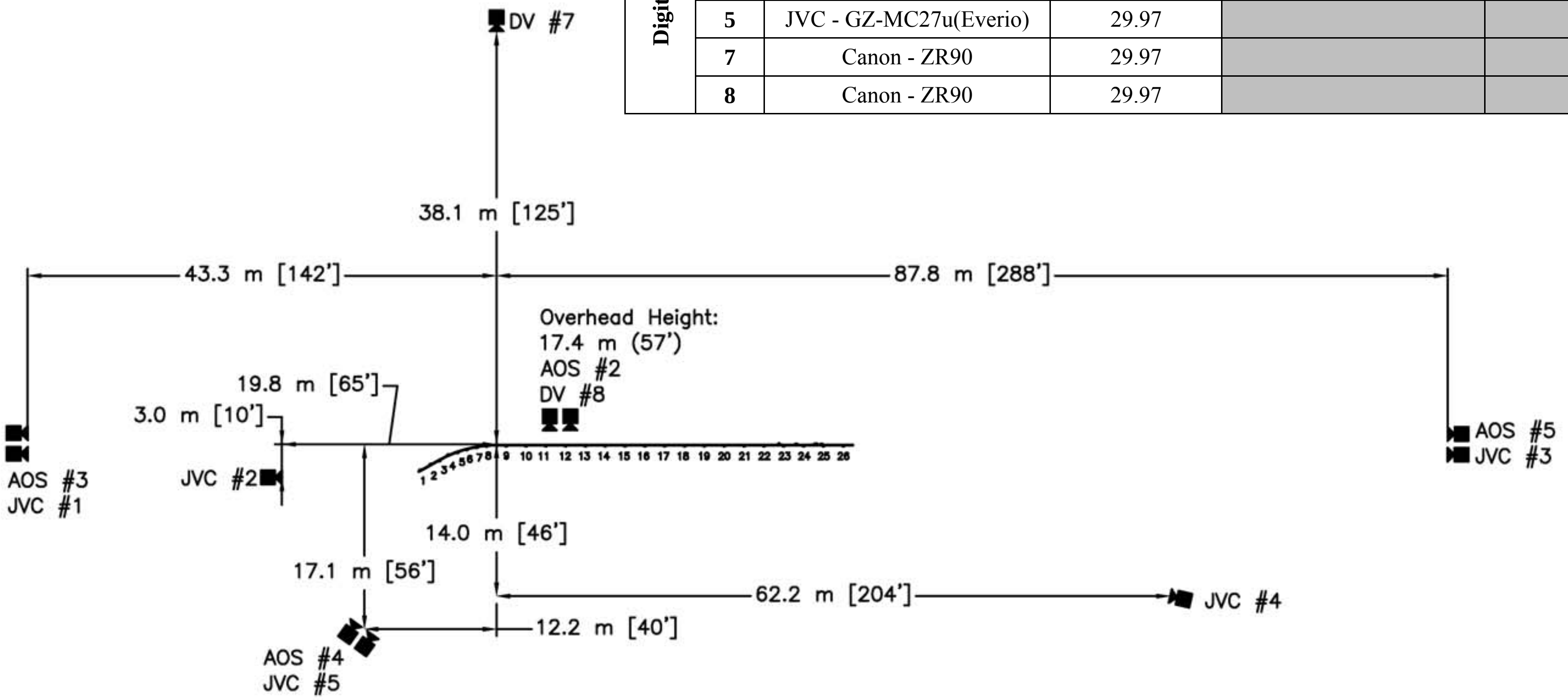


Figure 32. Location of Cameras, Test No. NYBBT-5

	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	**2**	AOS VITcam CTM	500	8 mm fixed	- -
	3	AOS VITcam CTM	500	12.5 mm fixed	- -
	4	AOS VITcam CTM	500	Sigma 24-70	70
	5	AOS X-PRI Gigabit	500	Sigma 70-200	70
Digital Video	**1**	JVC - GZ-MC500 (Everio)	29.97		
	2	JVC - GZ-MC40u(Everio)	29.97		
	3	JVC - GZ-MC40u(Everio)	29.97		
	4	JVC - GZ-MC40u(Everio)	29.97		
	5	JVC - GZ-MC27u(Everio)	29.97		
	7	Canon - ZR90	29.97		
	8	Canon - ZR90	29.97		

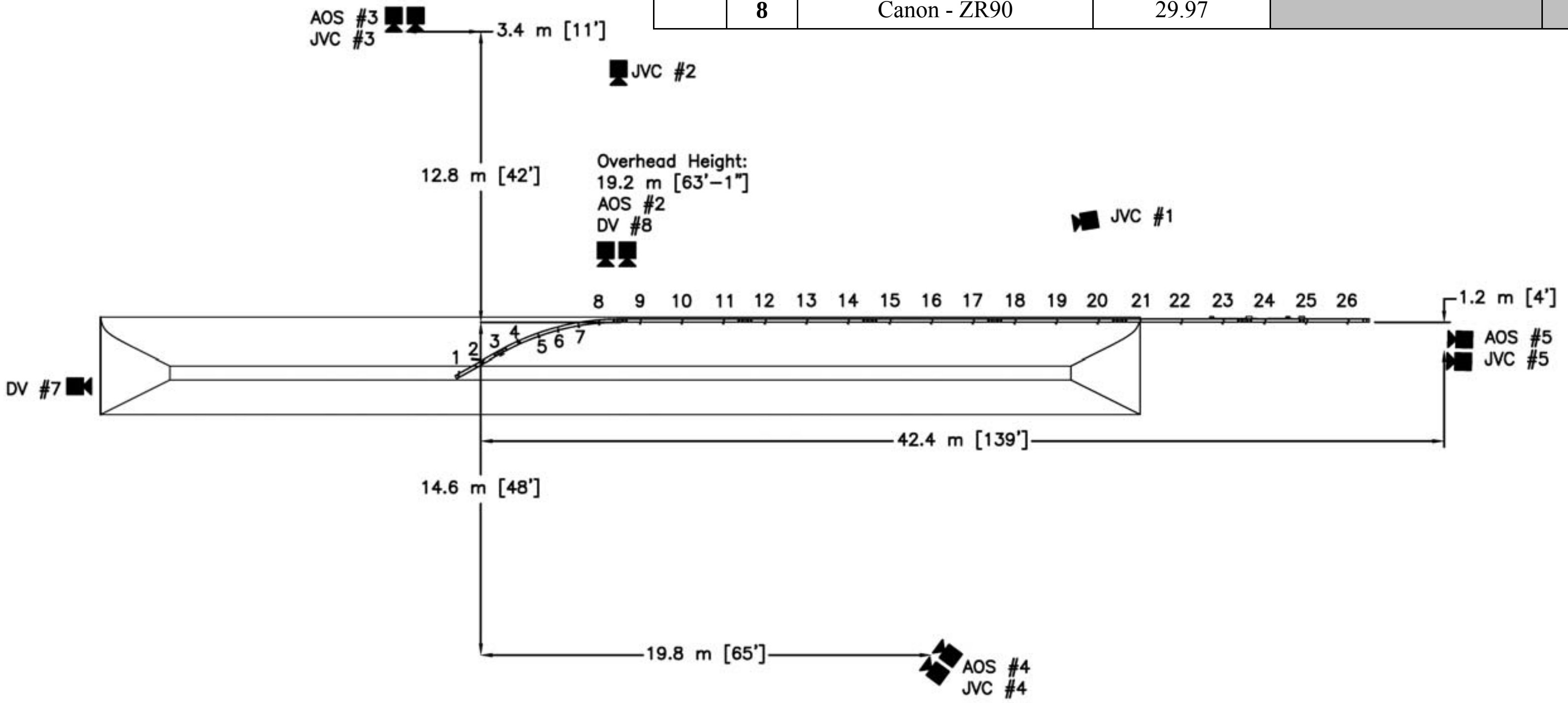
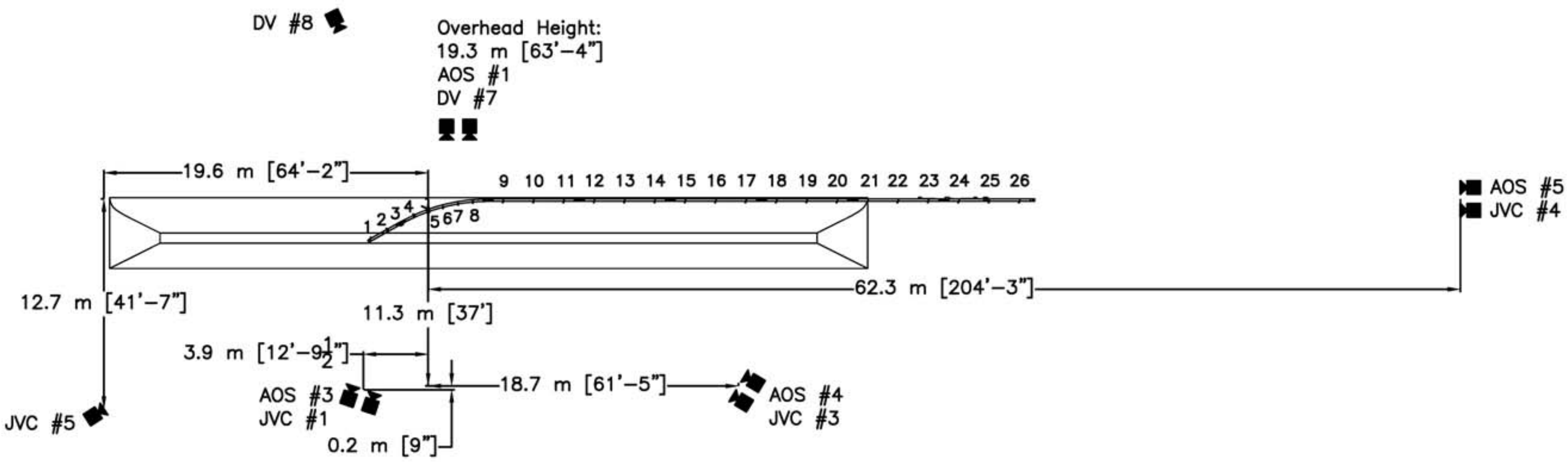
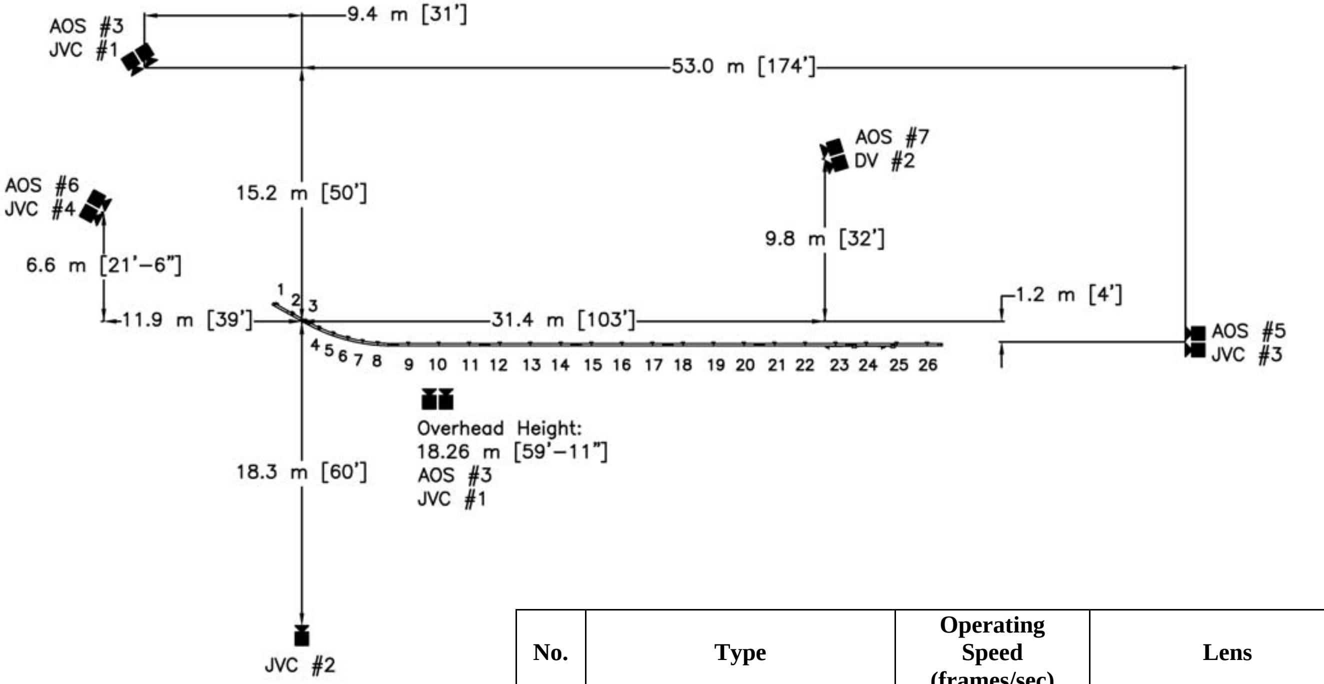


Figure 33. Location of Cameras, Test No. NYBBT-6



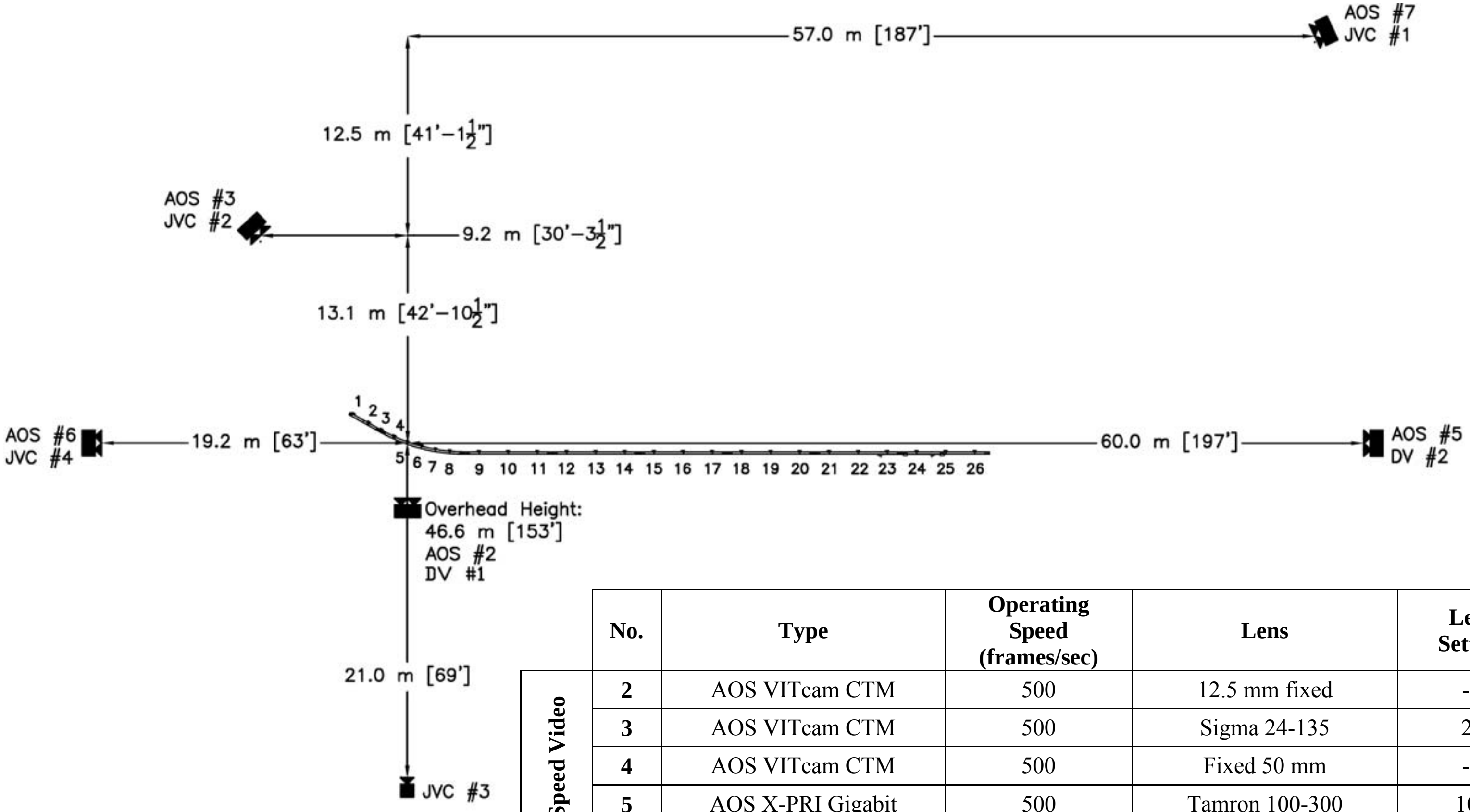
	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	2	AOS VITcam CTM	500	12.5 mm fixed	- -
	3	AOS VITcam CTM	500	Sigma 24-135	24
	4	AOS VITcam CTM	500	Fixed 50 mm	- -
	5	AOS X-PRI Gigabit	500	Sigma 70-200	100
Digital Video	1	JVC - GZ-MC500 (Everio)	29.97		
	3	JVC - GZ-MC40u(Everio)	29.97		
	4	JVC - GZ-MC40u(Everio)	29.97		
	5	JVC - GZ-MC27u(Everio)	29.97		
	7	Canon - ZR90	29.97		
	8	Canon - ZR90	29.97		

Figure 34. Location of Cameras, Test No. NYBBT-7



	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	2	AOS VITcam CTM	500	12.5 mm fixed	- -
	3	AOS VITcam CTM	500	Fujinon Fixed 50 mm	- -
	5	AOS X-PRI Gigabit	500	Tamron 100-300	100
	6	AOS X-PRI Gigabit	500	Sigma 24-70	24
	7	AOS X-PRI Gigabit	500	Sigma 50 mm Fixed	- -
Digital Video	1	JVC - GZ-MC500 (Everio)	29.97		
	2	JVC - GZ-MG27u(Everio)	29.97		
	3	JVC - GZ-MG27u(Everio)	29.97		
	4	JVC - GZ-MG27u(Everio)	29.97		
	1	Canon - ZR90	29.97		
	2	Canon - ZR10	29.97		

Figure 35. Location of Cameras, Test No. NYBBT-8



	No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
High-Speed Video	**2**	AOS VITcam CTM	500	12.5 mm fixed	- -
	3	AOS VITcam CTM	500	Sigma 24-135	24
	4	AOS VITcam CTM	500	Fixed 50 mm	- -
	5	AOS X-PRI Gigabit	500	Tamron 100-300	100
	6	AOS X-PRI Gigabit	500	Fujinon Fixed 50 mm	- -
	7	AOS X-PRI Gigabit	500	Sigma 24-70	Unknown
Digital Video	**1**	JVC - GZ-MC500 (Everio)	29.97		
	2	JVC - GZ-MC27u(Everio)	29.97		
	3	JVC - GZ-MC27u(Everio)	29.97		
	4	JVC - GZ-MC27u(Everio)	29.97		
	1	Canon - ZR90	29.97		
	2	Canon - ZR10	29.97		

Figure 36. Location of Cameras, Test No. NYBBT-9

5 TYPE II END TERMINAL - NYBBT-1 SYSTEM DETAILS

The 41.2-m (135.2-ft) long test installation consisted of 38.1 m (125 ft) of the NYSDOT's standard TS 152-mm x 152-mm x 4.8-mm (6-in. x 6-in. x 3/16-in.) steel tube box-beam guide rail with a Type II terminal. Design details are shown in Figures 37 through 49. The corresponding English-unit drawings are shown in Appendix B. Photographs of the test installation are shown in Figures 50 through 53.

The entire system was supported by twenty-two S76x8.5 (S3x5.7) steel guide rail posts with 610-mm x 203-mm x 6-mm (24-in. x 8-in. x 1/4-in.) soil plates. All posts were 1,600 mm (63 in.) long, except the two mounting posts utilized for post no. 1, which were 838 mm (33 in.) long. Post nos. 1 and 2 were spaced 3,459 mm (136 3/16 in.) on center, while the other posts were spaced 1,829 mm (72 in.) on centers. The embedment depths for post nos. 1, 2, 3, 4, as well as for 5 through 22 were 708 mm (27 7/8 in.), 1,073 mm (42 1/4 in.), 1,003 mm (39 1/2 in.), 933 mm (36 3/4 in.), and 914 mm (36 in.), respectively. The tops of the posts were positioned flush with the top of the rail, as shown in Figure 42. The top height for the standard box beam rail was 686 mm (27 in.). The rail was connected to box beam shelf angles on post nos. 2 through 22 with a 9.5-mm (3/8-in.) diameter by 191-mm (7 1/2-in.) long, ASTM A307 hex head bolt. The 127-mm x 89-mm x 9.5-mm (5-in. x 3 1/2-in. x 3/8-in.) box beam shelf angle was connected to the posts with one 12.7-mm (1/2-in.) diameter by 51-mm (2-in.) long, ASTM A307 hex head bolt with a 12.7-mm (1/2-in.) narrow washer.

The box beam rail was comprised of ASTM A500B structural steel tubes. Each section of steel tube was 5,486 mm (18 ft) long. The steel tube sections were connected together with splices located at the midspan between two posts. The rail between post nos. 1 and 5 tapered down at a slope of 26.4:1, as shown in Figures 37 and 38. The end assembly rail was tapered with a slope of 4.6:1 until the ground, as shown in Figures 37, 38, and 43.

The Type II terminal utilized two S76x8.5 (S3x5.7) steel posts driven flush with the end of the rail, one on either side, to provide lateral resistance, as shown in Figures 38, 42, and 51. A 9.5-mm (3/8-in.) diameter by 254-mm (10-in.) long, ASTM A307 hex head bolt connected the rail to the posts at post no. 1. For reverse direction impacts, the bolt was intended to shear, thus releasing the rail to prevent snagging. The end of the terminal was partially buried in the ground, as shown in Figures 38, 42, and 51.

Between post nos. 19 and 20, the rail was anchored to the ground using a reverse cable anchorage system to develop the longitudinal resistance in the rail for end-on impacts. The upper end of the cable was connected to a mounting plate bolted to the box beam splice, while the lower end of the cable was connected to a buried pile end anchor, as shown in Figures 37 and 53.

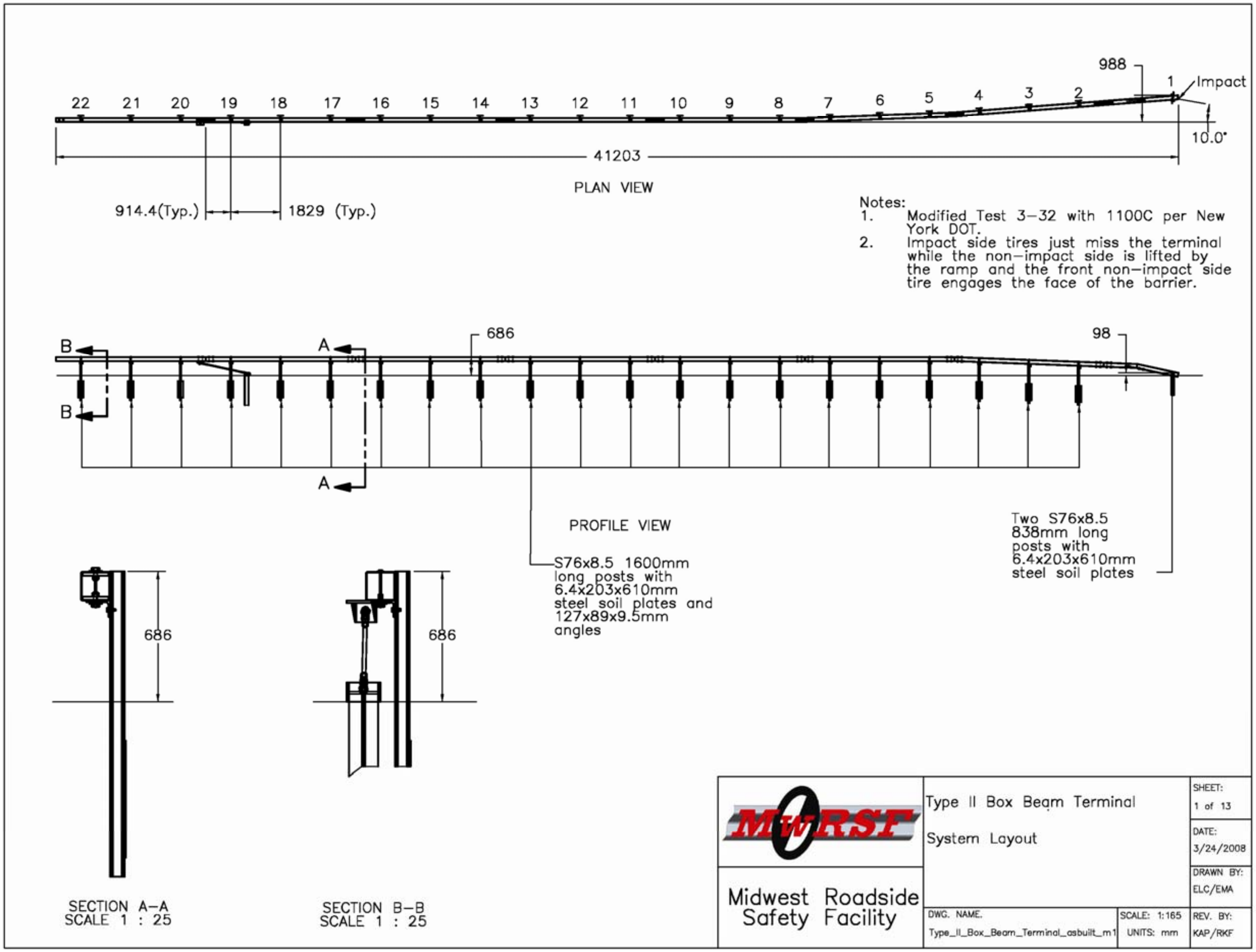


Figure 37. Type II Box Beam System Details, Test No. NYBBT-1

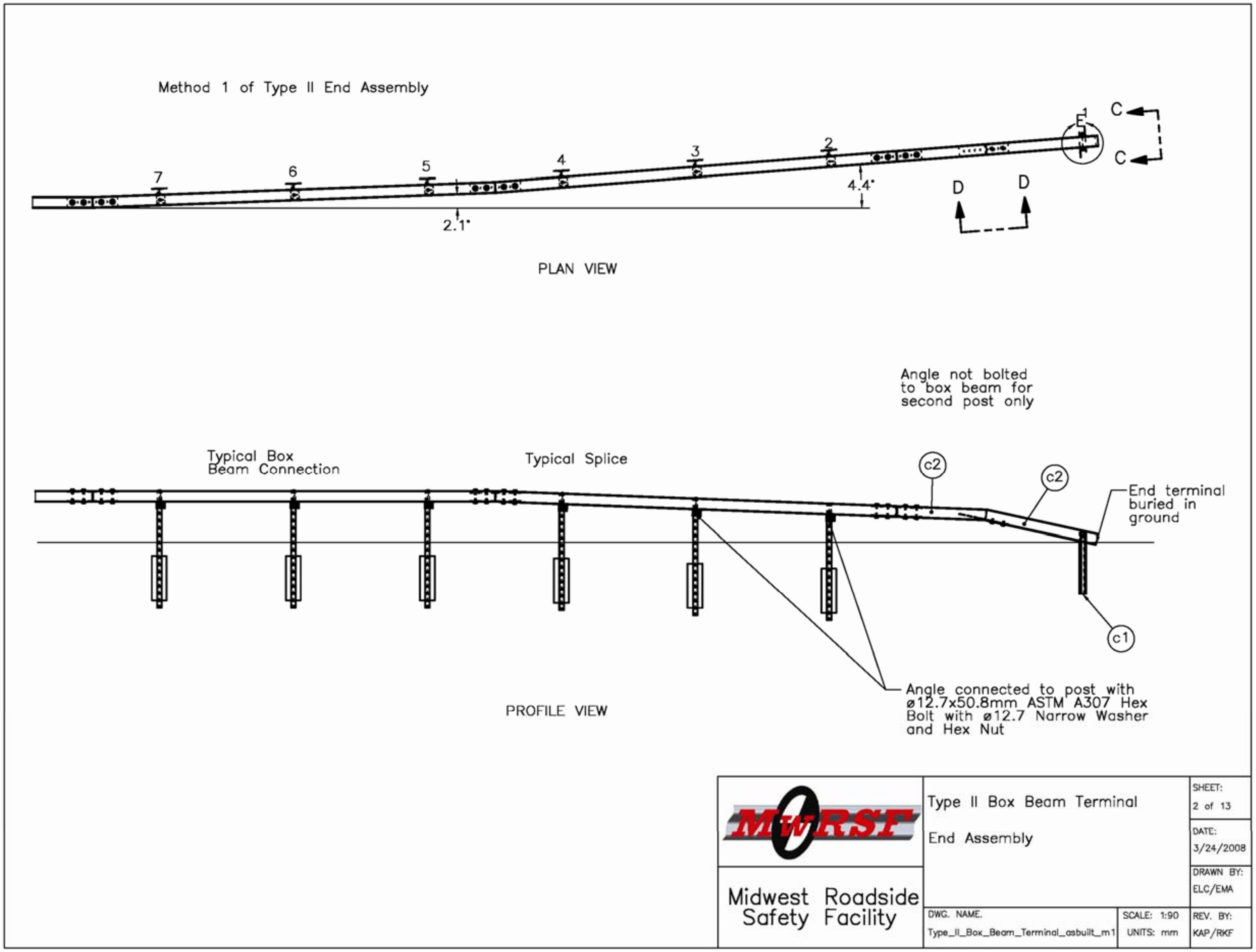


Figure 38. Type II Box Beam System Details, Test No. NYBBT-1

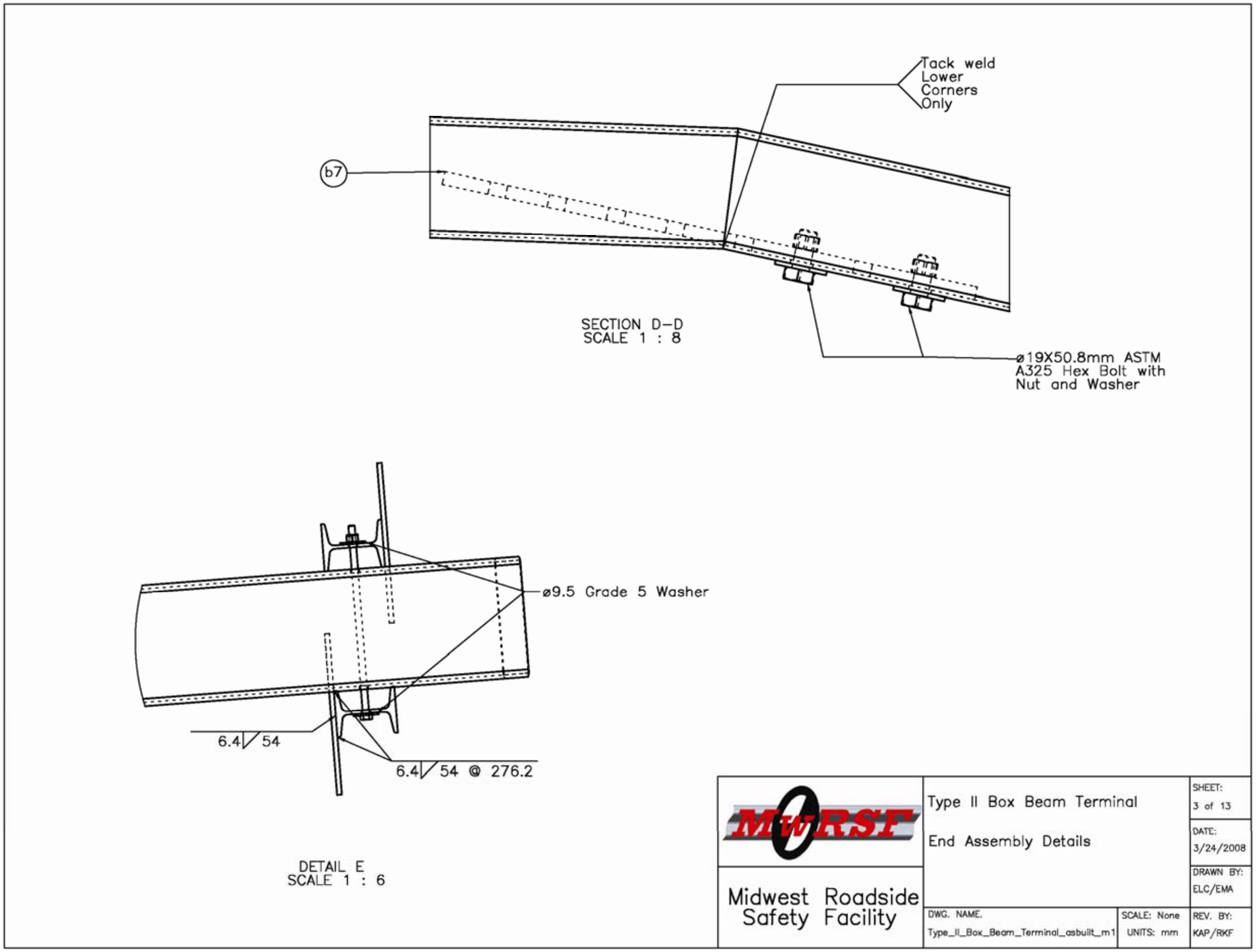


Figure 39. Type II Box Beam System Details, Test No. NYBBT-1

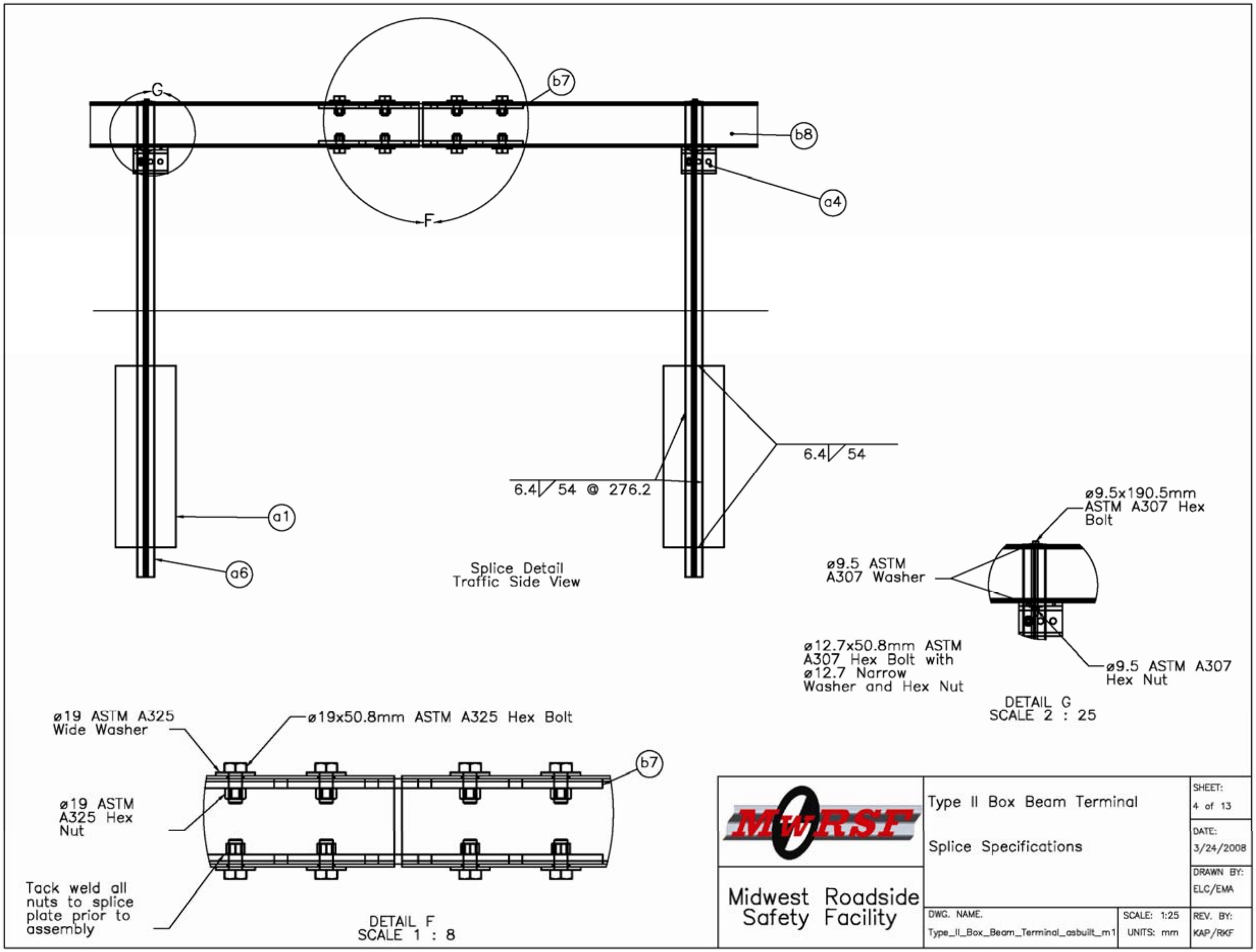


Figure 40. Type II Box Beam System Details, Test No. NYBBT-1

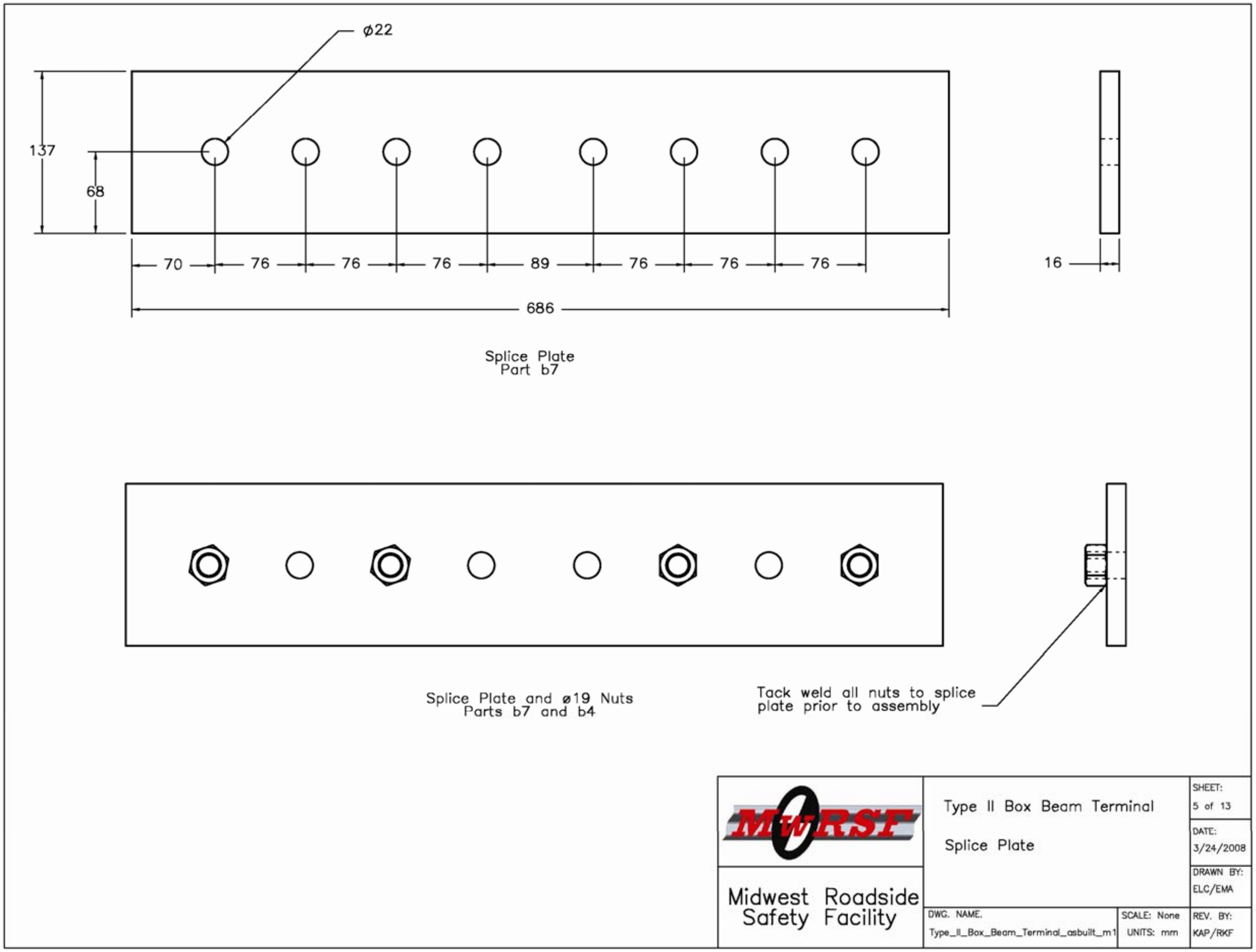


Figure 41. Type II Box Beam System Details, Test No. NYBBT-1

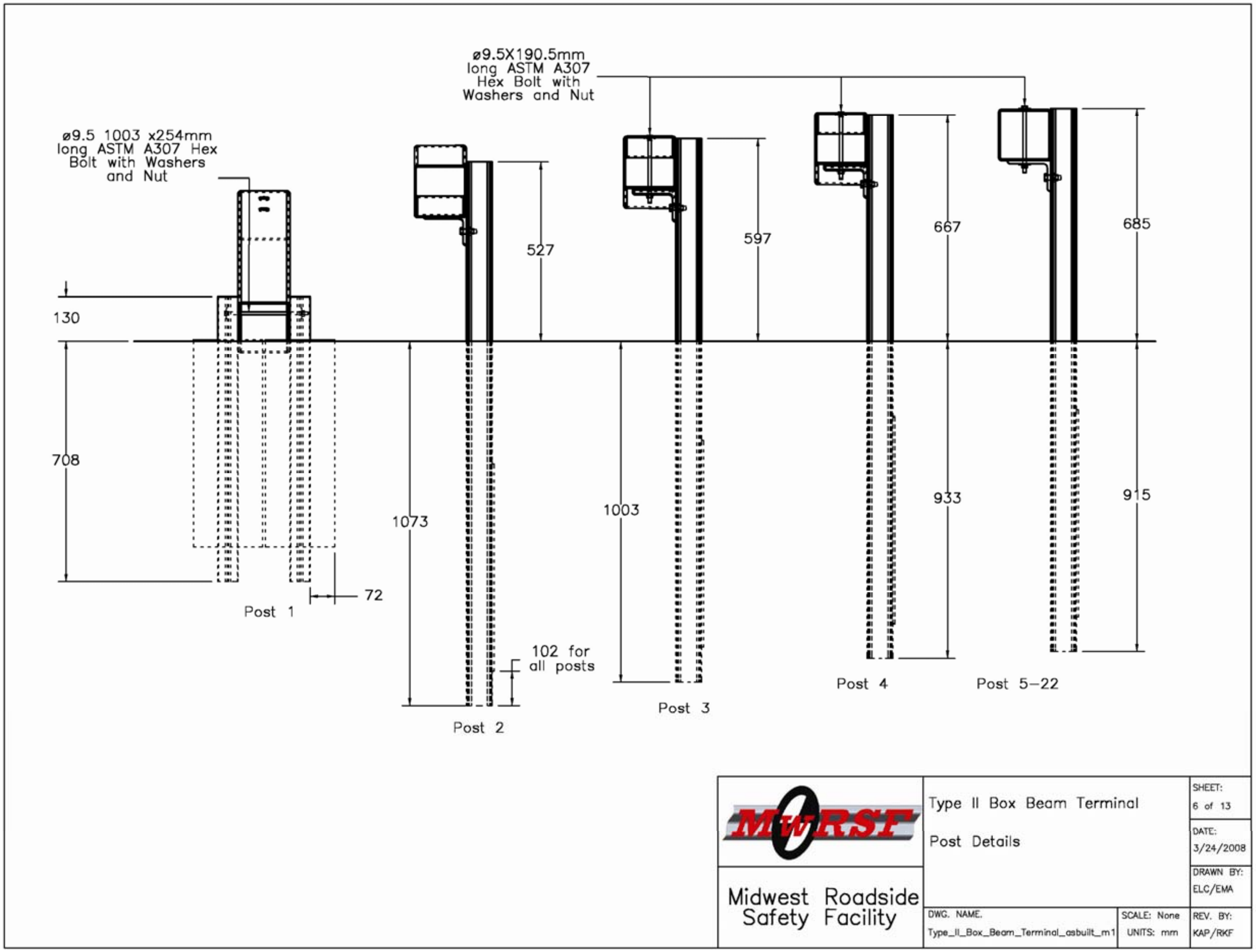


Figure 42. Type II Box Beam System Details, Test No. NYBBT-1

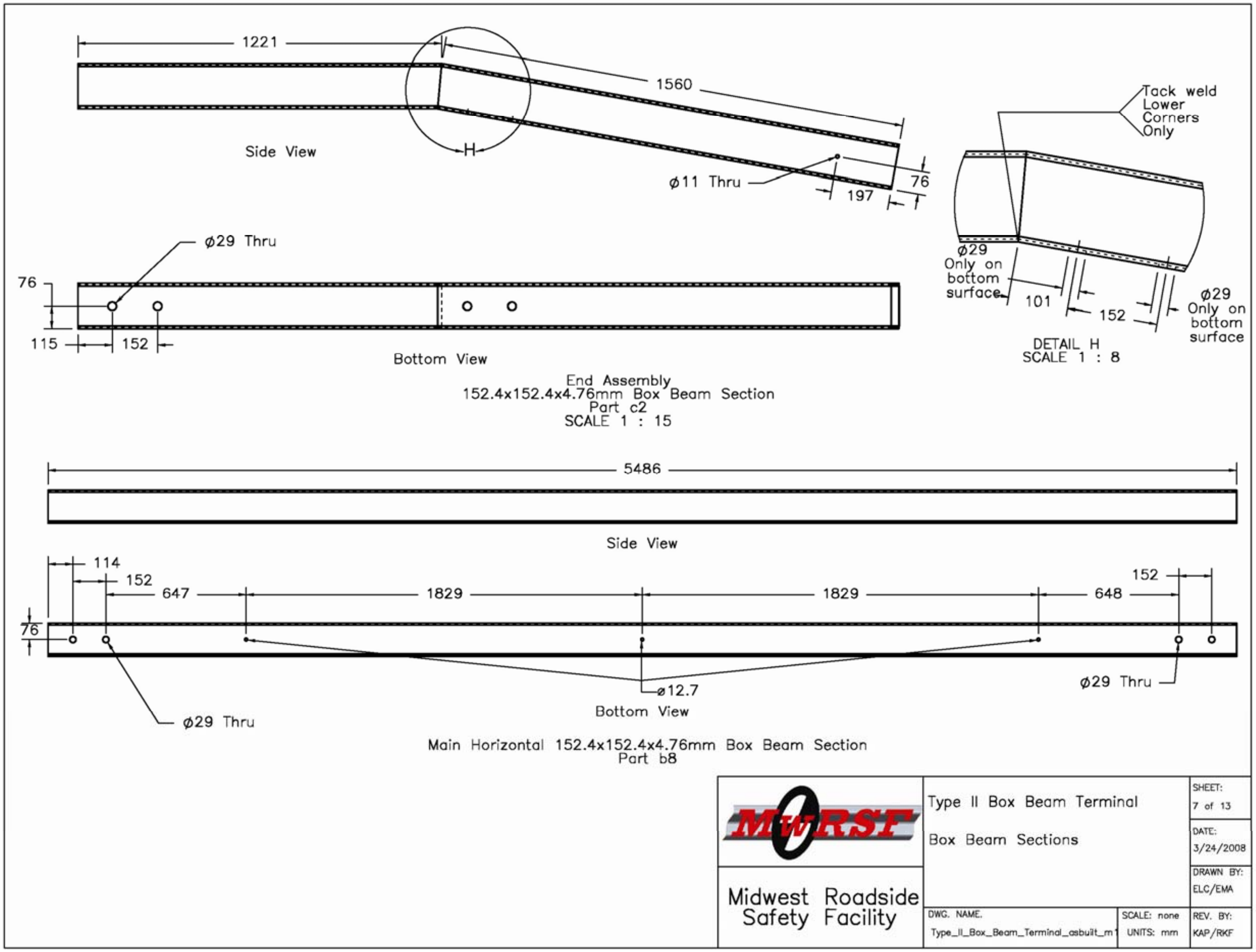


Figure 43. Type II Box Beam System Details, Test No. NYBBT-1

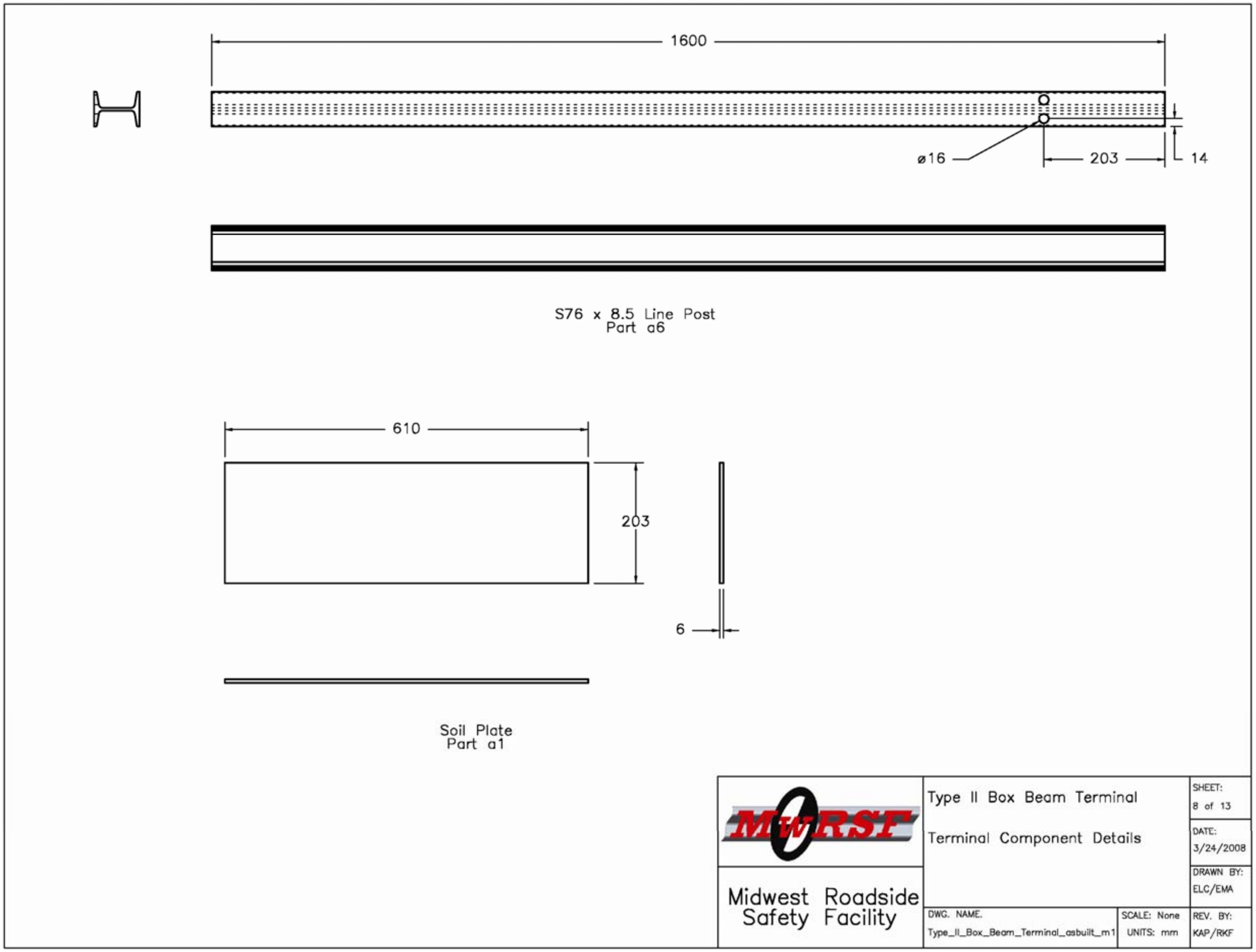


Figure 44. Type II Box Beam System Details, Test No. NYBBT-1

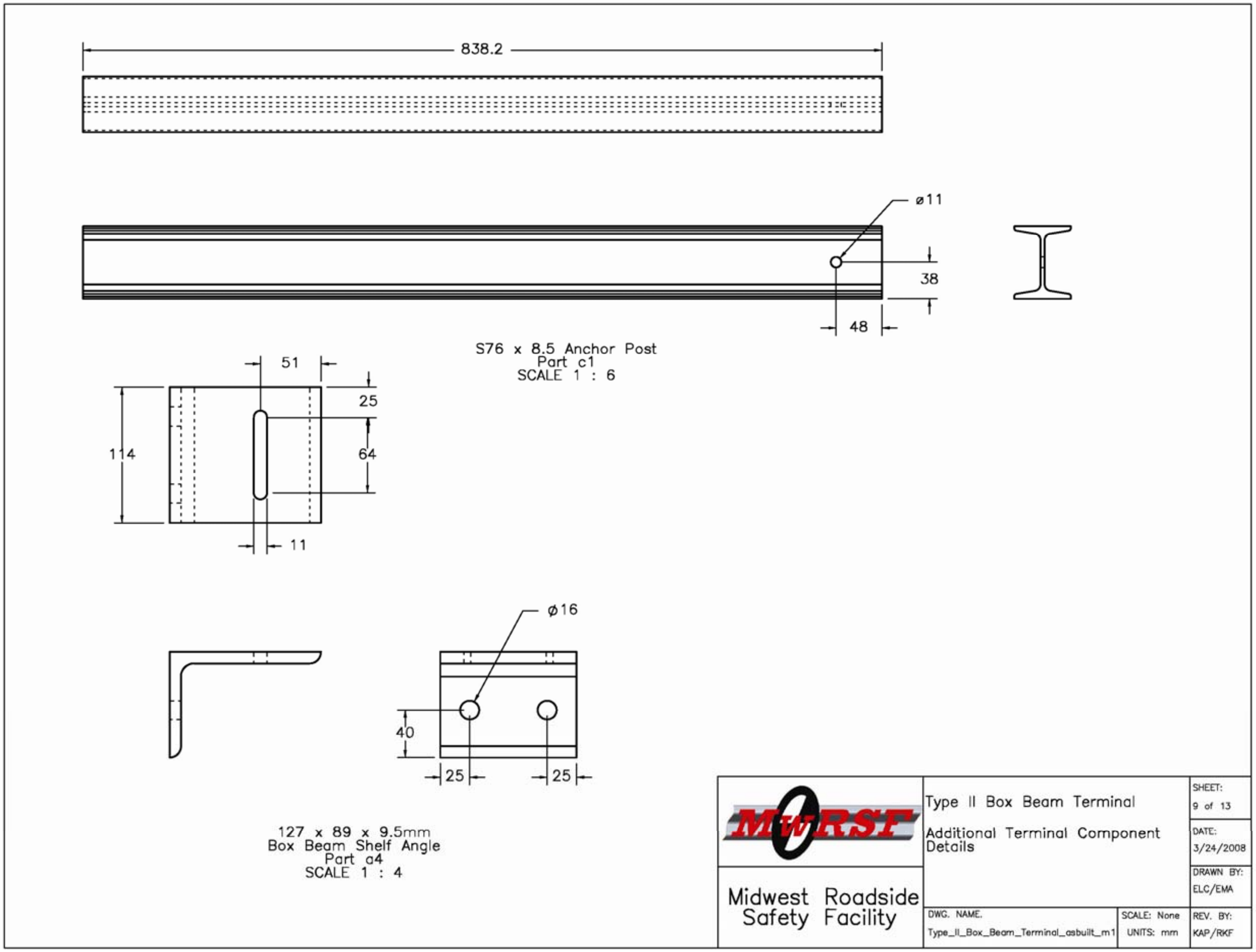


Figure 45. Type II Box Beam System Details, Test No. NYBBT-1

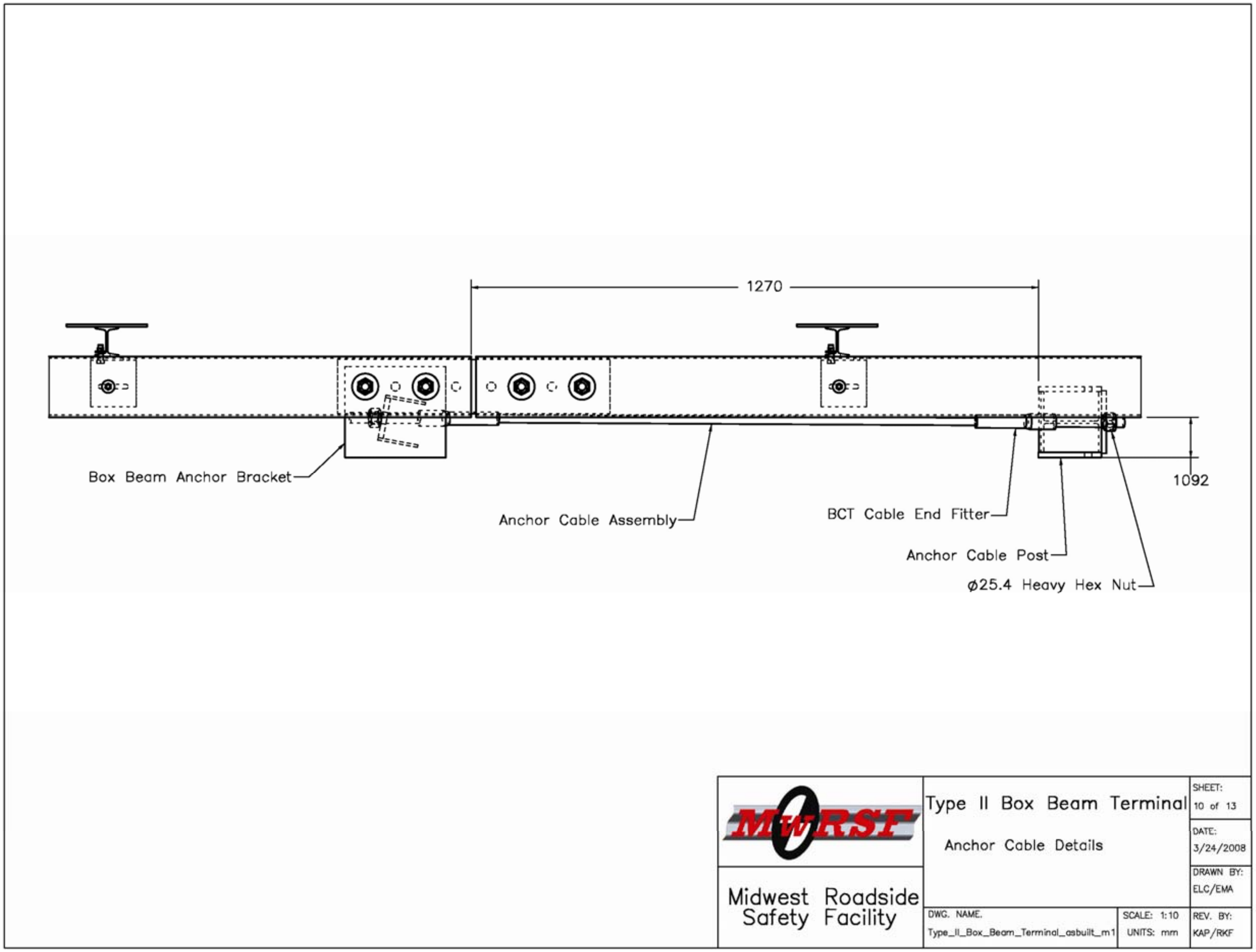


Figure 46. Type II Box Beam System Details, Test No. NYBBT-1

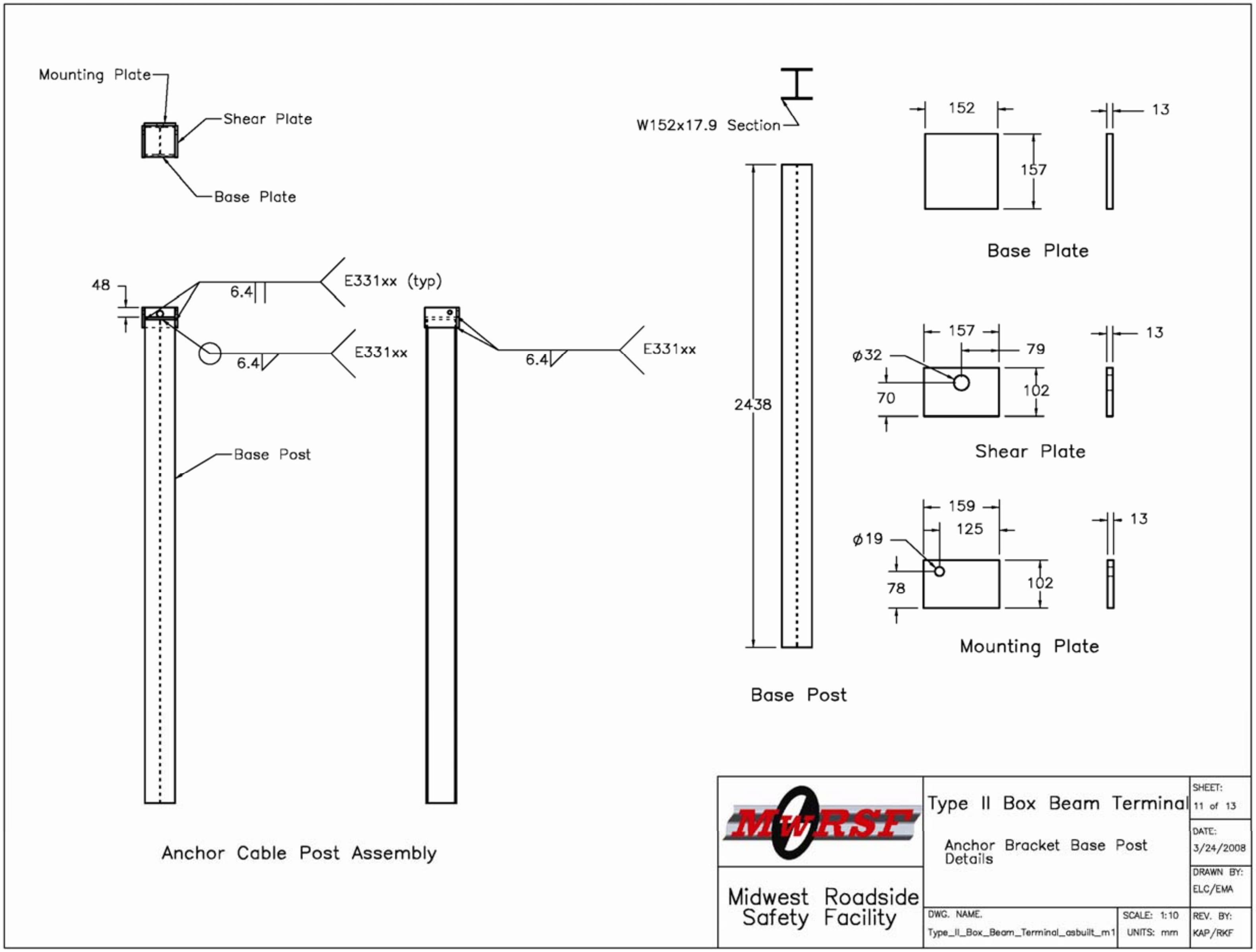


Figure 47. Type II Box Beam System Details, Test No. NYBBT-1

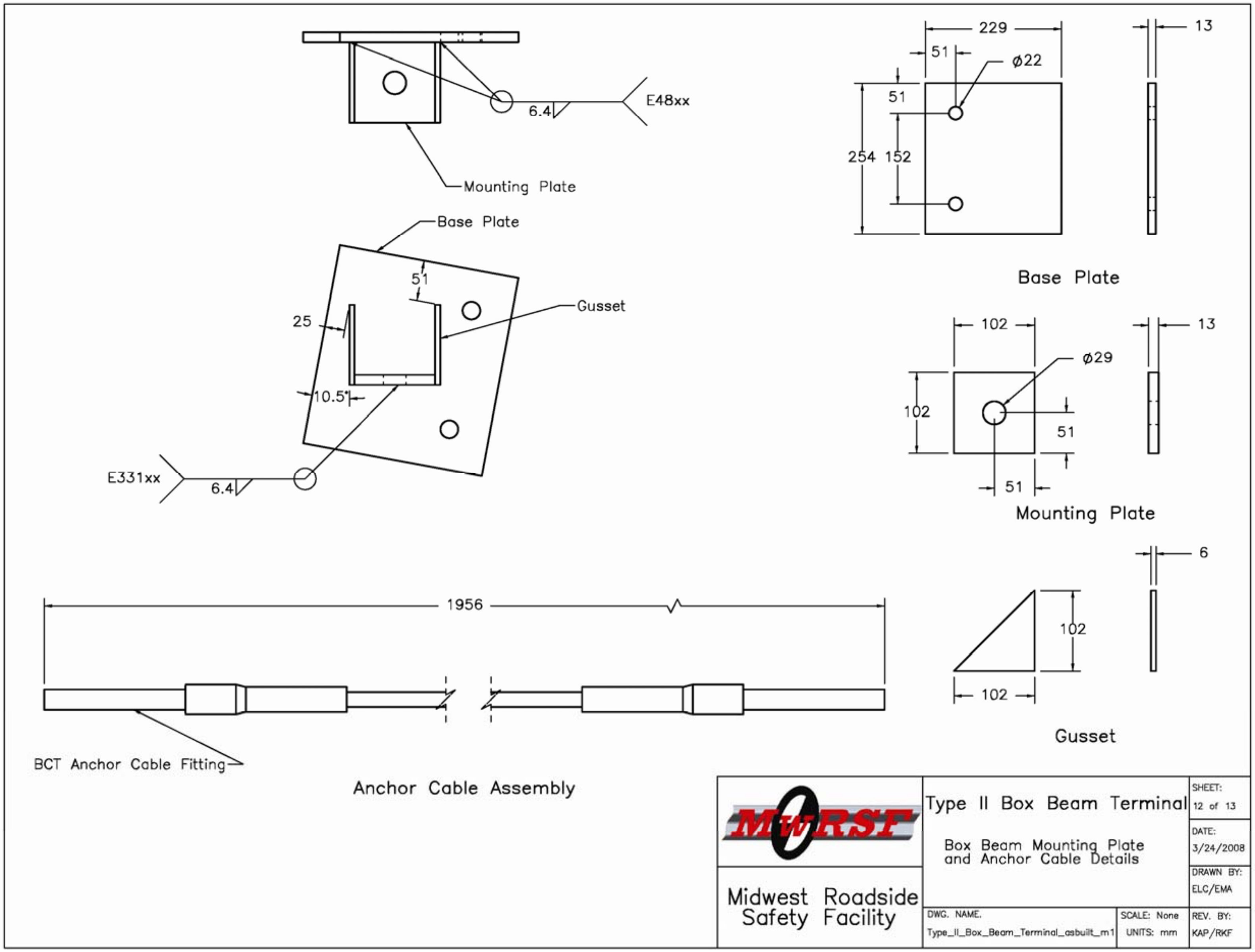


Figure 48. Type II Box Beam System Details, Test No. NYBBT-1

Type II Box Beam Terminal

Item No.	Quantity	Description	Material Specification
a1	23	6.4 x 203 x 610mm steel soil plate	A36 Steel
a2	19	ø 12.7mm coarse thread 50.8mm long hex bolt	ASTM A307
a3	7	ø 12.7 hex nut	ASTM A307
a4	21	127 x 89 x 9.5 box beam shelf angle	A36 Steel
a5	19	ø 12.7 narrow washer	ASTM A307
a6	21	S76 x 8.5 1600mm long post	A36 Steel
b1	20	ø 9.5 coarse thread 190.5mm long hex bolt	ASTM A307
b2	33	ø 9.5 hex nut	ASTM A307
b3	42	ø 9.5 wide washer	ASTM A307
b4	50	ø 19 hex nut	ASTM A325
b5	58	ø 19 wide washer	ASTM A325
b6	58	ø 19 coarse thread 50.8mm long hex bolt	ASTM A325
b7	15	679.5 x 135 x 15.9mm splice plate	A36 Steel
b8	7	152.4 x 152.4 x 4.76 5486.4mm long box beam	ASTM A500 Grade B
c1	2	S76 x 8.5 838.2mm long post	A36 Steel
c2	1	152.4 x 152.4 x 4.76mm box beam end assembly	ASTM A500 Grade B
c4	1	ø 7.94 coarse thread 238.1mm long hex bolt	ASTM A307
c5	2	ø 6.4 hex nut	ASTM A307
c6	2	ø 6.4 x 38.2mm long hex bolt	ASTM A307
c7	4	ø 6.4 wide washer	ASTM A307
d1	1	Box beam cable anchor	A36 steel, galvanized
d2	1	Lower end post	A36 steel, galvanized
d3	2	BCT Anchor Cable End	A36 steel, galvanized
d4	1	Anchor cable	3 x 7 galvanized cable
d5	2	22.2 diameter hex nut	ASTM A307

MwRSF
Midwest Roadside Safety Facility

Type II Box Beam Terminal
Bill of Materials

SHEET: 13 of 13
DATE: 3/24/2008
DRAWN BY: ELC/EMA
DWG. NAME. Type_II_Box_Beam_Terminal_asbuilt_m1
SCALE: None
UNITS: mm
REV. BY: KAP/RKF

Figure 49. Type II Box Beam System Details, Test No. NYBBT-1

Figure 50. NYBBT-1 System Details

Figure 51. NYBBT-1 System Details

Figure 52. NYBBT-1 System Details

Figure 53. NYBBT-1 System Details

6 FULL-SCALE CRASH TEST NO. 1 (TYPE II END TERMINAL)

6.1 Test No. NYBBT-1 (Modified Test Designation 3-32)

The 1,173-kg (2,586-lb) Kia Rio, with a dummy placed in the left-front seat, impacted the Type II box beam terminal system at a speed of 99.6 km/h (61.9 mph) and at an angle of 7.9 degrees with respect to the tangent. A summary of the test results and sequential photographs are shown in Figure 54. An English-unit summary of the test results and sequential photographs are shown in Appendix C. Additional sequential photographs are shown in Figures 55 through 57. Documentary photographs of the crash test are shown in Figure 58.

6.2 Weather Conditions

Test no. NYBBT-1 was conducted on August 14, 2007 at approximately 12:15 pm. The weather conditions were reported as shown in Table 4.

Table 4. Weather Conditions, Test No. NYBBT-1

Temperature	91° F
Humidity	45 %
Wind Speed	3 mph
Wind Direction	215° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.12 in.
Previous 7-Day Precipitation	2.36 in.

6.3 Test Description

Initial vehicle impact was to occur with the right-side tires missing the terminal end by 152 mm (6 in.), as shown in Figure 59. Vehicle impact was first noticeable at 64 mm (2 1/2 in.) downstream from the upstream end of the box beam terminal. At 0.010 sec after impact, the box beam deformed downward. At 0.044 sec, the splice between post nos. 4 and 5 was stretched as the beam section between post nos. 1 and 2 deflected downward. At 0.058 sec, the right-front tire of the vehicle became airborne. At 0.094 sec, the left-front tire of the vehicle became airborne. At 0.116 sec, the front of the vehicle rose up and rode along the top of the box beam. At 0.118 sec, the vehicle front end yawed toward its left side. At 0.162 sec, the first section of box beam between post nos. 1 and 2 was flat on the ground. At 0.186 sec, the left-rear and right-rear tires of the vehicle became airborne, resulting in the vehicle being completely airborne. At 0.222 sec, the vehicle entered into a clockwise roll as it continued to ride up the box beam rail. At 0.254 sec, the vehicle lost contact with the system at a speed of 98.9 km/h (61.5 mph) and at an angle of 10.6 degrees. The vehicle continued rolling clockwise while airborne after exiting the system. At 0.556 sec, the vehicle's right-front tire contacted the ground. The vehicle continued to roll over after coming in contact with the ground. The vehicle came to rest 55.3 m (181.4 ft) downstream from impact and 4.4 m (14.6 ft) laterally behind the traffic-side face of the barrier. The trajectory and final position of the passenger car are shown in Figures 54 and 60.

6.4 System and Component Damage

Damage to the end terminal system was moderate, as shown in Figures 61 through 63. Damage consisted of fractured and deformed box beam, disengaged steel posts, and contact marks on a box beam section. The vehicle overrode the box beam terminal between post nos. 1 and 4. Tire marks and scrapes span 5,537 mm (218 in.) along the top and traffic-side faces of the barrier, from the upstream end of the terminal through 140 mm (5 1/2 in.) downstream from the centerline of post no. 3.

Moderate deformation and yielding of the impacted section of box beam rail occurred between post nos. 1 and 4. The weld at the weakened joint between post nos. 1 and 2 separated, as it was designed to do when the vehicle applied a vertical load to the box beam, as shown in

Figure 62. The box beam rail bent downward between post no. 1 and the weakened joint location found between post nos. 1 and 2.

A soil gap of 51 mm (2 in.) was found at the traffic-side face of post no. 2. Post no. 2 also disengaged from the box beam. Soil gaps of 19 mm (3/4 in.) and 32 mm (1 1/4 in.) were found at the front and back faces of post no. 3, respectively. A 6-mm (1/4-in.) soil gap was found at the front and back faces of post no. 4. The downstream anchor had a soil gap of 13 mm (1/2 in.). The remainder of the system was undamaged.

