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Crash Testing and Evaluation of Retrofit Bridge Railings and Transition

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VANDAL PROTECTION FENCE ON NEW JERSEY SAFETY SHAPE BRIDGE RAILING

TEST ARTICLE

The New Jersey safety shape bridge railing used during a previous contract was used as the retrofit railing. The vandal protection fence was attached to the existing bridge railing. Total installation length was 30 m (100 ft). A cross section of the prototype test installation is shown in figure 40 and photographs of the completed installation are shown in figures 41 and 42.

The total height of the New Jersey safety shape is 813 mm (32 in). Thickness of the unit is 381 mm (15 in) at its base and varies along the height, tapering to a minimum of 152 mm (6 in) at the top. Eight 13 mm (#4) longitudinal bars were used in the safety shape. The vertical steel was 16 mm (#5) stirrups at 203 mm (8 in) spacing. Specified concrete strength was 24 804 kPa (3600 psi) at 28 days, and specified steel yield was 413 400 kPa (60,000 psi). The cantilevered deck was supported on a foundation so that the deck overhang was 991 mm (39 in).

The vandal protection fence was mounted on 2.2 m (7.3 ft) long by 73 mm (2.875 in) OD (schedule 40 pipe) straight posts mounted to the back of the safety shape with two clamps and anchored with 0.625 m by 76 mm (5/8 in by 3 in) anchor bolts. The clamps were formed from 76 mm (3.0 in) wide by 6.35 mm (0.25 in) flat steel. The first post is placed 0.3 m (1 ft) from the end of the safety shape with the next post at 2.7 m (9.0 ft), then 8 spaces at 3.0 m (10.0 ft), and ending with one spaced at 2.7 m (9.0 ft). Attached to these posts are three 42 mm (1.66 in) OD (schedule 40 pipe) horizontal line rails spaced at 0.9 m (3.0 ft) with 25 mm by 25 mm (1 in by 1 in) wire fabric (11 gage core wires, PVC coated). Height to the top of the fence is 1.8 m (6.0 ft) above the safety shape. Total height of the installation is 2.6 m (8.7 ft) above the roadway surface.

CRASH TEST RESULTS

Test 472070-6

One crash test was conducted on the vandal protection fence mounted on the New Jersey safety shape bridge railing. The test was the AASHTO performance level two pickup truck test with a 2450 kg (5400 lb) pickup, impacting the length-of-need section at a nominal speed and angle of 100 km/h (62.2 mi/h) and 20 degrees. The impact point was selected to be near the 1/3 point of the test installation. The purpose of this crash test is to evaluate the strength of the section in containing and redirecting the pickup and the interaction of the vehicle with the fence.

