September 5, 2002

HSA-10/ B105

Phil TenHulzen, P.E.
Standard Plans Engineer
Nebraska Department of Roads
PO Box 94759
Lincoln, NE 68509-4759

Dear Mr. TenHulzen:

In response to your e-mail request last May, please be advised that the Nebraska Bridge Approach Section described in the Texas Transportation Institute's report entitled "NCHRP Report 350 Test 3-21 of the Nebraska Thrie-Beam Transition" may be considered a test level 3 (TL-3) transition design and used on the National Highway System when such use is acceptable to the contracting agency.

Your non-proprietary design consists of 3810 mm of nested 12-gauge Thrie-beam supported on two W150 x 37 x 2591-mm long steel posts, followed by four 150W x 22 x 2134-mm long steel posts. The first post from the bridge is 1220 mm from the concrete parapet and the next four posts are on 952-mm centers. A similar design using 250 x 250 x 2591-mm long wood posts and 200 x 200 x 2135-mm long wood posts for their steel post counterparts is also acceptable. A TS 102 x 102 x 7.9 steel tube spans the gap between the bridge end and the first post and connects to each with special steel brackets. This tube is used to support a wood offset block centered approximately 300 mm from the end of the concrete parapet. These and other details are included in the enclosed test report.

The enclosed test report indicates that a "pipe spacer" between the concrete parapet and the nested Thrie-beam elements was crushed 25 mm in the test. As can be seen in the photographs, and as you later verified, your design does not incorporate a spacer. However, the end of the parapet was damaged in the crash and there was significant snagging on the concrete underneath the Thrie-beam rail. Nevertheless, all Report 350 evaluation criteria were met as noted on the test results summary sheet included in the report.

I understand that CAD drawings of this design are available through your office upon request and that you can be contacted directly via e-mail at ptenhulz@dor.state.ne.us.

Sincerely yours,

(original signed by Carol H. Jacoby)

Carol H. Jacoby, P.E.
Director, Office of safety design

NEBRASKA TRANSITION
(*NCHRP REPORT 350* TEST NO. 3-21)

Test Conditions

The test performed on the Nebraska transition corresponds to *NCHRP Report 350* test designation 3-21. The BARRIER VII simulation program was used to select the CIP for this test. The program indicated the CIP to be 1.8 m from the end of the concrete parapet.

Test Article

The Nebraska thrie beam transition consists of 3810 mm of two nested 12-gauge thrie beam guardrails followed by a 12-gauge W-beam to 12-gauge thrie beam transition piece. This transition piece connected to 7.62 m of W-beam guardrail that was anchored with a LET End Treatment. The height of the thrie beam transition was approximately 804 mm. The height of the W-beam guardrail was approximately 706 mm. TTI received AutoCAD drawing details for this transition from Dr. Ron Faller with Midwest Roadside Safety Facility in September 1999. TTI received additional drawings from FHWA Eastern Federal Lands Highway Division (EFLHD) for the concrete parapet supported by two drilled shafts in February 2000.

TTI constructed 2.23 m of concrete parapet from details provided to TTI by EFLHD. This parapet was 835 mm in height and 350 mm wide. At the guardrail transition end, the parapet tapered from 350 mm wide to 150 mm over a distance of 630 mm. The parapet was supported by a 600-mm × 650-mm footing that was supported by two 450-mm-diameter drilled shafts spaced approximately 1.35 m apart. These drilled shafts extended 3.0 m below the footing, which was constructed flush with grade. Reinforcement in the parapet consisted of #19 "U" shaped and straight vertical bars at 150 mm on centers on each face of the parapet. Horizontal reinforcement in the parapet consisted of eight sets of overlapping #13 "U" and "V" shaped bars equally spaced. Reinforcement in the concrete footing consisted of #13 closed stirrups at 150 mm on centers. These stirrups were not closed in the areas of the vertical reinforcement for the drilled shafts extending into the footing. Longitudinal reinforcement in the footing consisted of 10 #16 bars inside the stirrups. Reinforcement for the drilled shafts consisted of 12 #19 bars equally spaced inside #13 spiral reinforcement. The outside diameter of the spiral reinforcement was approximately 300 mm. The #13 spiral reinforcement was constructed with a 45-mm pitch. The average compressive strength of the parapet and footing concrete measured 31 MPa (4500 psi) and 32 MPa (4636 psi), respectively. All reinforcement used in the parapet was bare steel (not epoxy coated) and had an approximate yield strength of 420 MPa (60 ksi). Details of the parapet are shown on page 1 of figure 42.

The nested thrie beam transition was attached to the concrete parapet with a 10-gauge thrie beam terminal connector attached to the parapet using five 22-mm diameter ASTM A325 bolts. The centerline of post 1 was located approximately 1220 mm from the end of the parapet. The Nebraska thrie beam transition design incorporates a special "hidden post" design using a TS 102 × 102 × 7.9 steel tube that attaches to the end of the parapet and is supported by post 1. This steel tube supports a

