Triple T: Truck Thrie Beam Transition

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The Truck Thrie Beam Transition (Triple T), an 813-mm (32-in.) thrie beam transition, was developed under a recently completed pooled funds study. The study involved 23 states, the District of Columbia, and the Federal Highway Administration. The Triple T was crash-tested according to Performance Level 2 (PL2) requirements of the 1989 AASHTO guide. The transition performed acceptably after modifications were made to the end terminal connection. For testing, the transition was attached to the end of the 813-mm (32-in.) vertical-faced concrete parapet bridge railing. The Triple T is acceptable for use on other PL2 bridge railings if suitable attachment to the bridge railing (such as the modified end terminal connector) is used.

The transportation industry is continually upgrading performance requirements of bridge railing systems. The 1989 AASHTO *Guide Specifications for Bridge Railings* (*1*) defines three levels of performance for bridge railing systems. The demand for Performance Level 2 (PL2) bridge railings, which are used in many states, is expected to increase.

During a recent pooled funds study, a collection of railing designs was developed. The study was sponsored by the FHWA, the District of Columbia, and 23 states. Twelve bridge railing designs were tested at various performance levels to evaluate the different needs of various states (*2*). Four of the bridge railing designs met PL2 requirements of the 1989 AASHTO guide.

Standard W-beam guardrails are used as approach railings to most bridge railings. A transition is used to attach these semirigid railings to the stiffer bridge railings. Transition railings are also semirigid and PL2 bridge railings are usually rigid. Therefore, guardrail-to-bridge rail transitions must be designed to prevent errant vehicles from deflecting the guardrail sufficiently for the vehicle to snag the end of the rigid bridge railing. A transition that prevents this snagging reduces property damage, injuries, and fatalities.

The results of the work performed to develop and test the Truck Thrie Beam Transition (Triple T), an 813-mm (32-in.) thrie beam transition, to meet PL2 requirements, are presented (*2,3*). According to the 1989 AASHTO guide, three tests are required on the transition to meet PL2. The test matrix includes one test with an 817-kg (1,800-lb) passenger car traveling 97 km/hr (60 mph) and at an angle of 20 degrees; one with a 2,452-kg (5,400-lb) pickup truck traveling 97 km/hr (60 mph) and at an angle of 20 degrees; and a third with an 8,172-kg (18,000-lb) single-unit truck traveling 80 km/hr (50 mph) and at an angle of 15 degrees. Four tests were performed on the transition. During the test with a pickup, the end terminal snagged the door, and the door remained lodged on the edge of the terminal. Modifications were made to the end terminal splice bolt connection. Using the modified end terminal design, the pickup truck test was repeated, and the single-unit truck test was conducted.

Details of the design of the transition and modifications made to the end terminal attachment, are discussed in the next section. Crash test procedures and results of the full-scale crash tests are given. After modifications and further testing, the Triple T performed acceptably for PL2 of the 1989 guide specifications.

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DESIGN OF TRUCK THRIE BEAM TRANSITION (TRIPLE T)

The prototype Triple T was attached to an 813-mm (32-in.) vertical-faced concrete parapet bridge railing for testing. Elevation and cross-section views of the transition are shown in Figure 1. The height to the top of the transition thrie beam rail element is 790 mm (31 in.) above the ground. The transition is supported by W6 × 15 posts and 152-mm (6-in.) blocks spaced at 1-m (3-ft 1½-in.) intervals, center-to-center, with a 768-mm (2-ft 6 ¼-in.) space adjacent to the end of the concrete parapet. The transition is composed of two 3.8-m (12 ft-6 in.) sections of 12-gauge thrie beam, one nested inside the other. One 3.8-m (12-ft 6-in.) section of 12-gauge thrie beam is spliced into the nested thrie beams. The single 12-gauge thrie beam transitions to a 3.8 m (12 ft 6 in.) long section of standard W-beam guardrail. The standard W-beam guardrail terminates with a 11.4-m (37-ft 6-in.) breakaway cable terminal. The total installation is 26 m (85 ft) long. Photographs of the completed installation are given in Figure 2.

The nested thrie beams are attached to the 813-mm (32-in.) vertical-faced concrete parapet with a standard American Road and Transportation Builders Association (ARTBA) terminal connector (see Figure 3). The standard ARTBA terminal connector is a section formed in the shape of a thrie beam at one end and tapered to a flat section at the other end. The flat portion of the terminal connector attaches to a bridge abutment or parapet wall, and the rail end is spliced to the guardrail. It is impossible to connect the two layers of nested thrie beam elements to a standard ARTBA terminal connector without damaging the elements. For the first two tests, the terminal connector was lapped onto the traffic face with two layers of thrie beam sandwiched between the terminal connector and the parapet. During the test with the pickup (Test 20), the vehicle's door was peeled off by the exposed edge of the terminal connector. This unacceptable performance showed that a more suitable attachment to the concrete parapet was needed.

Three thicknesses of thrie beam material cannot be bolted together if the conventional hole patterns on the end terminals are used. A proposed remedy for this problem is to punch slotted holes in the terminal connectors, with the holes slanted approximately 45 degrees to the longitudinal axis of the connector. Although such a hole pattern allows the three layers to be bolted together, the strength of such a terminal connection is questionable. Static, axial-load tension tests were performed on several thrie beam and W-beam terminal connectors with different splice bolt patterns to determine their strengths and failure modes (*4*). The different configurations tested are shown in Figure 4, and the results of the