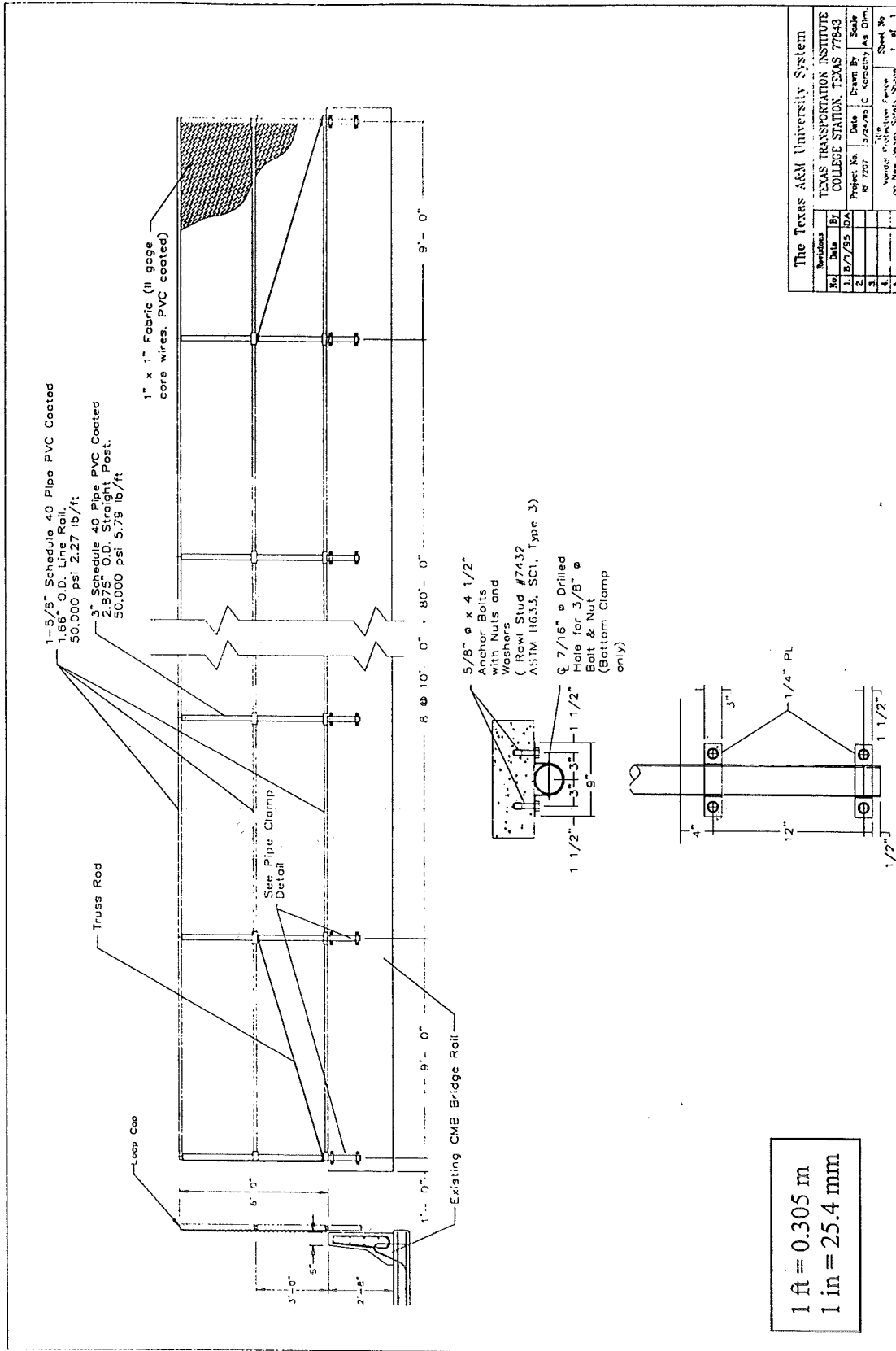


Figure 40. Details of vandal protection fence on New Jersey safety shape bridge railing.

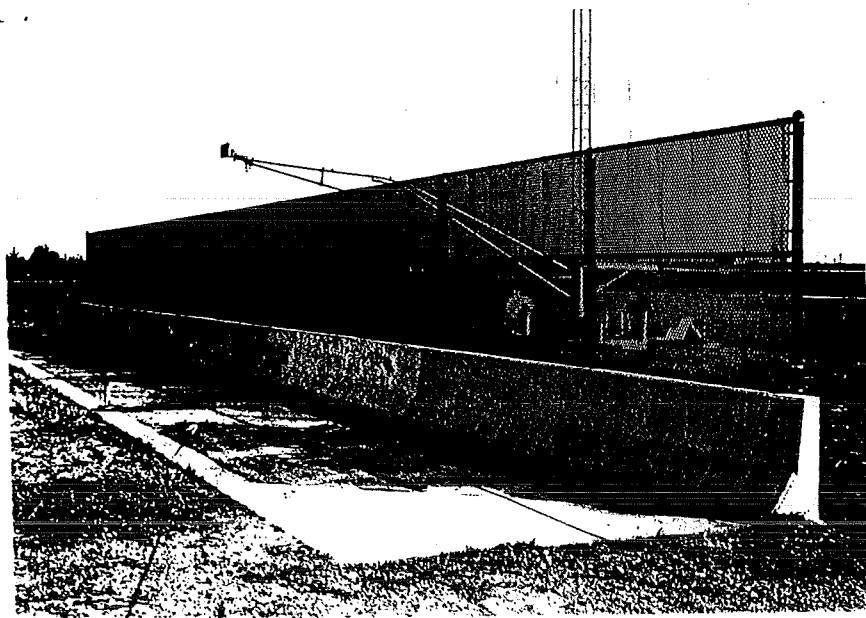
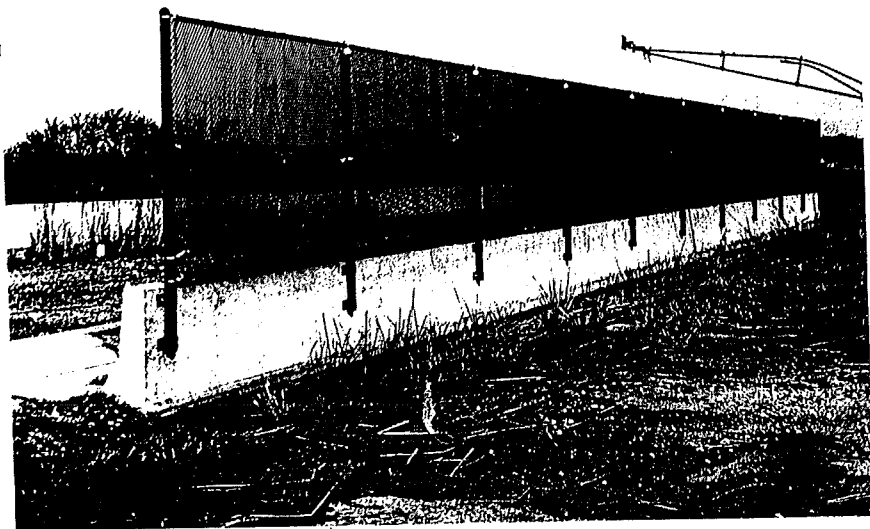


Figure 41. Vandal protection fence on the New Jersey safety shape bridge railing.