The permanent set deformation of the end terminal system is shown in Figure 61. The maximum lateral permanent set rail deflection was 31 mm (1 3/16 in.) at the upstream side of the splice between post nos. 1 and 2, as determined from high-speed digital video analysis. The maximum lateral dynamic rail deflection was 68 mm (2 11/16 in.) at the upstream side of the splice between post nos. 1 and 2, as determined from high-speed digital video analysis.

6.5 Vehicle Damage

Exterior vehicle damage was extensive, as shown in Figures 64 and 65. The occupant compartment was severely damaged due to vehicle rollover. The roof crushed into the occupant compartment. Complete occupant compartment deformations and the corresponding locations are provided in Appendix D. The damage to the side and top of the vehicle was due to the rollover. Minor scrapes and scratches were found on the undercarriage of the vehicle due to the vehicle overriding the system.

6.6 Occupant Risk Values

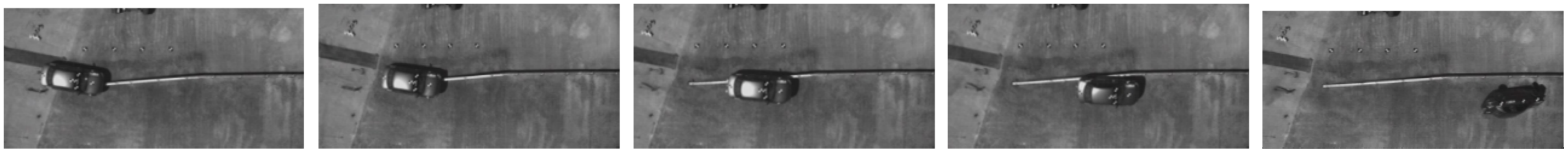
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 5. It is noted that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 5. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 54. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E. Due to technical difficulties, the DTS and EDR-4 recorders did not collect angular data, but the EDR-4 recorder did collect accelerometer data.

Table 5. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYBBT-1

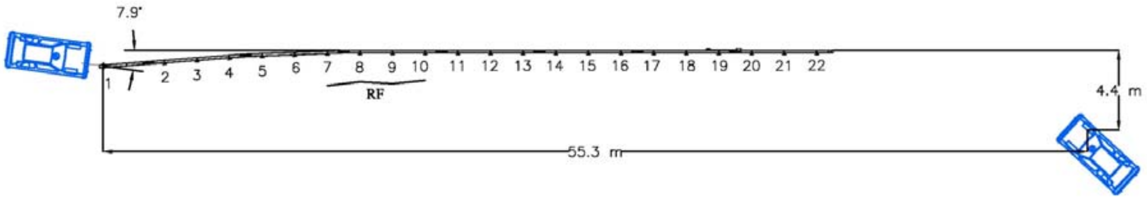
Evaluation Criteria		**Transducer**	
		EDR-3	**EDR-4**
OIV m/s (ft/s)	Longitudinal	-2.58 (-8.46)	-1.27 (-4.17)
	Lateral	-2.14 (-7.02)	-2.32 (-7.60)
ORA g's	Longitudinal	11.19	10.47
	Lateral	11.91	12.29
THIV m/s (ft/s)		NA	NA
PHD g's		NA	NA
ASI		NA	NA

6.7 Discussion

The analysis of the test results for test no. NYBBT-1 showed that the NYSDOT Type II box beam end terminal system did not contain nor redirect the 1100C vehicle, since the vehicle did not remain upright after collision with the barrier. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did occur with the deformations of the vehicle's roof. Therefore, test no. NYBBT-1 conducted on the Type II end terminal was determined to be unacceptable according to a modified test designation no. 3-32 of the TL-3 safety performance criteria found in MASH.



0.000 sec 0.118 sec 0.234 sec 0.306 sec 0.550 sec



●Test Agency	MwRSF
●Test Number	NYBBT-1
●Date	8/14/07
●MASH Test Designation	Modified 3-32
●Appurtenance	Type II End Terminal
●Total Length	41.2 m
●Key Element – Steel Box Beam	
Size	152 mm x 152 mm x 4.8 mm
Length	5,486 mm
Top Mounting Height	686 mm
●Key Elements - Steel Post	
Post No. 1	S76x8.5 by 838 mm long
Post Nos. 2-22	S76x8.5 by 1,600 mm long
●Type of Soil	Grading B - AASHTO M 147-65 (1990)
●Test Vehicle	
Type/Designation	1100C
Make and Model	2002 Kia Rio
Curb	1,101 kg
Test Inertial	1,087 kg
Gross Static	1,173 kg
●Impact Conditions	
Speed	99.6 km/h
Angle (trajectory)	7.9 degrees
Target Impact Location	on upstream end of terminal
Actual Impact Location	64 mm downstream from end of terminal
●Exit Conditions	
Speed	98.9 km/h
Angle	10.6 degrees
Exit Box Criterion	NA
●Post-Impact Trajectory	
Vehicle Stability	Unsatisfactory
Stopping Distance	55.3 m downstream 4.4 m laterally behind traffic-side face

●Occupant Impact Velocity (EDR-3)	
Longitudinal	-2.58 m/s < 12.2 m/s
Lateral	-2.14 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-3)	
Longitudinal	11.19 g's < 20.49 g's
Lateral	11.91 g's < 20.49 g's
●Occupant Impact Velocity (EDR-4)	
Longitudinal	-1.27 m/s < 12.2 m/s
Lateral	-2.31 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-4)	
Longitudinal	10.47 g's < 20.49 g's
Lateral	12.29 g's < 20.49 g's
●THIV (not required)	NA
●PHD (not required)	NA
●ASI (EDR-3 - not required)	NA
●Test Article Damage	Moderate
●Test Article Deflections	
Permanent Set	31 mm
Dynamic	68 mm
Working Width	NA
●Vehicle Damage	Extensive
VDS[12]	01-L&T-5
CDC[13]	01-FDAO9
Maximum Deformation	NA
●Angular Displacement	
Roll	NA
Pitch	NA
Yaw	188 degrees

Figure 54. Summary of Test Results and Sequential Photographs, Test No. NYBBT-1


0.000 sec


0.020 sec


0.032 sec


0.054 sec


0.174 sec


0.188 sec


0.222 sec


0.262 sec


0.304 sec


0.494 sec

Figure 55. Additional Sequential Photographs, Test No. NYBBT-1

0.000 sec

0.094 sec

0.116 sec

0.162 sec

0.186 sec

0.218 sec

0.226 sec

0.302 sec

0.340 sec

0.350 sec

Figure 56. Additional Sequential Photographs, Test No. NYBBT-1

0.000 sec

0.024 sec

0.060 sec

0.126 sec

0.182 sec

0.334 sec

0.514 sec

0.696 sec

1.006 sec

1.648 sec

Figure 57. Additional Sequential Photographs, Test No. NYBBT-1

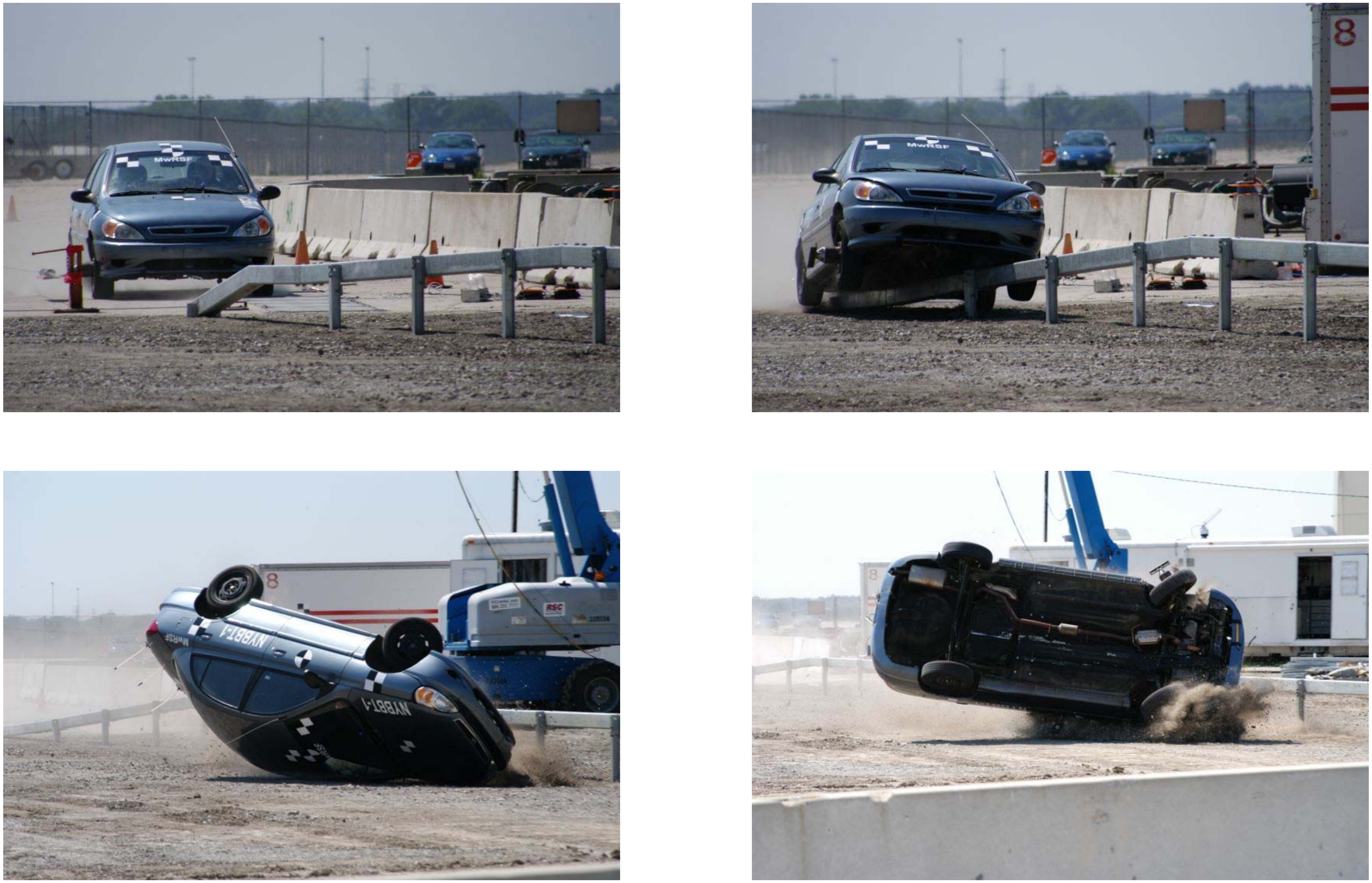


Figure 58. Documentary Photographs, Test No. NYBBT-1

Figure 59. Impact Location, Test No. NYBBT-1

Figure 60. Vehicle Final Position and Trajectory, Test No. NYBBT-1

Figure 61. System Damage, Test No. NYBBT-1

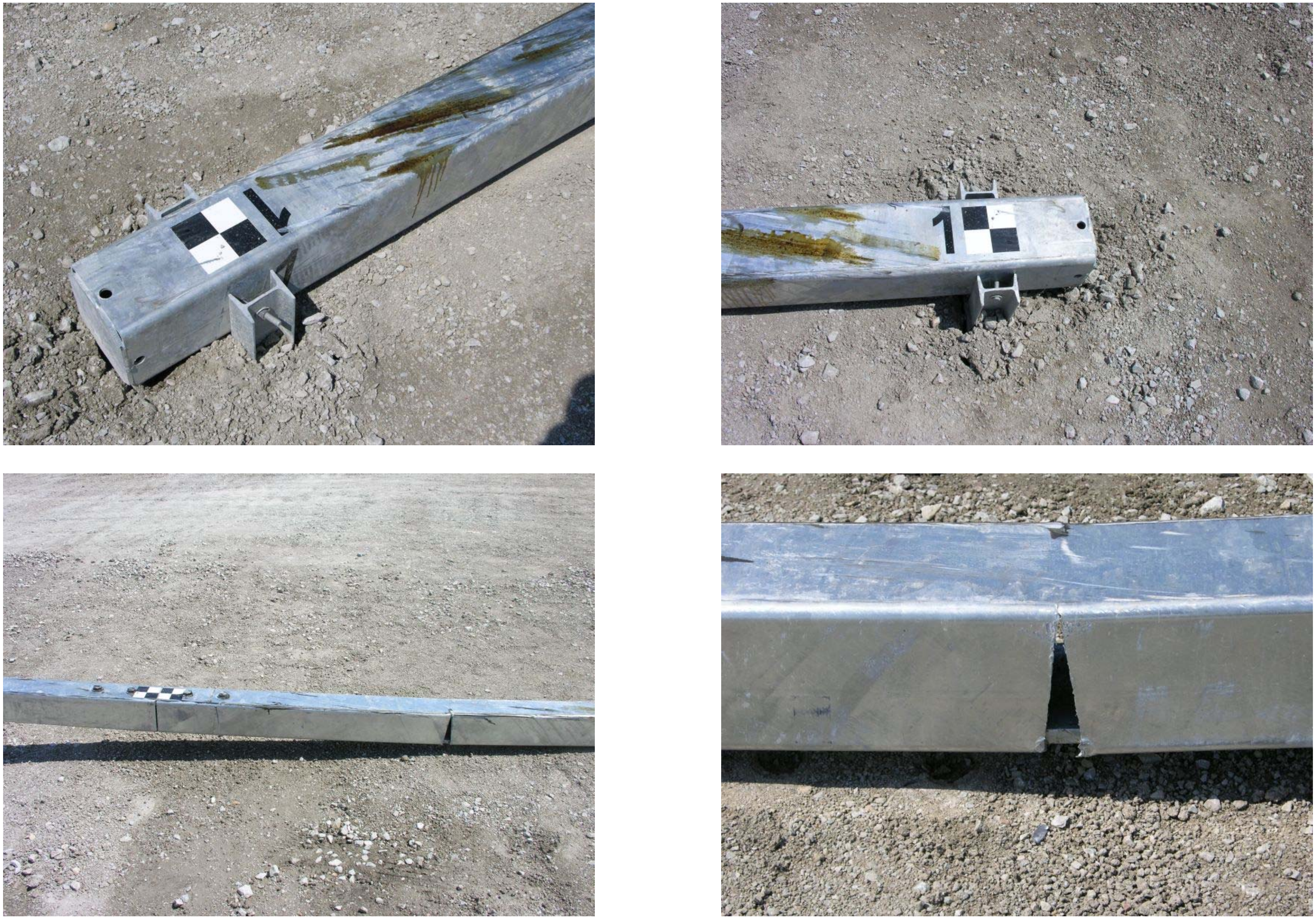


Figure 62. System Damage, Test No. NYBBT-1

Figure 63. System Damage, Test No. NYBBT-1

Figure 64. Vehicle Damage, Test No. NYBBT-1

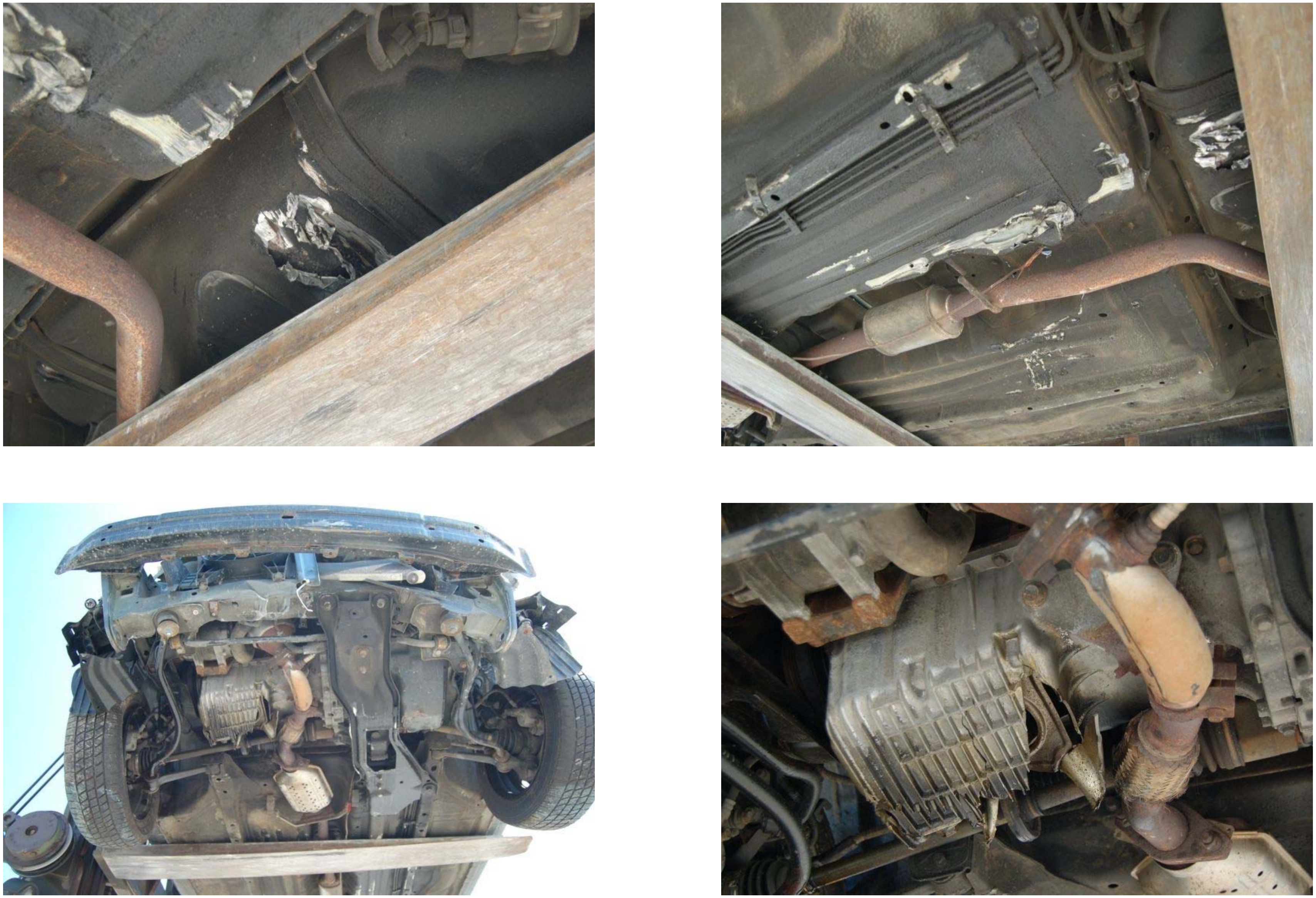


Figure 65. Undercarriage Damage, Test No. NYBBT-1

7 TYPE IIA END TERMINAL – NYBBT-2 AND NYBBT-3 SYSTEM DETAILS

The test installation was identical for test nos. NYBBT-2 and NYBBT-3, except the anchorages. The 40.2-m (132-ft) long test installation consisted of 38.1 m (125 ft) of the NYSDOT's standard TS 152-mm x 152-mm x 4.8-mm (6-in. x 6-in. x 3/16-in.) steel tube box-beam guide rail with a Type IIA terminal. The end terminal consisted of a constant radius flare, with a radius of 10.7 m (35 ft). Design details are shown in Figures 66 through 78. The corresponding English-unit drawings for test no. NYBBT-2 are shown in Appendix F. Complete system drawings in both metric and English units for test no. NYBBT-3 are shown in Appendix G. Photographs of the test installation are shown in Figures 79 through 82.

The entire system was supported by twenty-three S76x8.5 (S3x5.7) steel guide rail posts with 601-mm x 203-mm x 6-mm (24-in. x 8-in. x 1/4-in.) soil plates. All posts were 1,600 mm (63 in.) long except post no. 1, which was 1,194 mm (47 in.) long. Post nos. 1 and 2 were spaced 1,070 mm (42 1/8 in.) on center, while the other posts were spaced 1,829 mm (72 in.) on center. All posts had a soil embedment depth of 914 mm (36 in.), as shown in Figures 66 and 67. The tops of the posts were positioned flush with the top of the rail, as shown in Figures 66 through 68 and 78. The top height of the standard box beam rail was 686 mm (27 in.). The rail was connected to a box beam shelf angle at post nos. 2 through 23 with a 9.5-mm (3/8-in.) diameter by 191-mm (7 1/2-in.) long, ASTM A307 hex head bolt. The 127-mm x 89-mm x 9.5-mm (5-in. x 3 1/2-in. x 3/8-in.) box beam shelf angle was connected to the posts with one 12.7-mm (1/2-in.) diameter by 51-mm (2-in.) long, ASTM A307 hex head bolt with a 12.7-mm (1/2-in.) narrow washer.

The box beam guide rail was comprised of ASTM A500B structural steel tubes. Each section of steel tube was 5,486 mm (18 ft) long. The steel tube sections were connected together with splices located at the midspan between two posts. The end assembly rail was tapered with a slope of 2:1 beginning at the welded joint between post nos. 1 and 2.

The Type IIA terminal utilized one post driven behind the end of the terminal. The end of the box beam terminal was supported by an angle support bracket, attached by a single 19-mm (3/4-in.) diameter by 191-mm (7 1/2-in.) long, ASTM A307 coarse thread, hex head bolt.

Similar to test no. NYBBT-1, the rail was anchored to the ground between post nos. 20 and 21 using a reverse cable anchorage system to develop the longitudinal resistance in the rail. The upper end of the cable was connected to a mounting plate bolted to the box beam splice, while the lower end of the cable was connected to a buried steel pile anchorage, as shown in Figures 66 and 82. For test no. NYBBT-3, an additional cable anchorage device was placed at the splice between post nos. 17 and 18, as shown in Figures 78 and 82.

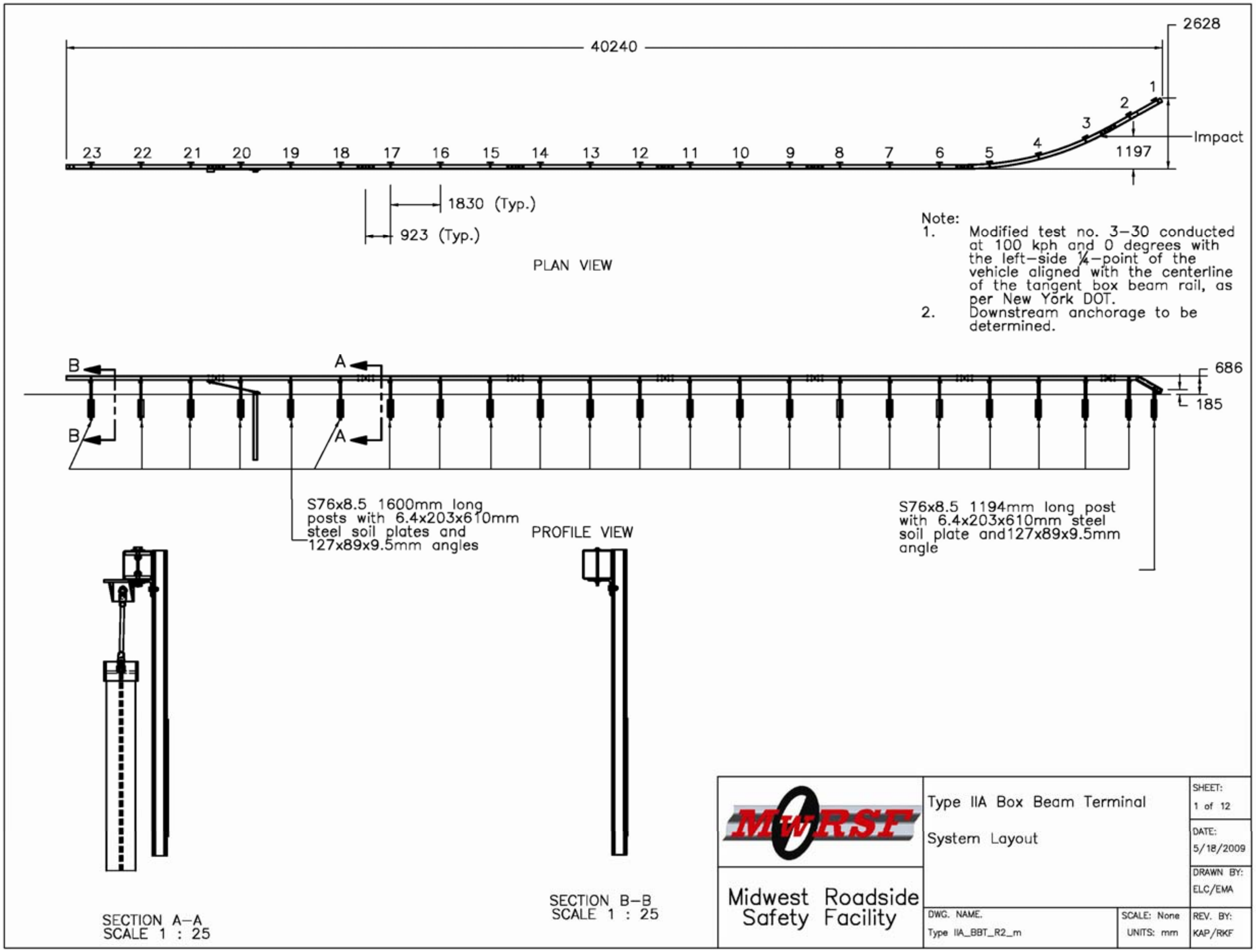


Figure 66. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

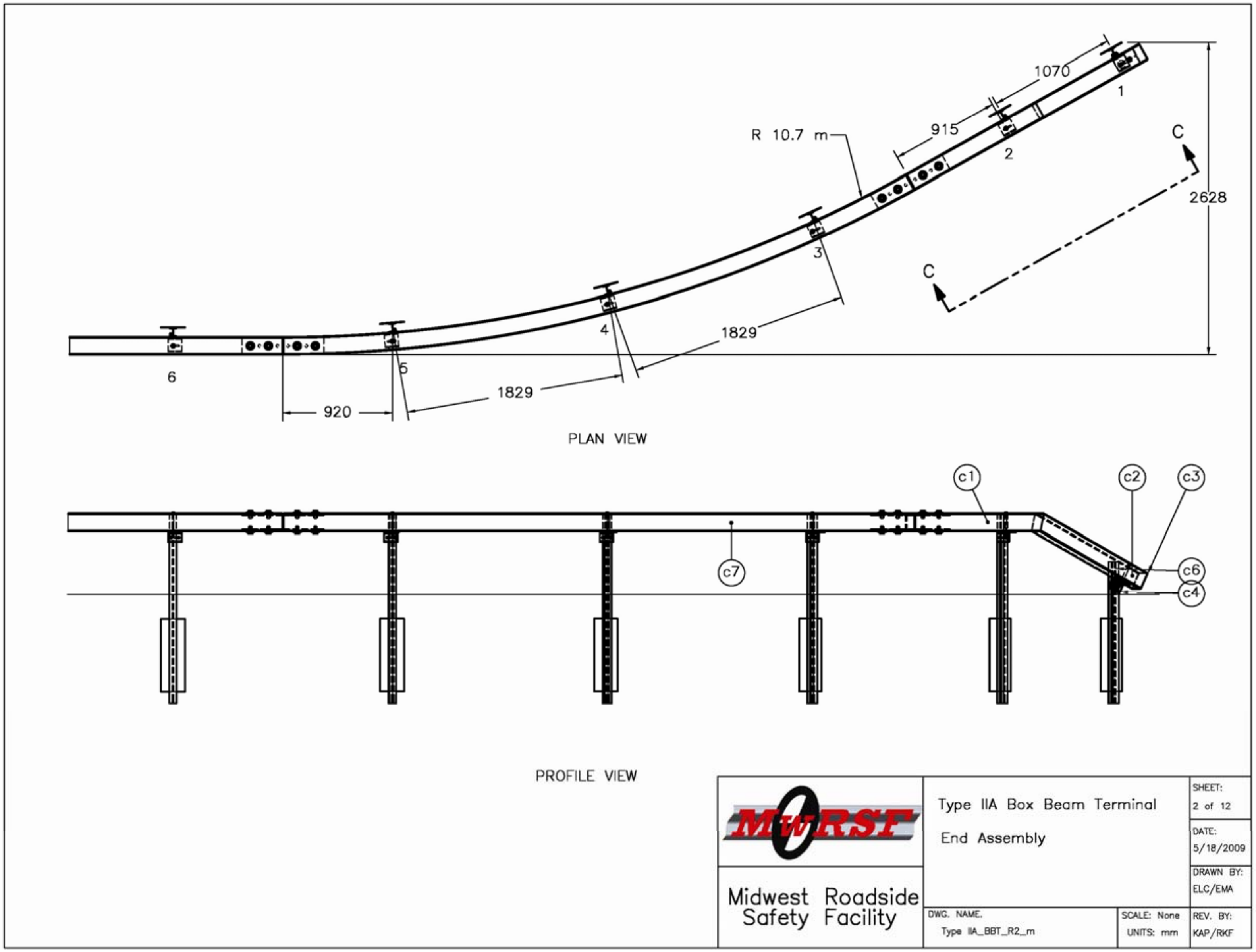


Figure 67. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

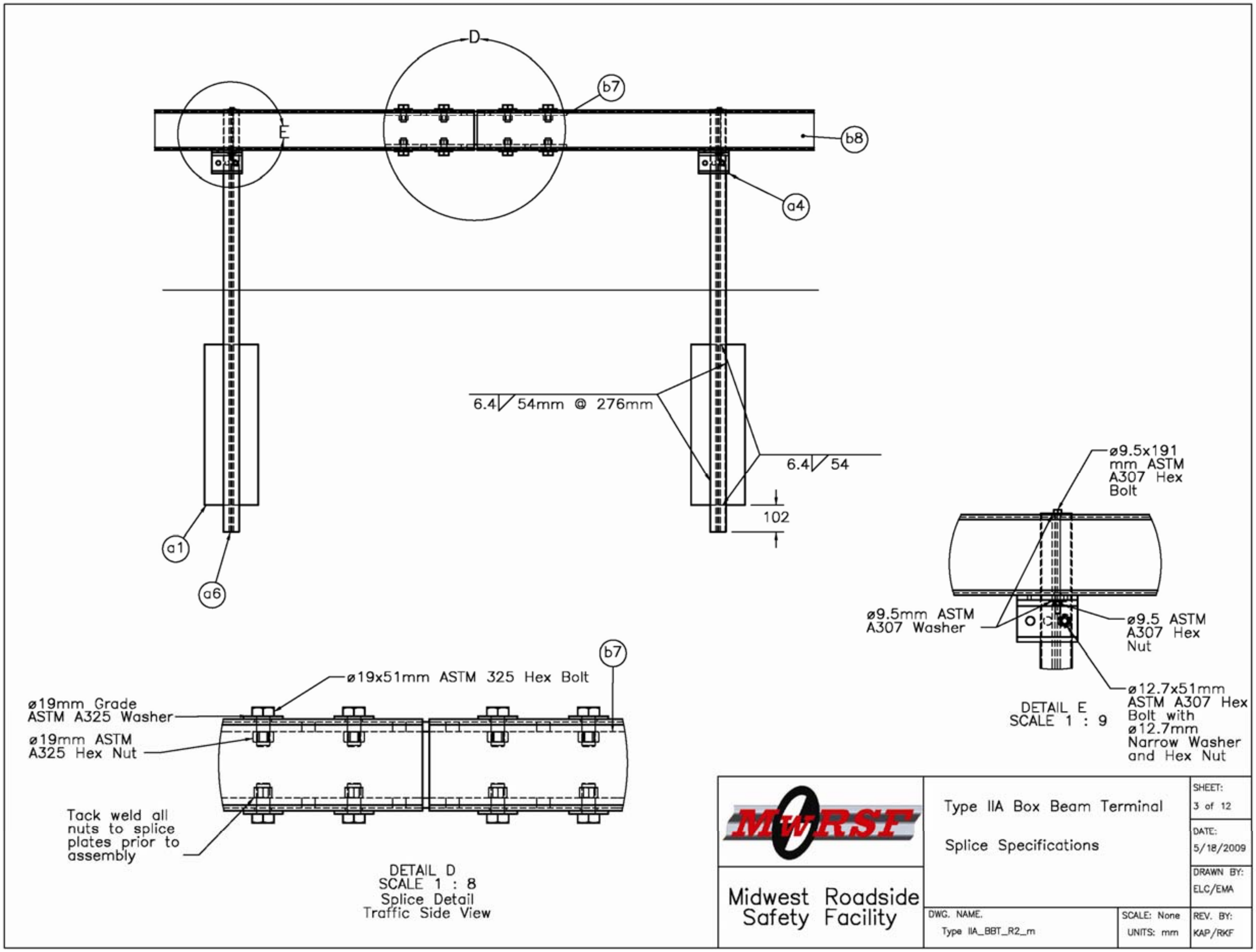


Figure 68. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

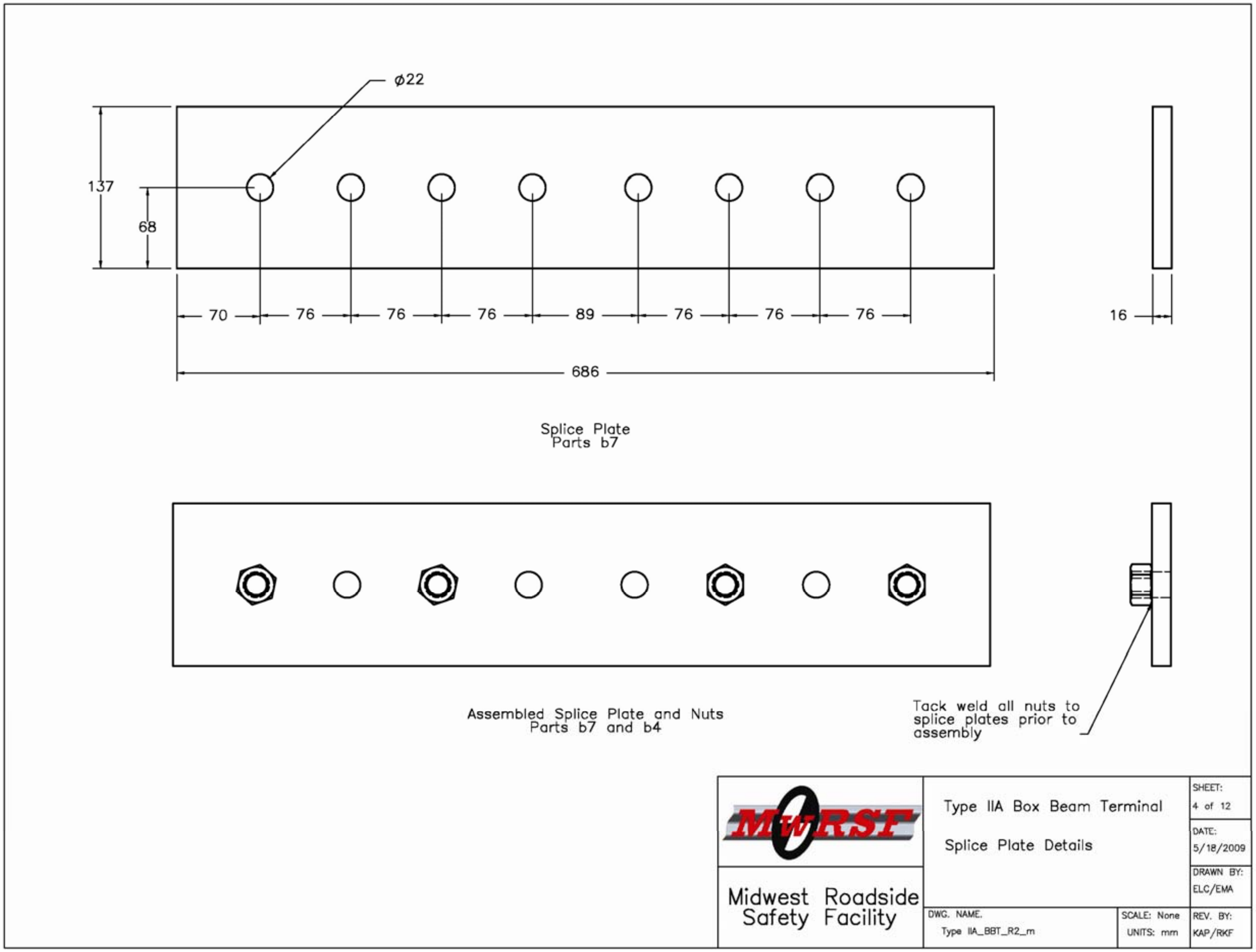


Figure 69. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

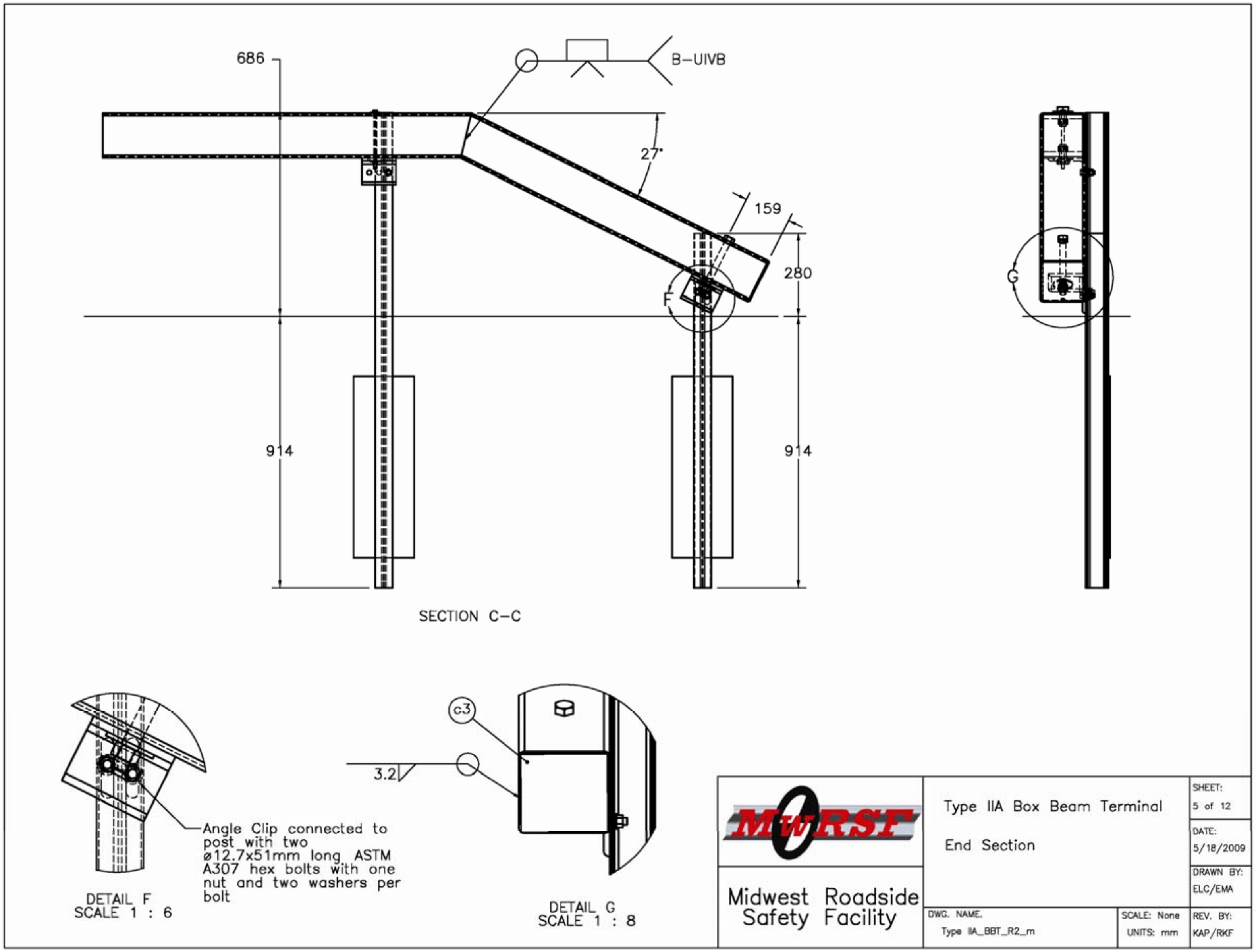


Figure 70. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

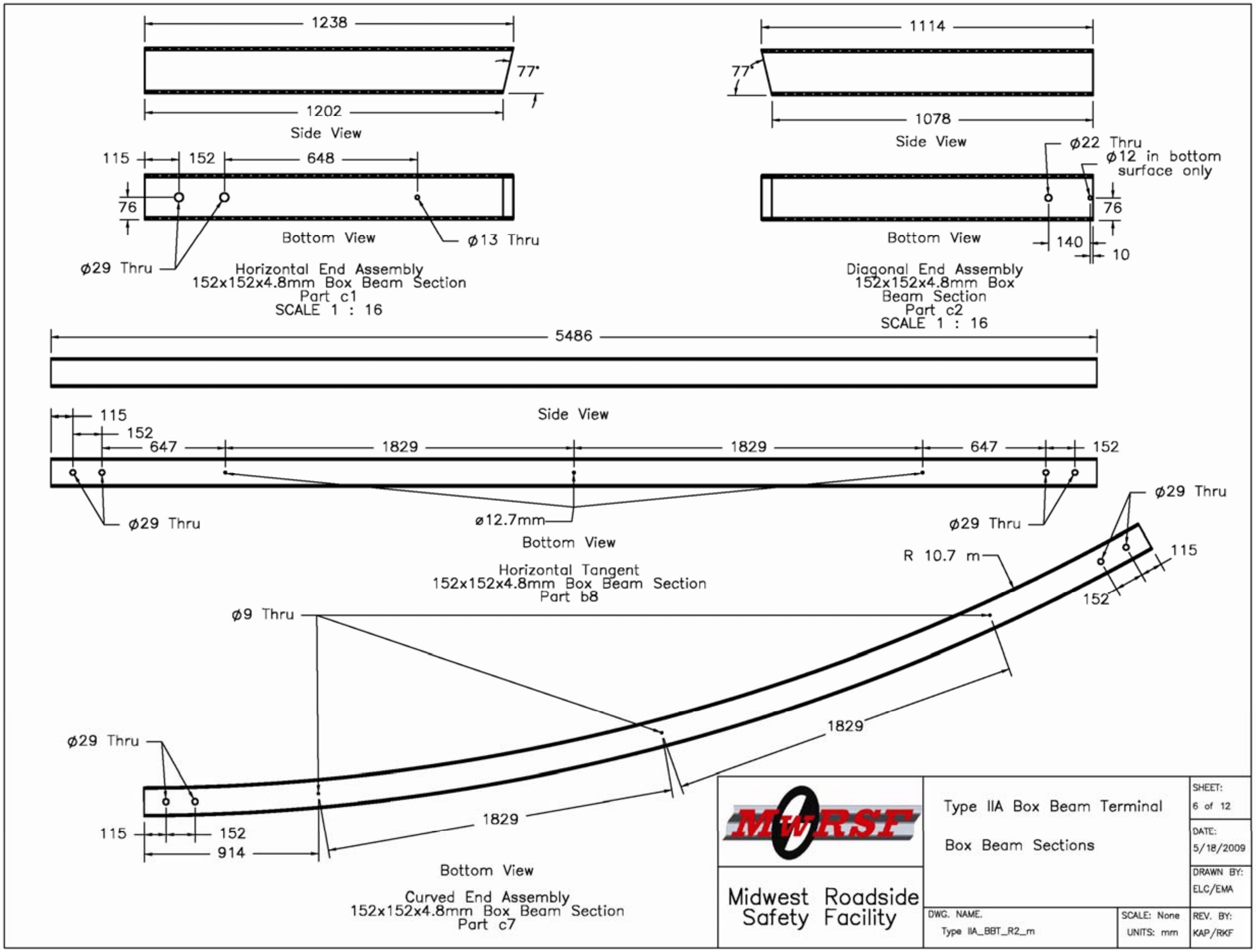


Figure 71. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

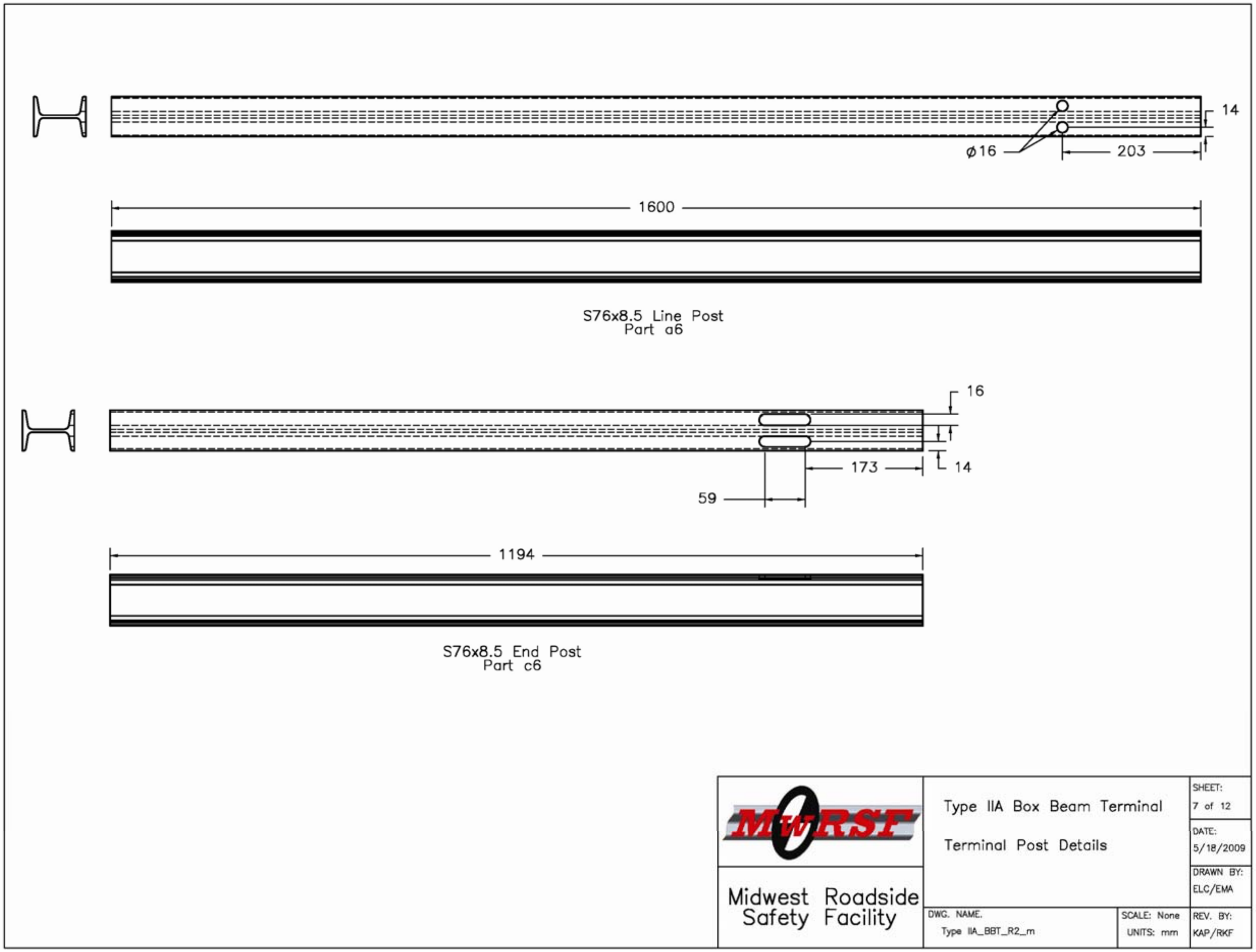


Figure 72. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

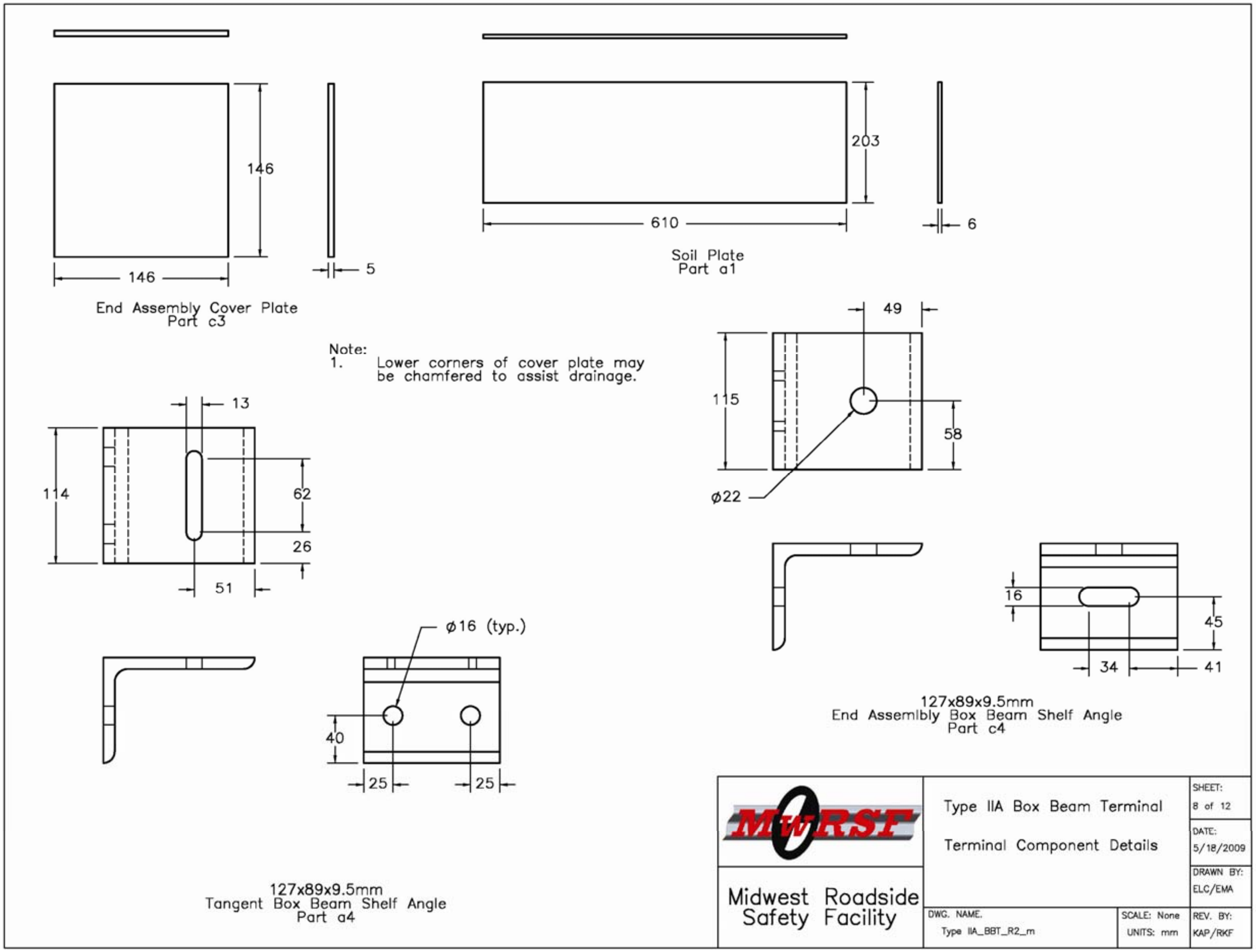


Figure 73. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

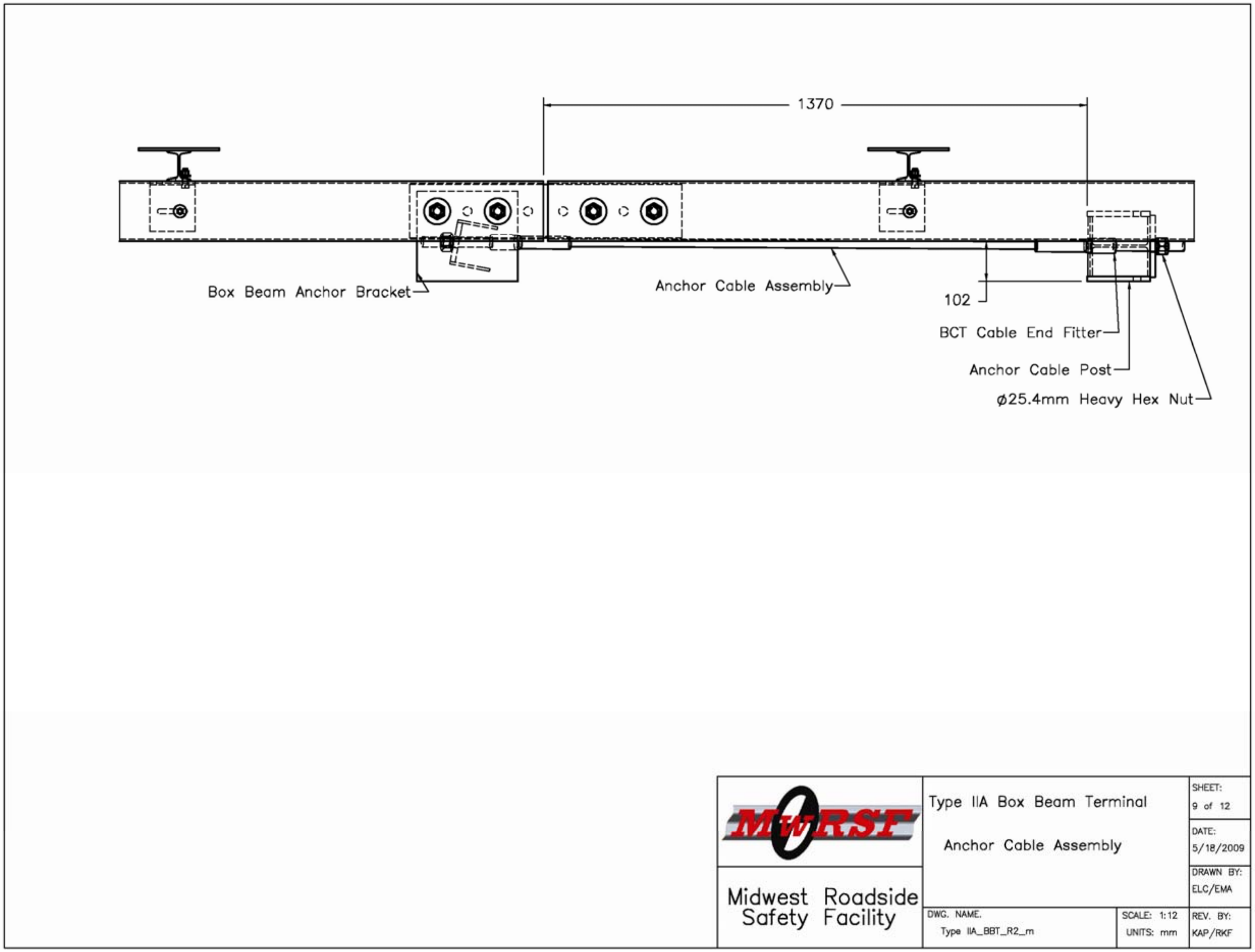


Figure 74. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

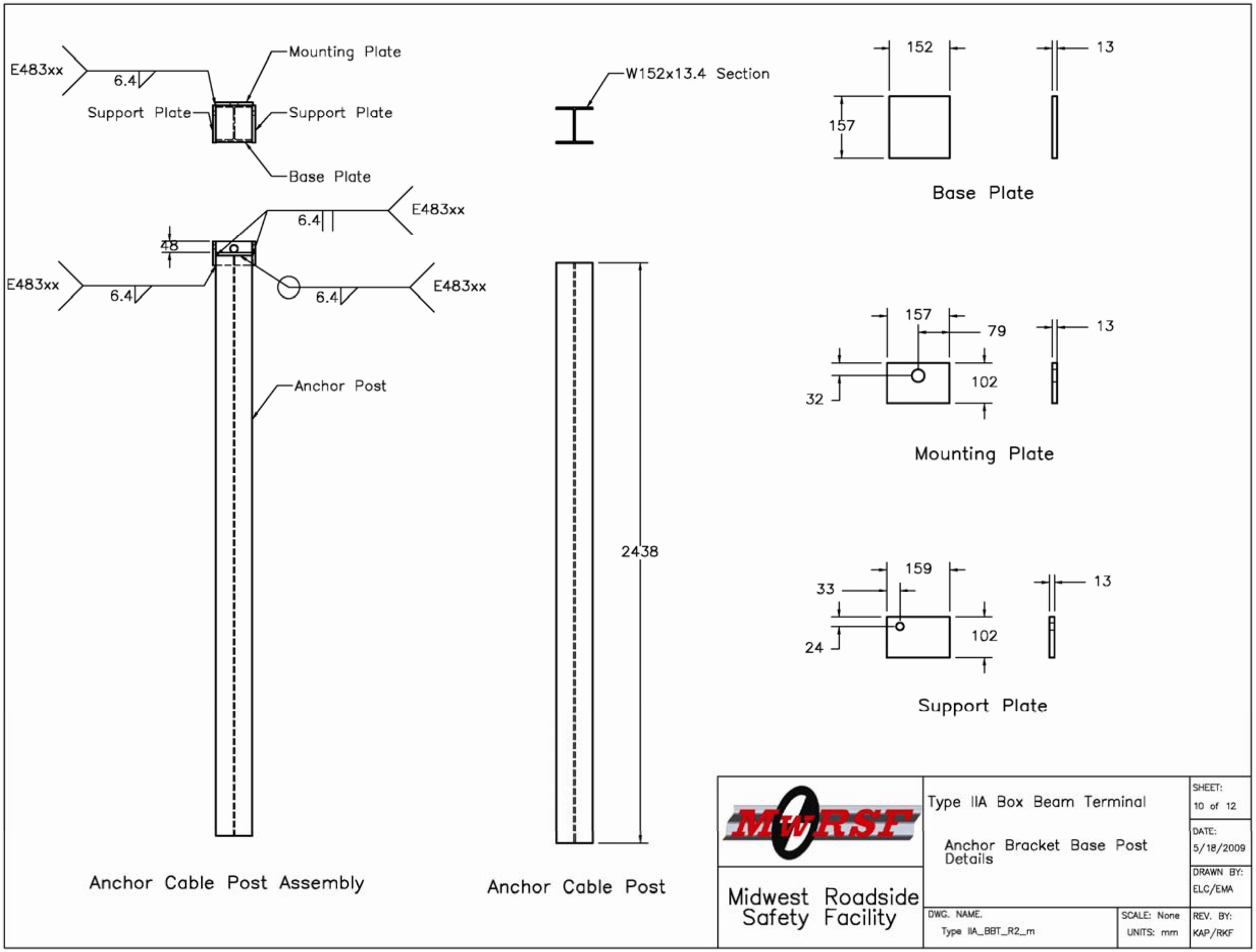


Figure 75. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

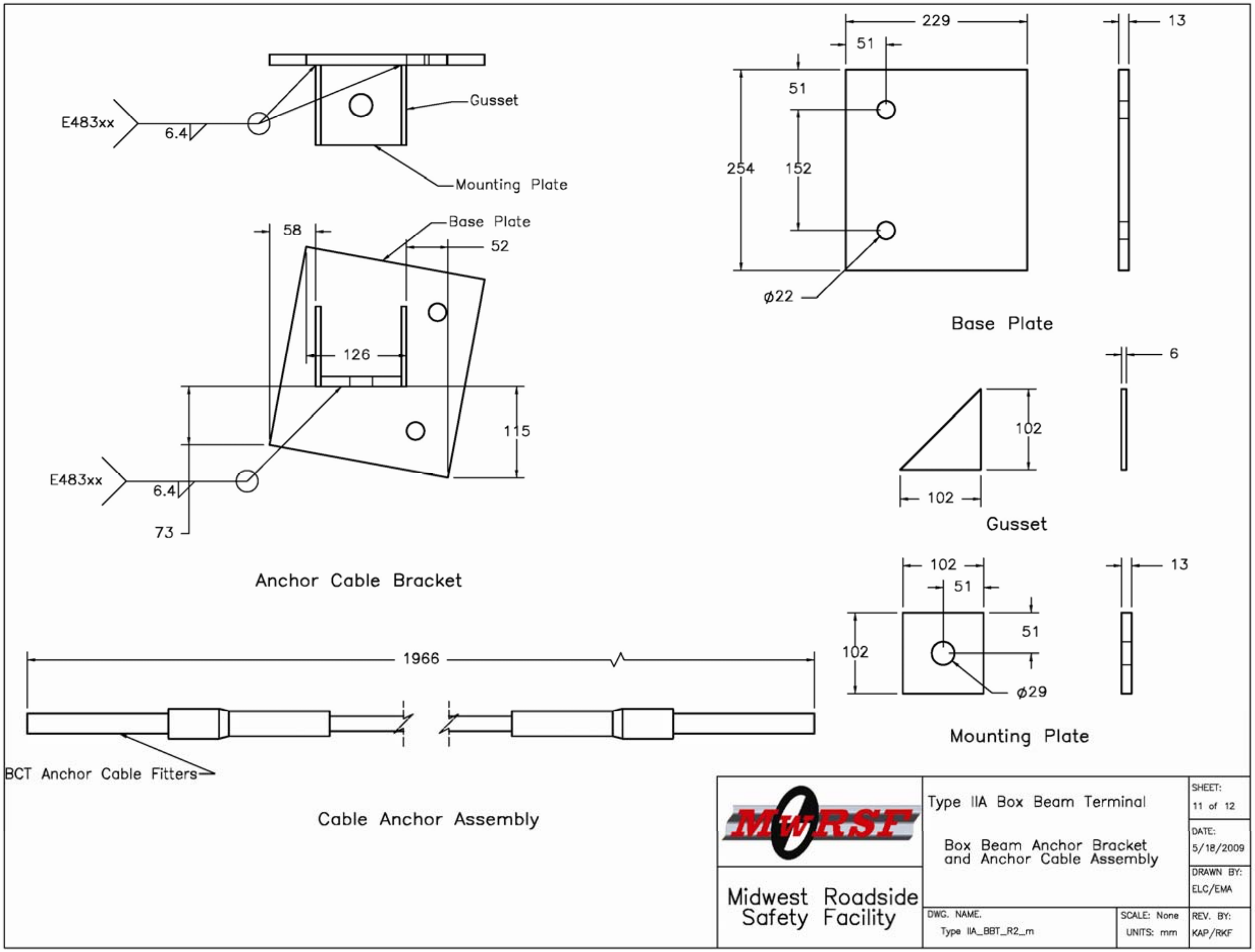


Figure 76. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

Type IIA Box Beam Terminal

Item No.	QTY.	Description	Material Specification
a1	23	6.4 x 203 x 610mm steel soil plate	A36 Steel
a2	24	ø 12.7mm coarse thread 51mm long hex bolt	ASTM A307
a3	24	ø 12.7mm hex nut	ASTM A307
a4	22	127 x 89 x 9.5mm box beam shelf angle	A36 Steel
a5	24	ø 12.7mm narrow washer	ASTM A307
a6	22	S76 x 8.5 1600mm long post	A36 Steel
b1	22	ø 9.5mm coarse thread 191mm long hex bolt	ASTM A307
b2	22	ø 9.5mm hex nut	ASTM A307
b3	44	ø 9.5mm wide washer	ASTM A307
b4	56	ø 19mm hex nut	ASTM A325
b5	56	ø 19mm wide washer	ASTM A325
b6	56	ø 19mm coarse thread 51mm long hex bolt	ASTM A307
b7	14	686 x 137 x 16mm splice plate	A36 Steel
b8	6	152 x 152 x 4.8mm 5486mm long box beam	ASTM A500 Grade B
c1	1	End assembly horizontal 152 x 152 x 4.8mm box beam	ASTM A500 Grade B
c2	1	End assembly diagonal 152 x 152 x 4.8mm box beam	ASTM A500 Grade B
c3	1	End assembly 4.8mm thick cover plate	A36 Steel
c4	1	127 x 89 x 9.5mm box beam shelf angle	A36 Steel
c5	1	ø 19mm coarse thread 191mm long hex bolt	ASTM A307
c6	1	S76 x 8.5 1194mm long post	A36 Steel
c7	1	152 x 152 x 4.8mm R10.7m Curved Box Beam	ASTM A500 Grade B
–	1	Box Beam Cable Anchor Mounting Plate	A36 steel, galvanized
–	2	Box Beam Cable Anchor Gusset	A36 steel, galvanized
–	1	Box Beam Cable Anchor Base Plate	A36 steel, galvanized
–	1	Lower End Post	A36 Steel
–	1	Lower End Post Base Plate	A36, galvanized
–	1	Lower End Post Front Collar Plate	A36 steel, galvanized
–	2	Lower End Post Side Plate	A36 steel, galvanized
–	2	BCT Anchor Cable End	–

Midwest Roadside Safety Facility

Type IIA Box Beam Terminal

Bill of Materials

SHEET: 12 of 12

DATE: 5/18/2009

DRAWN BY: ELC/EMA

DWG. NAME. Type IIA_BBT_R2_m

SCALE: None

UNITS: mm

REV. BY: KAP/RKF

Figure 77. Type IIA Box Beam Terminal System Details, Test No. NYBBT-2

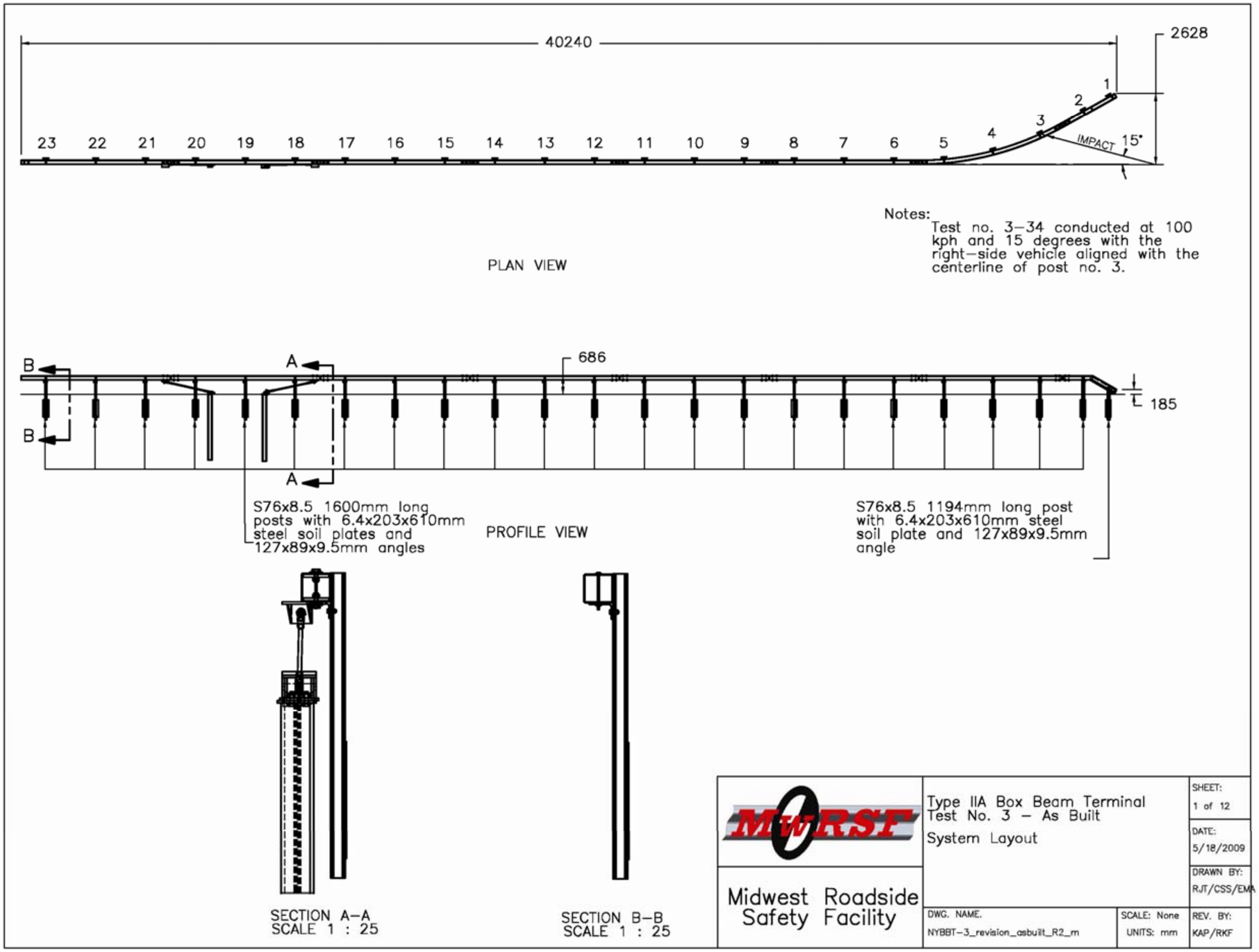


Figure 78. Type IIA Box Beam Terminal System Details, Test No. NYBBT-3

Figure 79. NYBBT-2 and NYBBT-3 System Details

Figure 80. NYBBT-2 and NYBBT-3 System Details

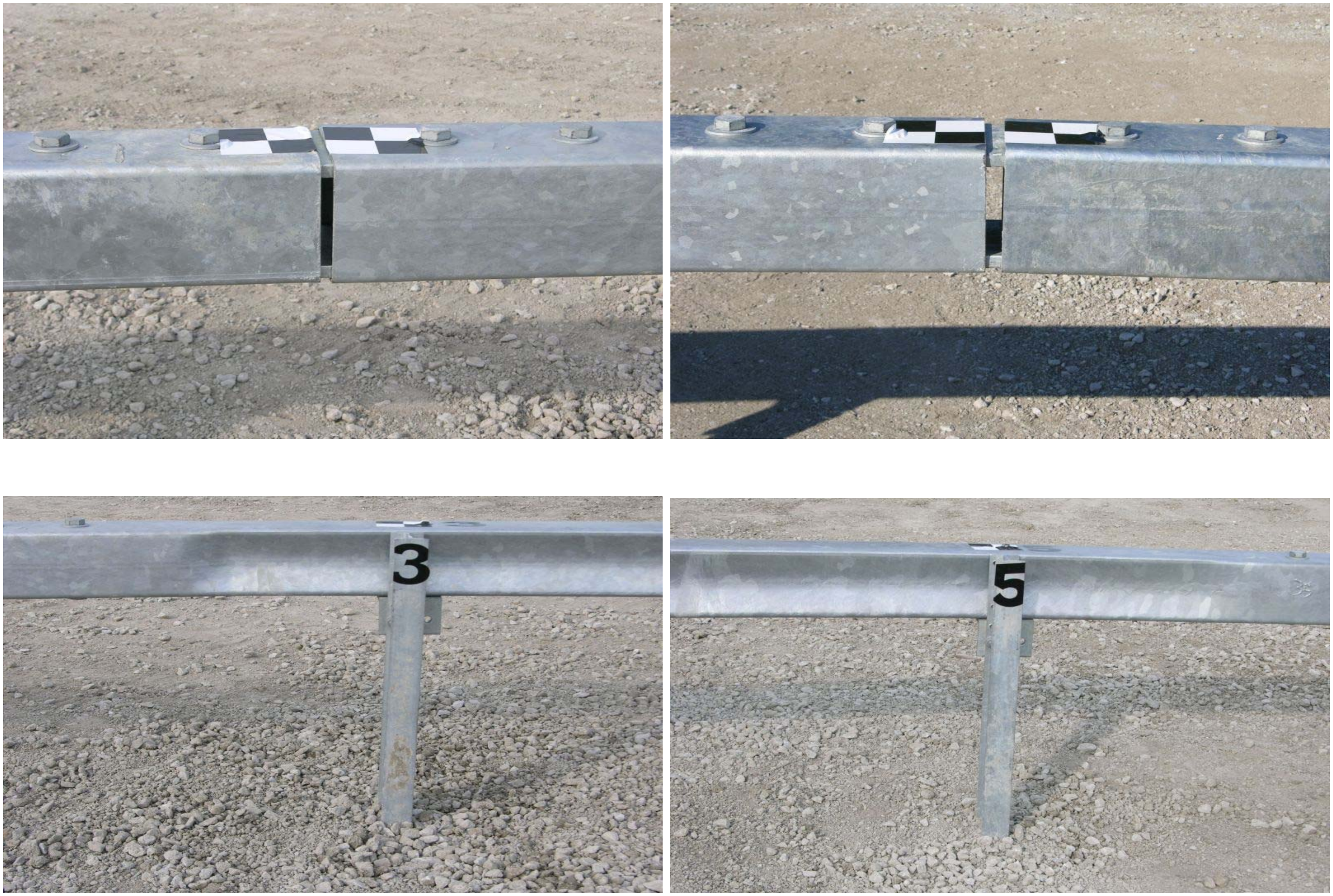


Figure 81. NYBBT-2 and NYBBT-3 System Details

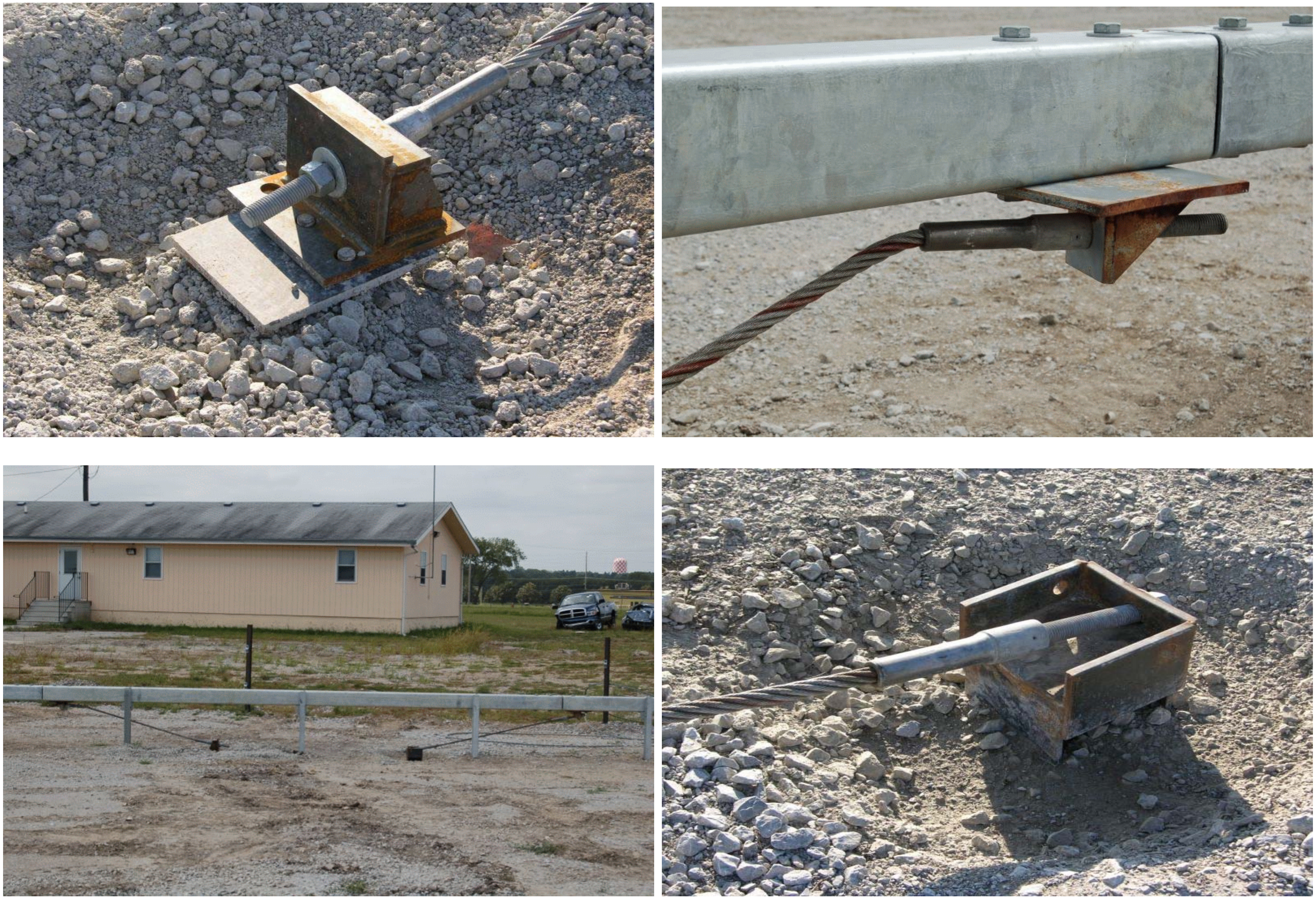


Figure 82. NYBBT-3 Downstream Anchorage Systems

8 FULL-SCALE CRASH TEST NO. 2 (TYPE IIA END TERMINAL)

8.1 Test No. NYBBT-2 (Modified Test Designation 3-30)

The 1,158-kg (2,553-lb) Kia Rio, with a dummy placed in the right-front seat, impacted the Type IIA box beam terminal system at a speed of 101.8 km/h (63.2 mph) and at an angle of 1.6 degrees with respect to the tangent. A summary of the test results and sequential photographs are shown in Figure 83. An English-unit summary of the test results and sequential photographs are shown in Appendix C. Additional sequential photographs are shown in Figures 84 and 85. Documentary photographs of the crash test are shown in Figure 86.