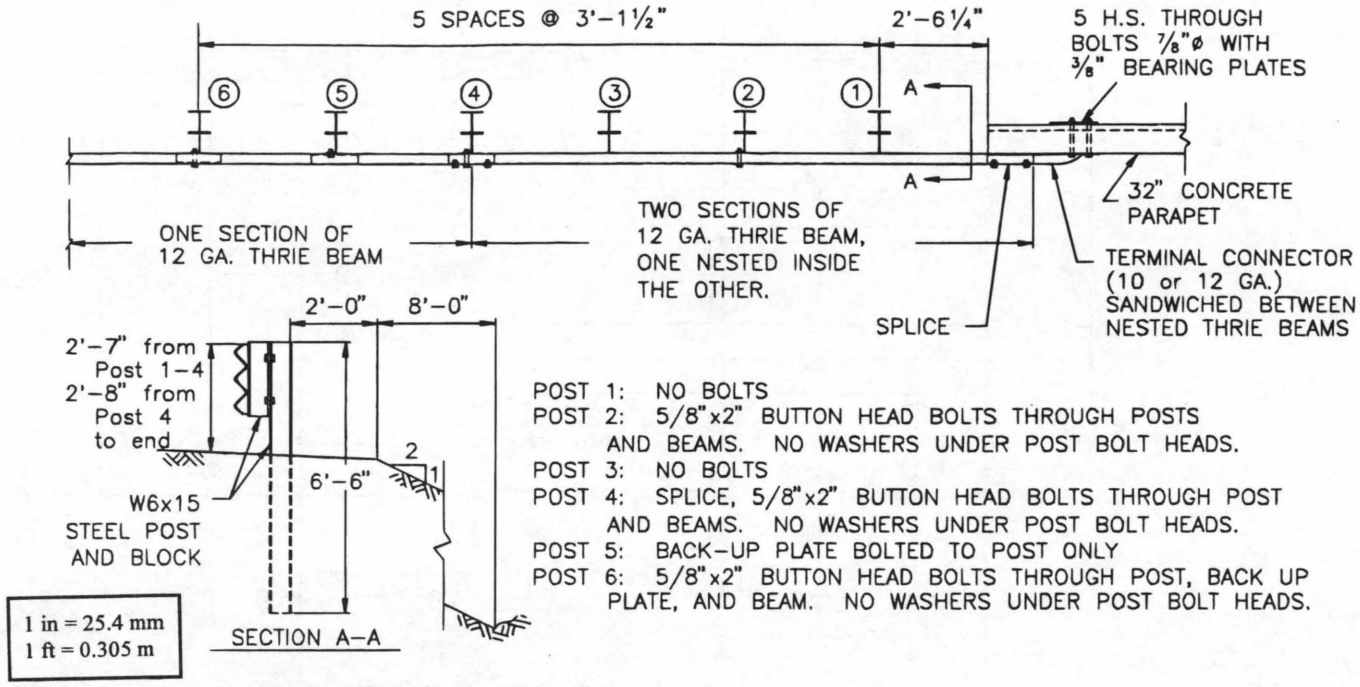


FIGURE 1 Triple T installation.

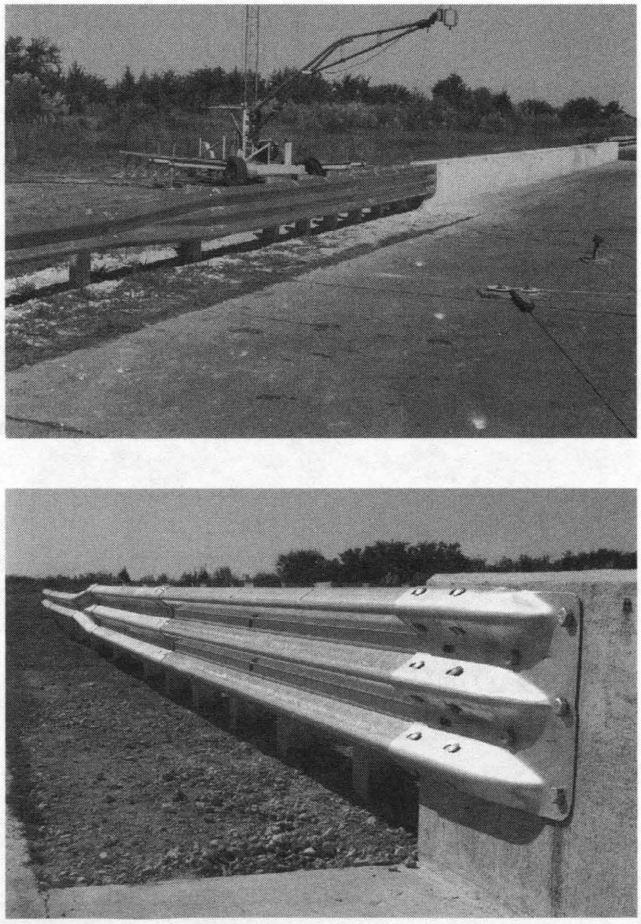


FIGURE 2 Triple T installation for Tests 19 and 20.

strength tests are summarized in Table 1. In all cases, the 25.4-mm (1-in.) holes in the flat section of the terminal exhibited plastic flow and tearing. Use of slotted, angled holes did not reduce the strength of the terminal connector.

Modifications were made only to the terminal connector that connects the transition to the concrete parapet. No modifications were made to the transition area; therefore, the small car test was not repeated. The modified terminal connector shown in Figure 5 was used for retesting the pickup truck (Test 21) and for testing the 8,172-kg (18,000-lb) single-unit truck (Test 29). The modified terminal connector has slanted, slotted holes to ease the assembly of the splice. The connector is sandwiched between the two layers of thrie beam rail element. In Test 21, the connector thickness was 12-gauge; in Test 29, it was 10-gauge.

FULL-SCALE CRASH TESTS

The Triple T was evaluated according to PL2 requirements of the 1989 AASHTO guide. Nominal test conditions for this performance level are as follows:

- 817-kg (1,800-lb) passenger car, 96.6 km/hr (60 mph), 20 degrees;
- 2,452-kg (5,400-lb) pickup, 96.6 km/hr (60 mph), 20 degrees;
- 8,172-kg (18,000-lb) single-unit truck, 80.5 km/hr (50 mph), 15 degrees.

Four tests were performed on the Triple T. The transition performed acceptably with the small car; however, during the pickup test, the exposed end of the terminal connector engaged the door of the test vehicle and separated the door from the vehicle. Modifications and strength tests were made on the end terminal splice con-

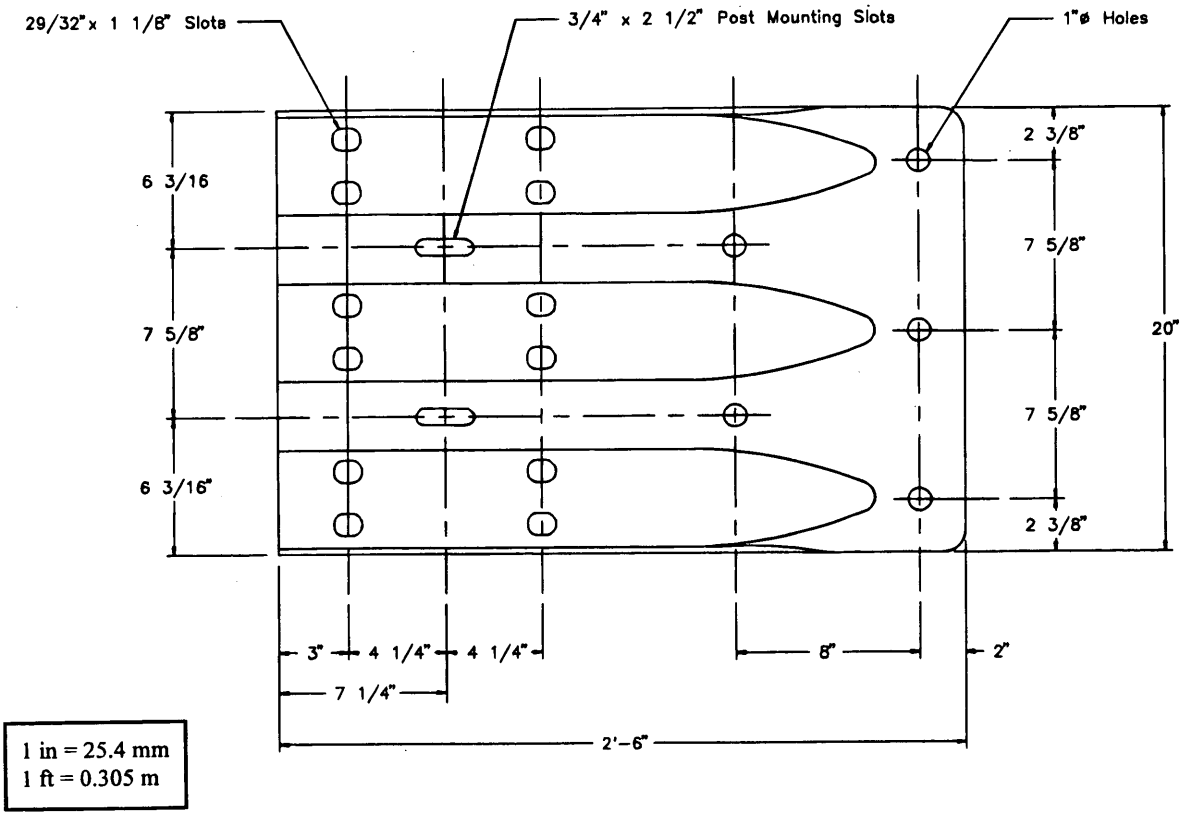


FIGURE 3 Standard ARTBA thrie beam end terminal connector.