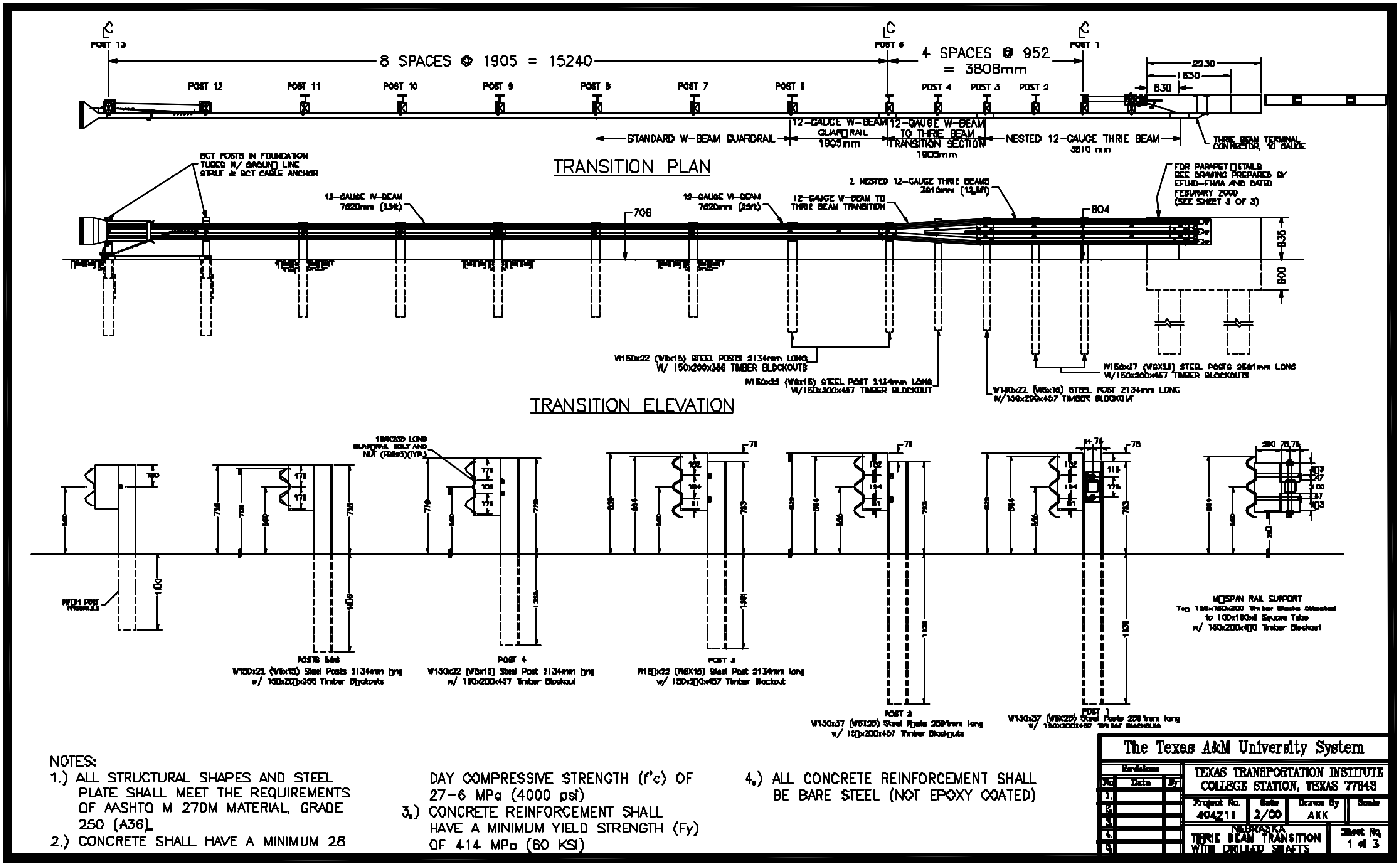


Figure 42. Details of the Nebraska thrie beam transition installation for test 404211-7.