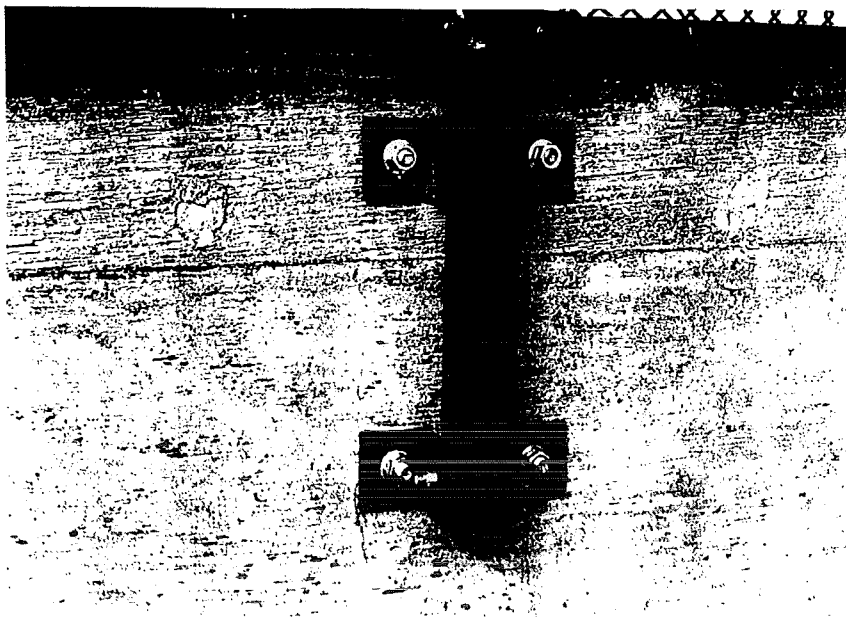
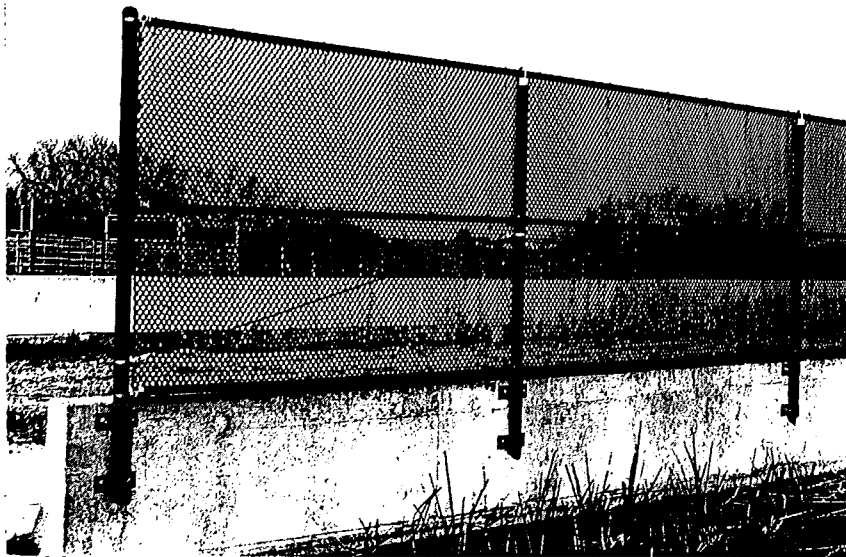


Figure 42. Connection of the vandal protection fence to the New Jersey safety shape.

Test Description

A 1991 Ford F250 (shown in figures 43 and 44) with a test inertia weight of 2540 kg (5397 lb) was used for the crash test. The gross static weight of the vehicle was 2525 kg (5562 lb) which included a restrained 50th percentile male anthropomorphic dummy placed in the driver's position of the vehicle. The heights to the upper and lower edges of the vehicle bumper were 740 mm (29.1 in) and 450 mm (17.7 in), respectively. Additional dimensions and information on the vehicle are given in appendix B, figure 64. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

The vehicle bumper contacted the length-of-need section of the New Jersey safety shape 1.02 m (3.33 ft) downstream of post 4 of the vandal protection fence. The vehicle was traveling at a speed of 79.6 km/h (49.5 mi/h) and an exit angle of approximately 4.4 degrees. Contact with the fence occurred at 0.032 second and redirection of the vehicle began at 0.039 second. The middle horizontal line rail pulled out of the post 5 connection at 0.089 second. Maximum deflection of the fence of 142 mm (5.6 in) occurred at 0.110 second. The bumper of the vehicle reached the top of the safety shape at 0.121 second and the front of the vehicle became airborne at 0.138 second. At 0.181 second the vehicle became parallel with the installation, traveling at 83.8 km/h (52.1 mi/h). The rear of the vehicle made contact with the safety shape at 0.195 second and the vehicle became totally airborne at 0.223 second. The vehicle lost contact with the safety shape at 0.274 second, traveling at a speed of 79.6 km/h (49.5 mi/h) and an exit angle of approximately 4.4 degrees. At 0.665 second the vehicle touched ground and yawed clockwise. Brakes were applied as the vehicle exited the test area, and the vehicle subsequently came to rest 28 m (91 ft) beyond and 3 m (9 ft) to the traffic side of the initial point of impact. Sequential photographs are shown in appendix C, figures 76 and 77.