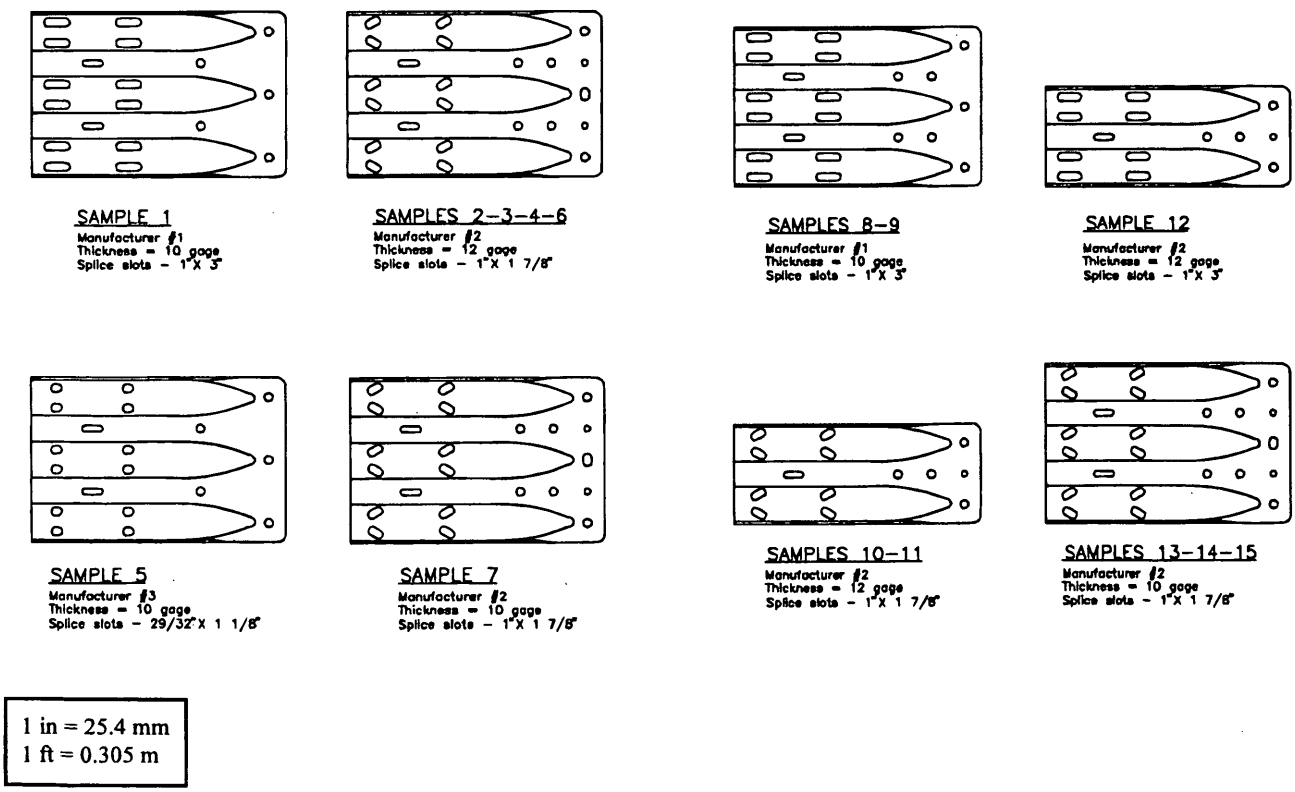


FIGURE 4 End terminal splice bolt configurations tested.

TABLE 1 Ultimate Loads and Properties of W-Beam and Thrie Beam Terminal Connectors

SAMPLE NO	MANUFACTURER	MODEL	HOLE PATTERN	THICKNESS	NO. HOLES	ULTIMATE LOAD
1	NUMBER ONE	THRIE BEAM	ST. LONG SLOTS	10 GAUGE	5[1]	95.9 KIPS (426.6 kN)
2	NUMBER TWO	THRIE BEAM	ANGLED SLOTS	12 GAUGE	9[2]	132.6 KIPS (589.8 kN)
3	NUMBER TWO	THRIE BEAM	ANGLED SLOTS	12 GAUGE	9[2]	126.9 KIPS (564.5 kN)
4	NUMBER TWO	THRIE BEAM	ANGLED SLOTS	12 GAUGE	9[2]	133.7 KIPS (594.7 kN)
5	NUMBER THREE	THRIE BEAM	ST. SHORT SLOTS	10 GAUGE	5[1]	116.7 KIPS (519.1 kN)
6	NUMBER TWO	THRIE BEAM	ANGLED SLOTS	12 GAUGE	9[1]	83.3 KIPS (370.5 kN)
7	NUMBER TWO	THRIE BEAM	ANGLED SLOTS	10 GAUGE	9[1]	---[4]
8	NUMBER ONE	THRIE BEAM	ST. LONG SLOTS	10 GAUGE	7[1]	93.8 KIPS (417.2 kN)
9	NUMBER ONE	THRIE BEAM	ST. LONG SLOTS	10 GAUGE	7[1]	87.7 KIPS (390.1 kN)
10	NUMBER TWO	W-BEAM	ANGLED SLOTS	12 GAUGE	4[3]	65.9 KIPS (293.1 kN)
11	NUMBER TWO	W-BEAM	ANGLED SLOTS	12 GAUGE	4[3]	66.4 KIPS (295.4 kN)
12	NUMBER TWO	W-BEAM	ST. LONG SLOTS	12 GAUGE	4[3]	71.1 KIPS (316.3 kN)
13	NUMBER TWO	THRIE BEAM	ANGLED SLOTS	10 GAUGE	9[1]	102.4 KIPS (455.5 kN)
14	NUMBER TWO	THRIE BEAM	ANGLED SLOTS	10 GAUGE	9[1]	99.3 KIPS (441.7 kN)
15	NUMBER TWO	THRIE BEAM	ANGLED SLOTS	10 GAUGE	9[1]	101.8 KIPS (452.8 kN)

NOTES:
1. Terminal connectors tested with 5-SAE Grade 8, 7/8-in (22-mm) bolts at the flat section.
2. Terminal connectors tested with 7-SAE Grade 8, 7/8-in (22-mm) bolts and 2-SAE Grade 8, 3/4-in (19-mm) bolts at the flat section.
3. Terminal connectors tested with 4-SAE Grade 8, 7/8-in (22-mm) bolts at the flat section.
4. Sample 7 was used in crash test 7069-29.