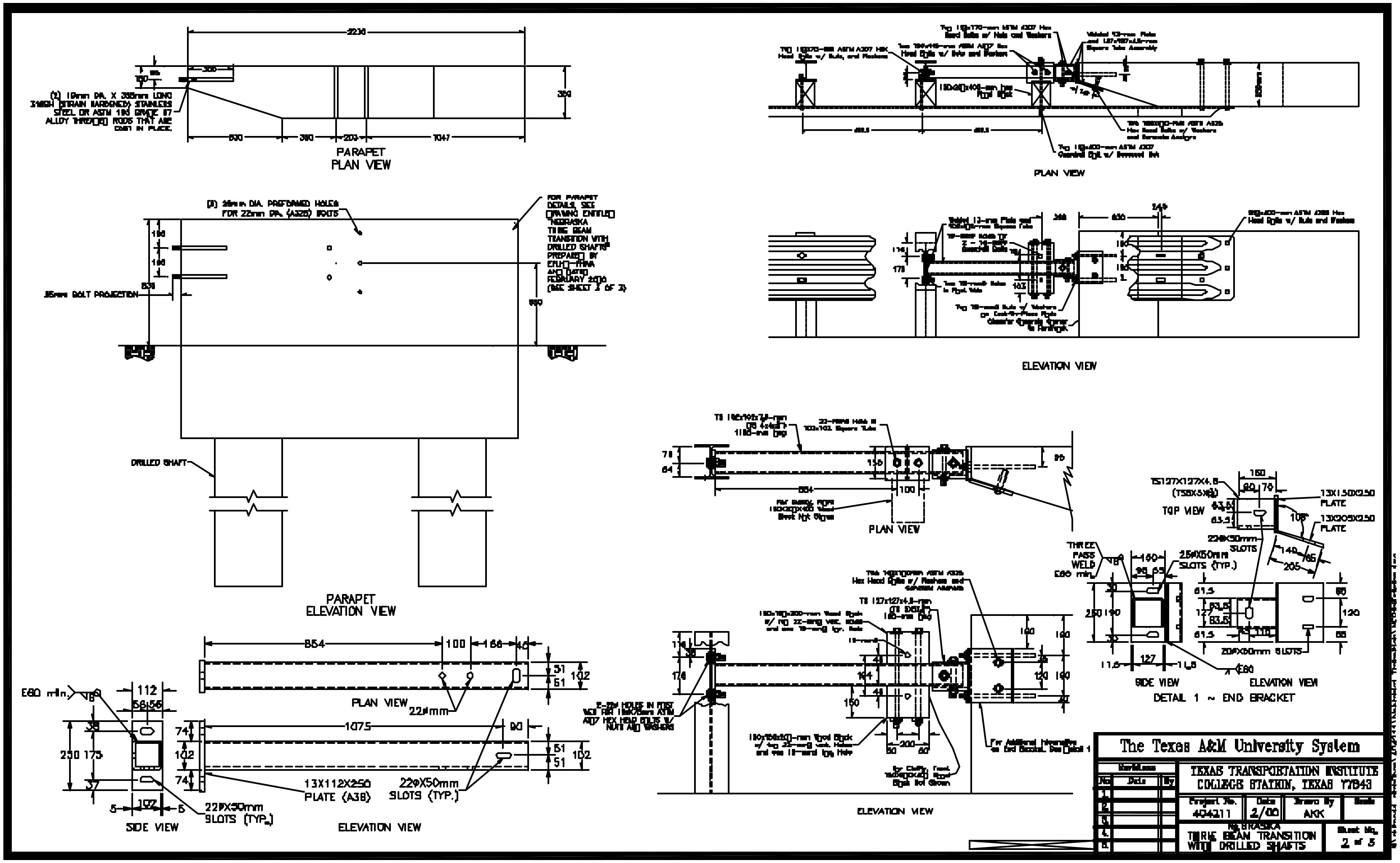


Figure 42. Details of the Nebraska thrie beam transition installation for test 404211-7 (continued).

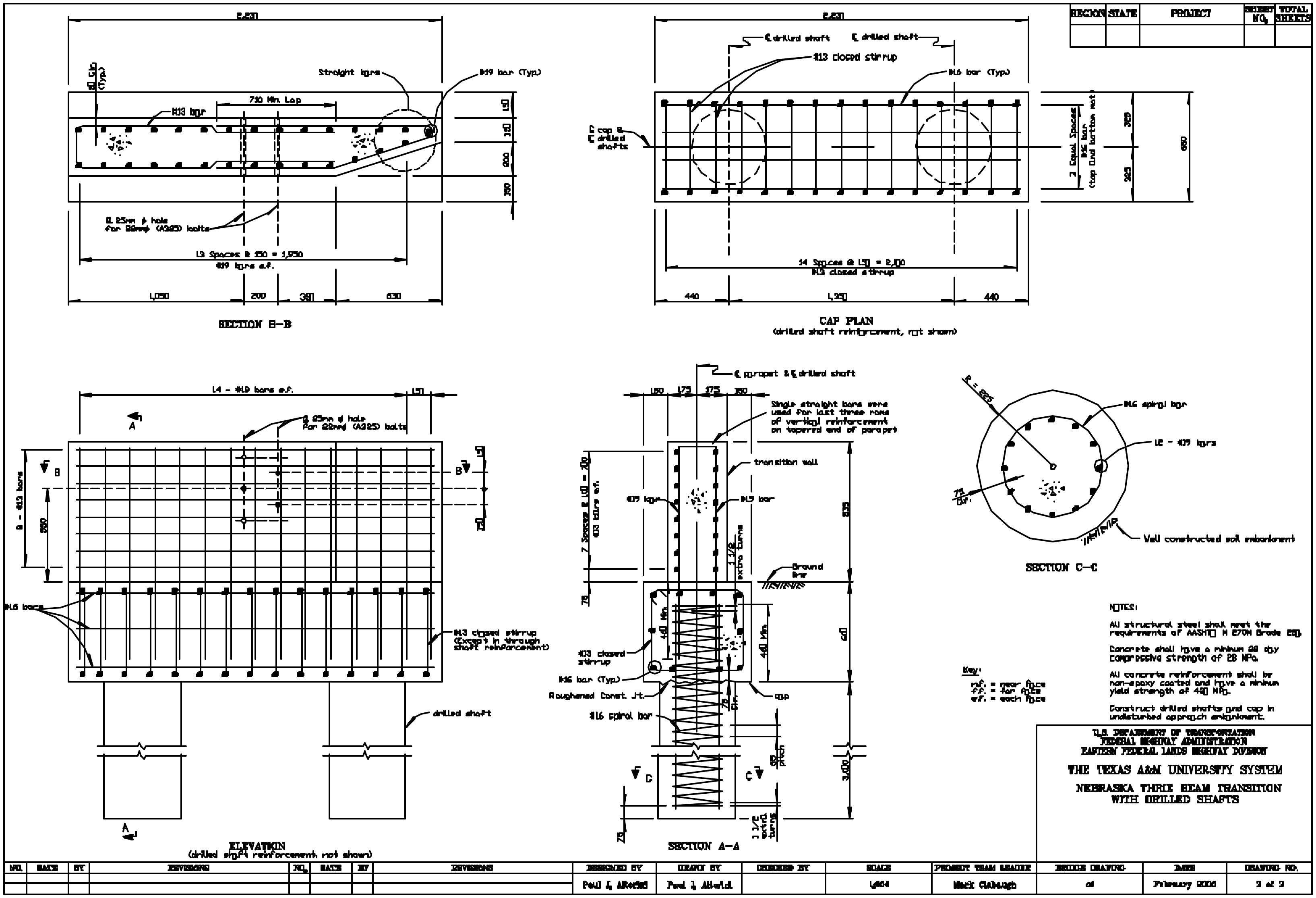


Figure 42. Details of the Nebraska thrie beam transition installation for test 404211-7 (continued).

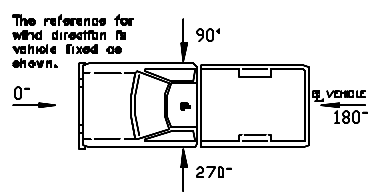
150-mm × 200-mm × 400-mm wood block that is located 298 mm from the end of the parapet, which, in turn, supports the nested thrie beam guardrail without the use of an embedded post at this location. A 112-mm × 250-mm × 13-mm thick A36 steel plate was welded to the end of the tube and was used to attach the steel tube to post 1 using two 22-mm-diameter A307 bolts that bolted through the plate and web of post 1. The steel tube is supported at the parapet by a steel plate bracket fabricated from 13-mm-thick plate with a 160-mm-long piece of TS 127 × 127 × 4.8 steel tube welded to the plate bracket. The TS 102 × 102 × 7.9 steel tube supporting the "hidden post" blockout fits inside the TS 127 × 127 × 4.8 tube welded to the bracket and is bolted with two 19-mm-diameter A307 bolts, 170 mm in length. The steel bracket was attached to the parapet with two 16-mm-diameter A325 mechanical anchors located on the sloped surface of the parapet. In addition, the bracket was secured with two chemically anchored ASTM 193 Grade B7 fully threaded rods embedded 300 mm at the end of the parapet. These bolts projected out from the end of the parapet approximately 55 mm.