8.2 Weather Conditions

Test no. NYBBT-2 was conducted on August 15, 2007 at approximately 12:00 pm. The weather conditions were reported as shown in Table 6.

Table 6. Weather Conditions, Test No. NYBBT-2

Temperature	82° F
Humidity	67 %
Wind Speed	8 mph
Wind Direction	190° from True North
Sky Conditions	Sunny
Visibility	7 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.12 in.
Previous 7-Day Precipitation	1.92 in.

8.3 Test Description

Initial vehicle impact was to occur with the vehicle’s left quarter-point aligned with the centerline of the tangent box beam, which placed the right-front quarter point 479 mm (18 7/8 in.) upstream of the center of post no. 3, as shown in Figure 87. Actual vehicle impact occurred with the right-front vehicle corner contacting the rail at 419 mm (16 1/2 in.) upstream from the centerline of post no. 3. At 0.010 sec after impact, the right-front corner of the engine hood protruded over the box beam rail. At 0.014 sec, the right-front corner of the bumper impacted post no. 3, and the rail deflected laterally away from the vehicle. At 0.020 sec, the box beam rail was engaged between the engine hood and the right-front corner of the bumper, and the front of the vehicle began to yaw toward its left side. At 0.024 sec, post nos. 4 and 5 deflected laterally. At this same time, the end of the box beam near post no. 1 was deflected upstream and laterally backward and dug into the ground. At 0.030 sec, post no. 3 detached from the rail which deflected toward the ground. At 0.032 sec, the right-front tire contacted post no. 3, and post no. 4 twisted backward. At 0.052 sec, the vehicle rolled toward the left side. At 0.074 sec, the bumper contacted post no. 4, which subsequently detached from the rail. As the vehicle continued to redirect, the box beam lifted and deflected laterally. At 0.174 sec, the box beam rail reached it maximum dynamic deflection, and the vehicle continued to redirect. At 0.254 sec, the curved box beam rail rebounded back toward the traffic side of the barrier. At 0.342 sec, the vehicle exited the system at a speed of 78.3 km/h (48.7 mph) and at an angle of 15.7 degrees with respect to the tangent line of the system. The vehicle continued downstream away from the system until coming to a rest at 53.8 m (176 ft - 7 in.) downstream from impact and 4.6 m (15 ft - 3 in.) laterally away from the traffic-side face of the rail. The trajectory and final position of the passenger car are shown in Figures 83 and 88.

8.4 System and Component Damage

Damage to the end terminal system was moderate, as shown in Figures 89 and 90. Damage consisted of deformed box beam and guide rail posts and contact marks on box beam rail sections. The length of vehicle contact was approximately 4.2 m (13.9 ft), which spanned from 419 mm (16.5 in.) upstream from the centerline of post no. 3 through the midspan between post nos. 5 and 6.

Post no. 1 bent backward and twisted downstream. The bolt slots on post no. 1 were deformed, and post no. 1 disengaged from the rail. Post no. 2 bent backward, with soil gaps of 13 mm (1/2 in.) and 76 mm (3 in.) at the front and back faces, respectively. The box beam rail was also pulled off of post nos. 3 through 5, and post nos. 3 through 5 deflected downstream. Post no. 5 developed soil gaps of 152 mm (6 in.) at all faces. Post no. 6 deflected laterally, with soil gaps of 64 mm (2 1/2 in.) and 57 mm (2 1/4 in.) at the front and back faces, respectively. Post no. 7 deflected slightly with soil gaps of 51 mm (2 in.) and 13 mm (1/2 in.) at the front and back faces, respectively. Soil gaps of 13 mm (1/2 in.) and 6 mm (1/4 in.) were found at the front faces of post nos. 8 and 9, respectively. The remaining posts in the system experienced no deflection.

The permanent set deflection of the end terminal system is shown in Figure 89. The maximum lateral permanent set rail deflection was 191 mm (7 1/2 in.) at the centerline of post no. 4, as measured in the field. The maximum lateral dynamic rail deflection was 612 mm (24 1/8 in.) at the centerline of post no. 4, as determined from high-speed digital video analysis. The working width of the system was found to be 2,790 mm (109 13/16 in.), measured laterally from the tangent portion of the rail.

8.5 Vehicle Damage

Exterior vehicle damage was moderate, as shown in Figures 91 and 92. Occupant compartment deformations to the right side of the floorboard were judged insufficient to cause serious injury to the vehicle occupants, as shown in Figure 93. Complete occupant compartment deformations and the corresponding locations are provided in Appendix D.

Damage was concentrated on the right-front corner of the bumper and the right side of the vehicle. The entire right side of the vehicle was dented and deformed. The right-front corner of the bumper disengaged from the vehicle. The right-side headlight was deformed into the engine compartment and was fractured. The front of the engine hood was dented at its center and right side. The top of the right-front door was ajar with a 25-mm (1-in.) gap between the door and the roof. The right-front quarter panel was deformed. The right-rear tire was deflated, and the rim was dented. The remainder of the vehicle and all window glass were undamaged.

8.6 Occupant Risk Values

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 7. It is noted that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 7. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 83. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix H. Due to technical difficulties, the DTS recorder did not collect acceleration nor angular data.

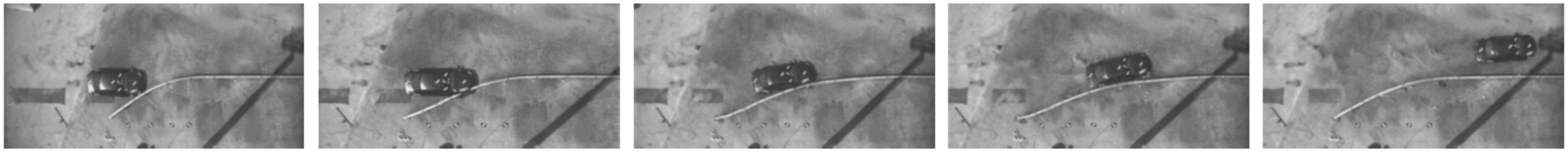
Table 7. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYBBT-2

Evaluation Criteria		**Transducer**	
		EDR-3	**EDR-4**
OIV m/s (ft/s)	Longitudinal	-4.38 (-14.38)	-3.80 (-12.47)
	Lateral	-4.49 (-14.75)	-4.49 (-14.73)
ORA g's	Longitudinal	-8.54	-7.26
	Lateral	-4.78	-3.91
THIV m/s (ft/s)		6.30 (20.67)*	NA
PHD g's		8.99*	NA
ASI		NA	NA

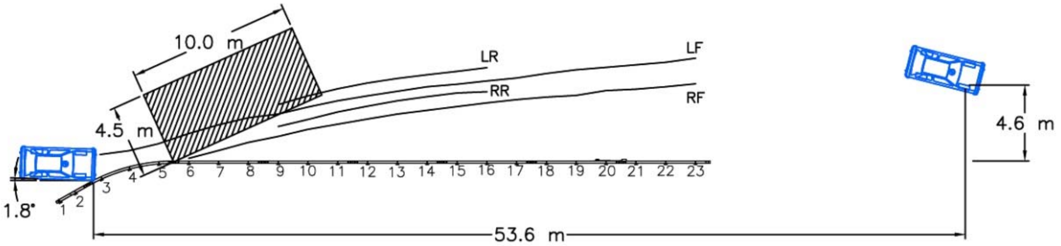
* For test no. NYBBT-2, the THIV and PHD values were calculated using angular data from the DTS transducer and accelerometer traces from the EDR-3 transducer.

8.7 Discussion

The analysis of the test results for test no. NYBBT-2 showed that the NYSDOT Type IIA box beam end terminal adequately contained and redirected the 1100C vehicle. There were no detached elements nor fragments which 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 override the barrier system and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacement 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 no. NYBBT-2 conducted on the Type IIA end terminal was determined to be acceptable according to a modified test designation no. 3-30 of the TL-3 safety performance criteria found in MASH.



0.000 sec — 0.06 sec — 0.158 sec — 0.224 sec — 0.476 sec

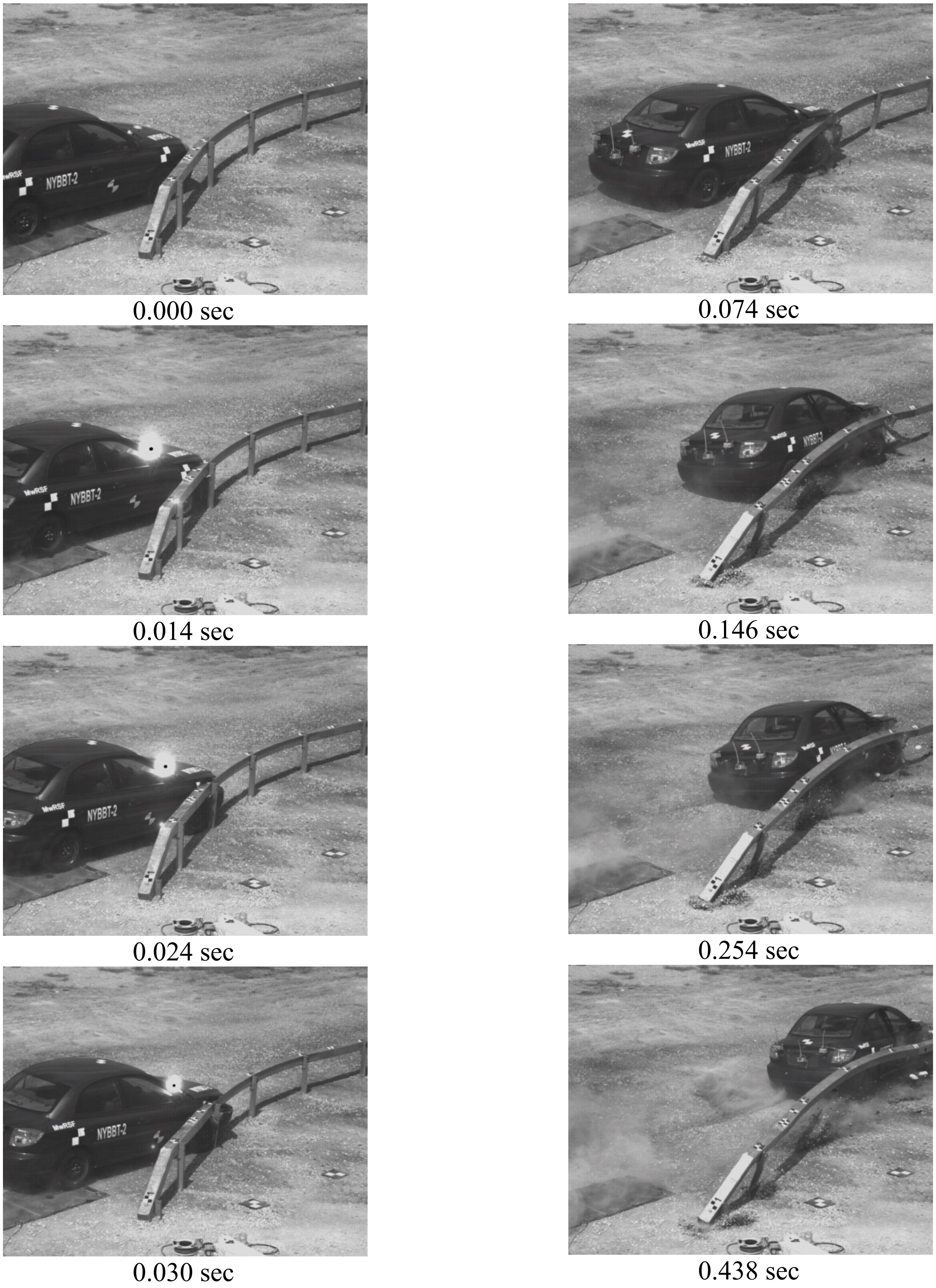


●Test Agency	MwRSF
●Test Number	NYBBT-2
●Date	8/15/07
●MASH Test Designation	Modified 3-30
●Appurtenance	Type IIA End Terminal
●Total Length	40.2 m
●Key Element - Steel-Box-Beam	
Size	152 mm x 152 mm x 4.8 mm
Length	5,486 mm
Top Mounting Height	686 mm
●Key Elements - Steel Post	
Post No. 1	S76x8.5 by 838 mm long
Post Nos. 2-23	S76x8.5 by 1,600 mm long
●Type of Soil	Grading B - AASHTO M 147-65 (1990)
●Test Vehicle	
Type/Designation	1100C
Make and Model	2002 Kia Rio
Curb	1,063 kg
Test Inertial	1,086 kg
Gross Static	1,158 kg
●Impact Conditions	
Speed	101.8 km/h
Angle (trajectory)	1.6 degrees
Target Impact Location	left ¼-point aligned w/ centerline tangent box beam
Actual Impact Location	419 mm upstream of post no. 3
●Exit Conditions	
Speed	78.3 km/h
Angle	15.7 degrees
Exit Box Criterion	Passed
●Post-Impact Trajectory	
Vehicle Stability	Satisfactory
Stopping Distance	53.6 m downstream 4.6 m laterally away from traffic-side face

●Occupant Impact Velocity (EDR-3)	
Longitudinal	-4.38 m/s < 12.2 m/s
Lateral	-4.49 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-3)	
Longitudinal	-8.54 g's < 20.49 g's
Lateral	-4.78 g's < 20.49 g's
●Occupant Impact Velocity (EDR-4)	
Longitudinal	-3.80 m/s < 12.2 m/s
Lateral	-4.49 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-4)	
Longitudinal	-7.26 g's < 20.49 g's
Lateral	-3.91 g's < 20.49 g's
●THIV (DTS - not required)*	6.30 m/s
●PHD (DTS - not required)*	8.99 g's
●ASI (EDR-3 - not required)	NA
●ASI (EDR-4 - not required)	NA
●Test Article Damage	Moderate
●Test Article Deflections	
Permanent Set	191 mm
Dynamic	612 mm
Working Width	2,790 mm
●Vehicle Damage	Moderate
VDS[12]	01-RFQ-3
CDC[13]	01-FZEW3
Maximum Deformation	NA
●Angular Displacement	
Roll	NA
Pitch	NA
Yaw	-15 degrees

Figure 83. Summary of Test Results and Sequential Photographs, Test No. NYBBT-2

* THIV and PHD values are calculated using angular data from the DTS and accelerometer traces from the EDR-3.



0.000 sec

0.014 sec

0.024 sec

0.030 sec

0.074 sec

0.146 sec

0.254 sec

0.438 sec

Figure 84. Additional Sequential Photographs, Test No. NYBBT-2

0.000 sec 0.000 sec

0.032 sec 0.052 sec

0.076 sec 0.148 sec

0.148 sec 0.204 sec

0.226 sec 0.322 sec

0.448 sec 0.454 sec

Figure 85. Additional Sequential Photographs, Test No. NYBBT-2

Figure 86. Documentary Photographs, Test No. NYBBT-2

Figure 87. Impact Location, Test No. NYBBT-2

Figure 88. Vehicle Final Position and Trajectory Marks, Test No. NYBBT-2

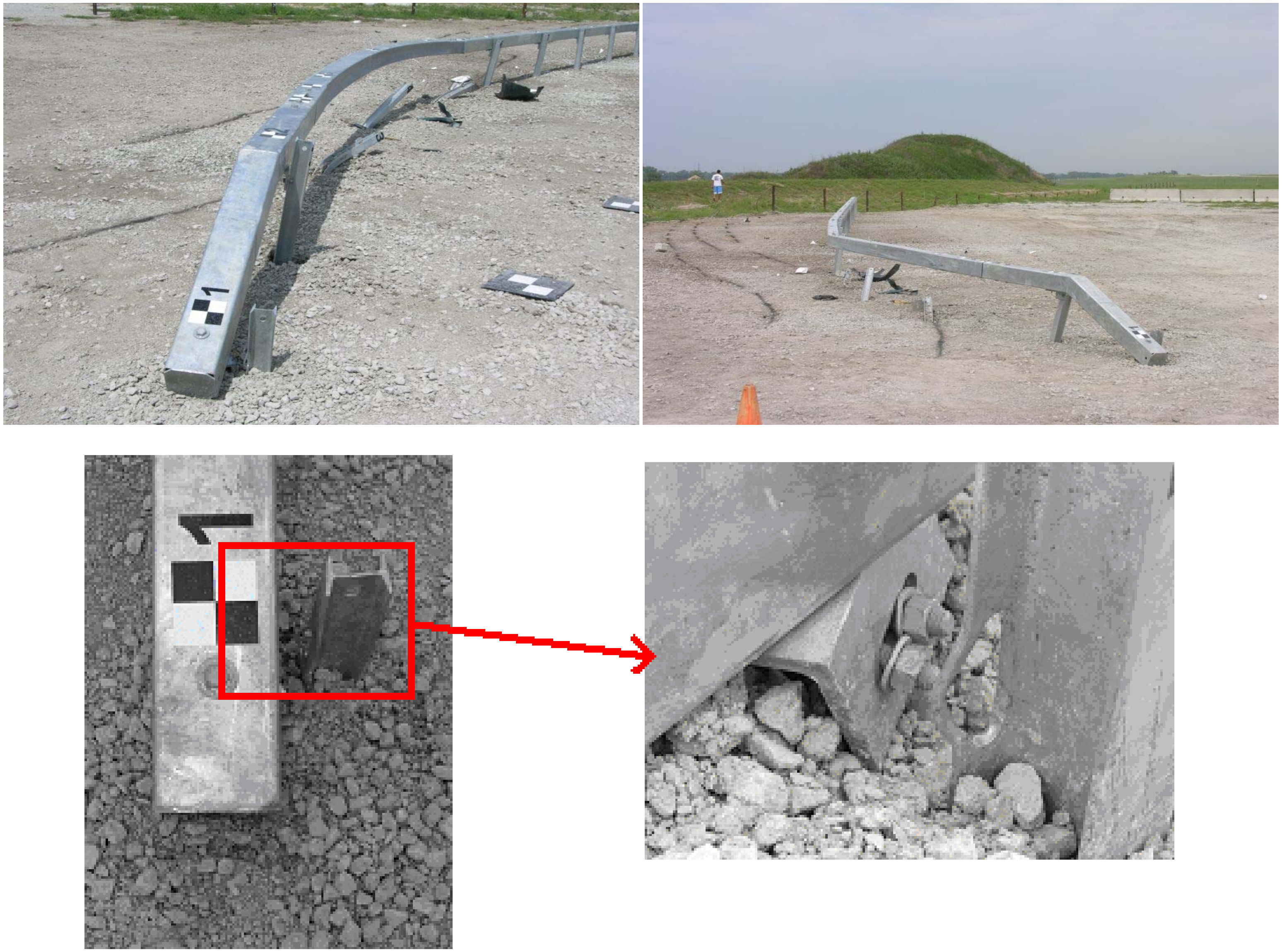


Figure 89. System Damage, Test No. NYBBT-2

Figure 90. System Damage, Test No. NYBBT-2

Figure 91. Vehicle Damage, Test No. NYBBT-2

Figure 92. Undercarriage Damage, Test No. NYBBT-2

Figure 93. Occupant Compartment Damage, Test No. NYBBT-2

9 FULL-SCALE CRASH TEST NO. 3 (TYPE IIA END TERMINAL)

9.1 Test No. NYBBT-3 (Test Designation 3-34)

The 1,176-kg (2,593-lb) Kia Rio, with a dummy placed in the right-front seat, impacted the Type IIA box beam terminal system at a speed of 102.5 km/h (63.7 mph) and at an angle of 16.6 degrees with respect to the tangent. A summary of the test results and sequential photographs are shown in Figure 94. An English-unit summary of the test results and sequential photographs are shown in Appendix C. Additional sequential photographs are shown in Figures 95 and 96. Documentary photographs of the crash test are shown in Figure 97.

9.2 Weather Conditions

Test no. NYBBT-3 was conducted on September 7, 2007 at approximately 12:00 pm. The weather conditions were reported as shown in Table 8.

Table 8. Weather Conditions, Test No. NYBBT-3

Temperature	76° F
Humidity	48 %
Wind Speed	16 mph
Wind Direction	340° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.01 in.
Previous 7-Day Precipitation	0.01 in.

9.3 Test Description

Initial vehicle impact was to occur with the right side of the vehicle aligned with the centerline of post no. 3, as shown in Figure 98. Actual impact occurred at 19 mm (3/4 in.) upstream from the centerline of post no. 3. Upon impact, the vehicle’s hood lifted and protruded over the rail. At 0.012 sec, the end rail section rotated about post no. 1. At 0.014 sec, the right-front corner of the vehicle crushed. At 0.016 sec, post no. 4 deflected and rose up from the ground as it rotated. At 0.020 sec, the vehicle impacted post no. 4. At 0.022 sec, post no. 3 deflected and rose up from the ground as it rotated. At this same time, a buckle point in the box beam formed downstream of post no. 3, causing the rail section to continue to rotate about post no. 1. At 0.030 sec, post no. 5 deflected, and the front of the vehicle yawed toward its left side. At 0.034 sec, post no. 3 detached from the rail. At 0.038 sec, the front bumper tore at the middle. At 0.090 sec, post no. 2 detached from the rail. At 0.102 sec, the rail section between post nos. 3 and 5 rotated away from the vehicle about the splice between post nos. 5 and 6. At 0.106 sec, the vehicle contacted post no. 5, and the post disengaged from the rail. At 0.332 sec, the vehicle yaw ceased. At 0.340 sec, the right rear of the vehicle contacted the guide rail. At 0.350 sec, the vehicle became parallel to the guide rail at the impact location with a speed of 65.1 km/h (40.5 mph). At 0.486 sec, the vehicle exited the system at a speed of 57.7 km/h (35.9 mph) and at an angle of 19.5 degrees with respect to the tangent line of the system. After exiting the box beam system, the vehicle traversed away from the system parallel to the guide rail in a stable manner. Prior to the vehicle coming to rest, the vehicle contacted the residual setup from another system and rolled over. The trajectory and final position of the passenger car are shown in Figures 94 and 99.

9.4 System and Component Damage

Damage to the end terminal system was moderate, as shown in Figures 100 through 103. Damage consisted of deformed box beam rail and guide rail posts and contact marks on box beam sections. The length of vehicle contact was approximately 7.3 m (24 ft), which spanned from 19 mm (3/4 in.) upstream from the centerline of post no. 3 through post no. 7.

Minor buckling occurred at post no. 6. Major buckling occurred downstream of post no. 3 and at post no. 7. The box beam splice between post nos. 8 and 9 was compressed, deformed, and twisted. The box beam rail disengaged from post nos. 1 through 8.

The bolt slots on post no. 1 were deformed, and the downstream slot tore through the flange. Post no. 2 bent backward and twisted at the ground line. Post no. 3 twisted and buckled at the ground line. Post no. 4 bent downstream and twisted slightly. Post no. 5 bent downstream and backward, and the back flange was dented. The bolt connecting the shelf angle to post no. 5 was deformed. Post no. 6 bent backward and twisted upstream, and the front flange encountered a gouge. The bolt connecting the shelf angle to post no. 6 tore through the post hole. Post no. 7 bent backward and downstream and was twisted slightly. Post no. 8 bent downstream. The bolt connecting the shelf angle to the post on post nos. 7 and 8 sheared off. Post nos. 9 and 10 rotated slightly backward. Contact and scrape marks were found on the upstream-front flange of post nos. 3 through 7. The shelf angle disengaged from post nos. 1, 4, and 6 through 8, while the shelf angle on post nos. 2, 3, and 5 were deformed. The remaining posts and shelf angles remained undamaged.

The permanent set deflection of the end terminal system is shown in Figure 100. The maximum lateral permanent set rail deflection was 6,246 mm (246 in.) at the centerline of post no. 3, as determined in the field and from high-speed digital video analysis. The working width of the system was found to be 7,312 mm (287 7/8 in.), measured laterally from the tangent portion of the rail.

9.5 Vehicle Damage

Exterior vehicle damage was moderate, as shown from Figures 104 and 105. The roof, windshield, and left-side exterior vehicle damage and occupant compartment deformations were the result of vehicle rollover from contact with the setup from another system and not the box beam terminal. Occupant compartment deformations and the corresponding locations are provided in Appendix D.

The entire right side of the vehicle was dented, deformed, and scratched. The right half of the front bumper cover disengaged, and the center of the bumper was deformed into the engine compartment. The grill was fractured. The front-right edge of the engine hood deformed under and inwards. The right-front door crushed in along its entire length at the rail height. A 737-mm (29-in.) tear was located along the bottom center of the right-front door. A smaller 76-mm (3-in.) tear was located along the bottom rear of the right-front door. The right-side headlight was deformed inward and was fractured. The right-front quarter panel was deformed inward toward the engine compartment. The right-side taillight was fractured. The right-front steel rim was bent. The lower end of the radiator support was torn and damaged. The engine oil pan developed a 127-mm (5-in.) long tear. Contact marks and dents were found along the entire underside of the floorboard.

9.6 Occupant Risk Values

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 9. It is noted that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 9. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 94. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix I. Due to technical difficulties, the EDR-4 and DTS recorders did not collect acceleration nor angular data.

Table 9. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYBBT-3

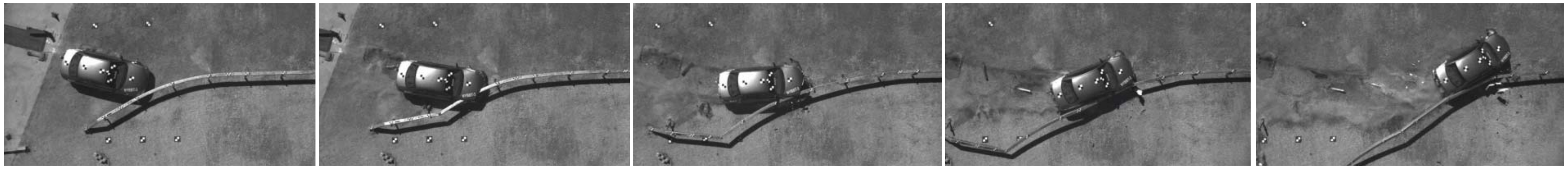
Evaluation Criteria		**Transducer**
		EDR-3
OIV m/s (ft/s)	Longitudinal	-5.23 (-17.16)
	Lateral	4.44 (14.57)
ORA g's	Longitudinal	-9.02
	Lateral	6.53
THIV m/s (ft/s)		6.39 (20.96)*
PHD g's		10.95*
ASI		NA

* Note: The THIV and PHD values were calculated using high-speed video analysis and EDR-3 accelerometer traces.

9.7 Discussion

The analysis of the test results for test no. NYBBT-3 showed that the NYSDOT Type IIA box beam end terminal system adequately contained and redirected the 1100C vehicle. The roof, left side, and windshield damage were the result of vehicle rollover from contact with the setup from another system after the vehicle had been safely redirected. There were no detached elements nor fragments which 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 override the barrier system and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacement during the initial impact event 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 no. NYBBT-3 conducted on the Type IIA end terminal was determined to be acceptable according to test designation no. 3-34 of the TL-3 safety performance criteria found in MASH.



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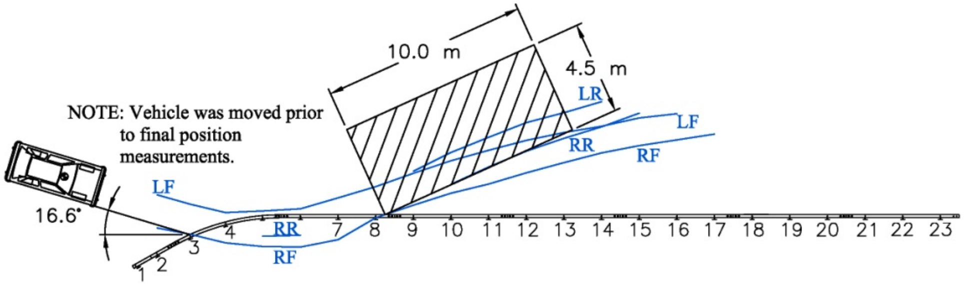
●Test Agency	MwRSF
●Test Number	NYBBT-3
●Date	9/7/07
●MASH Test Designation	3-34
●Appurtenance	Type IIA End Terminal
●Total Length	40.2 m
●Key Element – Steel Box Beam	
Size	152 mm x 152 mm x 4.8 mm
Length	5,486 mm
Top Mounting Height	686 mm
●Key Elements - Steel Post	
Post No. 1	S76x8.5 by 838 mm long
Post Nos. 2-23	S76x8.5 by 1,600 mm long
●Type of Soil	Grading B - AASHTO M 147-65 (1990)
●Test Vehicle	
Type/Designation	1100C
Make and Model	2002 Kia Rio
Curb	1,070 kg
Test Inertial	1,101 kg
Gross Static	1,176 kg
●Impact Conditions	
Speed	102.5 km/h
Angle (trajectory)	16.6 degrees
Target Impact Location	Centerline of post no. 3
Actual Impact Location	19 mm upstream of post no. 3
●Exit Conditions	
Speed	57.7 km/h
Angle	19.5 degrees
Exit Box Criterion	Passed
●Post-Impact Trajectory	
Vehicle Stability	Satisfactory
Stopping Distance	NA
●Occupant Impact Velocity (EDR-3)	
Longitudinal	-5.23 m/s < 12.2 m/s
Lateral	4.44 m/s < 12.2 m/s

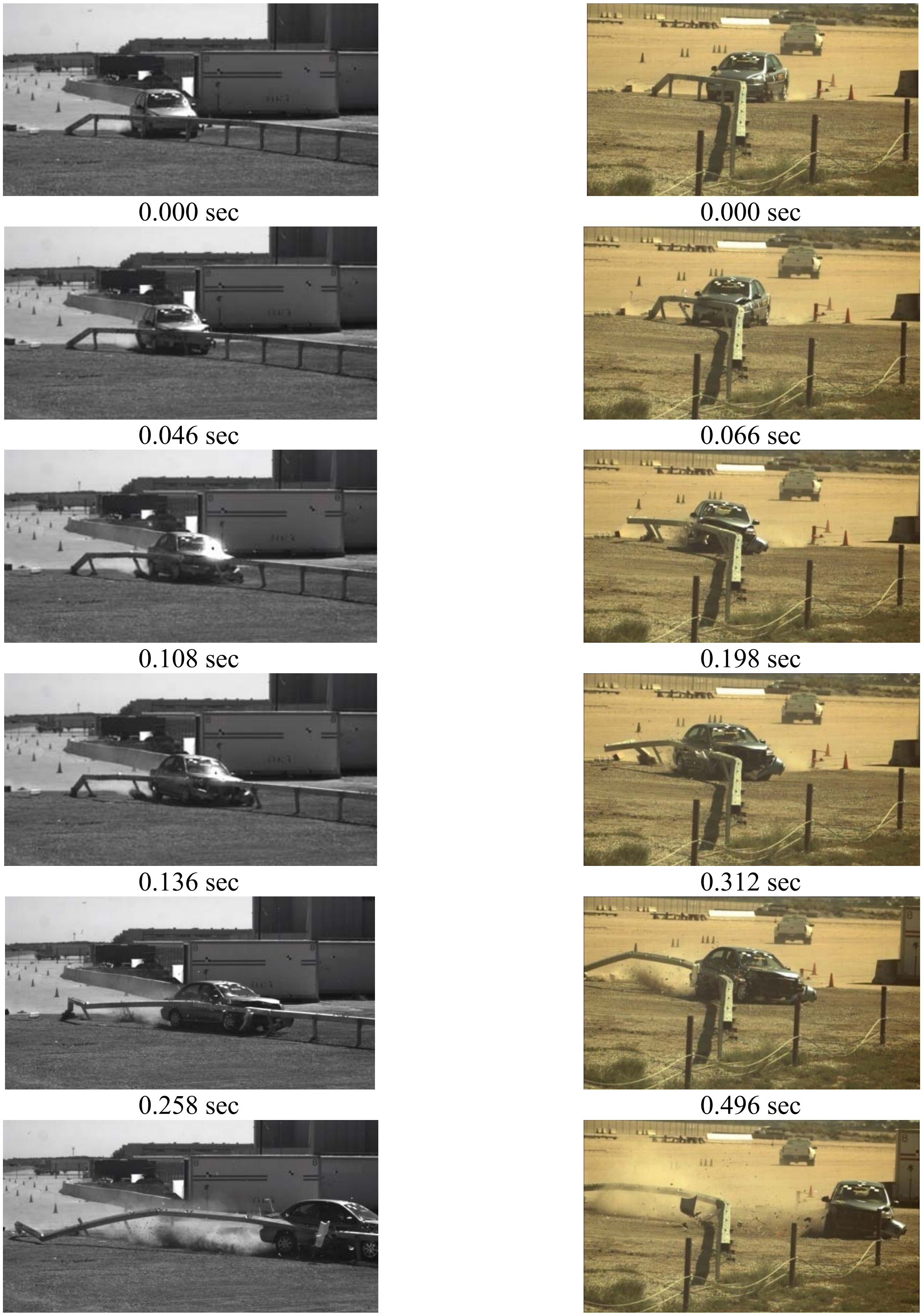


NOTE: Vehicle was moved prior to final position measurements.

●Occupant Ridedown Acceleration (EDR-3)	
Longitudinal	-9.02 g's < 20.49 g's
Lateral	6.53 g's < 20.49 g's
●THIV (EDR-3 - not required)*	6.39 m/s
●PHD (EDR-3 - not required)*	10.95 g's
●ASI (EDR-3 - not required)	NA
●Test Article Damage	Moderate
●Test Article Deflections	
Permanent Set	6,246 mm
Dynamic	NA
Working Width	7,312 mm
●Vehicle Damage	Moderate
VDS[12]	01-RFQ-6
CDC[13]	01-RYEW2
Maximum Deformation	NA
●Angular Displacement	
Roll	3 degrees
Pitch	NA
Yaw	-46 degrees

Figure 94. Summary of Test Results and Sequential Photographs, Test No. NYBBT-3

* The THIV and PHD values were calculated using high-speed video analysis and EDR-3 accelerometer data.



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0.046 sec

0.108 sec

0.136 sec

0.258 sec

0.504 sec

0.000 sec

0.066 sec

0.198 sec

0.312 sec

0.496 sec

0.972 sec

Figure 95. Additional Sequential Photographs, Test No. NYBBT-3

0.000 sec

0.090 sec

0.298 sec

0.392 sec

0.720 sec

Figure 96. Additional Sequential Photographs, Test No. NYBBT-3

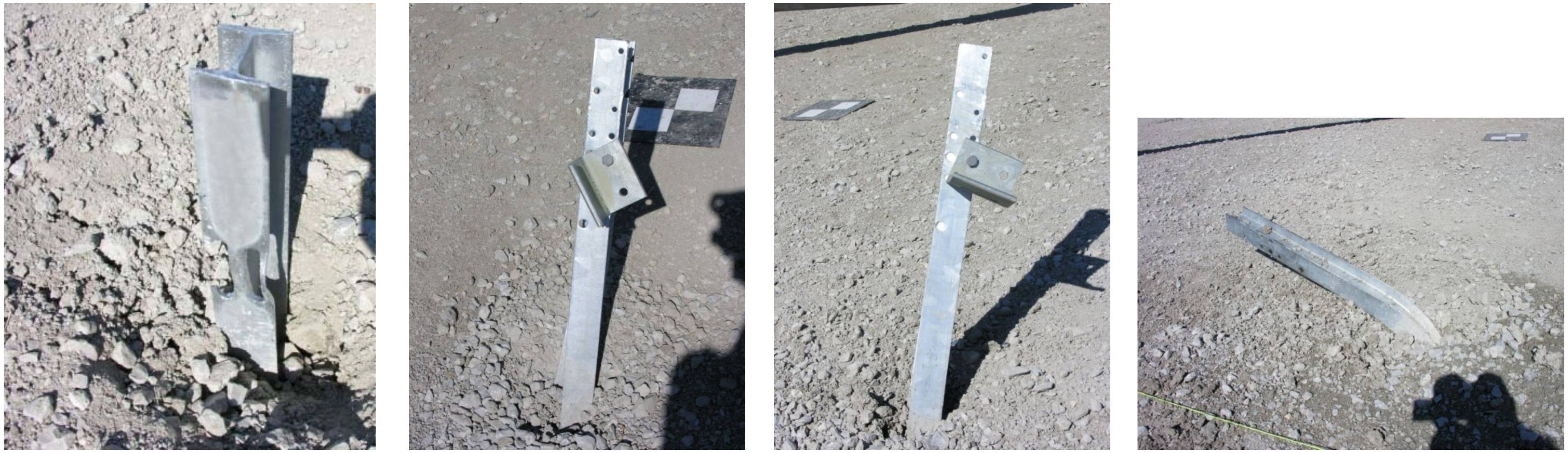
Figure 97. Documentary Photographs, Test No. NYBBT-3

Figure 98. Impact Location, Test No. NYBBT-3

Figure 99. Vehicle Final Position and Trajectory Marks, Test NYBBT-3

Figure 100. System Damage, Test No. NYBBT-3

Figure 101. Post Damage – Back View, Test No. NYBBT-3



Post No. 1 Post No. 2 Post No. 3 Post No. 4

Post No. 5 Post No. 6 Post No. 7

Figure 102. Post Damage – Front View, Test No. NYBBT-3

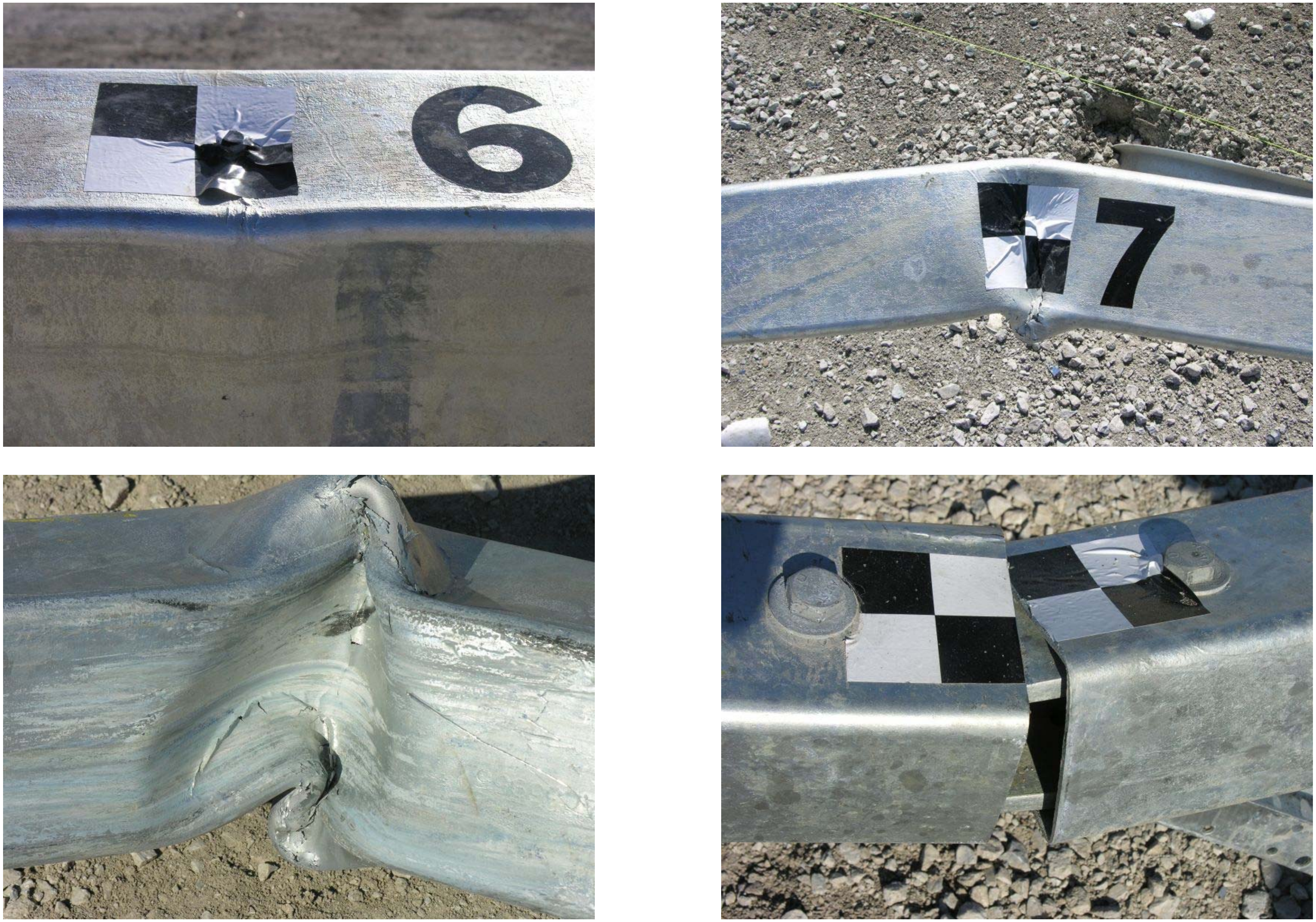


Figure 103. Rail Damage, Test No. NYBBT-3

Figure 104. Vehicle Damage, Test No. NYBBT-3
(The roof, windshield, and left side damage was due to the secondary impact with the setup from another system.)

Figure 105. Vehicle Damage, Test No. NYBBT-3
(The mirror damage was due to the secondary impact with the setup from another system.)

10 TYPE IIA END TERMINAL MODIFICATIONS – NYBBT-4 SYSTEM DETAILS

The Type IIA end terminal would be used mainly on secondary highways and often at driveways with adjoining ditches close to the shoulder. With this configuration, there exists a potential for vehicle underride when the terminal extends out over the slope of the ditch. Following an evaluation of the satisfactory results observed for test nos. NYBBT-2 and NYBBT-3 on the Type IIA end terminal, NYSDOT personnel deemed it necessary to incorporate design modifications that would improve barrier performance by preventing the potential for vehicle underride when ditches are located near the end terminal. The vehicle underride issue and the effectiveness of the design modifications were subsequently evaluated in test no. NYBBT-6.

For the initial Type IIA box beam end terminal system (test nos. NYBBT-2 and NYBBT-3), the first three posts consisted of S76x8.5 (S3x5.7) steel sections attached to the back side of the box beam with one 127-mm x 89-mm x 9.5-mm (5-in. x 3 1/2-in. x 3/8-in.) box beam shelf angle at each post. The first post was 1,194 mm (47 in.) long, while the second and third posts were 1,600 mm (63 in.) long.

In order to improve barrier performance for scenarios where the end terminal was located near a ditch, several design modifications were implemented into the Type IIA box beam end terminal system. Post nos. 1 through 3 still were fabricated with S76x8.5 (S3x5.7) steel sections, but they were lengthened to 2,134 mm (84 in.) long, as shown in Figure 106. Next, the embedment depth of post nos. 1 through 3 was changed from 914 mm (36 in.) to 1,854 mm (73 in.) for post no. 1 and 1,359 mm (53 1/2 in.) for post nos. 2 and 3, as shown in Figure 107. Third, post nos. 1 through 3 were moved from the back side of the box beam to the traffic-side face of the rail. Finally, a second box beam shelf angle was added above the top of the box beam at post nos. 2 and 3 to complement to the existing box beam shelf angle that was positioned under the bottom face of the box beam, as shown in Figure 108.

The post lengths were increased in order to account for a vertical drop in grade as a guide rail end terminal flares away from the roadway and extends into a ditch section. The placement of post nos. 2 and 3 on the upstream side, combined with a second bracket placed above the rail, were intended to permit a vehicle entering a ditch to strike the posts and have the posts push the rail ahead of the vehicle and pull it down toward the grill, rather than allowing the rail to come over the engine hood and contact the windshield.

The 40.2-m (132-ft) installation consisted of 38.1 m (125 ft) of the NYSDOT's standard TS 152-mm x 152-mm x 4.8-mm (6-in. x 6-in. x 3/16-in.) steel tube box-beam guide rail with a modified Type IIA end terminal. The top rail height was 686 mm (27 in.). The box beam rail was attached to each box beam shelf angle by a 9.5-mm diameter by 191-mm long (3/8-in. x 7 1/2-in.), ASTM A307 hex head bolt. One 12.7-mm (1/2-in.) diameter by 51-mm (2-in.) long, ASTM A307 hex head bolt with a 12.7-mm (1/2-in.) narrow washer was used to attach each box beam shelf angle to the post. Similar to that used in test no. NYBBT-3, the rail was anchored to the ground at post no. 22 using a reverse cable anchorage system to develop the longitudinal resistance in the rail, as shown in Figure 106. An additional cable anchorage device was placed at the splice between post nos. 20 and 21, as shown in Figure 106. Design details are shown in Figures 106 through 110. Complete barrier system drawings in both metric and English units are shown in Appendix J. Photographs of the test installation are shown in Figures 111 through 113.

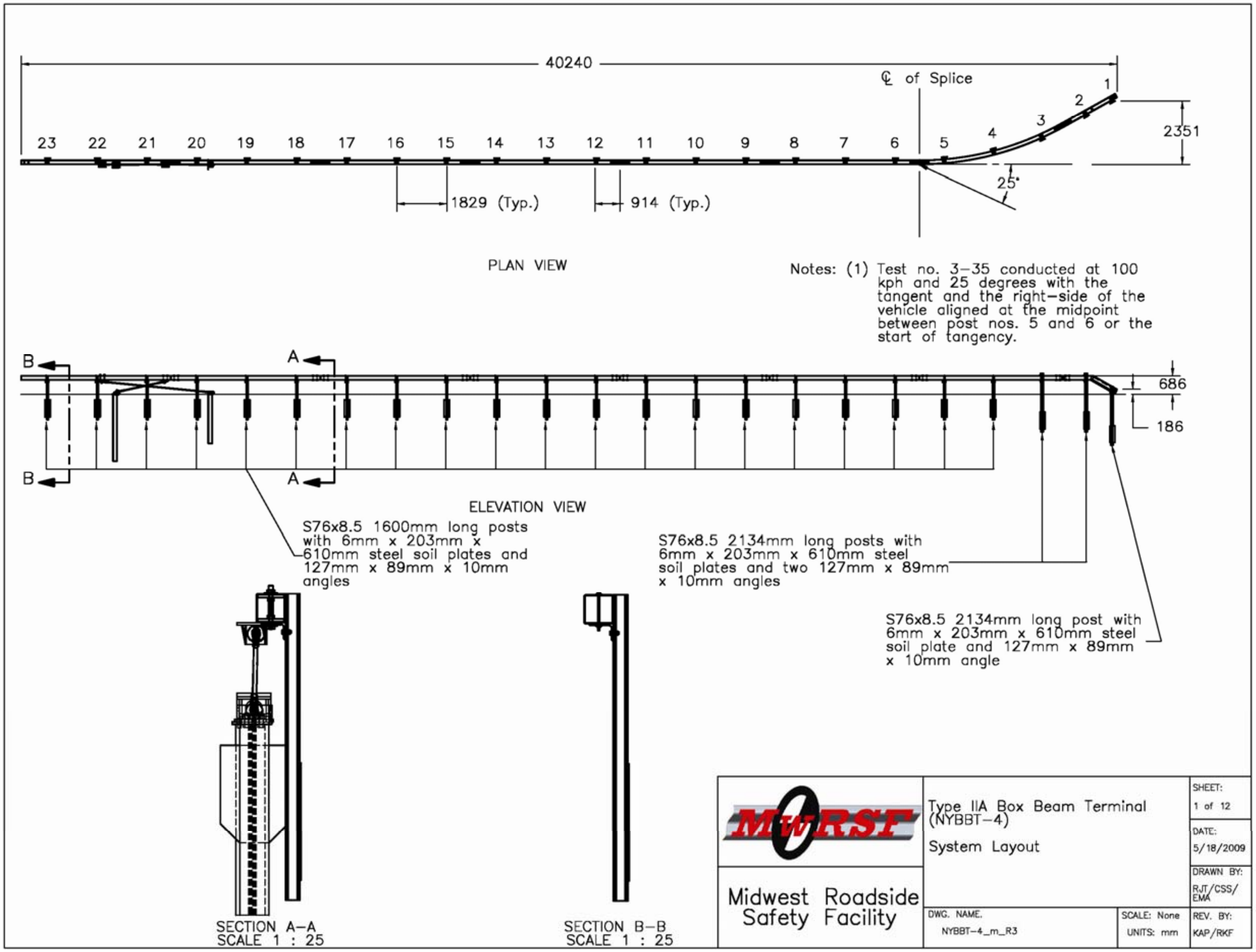


Figure 106. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-4

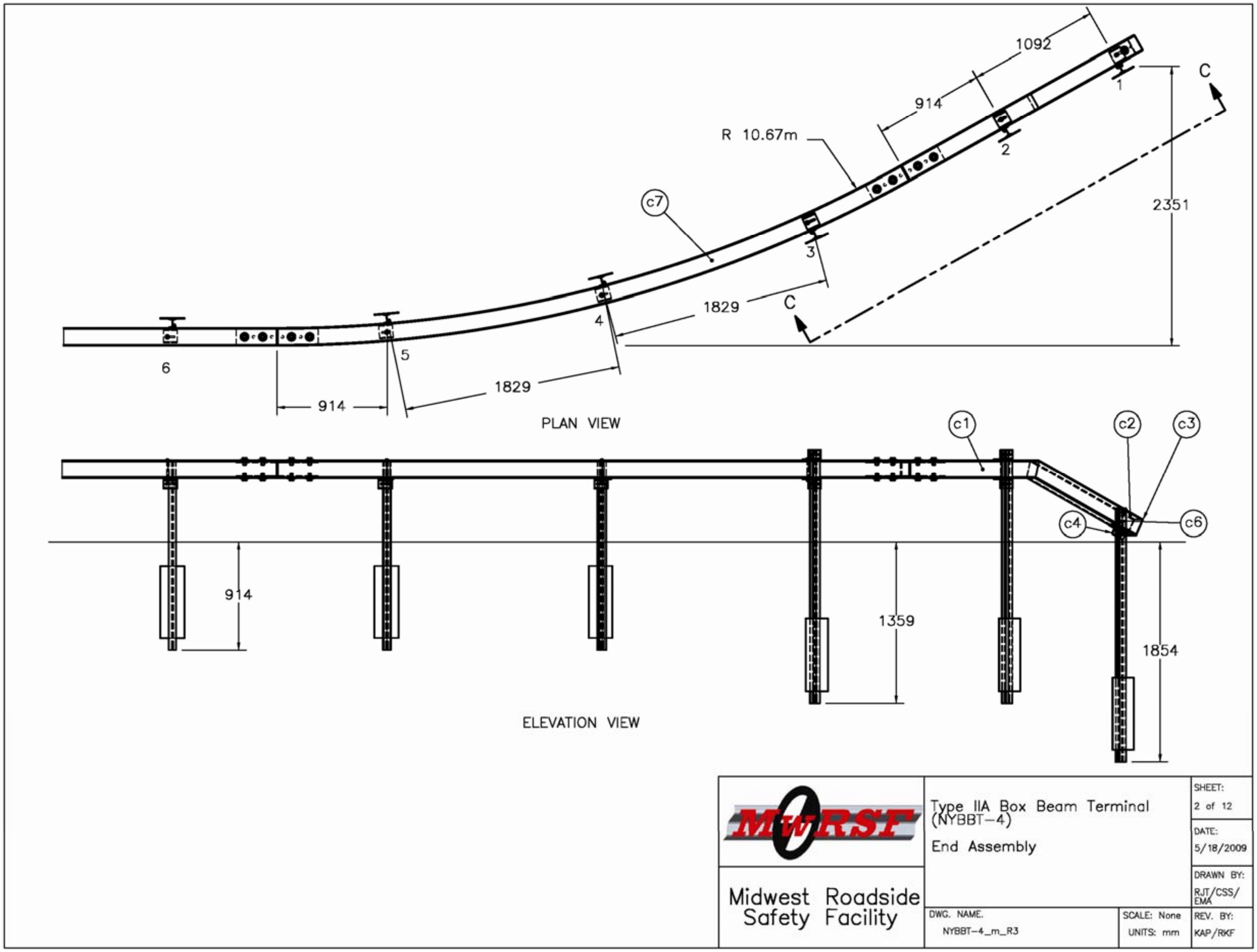


Figure 107. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-4

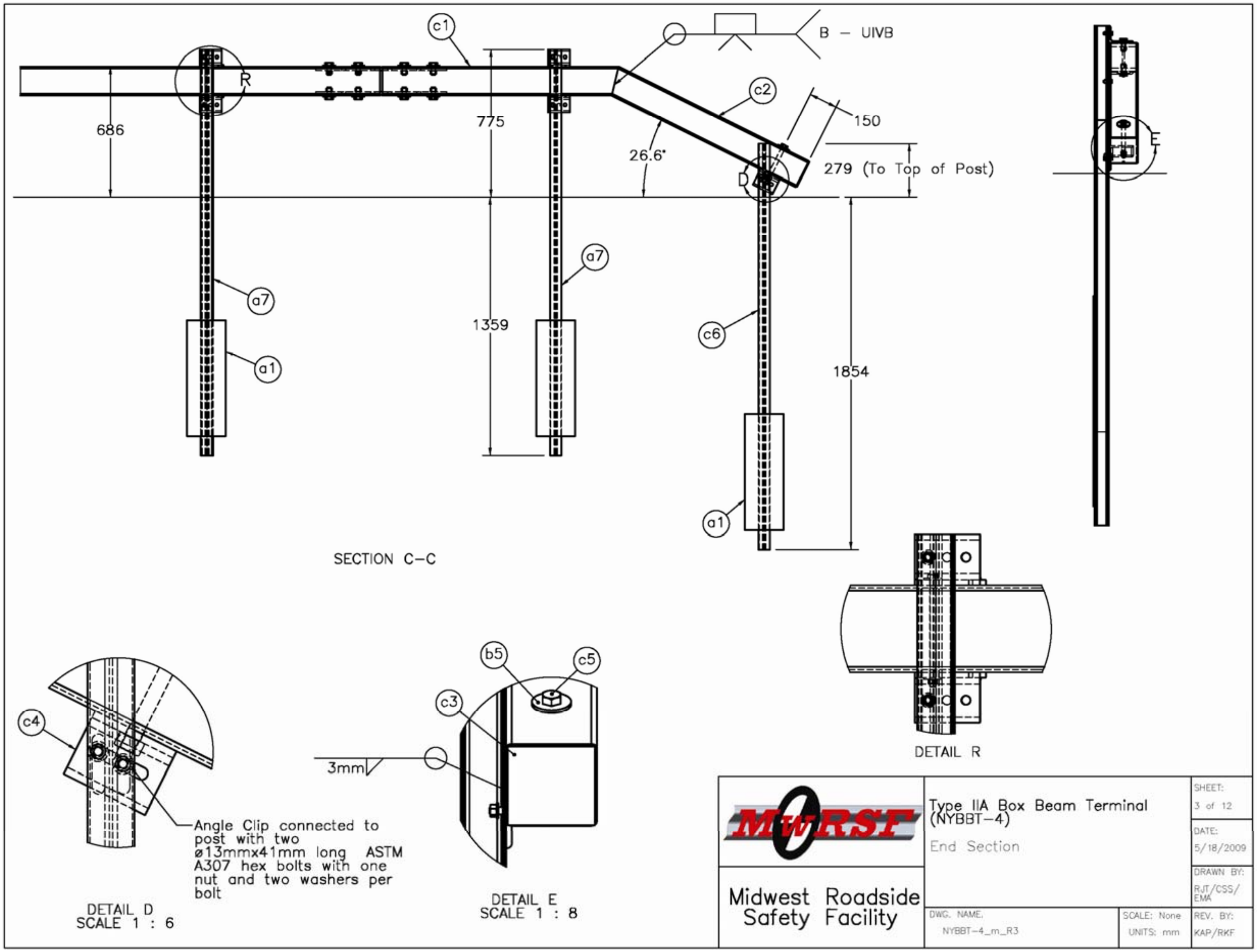


Figure 108. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-4

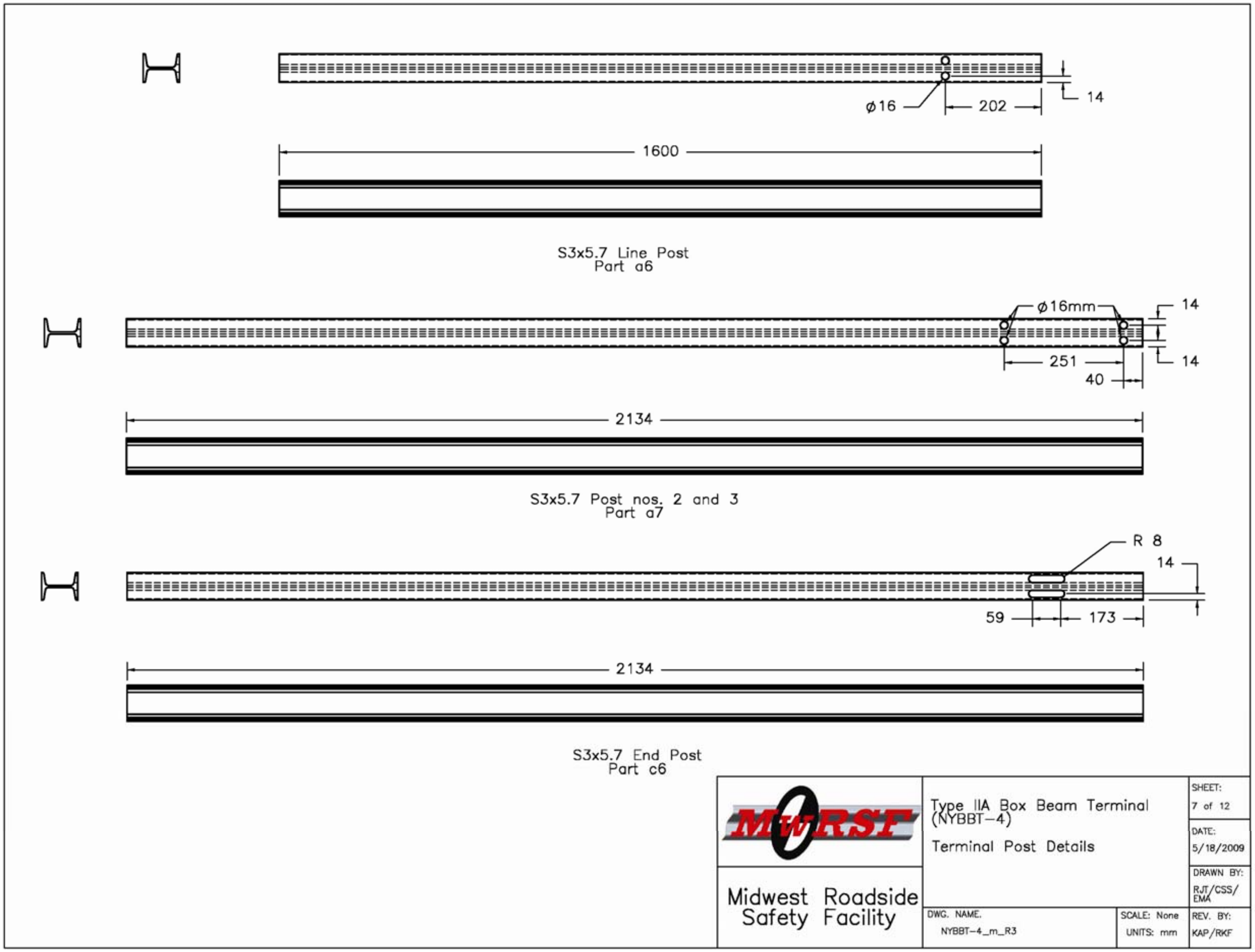


Figure 109. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-4

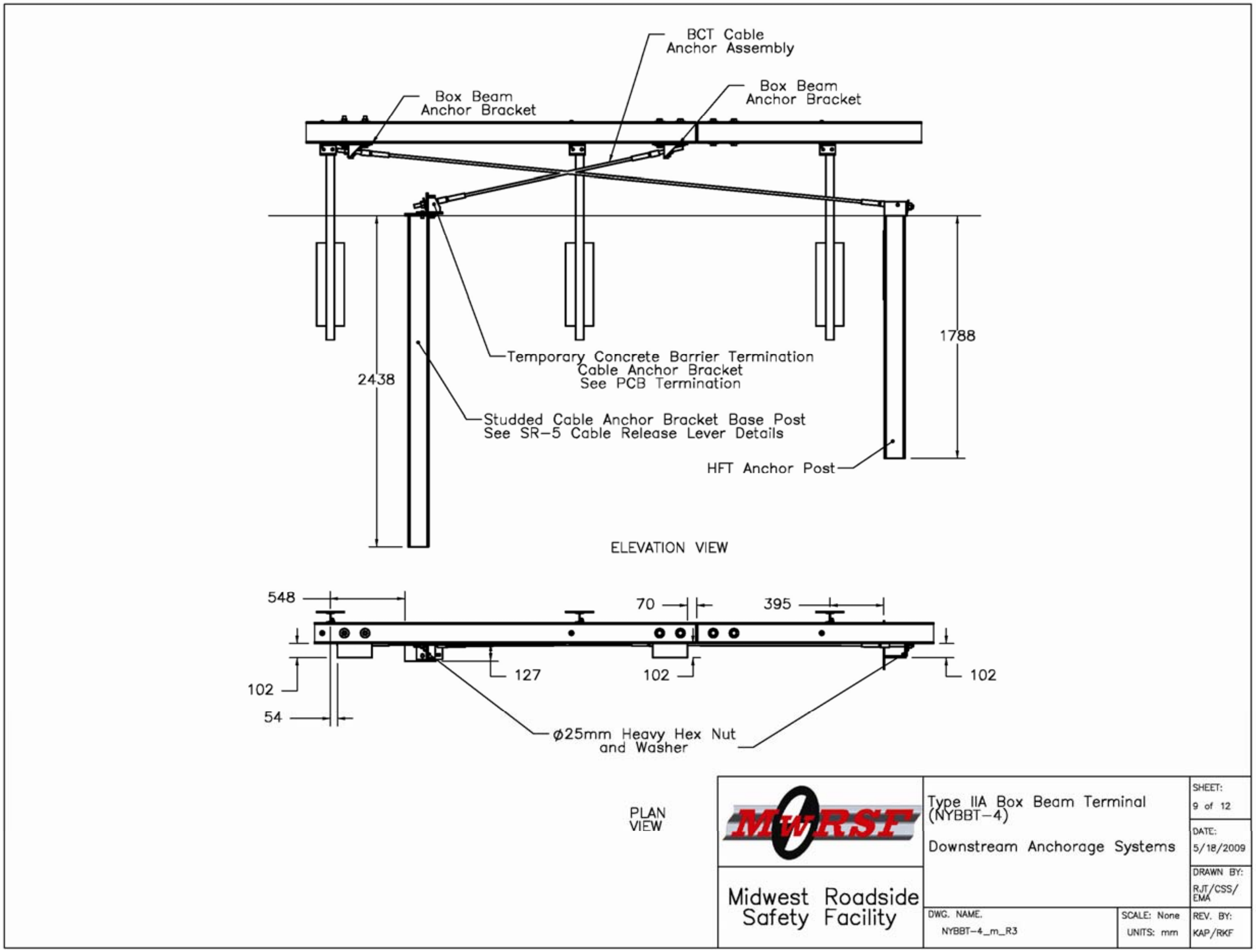


Figure 110. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-4

Figure 111. NYBBT-4 System Details

Figure 112. NYBBT-4 System Details

Figure 113. NYBBT-4 System Details

11 FULL-SCALE CRASH TEST NO. 4 (MODIFIED TYPE IIA END TERMINAL)

11.1 Static Soil Test

Before full-scale crash test no. NYBBT-4 was conducted, the strength of the foundation soil was evaluated with a static test, as described by MASH. The static test results, as shown in Appendix K, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and the barrier system was approved for full-scale crash testing.

11.2 Test No. NYBBT-4 (Test Designation 3-35)

The 2,348-kg (5,176-lb) Dodge Ram 1500 Quad Cab pickup truck, with a dummy placed in the right-front seat, impacted the modified Type IIA box beam terminal system at a speed of 100.0 km/h (62.1 mph) and at an angle of 22.9 degrees with respect to the tangent. A summary of the test results and sequential photographs are shown in Figure 114. An English-unit summary of the test results and sequential photographs are shown in Appendix C. Additional sequential photographs are shown in Figures 115 and 116. Documentary photographs of the crash test are shown in Figures 117 through 119.

11.3 Weather Conditions

Test no. NYBBT-4 was conducted on July 11, 2008 at approximately 12:00 pm. The weather conditions were reported as shown in Table 10.

Table 10. Weather Conditions, Test No. NYBBT-4

Temperature	92° F
Humidity	49 %
Wind Speed	21 mph
Wind Direction	190° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.11 in.
Previous 7-Day Precipitation	0.52 in.

11.4 Test Description

Initial vehicle impact was to occur with the vehicle aligned with the beginning of the tangent box beam, which placed the vehicle's right-front corner at the midspan between post nos. 5 and 6 or 914 mm (36 in.) upstream of post no. 6, as shown in Figure 120. Actual vehicle impact occurred 851 mm (33 1/2 in.) upstream of post no. 6. Upon impact, the right-front corner of the bumper deformed. At 0.004 sec, the rail and post no. 6 deflected laterally away from the vehicle. At 0.010 sec, post no. 5 deflected laterally away from the vehicle. At 0.020 sec, the splice plate located between post nos. 8 and 9 was bent, and post no. 8 twisted upstream. At this same time, post no. 4 twisted downstream, and the upstream box beam sections encountered tension. At 0.028 sec, post no. 4 deflected laterally away from the vehicle. At 0.038 sec, post no. 3 twisted downstream. At 0.048 sec, the right-front tire contacted the front-downstream flange of post no. 6, and post no. 6 twisted downstream and detached from the rail. At 0.060 sec, the vehicle began redirecting. At 0.074 sec, a buckle point formed in the box beam section between post nos. 6 and 7. At this same time, post no. 5 detached from the rail. At 0.096 sec, the vehicle rolled toward the right. At 0.148 sec, the hex bolt connecting the box beam to the shelf angles at post no. 3 fractured. At 0.206 sec, the left-front tire became airborne. At 0.224 sec, the left-rear tire became airborne. At 0.256 sec, the vehicle became parallel to the system with a resultant velocity of 86.9 km/h (54.0 mph). At this same time, post no. 4 detached from the rail. At 0.268 sec, the right-rear corner of the bumper contacted the top of the box beam section between post nos. 6 and 7 and deflected the rail downward. At 0.294 sec, the front of the vehicle pitched downward. At 0.320 sec, the vehicle right-rear tire contacted the box beam at post no. 9. At 0.356 sec, the hex bolt connecting the box beam to the shelf angles at post no. 2 fractured. At 0.454 sec, the right-rear tire overrode the rail. At 0.462 sec, post no. 1 detached from the rail. At

0.558 sec, the vehicle roll ceased, and the right-front corner of the bumper contacted the ground. At 0.638 sec, the vehicle pitch ceased. At 0.848 sec, the entire vehicle became airborne with the rear tires located above and behind the rail. At 1.162 sec, the left-rear tire contacted the back side of the rail. At 1.236 sec, the left-front tire contacted the ground. At 1.380 sec, the vehicle rolled toward the right. At 1.408 sec, the right-rear tire contacted the back side of the rail. At 1.574 sec, the right-rear tire of the vehicle detached, and the vehicle continued to roll toward the right. At 1.964 sec, the right-rear corner of the vehicle impacted the top of the rail. At 2.306 sec, the vehicle lost contact with the system while continuing to roll over. The trajectory and final position of the pickup truck are shown in Figures 114 and 121.

11.5 System and Component Damage

Damage to the end terminal system was extensive, as shown in Figures 122 through 136. Damage consisted of deformed box beam and guide rail posts and contact marks on box beam rail sections and guide rail posts. The length of vehicle contact was approximately 32.9 m (107.8 ft), which spanned from 851 mm (33 1/2 in.) upstream from the centerline of post no. 6 through the downstream end of the system.

Major buckling occurred 330 mm (13 in.) downstream from the centerline of post no. 6 and at post no. 13. The box beam splice between post nos. 5 and 6 was stretched and a 38-mm (1 1/2-in.) gap formed between the ends of these two sections. The box beam splices between post nos. 8 and 9 and post nos. 14 and 15 were also stretched. The box beam rail disengaged from post nos. 1 through 14, 16 through 21, and 23.

The back-side bolt slots on post no. 1 were deformed, and the upstream slot tore through the flange. The back-side flange of post nos. 2, 3, 8, 9, and 11 were deformed. Post nos. 4 and 5 bent backward and twisted downstream. Post no. 6 bent backward to a 45 degree angle. The traffic-side flange of post nos. 7 through 9 was deformed. Post nos. 7 and 8 bent downstream and backward. Post nos. 9 through 13 bent downstream. Contact and scrape marks were found on the front flange of post no. 13. Post no. 14 bent downstream and backward and twisted upstream. Post no. 15 bent backward. Post nos. 16 through 21 bent downstream. The front flange of post nos. 18, 19, and 21 were deformed. Post no. 20 twisted upstream. Post no. 23 rotated downstream.

Soil gaps of 203 mm (8 in.) were found at the upstream sides of post nos. 10 and 11. Soil gaps of 178 mm (7 in.) were found at the upstream side of post nos. 20 and 21. The downstream anchor remained undamaged. The bolt connecting the shelf angle to the rail at post nos. 2 through 13, 16, and 18 through 21 sheared off. The bolt connecting the shelf angle to post nos. 6, 7, 11, 12, and 19 sheared off. The bolt connecting the shelf angle to post nos. 14, 17, and 23 tore through the post hole flange. The shelf angle at post no. 22 deformed, but remained attached to the post and rail.

The permanent set deflection of the end terminal system is shown in Figure 122. The maximum lateral permanent set rail deflection was 7,169 mm (282 1/4 in.) at the centerline of post no. 6, as determined in the field and from high-speed digital video analysis. However, it should be noted that during the test, the deflected end terminal contacted test equipment, thus the total permanent set deflection was less than it could have been.

11.6 Vehicle Damage

Exterior vehicle damage was extensive, as shown in Figures 137 through 139. The occupant compartment was severely damaged due to vehicle rollover. The roof crushed into the occupant compartment. Complete occupant compartment deformations as well as the corresponding locations are provided in Appendix D. The damage to the sides and top of the vehicle and window fracture was due to the rollover. Both right-side wheel assemblies disengaged from the vehicle. Scrapes and scratches were found on the undercarriage of the vehicle due to the vehicle overriding the system, as shown in Figure 139.

