Crash Test of Modified Texas C202 Bridge Rail

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In 1980 a standard Texas traffic rail, C202, was modified to increase its height and strength to restrain and redirect an 80,000-lb (36 300-kg) van-type tractor-trailer under 50-mph (80.5-km/hr), 15-degree-angle impacts. The concrete parapet height was increased to 36 in. (91 cm), and an elliptical steel rail was mounted on steel posts to increase the rail height to 54 in. (137 cm). In 1980 one crash test was conducted on the bridge rail. The truck was restrained and smoothly redirected. This promising high-performance bridge rail was not tested at that time with passenger cars. The results of two successful crash tests with a 1,918-lb (871-kg) car traveling at 61.3 mph (98.6 km/hr) striking at a 21-degree angle and with a 4,400-lb (1998-kg) car traveling at 59.4 mph (95.6 km/hr) striking at a 25.9-degree angle are presented.

The bridge rail tested was selected and designed to restrain and redirect an 80,000-lb (36 287-kg) van-type tractor-trailer in 1980 (*1,2*). The design was based on procedures and test data presented by Hirsch (*3*) and Buth (*4*).

The rail was a modification of the concrete parapet, Texas traffic rail type C202. The modified C202 rail consisted of a concrete beam element 13 in. (33 cm) wide and 23 in. (58 cm) deep, mounted 36 in. (91 cm) high on concrete posts located at 10-ft (3-m) center-to-center spacing. The posts were concrete walls 7 in. (19 cm) thick × 5 ft (1.5 m) long with 5-ft (1.5-m) openings. The beam element contained considerable reinforcing steel and provides flexibility, thus minimizing cracking of the concrete when struck by heavy vehicles. The modified C202 concrete parapet can be placed in lengths that give good structural continuity and strength.

To increase the effective height of this bridge rail, another standard Texas steel rail, designated C4, was mounted on top of the concrete rail. The bridge deck strength was also increased to minimize cracking or damage when the bridge rail is struck by a heavy vehicle.

Research Report 230-4F (*1*) and Hirsch (*2*) presented the results of a crash test on this bridge rail that successfully redirected an 80,000-lb (36 287-kg) tractor-trailer traveling at nominally 50 mph (80 km/hr) and striking at a 15-degree angle. In addition to successfully redirecting the tractor-trailer, the modified C202 bridge rail with the C4 metal rail on top must also redirect a 1,800-lb (810-kg) automobile and a 4,500-lb (2025-kg) automobile in order to meet all of the requirements set forth in *NCHRP Report 230* (*5*).

DESCRIPTION OF BRIDGE RAIL AND DECK MODIFICATIONS

Drawings of this rail are shown in Figures 1 and 2. Figure 3 contains photographs comparing the size of the combination bridge rail with the truck used in previous crash tests (*1,2*).

The strength of the standard Texas bridge deck 7.5 in. (19 cm) thick was increased by the addition of welded wire fabric centered under each post and along the deck steel to within 1 in. (2.5 cm) of the edge of the slab. A drawing of the welded wire fabric is shown in Figure 4. The deformed wire has a minimum yield strength of 70 ksi (48.3 kN/cm^2), and the smooth wire has a minimum yield strength of 65 ksi (44.9 kN/cm^2).

The concrete post was 13 in. (33 cm) high × 7 in. (17.8 cm) thick × 60 in. (152 cm) long with a 60-in. (152-cm) open space between each post. Each concrete post was anchored to the bridge deck by means of 13 No. 4 bars (traffic side) and 5 No. 4 bars (field side). The 13 No. 4 bars contained an 8-in. (20-cm) lap splice on top of the bridge deck that was intended as a breakaway connection.

The concrete rail on top of the post was 13 in. (33 cm) thick × 23 in. (58 cm) high for the entire length of the rail. It contained two sections of square spiral, as shown, with 10 No. 8 bars along the length of the rail. The twin spirals were used instead of a single spiral because the square spiral was available from a producer of Texas standard prestressed square piling that requires this type of spiral.

The steel rail on top of the modified C202 concrete rail was the Texas standard C4 steel rail. It was made from standard steel pipe 6 in. (15 cm) in diameter (ASTM A53 Grade B) shaped into an 8-in. × 4⅞-in. (20-cm × 12.4-cm) ellipse and welded to a post and base plate made of 1-in. (2.54-cm) steel plates. This post was anchored to the concrete rail by means of four A325 bolts ¾ in. in diameter and 15 in. (38 cm) long. A high-cast steel conical washer was installed under each bolt nut. These washers were evidently the standard being supplied by the fabricator for this type of Texas bridge rail. The standard drawing indicates that only washers are to be supplied.