Posts 1 through 5 were spaced approximately 952 mm apart. Between posts 5 and 9 the post spacing was approximately 1905 mm. The posts were spaced approximately 1905 mm apart in the LET end anchorage system. Posts 1 and 2 were W150 × 37 steel posts, approximately 2591 mm in length, and embedded approximately 1838 mm below grade. Posts 3 through 6 were W150 × 22 steel posts, and 2134 mm in length. Posts 3, 4, 5, and 6 were embedded below grade approximately 1381 mm, 1355 mm, 1406 mm, and 1406 mm, respectively. Posts 7 through 9 were W150 × 13.5 steel posts, approximately 1830 mm in length, and embedded approximately 1100 mm below grade.

Wood blockouts were used at posts 1 through 13. Wood blockouts were not required for posts 14 and 15. For posts 1 through 4, 150-mm × 200-mm × 457-mm long wood blocks were used between the guardrail and posts. At posts 5 and 6, 150-mm × 200-mm × 356-mm long wood blockouts were used between the guardrail and posts. For posts 7 through 9, 150-mm × 200-mm × 356-mm routed wood blockouts were used between the guardrail and posts. Posts 1–4 used two 16-mm-diameter by 255-mm-long guardrail bolts and nuts to secure the guardrail and blockout to each post. In addition, posts 5–9 used one 16-mm-diameter by 255-mm-long guardrail bolt and nut to secure the guardrail and blockout to each post. Longer 16-mm-diameter bolts (460 mm) were used for the wood posts in the LET end anchorage system. All posts were embedded in compacted *NCHRP Report 350* standard soil with the moisture content within 4% +/- of optimum moisture content of the material. Additional detail drawings are shown on pages 2 and 3 of figure 42. Photographs of the completed test installation are shown in figure 43.

Soil and Weather Conditions

The crash test was performed the morning of May 16, 2000. Seven days prior to the test 38 mm of rainfall was recorded, and four days prior to the test 10 mm of rainfall was recorded. Soil moisture content was 5.6 percent, 7.0 percent, and 8.6 percent at posts 1, 3, and 5, respectively. Weather conditions at the time of testing were as follows: wind speed: 24 km/h; wind direction: 15 degrees with respect to the vehicle (vehicle was traveling in a southeasterly direction); temperature: 32EC; relative humidity: 55 percent.



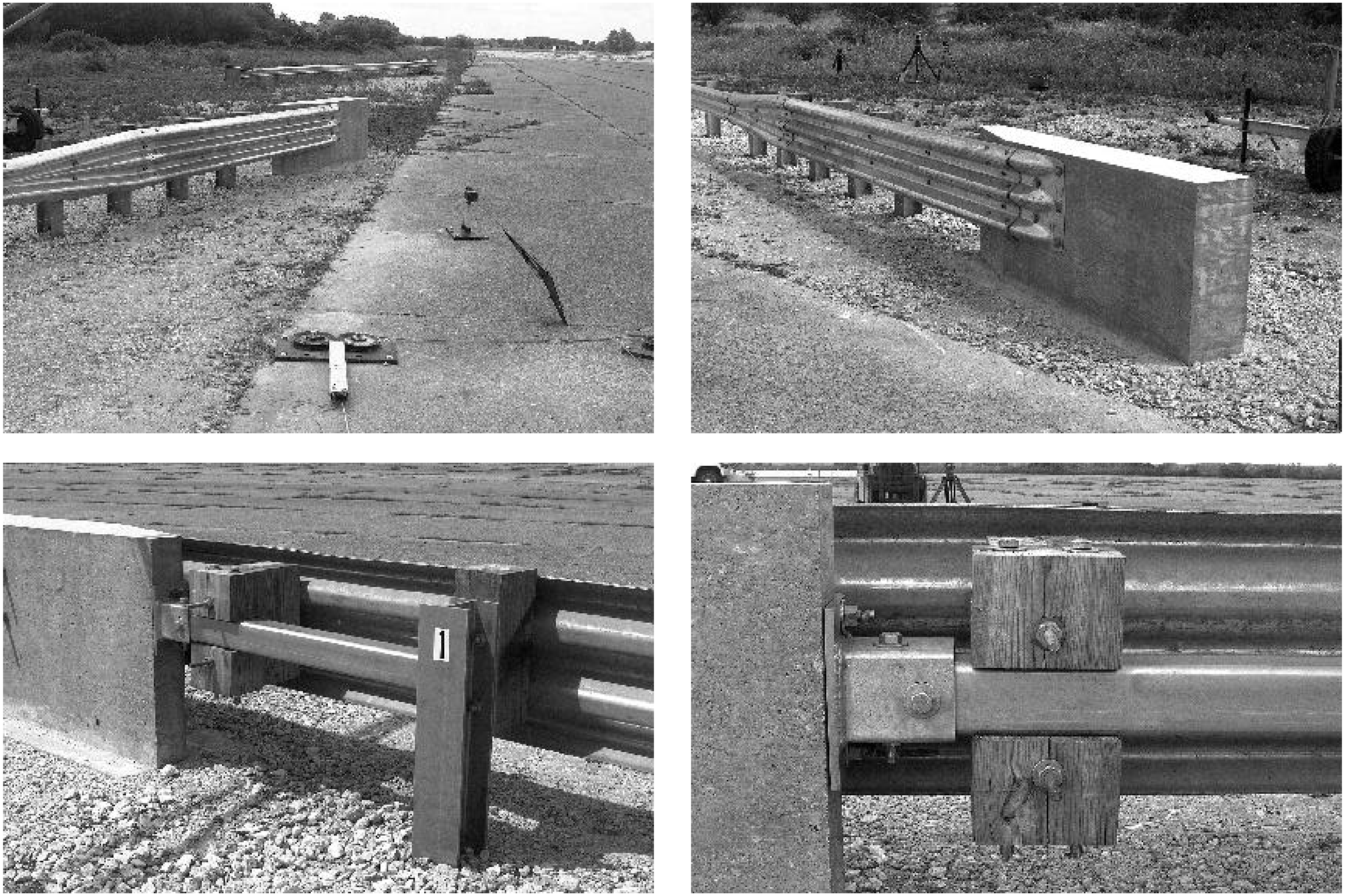


Figure 43. Nebraska thrie beam transition prior to test 404211-7.