11.7 Occupant Risk Values

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 11. It is noted that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 11. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 114. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix L. Due to technical difficulties, the EDR-4 recorder did not collect acceleration nor angular data.

Table 11. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYBBT-4

Evaluation Criteria		**Transducer**	
		EDR-3	**DTS**
OIV m/s (ft/s)	Longitudinal	-3.15 (-10.32)	-2.81 (-9.23)
	Lateral	4.06 (13.32)	4.12 (-13.53)
ORA g's	Longitudinal	-7.12	-6.38
	Lateral	11.90	11.32
THIV m/s (ft/s)		NA	5.34 (17.52)
PHD g's		NA	11.42
ASI		0.84	0.79

11.8 Discussion

The analysis for test no. NYBBT-4 showed that the modified NYSDOT Type IIA box beam end terminal system did not contain nor redirect the 2270P vehicle, since the vehicle did not remain upright after collision with the barrier. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did occur with the deformations of the vehicle’s roof. Therefore, test no. NYBBT-4 conducted on the modified Type IIA end terminal was determined to be unacceptable according to test designation no. 3-35 of the TL-3 safety performance criteria found in MASH.

Following a review of the test results from test no. NYBBT-4, the following observations should be noted: (1) the pickup truck appeared to be redirecting well for a significant period of time and (2) the vertical mounting bolts at post nos. 2 and 3 did not allow for those posts to be utilized effectively as the posts were not deformed after the test. Therefore, the failure of the 2270P crash test was a direct result of: (1) the rail releasing prematurely from several posts and possibly the upstream anchorage; (2) several posts not providing adequate lateral resistance nor energy dissipation; (3) the rail falling down and not capturing the truck’s rear end; and (4) the truck’s rear end traveling over the rail to the back side of the barrier system. Vehicle rollover occurred later in the impact event and after the truck had traveled downstream with the rear end of the vehicle on the back side of the barrier.

Thus, the researchers felt that the safety performance of the barrier system could be improved by considering several general design modifications. First, a stronger connection between the box beam rail and post nos. 2 and 3 could impart greater redirective forces to the vehicle, improve vehicle to rail interlock and containment, as well as provide increased energy dissipation during the impact event. Second, the placement of additional steel guardrail posts downstream from post no. 3 could also aid in effectively capturing the pickup truck under high-speed, high-energy impacts. During these crash events, an adequately positioned rail would prevent the truck's rear end from excessively extending over the barrier, thus reducing the vehicle's counterclockwise yaw motion as well as the potential for vehicle override of the barrier system. Finally, the barrier's safety performance could be increased by providing greater tensile capacity in the rail with changes to the anchorage on the upstream end of the system.

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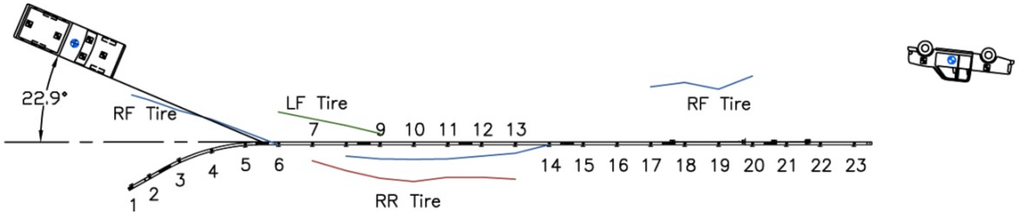

●Test Agency	MwRSF
●Test Number	NYBBT-4
●Date	7/11/08
●MASH Test Designation	3-35
●Appurtenance	Modified Type IIA End Terminal
●Total Length	40.2 m
●Key Element – Steel Box Beam	
Size	152 mm x 152 mm x 4.8 mm
Length	5,486 mm
Top Mounting Height	686 mm
●Key Elements - Steel Post	
Post Nos. 1-3	S76x8.5 by 2,134 mm long
Post Nos. 4-23	S76x8.5 by 1,600 mm long
●Type of Soil	Grading B - AASHTO M 147-65 (1990)
●Test Vehicle	
Type/Designation	2270P
Make and Model	2002 Dodge Ram 1500 Quad Cab Pickup
Curb	2,312 kg
Test Inertial	2,270 kg
Gross Static	2,348 kg
●Impact Conditions	
Speed	100.0 km/h
Angle (trajectory)	22.9 degrees
Target Impact Location	Midspan between post nos. 5 and 6
Actual Impact Location	851 mm upstream of post no. 6
●Exit Conditions	
Speed	NA
Angle	NA
Exit Box Criterion	NA
●Post-Impact Trajectory	
Vehicle Stability	Unsatisfactory
Stopping Distance	NA

●Occupant Impact Velocity (EDR-3)	
Longitudinal	-3.15 m/s < 12.2 m/s
Lateral	4.06 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-3)	
Longitudinal	-7.12 g's < 20.49 g's
Lateral	11.90 g's < 20.49 g's
●Occupant Impact Velocity (DTS)	
Longitudinal	-2.81 m/s < 12.2 m/s
Lateral	4.12 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (DTS)	
Longitudinal	-6.38 g's < 20.49 g's
Lateral	11.32 g's < 20.49 g's
●THIV (DTS - not required)	5.34 m/s
●PHD (DTS - not required)	11.42 g's
●ASI (EDR-3 - not required)	0.84
●ASI (DTS - not required)	0.79
●Test Article Damage	Extensive
●Test Article Deflections	
Permanent Set	7,169 mm
Dynamic	NA
Working Width	NA
●Vehicle Damage	Extensive
VDS[12]	01-R&T-4
CDC[13]	01-RDAO9
●Maximum Deformation	32 mm at right-center floorboard
●Angular Displacement (Note: Angular data was not available after 3.8 seconds)	
Roll	193 degrees
Pitch	90 degrees
Yaw	132 degrees

Figure 114. Summary of Test Results and Sequential Photographs, Test No. NYBBT-4


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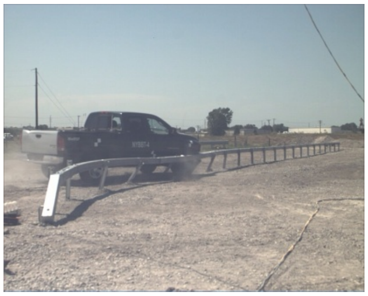
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0.462 sec


0.848 sec


1.162 sec


1.380 sec


1.964 sec


2.688 sec

Figure 115. Additional Sequential Photographs, Test No. NYBBT-4


0.000 sec


0.096 sec


0.294 sec


0.454 sec


0.668 sec


0.848 sec


1.142 sec


1.302 sec


1.574 sec

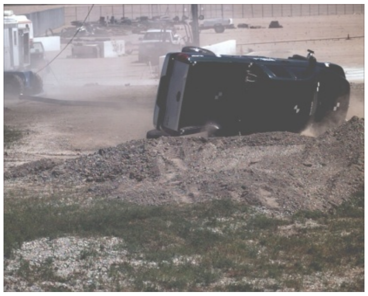
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Figure 116. Additional Sequential Photographs, Test No. NYBBT-4

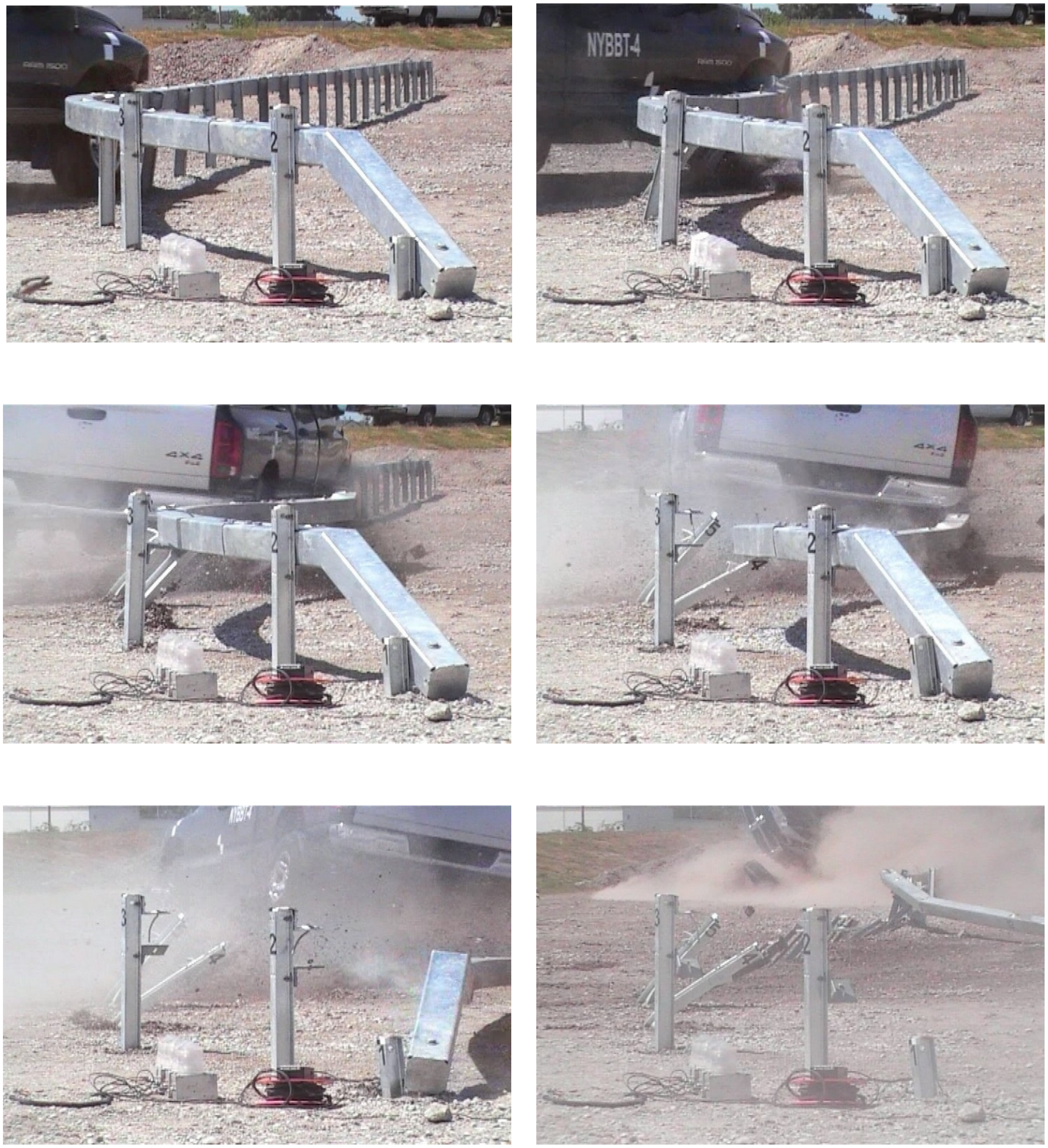


Figure 117. Documentary Photographs, Test No. NYBBT-4

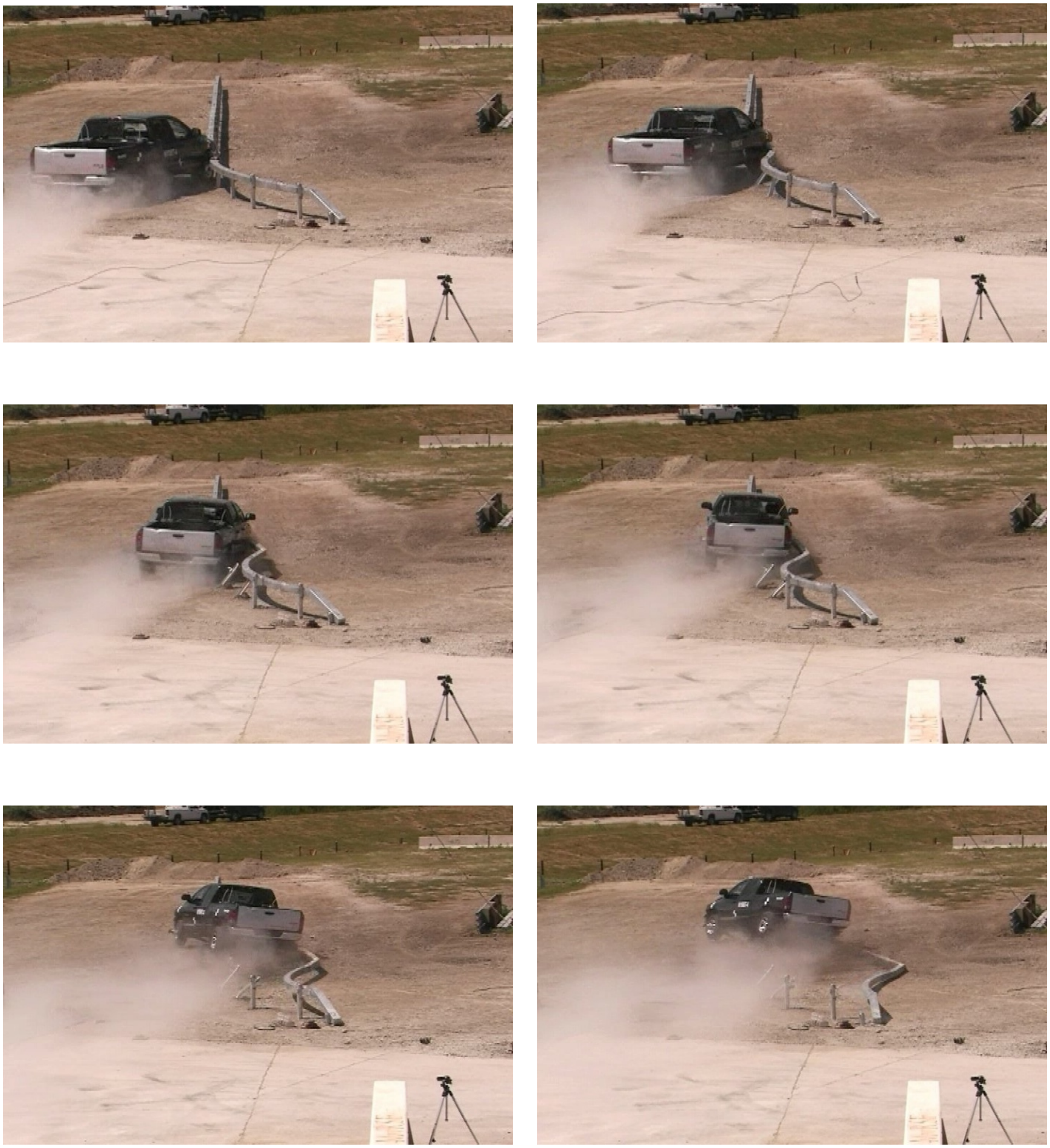


Figure 118. Documentary Photographs, Test No. NYBBT-4

Figure 119. Documentary Photographs, Test No. NYBBT-4

Figure 120. Impact Location, Test No. NYBBT-4

Figure 121. Vehicle Final Position and Trajectory Marks, Test No. NYBBT-4

Figure 122. Barrier Damage, Test No. NYBBT-4

Figure 123. Barrier Damage, Test No. NYBBT-4

Figure 124. Barrier Damage, Test No. NYBBT-4

Figure 125. Post Nos. 1 and 2 Damage, Test No. NYBBT-4

Figure 126. Post Nos. 3 and 4 Damage, Test No. NYBBT-4

Figure 127. Post Nos. 5 and 6 Damage, Test No. NYBBT-4

Figure 128. Post Nos. 7 and 8 Damage, Test No. NYBBT-4

Figure 129. Post Nos. 9 and 10 Damage, Test No. NYBBT-4

Figure 130. Post Nos. 11 and 12 Damage, Test No. NYBBT-4

Figure 131. Post Nos. 13 and 14 Damage, Test No. NYBBT-4

Figure 132. Post Nos. 15 and 16 Damage, Test No. NYBBT-4

Figure 133. Post Nos. 17 and 18 Damage, Test No. NYBBT-4

Figure 134. Post Nos. 19 and 20 Damage, Test No. NYBBT-4

Figure 135. Post Nos. 21 and 22 Damage, Test No. NYBBT-4

Figure 136. Post No. 23 and End Anchorage Damage, Test No. NYBBT-4

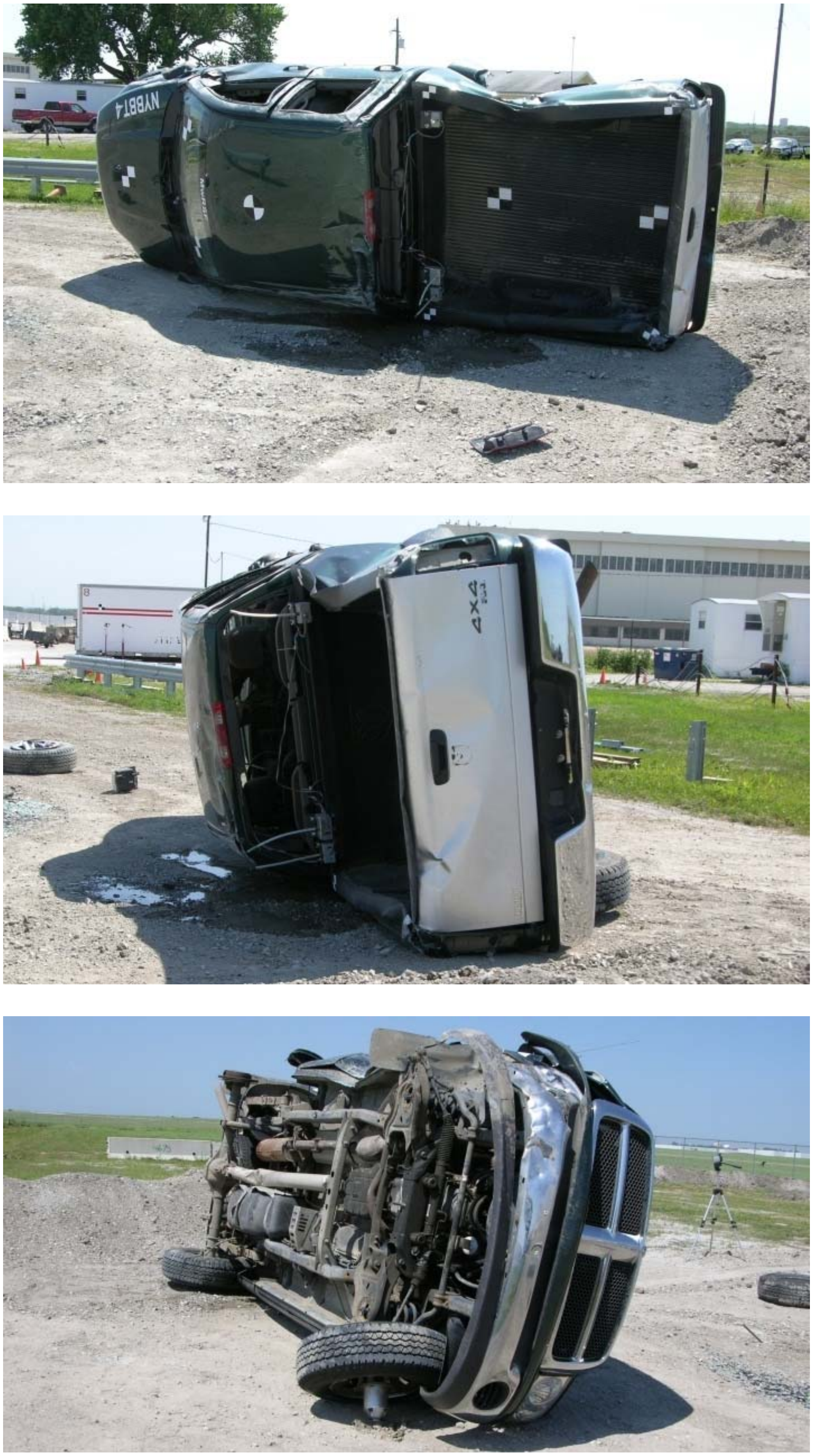


Figure 137. Vehicle Damage, Test No. NYBBT-4

Figure 138. Vehicle Damage, Test No. NYBBT-4

Figure 139. Undercarriage Damage, Test No. NYBBT-4

12 TYPE IIA END TERMINAL MODIFICATIONS – NYBBT-5 SYSTEM DETAILS

As stated previously, the pickup truck test was unsuccessful when the vehicle overrode the barrier and subsequently rolled over. Following the unsatisfactory results observed for test no. NYBBT-4, the researchers and NYSDOT personnel deemed it necessary to incorporate design modifications that would improve barrier performance.

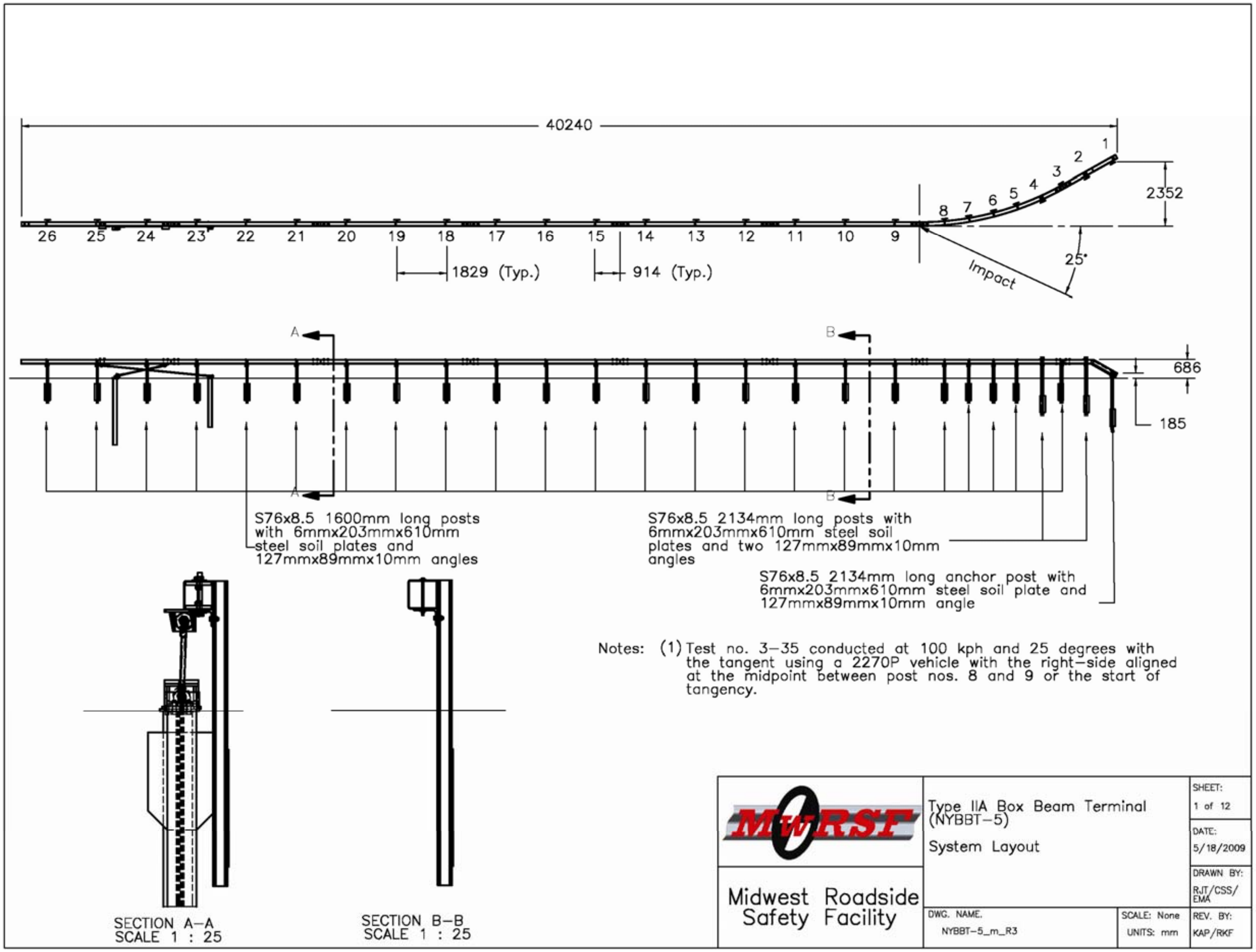
For the Type IIA box beam end terminal system (test no. NYBBT-4), the curved box beam end terminal sections were supported by five posts, as shown in Figures 140 through 142. Post nos. 1 through 3 were 2,134 mm (84 in.) long, S76x8.5 (S3x5.7) sections and were attached to the traffic side of the box beam. Post nos. 4 and 5 were 1,600 mm (63 in.) long, S76x8.5 (S3x5.7) sections and were attached to the back side of the box beam. In addition, two shelf angles connected the box beam to post nos. 2 and 3, with one above the top face and one below the bottom face of the box beam rail. One 9.5-mm (3/8-in.) diameter by 191-mm (7 1/2-in.) long ASTM A307 hex bolt with one 9.5-mm (3/8-in.) diameter, ASTM A307 washer above and below the box beam, and one 9.5-mm (3/8-in.) diameter nut connected the shelf angles to the rail.

In order to improve barrier performance, several design modifications were implemented into the Type IIA box beam end terminal depicted in Figure 106, which was used for test no. NYBBT-4. First, three intermediate line posts were added at the midspan locations between original post nos. 2 and 5 and positioned on the back side of the rail. The posts added between post nos. 2 and 3, 3 and 4, and 4 and 5 were standard 1,600-mm (63-in.) long, S76x8.5 (S3x5.7) steel sections used for standard box beam line posts, as now shown in Figures 140 through 142.

Next, the box beam rail was attached to the shelf angles at post no. 2 and post no. 4 (post no. 3 in test no. NYBBT-4) by a 12.7-mm (1/2-in.) diameter by 203-mm (8-in.) long, ASTM

A307 hex bolt with two 12.7-mm (1/2-in.) washers and a 12.7-mm (1/2-in.) hex nut, as shown in Figures 140 through 142. Lastly, the box beam rail was not connected to the shelf angle at new post no. 3.

Once again, the 40.2-m (132.0-ft) long test installation consisted of 38.1 m (125 ft) of the NYSDOT's standard TS 152-mm x 152-mm x 4.8-mm (6-in. x 6-in. x 3/16-in.) steel tube box-beam guide rail with a modified Type IIA end terminal. The top rail height was 686 mm (27 in.). The box beam rail was attached to the shelf angles at post nos. 5 through 26 by a 9.5-mm diameter by 191-mm long (3/8-in. x 7 1/2-in.) ASTM A307 hex head bolt. Also, one 12.7-mm (1/2-in.) diameter by 51-mm (2-in.) long ASTM A307 hex head bolt with a 12.7-mm (1/2-in.) narrow washer was used to attach each box beam shelf angle to the post. Similar to that used in test no. NYBBT-4, the rail was anchored to the ground at post no. 25 using a reverse cable anchorage system to develop the longitudinal resistance in the rail, as shown in Figure 140. An additional cable anchorage device was also placed at the splice between post nos. 23 and 24, as shown in Figure 140. Design details are shown in Figures 140 through 142. Complete system drawings in both metric and English units are shown in Appendix M. Photographs of the test installation are shown in Figures 143 through 145.



S76x8.5 1600mm long posts with 6mmx203mmx610mm steel soil plates and 127mmx89mmx10mm angles

S76x8.5 2134mm long posts with 6mmx203mmx610mm steel soil plates and two 127mmx89mmx10mm angles

S76x8.5 2134mm long anchor post with 6mmx203mmx610mm steel soil plate and 127mmx89mmx10mm angle

Notes: (1) Test no. 3–35 conducted at 100 kph and 25 degrees with the tangent using a 2270P vehicle with the right–side aligned at the midpoint between post nos. 8 and 9 or the start of tangency.

Figure 140. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-5

Post No.	X–Coordinate	Y–Coordinate
9	0	0
8	1810mm	40mm
7	2697mm	154mm
6	3612mm	352mm
5	4448mm	611mm
4	5396mm	748mm
3	6099mm	1360mm
2	7009mm	1608mm
1	7961mm	2143mm

Note: (1) All coordinates dimensioned from the centerline of post no. 9 to the centerline of each post.

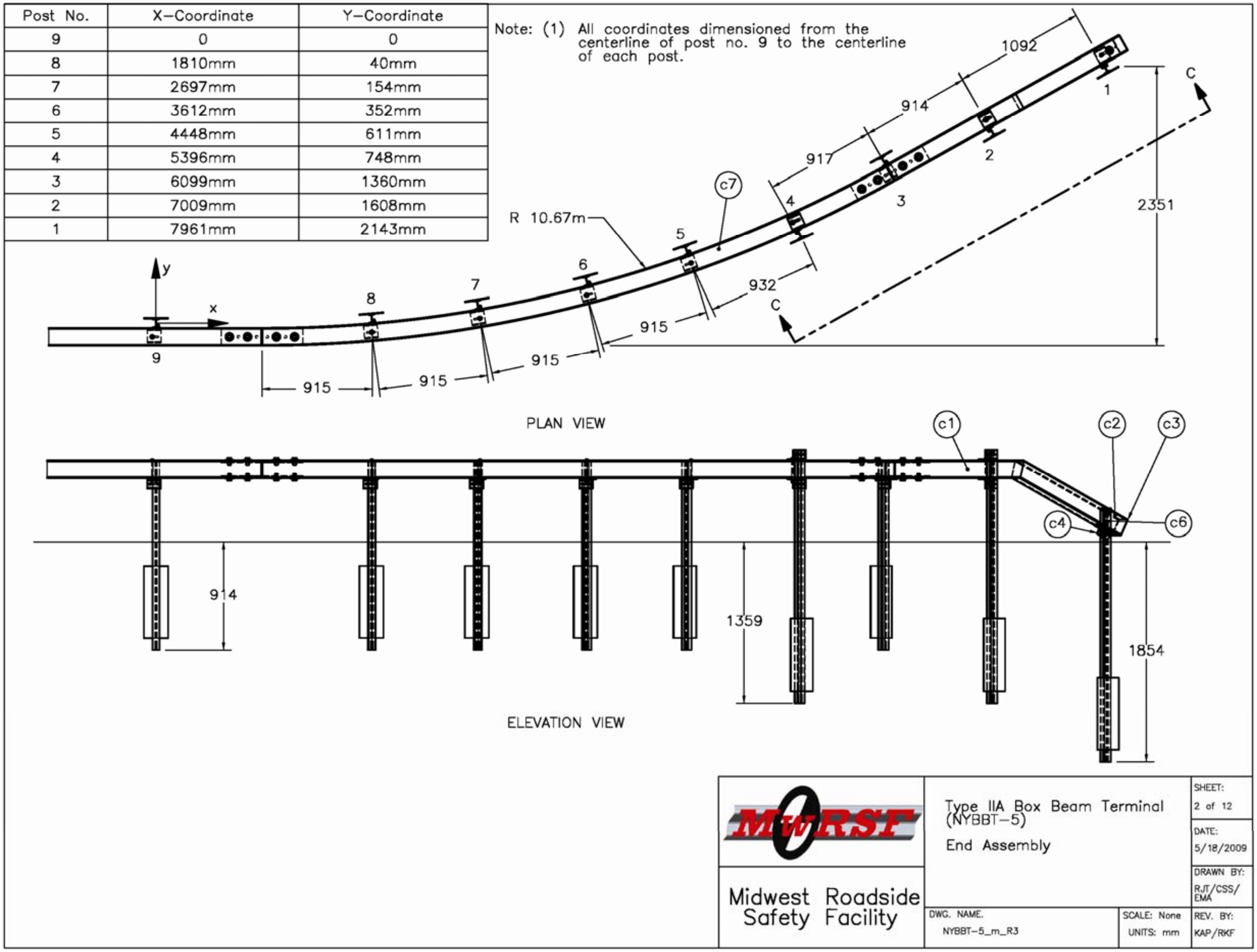


Figure 141. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-5

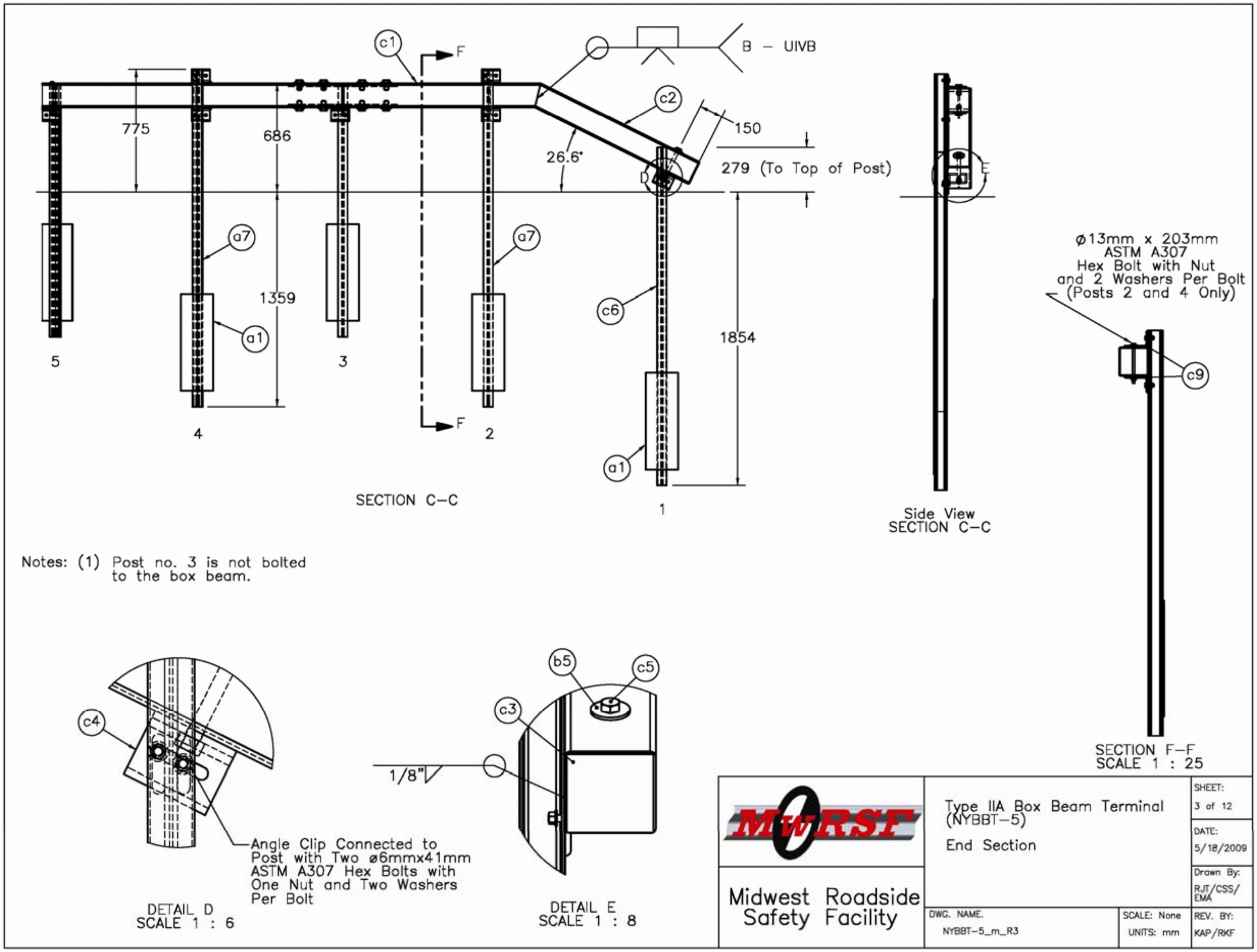


Figure 142. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-5

Figure 143. NYBBT-5 System Details

Figure 144. NYBBT-5 System Details

Figure 145. NYBBT-5 System Details

13 FULL-SCALE CRASH TEST NO. 5 (MODIFIED TYPE IIA END TERMINAL)

13.1 Static Soil Test

Before full-scale crash test no. NYBBT-5 was conducted, the strength of the foundation soil was evaluated with a static test, as described by MASH. The static test results, as shown in Appendix K, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and the barrier system was approved for full-scale crash testing.

13.2 Test No. NYBBT-5 (Test Designation 3-35)

The 2,354-kg (5,190-lb) Dodge Ram 1500 Quad Cab pickup truck, with a dummy placed in the right-front seat, impacted the modified Type IIA box beam terminal system at a speed of 99.9 km/h (62.1 mph) and at an angle of 23.6 degrees with respect to the tangent. A summary of the test results and sequential photographs are shown in Figure 146. An English-unit summary of the test results and sequential photographs are shown in Appendix C. Additional sequential photographs are shown in Figures 147 through 149. Documentary photographs of the crash test are shown in Figures 150 through 152.

13.3 Weather Conditions

Test no. NYBBT-5 was conducted on July 31, 2008 at approximately 12:30 pm. The weather conditions were reported as shown in Table 12.

Table 12. Weather Conditions, Test No. NYBBT-5

Temperature	92° F
Humidity	50 %
Wind Speed	13 mph
Wind Direction	200° from True North
Sky Conditions	Overcast
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

13.4 Test Description

Initial vehicle impact was to occur with the vehicle aligned with the beginning of the tangent box beam, which placed the vehicle's right-front corner at the midspan between post nos. 8 and 9 or 914 mm (36 in.) upstream of post no. 9, as shown in Figure 153. Actual vehicle impact occurred 864 mm (34 in.) upstream of post no. 9. Upon impact, the right-front corner of the bumper deformed, and post nos. 8 and 9 deflected laterally away from the vehicle. At 0.010 sec, post nos. 7 and 10 deflected laterally away from the vehicle, and post no. 6 twisted downstream. At 0.022 sec, the right-front tire contacted the box beam slightly upstream of post no. 9. At 0.028 sec, the right-front corner of the bumper contacted post no. 9, and the vehicle began redirecting. At 0.034 sec, post no. 5 rotated downstream. At 0.050 sec, the right-front wheel rim contacted post no. 9, and post no. 9 disengaged from the rail. At 0.054 sec, the vehicle rolled toward the right. At 0.090 sec, the right-front corner of the bumper contacted post no. 10. At 0.096 sec, a buckle point formed in the box beam section upstream of post no. 10. At 0.160 sec, the right-front corner of the bumper contacted post no. 11. At 0.186 sec, the right-rear tire contacted post no. 9 and deflated. At 0.230 sec, the front of the vehicle pitched downward. At 0.236 sec, the vehicle became parallel to the system with a resulting velocity of 83.6 km/h (51.9 mph). At 0.242 sec, the vehicle rolled toward the left. At 0.256 sec, the right-rear corner contacted the rail near post no. 10. At 0.316 sec, the left-rear tire became airborne. At 0.462 sec, the left-front tire became airborne. At 0.540, the vehicle pitched upward. At 0.606 sec, the left-rear tire contacted the ground. At 0.620 sec, the right-rear corner of the bumper lost contact with the rail. At 0.674 sec, the left-front tire contacted the ground. At 0.716 sec, the vehicle exited the system with a resulting velocity of 81.1 km/h (50.4 mph) and an angle of approximately 4 degrees. The vehicle came to rest 43.9 m (144.0 ft) downstream from impact and 762 mm (30 in.) laterally away from the traffic-side face of the rail. The trajectory and final position of the pickup truck are shown in Figures 146 and 154.

13.5 System and Component Damage

Damage to the end terminal system was moderate, as shown in Figures 155 through 165. Damage consisted of deformed box beam and guide rail posts and contact marks on box beam rail sections and guide rail posts. The length of vehicle contact was approximately 13.9 m (45.7 ft), which spanned from 864 mm (34 in.) upstream from the centerline of post no. 9 to 254 mm (10 in.) downstream from the centerline of post no. 16.

Minor buckling occurred at post no. 9 and upstream of post no. 11. Major buckling occurred 483 mm (19 in.) upstream of post no. 10. A 25-mm (1-in.) gap formed between the ends of the box beam sections between post nos. 8 and 9. The rail between post nos. 16 and 19 deformed upward 38 mm (1 1/2 in.) to form a gap between the rail and the shelf angles. The box beam rail disengaged from post nos. 7 through 15, 17, and 18.

Post nos. 1 through 5 bent downstream. Post no. 4 also twisted downstream, and post no. 5 also rotated backward. Post nos. 6 through 9 twisted downstream and post nos. 6 through 8 also rotated backward. Contact marks were found on the base of post no. 9. Post nos. 10 through 15 bent backward and downstream. The upstream flanges of post nos. 11 and 12 were deformed.

A 38-mm (1 1/2-in.) soil gap was found at the upstream side of post no. 1 and the back-side flange of post no. 16. Soil gaps of 64 mm (2 1/2 in.), 89 mm (3 1/2 in.), and 127 mm (5 in.) were found at the traffic-side flange of post nos. 6 through 8, respectively. The bolt connecting the shelf angle to post nos. 2, 3, and 16 was bent. The bolt connecting the shelf angle to post nos. 11 and 12 was sheared off. The bolt connecting the shelf angle to the rail at post nos. 7 through 15, 17, and 18 was sheared off. The shelf angles at post nos. 14 through 16 were deformed.

The permanent set deflection of the end terminal system is shown in Figure 155. The maximum lateral permanent set rail and post deflections were 1,092 mm (43 in.) at the centerline of post no. 10 and 629 mm (24 3/4 in.) at the centerline of post no. 14, respectively, as measured in the field. The maximum lateral dynamic rail deflection was 1,739 mm (68 1/2 in.) at the centerline of post no. 11, as determined from high-speed digital video analysis. The working width of the system was found to be 2,504 mm (98 5/8 in.), as measured laterally from the tangent portion of the rail.

13.6 Vehicle Damage

Exterior vehicle damage was moderate, as shown in Figures 166 through 168. Occupant compartment deformations to the right side of the floorboard were judged insufficient to cause serious injury to the vehicle occupants. Maximum longitudinal deflections of 6 mm (1/4 in.) were located near the middle-left area of the right-side floor pan. Maximum lateral deflections of 6 mm (1/4 in.) were located near the center of the right-side floor pan. Maximum vertical deflections of 13 mm (1/2 in.) were located near the right-front corner of the right-side floor pan. Complete occupant compartment deformations and the corresponding locations are provided in Appendix D.

Damage was concentrated on the right-front corner of the vehicle. The right side of the front bumper was deformed inward toward the engine compartment. The right side of the vehicle was dented and encountered contact marks from the front fender through the end of the vehicle. The right-side headlight was dislodged, and the right-side taillight disengaged from the vehicle. The sidewalls of the right-side tires were gouged, and the left-side tires were removed from the rims. All four tires were deflated. The windshield had “spider-web” cracking. The remainder of the vehicle and all other window glass remained undamaged. It should be noted that the left-side tire damage was due to contact with a dirt berm beyond the end of the system and not the box beam terminal.

13.7 Occupant Risk Values

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 13. It is noted that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 13. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 146. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix N. Due to technical difficulties, the EDR-4 recorder did not collect acceleration nor angular data.

Table 13. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYBBT-5

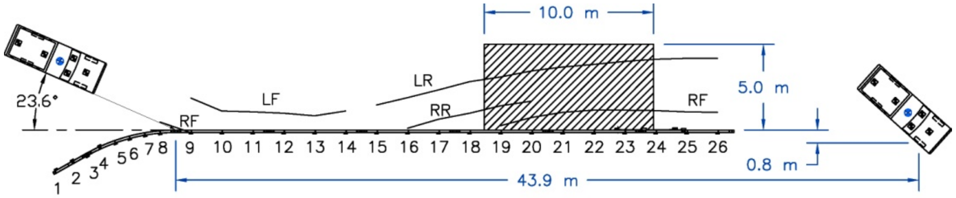
Evaluation Criteria		**Transducer**	
		EDR-3	**DTS**
OIV m/s (ft/s)	Longitudinal	-2.81 (-8.46)	-2.78 (-9.12)
	Lateral	4.12 (13.52)	4.17 (13.68)
ORA g's	Longitudinal	-4.85	-4.56
	Lateral	5.49	6.51
THIV m/s (ft/s)		NA	4.70 (15.42)
PHD g's		NA	6.57
ASI		0.50	0.51

Discussion

The analysis of the test results for test no. NYBBT-5 showed that the modified NYSDOT Type IIA box beam end terminal system adequately contained and redirected the 2270P vehicle.

There were no detached elements nor fragments which 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 override the barrier system and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacement 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 no. NYBBT-5 conducted on the modified Type IIA end terminal was determined to be acceptable according to test designation no. 3-35 of the TL-3 safety performance criteria found in MASH.

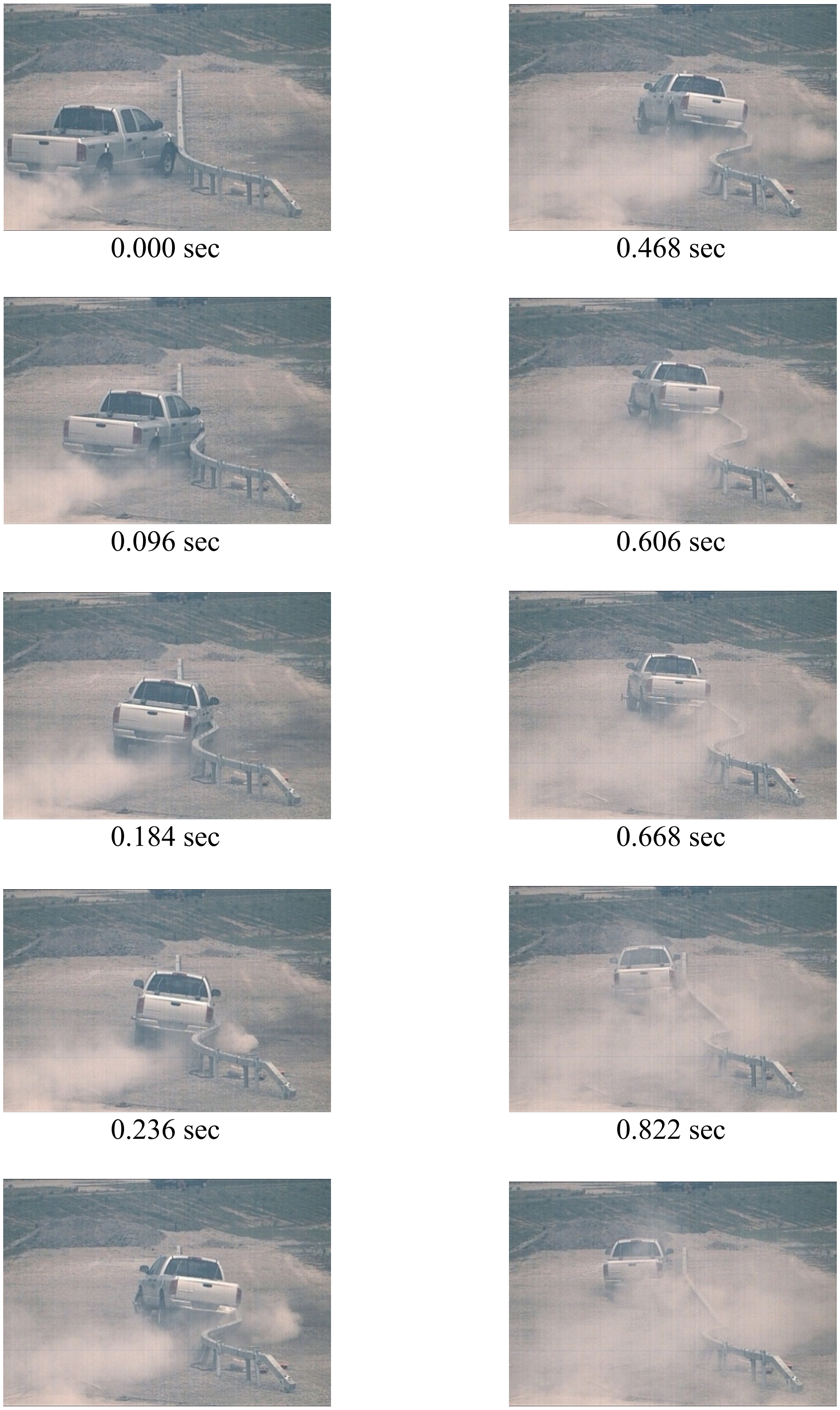

0.000 sec 0.058 sec 0.180 sec 0.268 sec 0.360 sec



●Test Agency	MwRSF
●Test Number	NYBBT-5
●Date	7/31/08
●MASH Test Designation	3-35
●Appurtenance	Modified Type IIA End Terminal
●Total Length	40.2 m
●Key Element – Steel Box Beam	
Size	152 mm x 152 mm x 4.8 mm
Length	5,486 mm
Top Mounting Height	686 mm
●Key Elements - Steel Post	
Post Nos. 1, 2, 4	S76x8.5 by 2,134 mm long
Post Nos. 3, 5-26	S76x8.5 by 1,600 mm long
●Type of Soil	Grading B - AASHTO M 147-65 (1990)
●Test Vehicle	
Type/Designation	2270P
Make and Model	2002 Dodge Ram 1500 Quad Cab Pickup
Curb	2,326 kg
Test Inertial	2,276 kg
Gross Static	2,354 kg
●Impact Conditions	
Speed	99.9 km/h
Angle (trajectory)	23.6 degrees
Target Impact Location	Midspan between post nos. 8 and 9
Actual Impact Location	863 mm upstream of post no. 9
●Exit Conditions	
Speed	81.1 km/h
Angle	4 degrees
Exit Box Criterion	Pass
●Post-Impact Trajectory	
Vehicle Stability	Satisfactory
Stopping Distance	43.9 m downstream 0.8 m laterally behind traffic-side face

●Occupant Impact Velocity (EDR-3)	
Longitudinal	-2.81 m/s < 12.2 m/s
Lateral	4.12 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-3)	
Longitudinal	-4.85 g's < 20.49 g's
Lateral	5.49 g's < 20.49 g's
●Occupant Impact Velocity (DTS)	
Longitudinal	-2.78 m/s < 12.2 m/s
Lateral	4.17 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (DTS)	
Longitudinal	-4.56 g's < 20.49 g's
Lateral	6.51 g's < 20.49 g's
●THIV (DTS - not required)	4.70 m/s
●PHD (DTS - not required)	6.57 g's
●ASI (EDR-3 - not required)	0.50
●ASI (DTS - not required)	0.51
●Test Article Damage	Moderate
●Test Article Deflections	
Permanent Set	1,092 mm
Dynamic	1,739 mm
Working Width	2,504 mm
●Vehicle Damage	Moderate
VDS[12]	01-RFQ-3
CDC[13]	01-RDEN2
●Maximum Deformation	13 mm at right-front floorboard
●Angular Displacement	
Roll	-19 degrees
Pitch	-10 degrees
Yaw	50 degrees

Figure 146. Summary of Test Results and Sequential Photographs, Test No. NYBBT-5



0.000 sec

0.096 sec

0.184 sec

0.236 sec

0.344 sec

0.468 sec

0.606 sec

0.668 sec

0.822 sec

0.908 sec

Figure 147. Additional Sequential Photographs, Test No. NYBBT-5

0.000 sec

0.044 sec

0.076 sec

0.096 sec

0.158 sec

0.186 sec

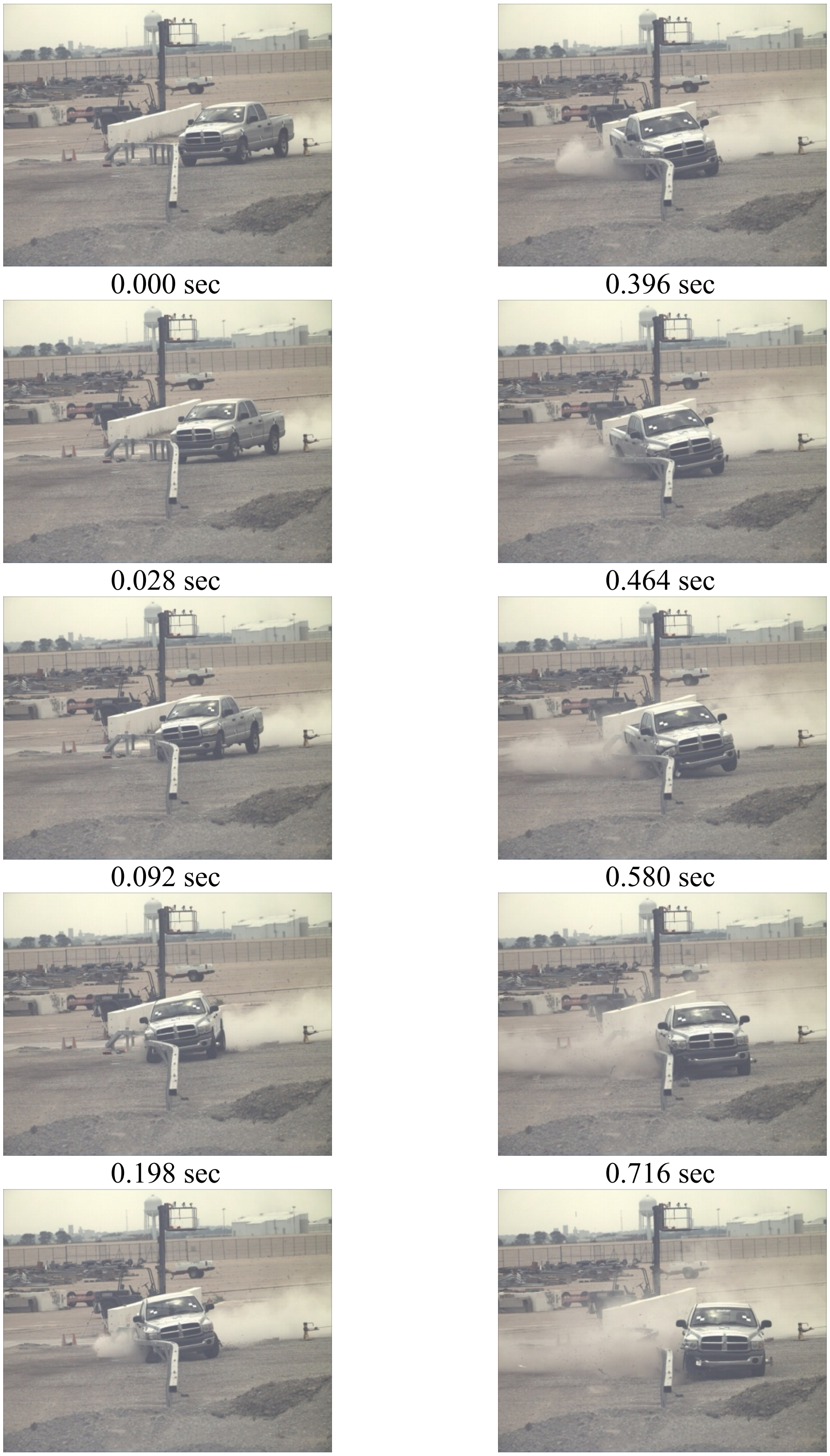
0.238 sec

0.274 sec

0.402 sec

0.716 sec

Figure 148. Additional Sequential Photographs, Test No. NYBBT-5



0.000 sec

0.028 sec

0.092 sec

0.198 sec

0.274 sec

0.396 sec

0.464 sec

0.580 sec

0.716 sec

0.840 sec

Figure 149. Additional Sequential Photographs, Test No. NYBBT-5

Figure 150. Documentary Photographs, Test No. NYBBT-5

Figure 151. Documentary Photographs, Test No. NYBBT-5

Figure 152. Documentary Photographs, Test No. NYBBT-5

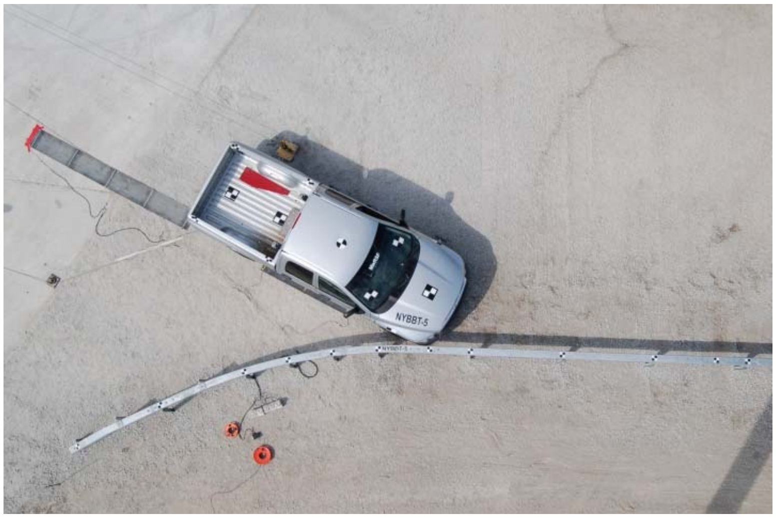


Figure 153. Impact Location, Test No. NYBBT-5

Figure 154. Vehicle Final Position and Trajectory Marks, Test No. NYBBT-5

Figure 155. Barrier Damage, Test No. NYBBT-5

Figure 156. Barrier Damage, Test No. NYBBT-5

Figure 157. Post Nos. 1 and 2 Damage, Test No. NYBBT-5

Figure 158. Post Nos. 3 and 4 Damage, Test No. NYBBT-5

Figure 159. Post Nos. 5 and 6 Damage, Test No. NYBBT-5

Figure 160. Post Nos. 7 and 8 Damage, Test No. NYBBT-5

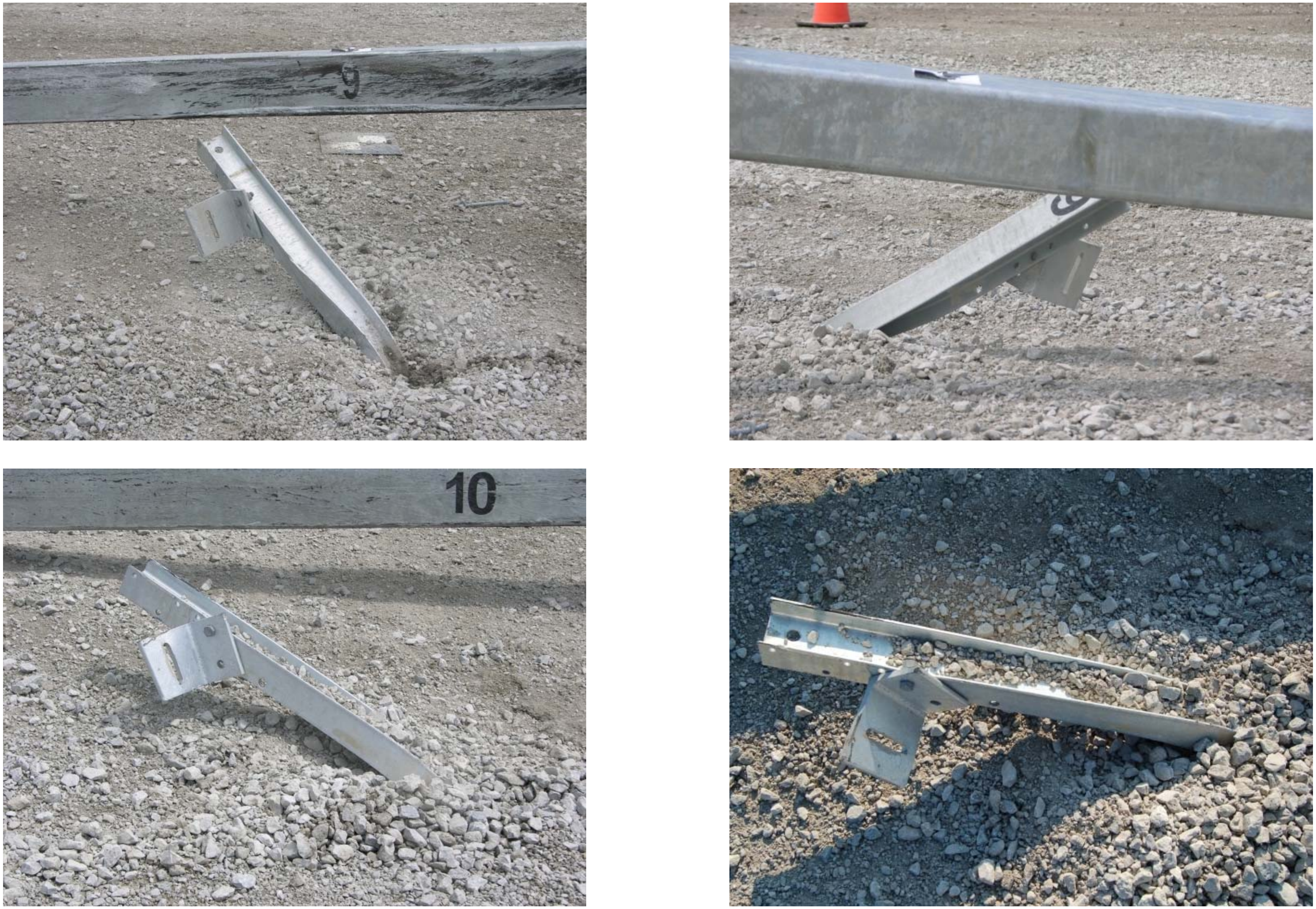


Figure 161. Post Nos. 9 and 10 Damage, Test No. NYBBT-5

Figure 162. Post Nos. 11 and 12 Damage, Test No. NYBBT-5

Figure 163. Post Nos. 13 and 14 Damage, Test No. NYBBT-5

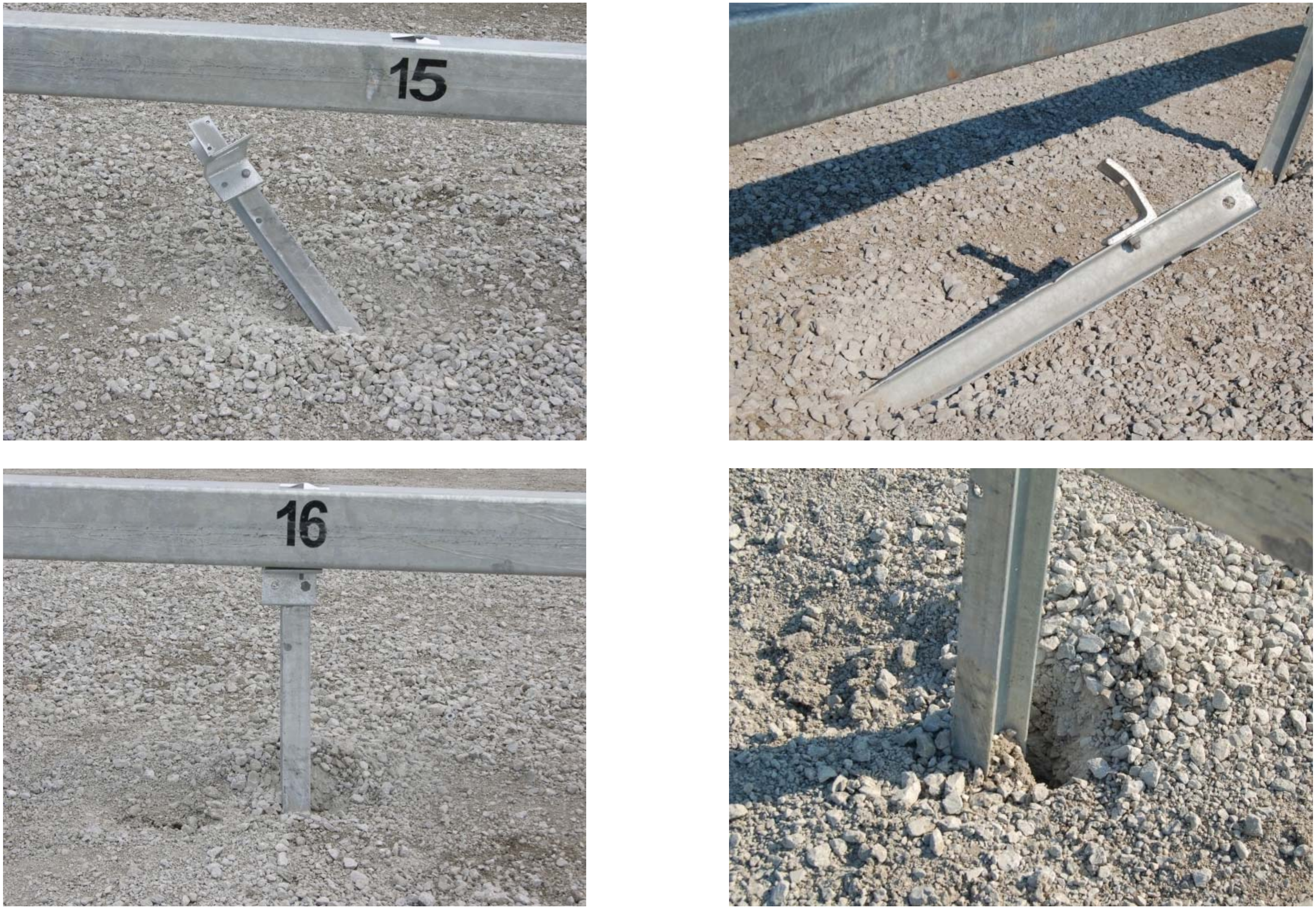


Figure 164. Post Nos. 15 and 16 Damage, Test No. NYBBT-5

Figure 165. Post Nos. 17 and 18 Damage, Test No. NYBBT-5

Figure 166. Vehicle Damage, Test No. NYBBT-5

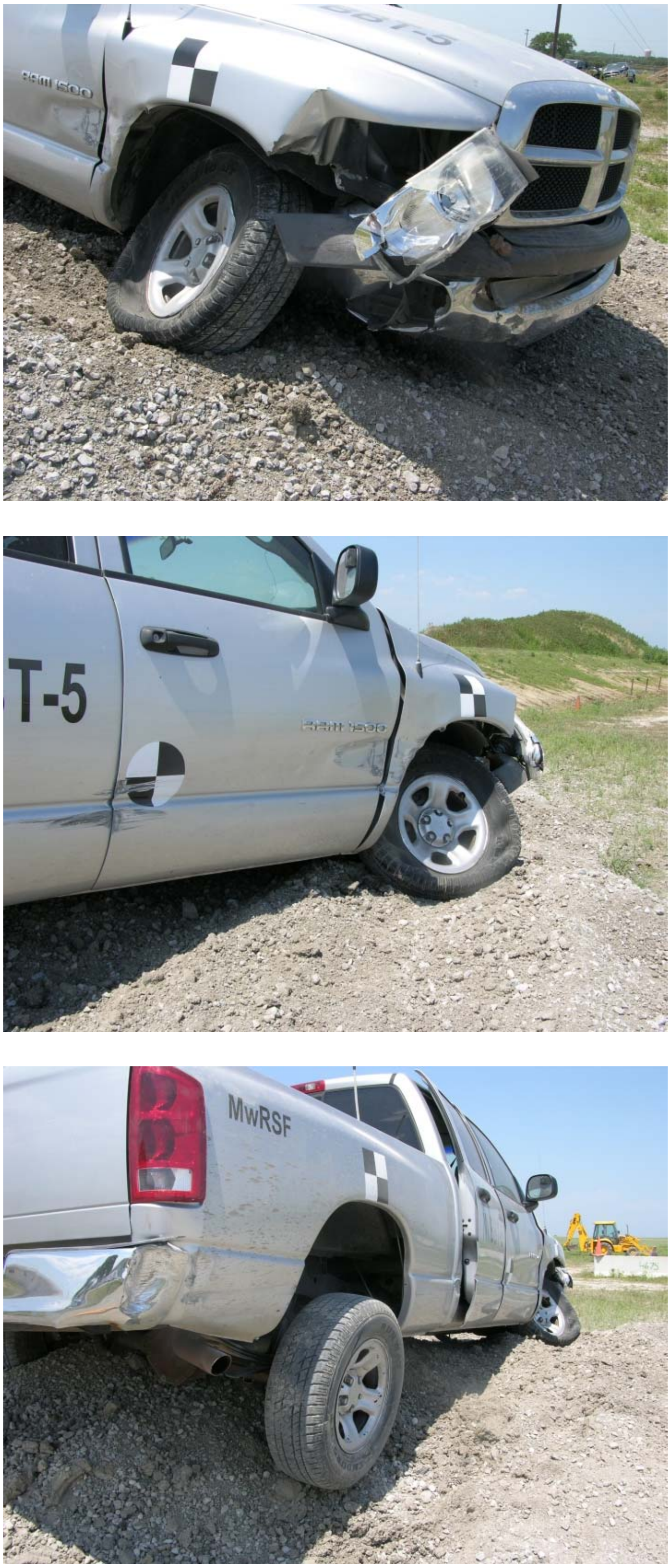


Figure 167. Vehicle Damage, Test No. NYBBT-5

Figure 168. Undercarriage Damage, Test No. NYBBT-5

14 MODIFIED TYPE IIA END TERMINAL IN DITCH – NYBBT-6 AND NYBBT-7 SYSTEM DETAILS

As stated previously, the Type IIA end terminal would often be used at driveways with adjoining steep slopes or ditches located close to the shoulder. It was anticipated that the vehicle would gate through the end terminal installed in a ditch, become destabilized by the back slope of the ditch, and ultimately fail the MASH standards. Nevertheless, NYSDOT personnel deemed it necessary to determine if the end terminal contributes to, mitigates, or has little or no effect on the crash severity. Thus, NYSDOT personnel requested that the system performance of the Type IIA end terminal be evaluated with both the 1100C and 2270P vehicles when installed in common field conditions, such as a ditch.

For test nos. NYBBT-6 and NYBBT-7, the modified Type IIA box beam end terminal system was identical to that used in test no. NYBBT-5, except that a trapezoidal ditch with 2:1 side slopes was placed adjacent to the back side of the system, as shown in Figure 169. A pit with a 2:1 foreslope and backslope was excavated behind the box beam system, as shown in Figures 169 through 187. The maximum pit dimensions were 4,267 mm (14 ft) wide and 762 mm (30 in.) deep. The length of the pit was 45.7 m (150 ft), spanning from 15.8 m (51 ft – 9 3/4 in.) upstream from the centerline of post no. 1 through post no. 21. The foreslope included a 1,219-mm (4-ft) radius vertical curve at the shoulder break point. The back sides of post nos. 9 through 26, which are the posts in the tangent portion of the system, were placed 305 mm (12 in.) laterally away from the shoulder break point, as shown in Figure 169.

In this situation, the terminal end extended above the ditch. In an attempt to address the potential for the vehicle to underride the system and the rail to contact the windshield, the leading end of the rail and terminal was depressed vertically 305 mm (12 in.). This change would increase the probability for the lower front portion of the vehicle to interact with the rail instead of the windshield. However, the embedment depth for post nos. 1 through 8 was changed by depressing the rail, as shown in Figures 170 and 180.

For test nos. NYBBT-6 and NYBBT-7, the 40.2-m (132-ft) long test installations consisted of 38.1 m (125 ft) of the NYSDOT's standard TS 152-mm x 152-mm x 4.8-mm (6-in. x 6-in. x 3/16-in.) steel tube box-beam guide rail with a modified Type IIA end terminal. The top rail height was 686 mm (27 in.) relative to the level terrain. For test no. NYBBT-6, design details are shown in Figures 169 through 184. For test no. NYBBT-7, only one design sheet is provided in order to denote the impact location. The corresponding English-unit drawings for test no. NYBBT-6 are shown in Appendix N. Complete system drawings in both metric and English units for test no. NYBBT-7 are shown in Appendix O. Photographs of the test installation are shown in Figures 185 through 187.