All steel bars in the concrete post and rail were grade 60, including the bent bars that anchor the post to the deck. The deck steel bars were grade 40. The concrete for the deck, post, and rail was such that its strength was 3,000 psi (2.068 kN/cm^2) at the time of the test.

HONDA CRASH TEST (TEST 1179-1)

This bridge rail was crash-tested with a 1979 Honda Civic weighing 1,750 lb (795 kg) but with a gross weight of 1,918

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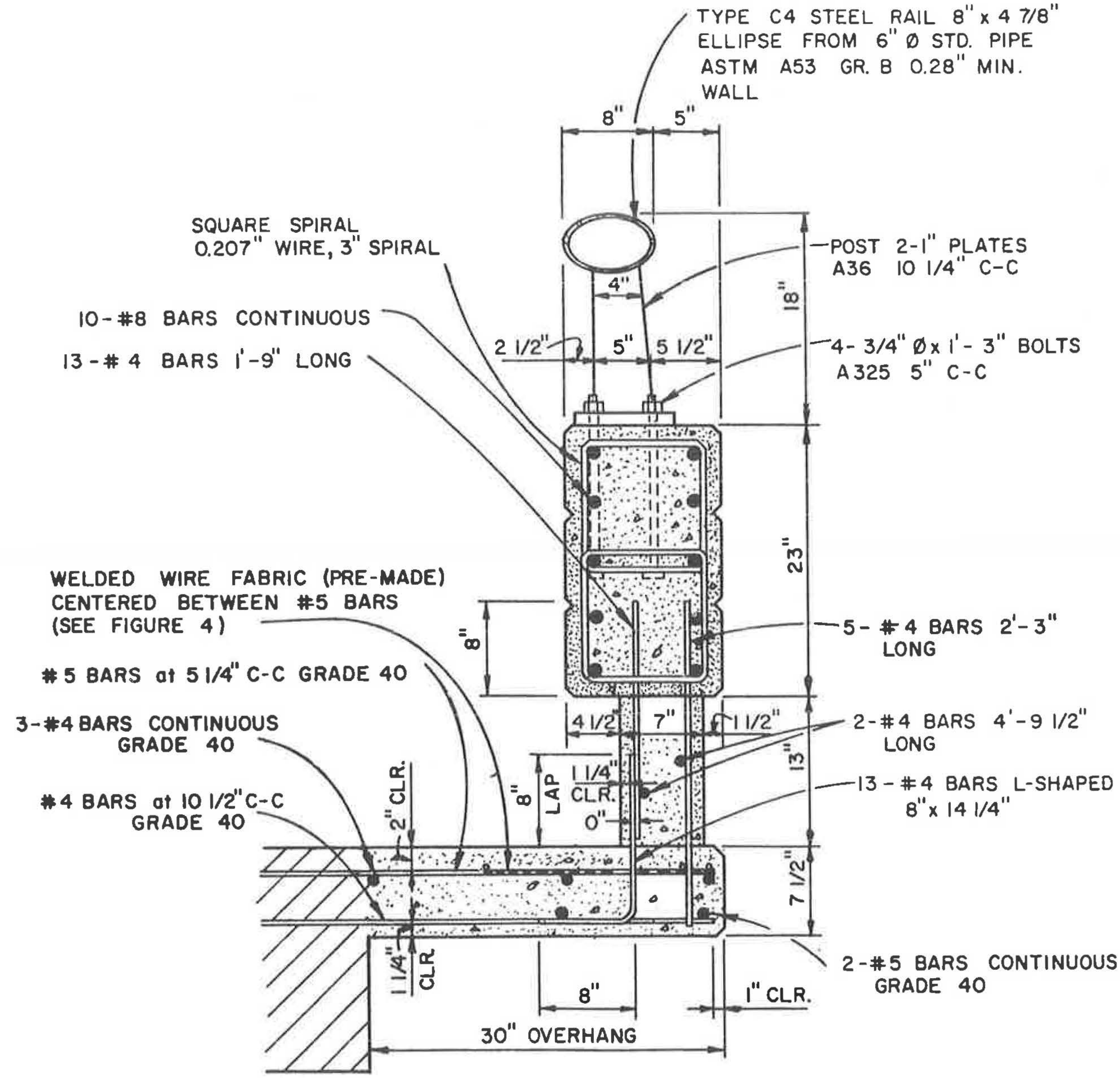


FIGURE 1 Cross section of modified C202 bridge rail.