Damage to Test Installation

As seen in figure 45, the installation received minimal damage. There were tire marks on the face of the safety shape and the lower edge of the wire fabric was pushed behind the lower horizontal line rail between post 5 and 6. The middle horizontal line rail was disconnected on the upstream side at the post 5 location and the post 5 anchor was pushed back 13 mm (0.5 in) as shown in figure 46. Maximum dynamic deflection of the fence was 142 mm (5.6 in) (measured at the top of the rail) and maximum residual deformation was 76 mm (3.0 in). Total length of contact with the installation was 5.2 m (17.0 ft).

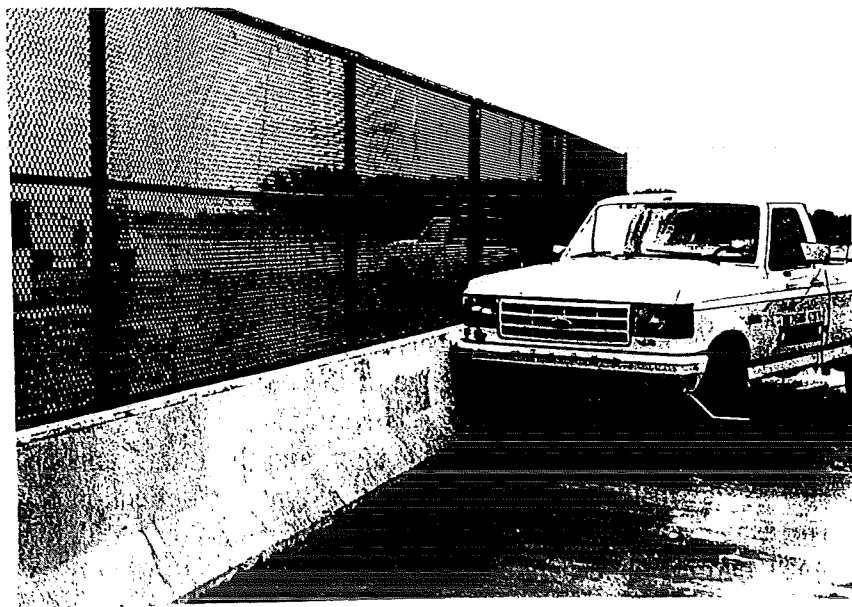
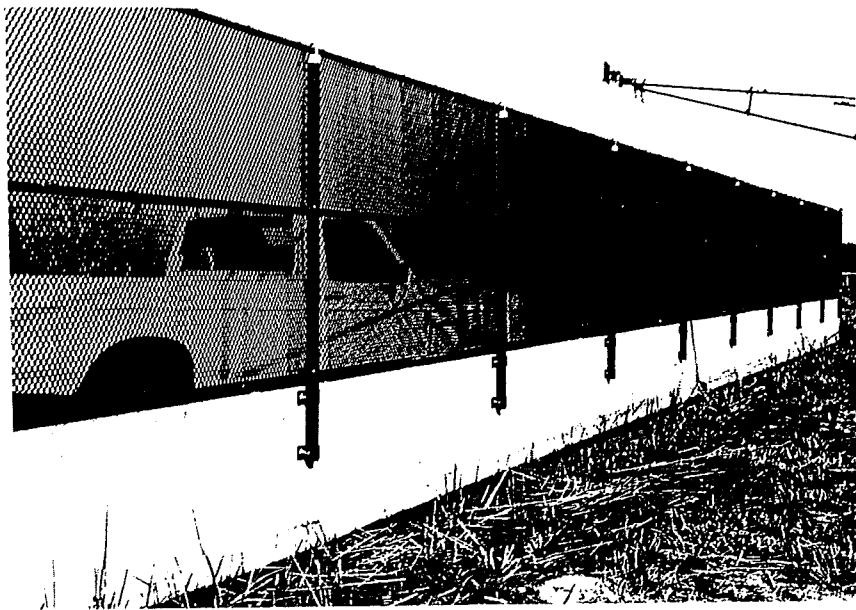


Figure 43. Vehicle/bridge rail geometrics for test 472070-6.

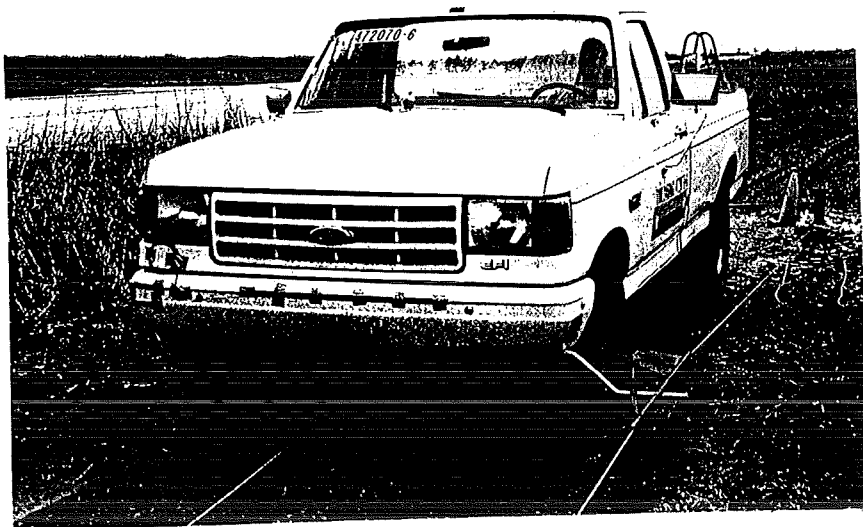


Figure 44. Vehicle prior to test 472070-6.