Test Vehicle

A 1995 Chevrolet 2500 pickup truck, shown in figure 44, was used for the crash test. Test inertia weight of the vehicle was 2000 kg, and its gross static weight was 2075 kg. The height to the lower edge of the vehicle front bumper was 370 mm and to the upper edge of the front bumper was 590 mm. Additional dimensions and information on the vehicle are given in appendix B, figure 86.

Impact Description

The 2000P vehicle traveling at 99.6 km/h impacted the transition 1.93 m from the end of the parapet at an impact angle of 24.6 degrees. Shortly after impact, posts 1 and 2 moved. At 0.022 s the left front wheel steered away from the rail and the vehicle began to redirect. At 0.027 s post 3 moved. The left front tire was traveling parallel with the rail at 0.037 s and began to angle under the rail element at 0.039 s. At 0.066 s movement was noted in the concrete parapet and at 0.095 s the left front tire contacted the end of the parapet. The dummy's head contacted the door glass at 0.120 s, but the glass did not break. The vehicle became parallel with the rail at 0.174 s and was traveling at a speed of 8l.6 km/h. The left rear of the vehicle impacted the rail at 0.186 s. At 0.298 s the vehicle lost contact with the transition and was traveling 78.3 km/h and an exit angle of 6.8 degrees. As the vehicle exited the transition both rear wheels were airborne. The left rear tire touched ground at 0.657 s. Brakes on the vehicle were applied at 1.75 s after impact, the vehicle yawed counterclockwise, and subsequently came to rest 75 m downstream from impact and 6 m forward of the front face of the transition. Sequential photographs of the test period are shown in appendix C, figures 106 and 107.

Damage to Test Article

The Nebraska thrie beam transition sustained minimal damage as shown in figure 45. No movement was noted in the end terminal. Posts 4 and 5 were disturbed, post 3 moved rearward 4 mm, and post 2 was pushed rearward 20 mm. The corner of the blockout at post 1 was missing and the post was pushed back 15 mm. The pipe spacer between the parapet and rail element was crushed 25 mm and the parapet base was disturbed 2 mm. Tire marks were on the flare of the parapet and cracks in the end of the parapet radiated from the bolts connecting the thrie beam. Length of contact of the vehicle with the transition was 3.07 m. Maximum dynamic deflection of the rail element during the test was 82 mm and maximum permanent deformation was 24 mm, both occurring at post 2.