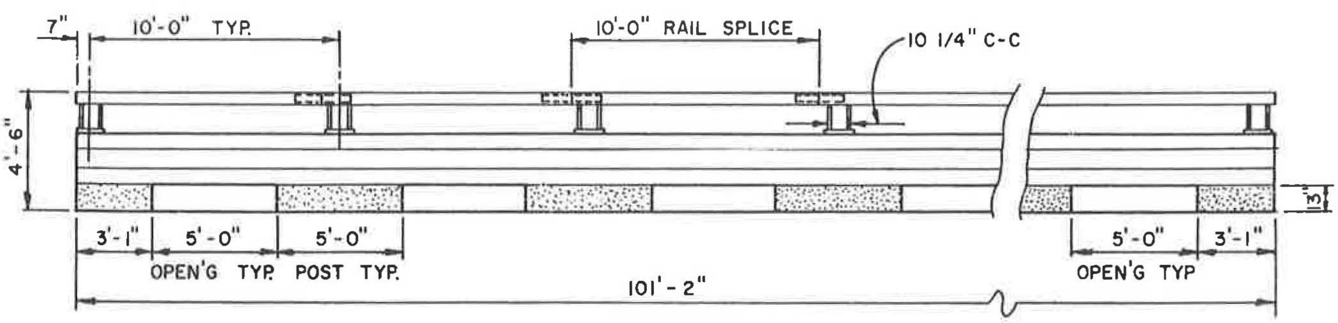


FIGURE 2 Elevation of modified C202 bridge rail.

FIGURE 3 Comparison of 80,000-lb truck with modified combination rail.