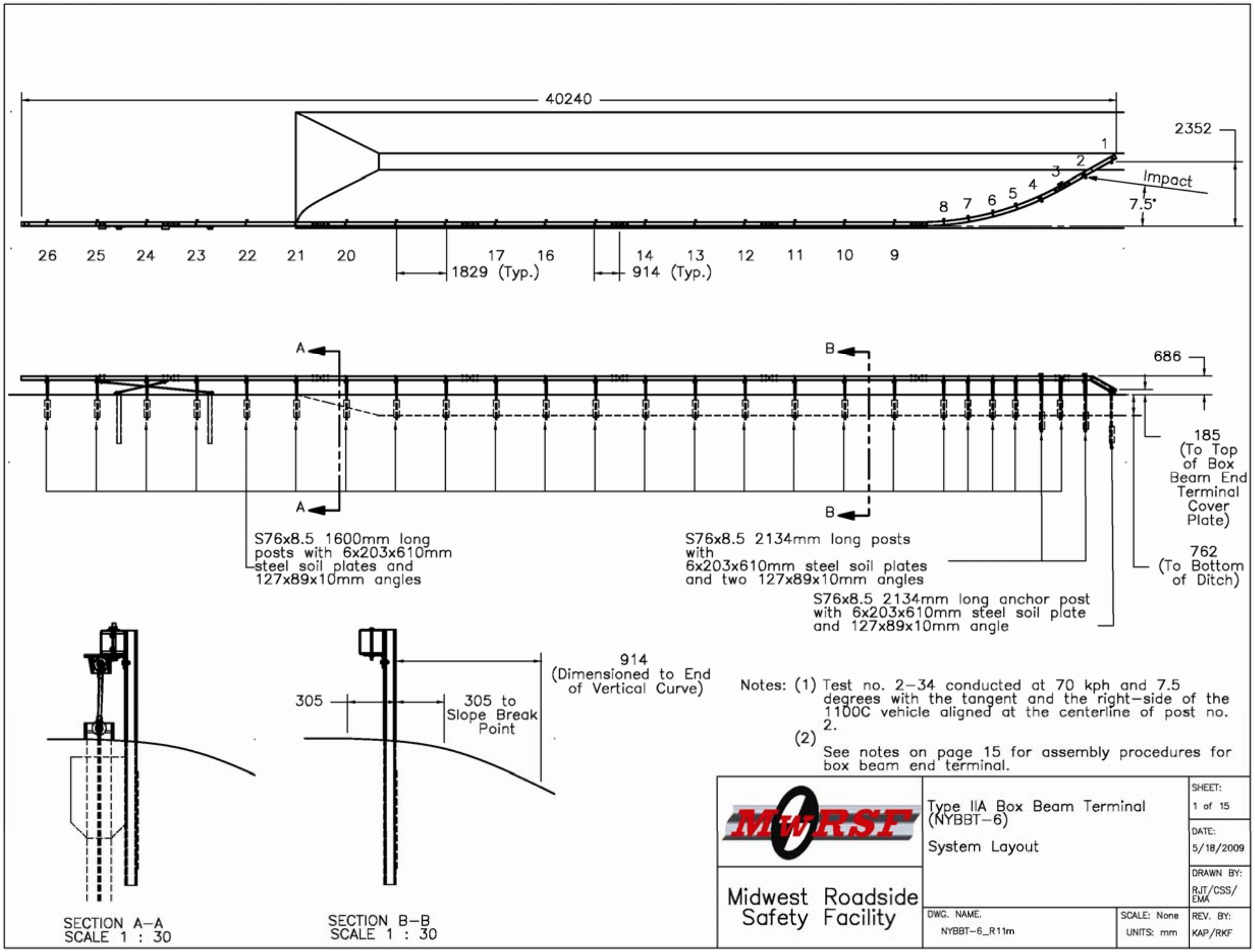
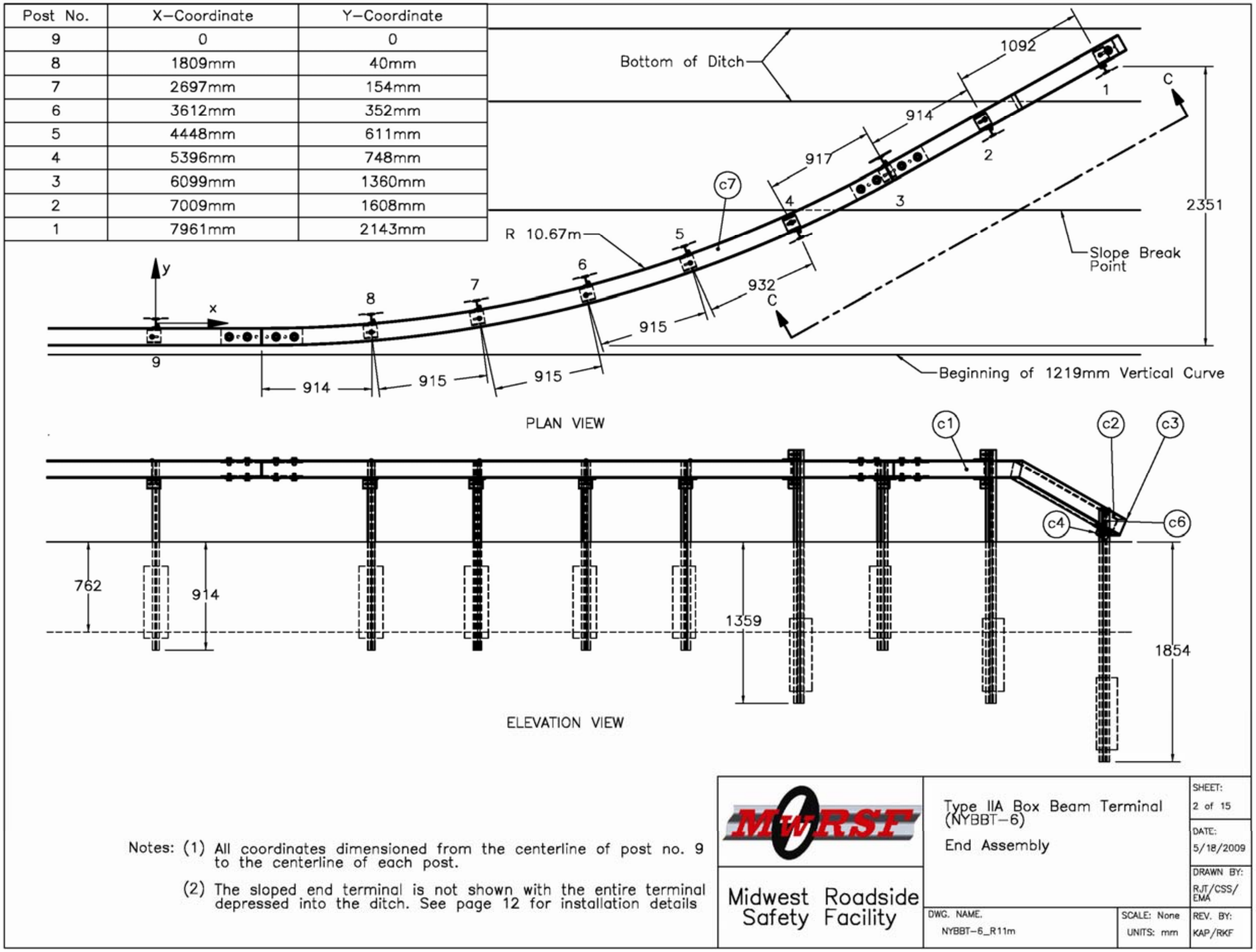


Figure 169. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6



Post No.	X–Coordinate	Y–Coordinate
9	0	0
8	1809mm	40mm
7	2697mm	154mm
6	3612mm	352mm
5	4448mm	611mm
4	5396mm	748mm
3	6099mm	1360mm
2	7009mm	1608mm
1	7961mm	2143mm

Notes: (1) All coordinates dimensioned from the centerline of post no. 9 to the centerline of each post.

(2) The sloped end terminal is not shown with the entire terminal depressed into the ditch. See page 12 for installation details

Midwest Roadside Safety Facility

Type IIA Box Beam Terminal (NYBBT–6)

End Assembly

SHEET: 2 of 15

DATE: 5/18/2009

DRAWN BY: RJT/CSS/EMA

DWG. NAME. NYBBT–6_R11m

SCALE: None

UNITS: mm

REV. BY: KAP/RKF

Figure 170. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

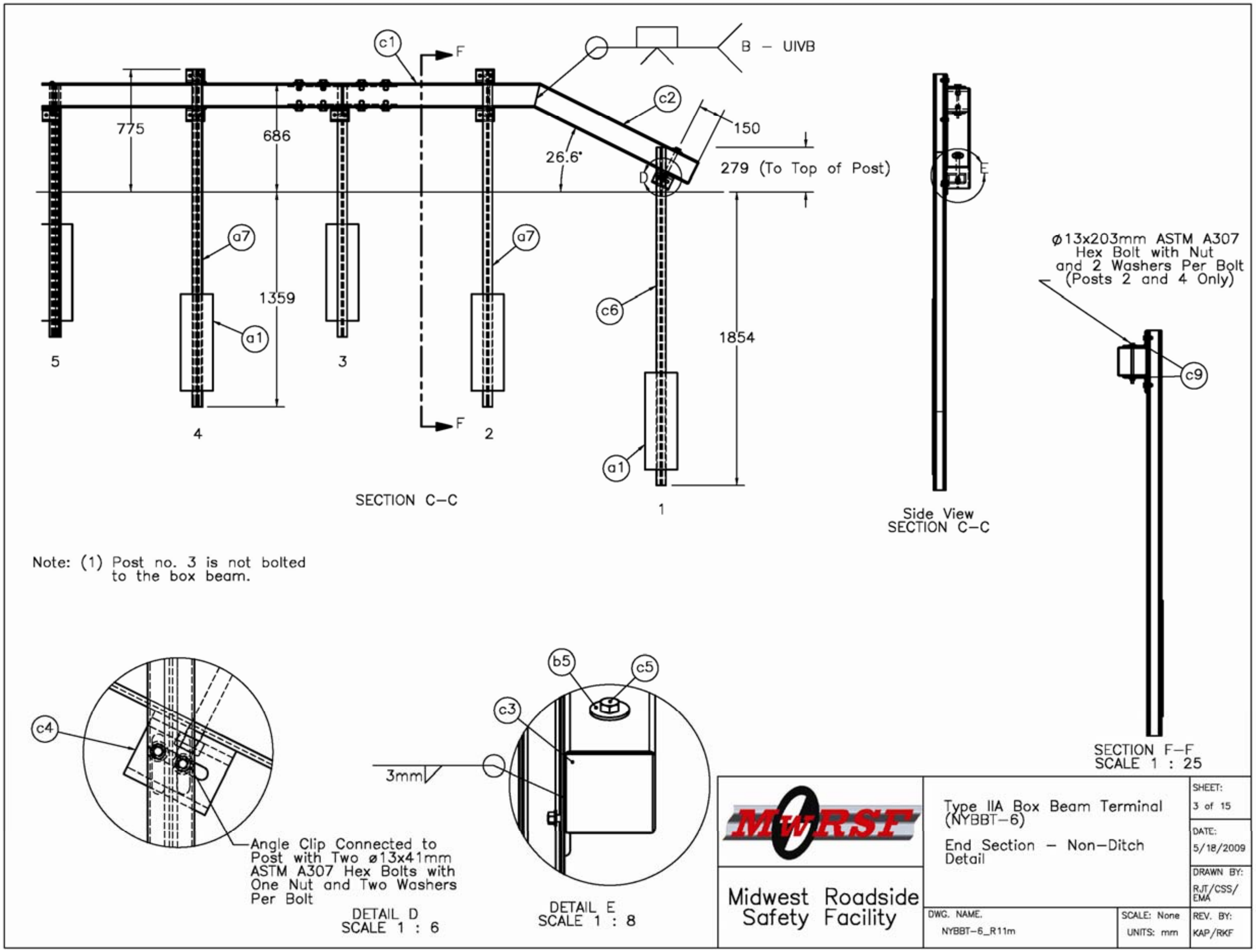


Figure 171. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

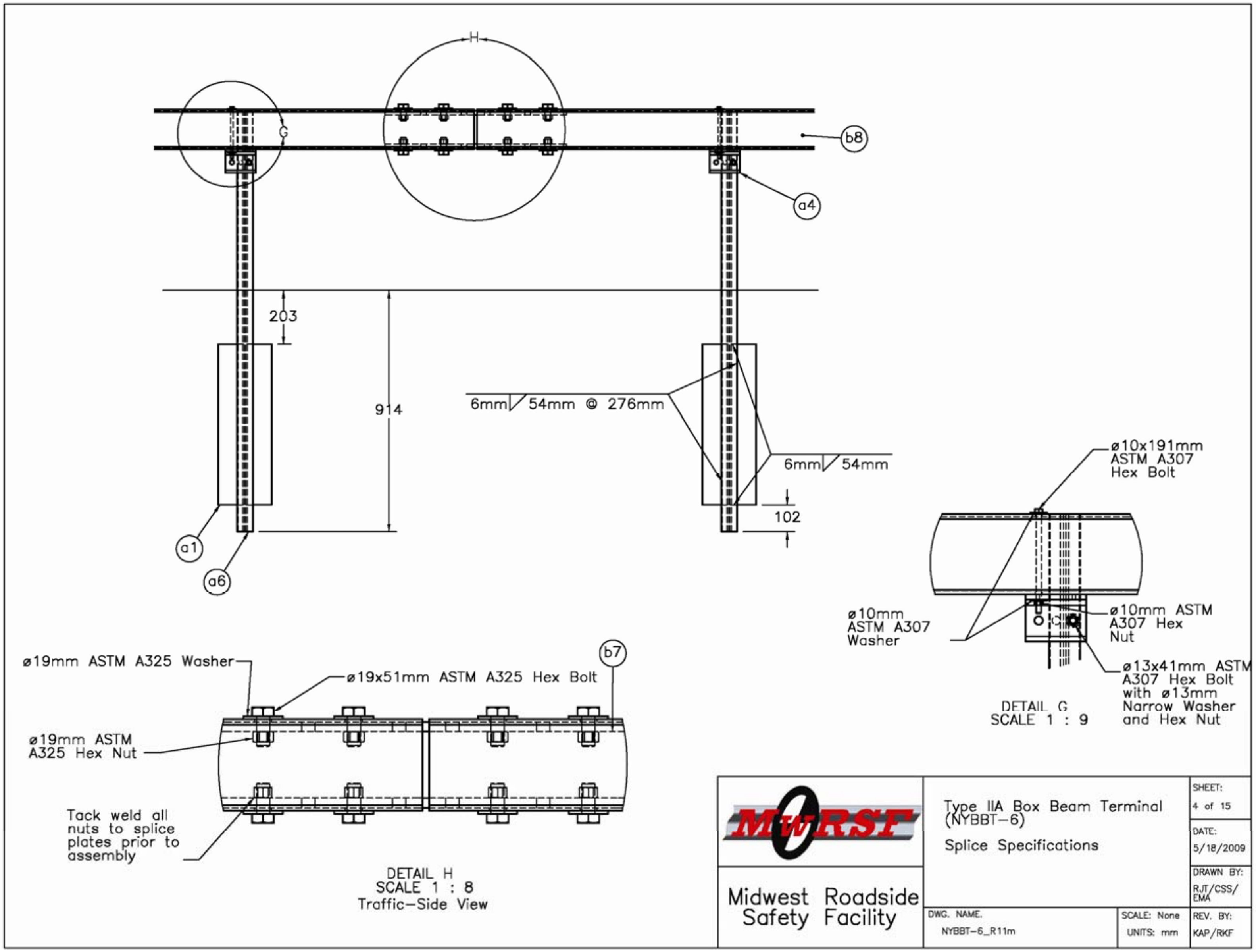


Figure 172. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

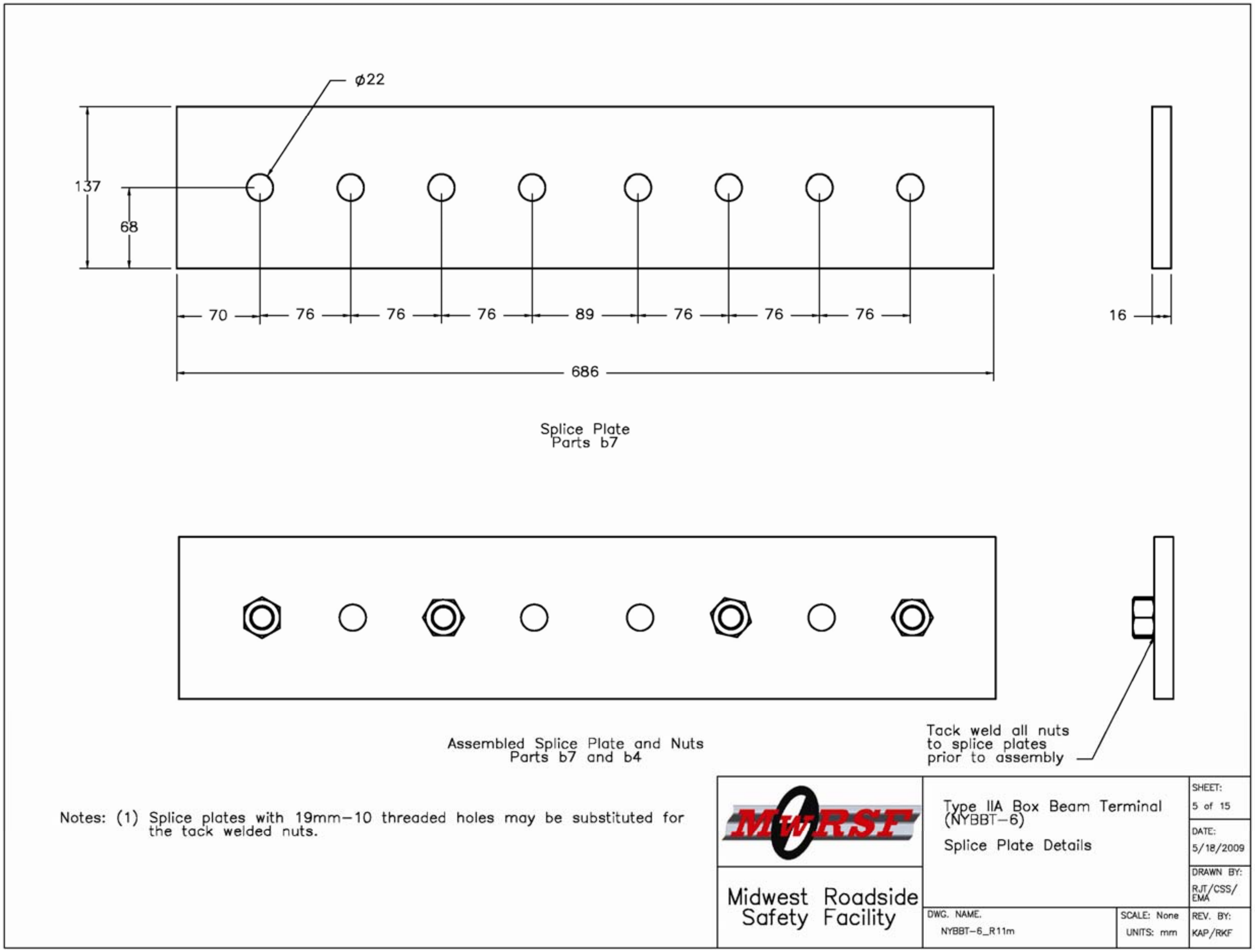


Figure 173. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

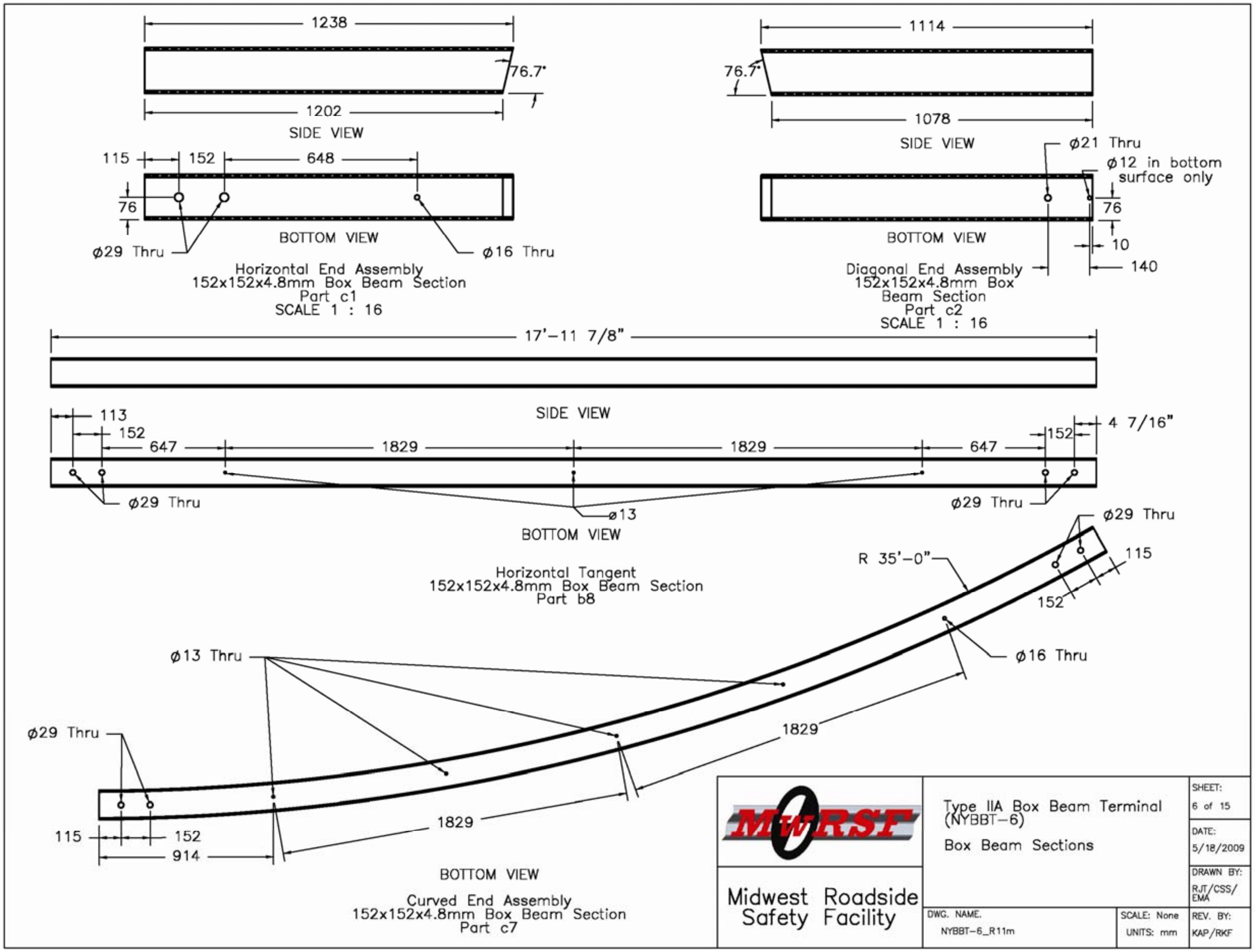


Figure 174. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

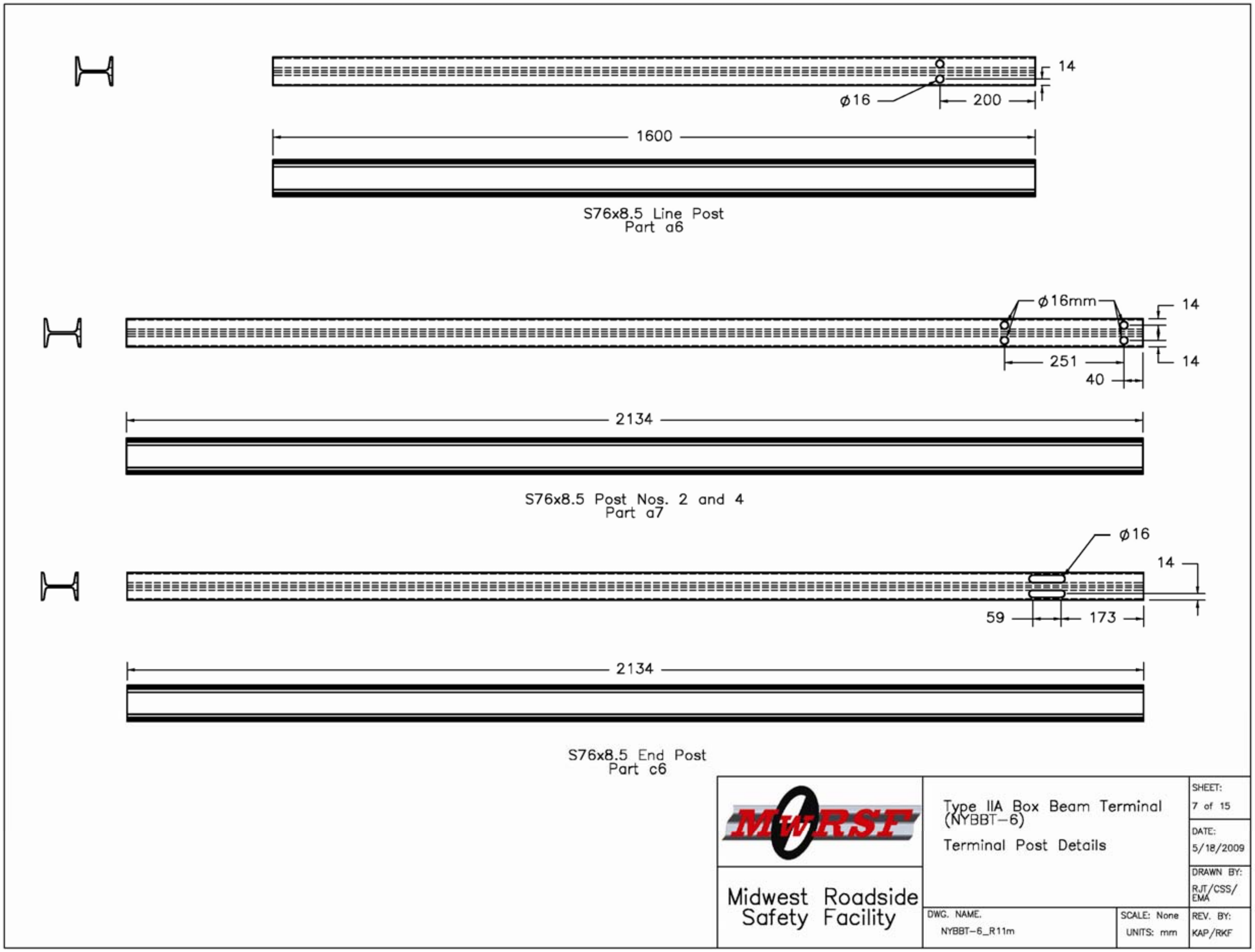


Figure 175. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

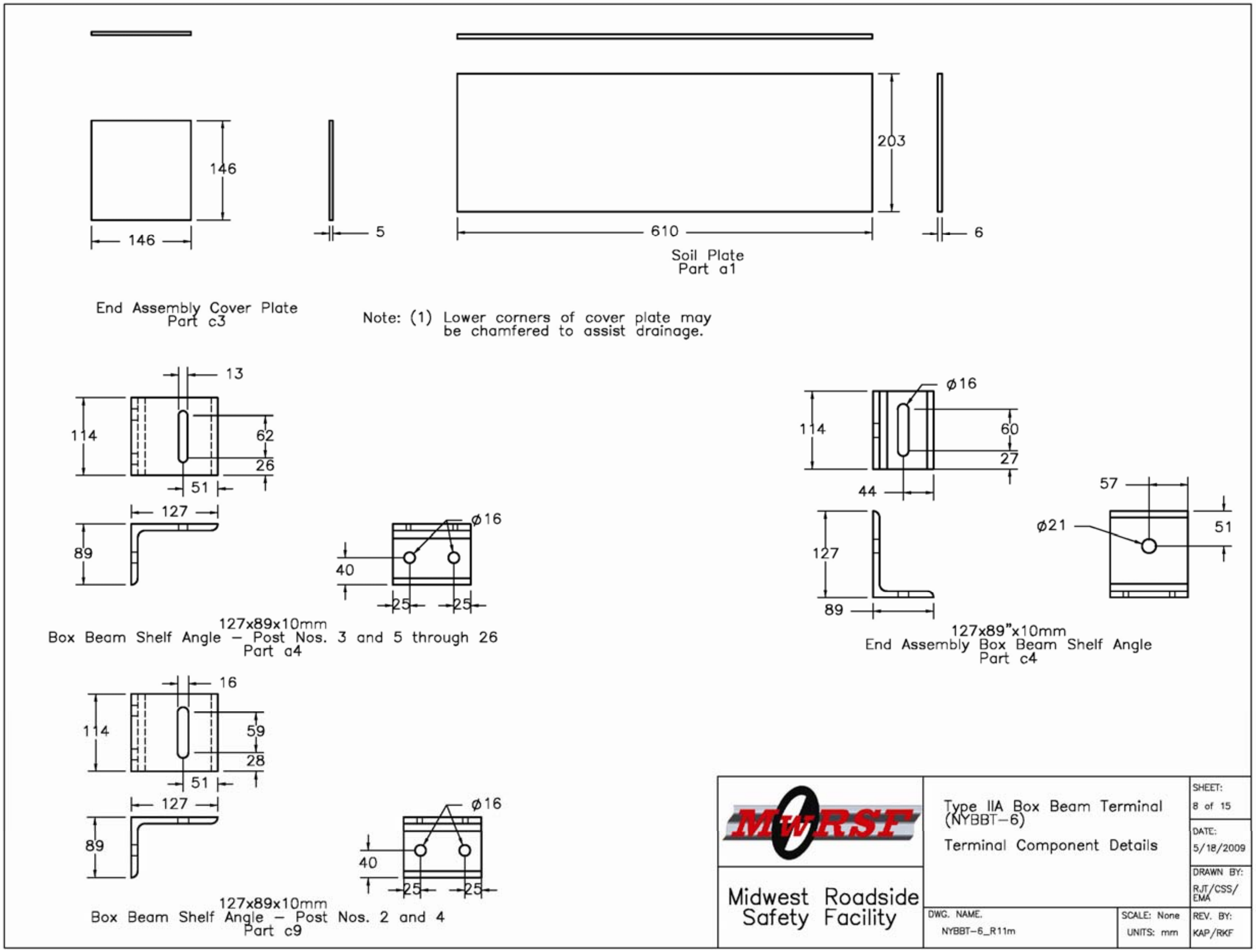


Figure 176. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

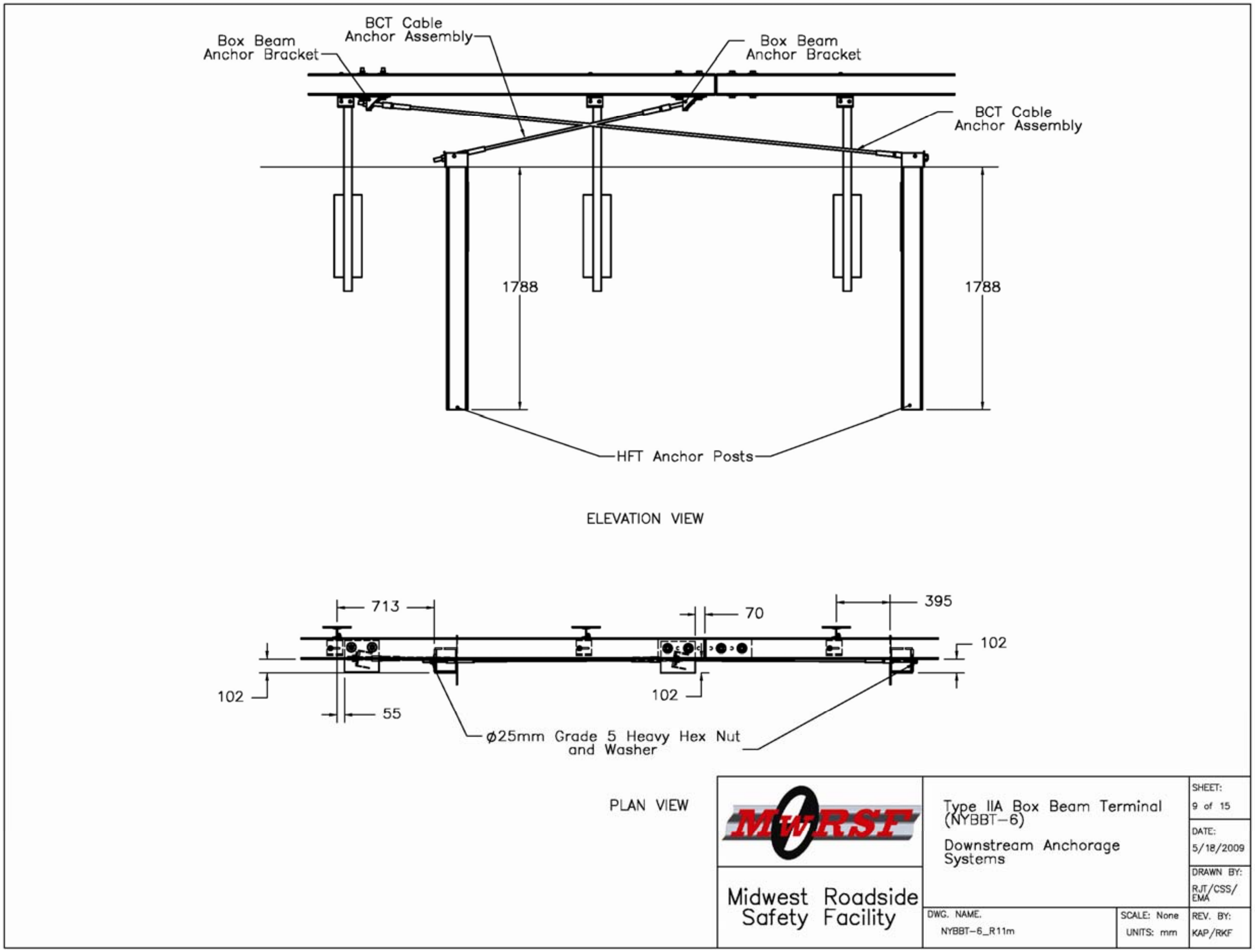


Figure 177. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

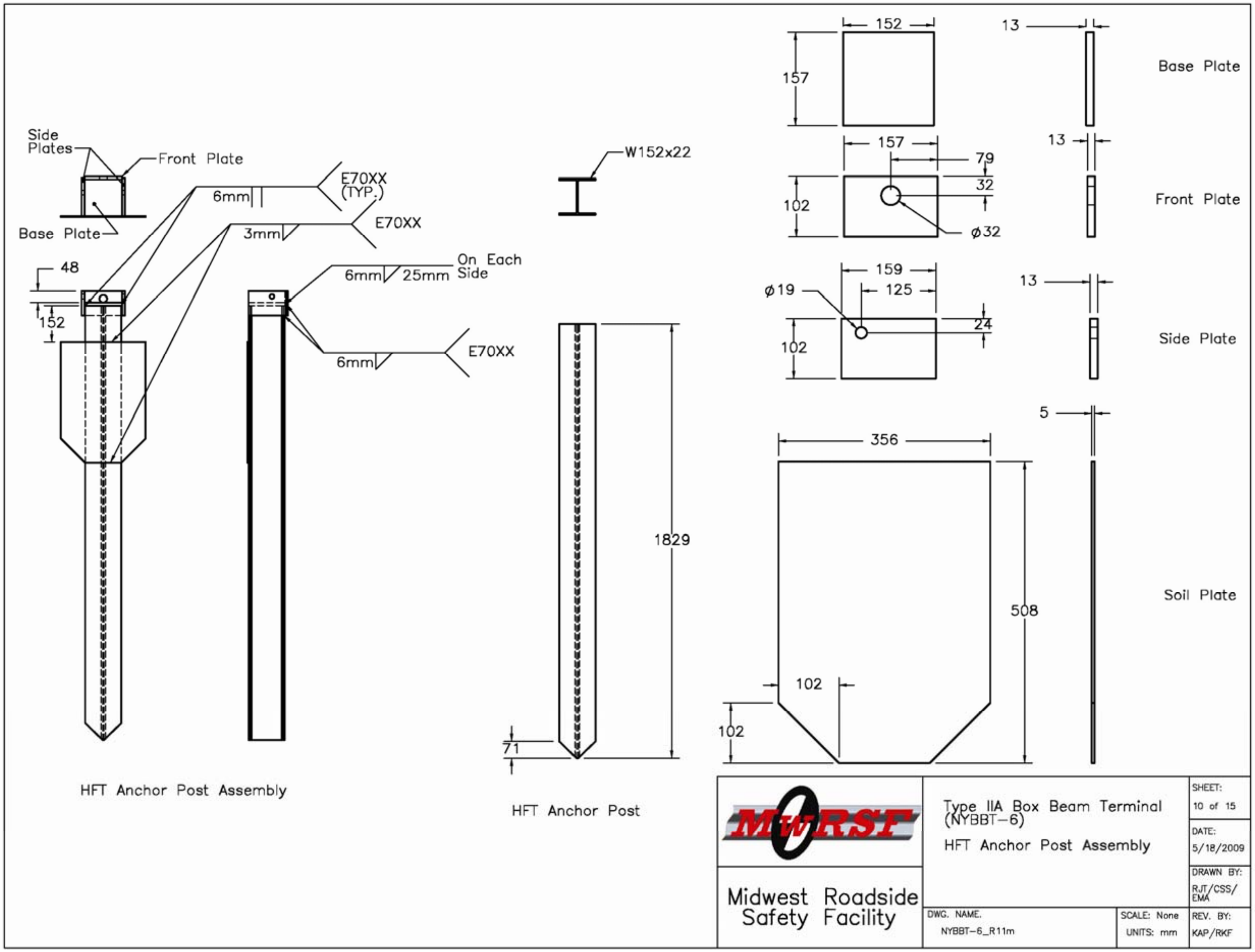


Figure 178. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

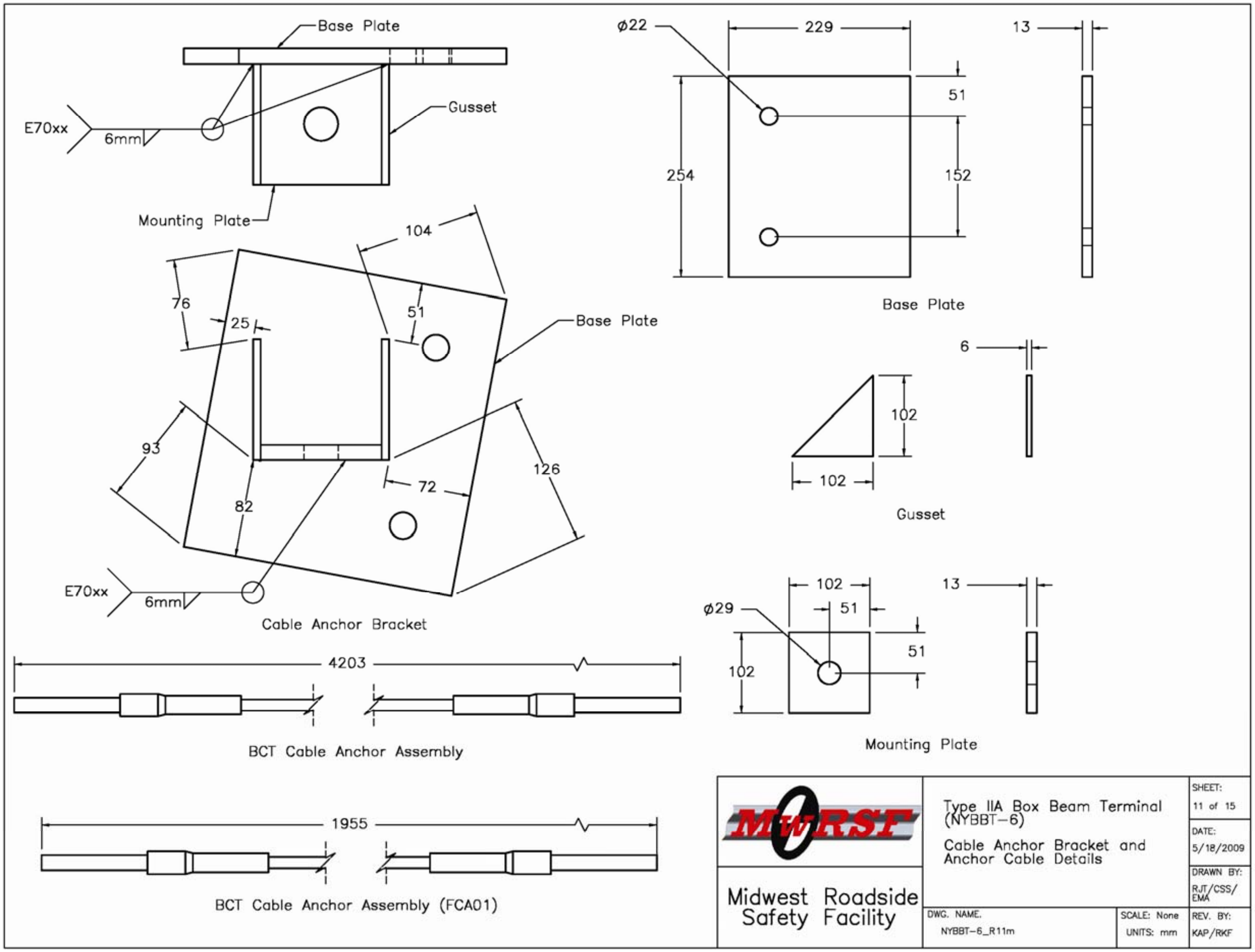
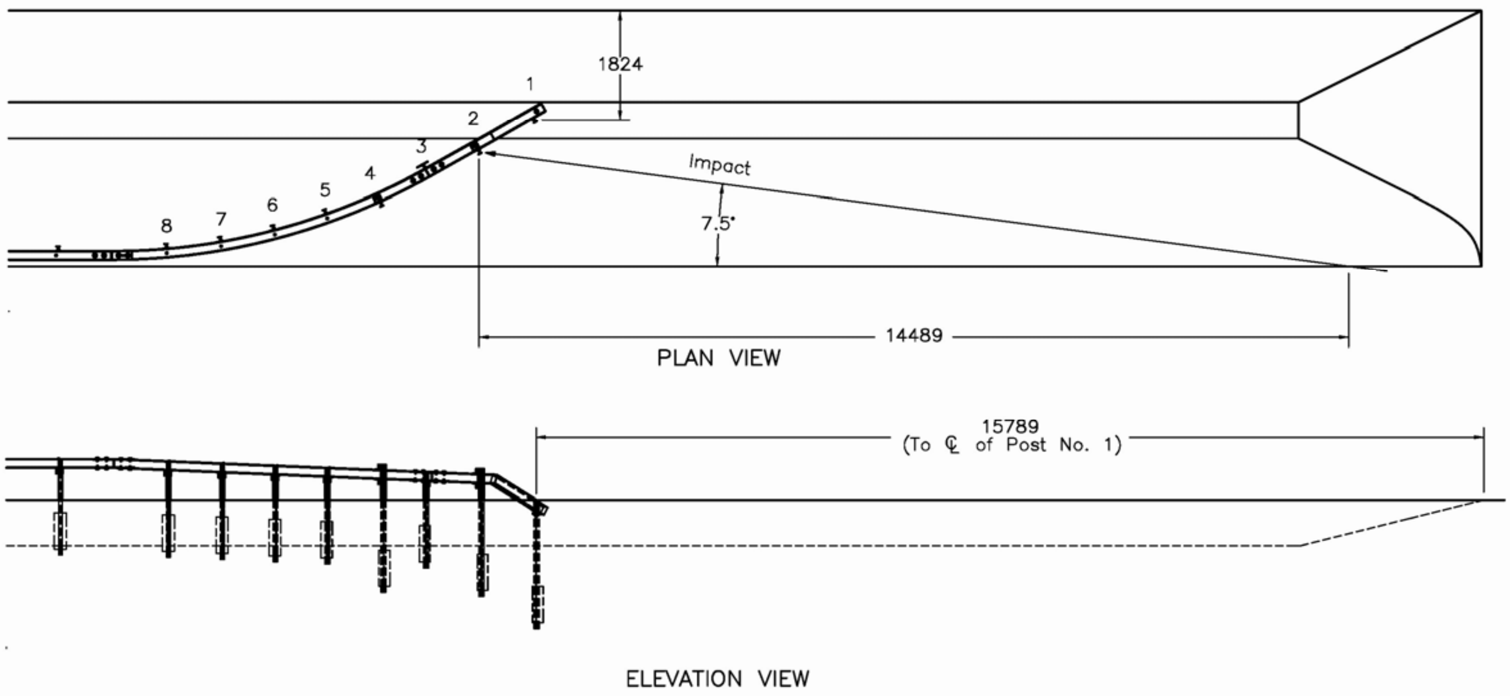


Figure 179. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6



Notes: (1) System shown with the end terminal depressed 305 millimeters.

(2) Embedment depth measured relative to the intersection of the slope with the centerline of each post.

Post No.	Embedment Depth (millimeters)
1	1397
2	964
3	614
4	1326
5	903
6	957
7	960
8	937

Midwest Roadside Safety Facility

Type IIA Box Beam Terminal (NYBBT-6)

System Position Relative to Ditch

SHEET: 12 of 15

DATE: 5/18/2009

DRAWN BY: RJT/CSS/EMA

DWG. NAME. NYBBT-6_R11m

SCALE: None
UNITS: mm

REV. BY: KAP/RKF

Figure 180. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

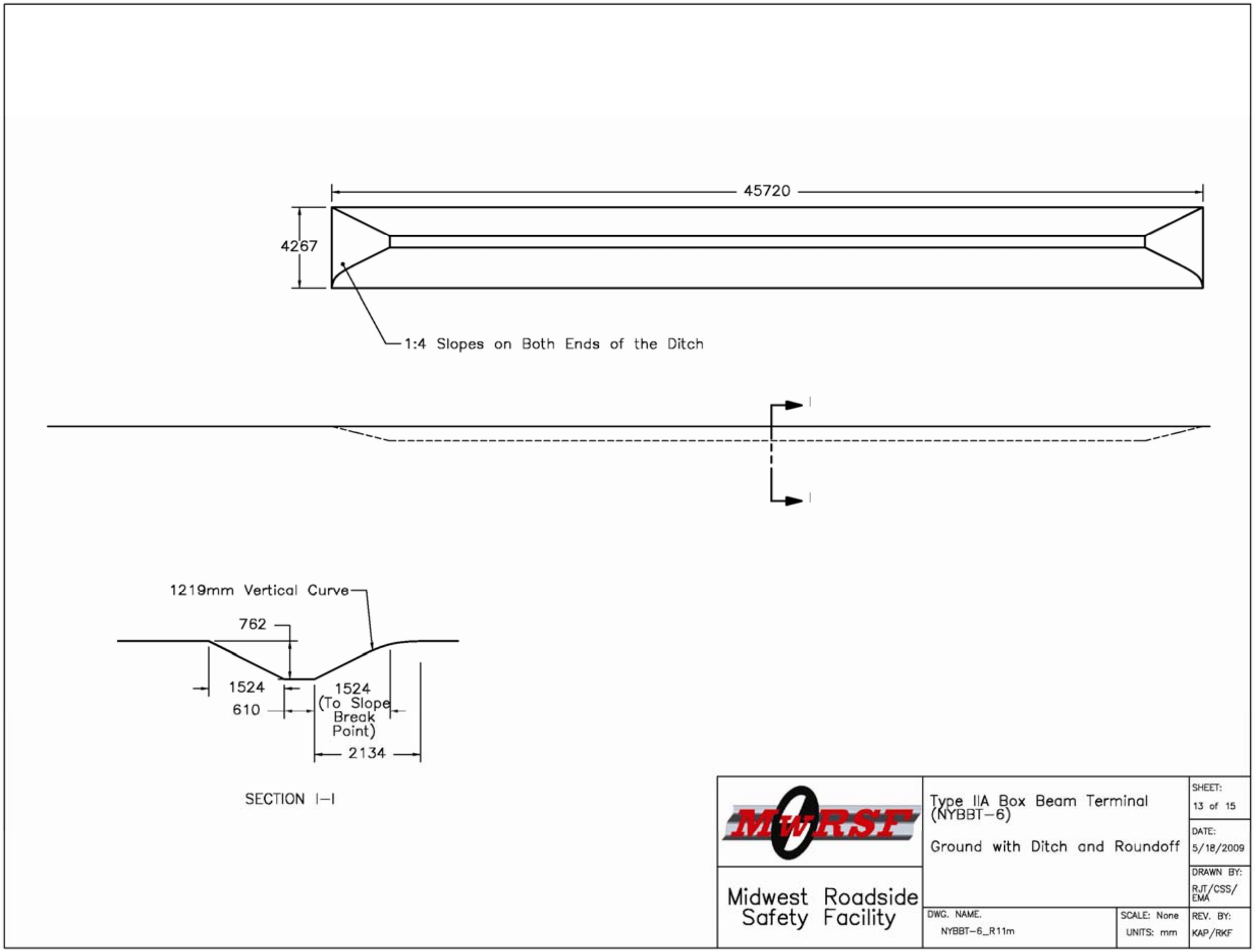


Figure 181. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

NYBBT-6

Item No.	QTY.	Description	Material Specifications
a1	26	6 x 203 x 610mm steel soil plate	A36 Steel
a2	29	ø 13mm coarse thread 41mm long hex bolt	ASTM A307
a3	31	ø 13mm hex nut	ASTM A307
a4	23	127 x 89 x 10mm box beam shelf angle	A36 Steel
a5	31	ø 13mm narrow washer	ASTM A307
a6	23	S76 x 8.5 1600mm long post	A36 Steel
a7	2	S76 x 8.5 2134mm long post	A36 Steel
b1	22	ø 10mm coarse thread 191mm long hex bolt	ASTM A307
b2	22	ø 10mm hex nut	ASTM A307
b3	44	ø 10mm wide washer	ASTM A307
b4	59	ø 19mm hex nut	ASTM A325
b5	61	ø 19mm wide washer	ASTM A325
b6	56	ø 19mm coarse thread 51mm long hex bolt	ASTM A307
b7	14	686 x 137 x 16mm splice plate	A36 Steel
b8	6	152 x 152 x 4.8mm by 5483mm long box beam	ASTM A500 Grade B
c1	1	End assembly horizontal 152 x 152 x 4.8mm box beam	ASTM A500 Grade B
c2	1	End assembly diagonal 152 x 152 x 4.8mm box beam	ASTM A500 Grade B
c3	1	End assembly 4.8mm thick cover plate	A36 Steel
c4	1	127 x 89 x 10mm box beam anchor post shelf angle	A36 Steel
c5	1	ø 19mm coarse thread 197mm long hex bolt	ASTM A307
c6	1	S76 x 8.5 2134mm long post anchor post	A36 Steel
c7	1	152 x 152 x 4.8mm R 7620mm Curved Box Beam	ASTM A500 Grade B
c8	2	ø 13mm coarse thread 203mm long hex bolt	ASTM A307
c9	4	127 x 89 x 10mm box beam shelf angle with ø16mm slot	A36 Steel
c10	4	ø 13mm wide washer	ASTM A307

MwRSF
Midwest Roadside Safety Facility

Type IIA Box Beam Terminal (NYBBT-6)
Bill of Materials

SHEET: 14 of 15
DATE: 5/18/2009
DRAWN BY: RJT/CSS/EMA
DWG. NAME. NYBBT-6_R11m
SCALE: None
UNITS: mm
REV. BY: KAP/RKF

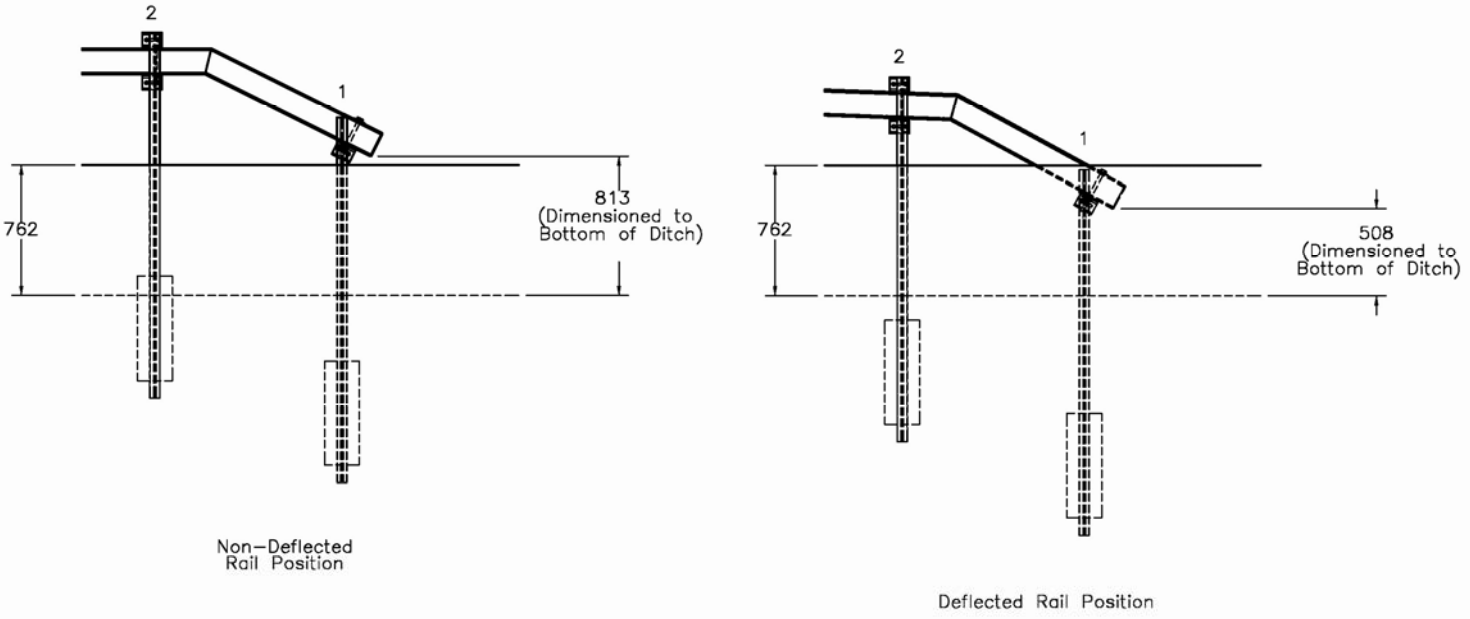
Figure 182. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6

Notes: (1) When constructing the end terminal section (curved box beam and post nos. 1 through 8), set post nos. 6 through 8 in the soil, attach rail to post no. 8, and attach the curved end section of box beam loosely at the splice between post nos. 8 and 9. Allow the box beam to hang free over the ditch in order to acquire the deflection in the end terminal. Utilizing only a reasonable amount of downward force, the deflection should be approximately 152 millimeters or more when compared to the end terminal section on flat ground (see detail below). Finally, set and attach post nos. 1, 2, and 4 through 8, and tighten remaining hardware in end terminal system. Note that post no. 3 is not attached to the rail.

(2) During the process, document the amount of effort required to achieve the deflection of the end section for use in future New York Box Beam End Terminal drawings. Also, document the actual amount of deflection that was achieved.

(3) If 152mm of deflection cannot be attained with the use of reasonable downward force, contact the office to determine whether full amount of deflection is needed.

(4) If rail end is depressed 152mm, the top and bottom of the rail end will be approximately 795mm and 660mm, respectively, above the ditch bottom.



Non-Deflected Rail Position

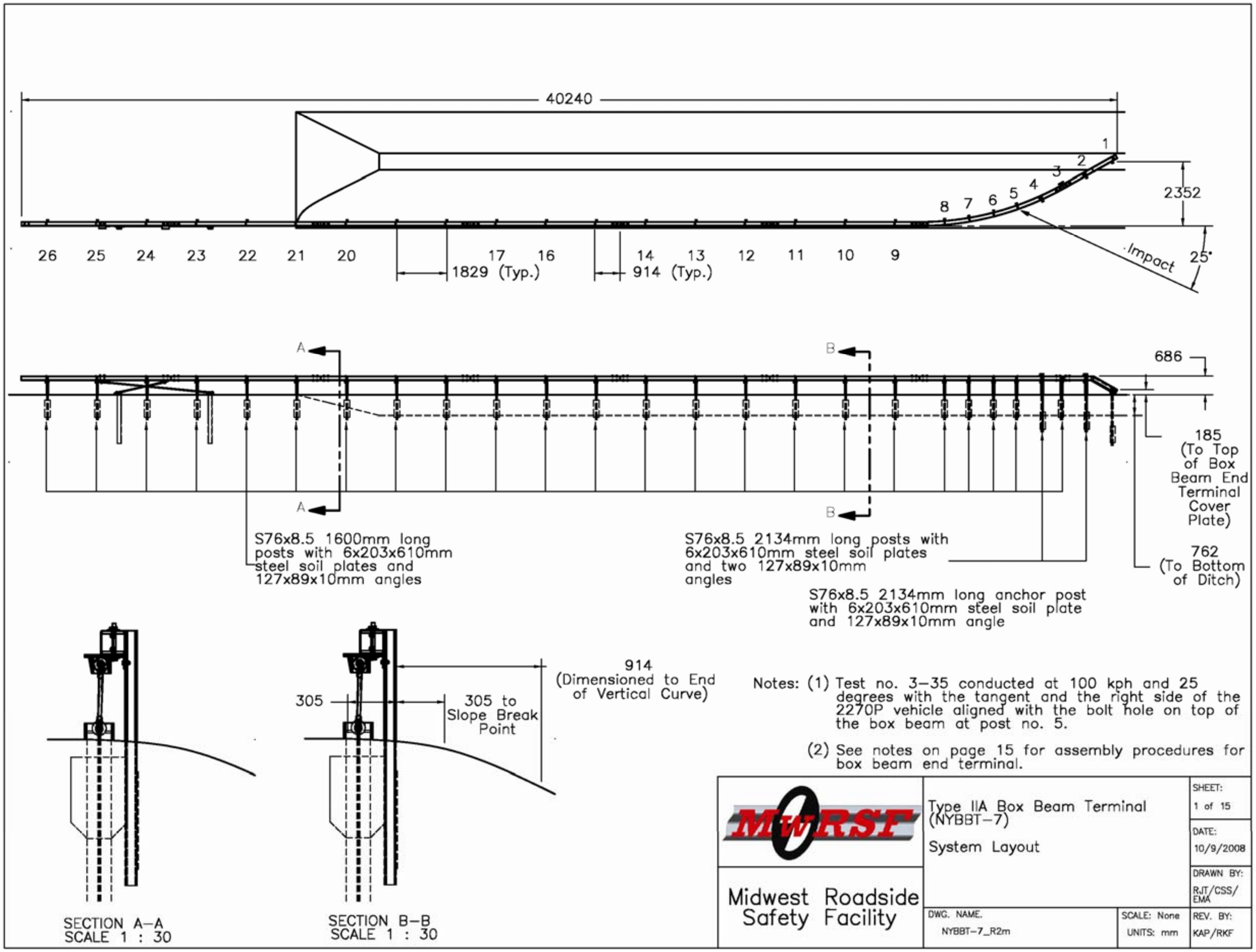
Deflected Rail Position

Midwest Roadside Safety Facility

Type IIA Box Beam Terminal (NYBBT-6)
Additional Notes

SHEET: 15 of 15
DATE: 5/18/2009
DRAWN BY: RJT/CSS/EMA
REV. BY: KAP/RKF
DWG. NAME. NYBBT-6_R11m
SCALE: None
UNITS: mm

Figure 183. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-6



Notes: (1) Test no. 3–35 conducted at 100 kph and 25 degrees with the tangent and the right side of the 2270P vehicle aligned with the bolt hole on top of the box beam at post no. 5.

(2) See notes on page 15 for assembly procedures for box beam end terminal.

Figure 184. Modified Type IIA Box Beam Terminal System Installed in a Ditch Details, Test No. NYBBT-7

Figure 185. NYBBT-6 and NYBBT-7 System Details

Figure 186. NYBBT-6 and NYBBT-7 System Details

Figure 187. NYBBT-6 and NYBBT-7 System Details

15 FULL-SCALE CRASH TEST NO. 6 (MODIFIED TYPE IIA END TERMINAL IN DITCH)

15.1 Static Soil Test

Before full-scale crash test no. NYBBT-6 was conducted, the strength of the soil foundation was evaluated with a static test, as described by MASH. The static test results, as shown in Appendix K, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and the barrier system was subjected to full-scale crash testing.

15.2 Test No. NYBBT-6 (Modified Test Designation 2-34)

The 1,176-kg (2,593-lb) Kia Rio, with a dummy placed in the right-front seat, impacted the modified Type IIA box beam terminal system installed in a ditch. When the right-front tire entered the ditch, the vehicle was traveling at a speed of 73.6 km/h (45.7 mph) and at an angle of 7.5 degrees with respect to the tangent. A summary of the test results and sequential photographs are shown in Figure 188. An English-unit summary of the test results and sequential photographs are shown in Appendix C. Additional sequential photographs are shown in Figures 189 and 190. Documentary photographs of the crash test are shown in Figures 191 through 193.

15.3 Weather Conditions

Test no. NYBBT-6 was conducted on October 3, 2008 at approximately 1:15 pm. The weather conditions were reported as shown in Table 14.

Table 14. Weather Conditions, Test No. NYBBT-6

Temperature	76° F
Humidity	36 %
Wind Speed	6 mph
Wind Direction	120° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.13 in.

15.4 Test Description

Initial vehicle impact was to occur at the centerline of post no. 2, as shown in Figure 194. Actual vehicle impact occurred 273 mm (10 3/4 in.) downstream of post no. 2. At 0.404 sec before impact with the system, the right-front tire of the vehicle encroached upon the ditch, and the vehicle rolled toward the right and the front pitched downward. At 0.012 sec after impact, the right-front corner of the bumper contacted post no. 3, which deflected backward. At 0.028 sec, the right-front door jamb contacted the rail. At 0.040 sec, the middle of the front bumper contacted post no. 4, which separated from the rail. At 0.060 sec, the rail contacted and crushed the windshield. At 0.102 sec, the middle of the front bumper contacted post no. 5, which separated from the rail. At this same time, the right-front window shattered. At 0.140 sec, the vehicle rolled toward the left. At 0.170 sec, the left corner of the front bumper contacted post no. 6, which separated from the rail. At 0.230 sec, the vehicle roll ceased. At 0.252 sec, the vehicle pitched upward. At 0.278 sec, the front end yawed away from the barrier. At 0.504 sec, the vehicle came to rest positioned under the box beam rail at 4.0 m (13 ft - 1 in.) downstream from impact and 0.2 m (6 in.) laterally behind the traffic-side face of the tangent rail. The trajectory and final position of the passenger car are shown in Figures 188 and 195.

15.5 System and Component Damage

Damage to the end terminal system was moderate, as shown in Figures 196 through 198. Damage consisted of deformed box beam and guide rail posts as well as contact marks on box beam rail sections and guide rail posts. The length of vehicle contact was approximately 4.0 m (13.2 ft), which spanned from 273 mm (10 3/4 in.) downstream of post no. 2 to post no. 7.

Contact marks were found on the rail 191 mm (7 1/2 in.) upstream from the centerline of post no. 2. The splice at post no. 3 deflected backward and downward, and a 19-mm (3/4-in.) gap formed at the top face. The splices between post nos. 8 and 9 as well as 11 and 12 were twisted and bent. The box beam disengaged from post nos. 3 through 7.

Post nos. 1, 2, and 4 through 6 bent downstream and rotated backward. The post bolt slot on post no. 1 was deformed. Contact marks were found on post no. 2. Post no. 3 pulled completely out of the ground. Post no. 7 also bent downstream. Post nos. 8 through 10 rotated backward. No significant damage occurred downstream of post no. 10.

Soil gaps of 86 mm (3 3/8 in.) and 146 mm (5 3/4 in.) were found on the upstream sides of post nos. 1 and 2, respectively. A 559-mm (22-in.) diameter hole was found at the original position of post no. 3. Soil gaps of 102 mm (4 in.), 51 mm (2 in.), and 25 mm (1 in.) were found at the traffic-side flanges of post nos. 8 through 10, respectively. The bolt connecting the shelf angle to post nos. 3 through 5 was sheared off. The bolt connecting the shelf angles to the rail at post nos. 4 through 7 were sheared off.

The permanent set deflection of the end terminal system is shown in Figure 196. The maximum lateral permanent set rail and post deflections were 584 mm (23 in.) at the centerline of post no. 3 and 279 mm (11 in.) at post no. 1, respectively, as measured in the field. The maximum lateral dynamic rail deflection was 670 mm (26 3/8 in.) at the centerline of post no. 3, as determined from high-speed digital video analysis.

15.6 Vehicle Damage

Exterior vehicle damage was extensive, as shown in Figures 199 and 200. The occupant compartment was severely damaged due to penetration of the rail through the windshield. Complete occupant compartment deformations and the corresponding locations are provided in Appendix D.

Damage was concentrated on the front and right side of the vehicle. The bumper cover disengaged from the vehicle, and the bumper was dented. The rail across the radiator was bent and the right side crushed inward. The right-front quarter panel was crushed and deformed upward. The right-rear door was ajar at the top. The right side of the engine hood was deformed upward. The right-front door was deformed inward, and the door skin was removed from the door. The right-side mirror disengaged from the vehicle. The right-side headlight was dislodged. The roof and right-side A-pillar were crushed downward. A large dent was found in the right-rear portion of the roof. The right side of the dash was displaced backward. The rear axle was scratched. The windshield was torn and shattered, and the lower-right corner was separated from the vehicle. The right-front door window was also shattered. The remainder of the vehicle and all other window glass remained undamaged.

15.7 Occupant Risk Values

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 15. It is noted that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 15. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 188. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix Q. Due to technical difficulties, the EDR-4 recorder did not collect acceleration nor angular data.

Table 15. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYBBT-6

Evaluation Criteria		Transducer	
		EDR-3	DTS
OIV m/s (ft/s)	Longitudinal	-8.61 (-28.23)	-8.08 (-26.49)
	Lateral	3.03 (9.94)	3.21 (10.52)
ORA g's	Longitudinal	-12.50	-10.91
	Lateral	5.32	6.96
THIV m/s (ft/s)		NA	7.94 (26.05)
PHD g's		NA	12.58
ASI		0.78	0.76

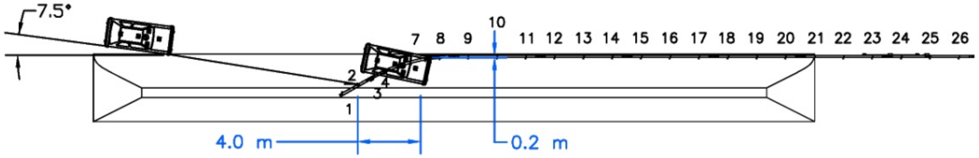
15.8 Discussion

The analysis of the test results for test no. NYBBT-6 showed that the modified NYSDOT Type IIA box beam end terminal system installed in a ditch contained the 1100C vehicle, but it did not redirect the vehicle since the vehicle did not exit the system after impact. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did occur with the penetration of the windshield by the box beam rail. Therefore, test no. NYBBT-6 conducted on the modified Type IIA end terminal installed in a ditch was determined to be unacceptable according to a modified test designation no. 2-34 of the TL-2 safety performance criteria found in MASH.

Following a review of the test results for test no. NYBBT-6, the following observations should be noted. The vehicle smoothly traversed down the ditch prior to impact with the end terminal. The two upstream posts (post nos. 2 and 4), which were intended to push the rail ahead of the vehicle and pull it down, were not effective. The right-front corner of the vehicle did not contact post no. 2, and initial impact occurred between the right-front corner of the engine hood and the underside of the box beam rail. As the vehicle continued downstream, the box beam rail scraped across the top of the engine hood and deflected backward and upward. As the curved rail section straightened out, post no. 2 deflected laterally without significant vertical deflection, and it failed to push the rail downward to interact with the vehicle's grill. Subsequently, the left-front corner of the vehicle contacted the upstream side of post no. 4, and the post deflected laterally toward the front of the system. At the same time, the bolts connecting the shelf angles to post no. 4 sheared. When the vehicle contacted the end terminal, the box beam rail was positioned above the vehicle's hood, which did not allow for the vehicle's front end to interact with the box beam rail. Therefore, the front of the vehicle underrode the rail immediately upon impact. In addition, the box beam rail disengaged from post nos. 4 through 7, but it remained attached to post nos. 1 and 2. Recall, post no. 3 in this design was not connected to the rail. The vehicle did not redirect, and while it continued underriding the system, the rail impacted and deformed the windshield and ultimately intruded into the occupant compartment.

Consequently, the modified end terminal did not mitigate the potentially hazardous results of a vehicle traveling through a non-traversable ditch section. Instead, the vehicle crash into the modified end terminal placed in a ditch may have actually resulted in a more severe impact event than if the vehicle would have just traversed through the ditch.