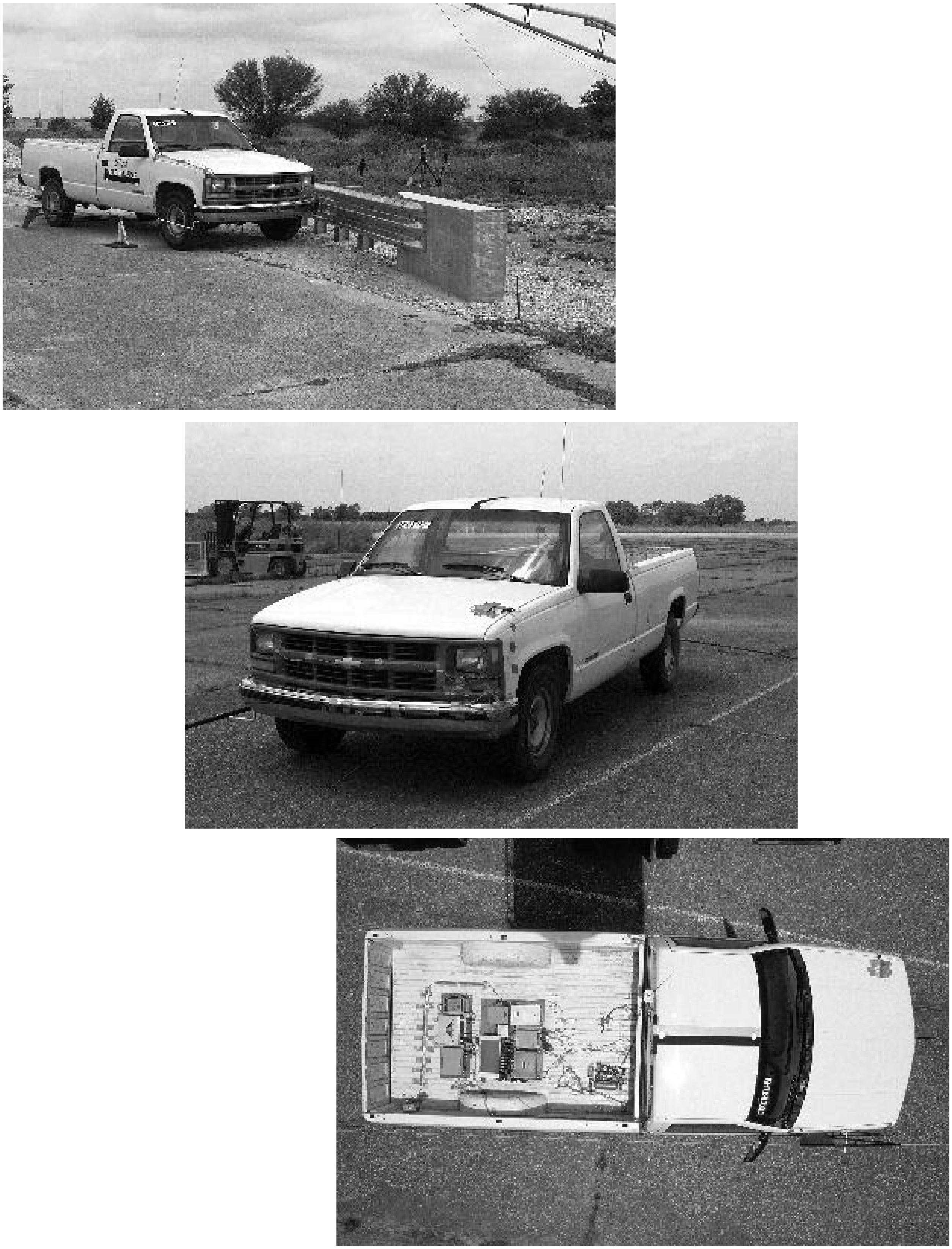


Figure 44. Vehicle before test 404211-7.

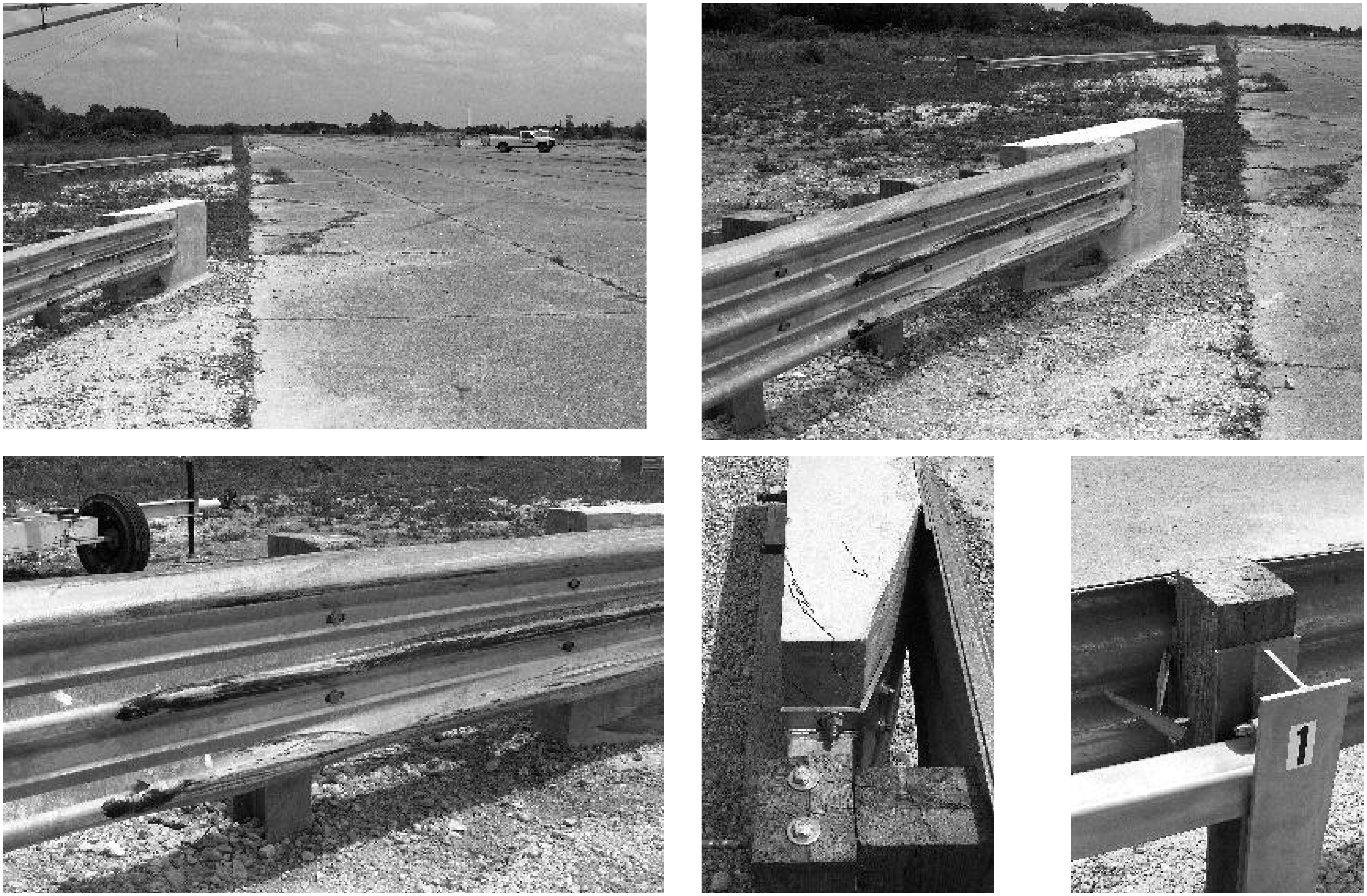


Figure 45. Installation after test 404211-7.

Vehicle Damage

Moderate damage was imparted to the 2000P vehicle as shown in figure 46. The following vehicle components received structural damage: the frame at the left front, steering arm, stabilizer bar, left side rod ends, left upper and lower A-arms, and left front spindle, rotor and tire. Also damaged were the front bumper, fan, radiator, left front quarter-panel, left door, left side of the bed, and the left rear rim. The floor pan and firewall were deformed and the seam where the floor pan and firewall connect were separated. Maximum exterior crush to the left front corner was 400 mm. Maximum interior deformation was 129 mm at the left side floor pan area. Exterior vehicle crush and occupant compartment measurements are shown in appendix B, tables 39 and 40.