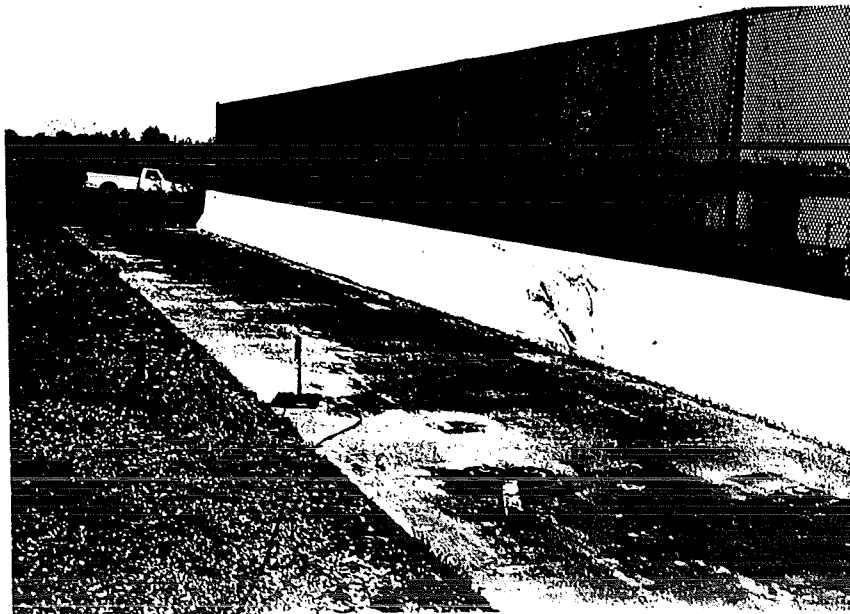
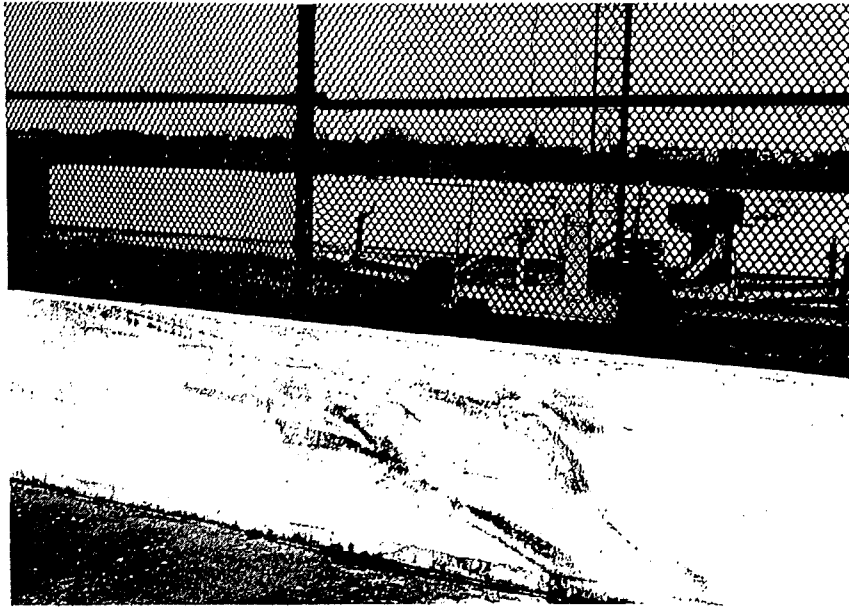


Figure 45. Vandal protection fence on New Jersey safety shape after test 472070-6.