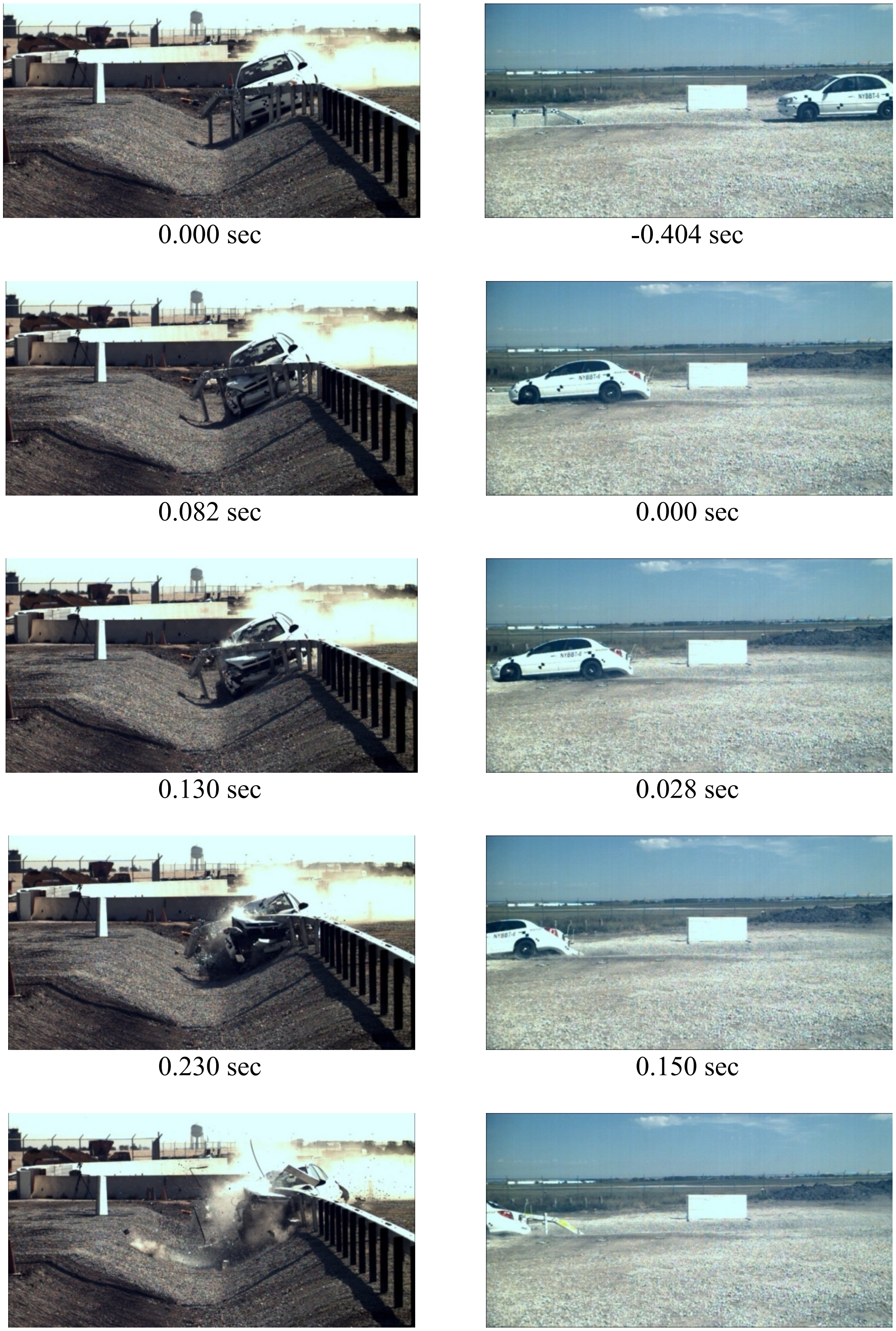
-0.404 sec   0.000 sec   0.042 sec   0.126 sec   0.286 sec



●Test Agency	MwRSF
●Test Number	NYBBT-6
●Date	10/3/08
●MASH Test Designation	Modified 2-34
●Appurtenance	Modified Type IIA End Terminal in Ditch
●Total Length	40.2 m
●Key Element – Steel Box Beam	
Size	152 mm x 152 mm x 4.8 mm
Length	5,486 mm
Top Mounting Height	686 mm
●Key Elements - Steel Post	
Post Nos. 1, 2, 4	S76x8.5 by 2,134 mm long
Post Nos. 3, 5-26	S76x8.5 by 1,600 mm long
●Type of Soil	Grading B - AASHTO M 147-65 (1990)
●Test Vehicle	
Type/Designation	1100C
Make and Model	2002 Kia Rio
Curb	1,082 kg
Test Inertial	1,100 kg
Gross Static	1,176 kg
●Impact Conditions	
Speed	73.6 km/h
Angle (trajectory)	7.5 degrees
Target Impact Location	Centerline of post no. 2
Actual Impact Location	273 mm downstream of post no. 2
●Exit Conditions	
Speed	NA
Angle	NA
Exit Box Criterion	NA
●Post-Impact Trajectory (measured to left-front tire)	
Vehicle Stability	Satisfactory
Stopping Distance	4.0 m downstream 0.2 m laterally behind traffic-side face

●Occupant Impact Velocity (EDR-3)	
Longitudinal	-8.61 m/s < 12.2 m/s
Lateral	3.03 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-3)	
Longitudinal	-12.50 g's < 20.49 g's
Lateral	5.32 g's < 20.49 g's
●Occupant Impact Velocity (DTS)	
Longitudinal	-8.08 m/s < 12.2 m/s
Lateral	3.21 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (DTS)	
Longitudinal	-10.91 g's < 20.49 g's
Lateral	6.96 g's < 20.49 g's
●THIV (DTS - not required)	7.94 m/s
●PHD (DTS - not required)	12.58 g's
●ASI (EDR-3 - not required)	0.78
●ASI (DTS - not required)	0.76
●Test Article Damage	Moderate
●Test Article Deflections	
Permanent Set	584 mm
Dynamic	670 mm
Working Width	NA
●Vehicle Damage	Moderate
VDS[12]	01-RFQ-6
CDC[13]	01-RYAW9
●Maximum Deformation	13 mm at right-front floorboard
●Angular Displacement	
Roll	10 degrees
Pitch	4 degrees
Yaw	8 degrees

Figure 188. Summary of Test Results and Sequential Photographs, Test No. NYBBT-6



0.000 sec

-0.404 sec

0.082 sec

0.000 sec

0.130 sec

0.028 sec

0.230 sec

0.150 sec

0.492 sec

0.320 sec

Figure 189. Additional Sequential Photographs, Test No. NYBBT-6

0.000 sec

0.038 sec

0.060 sec

0.086 sec

0.110 sec

0.130 sec

0.170 sec

0.278 sec

0.298 sec

0.504 sec

Figure 190. Additional Sequential Photographs, Test No. NYBBT-6

Figure 191. Documentary Photographs, Test No. NYBBT-6

Figure 192. Documentary Photographs, Test No. NYBBT-6

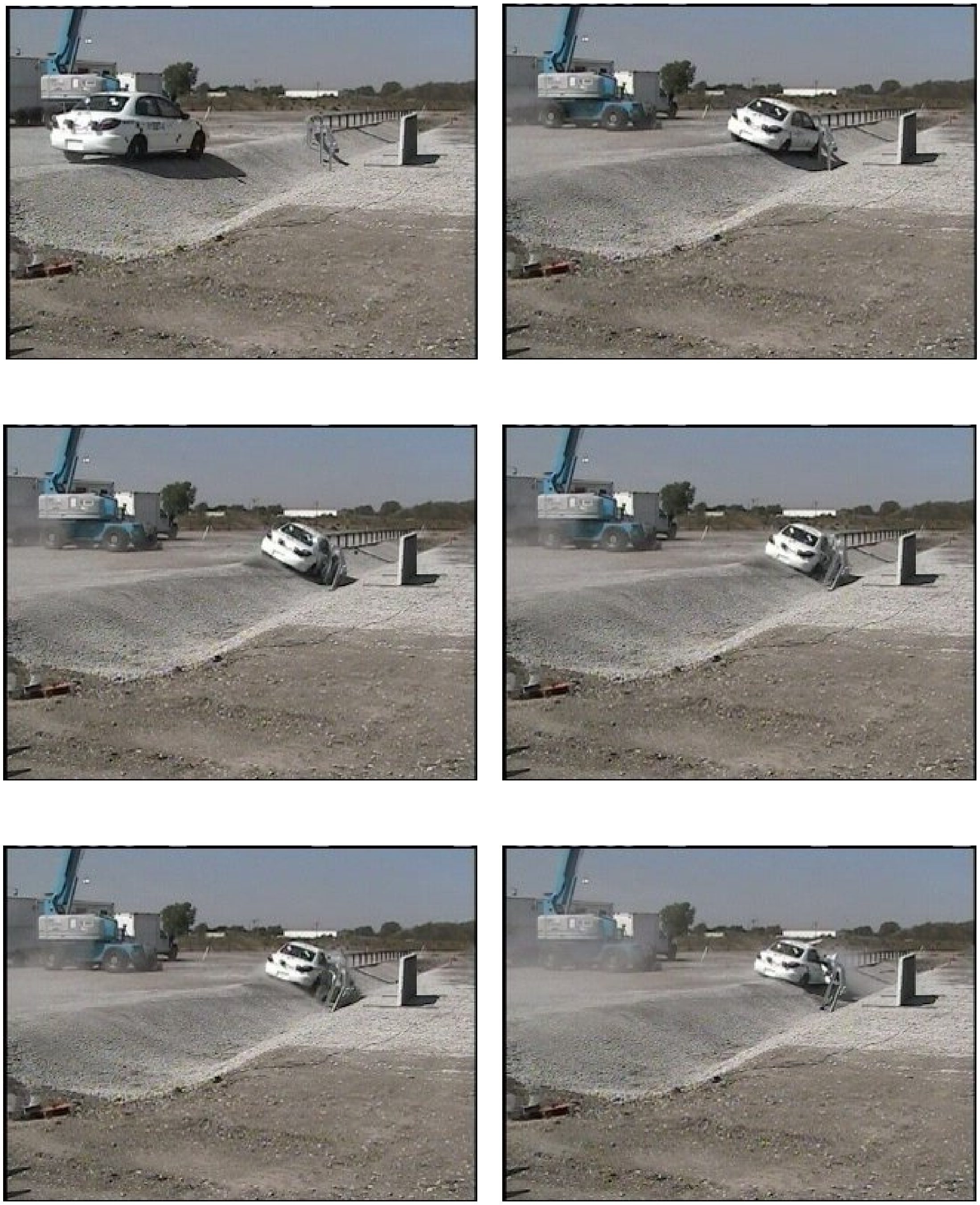


Figure 193. Documentary Photographs, Test No. NYBBT-6

Figure 194. Impact Location, Test No. NYBBT-6

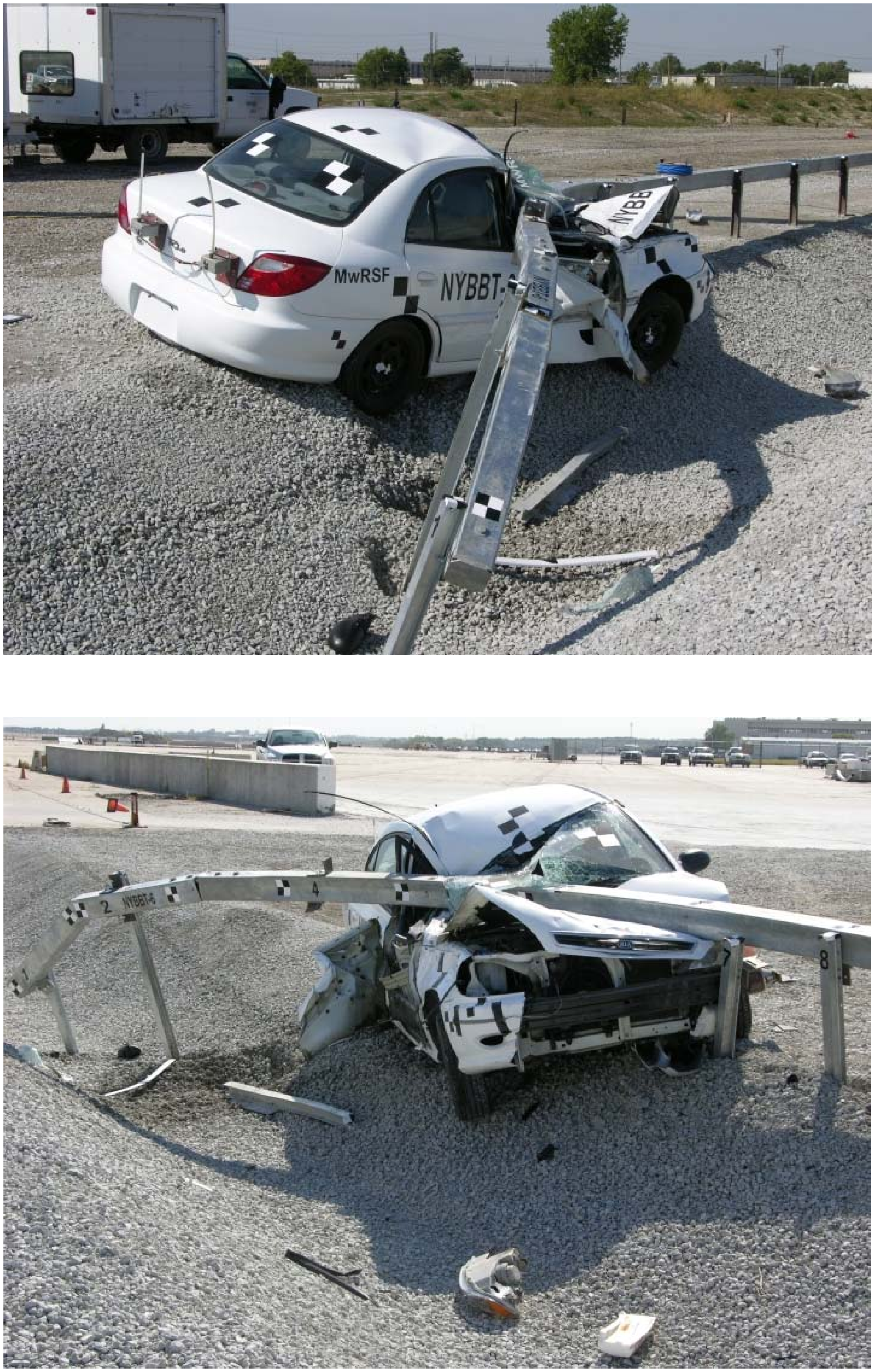
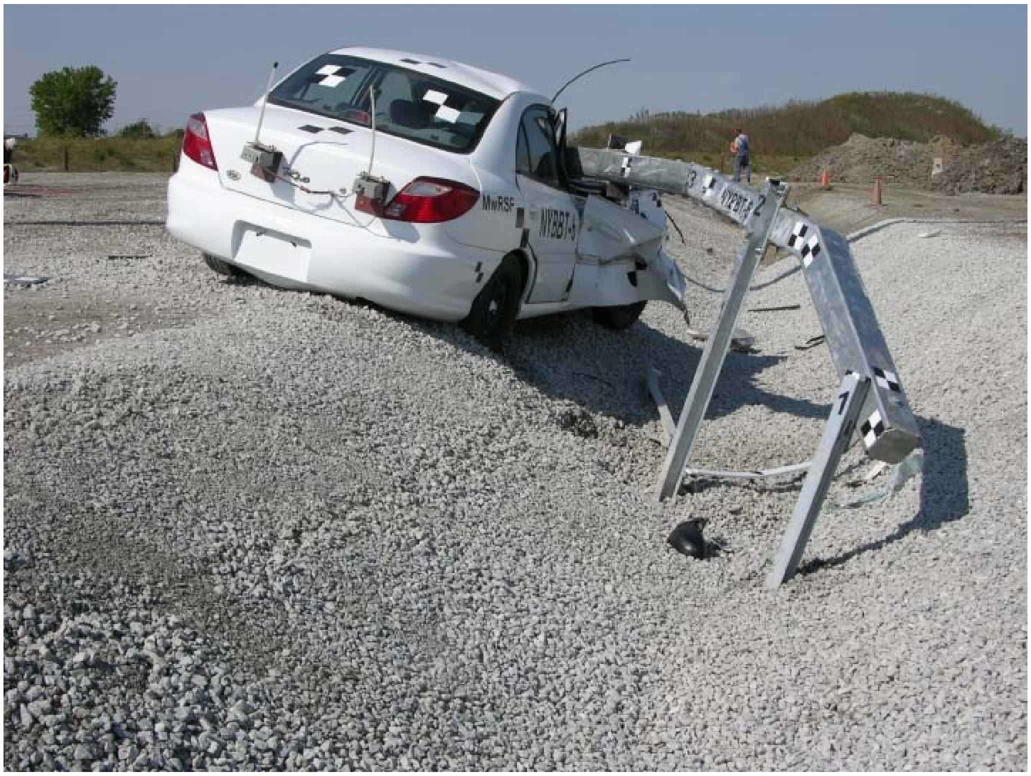


Figure 195. Vehicle Final Position and Trajectory Marks, Test No. NYBBT-6



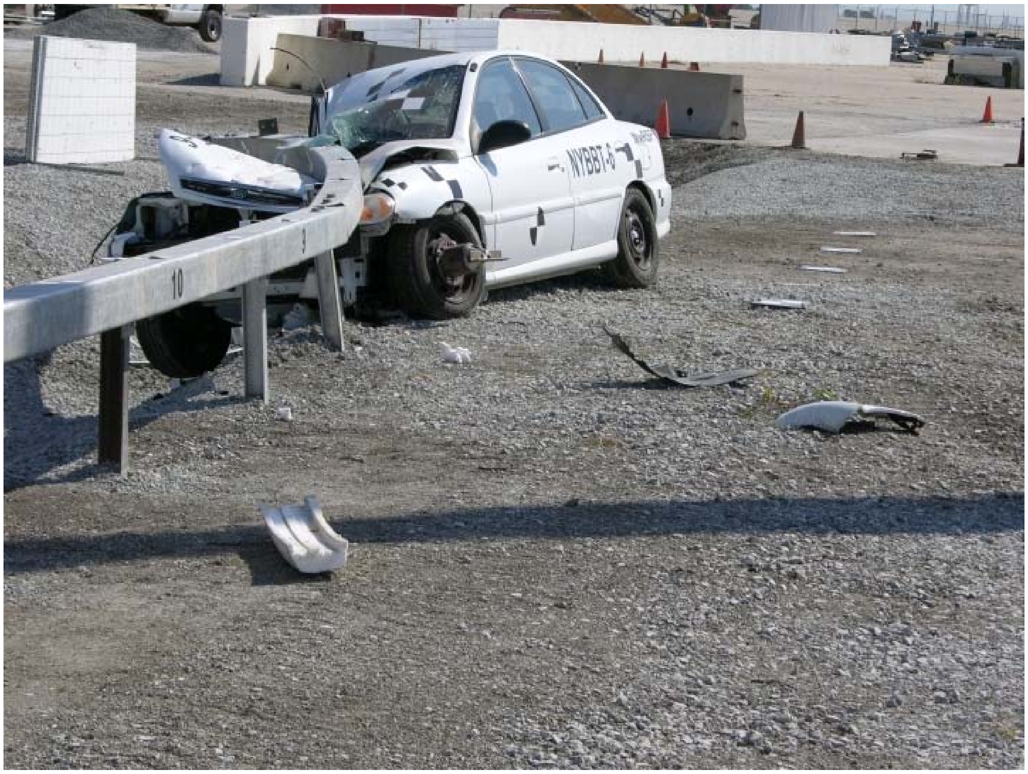
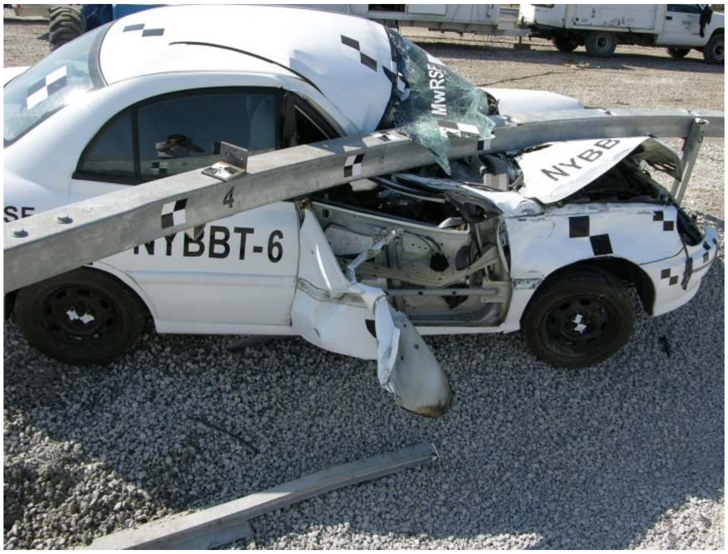


Figure 196. Barrier Damage, Test No. NYBBT-6

Figure 197. Barrier Damage, Test No. NYBBT-6

Figure 198. Post Nos. 1 through 8 Damage, Test No. NYBBT-6



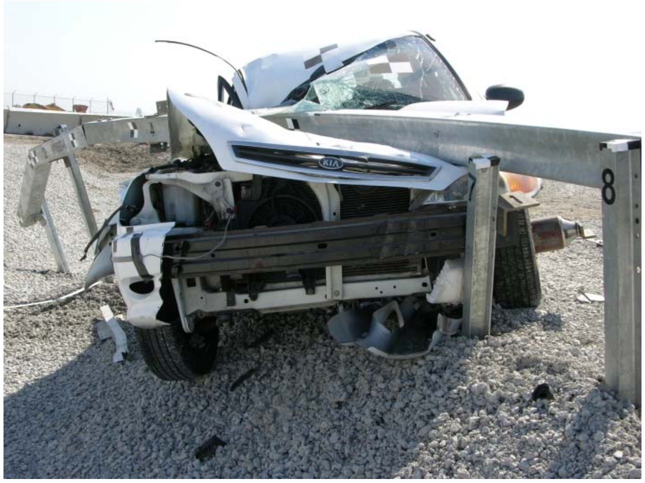


Figure 199. Vehicle Damage, Test No. NYBBT-6

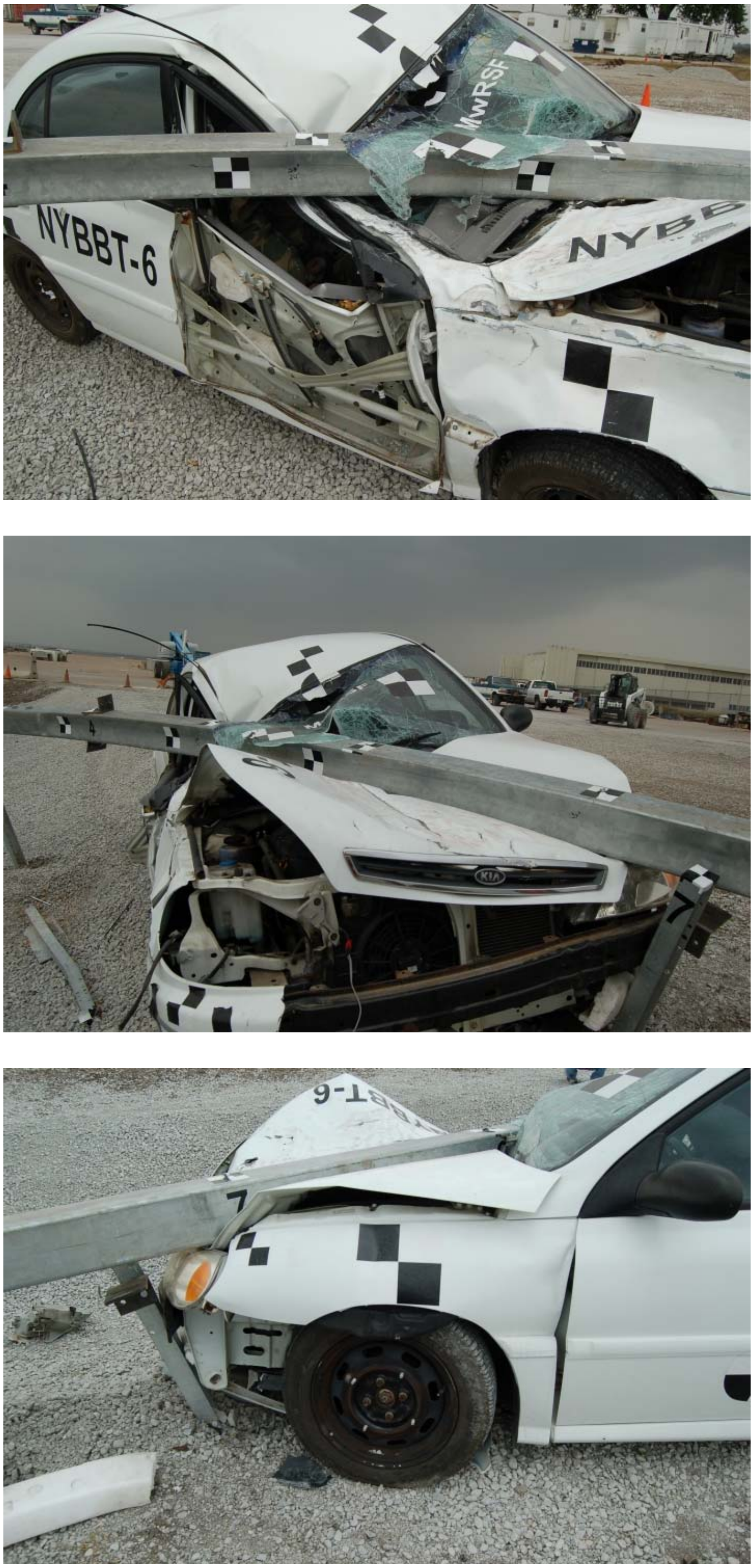


Figure 200. Vehicle Damage, Test No. NYBBT-6

16 FULL-SCALE CRASH TEST NO. 7 (MODIFIED TYPE IIA END TERMINAL IN DITCH)

16.1 Static Soil Test

Before full-scale crash test no. NYBBT-7 was conducted, the strength of the soil foundation was evaluated with a static test, as described by MASH. The static test results, as shown in Appendix K, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and the barrier system was subjected to full-scale crash testing.

16.2 Test No. NYBBT-7 (Modified Test Designation 3-35)

The 2,351-kg (5,184-lb) Dodge Ram 1500 Quad Cab pickup truck, with a dummy placed in the right-front seat, impacted the modified Type IIA box beam terminal system installed in a ditch at a speed of 100.8 km/h (62.6 mph) and at an angle of 25.8 degrees with respect to the tangent. A summary of the test results and sequential photographs are shown in Figure 201. An English-unit summary of the test results and sequential photographs are shown in Appendix C. Additional sequential photographs are shown in Figures 202 through 204. Documentary photographs of the crash test are shown in Figures 205 and 206.

16.3 Weather Conditions

Test no. NYBBT-7 was conducted on November 3, 2008 at approximately 2:45 pm. The weather conditions were reported as shown in Table 16.

Table 16. Weather Conditions, Test No. NYBBT-7

Temperature	79° F
Humidity	31 %
Wind Speed	24 mph
Wind Direction	190° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

16.4 Test Description

Initial vehicle impact was to occur with the vehicle's right-front corner at the centerline of post no. 5, as shown in Figure 207. Actual vehicle impact occurred at the targeted impact location. Upon impact, the right-front corner of the bumper was deformed. At 0.004 sec, post nos. 4 through 6 deflected laterally away from the vehicle. At 0.016 sec, the right-front tire contacted the box beam at post no. 5 and became airborne. At this same time, post nos. 2 and 4 rotated downstream. At 0.020 sec, a buckle point formed in the rail at post no. 5, and the bolt connecting the shelf angle to the rail at post no. 5 sheared. At 0.024 sec, post no. 1 rotated downstream and post no. 6 rotated upstream. At 0.032 sec, the bolt connecting the shelf angles to the rail at post no. 4 sheared, while post nos. 7 and 8 rotated upstream. At this same time, the vehicle appeared to have begun redirecting. At 0.036 sec, the bolt connecting the shelf angle to the rail at post no. 6 sheared. At 0.040 sec, the bolt connecting the shelf angle to the rail at post no. 7 sheared. At 0.056 sec, the bolt connecting the shelf angle to the rail at post no. 8 sheared, and post no. 9 rotated upstream. At 0.066 sec, the bolt connecting the shelf angles to the rail at post no. 2 sheared. At 0.074 sec, the right-front tire contacted post no. 6, and post no. 10 rotated upstream. At 0.086 sec, post no. 11 rotated upstream. At 0.100 sec, the undercarriage of the vehicle contacted post no. 7, the bolt connecting the shelf angle to post no. 7 sheared, and the left-front tire became airborne. At 0.132 sec, the vehicle rolled toward the right. At 0.154 sec, the bolt connecting the shelf angles to the rail at post no. 2 was pulled through the rail. At 0.164 sec, the front of the vehicle pitched downward. At 0.214 sec, the left-rear tire became airborne. At 0.228 sec, the bolt connecting the shelf angle to post no. 1 sheared. At 0.236 sec, the right-rear tire became airborne, thus the entire vehicle was airborne. At 0.248 sec, a buckle point formed in the rail between post nos. 9 and 10. At this same time, the rail at post no. 5 contacted the backslope. At 0.276 sec, the right-front corner of the bumper was on top of the rail, and the vehicle rolled significantly to the right. At 0.406 sec, the left-front tire contacted the rail at post no. 11, and the rail disengaged from post nos. 12 through 17. At 0.446 sec, the right-rear tire contacted the backslope of the ditch. At 0.550 sec, the right side of the vehicle contacted the backslope. At 0.618 sec, the right-side A-pillar contacted the ground as the vehicle rolled over. The vehicle continued rolling downstream and came to rest 22.1 m (72 ft – 6 in.) downstream from impact and 1.9 m (75 in.) laterally away from the traffic-side face of the tangent rail. The trajectory and final position of the pickup truck are shown in Figures 201 and 208.

16.5 System and Component Damage

Damage to the end terminal system was extensive, as shown in Figures 210 through 223. Damage consisted of deformed box beam and guide rail posts, buckled box beam, and contact marks on box beam rail sections and guide rail posts. The length of vehicle contact was approximately 8.5 m (28.0 ft), which spanned from the centerline of post no. 5 through 305 mm (12 in.) downstream of post no. 11.

Scrapes and contact marks were found on the front face of the rail between post nos. 5 and 8. Gouges were found in the rail at 914 mm (36 in.) downstream of post no. 10 and 610 mm (24 in.) upstream of post no. 11. Buckling of the rail was found at post nos. 5, 11, and 12. Major buckling of the rail was also found 914 mm (36 in.) downstream of post no. 9 and 610 mm (24 in.) downstream of post no. 10. The rail at post no. 12 was bent to an angle greater than 90 degrees. The splice plates between post nos. 14 and 15 were bent. The box beam rail disengaged from post nos. 1 through 17.

Post nos. 1, 3, and 5 through 12 were bent downstream and rotated backward. The downstream post bolt slot on post no. 1 tore through the back flange. The bolts connecting the shelf angles to post nos. 2, 8 through 13, and 18 were bent. The shelf angles at post nos. 5 and 9 through 11 bent. Post nos. 5 through 9 also twisted. The upstream traffic-side flange of post no. 7 experienced vehicle contact deformation. Post no. 9 was pulled up out of the ground, thus exposing the soil plate. Contact marks were found on the upstream side of post no. 12. Post nos. 14 through 16 and 19 through 26 did not experience any visible deflection or post deformation.

A soil gap of 76 mm (3 in.) was found at the upstream side of post no. 2. A soil gap of 305 mm (12 in.) was found at the traffic-side face of post no. 9. Soil gaps of 25 mm (1 in.) were found at the traffic-side face of post no. 13 and back side of post no. 18. A soil gap of 38 mm (1 1/2 in.) was found at the traffic-side face of post no. 17. The bolts connecting the shelf angles to the rail at post nos. 2 and 4 through 17 were sheared off.

The permanent set deflection of the end terminal system is shown in Figure 210. The maximum lateral permanent set rail and post deflections were 4,845 mm (190 3/4 in.) at the centerline of post no. 5 and 826 mm (32 1/2 in.) at post no. 9, respectively, as measured in the field. The maximum dynamic system deflection was not calculated because the end terminal continued to deflect beyond the view of the high-speed overhead digital video.

16.6 Vehicle Damage

Exterior vehicle damage was extensive, as shown in Figures 223 through 225. Most of the damage to the vehicle was due to contact with the backslope of the ditch and the subsequent vehicle rollover. Occupant compartment deformations to the right side of the floorboard were judged insufficient to cause serious injury to the vehicle occupants. Complete occupant compartment deformations and the corresponding locations are provided in Appendix D.

The left-front and right-rear tires were removed from the steel rims. The right-front wheel assembly was disengaged from the vehicle. The right-front, left-front, and left-rear quarter panels, bumper, roof, and engine hood were deformed inward. The top-rear corner of the left-rear door and right-rear door were deformed inward. The top of the right-front door was crushed inward and was ajar. The right-front upper control arm and ball joint were bent. The drive shaft was detached. The right-rear axle was deformed downward. The right-rear shock absorber and leaf spring were fractured. The right-rear door window and rear window were shattered. The right-front door window protruded out of its frame.

16.7 Occupant Risk Values

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in

. It is noted that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in

. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 201. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix R.

Table 17. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYBBT-7

Evaluation Criteria		**Transducer**		
		EDR-3	**EDR-4**	**DTS**
OIV m/s (ft/s)	Longitudinal	-4.52 (-14.83)	-3.85 (-12.64)	-4.10 (-13.44)
	Lateral	2.86 (9.38)	2.60 (8.54)	2.73 (8.96)
ORA g's	Longitudinal	-15.39	-13.57	-14.28
	Lateral	12.12	12.80	14.45
THIV m/s (ft/s)		NA	4.57 (15.00)	4.98 (16.34)
PHD g's		NA	13.73	14.48
ASI		0.98	0.97	1.08

16.8 Backslope Impact Severity Reduction

For test no. NYBBT-7, NYSDOT personnel were interested in the degree of attenuation that the end terminal could provide for a vehicle headed toward the back of a non-traversable ditch, rather than to obtain a passing test. As such, an estimate was made to determine the reduction in vehicle velocity and a percentage of kinetic energy dissipated by the end terminal system, including other energy losses such as vehicle crush, prior to impacting the back slope. As noted previously, the vehicle impacted the barrier face at a speed of 100.8 km/h (62.6 mph). At 0.446 sec, the right-rear tire of the test vehicle impacted the back slope, as determined by high-speed film analysis. At the time of vehicle impact with the back of the ditch, the longitudinal velocity was found to range between 64.4 km/h (40.0 mph) and 66.9 km/h (41.6mph), as determined by four different accelerometer sensors. As such, a reduction in the vehicle’s longitudinal velocity ranged between 33.9 to 36.4 km/h (21.1 to 22.6 mph), thus resulting in a 33.5 to 36.1 percent reduction in the vehicle’s speed.

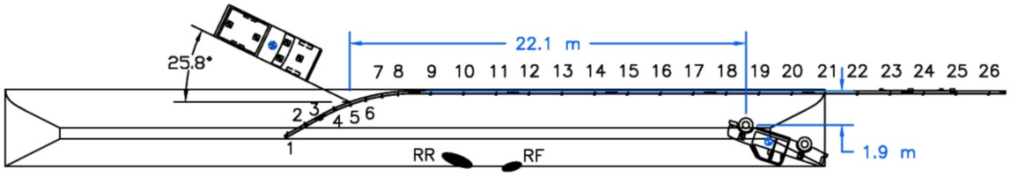
If the end terminal had not been installed and the vehicle would have impacted the back side of the ditch at the original impact speed, then one would have expected a reduction in impact severity of approximately 55.8 and 59.2 percent for a vehicle first passing through the end terminal system before striking the back side of the ditch. However, it should be noted that full-scale vehicle crash testing provides the only reliable method for evaluating the severity of a high-speed vehicle crash into the noted ditch section.

16.9 Discussion

The analysis of the test results for test no. NYBBT-7 showed that the modified NYSDOT Type IIA box beam end terminal system installed in a ditch did not contain nor redirect the 2270P vehicle, since the vehicle did not remain upright after collision with the barrier. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. The test vehicle overrode the barrier system and did not remain upright during and after the collision. Therefore, test no. NYBBT-7 conducted on the modified Type IIA end terminal installed in a ditch was determined to be unacceptable according to a modified test designation no. 3-35 of the TL-3 safety performance criteria found in MASH.

Following a review of the test results for test no. NYBBT-7, the following observations should be noted. The vehicle experienced minor roll, pitch, and yaw angular displacements as it traversed over the slope break point prior to the lower portion of the front bumper impacting the end terminal. When the lower portion of the front bumper contacted the box beam rail, it deflected the box beam rail both backward and downward. The rail disengaged from post no. 4 almost immediately upon impact. By 0.056 sec after impact, post nos. 5 through 8 disengaged from the box beam rail as the vehicle continued to deflect the system backward and downward. Post nos. 1 and 2 remained attached to the rail until the system had deflected significantly and disengaged at 0.228 and 0.154 sec, respectively. Once post nos. 1 and 2 disengaged from the box beam rail, the barrier system lost its redirective capability, and the box beam then began to rapidly disengage from the downstream posts. The vehicle began to redirect, but it did not complete the process by the time the rail disengaged from the upstream anchor, thus allowing the vehicle to penetrate behind the system and into the ditch. After the right-side wheels had contacted the back slope of the ditch, the vehicle encountered significant pitching and rollover. Finally, as stated previously, the end terminal reduced the vehicle’s velocity and impact severity for the vehicle’s impact with the ditch backslope. However, the vehicle rolled over following the contact with the backslope of the ditch.

0.000 sec 0.076 sec 0.152 sec 0.300 sec 0.486 sec



●Test Agency	MwRSF
●Test Number	NYBBT-7
●Date	11/03/08
●MASH Test Designation	Modified 3-35
●Appurtenance	Modified Type IIA End Terminal in Ditch
●Total Length	40.2 m
●Key Element – Steel Box Beam	
Size	152 mm x 152 mm x 4.8 mm
Length	5,486 mm
Top Mounting Height	686 mm
●Key Elements - Steel Post	
Post Nos. 1, 2, 4	S76x8.5 by 2,134 mm long
Post Nos. 3, 5-26	S76x8.5 by 1,600 mm long
●Type of Soil	Grading B - AASHTO M 147-65 (1990)
●Test Vehicle	
Type/Designation	2270P
Make and Model	2002 Dodge Ram 1500 Quad Cab Pickup
Curb	2,299 kg
Test Inertial	2,273 kg
Gross Static	2,351 kg
●Impact Conditions	
Speed	100.8 km/h
Angle	25.8 degrees
Target Impact Location	Centerline of post no. 5
Actual Impact Location	Centerline of post no. 5
●Exit Conditions	
Speed	NA
Angle	NA
Exit Box Criterion	NA
●Post-Impact Trajectory	
Vehicle Stability	Satisfactory
Stopping Distance	22.1 m downstream 1.9 m laterally behind traffic-side face
●Occupant Impact Velocity (EDR-3)	
Longitudinal	-4.52 m/s < 12.2 m/s
Lateral	2.86 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-3)	
Longitudinal	-15.39 g's < 20.49 g's
Lateral	12.12 g's < 20.49 g's

●Occupant Impact Velocity (EDR-4)	
Longitudinal	-3.85 m/s < 12.2 m/s
Lateral	2.60 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-4)	
Longitudinal	-13.57 g's < 20.49 g's
Lateral	12.80 g's < 20.49 g's
●Occupant Impact Velocity (DTS)	
Longitudinal	-4.10 m/s < 12.2 m/s
Lateral	2.73 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (DTS)	
Longitudinal	-14.28 g's < 20.49 g's
Lateral	14.45 g's < 20.49 g's
●THIV (EDR-4 - not required)	4.98 m/s
●PHD (EDR-4 - not required)	14.48 g's
●THIV (DTS - not required)	4.57 m/s
●PHD (DTS - not required)	13.73 g's
●ASI (EDR-3 - not required)	0.98
●ASI (EDR-4 - not required)	0.97
●ASI (DTS - not required)	1.08
●Test Article Damage	Extensive
●Test Article Deflections	
Permanent Set	4,845 mm
Dynamic	NA
Working Width	NA
●Vehicle Damage	Extensive
VDS[12]	01-R&T-5
CDC[13]	01-RDAO9
●Maximum Deformation	19 mm at center of passenger floorboard
●Angular Displacement	
Roll	612 degrees
Pitch	-58 degrees
Yaw	-170 degrees

Figure 201. Summary of Test Results and Sequential Photographs, Test No. NYBBT-7

0.000 sec

0.014 sec

0.042 sec

0.058 sec

0.094 sec

0.118 sec

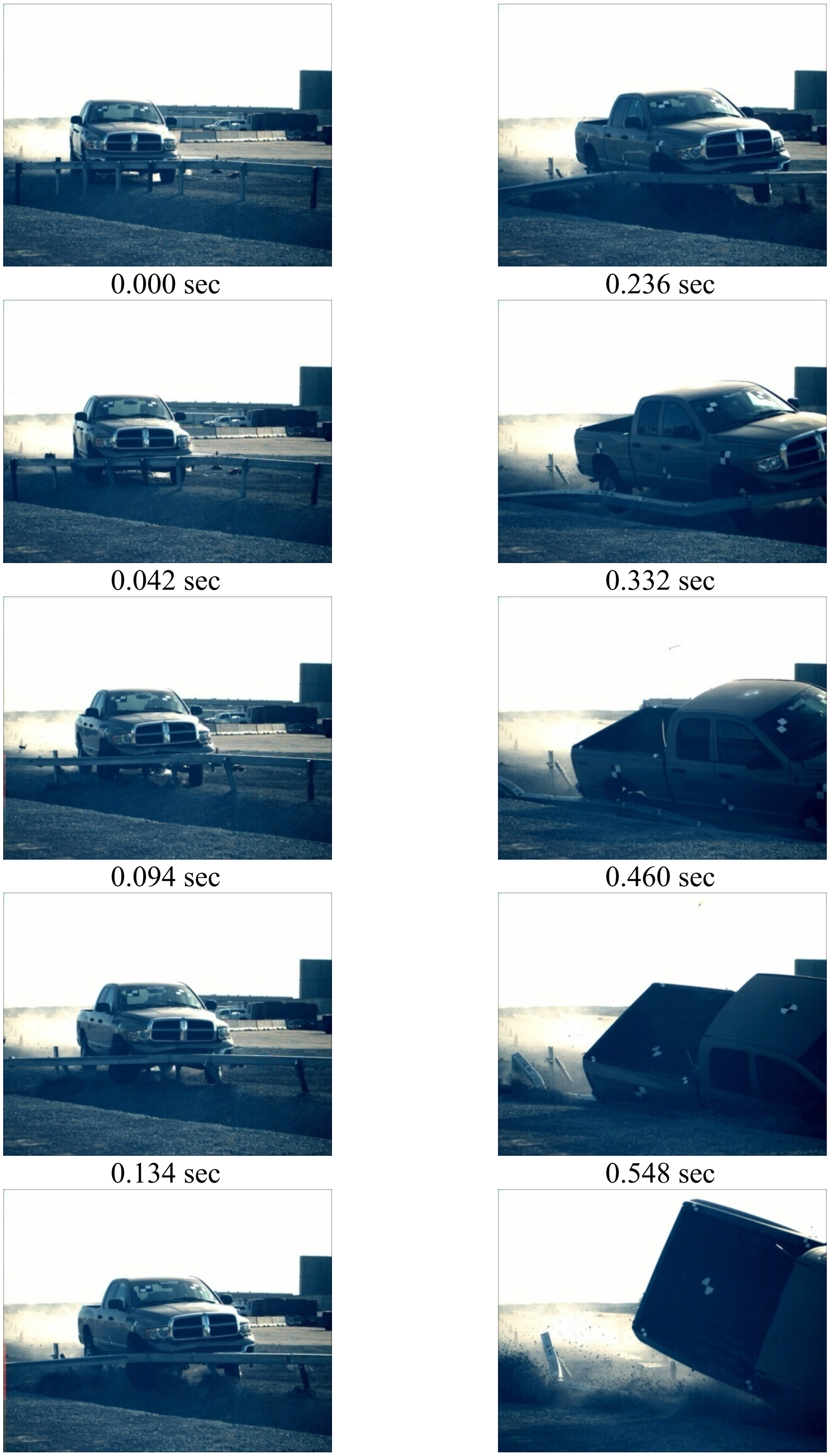
0.154 sec

0.214 sec

0.248 sec

0.324 sec

Figure 202. Additional Sequential Photographs, Test No. NYBBT-7



0.000 sec

0.042 sec

0.094 sec

0.134 sec

0.174 sec

0.236 sec

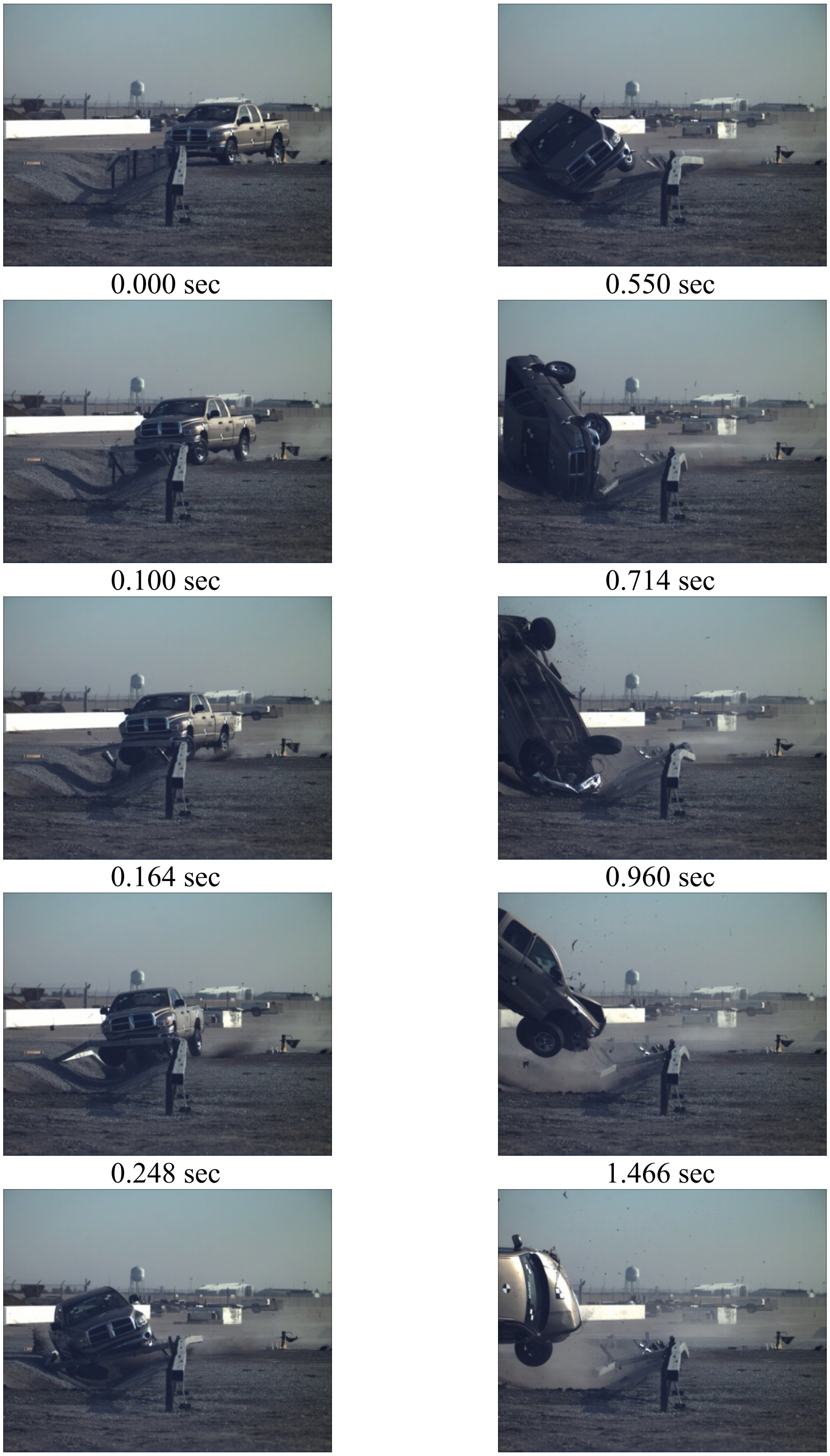
0.332 sec

0.460 sec

0.548 sec

0.674 sec

Figure 203. Additional Sequential Photographs, Test No. NYBBT-7



0.000 sec

0.100 sec

0.164 sec

0.248 sec

0.446 sec

0.550 sec

0.714 sec

0.960 sec

1.466 sec

1.756 sec

Figure 204. Additional Sequential Photographs, Test No. NYBBT-7

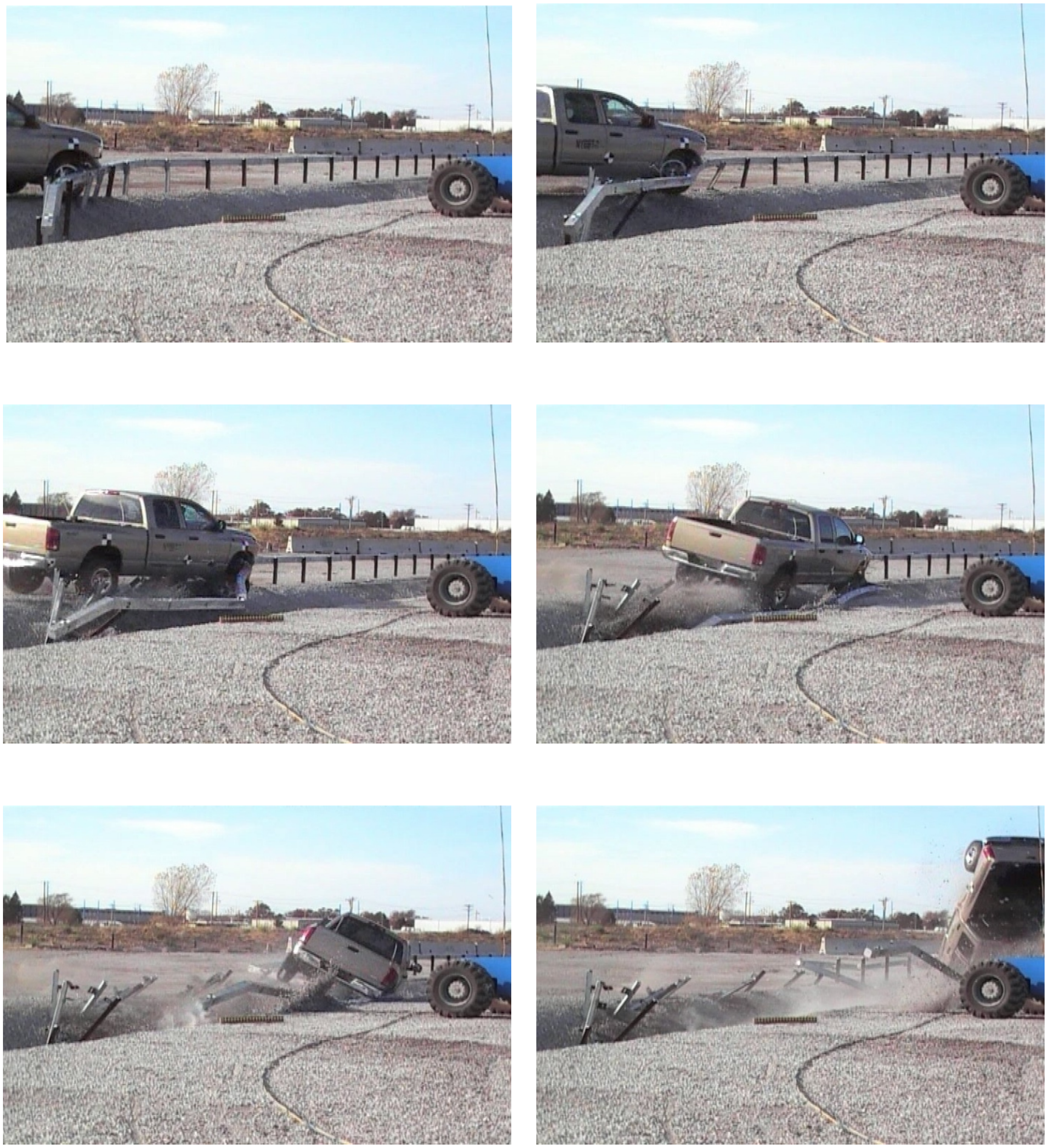


Figure 205. Documentary Photographs, Test No. NYBBT-7

Figure 206. Documentary Photographs, Test No. NYBBT-7

Figure 207. Impact Location, Test No. NYBBT-7

Figure 208. Vehicle Final Position and Trajectory Marks, Test No. NYBBT-7

Figure 209. Barrier Damage, Test No. NYBBT-7

Figure 210. Barrier Damage, Test No. NYBBT-7

Figure 211. Barrier Damage, Test No. NYBBT-7

Figure 212. Barrier Damage, Test No. NYBBT-7

Figure 213. Barrier Damage, Test No. NYBBT-7

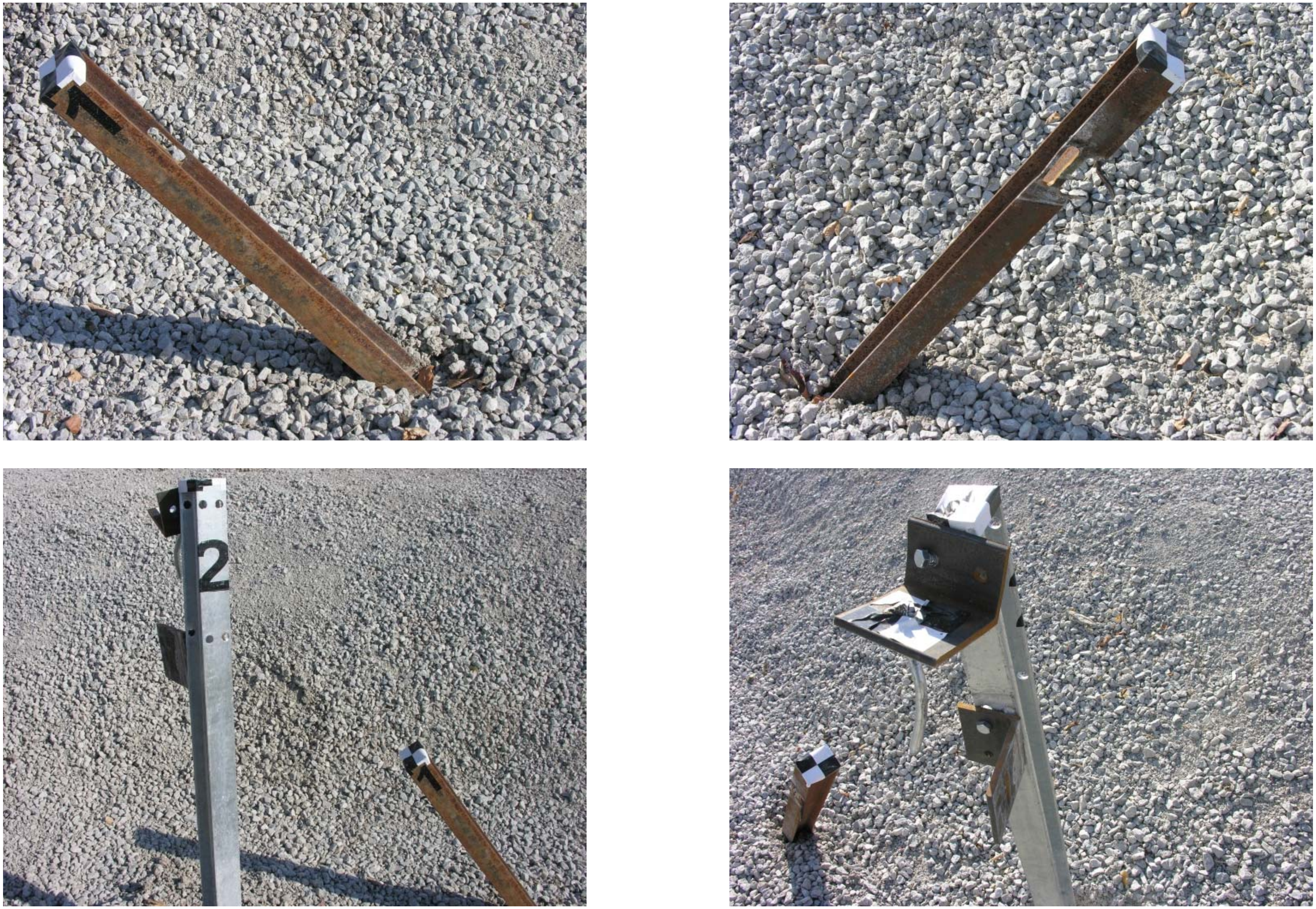


Figure 214. Post Nos. 1 and 2 Damage, Test No. NYBBT-7

Figure 215. Post Nos. 3 and 4 Damage, Test No. NYBBT-7

Figure 216. Post Nos. 5 and 6 Damage, Test No. NYBBT-7

Figure 217. Post Nos. 7 and 8 Damage, Test No. NYBBT-7

Figure 218. Post Nos. 9 and 10 Damage, Test No. NYBBT-7

Figure 219. Post Nos. 11 and 12 Damage, Test No. NYBBT-7

Figure 220. Post Nos. 13 and 14 Damage, Test No. NYBBT-7

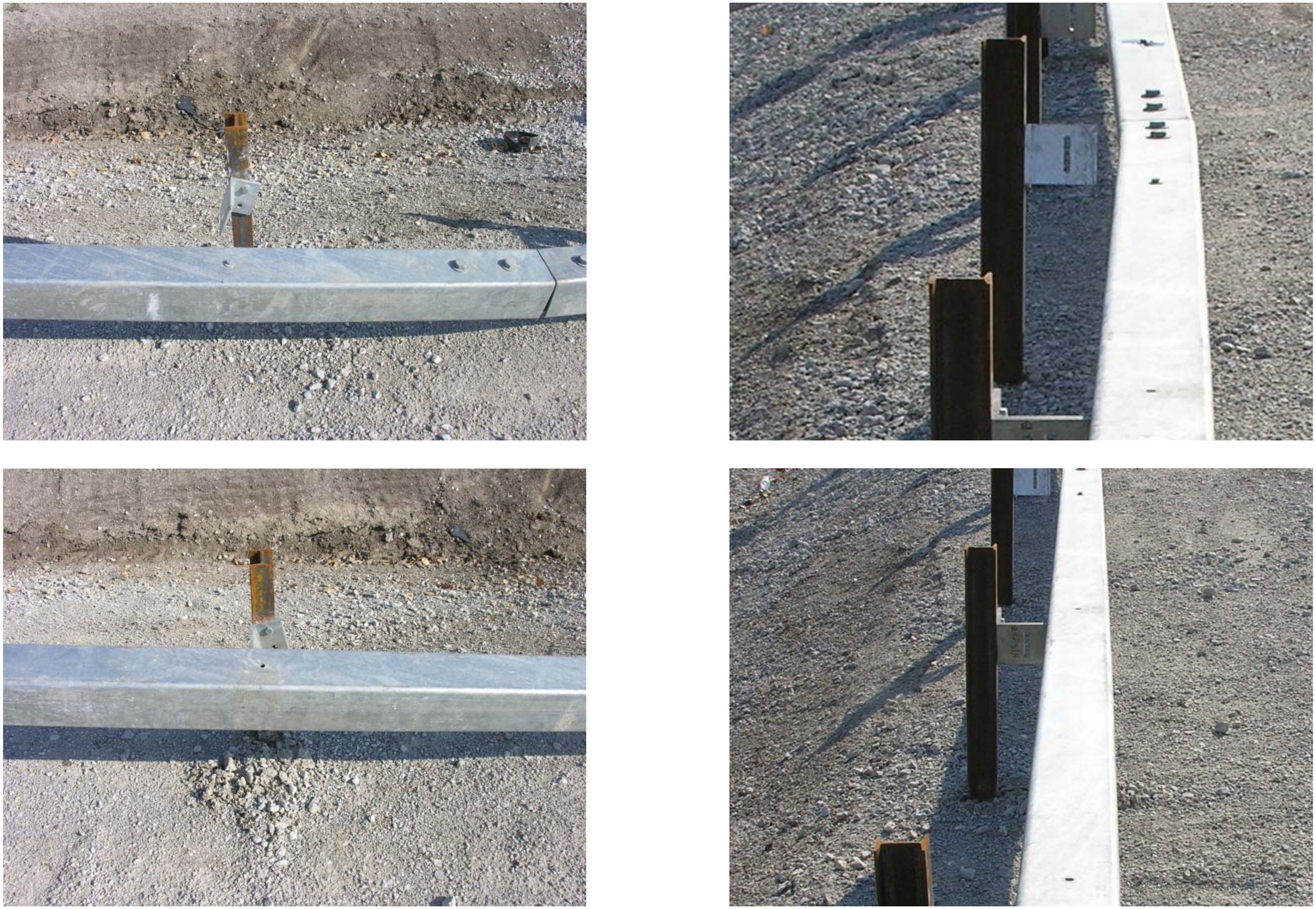


Figure 221. Post Nos. 15 and 16 Damage, Test No. NYBBT-7

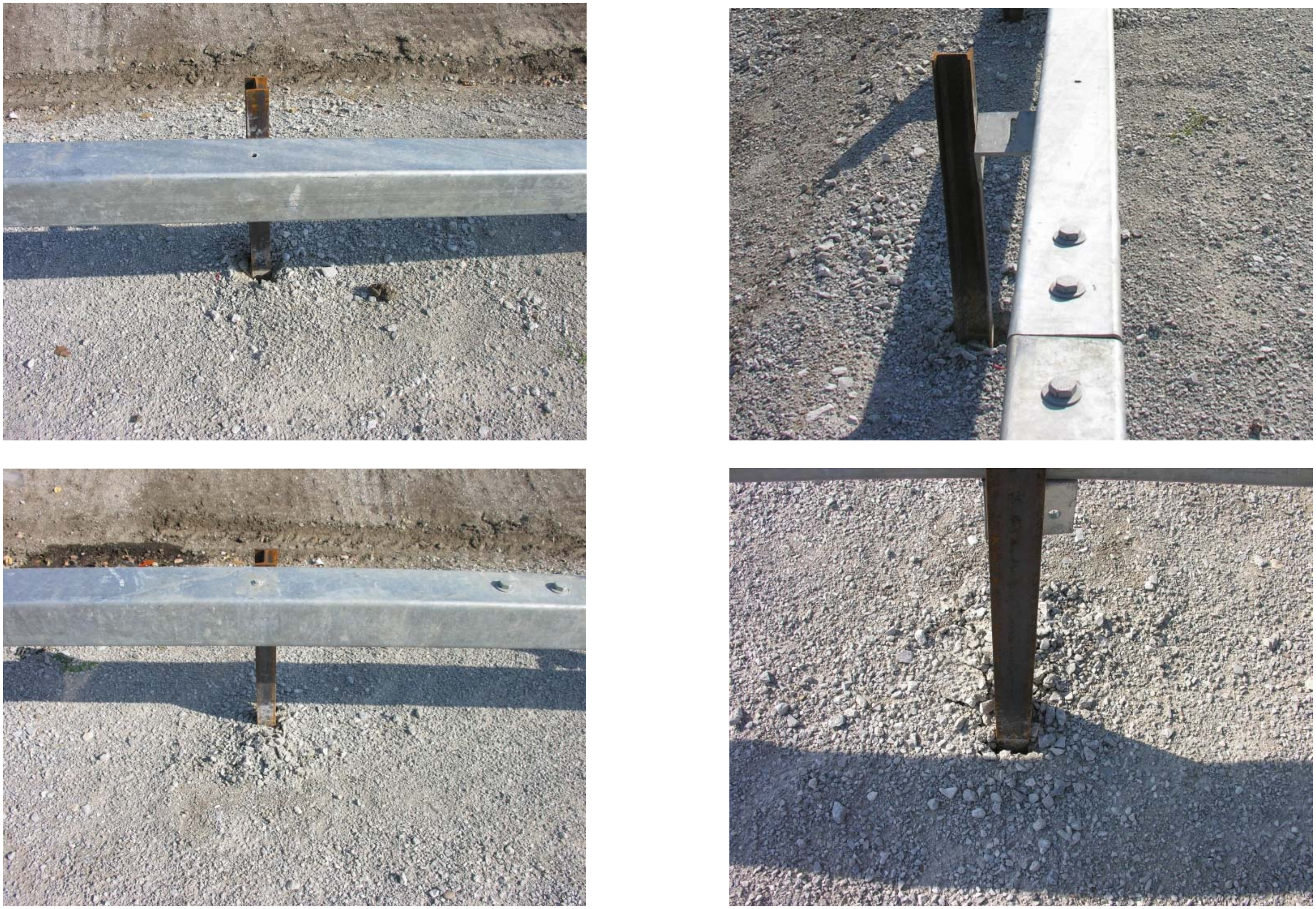


Figure 222. Post Nos. 17 and 18 Damage, Test No. NYBBT-7

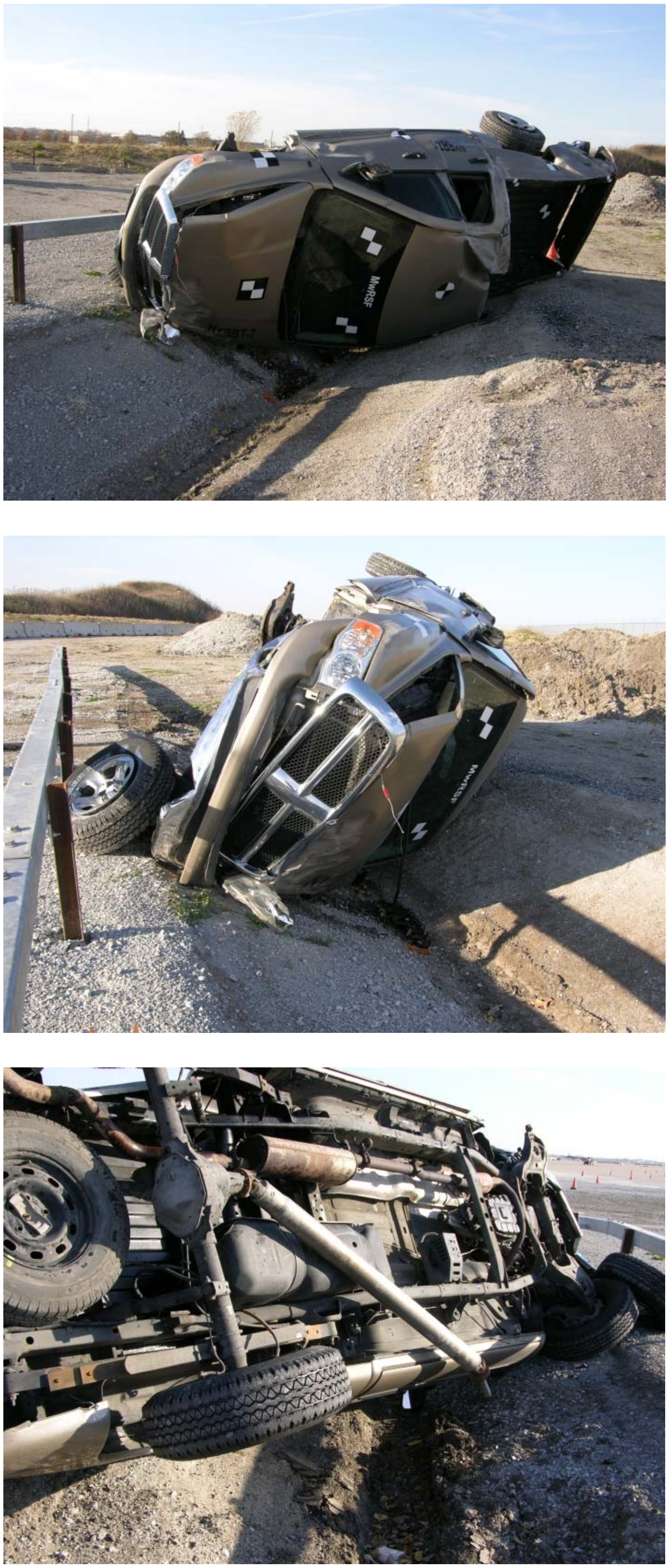


Figure 223. Vehicle Damage, Test No. NYBBT-7

Figure 224. Vehicle Damage, Test No. NYBBT-7
(Note: Vehicle shown is after it was rolled back over.)

Figure 225. Vehicle Damage, Test No. NYBBT-7
(Note: Vehicle shown is after it was rolled back over)

17 TYPE IIA END TERMINAL MODIFICATIONS – NYBBT-8 AND NYBBT-9 SYSTEM DETAILS

Following the evaluation of the Type IIA end terminal installed in a ditch (test nos. NYBBT-6 and NYBBT-7), the NYSDOT personnel deemed it necessary to evaluate the performance of the end terminal under standard test conditions (i.e., level terrain). After reviewing the results of test no. NYBBT-7, the traffic-side posts (post nos. 1, 2, and 4) remained undamaged and did not adequately contribute to vehicle redirection. Thus, the NYSDOT personnel requested that post nos. 1, 2, and 4 be moved from the traffic-side face of the box beam to the back-side face of the rail. Thus, for test nos. NYBBT-8 and NYBBT-9, the modified Type IIA box beam end terminal system was identical to that used in test no. NYBBT-5, except that the three traffic-side posts were moved to the back side of the system.

For test nos. NYBBT-8 and NYBBT-9, the 40.2-m (132-ft) long test installation consisted of 38.1 m (125 ft) of the NYSDOT's standard TS 152-mm x 152-mm x 4.8-mm (6-in. x 6-in. x 3/16-in.) steel tube box-beam guide rail with a modified Type IIA end terminal. The top rail height was 686 mm (27 in.). In addition, the box beam rail was attached to the shelf angles at post nos. 2 and 4 by a 12.7-mm (1/2-in.) diameter by 203-mm (8-in.) long, ASTM A307 hex bolt with two 12.7-mm (1/2-in.) washers and a 12.7-mm (1/2-in.) hex nut. The box beam rail was not connected to the rail at post no. 3. For test no. NYBBT-8, design details are shown in Figures 226 through 241. For test no. NYBBT-9, only one design sheet is provided in order to denote the impact location, as shown in Figure 242. The corresponding English-unit drawings for test no. NYBBT-8 have been prepared and are shown in Appendix S. Complete system drawings have been prepared in both metric and English units for test no. NYBBT-9 and are shown in Appendix T. Photographs of the test installation are shown in Figure 243.

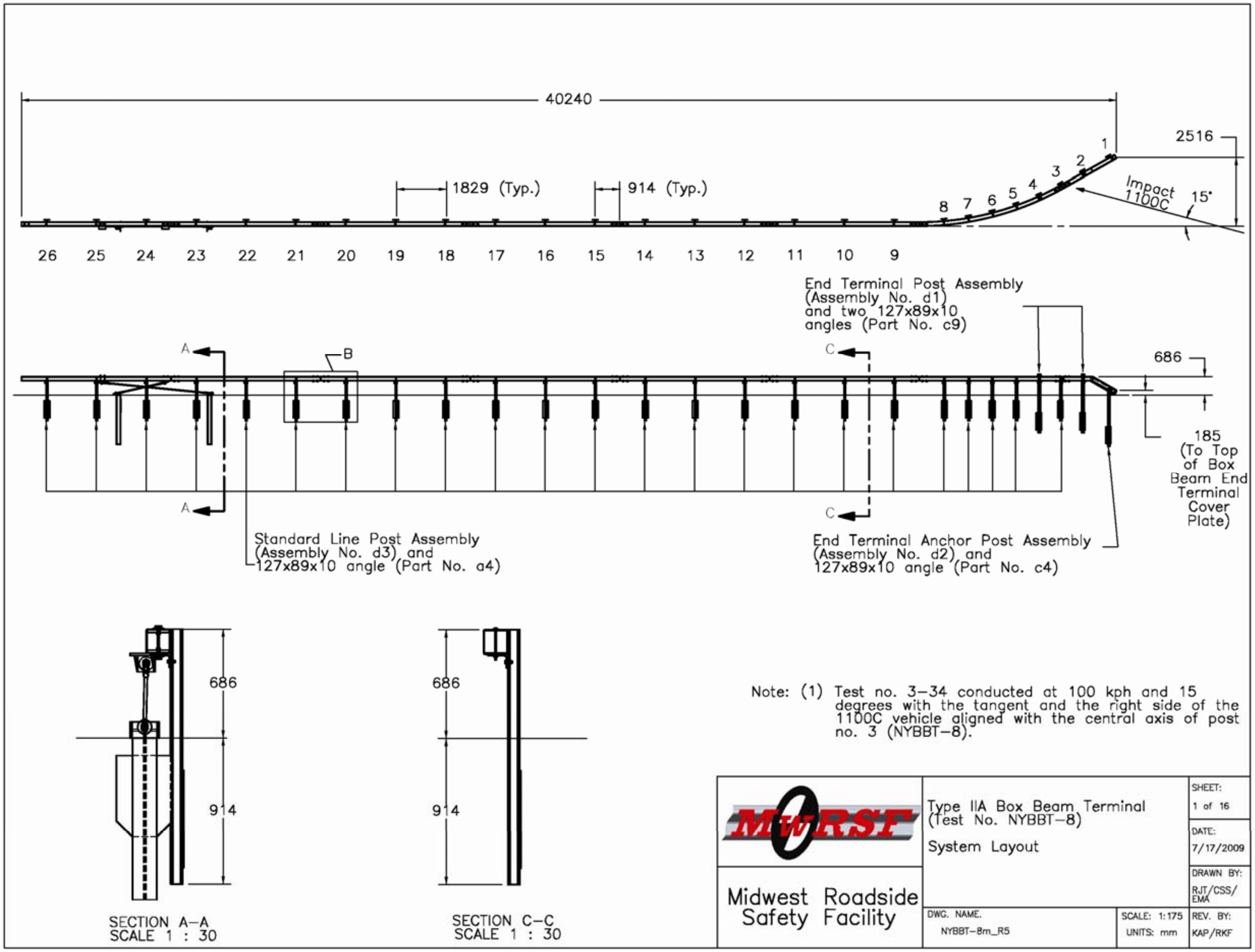
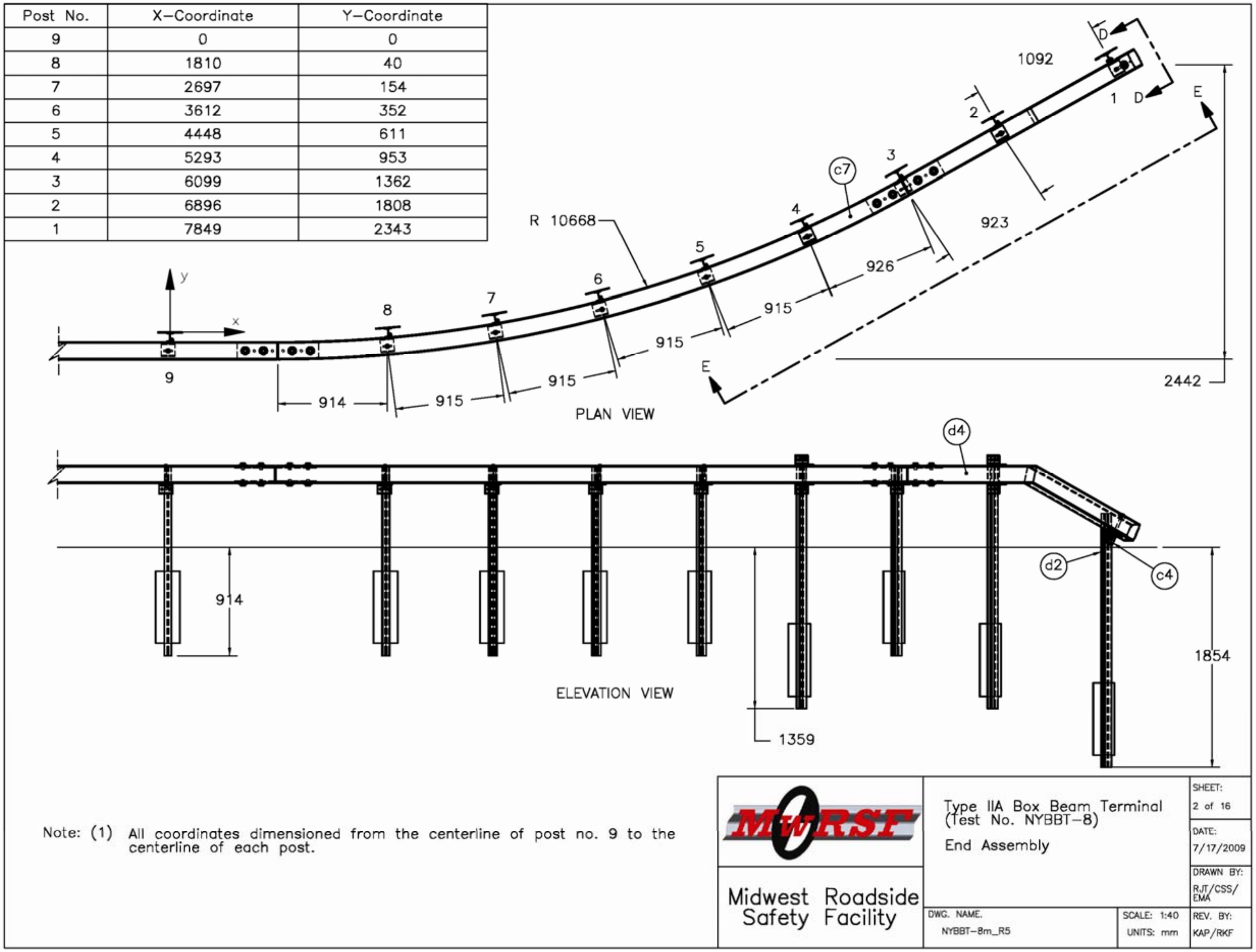


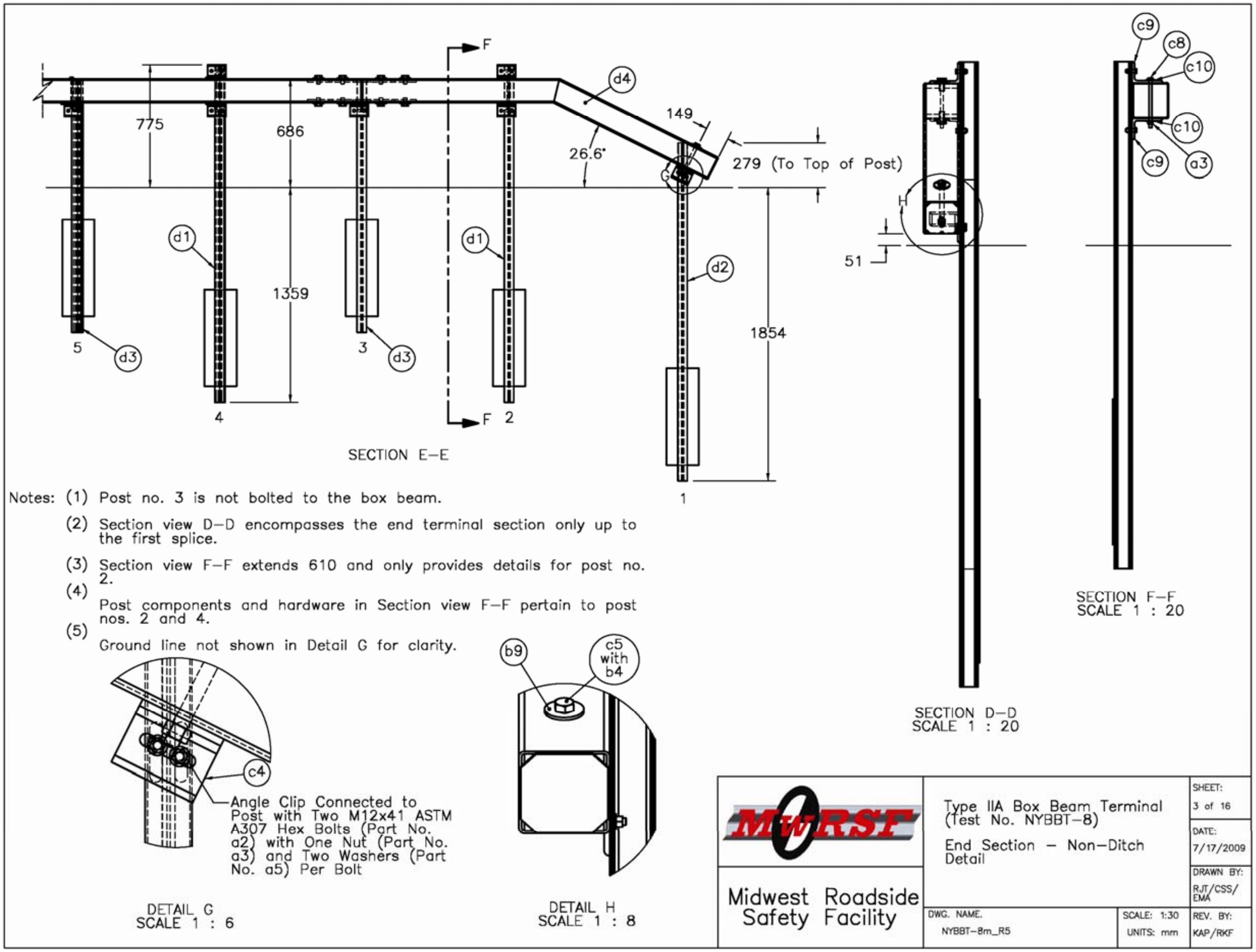
Figure 226. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8



Post No.	X-Coordinate	Y-Coordinate
9	0	0
8	1810	40
7	2697	154
6	3612	352
5	4448	611
4	5293	953
3	6099	1362
2	6896	1808
1	7849	2343

Note: (1) All coordinates dimensioned from the centerline of post no. 9 to the centerline of each post.