Occupant Risk Factors

In the longitudinal direction, occupant impact velocity was 5.0 m/s at 0.100 s, maximum 0.010-s ridedown acceleration was -13.9 g's from 0.114 to 0.124 s, and the maximum 0.050-s average was -8.2 g's between 0.050 and 0.100 s. In the lateral direction, the occupant impact velocity was 8.1 m/s at 0.100 s, the highest 0.010-s occupant ridedown acceleration was 11.9 g's from 0.114 to 0.124 s, and the maximum 0.050-s average was 12.5 g's between 0.050 and 0.100 s. These data and other information pertinent to the test are presented in figure 47. Vehicle angular displacements are presented in appendix D, figure 125, and accelerations versus time traces are shown in appendix E, figures 202 through 212.

Assessment of Test Results

The following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  i. *Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*

  Result: The Nebraska thrie beam transition contained and redirected the vehicle with minimal deformation of the rail element. The 2000P vehicle did not penetrate, underride, or override the installation.

- **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*

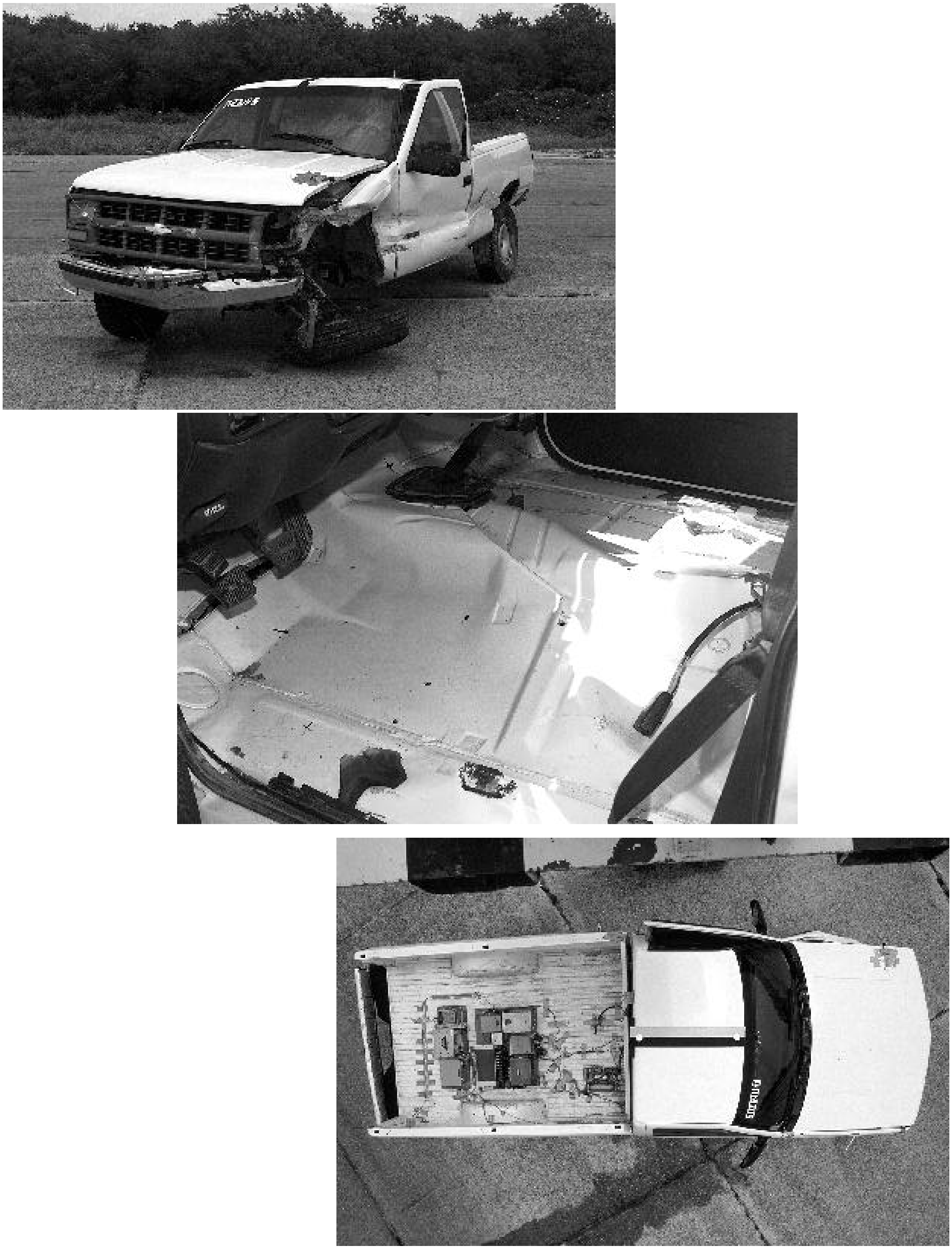
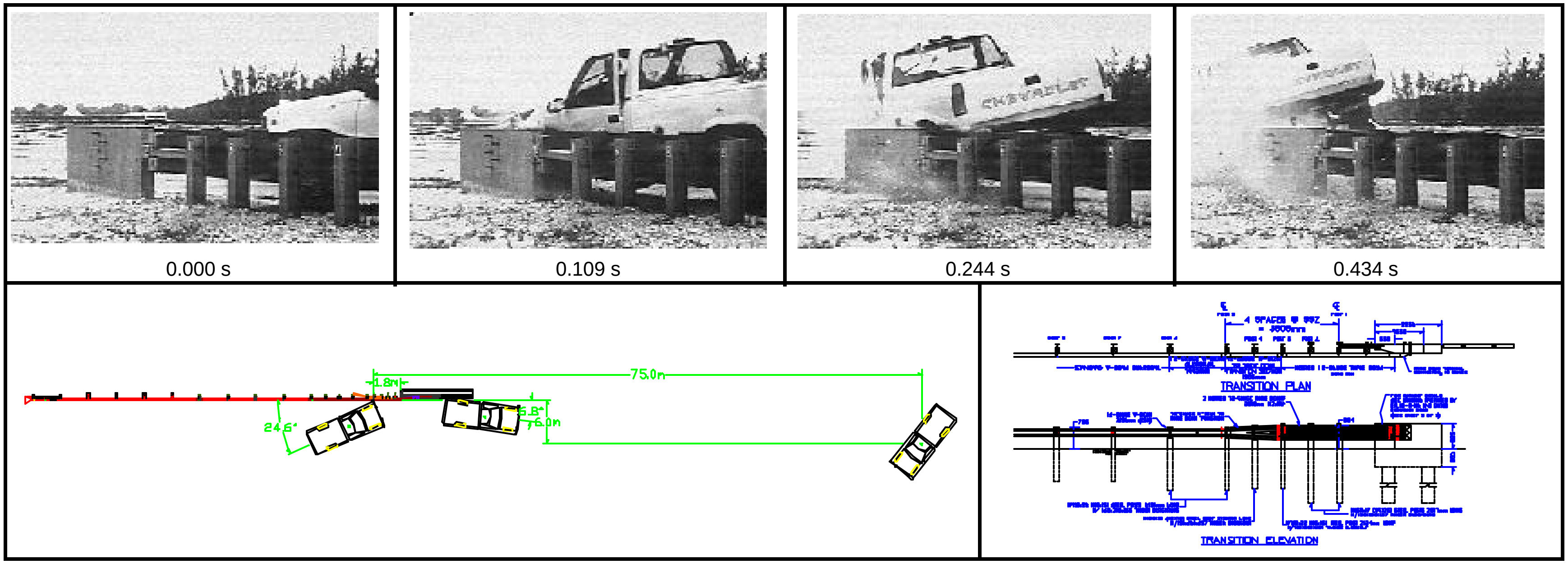