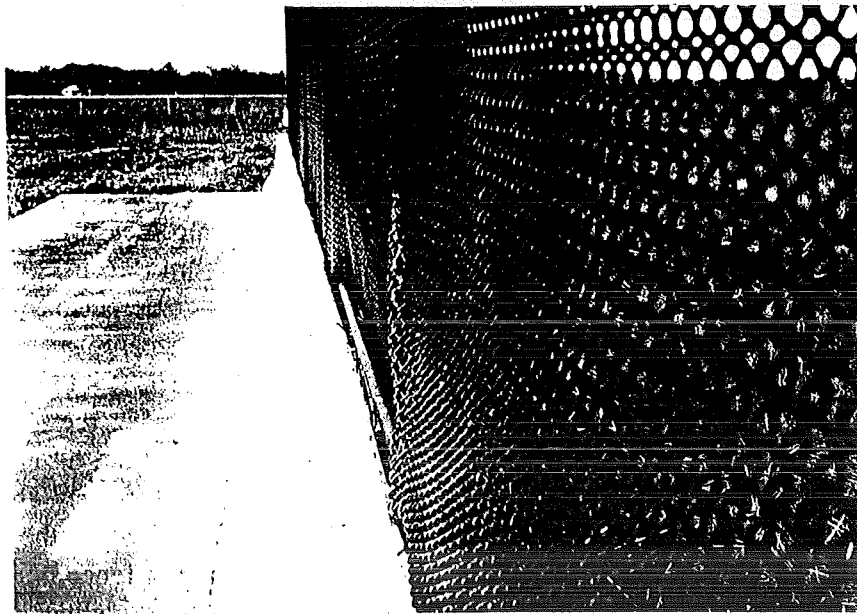
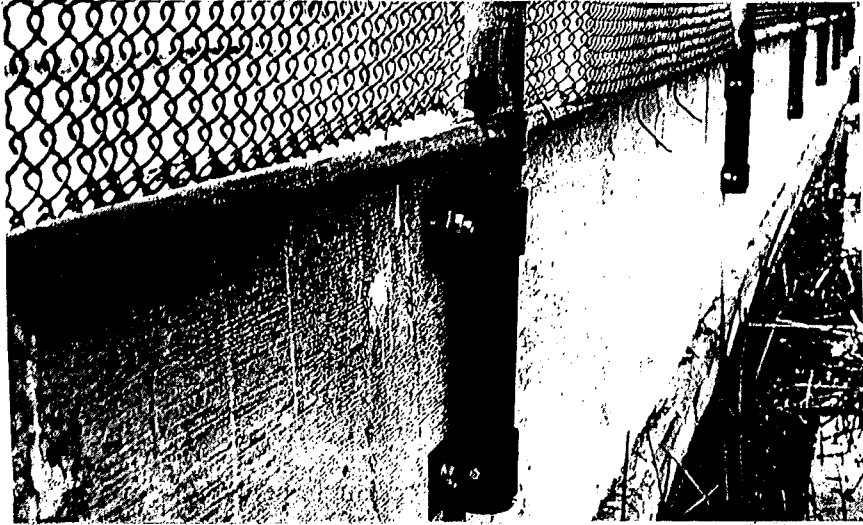


Figure 46. Damage to vandal protection fence after test 472070-6.

Damage to Test Vehicle

The vehicle sustained moderate damage as shown in figure 47. The stabilizer bar, floorpan, frame and front axle on the right side were bent and the windshield was cracked. The front bumper, hood, grill, right front quarter panel, both doors, and rear quarter panel were damaged. There was a small fold running diagonally in the floorpan of the occupant compartment. Maximum exterior crush at the right front corner of the vehicle was 170 mm (6.7 in). There was 70 mm (2.8 in) deformation into the occupant compartment of the firewall on the passenger side of the vehicle.

Occupant Risk Values

Data from the accelerometer located at the vehicle center-of-gravity were digitized for evaluation of occupant risk and were computed as follows. Occupant contact first occurred in the longitudinal direction. The longitudinal occupant impact velocity was 5.0 m/s (16.5 ft/s) at 0.184 second, the highest 0.010-second longitudinal occupant ridedown acceleration was -5.6 g between 0.184 and 0.194 second, and the maximum 0.050-second average was -8.4 g between 0.025 and 0.075 second. Lateral occupant impact velocity was 2.8 m/s (9.1 ft/s) at 0.226 second, the highest 0.010-second lateral occupant ridedown acceleration was -7.6 g between 0.195 second and 0.205 second, and the maximum 0.050-second average acceleration was -5.4 g between 0.780 and 0.830 second. These data and other information pertinent to the test are summarized in figure 48. Vehicular angular displacements during the test are displayed in appendix D, figure 84. Vehicular accelerations versus time traces filtered at 60 Hz are presented in appendix E, figures 101 through 103.

FINDINGS AND CONCLUSIONS

The vandal protection fence mounted on the New Jersey safety shape bridge railing successfully contained and redirected the vehicle and met all evaluation criteria set forth in the AASHTO *Guide Specifications for Bridge Railings* PL2 conditions for the pickup test. The vehicle did not penetrate or go over the installation. There was no measurable deformation to the safety shape and maximum deflection of the fence was 142 mm (5.6 in) measured at the top of the fence. Presence of the fence itself did not result in adverse performance. There were no detached elements or debris to exhibit undue hazard to adjacent traffic. The vehicle sustained moderate damage with minimal deformation (70 mm (2.8 in)) into the passenger compartment. The vehicle remained upright and stable during and after the impact sequence. The trajectory of the vehicle was judged to have posed minimal potential hazard to adjacent traffic as the vehicle exited the installation with a trajectory of 4.4 degrees. The coefficient of friction was calculated at 0.32. The occupant risk factors were well within the desirable limits. In summary, the impact performance of the vandal protection fence on the New Jersey safety shape bridge railing was considered satisfactory according to guidelines set forth by AASHTO, as shown in table 9.