Figure 227. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8



Notes:
(1) Post no. 3 is not bolted to the box beam.
(2) Section view D–D encompasses the end terminal section only up to the first splice.
(3) Section view F–F extends 610 and only provides details for post no. 2.
(4) Post components and hardware in Section view F–F pertain to post nos. 2 and 4.
(5) Ground line not shown in Detail G for clarity.

Figure 228. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

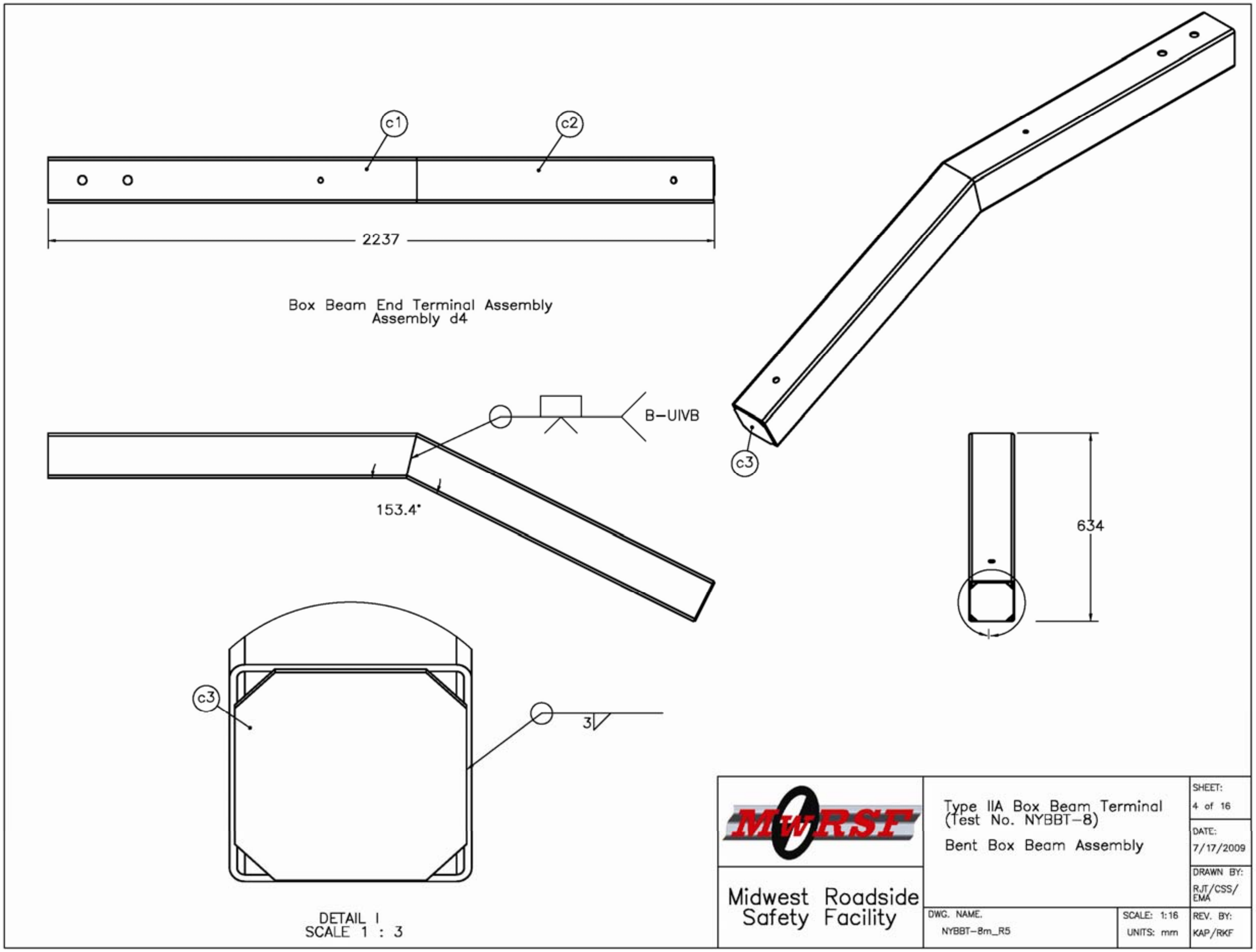


Figure 229. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

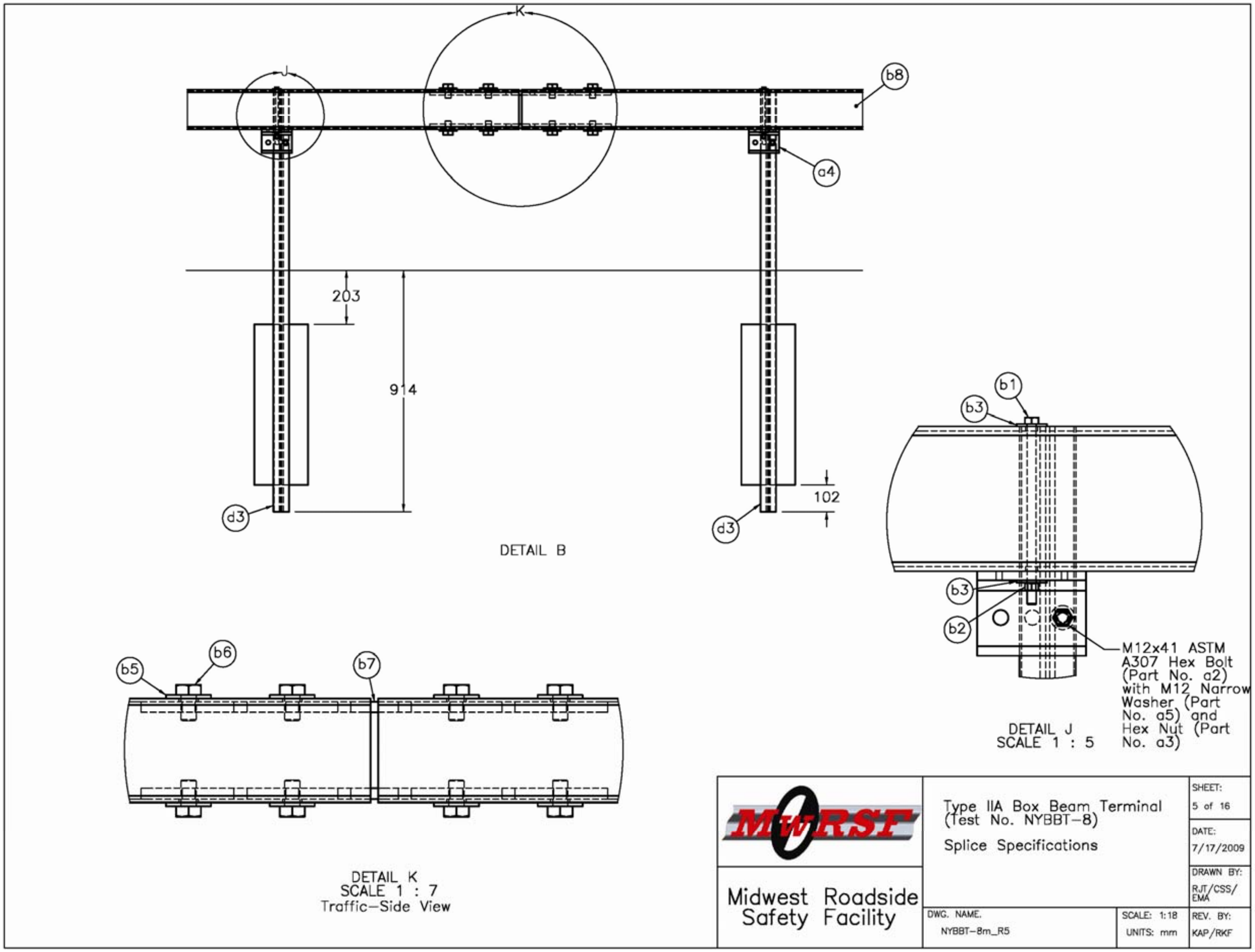


Figure 230. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

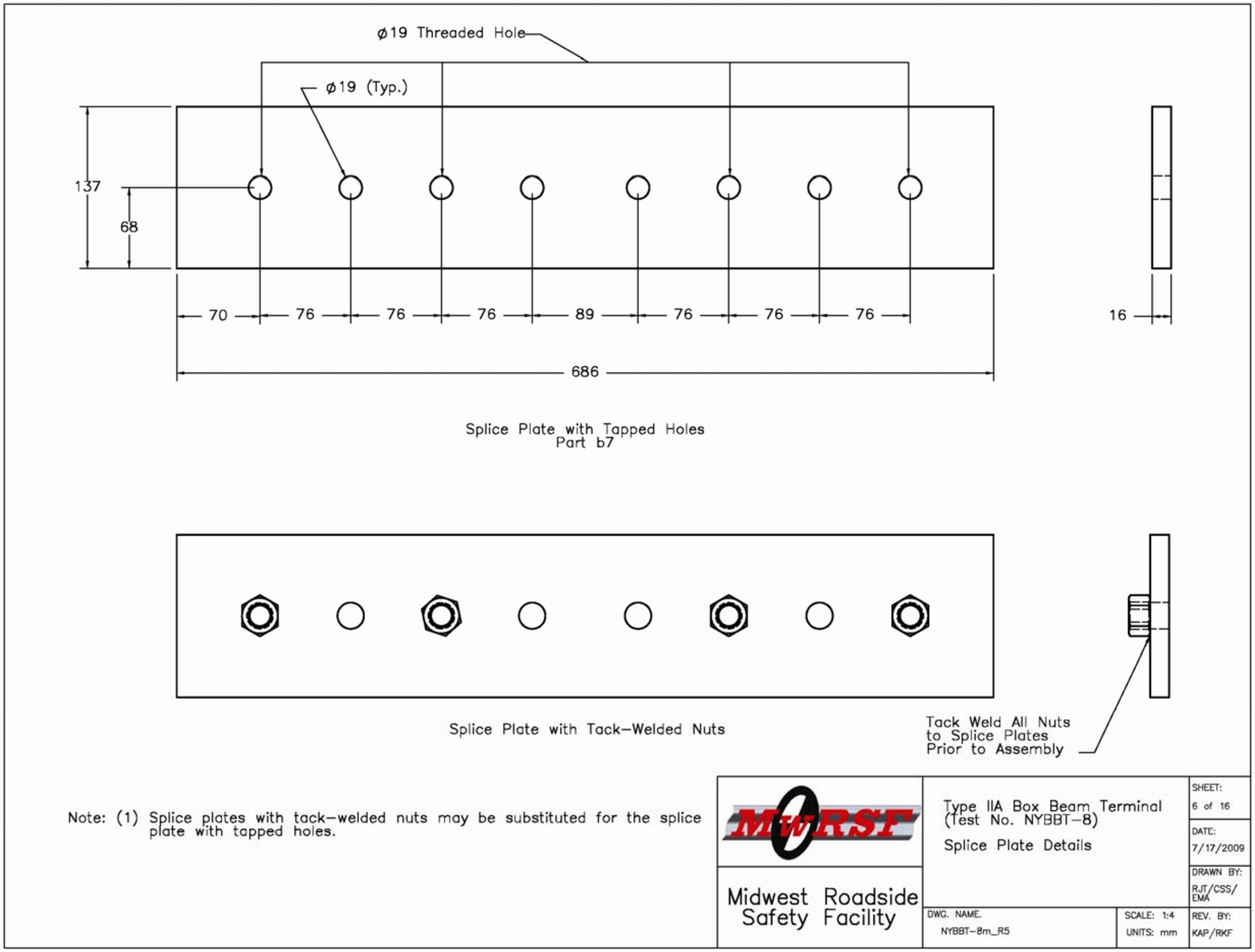


Figure 231. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

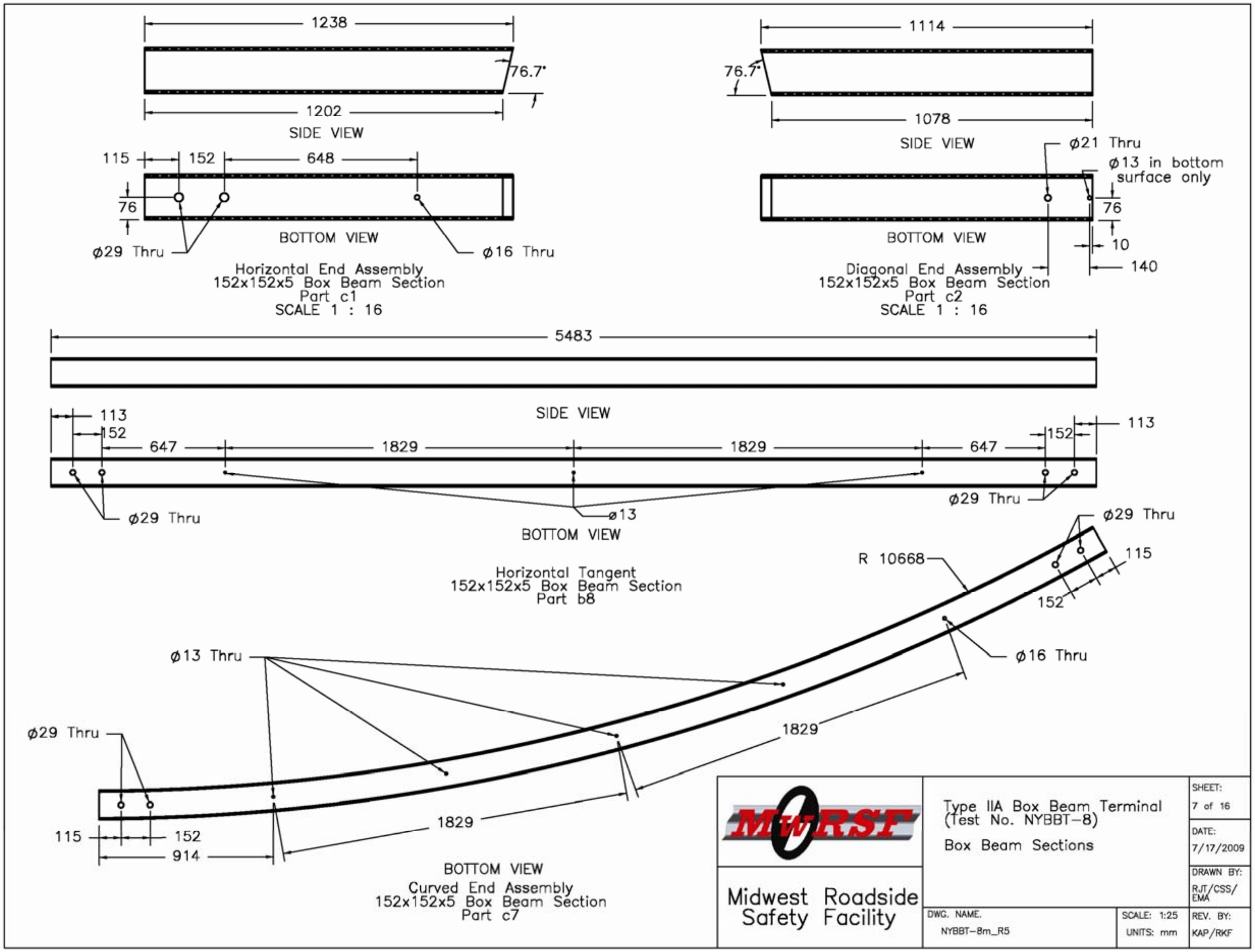


Figure 232. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

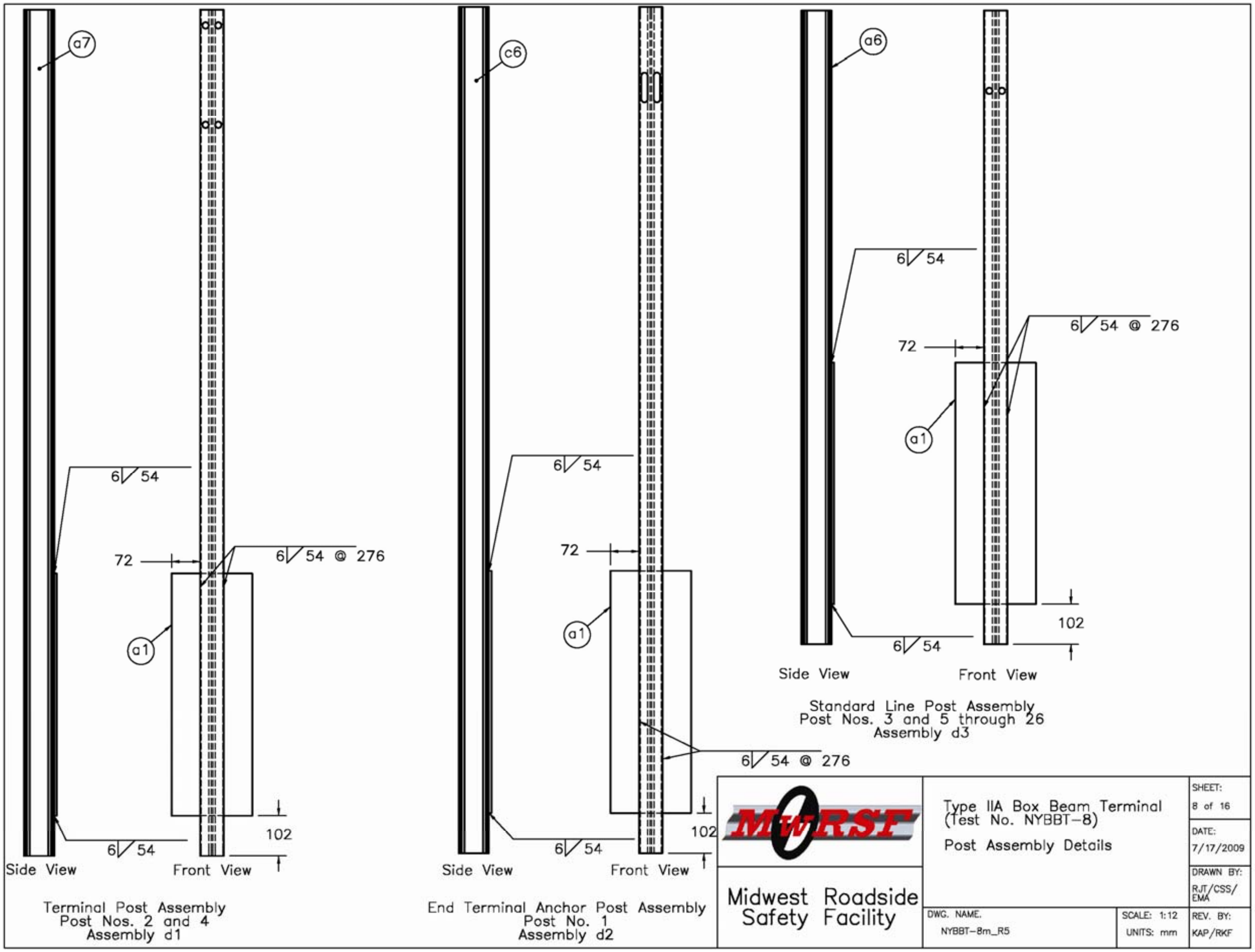


Figure 233. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

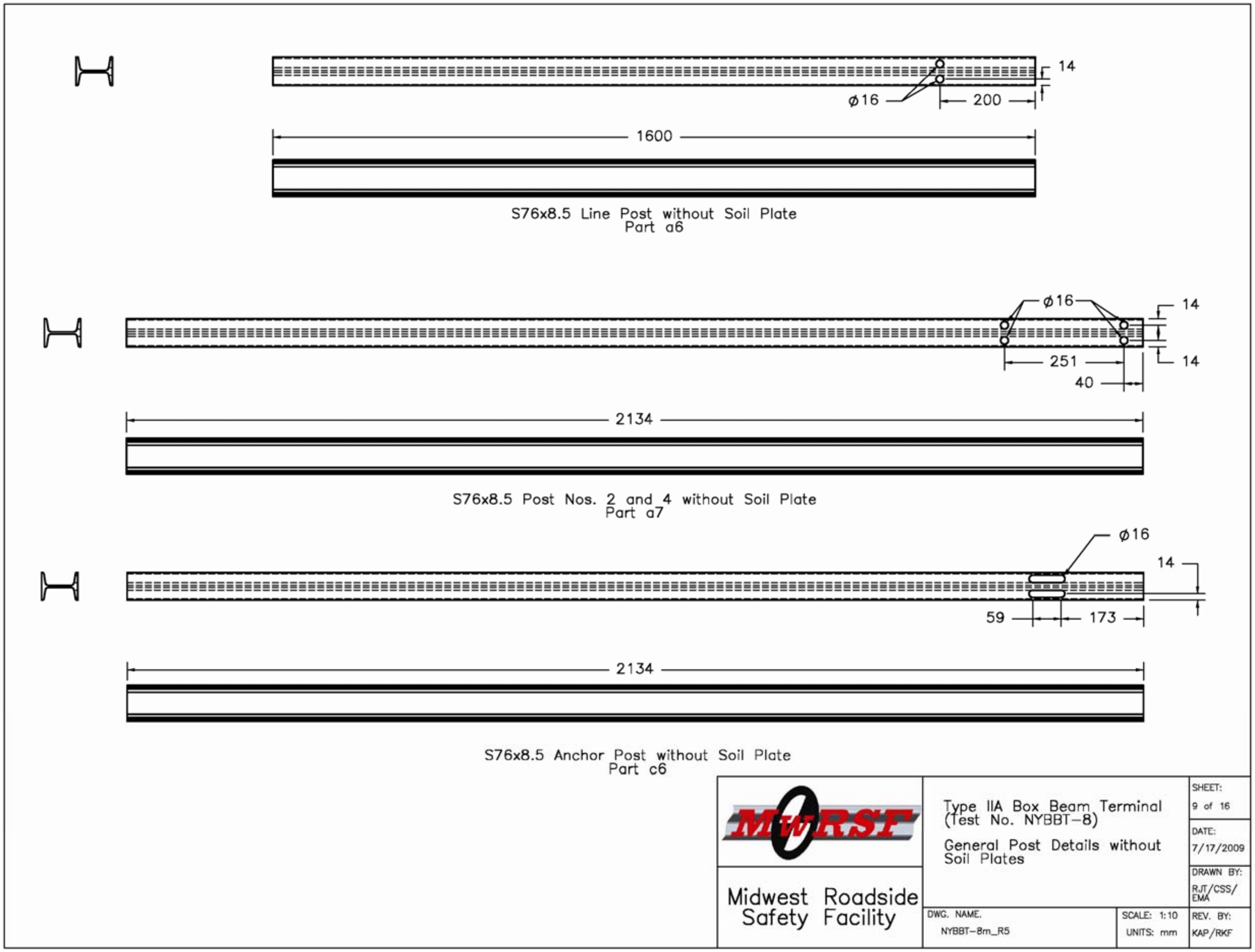


Figure 234. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

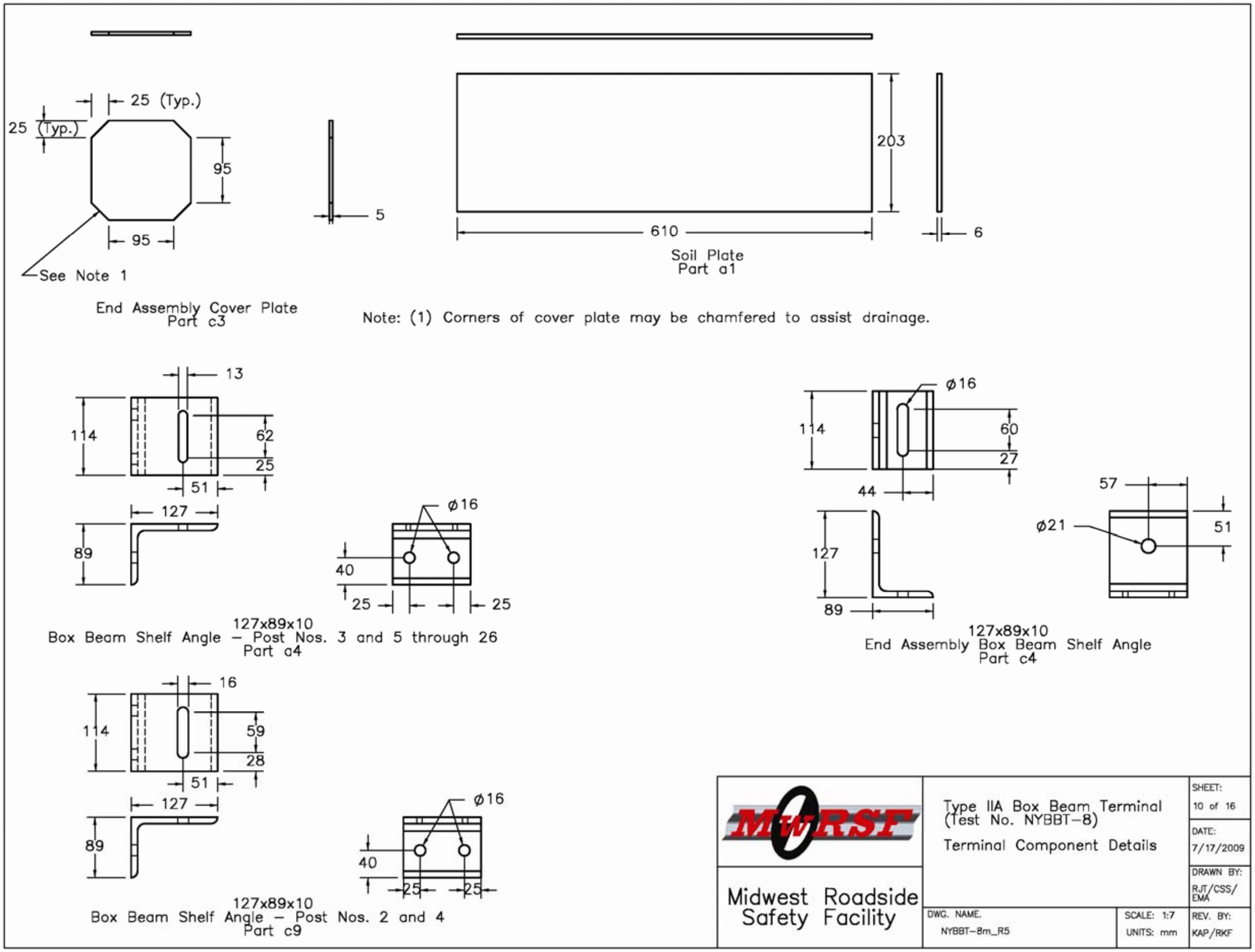


Figure 235. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

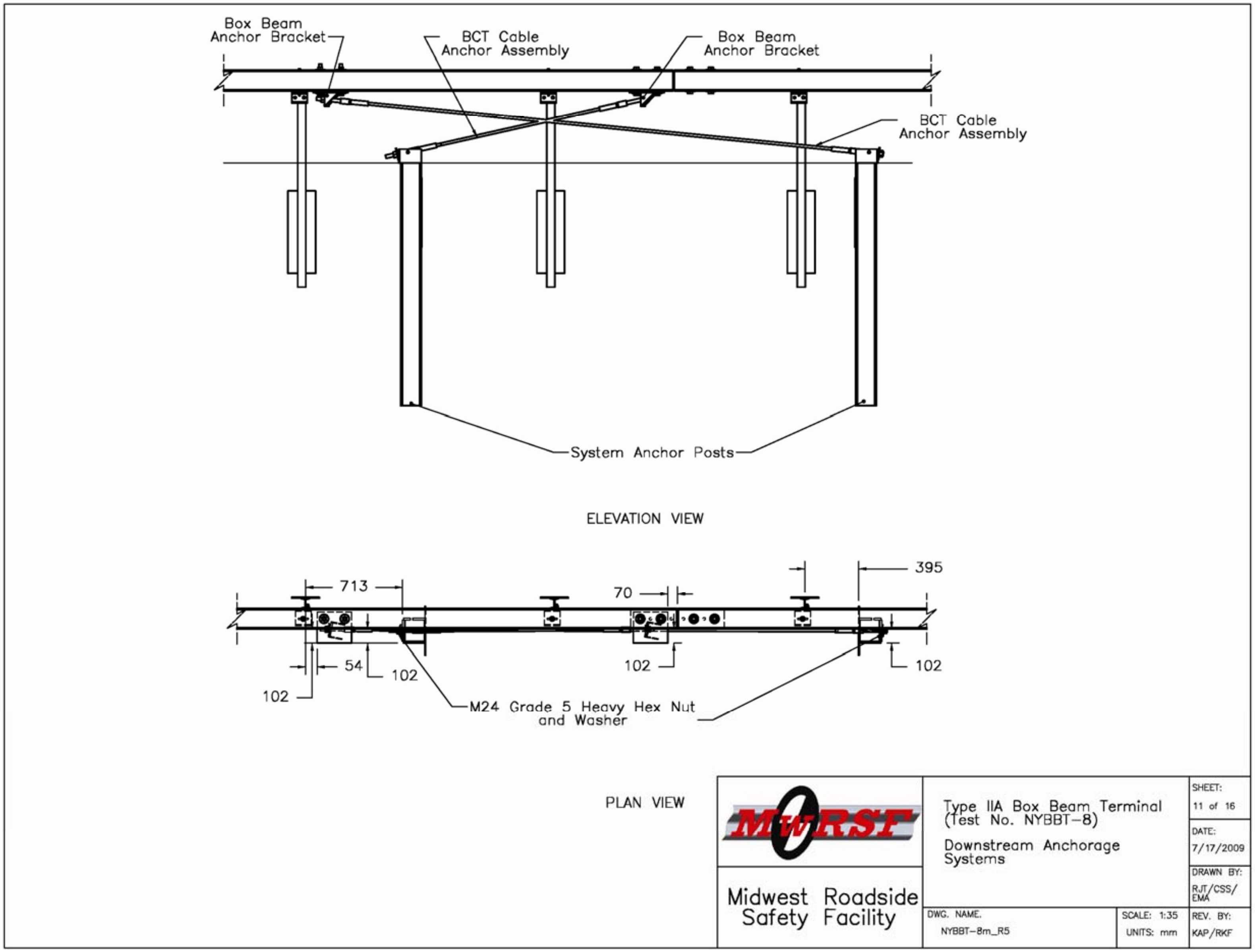


Figure 236. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

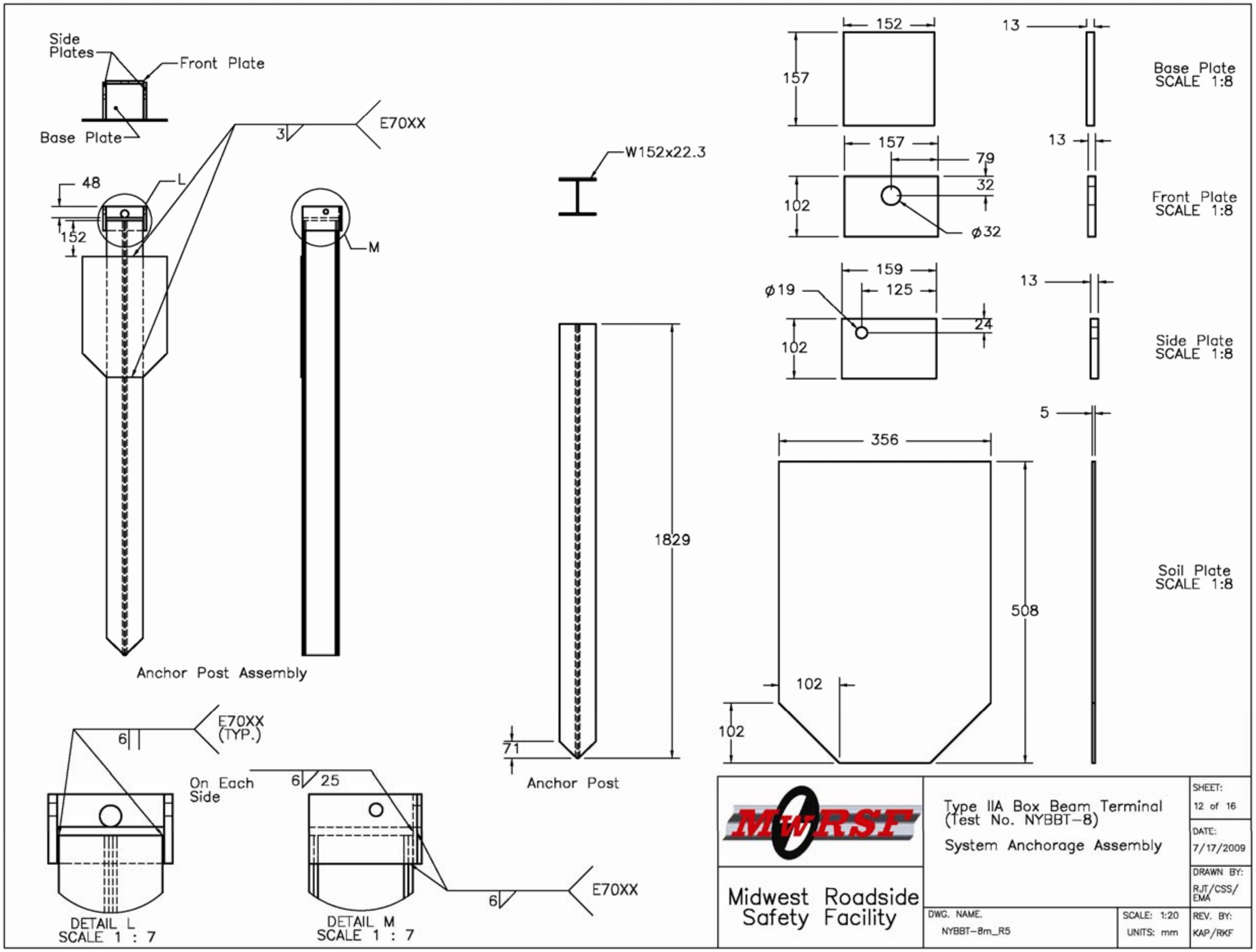


Figure 237. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

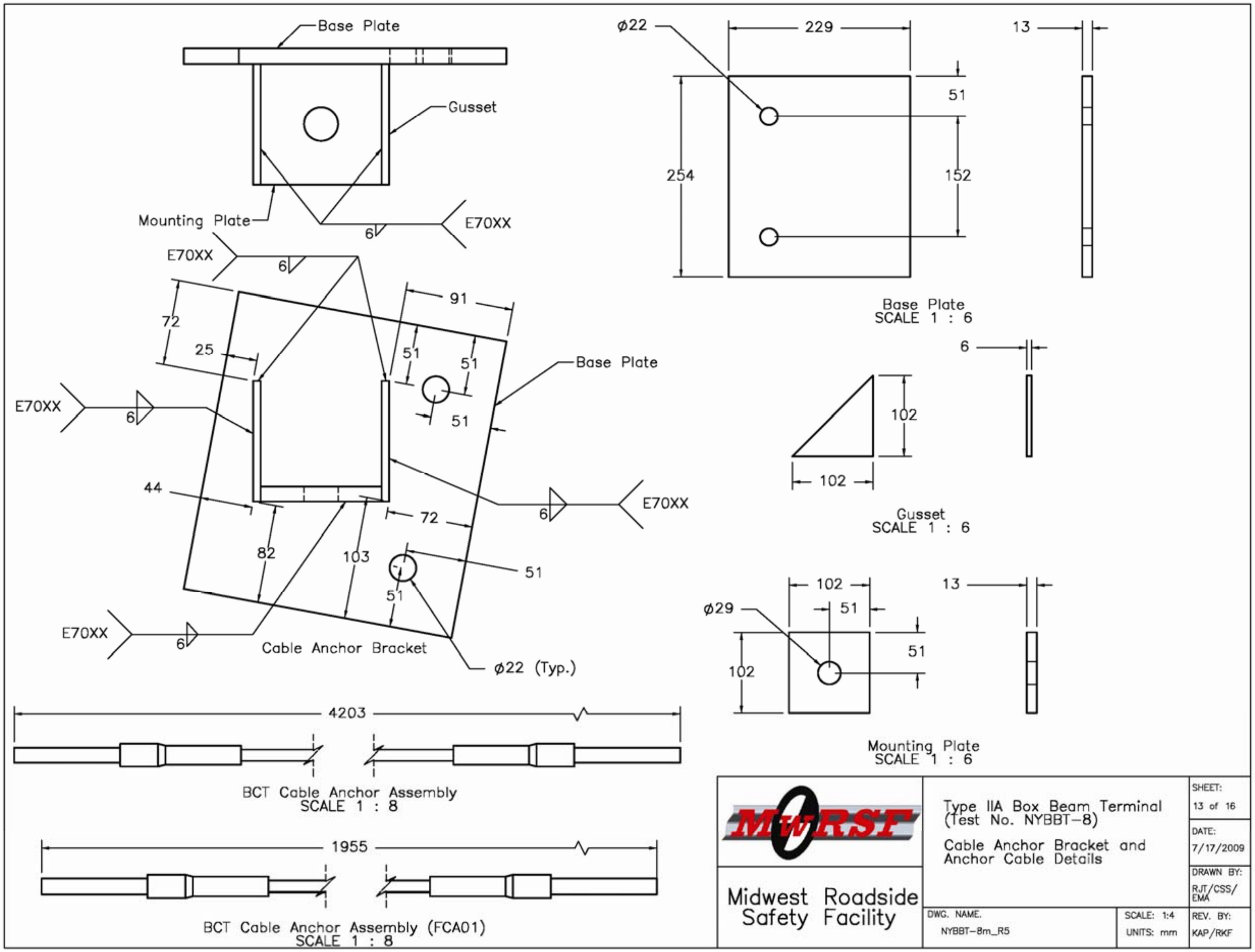


Figure 238. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

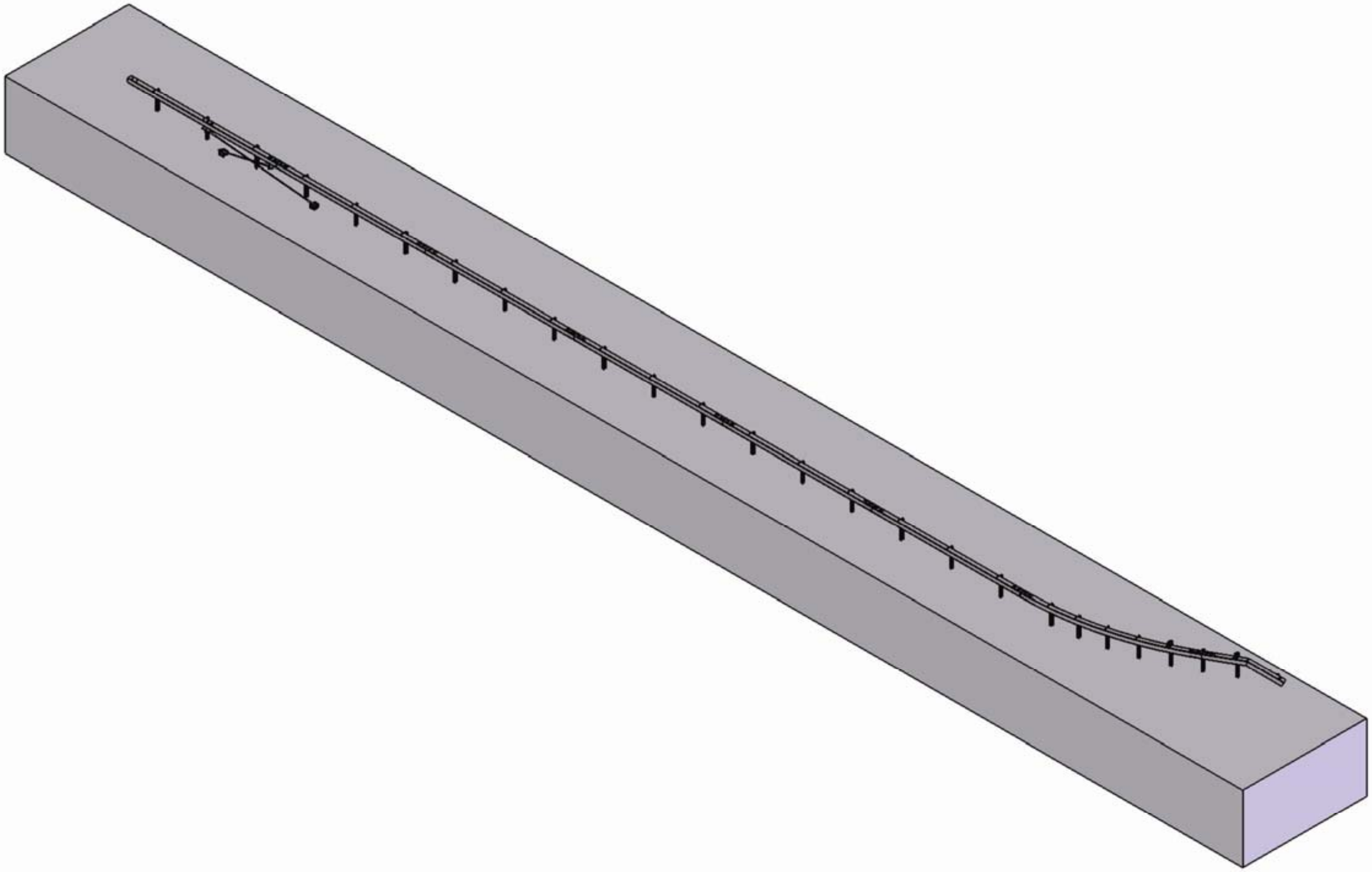
Test No. NYBBT-8			
Item No.	Quantity	Description	Material Specifications
a1	26	6 x 203 x 610mm steel soil plate	A36 Steel
a2	29	M12 coarse thread, 41mm long hex bolt	ASTM A307
a3	31	M12 hex nut	ASTM A307
a4	23	127 x 89 x 10mm box beam shelf angle	A36 Steel
a5	31	M12 narrow washer	ASTM A307
a6	23	S76 x 8.5, 1600mm long post	A36 Steel
a7	2	S76 x 8.5, 2134mm long post	A36 Steel
b1	22	M10 coarse thread, 191mm long hex bolt	ASTM A307
b2	22	M10 hex nut	ASTM A307
b3	44	M10 wide washer	ASTM A307
b4	1	M20 hex nut	ASTM A307
b5	56	M20 wide washer	ASTM A325
b6	56	M20 coarse thread, 38mm long hex bolt	ASTM A325
b7	14	686 x 137 x 16mm splice plate	A36 Steel
b8	6	152 x 152 x 5mm by 5483mm long box beam	ASTM A500 Grade B
b9	1	M20 wide washer	ASTM A307
c1	1	End assembly bent 152 x 152 x 5mm box beam	ASTM A500 Grade B
c2	1	End assembly diagonal 152 x 152 x 5mm box beam	ASTM A500 Grade B
c3	1	End assembly 5mm thick cover plate	A36 Steel
c4	1	127 x 89 x 10mm box beam anchor post shelf angle	A36 Steel
c5	1	M20 coarse thread, 197mm long hex bolt	ASTM A307
c6	1	S76 x 8.5, 2134mm long post anchor post	A36 Steel
c7	1	152 x 152 x 5mm, R 10.67m Curved Box Beam	ASTM A500 Grade B
c8	2	M12 coarse thread, 203mm long hex bolt	ASTM A307
c9	4	127 x 89 x 10mm box beam shelf angle with ø 16mm slot	A36 Steel
c10	4	M12 wide washer	ASTM A307
d1	2	Terminal Post Assembly	–
d2	1	Terminal Anchor Post Assembly	–
d3	23	Line Post Assembly	–
d4	1	Box Beam End Terminal Assembly	–

Midwest Roadside
Safety Facility

Type IIA Box Beam Terminal
(Test No. NYBBT-8)
Bill of Materials

SHEET: 14 of 16
DATE: 7/17/2009
DRAWN BY: RJT/CSS/EMA
DWG. NAME. NYBBT-8m_R5
SCALE: None
UNITS: mm
REV. BY: KAP/RKF

Figure 239. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8



Midwest Roadside Safety Facility

Type IIA Box Beam Terminal (Test No. NYBBT-8)

System Isometric

SHEET: 15 of 16

DATE: 7/17/2009

DRAWN BY: RJT/CSS/EMA

DWG. NAME. NYBBT-8m_R5

SCALE: 1:150
UNITS: mm

REV. BY: KAP/RKF

Figure 240. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8

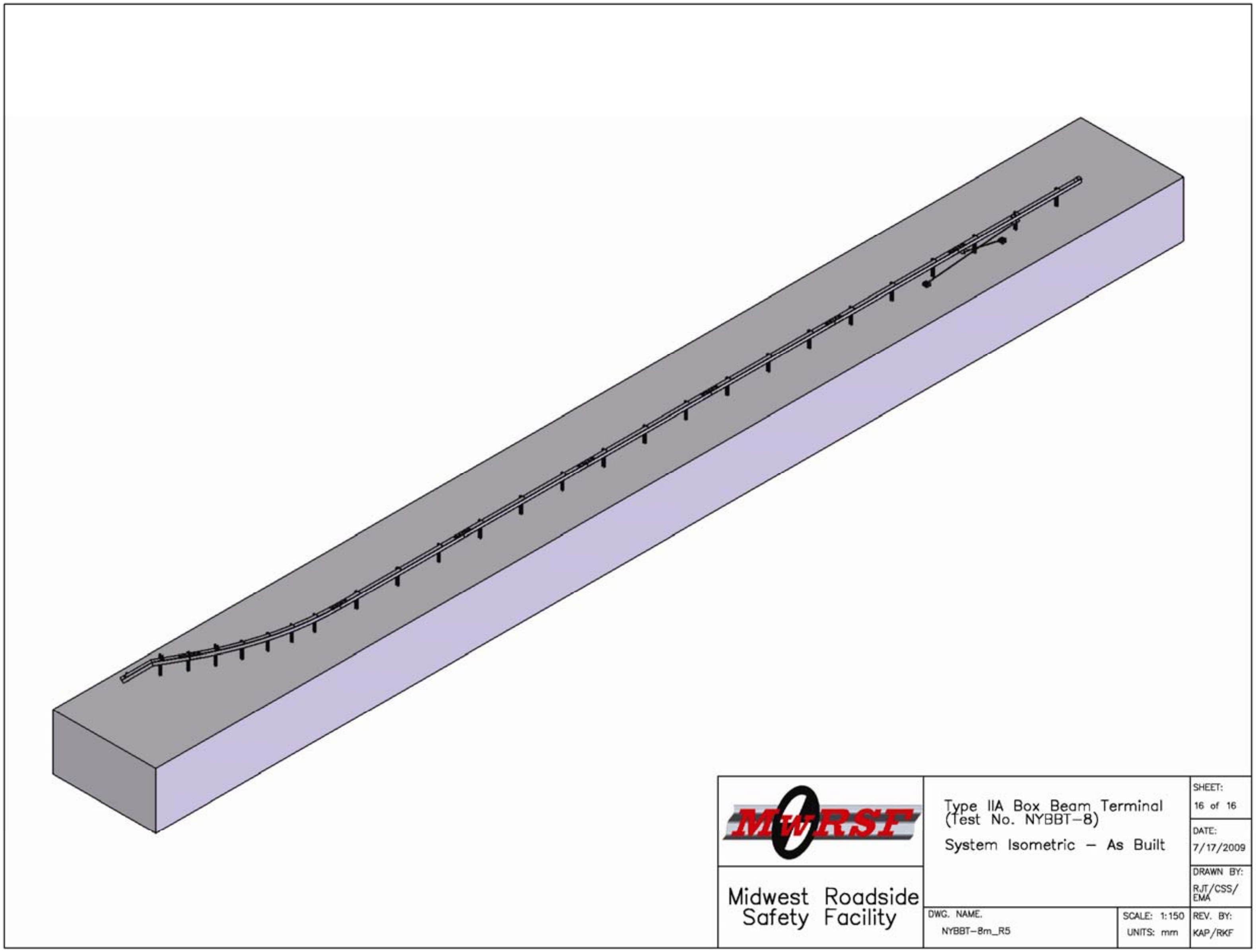
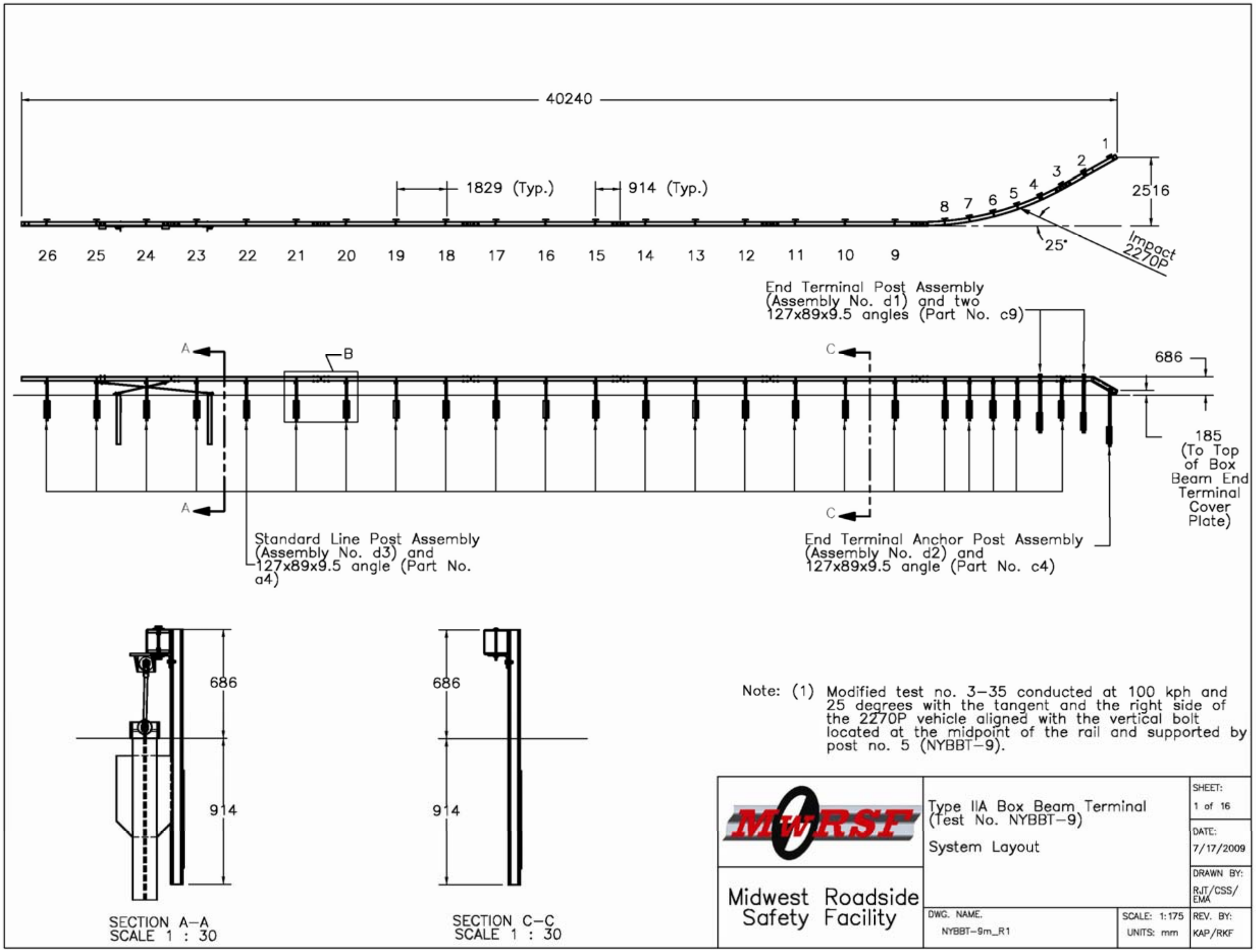


Figure 241. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-8



Note: (1) Modified test no. 3–35 conducted at 100 kph and 25 degrees with the tangent and the right side of the 2270P vehicle aligned with the vertical bolt located at the midpoint of the rail and supported by post no. 5 (NYBBT–9).

Figure 242. Modified Type IIA Box Beam Terminal System Details, Test No. NYBBT-9

Figure 243. NYBBT-8 and NYBBT-9 System Details

18 FULL-SCALE CRASH TEST NO. 8 (MODIFIED TYPE IIA END TERMINAL)

18.1 Static Soil Test

Before full-scale crash test no. NYBBT-8 was conducted, the strength of the soil foundation was evaluated with a static test, as described by MASH. The static test results, as shown in Appendix K, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and the barrier system was subjected to full-scale crash testing.

18.2 Test No. NYBBT-8 (Test Designation 3-34)

The 1,183-kg (2,608-lb) Kia Rio, with a dummy placed in the left-front seat, impacted the modified Type IIA box beam terminal system at a speed of 101.5 km/h (63.1 mph) and at an angle of 16.9 degrees with respect to the tangent. A summary of the test results and sequential photographs are shown in Figure 244. An English-unit summary of the test results and sequential photographs are shown in Appendix C. Additional sequential photographs are shown in Figures 245 through 248. Documentary photographs of the crash test are shown in Figure 249.

18.3 Weather Conditions

Test no. NYBBT-8 was conducted on July 15, 2009 at approximately 11:30 am. The weather conditions were reported as shown in Table 18.

Table 18. Weather Conditions, Test No. NYBBT-8

Temperature	81° F
Humidity	41 %
Wind Speed	11 mph
Wind Direction	0° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.21 in.
Previous 7-Day Precipitation	0.22 in.

18.4 Test Description

Initial vehicle impact was to occur with the vehicle's left-front corner at the centerline of post no. 3, as shown in Figure 250. Actual vehicle impact occurred 25 mm (1 in.) upstream of post no. 3. Upon impact, the left headlight deflected inward. At 0.004 sec, the left-front quarter panel deformed inward, and post no. 4 deflected backward. At 0.010 sec, the left-front corner of the engine hood contacted the rail and deformed inward. At 0.012 sec, post nos. 2 and 5 deflected backward, and post no. 5 also deflected downstream. At 0.014 sec, post no. 1 twisted downstream. At 0.016 sec, the left side of the front bumper contacted the upstream-front flange of post no. 4. At 0.018 sec, the bolt connecting post no. 4 to the lower shelf angle tore through the upstream-front flange, and the upstream side of the front flange deformed. At 0.020 sec, the bolt connecting the upper shelf angle to post no. 4 sheared. At 0.026 sec, the right-front corner of the engine hood contacted the rail and deformed inward. At this same time, post no. 4 twisted upstream. At 0.038 sec, the bolt connecting the rail to the shelf angle on post no. 5 sheared. At this same time, the left side of the windshield experienced cracking. At 0.044 sec, the vehicle began to redirect. At this same time, the right side of the windshield experienced cracking, and the front of the vehicle pitched downward. At 0.054 sec, a buckle point formed in the rail slightly upstream of post no. 4, and the front bumper contacted post no. 5. At 0.064 sec, the bolt connecting the rail to the shelf angle on post no. 6 sheared. At 0.070 sec, the bolts connecting the shelf angle to post no. 1 pulled through the flange, and post no. 2 deflected downstream. At this same time, the vehicle rolled toward the right. At 0.088 sec, the bolt connecting the rail to the shelf angle on post no. 7 sheared. At 0.090 sec, the front of the vehicle contacted post no. 6. At 0.122 sec, the vehicle pitched upward, and the bolt connecting the rail to the shelf angle on post no. 8 sheared. At 0.128 sec, the bolt connecting the rail to the two shelf angles on post no. 2

sheared, but it did not pull out of the rail. At 0.144 sec, the bolt connecting the upper shelf angle to post no. 2 sheared, and the rail was released from post no. 2. At 0.264 sec, the rail lost contact with the top of post no. 2. At 0.284 sec, the vehicle pitch ceased. At 0.432 sec, the vehicle rolled toward the left. At 0.588 sec, the vehicle was parallel to the rail at the impact location with a resultant velocity of 42.2 km/h (26.2 mph). At 0.660 sec, the vehicle exited the system with a resultant velocity of 41.1 km//h (25.5 mph) and at an angle of 25.7 degrees. The vehicle continued downstream and came to rest 24.3 m (79 ft – 10 1/4 in.) downstream from impact and 11.4 m (37 ft - 6 in.) laterally away from the traffic-side face of the tangent rail. The trajectory and final position of the passenger car are shown in Figures 244 and 251.

18.5 System and Component Damage

Damage to the end terminal system was moderate, as shown in Figures 252 through 267. Damage consisted of deformed box beam and guide rail posts, buckled box beam, twisted splice plates, and contact marks on box beam rail sections and guide rail posts. The length of vehicle contact was approximately 11.0 m (36 ft – 1 in.), which spanned from 25 mm (1 in.) upstream of post no. 3 through the midspan between post nos. 11 and 12.

Contact marks were found on the top of the rail starting 64 mm (2 1/2 in.) downstream of post no. 3 and continued through 267 mm (10 1/2 in.) downstream of post no. 7. Major buckling of the rail was found 254 mm (10 in.) upstream of post no. 4. The splice plates at splice nos. 2 through 7 were bent. The splice plates at splice nos. 2, 5, and 6 were also twisted. The box beam rail disengaged from post nos. 1 through 23.

The downstream post bolt slot at post no. 1 tore through the front flange, and the upstream post bolt slot was deformed. The shelf angle disengaged from post nos. 1, 4 through 7, and 10. Post nos. 2 and 4 through 8 twisted downstream and bent backward. The upstream top bolt slot on post no. 2 was deformed, and the top shelf angle disengaged from the post. The top of post no. 3 experienced minor scraping. Contact marks were found on post nos. 4 through 10. The upstream front flange on post no. 4 was deformed, and the upstream bottom bolt slot tore through the flange. Minor scraping and flange deformation were located on the upstream front flange of post nos. 6 and 7. The shelf angles at post nos. 8, 9, and 11 were bent. Post nos. 12 through 20 and 22 through 26 did not experience any visible deflection or post deformation.

A soil gap of 64 mm (2 1/2 in.) was found at the front side of post no. 2. A soil gap of 51 mm (2 in.) was found at the front side of post no. 3. A soil gap of 127 mm (5 in.) was found at the upstream side of post no. 4. A soil gap measuring 102 mm (4 in.) was found on the upstream side of post no. 5. A soil gap of 38 mm (1 1/2 in.) was found on the upstream side of post no. 9. Soil gaps of 10 mm (3/8 in.) were found at the front of post no. 11 and the back of post no. 21. The bolts connecting the rail to the shelf angle on post nos. 2 through 23 were missing.

The permanent set deflection of the end terminal system is shown in Figure 252. The maximum lateral permanent set rail and post deflections were 2,842 mm (111 7/8 in.) at the centerline of post no. 4 and 1,329 mm (53 1/8 in.) at post no. 4, respectively, as measured in the field. The maximum dynamic system deflection was not calculated because the end terminal continued to deflect beyond the view of the high-speed overhead digital video. The working width of the system was estimated using high-speed digital video analysis and found to be approximately 6.6 m (21 ft – 6 in.), as measured laterally from the tangent portion of the rail.

18.6 Vehicle Damage

Exterior vehicle damage was moderate, as shown in Figures 268 through 270. The maximum deformations of the occupant compartment are shown in Table 19. Complete occupant compartment deformations and the corresponding locations are provided in Appendix D.

Table 19. Maximum Occupant Compartment Deformations, Test No. NYBBT-8

Location	**Maximum Deformation Perpendicular to Surface**	**MASH Deformation Limits**
Roof	19 mm (3/4 in.)	102 mm (4 in.)
Wheel/Foot Well and Toe Pan	38 mm (1 1/2 in.)	229 mm (9 in.)
Side Front Panel (forward of A-pillar)	13 mm (1/2 in.)	305 mm (12 in.)
Front Side Door Area (above seat)	19 mm (3/4 in.)	229 mm (9 in.)
Front Side Door Area (below seat)	13 mm (1/2 in.)	305 mm (12 in.)
Floor Pan and Transmission Tunnel Areas	19 mm (3/4 in.)	305 mm (12 in.)

A 51-mm x 51-mm (2-in. x 2-in.) tear was found in the left-front tire's outside wall, and the tire was deflated. The left-front rim was deformed. The left-front quarter panel was deformed inward and backward with significant deformation above the left-front tire. The top of the left-side B-pillar, the front of the left-front door, the bottom of the left-rear door, and the right-front quarter panel were dented inward. Scrape marks were found on the entire left side. Both left-side doors were also dented and ajar at the top. A 127-mm x 38-mm (5-in. x 1 1/2-in.) puncture was found on the left side of the rear bumper. The front bumper was disengaged, and the grill and hood were deformed backward. Both headlights and the radiator were crushed inward. The windshield was cracked. The left-rear stabilizer buckled. Contact marks and scrapes were found on the skid plate covering the oil pan, and the skid plate was bent. The oil pan plug, the right-side steering arm and rack, and the vertical stabilizer bar were detached. It should be noted that the front of the vehicle impacted a concrete retaining barrier prior to coming to rest, which may have contributed to some of the damage to the grill, hood, and right-front quarter panel.

18.7 Occupant Risk Values

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table

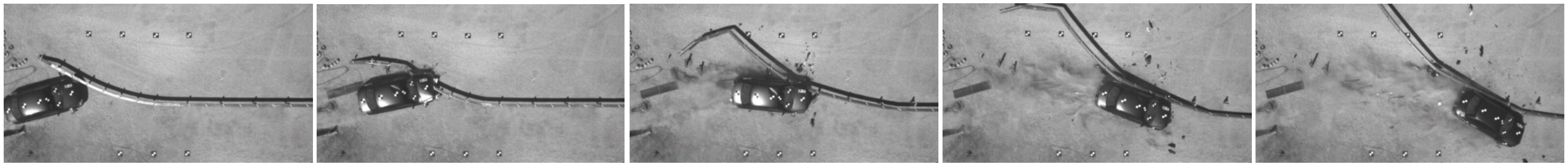
20. It is noted that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 20. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 244. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix U. Due to technical difficulties, the DTS recorder did not collect acceleration nor angular data.

Table 20. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYBBT-8

Evaluation Criteria		**Transducer**	
		EDR-3	**EDR-4**
OIV m/s (ft/s)	Longitudinal	-9.74 (-31.96)	-9.34 (-30.63)
	Lateral	4.36 (14.32)	4.43 (14.54)
ORA g's	Longitudinal	-11.15	-10.31
	Lateral	7.08	5.62
THIV m/s (ft/s)		NA	9.51 (31.20)
PHD g's		NA	10.41
ASI		1.24	1.16

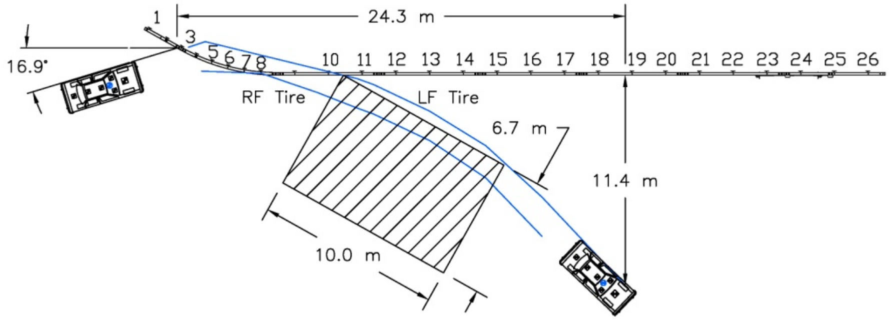
18.8 Discussion

The analysis of the test results for test no. NYBBT-8 showed that the modified NYSDOT Type IIA box beam end terminal system adequately contained and redirected the 1100C vehicle. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor override the barrier system and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were noted, as shown in Appendix U, and 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 other traffic lanes. In addition, the vehicle exited the barrier within the exit box. Therefore, test no. NYBBT-8 conducted on the modified Type IIA end terminal was determined to be acceptable according to test designation no. 3-34 of the TL-3 safety performance criteria found in MASH.