Figure 46. Vehicle after test 404211-7.



General Information

Test Agency	Texas Transportation Institute
Test No.	404211-7
Date	05/17/00

Test Article

Type	Transition
Name	Nebraska Thrie Beam Transition
Installation Length (m)	22.2
Material or Key Elements	Nested Thrie Beam on Steel Posts with Wood Blockouts
Soil Type and Condition	Standard Soil, Dry

Test Vehicle

Type	Production
Designation	2000P
Model	1995 Chevrolet 2500 Pickup Truck
Mass (kg)	
Curb	1932
Test Inertial	2000
Dummy	75
Gross Static	2075

Impact Conditions

Speed (km/h)	99.6
Angle (deg)	24.6

Exit Conditions

Speed (km/h)	78.3
Angle (deg)	6.8

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	5.0
y-direction	8.1
THIV (km/h)	33.0
Ridedown Accelerations (g's)	
x-direction	-13.9
y-direction	11.9
PHD (g's)	18.8
ASI	1.82
Max. 0.050-s Average (g's)	
x-direction	-8.2
y-direction	12.5
z-direction	-11.2

Test Article Deflections (m)

Dynamic	0.08
Permanent	0.02

Vehicle Damage

Exterior	
VDS	11LFQ4
CDC	11FLEK3 & 11LDEW3
Maximum Exterior Vehicle Crush (mm)	400
Interior	
OCDI	FS02000000
Max. Occ. Compart. Deformation (mm)	129

Post-Impact Behavior
(during 1.0 s after impact)

Max. Yaw Angle (deg)	41
Max. Pitch Angle (deg)	-5
Max. Roll Angle (deg)	-23

Figure 47. Summary of results for Nebraska Transition test, *NCHRP Report 350* test 3-21.

present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.

Result: No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. The floor pan and firewall were deformed and the seam where the floor pan meets the firewall was separated. Maximum occupant compartment deformation was 129 mm and damage to the interior was judged to not cause serious injury.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.*

Result: The vehicle remained upright during and after the collision period.

! **Vehicle Trajectory**

K. *After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

Result: Intrusion into adjacent traffic lanes was minimal, i.e., the vehicle came to rest 6 m forward from the face of the transition.

L. *The occupant impact velocity in the longitudinal direction should not exceed 12 m/s and the occupant ridedown acceleration in the longitudinal direction should not exceed 20 G's.*

Result: Longitudinal occupant impact velocity was 5.0 m/s and longitudinal ridedown acceleration was -13.9 g's.

M. *The exit angle from the test article preferably should be less than 60 percent of the test impact angle, measured at time of vehicle loss of contact with the test device.*

Result: Exit angle at loss of contact was 6.8 degrees, which was 28 percent of the impact angle.

The following supplemental evaluation factors and terminology were used for visual assessment of test results:

— **PASSENGER COMPARTMENT INTRUSION**

1. Windshield Intrusion

- (a.) <u>No windshield contact</u>
- b. Windshield contact, no damage
- c. Windshield contact, no intrusion
- d. Device embedded in windshield, no significant intrusion
- e. Complete intrusion into passenger compartment
- f. Partial intrusion into passenger compartment

2. Body Panel Intrusion yes or (<u>no</u>)

— **LOSS OF VEHICLE CONTROL**

(1.) <u>Physical loss of control</u>

2. Loss of windshield visibility

3. Perceived threat to other vehicles

4. Debris on pavement

— **PHYSICAL THREAT TO WORKERS OR OTHER VEHICLES**

1. Harmful debris that could injure workers or others in the area

2. Harmful debris that could injure occupants in other vehicles

No debris present.

— **VEHICLE AND DEVICE CONDITION**

1. Vehicle Damage

- a. None
- b. Minor scrapes, scratches or dents
- c. Significant cosmetic dents
- d. Major dents to grill and body panels
- (e.) <u>Major structural damage</u>

2. Windshield Damage

- (a.) <u>None</u>
- b. Minor chip or crack
- c. Broken, no interference with visibility
- d. Broken and shattered, visibility restricted but remained intact
- e. Shattered, remained intact but partially dislodged
- f. Large portion removed
- g. Completely removed

3. Device Damage

- a. None
- (b.) <u>Superficial</u> (rail element)
- c. Substantial, but can be straightened
- (d.) <u>Substantial, replacement parts needed for repair (parapet)</u>
- e. Cannot be repaired