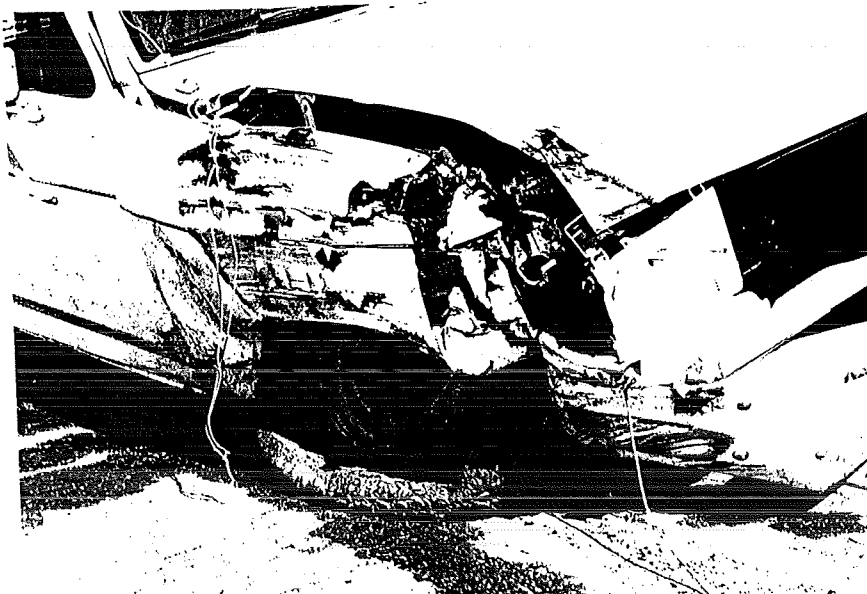
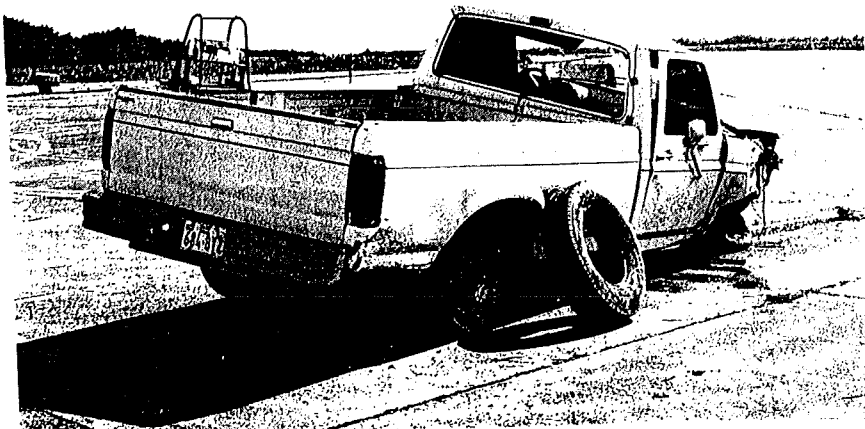
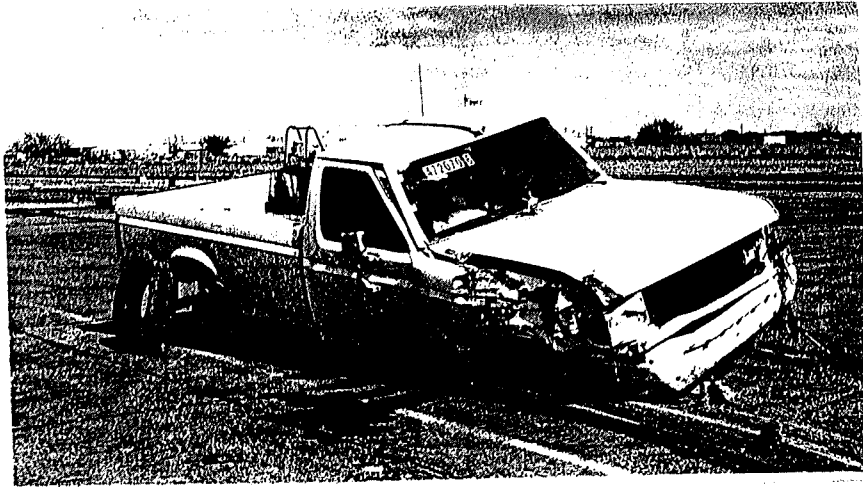
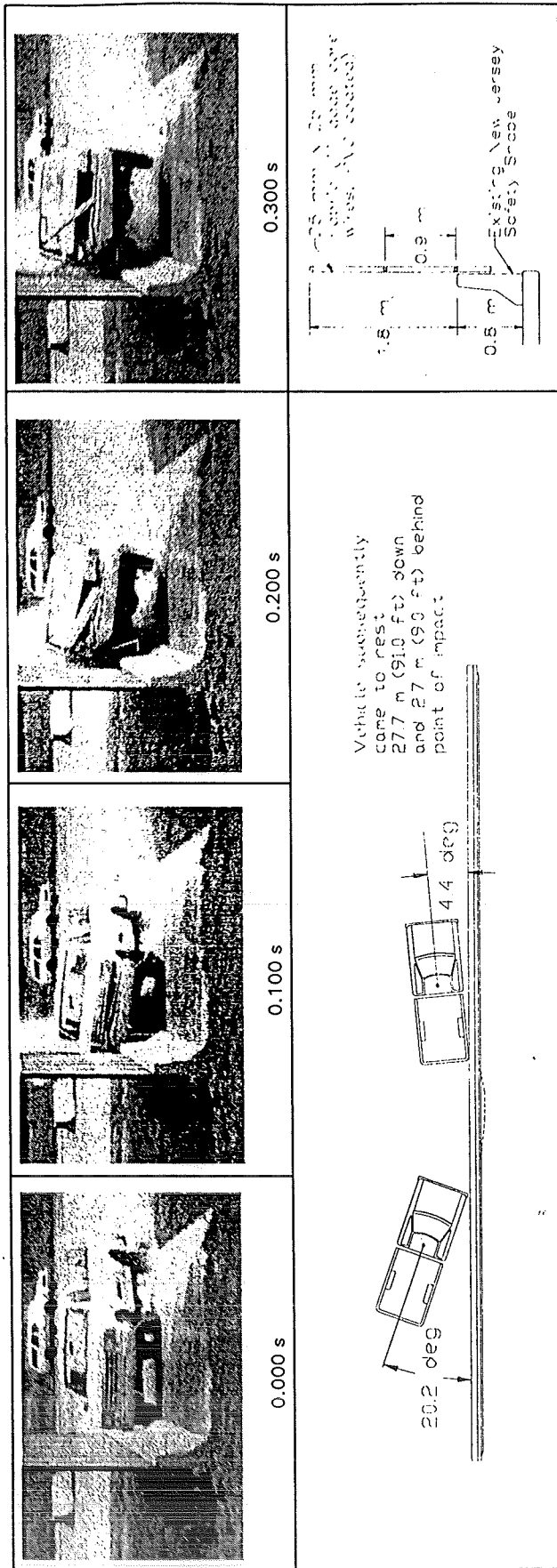