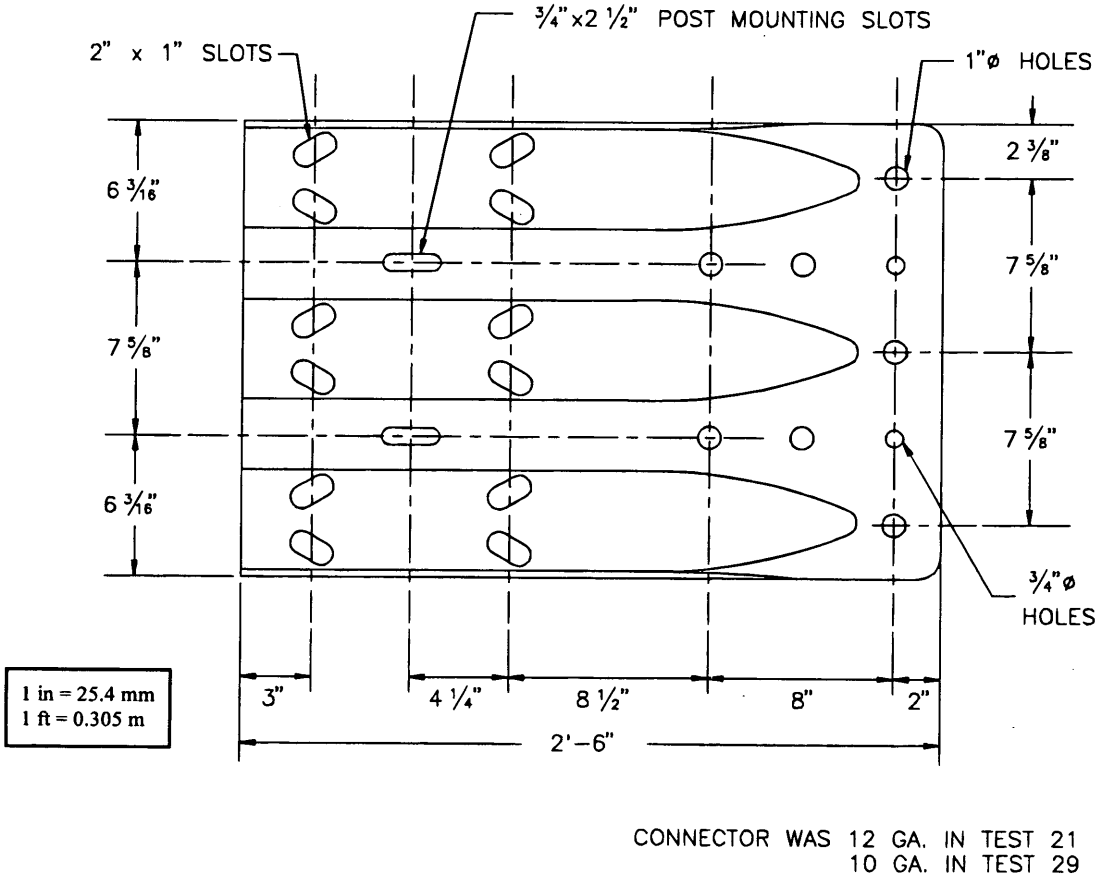


FIGURE 5 Modified end terminal connector used in Tests 21 and 29.

nection, and the pickup test was repeated using a modified end terminal connection on the transition. The modified end terminal connector was also used during the single-unit truck test. The small car test was not repeated because failure during the pickup test occurred at the terminal connector, not on the transition.

All other testing, evaluation, and reporting requirements were in accordance with specifications set forth in NCHRP Report 230 (*5*).

Test 19

For the test with the 817-kg (1,800-lb) passenger car, a 1983 Honda Civic was directed into the Triple T. Test inertia mass of the vehicle was 817 kg (1,800 lb). The gross static mass was 894 kg (1,970 lb). The speed of the vehicle at time of impact was 97.3 km/hr (60.5 mph), and the angle of impact was 19.9 degrees. The vehicle contacted the transition approximately 2.1 m (5.0 ft) from the end of the concrete parapet.

The vehicle began to redirect shortly after impact with the transition. By 0.137 sec, the vehicle was traveling parallel to the transition at a speed of 82.1 km/hr (51.0 mph). At approximately the same time, the rear of the vehicle contacted the transition. The vehicle lost contact with the transition at 0.219 sec, traveling at 76.7 km/hr (47.7 mph) and 6.9 degrees. After the brakes were applied, the vehicle yawed clockwise and subsequently came to rest 73 m (240 ft) down and 30 m (100 ft) forward of the point of impact.

The transition received minor cosmetic damage (see Figure 6). Maximum lateral deformation of the transition was 13 mm (0.5 in.) and occurred at Post 2. Damage to the vehicle included the strut and constant velocity joint on the left side. The left front wheel was canted inward at the bottom and pushed back into the fender well. Maximum crush of the vehicle was 279 mm (11.0 in.) at the left front corner at bumper height.

The transition contained the test vehicle with minimal lateral movement of the transition. Although there was minimal deformation to the occupant compartment, there was no intrusion. The vehicle remained upright and relatively stable during and after the impact sequence. The transition smoothly redirected the vehicle. Effective coefficient of friction (smoothness of the interaction of the vehicle and the transition) was considered fair.

The lateral occupant impact velocity of 7.9 m/sec (25.9 ft/sec) in this test was marginally over the 7.6 m/sec (25 ft/sec) limit specified in the 1989 AASHTO guide. The longitudinal occupant impact velocity and the longitudinal and lateral occupant ridedown accelerations were within the limits. The vehicle trajectory at loss of contact with the transition indicated minimum intrusion into adjacent traffic lanes.

Although the lateral occupant impact velocity was technically over the limit specified in the 1989 guide, performance of the transition in this test was judged acceptable (see Figure 7 and Table 2).

Test 20

The second test used a 1981 Chevrolet C-20 pickup with a test inertia mass of 2,452 kg (5,400 lb). Gross static mass of the pickup was 2,529 kg (5,570 lb). The pickup was traveling 100.9 km/hr (62.7 mph) and contacted the transition at an angle of 19.0 degrees and approximately 2.1 m (7.0 ft) from the end of the concrete parapet.

The vehicle began to redirect shortly after impact with the transition. At approximately 0.103 sec, the driver's-side door began to open and the front edge of the door began to peel away from the hinges. By 0.204 sec, the vehicle was traveling parallel to the transition at a speed of 75.3 km/hr (46.8 mph). At approximately the same time, the rear of the vehicle contacted the transition. Maximum lateral deflection of 274 mm (10.8 in.) occurred at 0.231 sec. The vehicle lost contact with the transition at 0.308 sec, traveling at 67.4 km/hr (41.9 mph). Although the vehicle exited the barrier yawing counterclockwise, the exit angle between the vehicle path and the transition was 9.0 degrees. As the brakes on the vehicle were applied, the vehicle continued to yaw counterclockwise, subsequently coming to rest 41 m (135 ft) down from the point of impact.