0.000 sec 0.090 sec 0.278 sec 0.468 sec 0.660 sec

●Test Agency	MwRSF
●Test Number	NYBBT-8
●Date	7/15/09
●MASH Test Designation	3-34
●Appurtenance	Modified Type IIA End Terminal
●Total Length	40.2 m
●Key Element – Steel Box Beam	
Size	152 mm x 152 mm x 4.8 mm
Length	5,486 mm
Top Mounting Height	686 mm
●Key Elements - Steel Post	
Post Nos. 1, 2, 4	S76x8.5 by 2,134 mm long
Post Nos. 3, 5-26	S76x8.5 by 1,600 mm long
●Type of Soil	Grading B - AASHTO M 147-65 (1990)
●Test Vehicle	
Type/Designation	1100C
Make and Model	2003 Kia Rio
Curb	1,104 kg
Test Inertial	1,106 kg
Gross Static	1,183 kg
●Impact Conditions	
Speed	101.5 km/h
Angle	16.9 degrees
Target Impact Location	Centerline of post no. 3
Actual Impact Location	25 mm upstream of centerline of post no. 3
●Exit Conditions	
Speed	41.1 km/h
Angle	25.7 degrees
Exit Box Criterion	Pass
●Post-Impact Trajectory	
Vehicle Stability	Satisfactory
Stopping Distance	24.3 m downstream 11.4 m laterally away traffic-side face
●Occupant Impact Velocity (EDR-3)	
Longitudinal	-9.74 m/s < 12.2 m/s
Lateral	4.36 m/s < 12.2 m/s



●Occupant Ridedown Acceleration (EDR-3)	
Longitudinal	-11.15 g's < 20.49 g's
Lateral	7.08 g's < 20.49 g's
●Occupant Impact Velocity (EDR-4)	
Longitudinal	-9.34 m/s < 12.2 m/s
Lateral	4.43 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (EDR-4)	
Longitudinal	-10.31 g's < 20.49 g's
Lateral	5.62 g's < 20.49 g's
●THIV (EDR-4 - not required)	9.51 m/s
●PHD (EDR-4 - not required)	10.41 g's
●ASI (EDR-3 - not required)	1.24
●ASI (EDR-4 - not required)	1.16
●Test Article Damage	Moderate
●Test Article Deflections	
Permanent Set	2,842 mm
Dynamic	NA
Working Width	6.6 m (estimate)
●Vehicle Damage	Moderate
VDS[12]	11-LFQ-6
CDC[13]	11-LYAW9
●Maximum Deformation	102 mm at the front of the side panel
●Angular Displacement	
Roll	7 degrees
Pitch	-7 degrees
Yaw	55 degrees

Figure 244. Summary of Test Results and Sequential Photographs, Test No. NYBBT-8

0.000 sec

0.024 sec

0.064 sec

0.088 sec

0.122 sec

0.144 sec

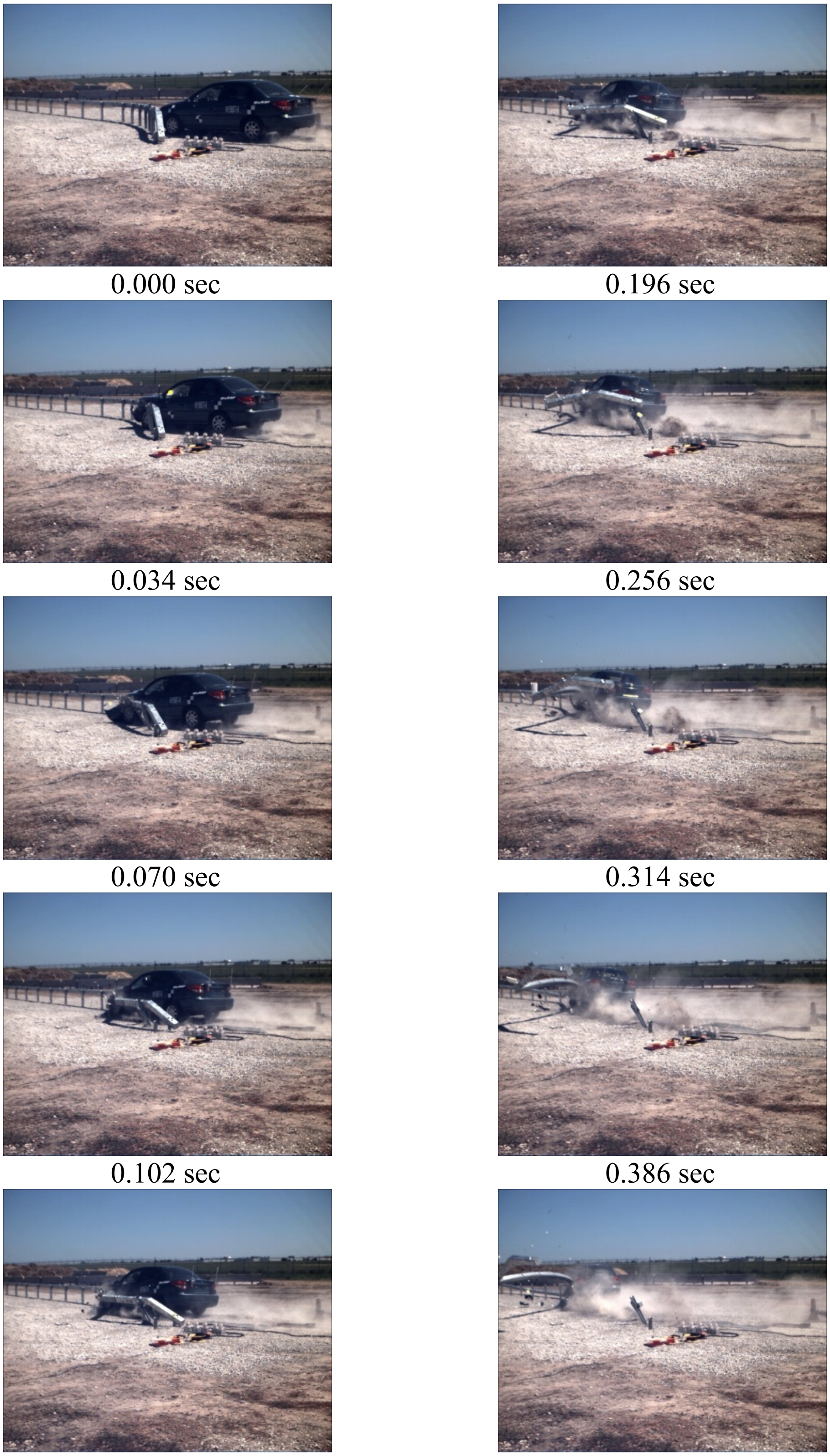
0.170 sec

0.232 sec

0.296 sec

0.326 sec

Figure 245. Additional Sequential Photographs, Test No. NYBBT-8



0.000 sec

0.034 sec

0.070 sec

0.102 sec

0.130 sec

0.196 sec

0.256 sec

0.314 sec

0.386 sec

0.472 sec

Figure 246. Additional Sequential Photographs, Test No. NYBBT-8


0.000 sec


0.026 sec


0.054 sec


0.090 sec


0.144 sec


0.264 sec

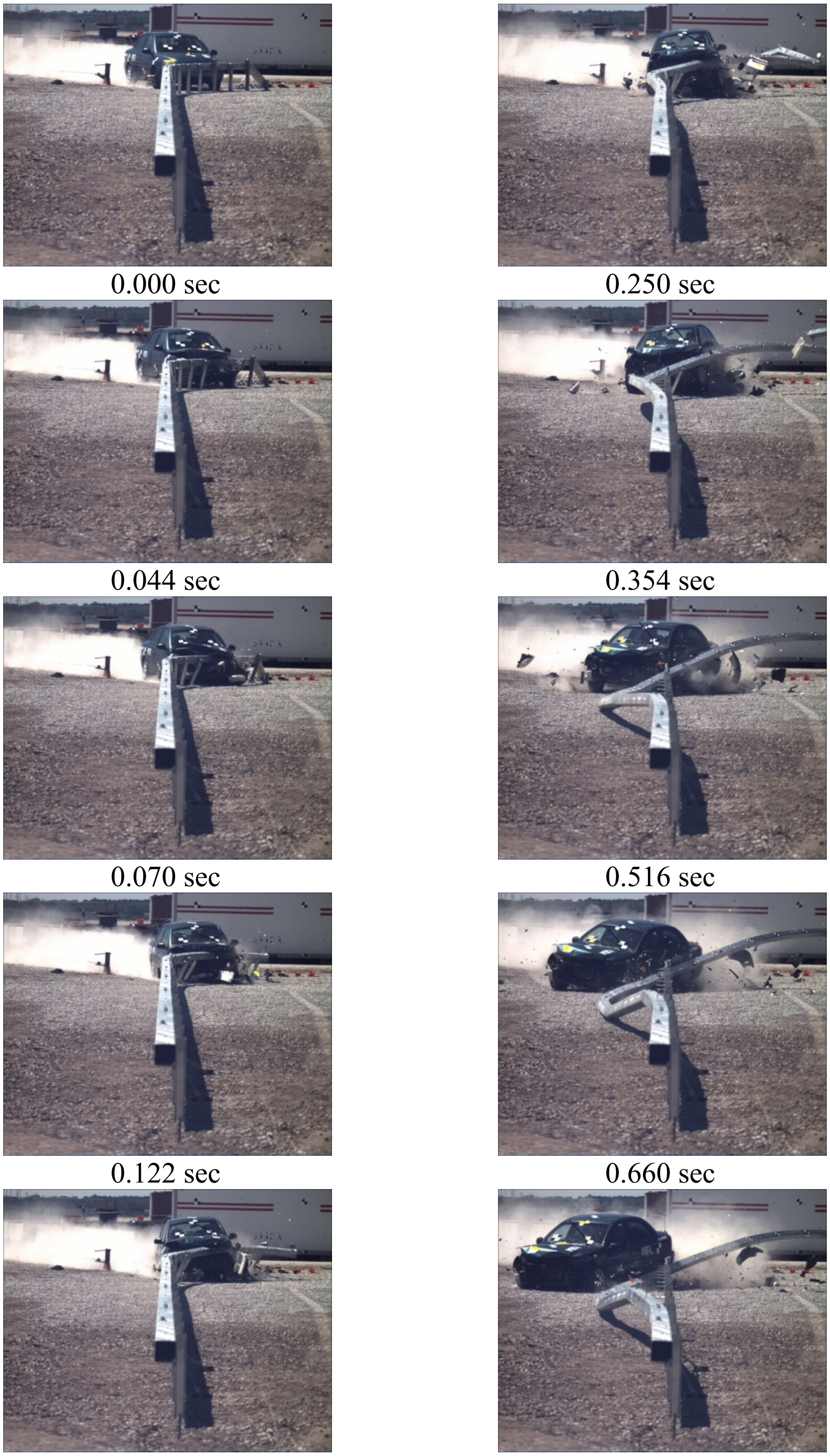

0.370 sec


0.484 sec


0.652 sec


0.806 sec

Figure 247. Additional Sequential Photographs, Test No. NYBBT-8



0.000 sec

0.044 sec

0.070 sec

0.122 sec

0.180 sec

0.250 sec

0.354 sec

0.516 sec

0.660 sec

0.792 sec

Figure 248. Additional Sequential Photographs, Test No. NYBBT-8

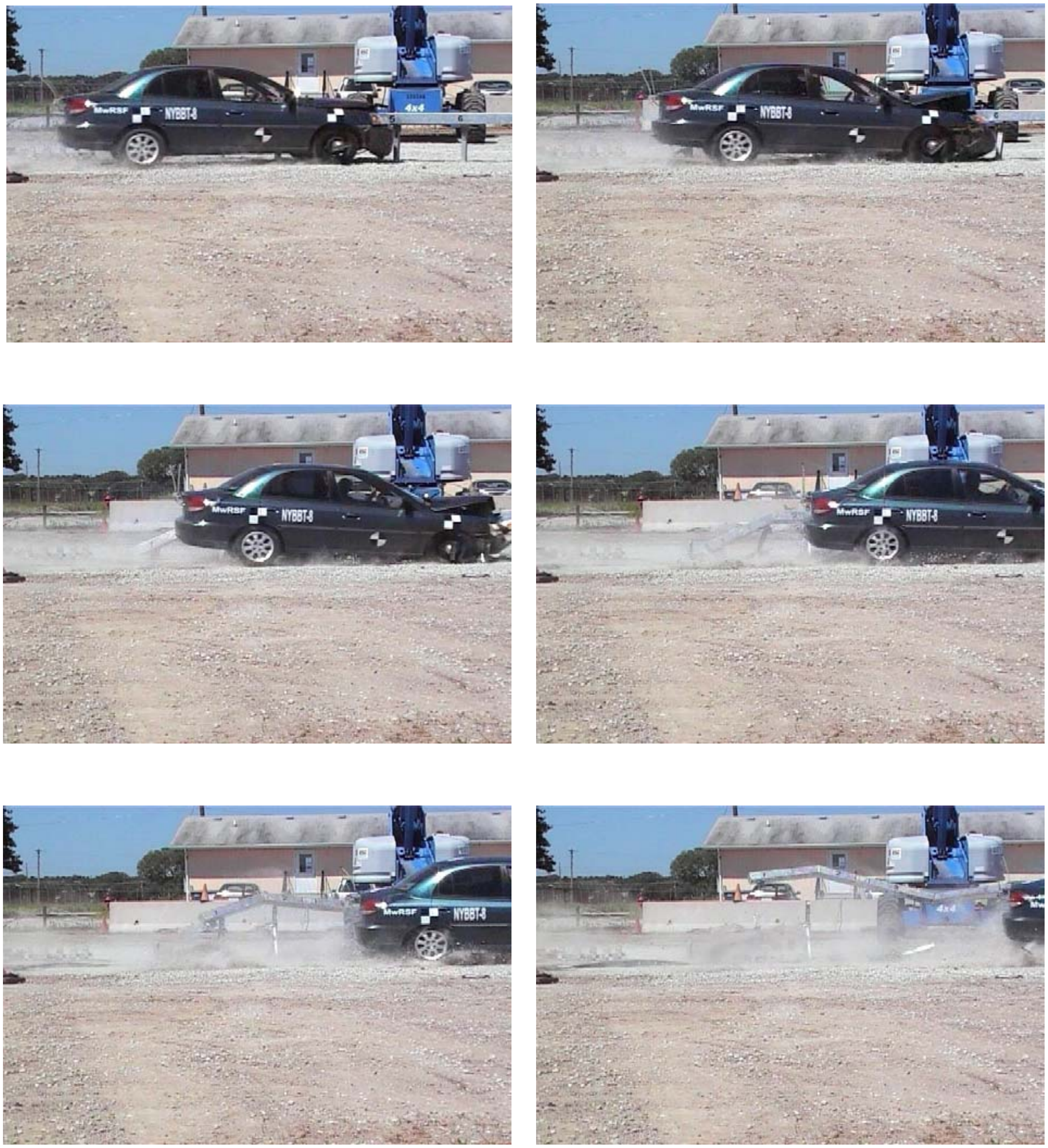


Figure 249. Documentary Photographs, Test No. NYBBT-8

Figure 250. Impact Location, Test No. NYBBT-8

Figure 251. Vehicle Final Position and Trajectory Marks, Test No. NYBBT-8

Figure 252. Barrier Damage, Test No. NYBBT-8

Figure 253. Barrier Damage, Test No. NYBBT-8

Figure 254. Barrier Damage, Test No. NYBBT-8

Figure 255. Post Nos. 1 and 2 Damage, Test No. NYBBT-8

Figure 256. Post Nos. 3 and 4 Damage, Test No. NYBBT-8

Figure 257. Post Nos. 5 and 6 Damage, Test No. NYBBT-8

Figure 258. Post Nos. 7 and 8 Damage, Test No. NYBBT-8

Figure 259. Post Nos. 9 and 10 Damage, Test No. NYBBT-8

Figure 260. Post Nos. 11 and 12 Damage, Test No. NYBBT-8

Figure 261. Post Nos. 13 through 16 Damage, Test No. NYBBT-8

Figure 262. Post Nos. 17 through 20 Damage, Test No. NYBBT-8

Figure 263. Post Nos. 21 and 22 Damage, Test No. NYBBT-8

Figure 264. End Plate and Splice No. 1 Damage, Test No. NYBBT-8

Figure 265. Splice Nos. 2 and 3 Damage, Test No. NYBBT-8

Figure 266. Splice Nos. 4 and 5 Damage, Test No. NYBBT-8

Figure 267. Splice Nos. 6 and 7 Damage, Test No. NYBBT-8

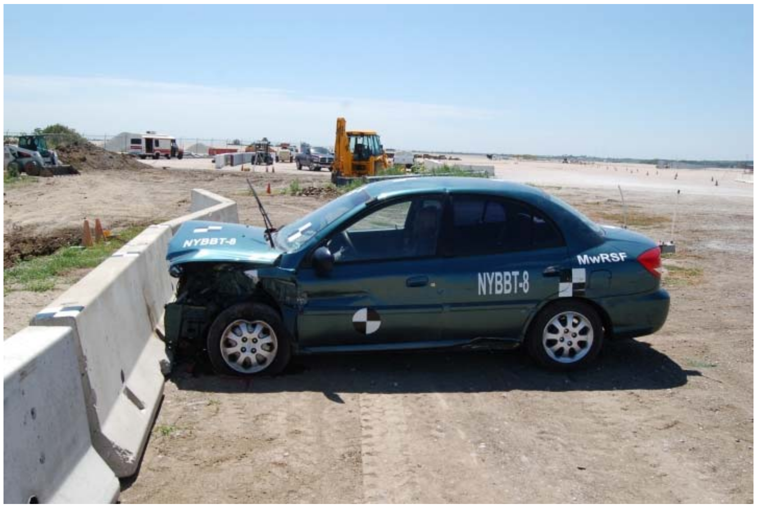


Figure 268. Vehicle Damage, Test No. NYBBT-8

Figure 269. Vehicle Damage, Test No. NYBBT-8

Figure 270. Vehicle Undercarriage Damage, Test No. NYBBT-8

19 FULL-SCALE CRASH TEST NO. 9 (MODIFIED TYPE IIA END TERMINAL)

19.1 Static Soil Test

Before full-scale crash test no. NYBBT-9 was conducted, the strength of the soil foundation was evaluated with a static test, as described by MASH. The static test results, as shown in Appendix K, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and the barrier system was subjected to full-scale crash testing.

19.2 Test No. NYBBT-9 (Modified Test Designation 3-35)

The 2,340-kg (5,159-lb) Dodge Ram 1500 Quad Cab pickup, with a dummy placed in the left-front seat, impacted the modified Type IIA box beam terminal system at a speed of 101.9 km/h (63.3 mph) and at an angle of 25.0 degrees with respect to the tangent. A summary of the test results and sequential photographs are shown in Figure 271. An English-unit summary of the test results and sequential photographs are shown in Appendix C. Additional sequential photographs are shown in Figures 272 through 275. Documentary photographs of the crash test are shown in Figure 276.

19.3 Weather Conditions

Test no. NYBBT-9 was conducted on August 6, 2009 at approximately 11:15 am. The weather conditions were reported as shown in Table 21.

Table 21. Weather Conditions, Test No. NYBBT-9

Temperature	76° F
Humidity	60 %
Wind Speed	9 mph
Wind Direction	130° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.11 in.
Previous 7-Day Precipitation	0.43 in.

19.4 Test Description

Initial vehicle impact was to occur with the vehicle's left-front corner at the centerline of the vertical bolt at the midpoint of the rail at post no. 5, as shown in Figure 277. Actual vehicle impact occurred at the intended impact location. Upon impact, the left corner of the front bumper deflected inward. At 0.002 sec, post nos. 5 and 6 deflected laterally backward. At 0.004 sec, post nos. 4 and 7 deflected laterally backward. At 0.008 sec, post no. 8 deflected laterally backward, and the right corner of the front bumper deflected downward. At 0.016 sec, post no. 2 twisted downstream, and post no. 3 deflected laterally backward. At 0.022 sec, the vehicle started to redirect downstream, and post no. 1 deflected laterally forward. At this same time, the bolt connecting the shelf angle to the rail at post no. 6 sheared as the left corner of the front bumper contacted the shelf angle. At 0.034 sec, the left-front tire contacted the base of post no. 5, and the vehicle rolled toward the left. At 0.042 sec, the bolt connecting the shelf angle to the rail at post nos. 5 and 7 sheared. At 0.046 sec, the left corner of the front bumper contacted post no. 7. At 0.050 sec, the bolt connecting the top shelf angle to post no. 4 sheared. At 0.054 sec, the bolt connecting the shelf angle to post no. 8 sheared. At 0.064 sec, the bolt connecting the shelf angles to the rail at post no. 4 sheared. At 0.068 sec, the bolt connecting the top shelf angle to post no. 2 sheared. At 0.072 sec, the bolts connecting the shelf angle to post no. 1 pulled through the front flange. At this same time, the bolt connecting the rail to the shelf angle on post no. 9 sheared. At 0.106 sec, post no. 2 deflected longitudinally downstream. At 0.126 sec, the bolt connecting the rail to the shelf angles on post no. 2 sheared. At 0.150 sec, the bolt connecting the rail to the shelf angle on post no. 10 sheared. At 0.172 sec, the center of the front bumper deflected upward. At this same time, splice no. 2 bent as the left-front corner of the vehicle contacted the downstream end of the splice. At 0.180 sec, splice no. 3 bent. At 0.194 sec, the right-front tire contacted post no. 9. At 0.248 sec, the right corner of the front bumper contacted post no. 10. At 0.364 sec, a buckle point formed in the rail at post no. 13. At 0.352 sec, the right-rear tire became airborne. At 0.378 sec, the vehicle rolled toward the right. At 0.482 sec, the right corner of the front bumper contacted post no. 12. At 0.578 sec, a buckle point formed in the rail at post no. 14. At 0.640 sec, the vehicle rolled toward the left. At 0.692, the rail terminal rotated about post no. 14. At 0.838 sec, the left-front tire separated from the rim. At 0.850 sec, the vehicle pitched downward. At 0.876 sec, the right-front tire became airborne. At 0.900, the right-rear quarter panel contacted the rail at post no. 10. At 1.010 sec, the right-front quarter panel lost contact with the rail just upstream of post no. 13. At 1.266 sec, the vehicle pitched upward. At 1.320 sec, the vehicle rolled toward the right. At 1.496 sec, the vehicle exited the system with a resultant velocity of 83.9 km/h (52.1 mph) and at an angle of 31.0 degrees. At 1.652 sec, the right-front tire contacted the ground. At 1.766 sec, the right-rear tire contacted the ground. At 1.802 sec, vehicle roll ceased. At 1.990 sec, vehicle pitch ceased. At 2.300 sec, the rail at post no. 2 contacted the back side of post no. 22. The vehicle came to rest 17.4 m (57 ft – 1 in.) downstream from impact and 6.8 m (22 ft - 4 in.) laterally behind the traffic-side face of the tangent rail. The trajectory and final position of the pickup truck are shown in Figures 271 and 278. The position of the vehicle at several points during gating is shown in Figure 279.

19.5 System and Component Damage

Damage to the end terminal system was extensive, as shown in Figures 280 through 295. Damage consisted of deformed box beam and guide rail posts, buckled box beam, bent splice plates, and contact marks on box beam rail sections and guide rail posts. The length of vehicle contact was approximately 12.0 m (39 ft – 4 in.), which spanned from 51 mm (2 in.) upstream of post no. 5 through 51 mm (2 in.) downstream of post no. 13.

Contact marks were found on the top face of the rail beginning 254 mm (10 in.) downstream of post no. 5 and continued through post no. 8. Buckling of the rail was found 610 mm (24 in.) downstream of post no. 5, 368 mm (14 1/2 in.) downstream of the midpoint between post nos. 8 and 9, and at post no. 10. Rail tearing was also found at post no. 10. Major buckling was found at post nos. 13 and 14. The splice plates at splice nos. 1 through 5 were bent. The splice plates at splice no. 3 were twisted. A 51-mm (2-in.) gap between box beam sections was found at splice no. 3. The bottom of the rail at splice no. 3 was deformed around the splice bolts. The box beam rail disengaged from post nos. 1 through 22.

The upstream and downstream post bolt slots on post no. 1 tore through the front flange. The shelf angle disengaged from post nos. 1 and 6 through 8. Post nos. 2, 6, 9, and 13 twisted downstream. Post nos. 2 and 6 through 14 were bent downstream. The top-upstream bolt slot on post no. 2 was deformed. The top shelf angle was detached from post nos. 2 and 4. The bottom shelf angle on post no. 2 and the shelf angle on post nos. 5, 9 through 12, and 14 were bent. Post nos. 3, 7, 8, 10, and 11 were twisted upstream. Post nos. 3 through 5 were bent upstream. Post nos. 3 through 13 were bent backward. Minor scraping was observed on the front flange of post no. 3. Post no. 4 rotated upstream at the base and downstream at the top. Contact marks were found on the shelf angle and the front flange of post no. 5, the upstream edges of the front and back flanges of post no. 6, and the front flange of post nos. 7 and 9. The front flange of post nos. 7 and 9 were deformed. Contact marks were also found on the front and back flanges of post no. 8 and 11 through 14 and on the shelf angle and the back flange of post no. 10.

A soil gap of 22 mm (7/8 in.) was found at the front and back sides of post no. 3. Soil gaps of 76 mm (3 in.) and 13 mm (1/2 in.) were found at the front and back sides of post no. 4, respectively. A soil gap of 32 mm (1 1/4 in.) was found at the upstream side of post nos. 6 and

10. A soil pit measuring 445 mm (17 1/2 in.) longitudinally by 203 mm (8 in.) laterally was found on the upstream side of post no. 7. A soil gap of 48 mm (1 7/8 in.) was found on the upstream side of post no. 9. A soil gap of 41 mm (1 5/8 in.) was found at the front of post no. 11. Soil gaps of 57 mm (2 1/4 in.) and 13 mm (1/2 in.) were found at the front and back sides of post no. 12, respectively. A soil gap of 19 mm (3/4 in.) was found at the front face of post no. 13. Soil gaps measuring up to 13 mm (1/2 in.) were found on the front and back faces of post nos. 2, 14 through 18, and 20 through 26. Post no. 19 was the only post that did not experience any visible deflection or post deformation.

The permanent set deflection of the end terminal system is shown in Figure 280. The maximum lateral permanent set rail and post deflections were 1,080 mm (42 1/2 in.) at the midpoint between post nos. 11 and 12 and 502 mm (19 3/4 in.) at post no. 4, respectively, as measured in the field. The maximum dynamic system deflection was not calculated because the end terminal continued to deflect beyond the view of the high-speed overhead digital video. The working width was found to be 17.8 m (58 ft - 5 9/16 in.), as measured laterally from the front of the tangent rail.

19.6 Vehicle Damage

Exterior vehicle damage was moderate, as shown in Figures 296 through 299. Occupant compartment deformations are summarized in Table 22. Complete occupant compartment deformations and the corresponding locations are provided in Appendix D.

The left-front and right-front tires were partially detached from the rims and deflated. A 25-mm x 44-mm (1-in. x 1 3/4-in.) puncture was found in the wheel well of the left-front tire and a 44-mm (1 3/4-in.) long tear in the tread. The left-front rim was bent and encountered gouges along the edge. The left-front quarter panel was deformed inward. The left headlight and engine hood were dislodged. The front bumper was deformed inward at the bottom, and protruded upward and outward along the top. A gouge was found on the edge of the right-front rim. The left taillight was disengaged. Dents were found on the left side of the rear bumper. The left-rear quarter panel deformed inward at the base between the wheel well and the rear bumper. The left-rear rim was deformed along the edge. A gap formed between the left-front door and the quarter panel. A tear was found in the structural member connecting the lower control arms to the frame. The left-side vertical stabilizer was bent toward the right, and the left-side frame horn was bent inward 76 mm (3 in.). The radiator and bumper support were also damaged. The rest of the vehicle and all window glass remained undamaged.

Table 22. Maximum Occupant Compartment Deformations, Test No. NYBBT-9

Location	Maximum Deformation Perpendicular to Surface	MASH Deformation Limits
Roof	NA	102 mm (4 in.)
Wheel/Foot Well and Toe Pan	19 mm (3/4 in.)	229 mm (9 in.)
Side Front Panel (forward of A-pillar)	6 mm (1/4 in.)	305 mm (12 in.)
Front Side Door Area (above seat)	6 mm (1/4 in.)	229 mm (9 in.)
Front Side Door Area (below seat)	6 mm (1/4 in.)	305 mm (12 in.)
Floor Pan and Transmission Tunnel Areas	6 mm (1/4 in.)	305 mm (12 in.)

19.7 Occupant Risk Values

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 23. It is noted that the OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 23. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 271. The recorded data from the accelerometers and the rate transducers are shown graphically in

Appendix V. Due to technical difficulties, the EDR-4 recorder did not collect acceleration nor angular data.

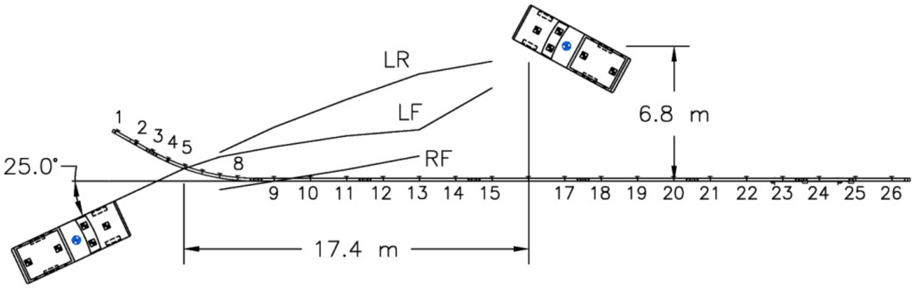
Table 23. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NYBBT-9

Evaluation Criteria		**Transducer**	
		EDR-3	**DTS**
OIV m/s (ft/s)	Longitudinal	-4.37 (-14.34)	-4.41 (-14.47)
	Lateral	3.03 (9.94)	2.81 (9.23)
ORA g's	Longitudinal	-7.77	-7.37
	Lateral	4.38	4.84
THIV m/s (ft/s)		NA	4.84 (15.89)
PHD g's		NA	7.67
ASI		0.82	0.73

19.8 Discussion

The analysis of the test results for test no. NYBBT-9 showed that the modified NYSDOT Type IIA box beam end terminal system allowed controlled penetration of the 2270P vehicle through the system. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were noted, as shown in Appendix V, and were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. Therefore, test no. NYBBT-9 conducted on the modified Type IIA end terminal was determined to be acceptable according to modified test designation no. 3-35 of the TL-3 safety performance criteria found in MASH.

0.000 sec | 0.094 sec | 0.268 sec | 0.446 sec | 0.636 sec



●Test Agency	MwRSF
●Test Number	NYBBT-9
●Date	8/6/09
●MASH Test Designation	Modified 3-35
●Appurtenance	Modified Type IIA End Terminal
●Total Length	40.2 m
●Key Element – Steel Box Beam	
Size	152 mm x 152 mm x 4.8 mm
Length	5,486 mm
Top Mounting Height	686 mm
●Key Elements - Steel Post	
Post Nos. 1, 2, 4	S76x8.5 by 2,134 mm long
Post Nos. 3, 5-26	S76x8.5 by 1,600 mm long
●Type of Soil	Grading B - AASHTO M 147-65 (1990)
●Test Vehicle	
Type/Designation	2270P
Make and Model	2003 Dodge Ram 1500 Quad Cab Pickup
Curb	2,283 kg
Test Inertial	2,263 kg
Gross Static	2,340 kg
●Impact Conditions	
Speed	101.9 km/h
Angle	25.0 degrees
Target Impact Location	Centerline of vertical bolt at midpoint of rail at post no. 5
Actual Impact Location	51 mm upstream of centerline of post no. 5
●Exit Conditions	
Speed	83.9 km/h
Angle	31.0 degrees
Exit Box Criterion	NA
●Post-Impact Trajectory	
Vehicle Stability	Satisfactory
Stopping Distance	17.4 m downstream 6.8 m laterally behind traffic-side face
●Occupant Impact Velocity (EDR-3)	
Longitudinal	-4.37 m/s < 12.2 m/s
Lateral	3.03 m/s < 12.2 m/s

●Occupant Ridedown Acceleration (EDR-3)	
Longitudinal	-7.77 g's < 20.49 g's
Lateral	4.38 g's < 20.49 g's
●Occupant Impact Velocity (DTS)	
Longitudinal	-4.41 m/s < 12.2 m/s
Lateral	2.81 m/s < 12.2 m/s
●Occupant Ridedown Acceleration (DTS)	
Longitudinal	-7.37 g's < 20.49 g's
Lateral	4.84 g's < 20.49 g's
●THIV (DTS - not required)	4.84 m/s
●PHD (DTS - not required)	7.67 g's
●ASI (EDR-3 - not required)	0.82
●ASI (DTS - not required)	0.73
●Test Article Damage	Extensive due to gating
●Test Article Deflections	
Permanent Set	1,080 mm
Dynamic	NA
Working Width	17,820 mm
●Vehicle Damage	Moderate
VDS[12]	11-LFQ-3
CDC[13]	11-LFEW8
●Maximum Deformation	19 mm at the left side of the dashboard
●Angular Displacement	
Roll	-22 degrees
Pitch	-5 degrees
Yaw	236 degrees

Figure 271. Summary of Test Results and Sequential Photographs, Test No. NYBBT-9

0.000 sec

0.010 sec

0.022 sec

0.042 sec

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0.090 sec

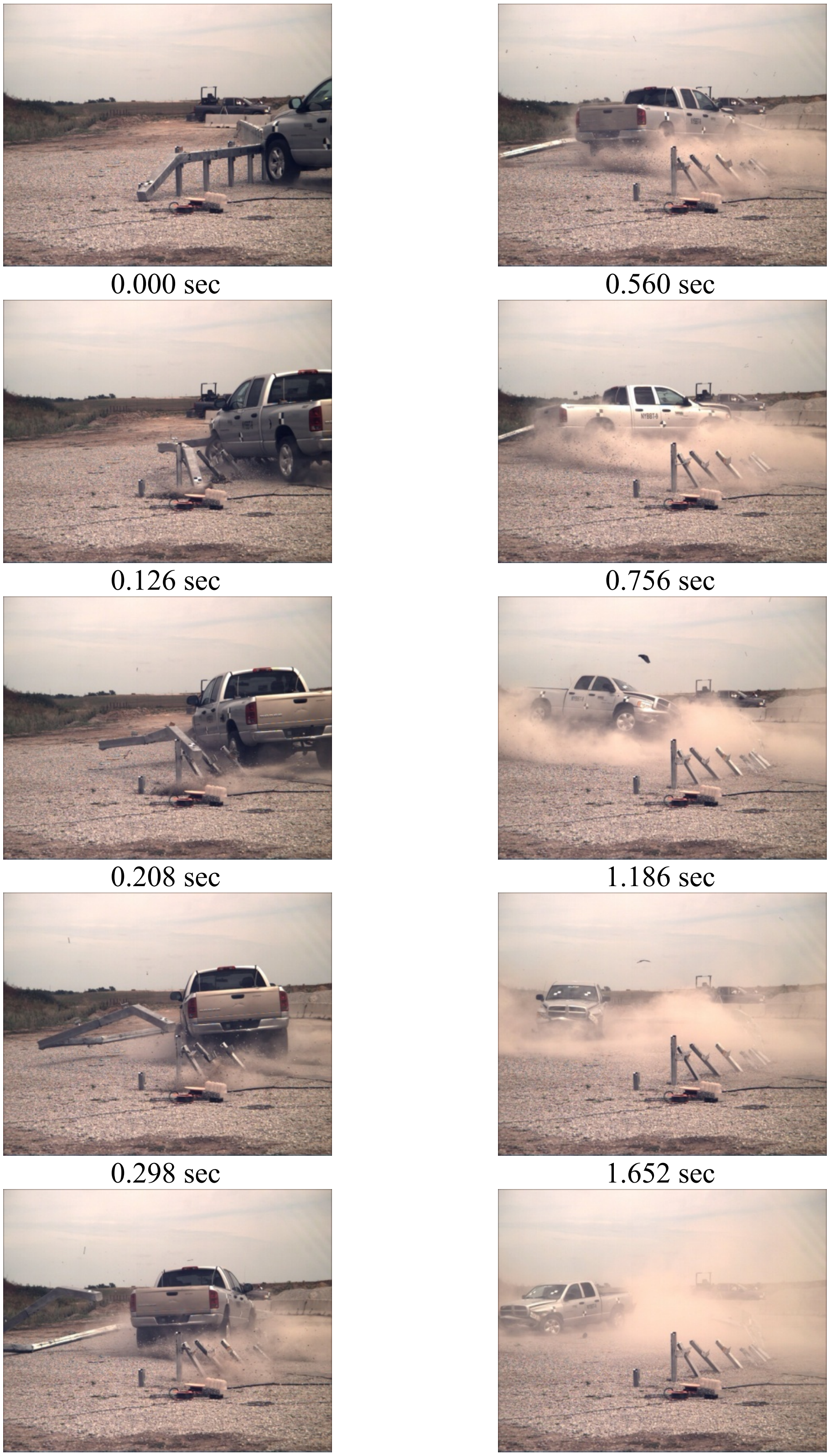
0.118 sec

0.160 sec

0.216 sec

0.286 sec

Figure 272. Additional Sequential Photographs, Test No. NYBBT-9



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0.560 sec

0.756 sec

1.186 sec

1.652 sec

2.706 sec

Figure 273. Additional Sequential Photographs, Test No. NYBBT-9

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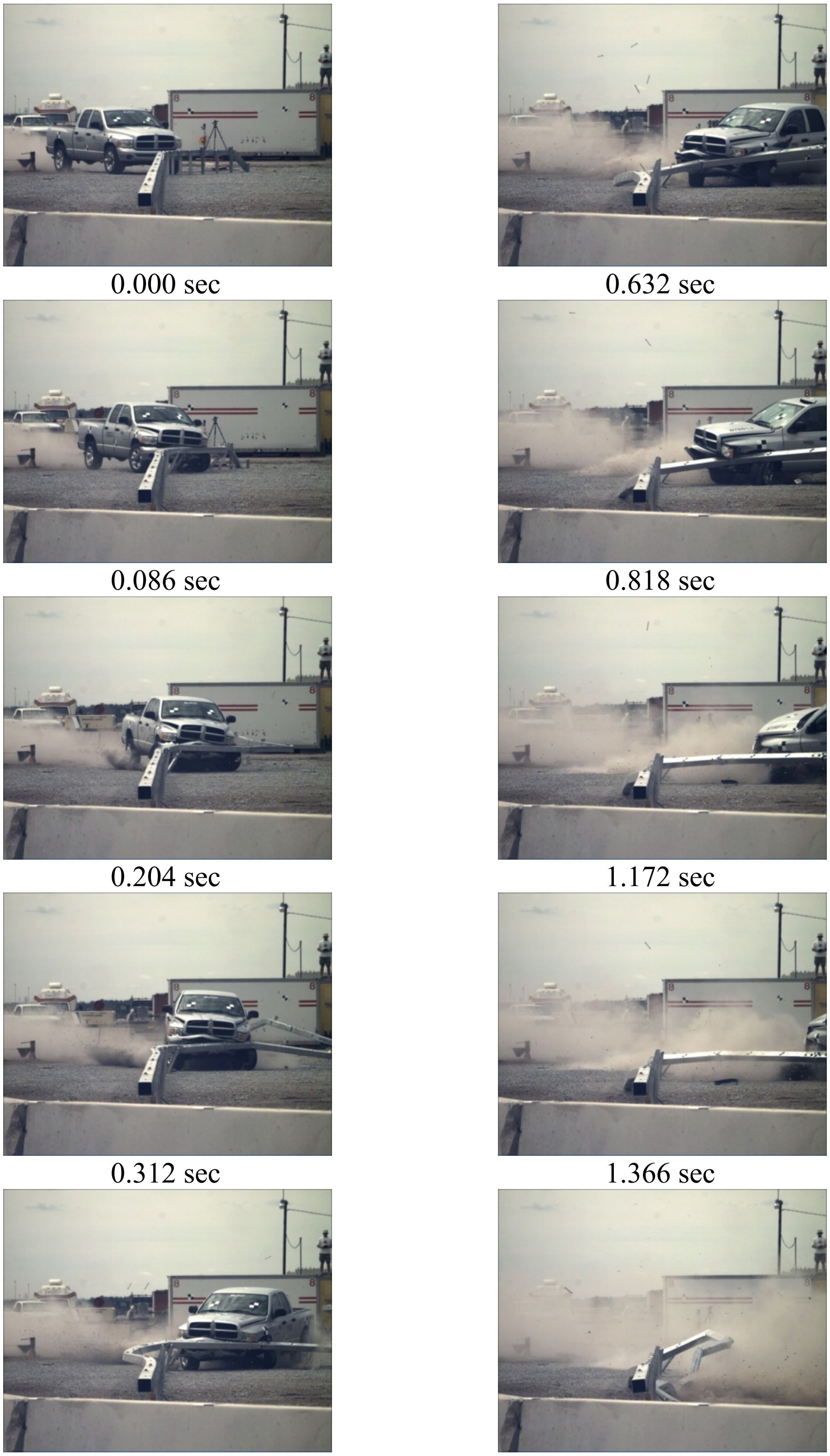
1.148 sec

1.320 sec

1.496 sec

2.550 sec

Figure 274. Additional Sequential Photographs, Test No. NYBBT-9



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1.366 sec

2.308 sec

Figure 275. Additional Sequential Photographs, Test No. NYBBT-9

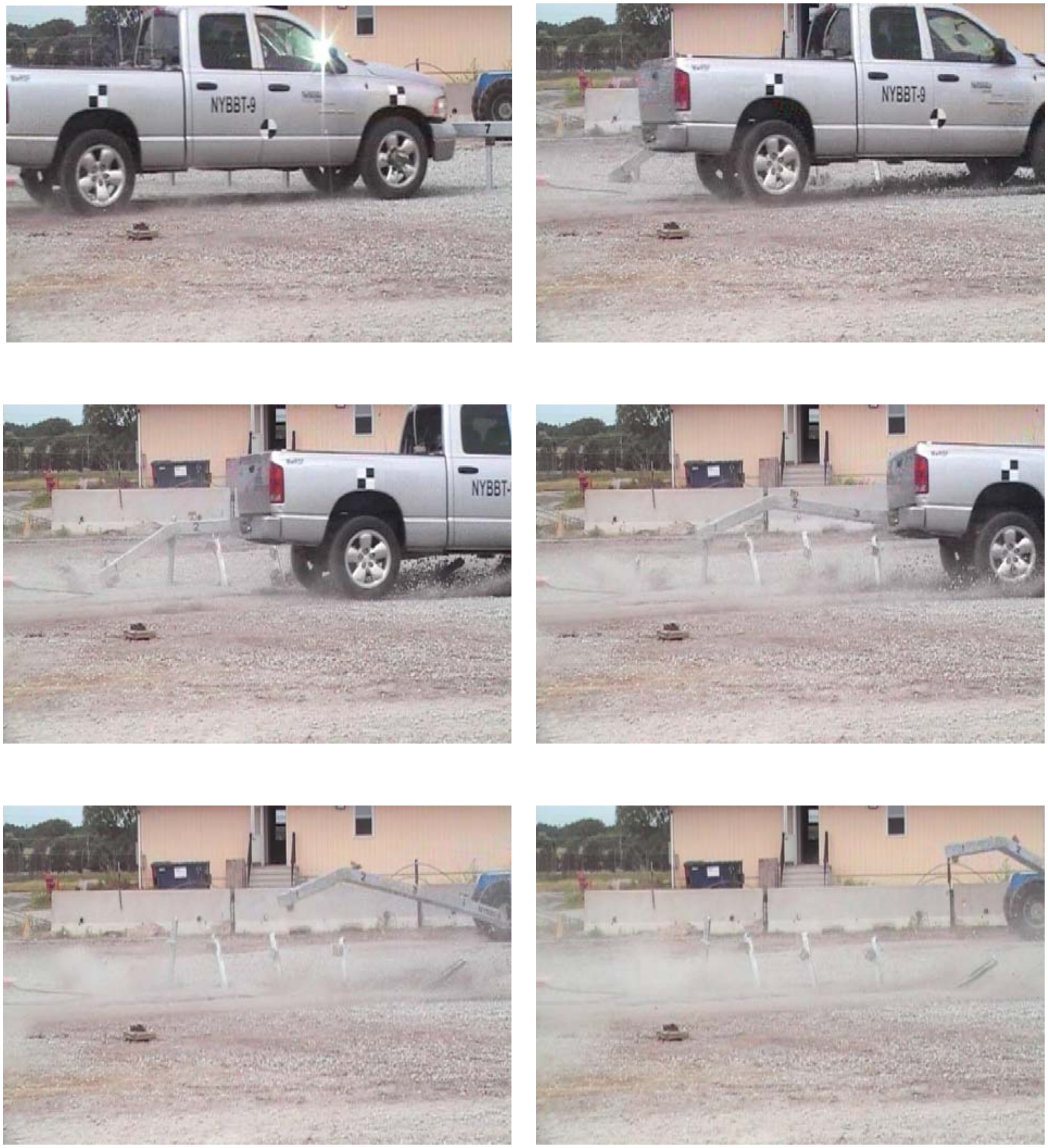

Figure 276. Documentary Photographs, Test No. NYBBT-9

Figure 277. Impact Location, Test No. NYBBT-9

Figure 278. Vehicle Final Position and Trajectory Marks, Test No. NYBBT-9

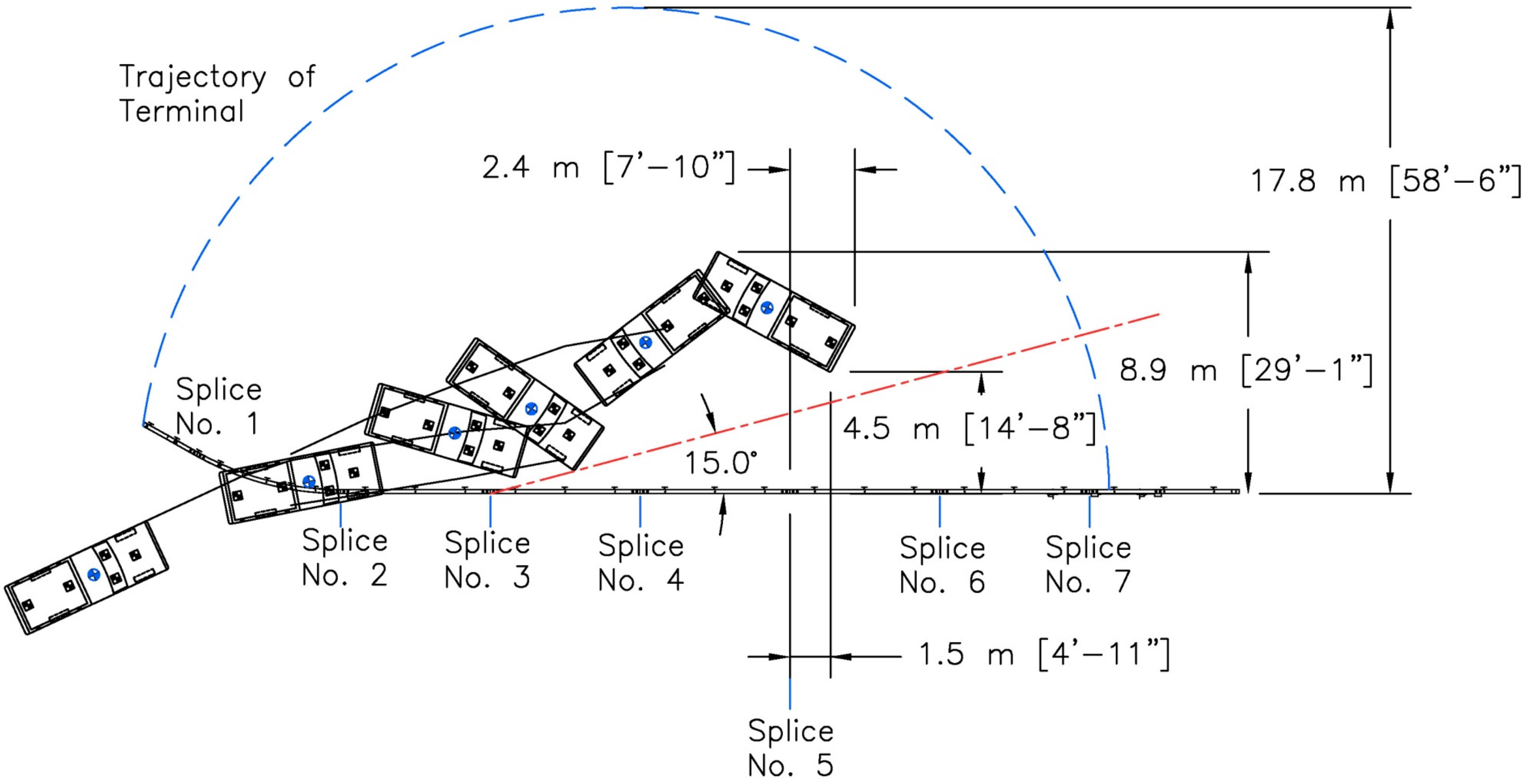

Figure 279. Vehicle Positions During Gating, Test No. NYBBT-9

Figure 280. Barrier Damage, Test No. NYBBT-9

Figure 281. Barrier Damage, Test No. NYBBT-9

Figure 282. Barrier Damage, Test No. NYBBT-9

Figure 283. Barrier Damage, Test No. NYBBT-9

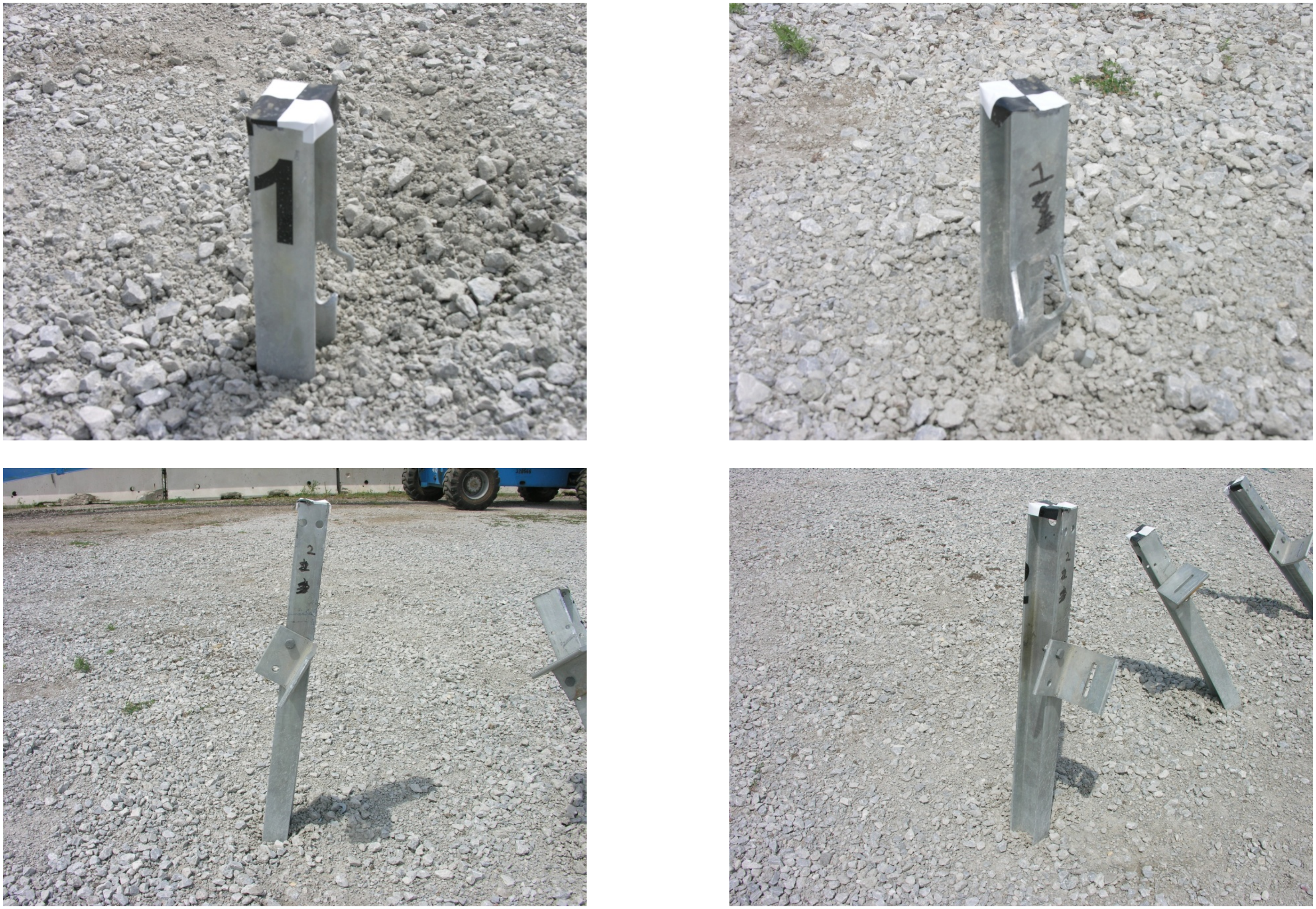

Figure 284. Post Nos. 1 and 2 Damage, Test No. NYBBT-9

Figure 285. Post Nos. 3 and 4 Damage, Test No. NYBBT-9

Figure 286. Post Nos. 5 and 6 Damage, Test No. NYBBT-9

Figure 287. Post Nos. 7 and 8 Damage, Test No. NYBBT-9

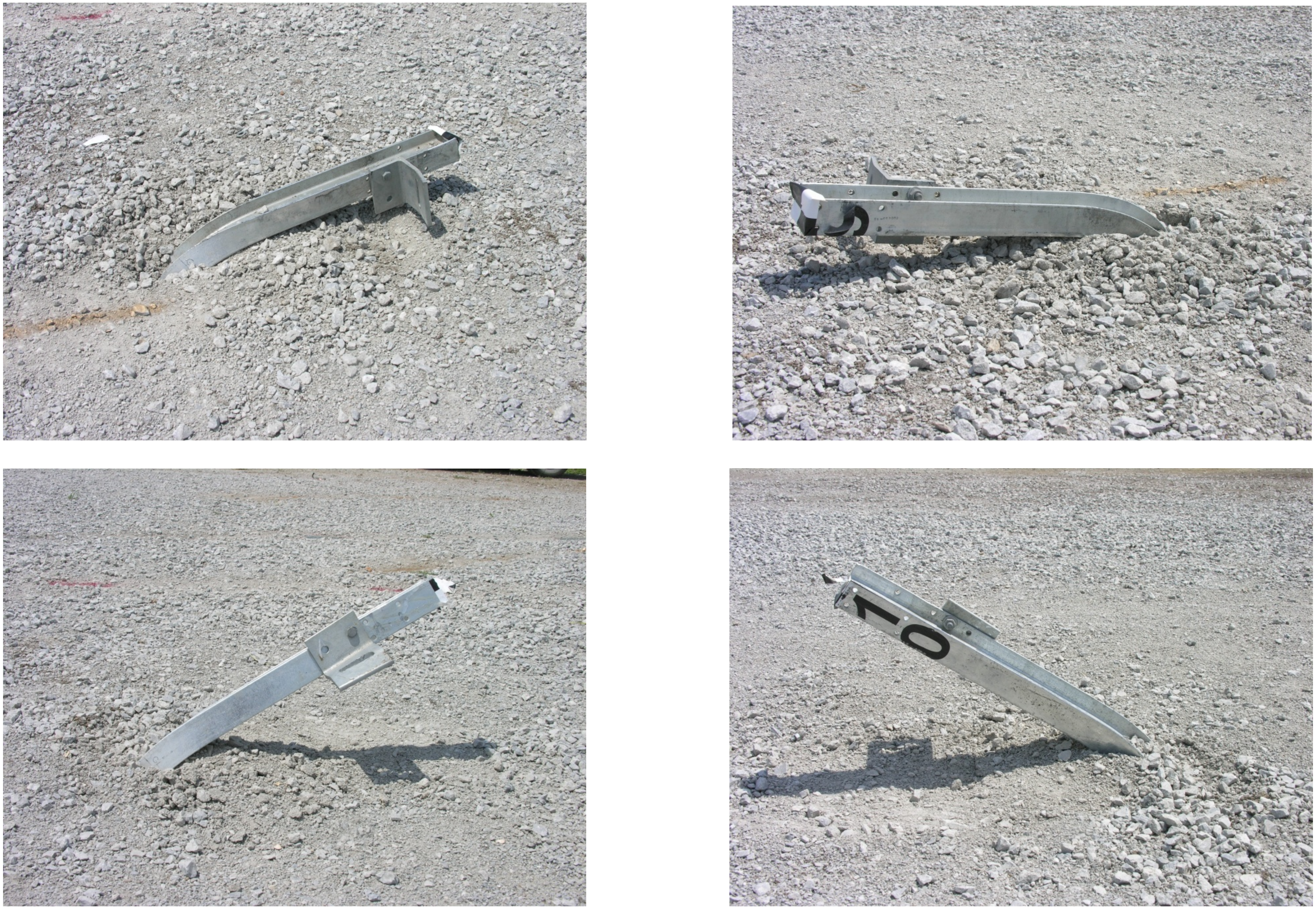

Figure 288. Post Nos. 9 and 10 Damage, Test No. NYBBT-9

Figure 289. Post Nos. 11 and 12 Damage, Test No. NYBBT-9

Figure 290. Post Nos. 13 and 14 Damage, Test No. NYBBT-9

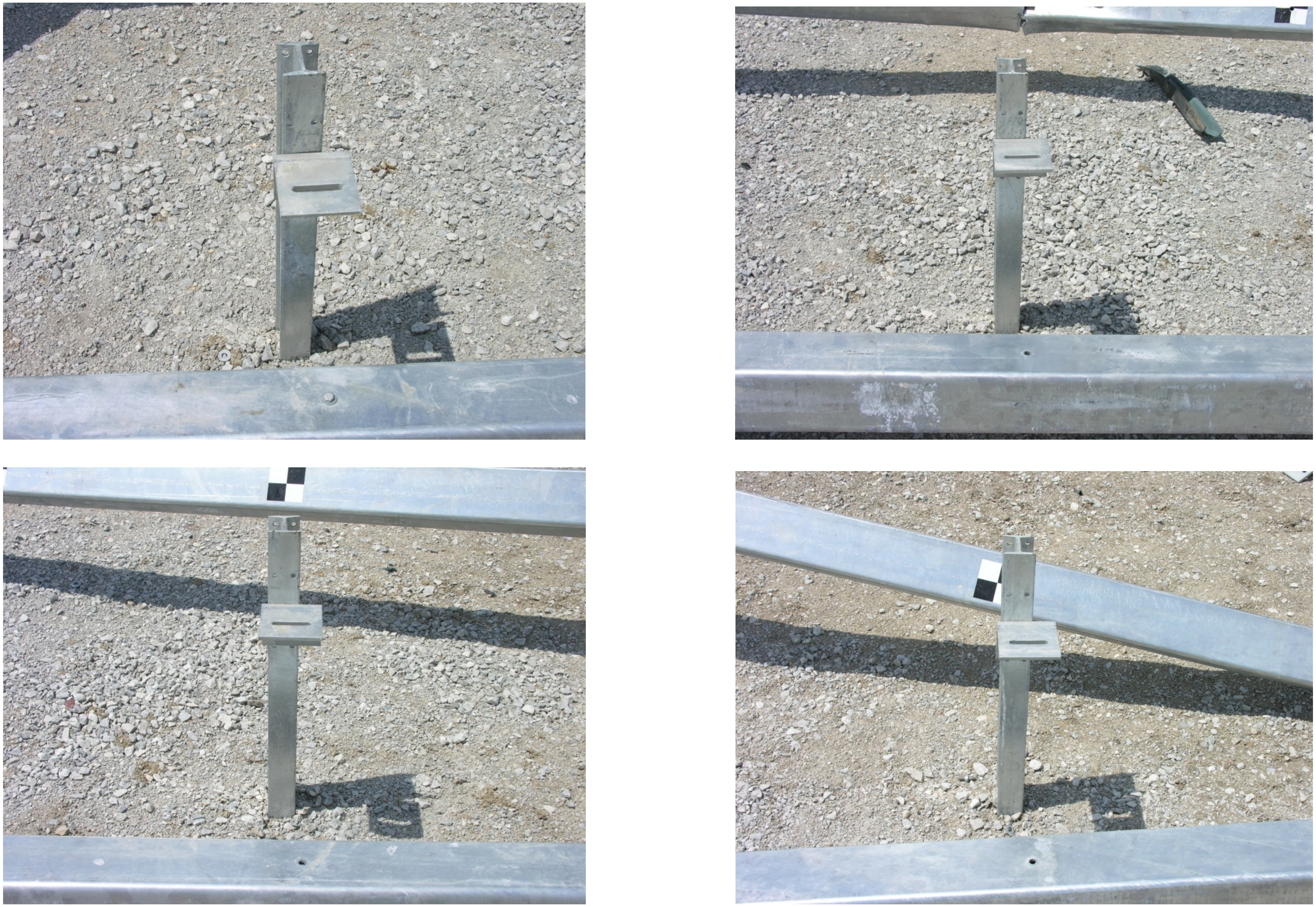

Figure 291. Post Nos. 15 through 18 Damage, Test No. NYBBT-9

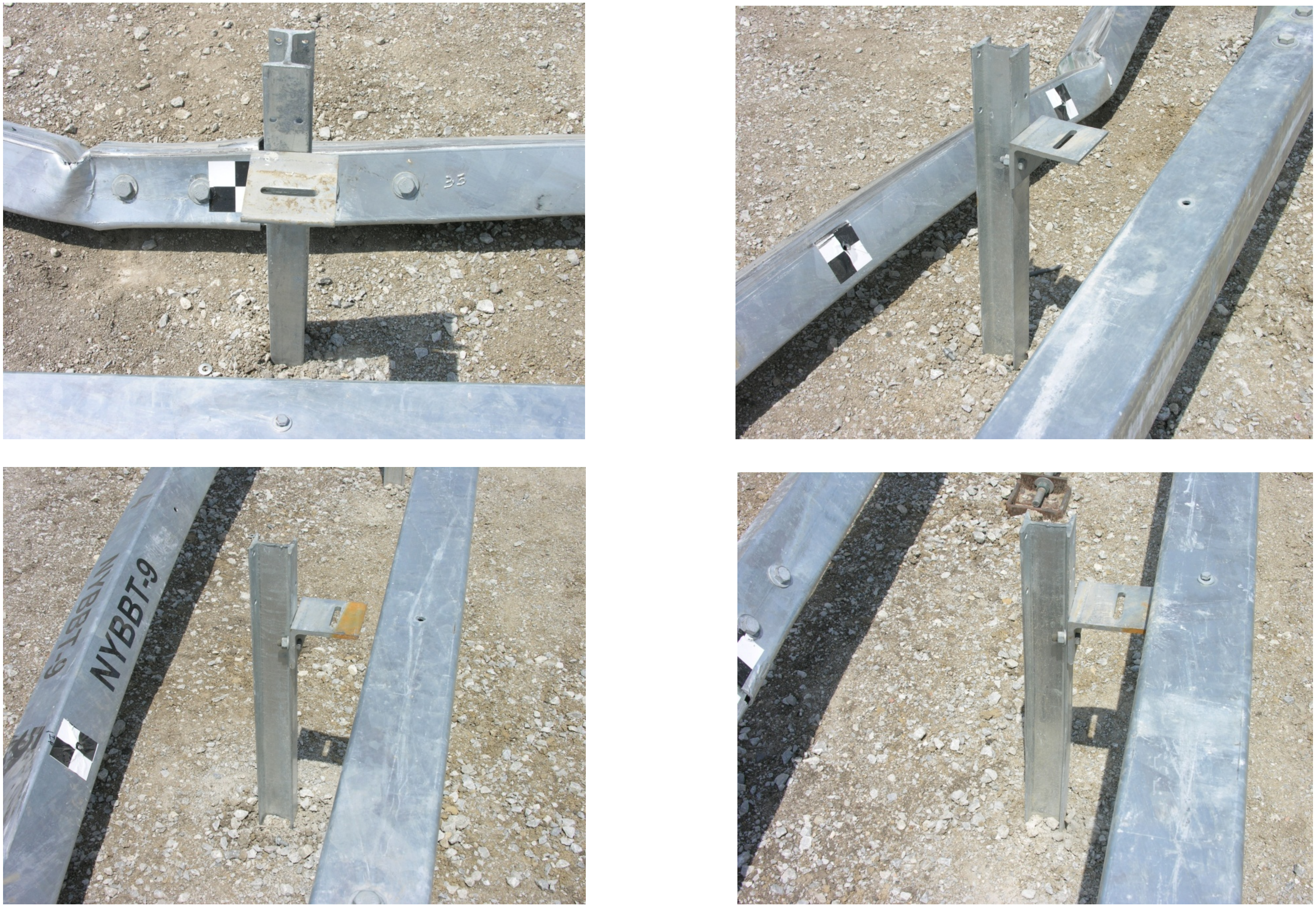

Figure 292. Post Nos. 19 through 22 Damage, Test No. NYBBT-9

Figure 293. End Plate and Splice No. 1 Damage, Test No. NYBBT-9

Figure 294. Splice Nos. 2 and 3 Damage, Test No. NYBBT-9

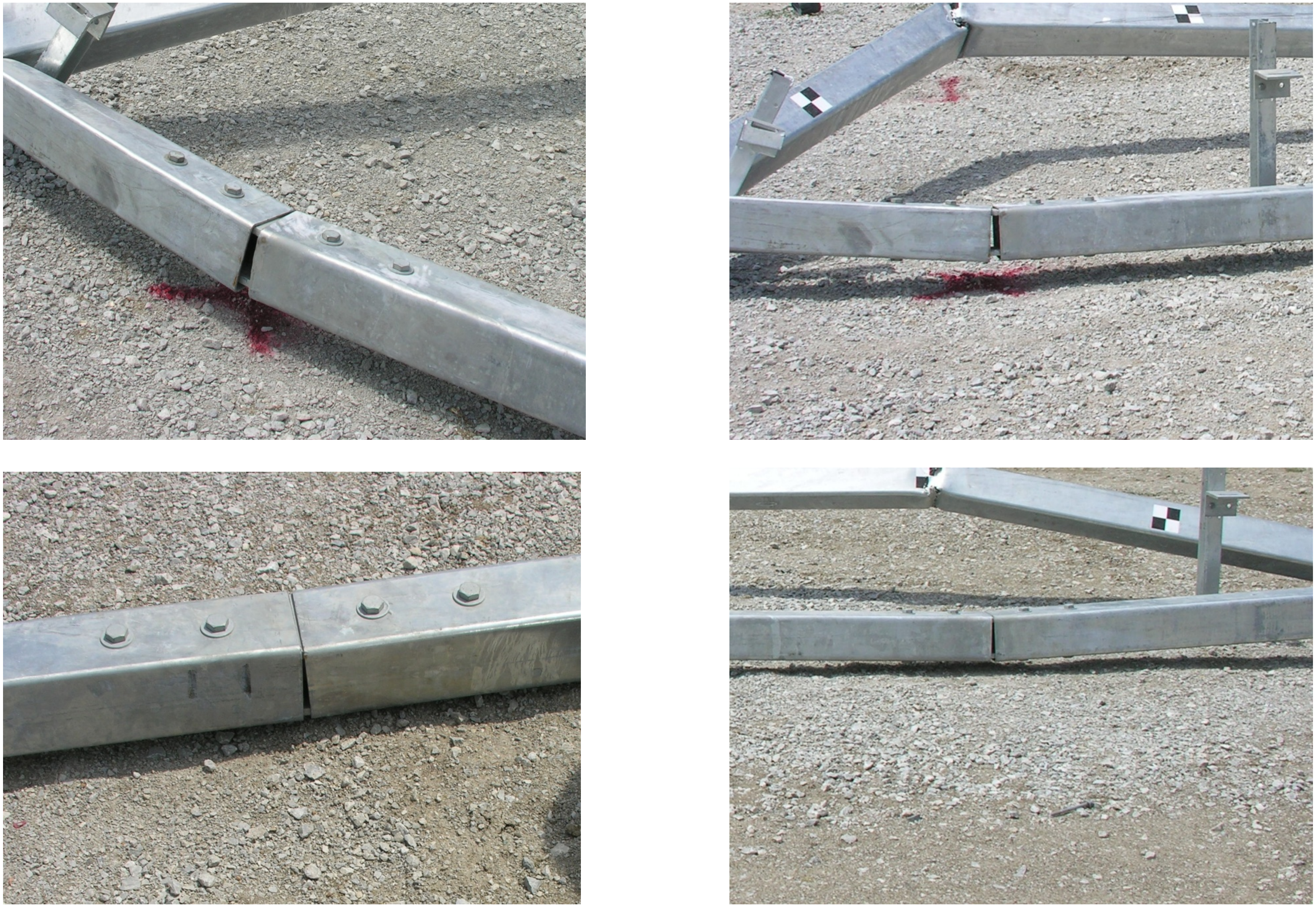

Figure 295. Splice Nos. 4 and 5 Damage, Test No. NYBBT-9

Figure 296. Vehicle Damage, Test No. NYBBT-9

Figure 297. Vehicle Damage, Test No. NYBBT-9

Figure 298. Vehicle Undercarriage Damage, Test No. NYBBT-9

Figure 299. Occupant Compartment Deformation, Test No. NYBBT-9

20 SUMMARY AND CONCLUSIONS

For the research project discussed herein, two NYSDOT box beam end terminal systems were evaluated through the use of full-scale vehicle crash testing in accordance with the TL-3 and TL-2 requirements of MASH guidelines. The two terminal systems included the Type II and Type IIA configurations. However, it should be noted that the Type IIA end terminal system evolved throughout the crash testing program with the incorporation of various design modifications.

Nine full-scale crash tests were performed. One test was completed on the Type II end terminal. Eight tests were performed on the Type IIA end terminal, which included several design variations. Two of the eight tests were performed on a version of the Type IIA end terminal installed in a ditch section. A test summary for the crash tests is provided in Table 24. A summary of the safety performance evaluations for the nine tests is provided in Table 25.

The first test, test no. NYBBT-1, was conducted according to a modified test designation no. 3-32 with a targeted impact angle of 10 degrees per NYSDOT's request. The test consisted of a 1,173-kg (2,586-lb) passenger car impacting the nose of the Type II end terminal at speed of 99.6 km/h (61.9 mph) and at an angle of 7.9 degrees with respect to the tangent. During the crash event, the vehicle climbed on top of and vaulted over the guide rail system, subsequently rolling over and landing on the back side of the system. Thus, the test was judged to be unacceptable according to the safety performance criteria in MASH due to vehicle rollover.

The second test, test no. NYBBT-2, was conducted according to a modified test designation no. 3-30 with the left quarter-point of the vehicle aligned with the centerline of the tangent portion of the box beam rail. The test consisted of a 1,158-kg (2,553-lb) passenger car impacting the Type IIA end terminal at a speed of 101.8 km/h (63.2 mph) and at an angle of 1.6

degrees with respect to the tangent. After impact, the vehicle was safely contained, redirected, and brought to a controlled stop. Thus, the test was judged to be acceptable according to the safety performance criteria provided in MASH.

The third test, test no. NYBBT-3, was conducted according to test designation no. 3-34 with the right-front corner of the vehicle aligned with the centerline of post no. 3. The test consisted of a 1,176-kg (2,593-lb) passenger car impacting the Type IIA end terminal at a speed of 102.5 km/h (63.7 mph) and at an angle of 16.6 degrees with respect to the tangent. After impact, the vehicle was safely contained, redirected, and brought to a controlled stop. Thus, the test was judged to be acceptable according to the safety performance criteria provided in MASH.

The fourth test, test no. NYBBT-4, was conducted according to test designation no. 3-35 with the right-front corner of the vehicle aligned with the beginning of the tangent section of box beam. The test consisted of a 2,348-kg (5,176-lb) pickup truck impacting the modified Type IIA end terminal at a speed of 100.0 km/h (62.1 mph) and at an angle of 22.9 degrees with respect to the tangent. The design modifications for the Type IIA end terminal are summarized in Table 24. The vehicle overrode the guide rail and subsequently rolled over. Thus, the test was judged to be unacceptable according to the safety performance criteria provided in MASH due to vehicle rollover.

The fifth test, test no. NYBBT-5, was conducted according to test designation no. 3-35 with the right-front corner of the vehicle aligned with the beginning of the tangent section of box beam. The test consisted of a 2,354-kg (5,190-lb) pickup truck impacting the further modified Type IIA end terminal at a speed of 99.9 km/h (62.1 mph) and at an angle of 23.6 degrees with respect to the tangent. Once again, the design modifications for the Type IIA end terminal are summarized in Table 24. The vehicle was safely contained, redirected, and brought to a controlled stop. Thus, the test was judged to be acceptable according to the safety performance criteria provided in MASH.

The sixth test, test no. NYBBT-6, was conducted according to a modified test designation no. 2-34 with the right-front corner of the vehicle aligned with the centerline of post no. 2 per NYSDOT's request. The test consisted of a 1,176-kg (2,593-lb) passenger car impacting the modified Type IIA end terminal installed in a ditch section at a speed of 73.6 km/h (45.7 mph) and at an angle of 7.5 degrees with respect to the tangent. The box beam guide rail and end terminal hardware was identical to that used in test no. NYBBT-5, as summarized in Table 24. The vehicle underrode the barrier, and extensive occupant compartment deformations and intrusions occurred. Thus, the test was judged to be unacceptable according to the safety performance criteria provided in MASH due to extensive occupant compartment deformation and intrusion.

The seventh test, test no. NYBBT-7, was conducted according to a modified test designation no. 3-35 with the right-front corner of the vehicle aligned with the centerline of post no. 5 per NYSDOT's request. The test consisted of a 2,351-kg (5,184-lb) pickup truck impacting the modified Type IIA end terminal installed in a ditch section at a speed of 100.8 km/h (62.6 mph) and at an angle of 25.8 degrees with respect to the tangent. The box beam guide rail and end terminal hardware was identical to that used in test nos. NYBBT-5 and NYBBT-6, as summarized in Table 24. The vehicle overrode the barrier, subsequently rolling over and landing in the ditch on the back side of the system. Thus, the test was judged to be unacceptable according to the safety performance criteria provided in MASH.

The eighth test, test no. NYBBT-8, was conducted according to test designation no. 3-34 with the left-front corner of the vehicle aligned with the centerline of post no. 3. The test consisted of a 1,183-kg (2,608-lb) passenger car impacting the modified Type IIA end terminal at a speed of 101.5 km/h (63.1 mph) and at an angle of 16.9 degrees with respect to the tangent. The design modifications for the Type IIA end terminal are summarized in Table 24. After impact, the vehicle was safely contained, redirected, and brought to a controlled stop. Thus, the test was judged to be acceptable according to the safety performance criteria provided in MASH.

The ninth test, test no. NYBBT-9, was conducted according to a modified test designation no. 3-35 with the left-front corner of the vehicle aligned with the centerline of the vertical bolt at the midpoint of the rail at post no. 5 per NYSDOT's request. The test consisted of a 2,340-kg (5,159-lb) pickup truck impacting the modified Type IIA end terminal at a speed of 101.9 km/h (63.3 mph) and at an angle of 25.0 degrees with respect to the tangent. The box beam guide rail and end terminal hardware was identical to that used in NYBBT-8, as summarized in Table 24. The vehicle penetrated through the end terminal and safely came to a controlled stop behind the system. Thus, the test was judged to be acceptable according to the safety performance criteria provided in MASH.

Following the completion of the NYSDOT's crash testing program, it should be noted that five tests were successfully performed on the Type IIA box beam end terminal and its associated design variations. The following conclusions were made:

(1) Test no. NYBBT-2 was successfully performed using a modified test designation no. 3-30. This crash test was performed on the initial Type IIA configuration that did not contain the additional guide rail posts along the terminal length. However, it is the researcher's opinion that the safety performance would not have been significantly degraded had the vehicle encountered the additional steel support posts used in test nos. NYBBT-5, NYBBT-8, and NYBBT-9.

(2) Test no. NYBBT-3 was successfully performed using test designation no. 3-34. This crash test was also performed on the initial Type IIA configuration that did not contain the additional guide rail posts along terminal length. Once again, it is the researcher's opinion that the safety performance would not have been significantly

degraded had the vehicle encountered the additional steel support posts used in test nos. NYBBT-5, NYBBT-8, and NYBBT-9.

(3) Test no. NYBBT-5 was successfully performed using test designation no. 3-35. This crash test was performed on a modified version of the Type IIA configuration that contained additional guide rail posts along the terminal length beyond those used in test nos. NYBBT-2 and NYBBT-3.

(4) Test no. NYBBT-8 was successfully performed using test designation no. 3-34. This crash test was performed on a modified version of the Type IIA configuration that contained additional guide rail posts along the terminal length beyond those used in test nos. NYBBT-2 and NYBBT-3.

(5) Test no. NYBBT-9 was successfully performed using a modified test designation no. 3-35. This crash test was performed on a modified version of the Type IIA configuration that contained additional guide rail posts along the terminal length beyond those used in test nos. NYBBT-2 and NYBBT-3.

Table 24. Summary of Crash Tests

Test No.	System Description	Test Designation No.	MASH Target Impact Conditions	Modified Impact Conditions	Impact Location	Test Results
NYBBT-1	Type II	Modified 3-32	1100C- 100 km/h @ 5-15 deg w/ centerline on nose of terminal	10 deg w/ impact side tires just missing end terminal	Nose of terminal w/ impact side tires just missing end terminal	Fail – vehicle rollover
NYBBT-2	Type IIA	Modified 3-30	1100C - 100 km/h @ 0 deg @ ¼-pt offset on nose toward front of system (right side ¼-pt)	¼-pt offset on nose toward back of system (left side ¼-pt)	Left side ¼-pt aligned w/ centerline tangent beam	Pass
NYBBT-3	Type IIA	3-34	1100C - 100 km/h @ 15 deg @ CIP of terminal		Right-front corner positioned @ post no. 3	Pass
NYBBT-4	Modified Type IIA (longer posts 1-3 and moved to front side, shelf angles added to top @ posts 2-3 w/ 13 mm (1/2 in.) dia. connecting bolts)	3-35	2270P - 100 km/h @ 25 deg @ beginning of LON of terminal	Impact @ point of tangency	Right-front corner positioned @ midspan between post nos. 5 and 6	Fail – vehicle rollover
NYBBT-5	Modified Type IIA (3 intermediate posts added between posts 2-5 and placed on back side, new post 3 not connected to box beam)	3-35	2270P - 100 km/h @ 25 deg @ beginning of LON of terminal	Impact @ point of tangency	Right-front corner positioned @ midspan between post nos. 8 and 9	Pass
NYBBT-6	Modified Type IIA in 2:1 ditch (Same system as in NYBBT-5)	Modified 2-34	1100C - 70 km/h @ 15 deg @ CIP of terminal	7.5 deg @ centerline of post no. 2 (selected by NYSDOT)	Right-front corner positioned @ centerline of post no. 2	Fail – extensive roof/windshield crush, occupant compartment intrusion
NYBBT-7	Modified Type IIA in 2:1 ditch (Same system as in NYBBT-5)	Modified 3-35	2270P - 100 km/h @ 25 deg @ beginning of LON of terminal	Impact @ the center of curved nose piece	Right-front corner positioned @ centerline of post no. 5	Fail – vehicle rollover
NYBBT-8	Modified Type IIA (Posts 1, 2, and 4 moved to back side)	3-34	1100C - 100 km/h @ 15 deg @ CIP of terminal		Left-front corner positioned @ centerline of post no. 3	Pass
NYBBT-9	Modified Type IIA (Same system as in NYBBT-8)	Modified 3-35	2270P - 100 km/h @ 25 deg @ beginning of LON of terminal	Impact @ the center of curved nose piece	Left-front corner positioned @ centerline of vertical bolt at midpoint of rail at post no. 5	Pass

Table 25. Summary of Safety Performance Evaluation Results

Evaluation Factors	Evaluation Criteria	Test No.								
		NYBBT-1 (Type II)	NYBBT-2 (Type IIA)	NYBBT-3 (Type IIA)	NYBBT-4 (Type IIA)	NYBBT-5 (Type IIA)	NYBBT-6 (Type IIA in Ditch)	NYBBT-7 (Type IIA in Ditch)	NYBBT-8 (Type IIA)	NYBBT-9 (Type IIA)
Structural Adequacy	A.	NA	NA	NA	U	S	NA	U	NA	S
	C.	U	S	S	NA	NA	S	NA	S	NA
Occupant Risk	D.	S	S	S	S	S	U	S	S	S
	F.	U	S	S	U	S	S	U	S	S
	H.	S	S	S	S	S	S	S	S	S
	I.	S	S	S	S	S	S	S	S	S
Vehicle Trajectory	N.	S	S	S	NA	NA	S	NA	S	NA
MASH Test Designation No.		Modified 3-32	Modified 3-30	3-34	3-35	3-35	Modified 2-34	Modified 3-35	3-34	Modified 3-35
Test Results		Fail	Pass	Pass	Fail	Pass	Fail	Fail	Pass	Pass

S - Satisfactory U – Unsatisfactory NA - Not Applicable

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