Figure 47. Vehicle after test 472070-6.



General Information		Impact Conditions		Test Article Deflections (m)	
Test Agency	Texas Transportation Institute	Speed (km/h)	101.1 (62.8 mi/h)	Dynamic	0.14 (0.47 ft)
Test No.	472070-6	Angle (deg)	20.2	Permanent	0.08 (0.25 ft)
Date	03/10/95	Exit Conditions		Vehicle Damage	
Test Article		Speed (km/h)	79.6 (49.5 mi/h)	Exterior	
Type	Retrofit Bridge Rail	Angle (deg)	4.4	VDS	01RFQ5
Name	Vandal Protection Fence on NJSS	Occupant Risk Values		CDC	01FREK2 & 01RDES3
Installation Length (m)	30 m (100 ft)	Impact Velocity (m/s)		Interior	
Size and/or dimension and material of key elements	1.8 m (6.0 ft) tall 25 mm x 25 mm Fabric (11 gauge core wires, PVC coated)	x-direction	5.0 (16.5 ft/s)	OCDI	RS0000000
Soil Type and Condition	on bridge deck, dry	y-direction	2.8 (9.1 ft/s)	Maximum Exterior Vehicle Crush (mm)	170 (6.7 in)
Test Vehicle		THIV (optional)		Max. Occ. Compartment Deformation (mm)	70 (2.8 in)
Type	Production	Ridedown Accelerations (g's)			
Designation	Pickup	x-direction	-5.6		
Model	1991 Ford F250	y-direction	-7.6		
Mass (kg)	2208 (4863 lb)	PHD (optional)			
Test Inertial Dummy	2450 (5397 lb)	ASI (optional)			
Gross Static	2525 (5562 lb)	Max. 0.050-s Average (g's)			
		x-direction	-8.4		
		y-direction	-5.4		
		z-direction	-8.0		
				Post-Impact Behavior	
				Max. Roll Angle (deg)	30
				Max. Pitch Angle (deg)	9
				Max. Yaw Angle (deg)	-19

Figure 48. Summary of results for test 472070-6.

Table 9. Assessment of results of test with the pickup on the vandal protection fence (according to AASHTO PL2 pickup truck test).

Test Agency: Texas Transportation Institute		Test No.: 472070-6	Test Date: 03/10/95
AASHTO EVALUATION CRITERIA*		TEST RESULTS	ASSESSMENT
A.	The test shall contain the vehicle; neither the vehicle nor its cargo shall penetrate or go over the installation. Controlled lateral deflection of the test article is acceptable.	Vehicle was contained. There was no measurable deflection of the safety shape and only 142 mm (5.6 in) deflection of the fence.	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.	There were no detached elements or other debris to penetrate or show undue hazard to other traffic.	Pass
C.	Integrity of the passenger compartment must be maintained with no intrusion and essentially no deformation.	There was 70 mm (2.8 in) deformation to the occupant compartment.	Pass
D.	The vehicle shall remain upright during and after collision.	The vehicle remained upright during and after the collision.	Pass
E.	The test article must smoothly redirect the vehicle.	The vehicle was smoothly redirected.	Pass
F.	The smoothness of the vehicle-railing interaction is further assessed by the effective coefficient of friction, μ : $\mu = \frac{0 - .25}{.26 - .35} > .35$ where $\mu = (\cos\theta - V_p V) / \sin\theta$	μ — .32 Assessment Fair	Pass
G.	The impact velocity shall be less than: Occupant Impact Velocity - m/s (ft/s) Longitudinal 9.2 (30) Lateral 7.6 (25) Occupant Ridedown Accelerations - g's Longitudinal 15 Lateral 15	Occupant Impact Velocity - m/s (ft/s) Longitudinal 5.0 (16.5) Lateral 2.8 (9.1) Occupant Ridedown Accelerations - g's Longitudinal -5.6 Lateral -7.6	Pass
H.	Vehicle exit angle from the barrier shall not be more than 12 degrees.	Exit angle was approximately 4.4 degrees.	Pass

*A, B, C, and D are required. E, F, G, and H are desired.