The transition received moderate damage, with a maximum lateral deformation of the transition of 165 mm (6.5 in.). The vehicle sustained damage to the left side as shown in Figure 8. Maximum crush at the left front corner at bumper height was 559 mm (22.0 in.). The sway bar and upper and lower control arms on the left side were damaged. The roof was bent and the driver's-side door was detached. The left front wheel was canted inward at the bottom and pushed back into the fender well.

The transition contained the test vehicle with minimal lateral movement of the transition. There was no intrusion of railing components into the occupant compartment; however, the door was

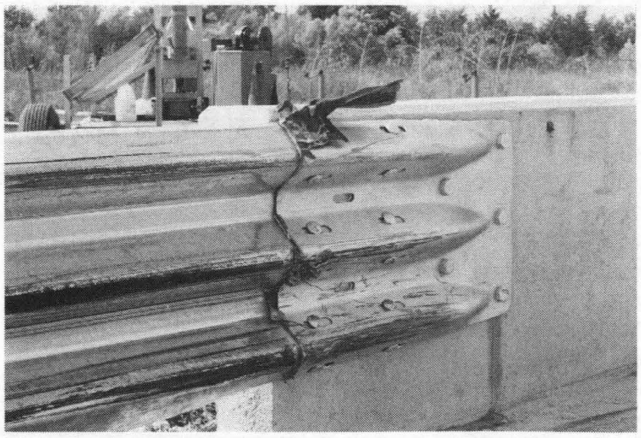
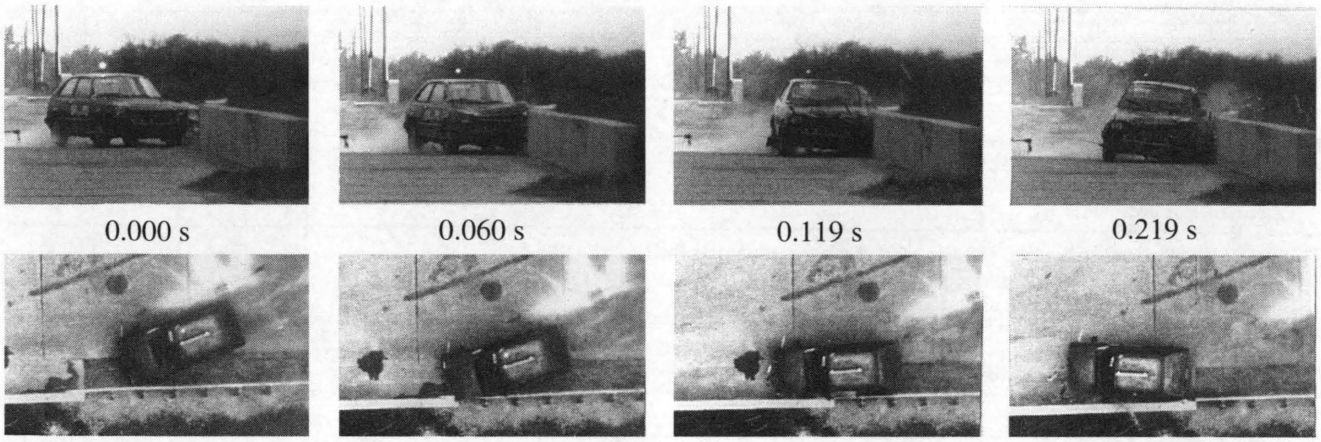
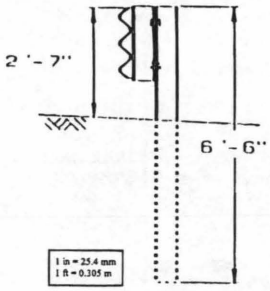


FIGURE 6 Vehicle and end terminal after Test 19.





Test No.	7069-19
Date	10/02/90
Test Installation	813 mm (32-in) Thrie Beam Transition
Installation Length	26 m (85 ft)
Test Vehicle	1983 Honda Civic
Vehicle Weight	
Test Inertia	817 kg (1,800 lb)
Gross Static	894 kg (1,970 lb)
Vehicle Damage Classification	
TAD	11FL4 & 11LD6
CDC	11FLEK2 & 11LDEW3
Maximum Vehicle Crush	279 mm (11.0 in)

Impact Speed	97.3 km/h (60.5 mi/h)
Impact Angle	19.9 deg
Speed at Parallel	82.1 km/h (51.0 mi/h)
Exit Speed	76.7 km/h (47.7 mi/h)
Exit Trajectory	6.9 deg
Vehicle Accelerations (Max. 0.050-sec avg)	
Longitudinal	-8.5 g
Lateral	-14.3 g
Occupant Impact Velocity at true c.g.	
Longitudinal	5.9 m/s (19.3 ft/s)
Lateral	7.9 m/s (25.9 ft/s)
Occupant Ridedown Accelerarions	
Longitudinal	-2.3 g
Lateral	-12.5 g

FIGURE 7 Summary of results for Test 19.

detached from the vehicle and remained lodged on the end terminal connector. The vehicle remained upright and relatively stable during and after the collision. The transition redirected the vehicle, but the effective coefficient of friction was quite high. Velocity change of the vehicle during the collision was 33.5 km/hr (20.8 mph). The occupant impact velocities and the occupant ridedown accelerations were within the limits of the 1989 AASHTO guide. The vehicle trajectory at loss of contact indicates minimum intrusion into adjacent traffic lanes.

The transition performed as designed for this test; however, the exposed end of the terminal connector peeled the door from the vehicle. Because of the undesirable performance of the end terminal connector, performance of the transition in this test was judged to be unacceptable (see Figure 9 and Table 2).

After Test 20 it was decided that a more suitable attachment of the transition to the bridge railing was needed before testing could continue. A discussion of these modifications can be found in the Design section.

Test 21

The pickup test was repeated on the Triple T with the modified 12-gauge terminal connector. The modified end terminal has slotted, angled splice bolt holes. A 1984 Chevrolet custom pickup with test inertia mass of 2,452 kg (5,400 lb) and gross static mass of 2,526 kg (5,565 lb) was directed into the transition. The pickup contacted the transition 2.1 m (7.0 ft) from the end of the concrete parapet. The pickup was traveling 98.8 km/hr (61.4 mph) and contacted the transition at an angle of 18.3 degrees.

Shortly after impact, the vehicle began to redirect and then contacted Post 1. Maximum lateral deflection of the transition was 244 mm (9.5 in.) at 0.060 sec after impact. At approximately 0.070 sec, the vehicle contacted the end of the concrete parapet and the left front wheel snagged slightly on the end of the parapet. By 0.178 sec, the vehicle was traveling parallel to the transition at a speed of 80.9 km/hr (50.3 mph). The rear of the vehicle contacted the transition at 0.188 sec. The vehicle lost contact with the transition at 0.314 sec, traveling 80.5 km/hr (50.0 mph) and at an angle of 8.2 degrees. The brakes were applied as the vehicle left the immediate area of the test site, and the vehicle subsequently came to rest 41 m (195 ft) from the point of impact.