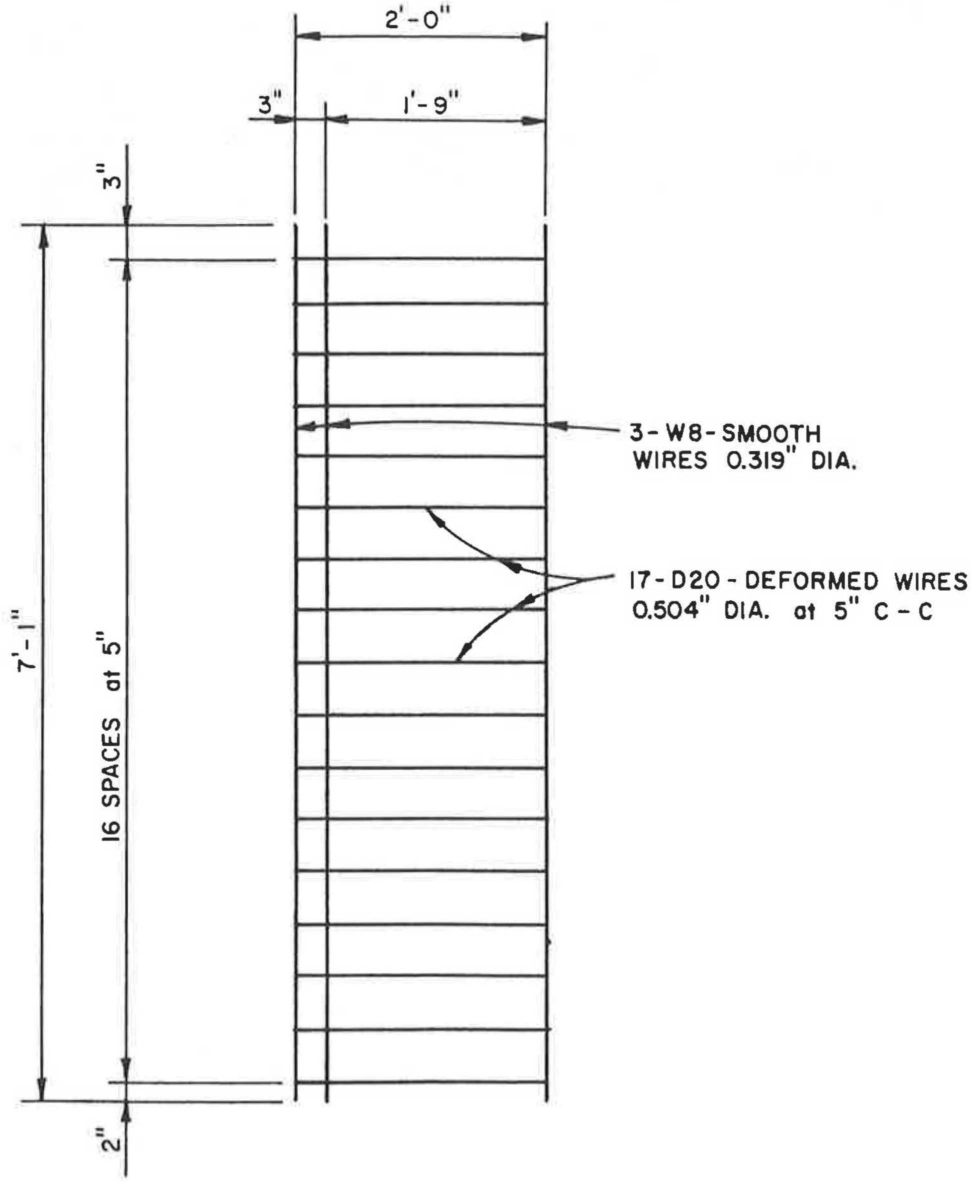


FIGURE 4 Detail of special slab reinforcement used under each concrete post.

FIGURE 5 Vehicle before and after Test 1179-1.

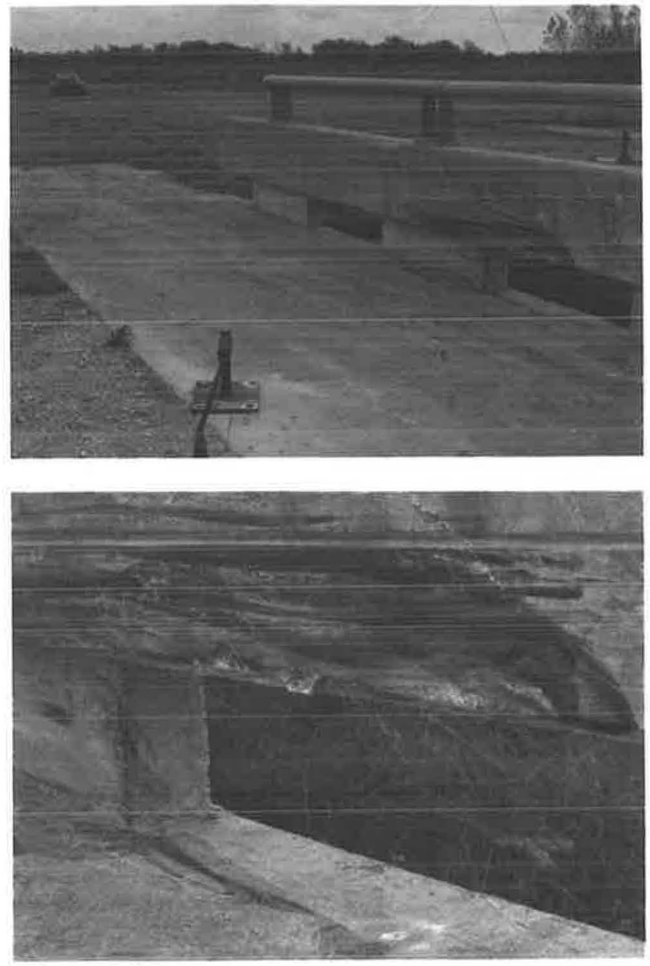


FIGURE 6 Bridge rail after Test 1179-1.

lb (871 kg) including a dummy. Photographs of the Honda before and after the test are presented in Figure 5.

The Honda struck the rail at 61.3 mph (98.6 km/hr) at a 21-degree angle. The impact occurred 7.0 ft upstream of Post 11 and was smoothly redirected. The exit angle of the Honda was only 0.6 degrees, and the car would have remained on the right-hand shoulder and not reentered the traffic lanes. Figure 6 shows the bridge rail and test site immediately after Test 1179-1. The Honda sustained damage to the right front and right side. The right front tire came in contact with Post 11, which can be seen in Figure 6. This contact caused some damage to the front right wheel and suspension; however, the wheel was still rolling after impact. An anthropomorphic dummy was placed in the driver's seat for this test. A summary of the crash test data is shown in Figure 7.

The Honda was equipped with roll, pitch, and yaw rate gyros, an x, y, and z accelerometer group on the floorboard 14.2 in. in front of the center of gravity, and an x and y accelerometer group 50.8 in. behind the center of gravity. Graphs of the filtered data from this instrumentation are presented in Figure 8, which shows a plot of the maximum 0.050-sec average accelerations along the vehicle length at 0.050 sec after impact. This is when the maximum lateral vehicle acceleration at the center of gravity occurred.