The transition received moderate damage with a maximum permanent deformation of 127 mm (5.0 in.). The vehicle sustained damage to the left side with a maximum crush of 381 mm (15.0 in.) at the left front corner at bumper height. The right front corner was deformed outward approximately 121 mm (4.8 in.). The sway bar, A-arms on the left side, and gas tank were damaged. The drive shaft, frame, and roof were bent. The floor pan was pushed into the occupant compartment approximately 127 to 178 mm (5 to 7 in.). The instrument panel moved inward approximately 76 mm (3 in.). The left front wheel was canted inward at the bottom and pushed back into the fender well, reducing the wheelbase on the driver's side by 356 mm (14.0 in.) (see Figure 10).

The transition contained the test vehicle with minimal lateral movement of the transition. Although there was deformation into

TABLE 2 Assessment of Results of Tests on Triple T

AASHTO EVALUATION CRITERIA	ASSESSMENT			
	Test 19	Test 20	Test 21	Test 29
A. The test shall contain the vehicle; neither the vehicle no its cargo shall penetrate or go over the installation. Controlled lateral deflection of the test article is acceptable.	Pass	Pass	Pass	Pass
B. Detached elements, fragments, or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.	Pass	Pass	Pass	Pass
C. Integrity of the passenger compartment must be maintained with no intrusion and essentially no deformation.	Pass	Fail	Marginal	Pass
D. The vehicle shall remain upright during and after collision.	Pass	Pass	Pass	Fail*
E. The test article must smoothly redirect the vehicle.	Pass*	Pass*	Pass*	Pass*
F. The smoothness of the vehicle-railing interaction is further assessed by the effective coefficient of friction, μ: μ — Assessment 0 - .25 — Good .26 - .35 — Fair >.35 — Marginal where $\mu = (\cos\theta - V_p/V)/\sin\theta$	Fair*	Marginal*	Marginal*	Good*
G. The impact velocity shall be less than: Occupant Impact Velocity - m/s (ft/s) Longitudinal — Lateral 9.2 (30) — 7.6 (25)	Fail	Pass*	Pass*	N/A
Occupant Ridedown Accelerations - g's Longitudinal — Lateral 15 — 15	Pass	Pass*	Pass*	N/A
H. Vehicle exit angle from the barrier shall not be more than 12 degrees.	Pass*	Pass*	Pass*	Pass*

*Desired but not required.

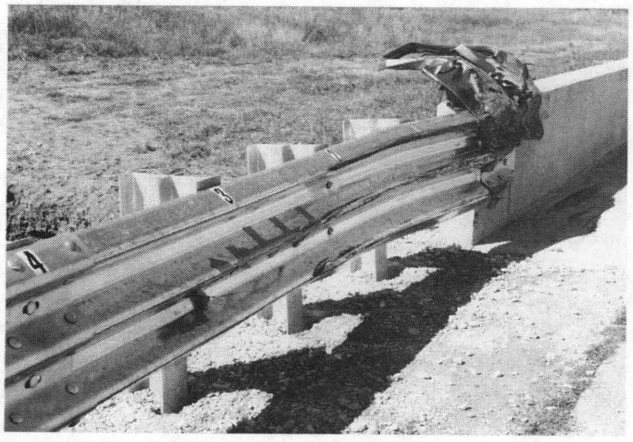
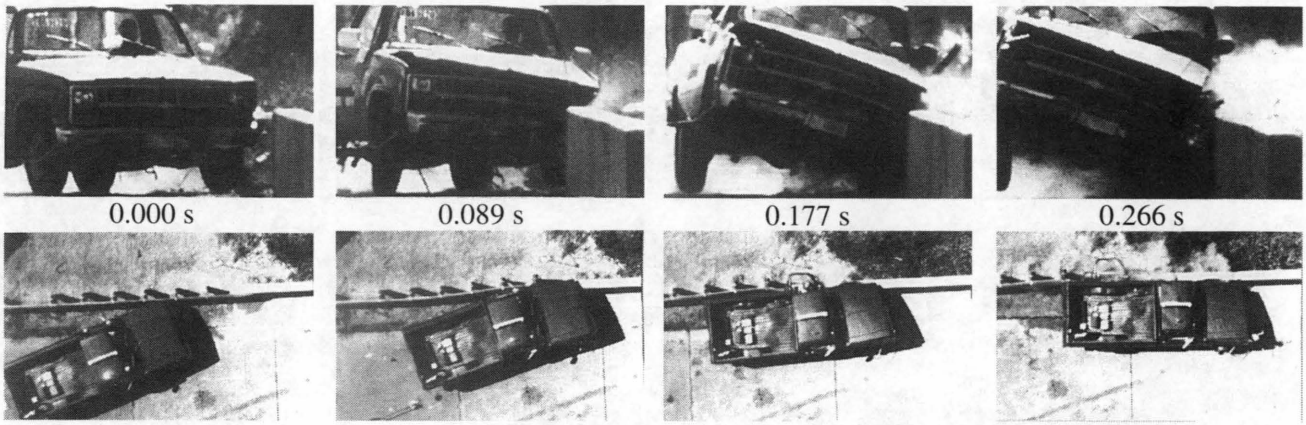
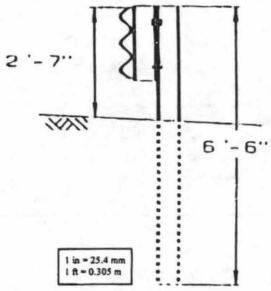


FIGURE 8 Vehicle and transition after Test 20.

the occupant compartment, there was no intrusion of railing components. The vehicle remained upright and relatively stable during and after the collision. The transition redirected the vehicle, but the effective coefficient of friction was quite high. Velocity change of the vehicle during the collision was 17.9 km/hr (11.1 mph). The occupant impact velocities and the occupant ridedown accelerations were within the limits specified in the 1989 AASHTO guide. The vehicle trajectory at loss of contact indicates minimum intrusion into adjacent traffic lanes.

The deformation of the floor pan was of some concern, but was not considered life-threatening. Performance of the transition in this test was judged acceptable (see Figure 11 and Table 2).





Test No.	7069-20
Date	10/19/90
Test Installation	813 mm (32-in) Thrie Beam Transition
Installation Length	26 m (85 ft)
Test Vehicle	1981 Chevrolet C-20 Pickup
Vehicle Weight	
Test Inertia	2 452 kg (5,400 lb)
Gross Static	2 529 kg (5,570 lb)
Vehicle Damage Classification	
TAD	11FL5 & 11LD7
CDC	11FLEK3 & 11LDEW3
Maximum Vehicle Crush	559 mm (22.0 in)
Impact Speed	100.9 km/h (62.7 mi/h)
Impact Angle	19.0 deg
Speed at Parallel	75.3 km/h (46.8 mi/h)
Exit Speed	67.4 km/h (41.9 mi/h)
Exit Trajectory	9.0 deg
Vehicle Accelerations (Max. 0.050-sec avg)	
Longitudinal	-6.4 g
Lateral	-7.7 g
Occupant Impact Velocity at true c.g.	
Longitudinal	5.9 m/s (19.3 ft/s)
Lateral	5.3 m/s (17.3 ft/s)
Occupant Ridedown Accelerations	
Longitudinal	-5.4 g
Lateral	-13.0 g

FIGURE 9 Summary of results for Test 20.

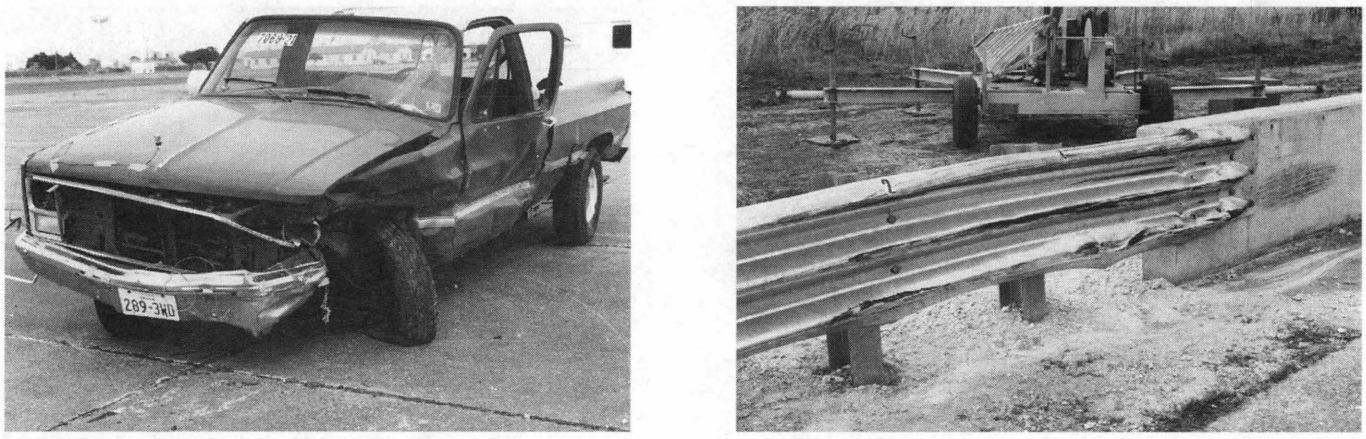
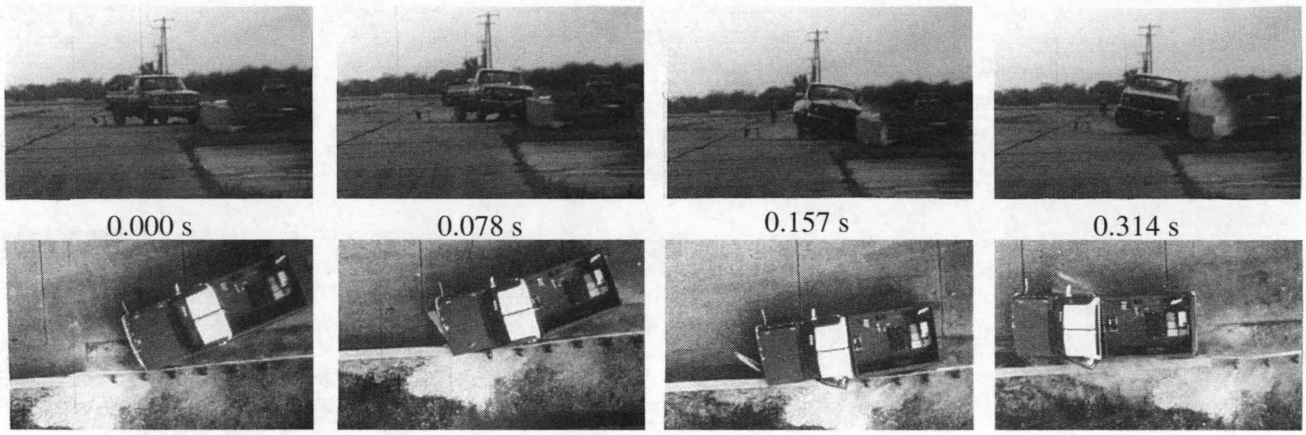


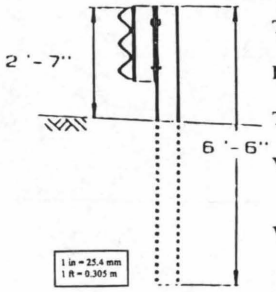
FIGURE 10 Vehicle and transition after Test 21.

Test 29

In this test, a modified 10-gauge terminal connector was used to attach the Triple T to the concrete parapet. A 1981 Ford single-unit truck was used in the crash test. Test inertia mass of the vehicle was 4,899 kg (10,790 lb), and its gross static mass was 8,172 kg (18,000 lb). The vehicle contacted the transition 3.4 m (11 ft) from the end of the concrete parapet. The speed of the vehicle at impact was 83.0 km/hr (51.6 mph), and the angle of impact was 14.6 degrees.

Shortly after impact the front wheels received a steer input to the left and the vehicle began to redirect. At 0.155 sec, the vehicle contacted the end of the concrete parapet. By 0.262 sec, the vehicle was traveling parallel to the transition at a speed of 78.7 km/hr (48.9 mph). At 0.341 sec, the rear of the vehicle contacted the transition. The vehicle lost contact with the terminal connector at 0.585 sec; however, the van-box remained in contact with the top of the concrete parapet until 1.718 sec after impact. As the vehicle continued forward, it began to yaw clockwise and roll counterclockwise. The brakes were applied at 2.5 sec after impact. The vehicle





Test No.	7069-21
Date	03/17/92
Test Installation	813 mm (32-in) Thrie Beam Transition
Installation Length	26 m (85 ft)
Test Vehicle	1984 Chevrolet Custom Pickup
Vehicle Weight	
Test Inertia	2 452 kg (5,400 lb)
Gross Static	2 527 kg (5,565 lb)
Vehicle Damage Classification	
TAD	11FL5 & 11LD6
CDC	11FLEK3 & 11LDEW4
Maximum Vehicle Crush	381 mm (15.0 in)
Impact Speed	98.8 km/h (61.4 mi/h)
Impact Angle	18.3 deg
Speed at Parallel	80.9 km/h (50.3 mi/h)
Exit Speed	80.5 km/h (50.0 mi/h)
Exit Trajectory	8.2 deg
Vehicle Accelerations (Max. 0.050-sec avg)	
Longitudinal	-6.9 g
Lateral	-10.3 g
Occupant Impact Velocity at true c.g.	
Longitudinal	5.9 m/s (19.3 ft/s)
Lateral	7.6 m/s (24.8 ft/s)
Occupant Ridedown Accelerarions	
Longitudinal	-3.7 g
Lateral	12.5 g

FIGURE 11 Summary of results for Test 21.

subsequently rolled and came to rest on its left side 50 m (165 ft) down and 14 m (45 ft) forward from the point of impact.

The transition received moderate damage with a maximum permanent deformation of 254 mm (10.0 in.). The end of the concrete parapet where the terminal connector attached was cracked, as shown in Figure 12. The vehicle sustained damage to the left side. Maximum crush at the left front corner at bumper height was 330 mm (13.0 in.). The floor pan was pushed inward, and the cab was bent and twisted. The windshield and rear glass were broken. The frame at the rear axle was bent, and the van box was twisted and torn.

The transition contained the test vehicle with minimal lateral movement of the transition. The floor pan was slightly deformed into the vehicle; however, there was no intrusion of railing components into the occupant compartment. The vehicle remained upright and relatively stable during the test sequence. After exiting the immediate area of the test installation, the vehicle rolled onto its left side. This rollover behavior was attributed to asymmetrical brake application as the vehicle exited the test site. The transition redirected the vehicle with the effective coefficient of friction rated as good. The vehicle trajectory at loss of contact indicates minimal intrusion into adjacent traffic lanes. Performance of the transition in this test was judged acceptable (see Figure 13 and Table 2).

SUMMARY AND CONCLUSIONS

Two tests were performed on the Triple T with a standard ARTBA end terminal connector. Problems were encountered with the end terminal connection attaching the nested thrie beam elements of the transition to the concrete parapet. It was not possible to connect the nested thrie beam elements to the terminal connector with the conventional splice bolt hole pattern without damaging the elements. During the first two tests, the terminal connector was lapped onto the traffic face with two layers of thrie beam sandwiched between the terminal connector and the concrete parapet. The exposed edge of the terminal connector engaged the door of the pickup during the second test, and the door remained lodged on the end terminal connector. To facilitate bolting the three thicknesses of material together, slotted holes were punched in the terminal connector, with the holes slanted 45 degrees to the longitudinal axis of the connector. Because the strength of such a terminal connection was questionable, tests were performed on various splice bolt patterns. During the strength tests, failure first occurred in the flat section of the terminal that attaches to the bridge railing. It was concluded that the splice bolt pattern did not affect the performance or static load capacity of the connection.

A modified terminal connector with slanted, slotted holes was used for retesting the pickup and for testing with the 8,172-kg (18,000-lb) single-unit truck. The Triple T and modified end terminal meet PL-2 criteria of the 1989 AASHTO guide.

The Triple T can be used to transition from the approach guardrail to PL2 bridge railings if an appropriate attachment to the bridge railing is made. Attachment to a bridge railing should provide a smooth tensile capacity of the transition rail element at least as high as values obtained from tests reported in Table 2. An ARTBA end terminal modified by punching angled, slotted holes in the splice bolt connection can be used to attach the Triple T to some PL2 bridge railings.

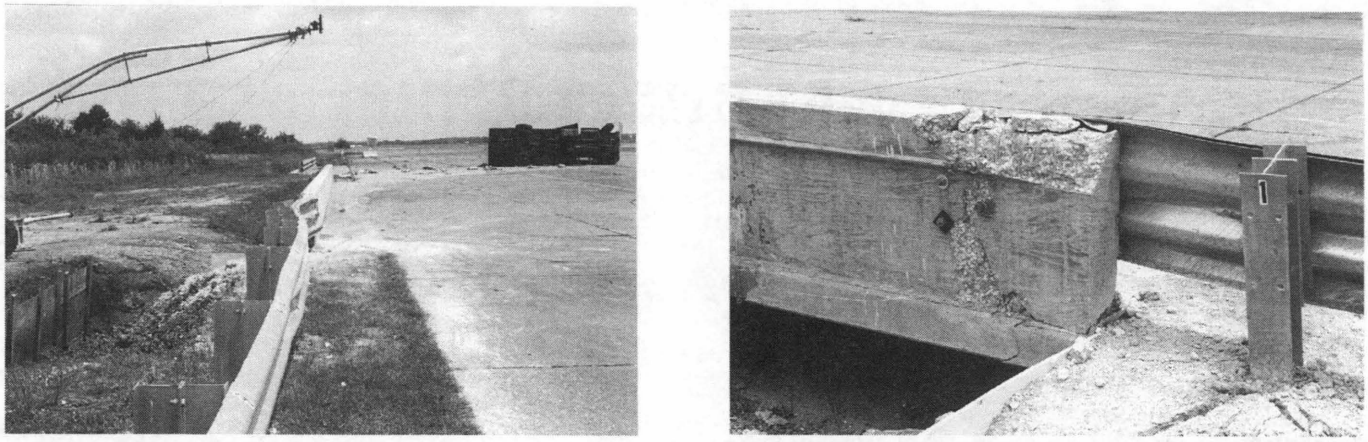
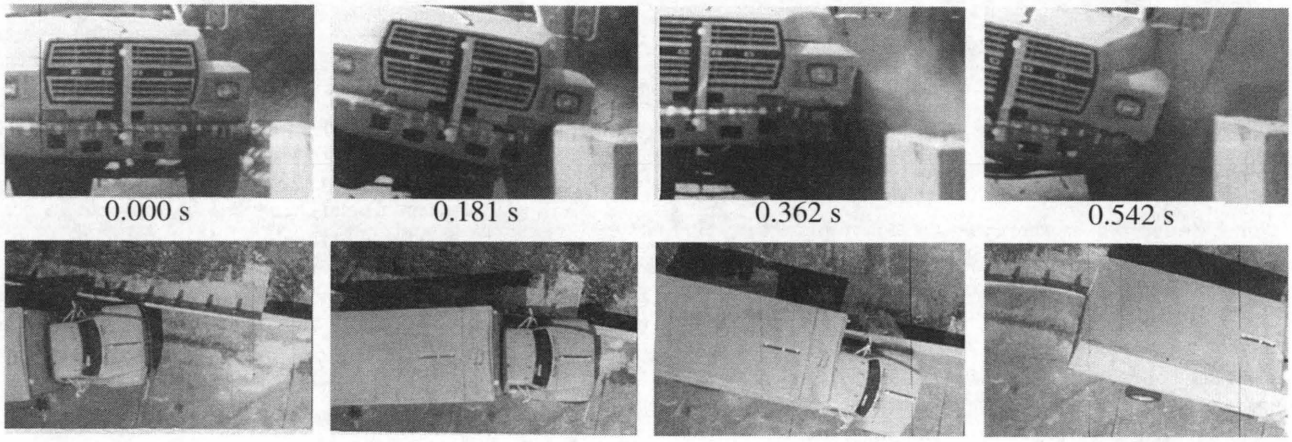
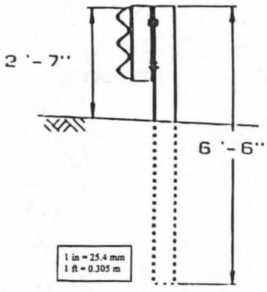


FIGURE 12 Transition after Test 29.





Test No.	7069-29
Date	06/05/92
Test Installation	813 mm (32-in) Thrie Beam Transition
Installation Length	26 m (85 ft)
Test Vehicle	1981 Ford Single-Unit Truck
Vehicle Weight	
Test Inertia	4 899 kg (10,790 lb)
Gross Static	8 172 kg (18,000 lb)
Maximum Vehicle Crush	330 mm (13.0 in)
Max. Perm. Deform.	254 mm (10.0 in)
Impact Speed	83.0 km/h (51.6 mi/h)
Impact Angle	14.6 deg
Speed at Parallel	78.7 km/h (48.9 mi/h)
Exit Speed	N/A
Exit Trajectory	11 deg
Vehicle Accelerations (Max. 0.050-sec avg)	
Longitudinal	-2.3 g
Lateral	6.3 g
Occupant Impact Velocity at true c.g.	
Longitudinal	2.9 m/s (9.4 ft/s)
Lateral	3.6 m/s (11.9 ft/s)
Occupant Ridedown Accelerarions	
Longitudinal	-4.1 g
Lateral	9.0 g

FIGURE 13 Summary of results for Test 29.

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