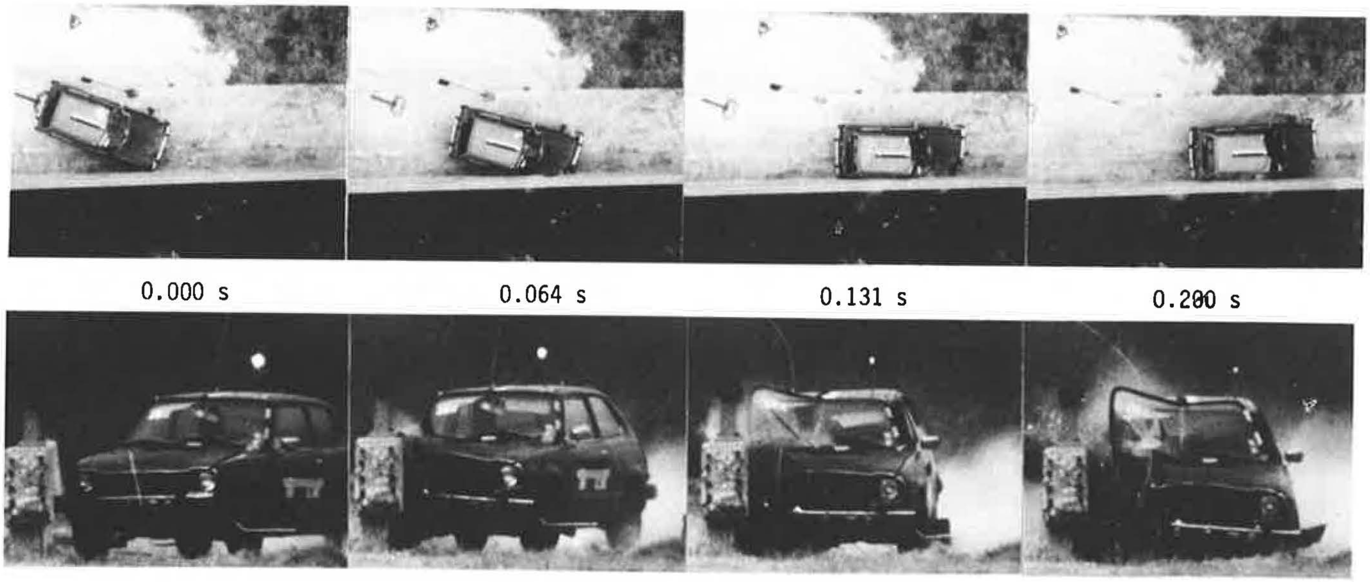
The vehicle and barrier met all of the evaluation criteria required by *NCHRP Report 230* (*5*) and the *Guide Specifications for Bridge Railings* (*6*).

CADILLAC CRASH TEST (TEST 1179-2)

This bridge rail was crash-tested with a 1979 Cadillac weighing 4,400 lb (1998 kg). Photographs of the Cadillac before and after the test are presented in Figures 9 and 10.

The Cadillac struck the rail at 59.4 mph (95.6 km/hr) and at a 25.9-degree angle. Impact occurred 7.5 ft upstream of Post 11 and was smoothly redirected. Figure 11 shows the bridge rail and test site immediately after Test 1179-2. The Cadillac sustained damage to the right front and right side. The right front tire made light contact with concrete Post 11 and the hood came in contact with the metal post directly above concrete Post 11, as shown in Figure 12. This contact caused slight damage to the front right tire and suspension; however, the wheel was still rolling after contact. Severe damage to the hood resulted when it struck the steel post. The impact cracked the right front windshield, which is shown in Figure 10. The hood pushed the windshield inward several inches but did not penetrate the passenger compartment. A summary of the crash data is shown in Figure 13.

The Cadillac was equipped with roll, pitch, and yaw rate gyros, an x, y, and z accelerometer group on the floorboard 16.2 in. in front of the center of gravity, and an x and y accelerometer group 104.8 in. behind the center of gravity. Graphs of the filtered data from this instrumentation are pre-



Test No	1179-1
Date.	11/24/87
Test Installation	C202 Bridge Rail with C4 Steel Rail
Length of Installation. . . .	101 ft (31 m)
Vehicle	1979 Honda Civic
Vehicle Weight	
Test Inertia.	1,750 lb (795 kg)
Gross Static.	1,918 lb (871 kg)
Vehicle Damage Classification	
TAD	01RFQ5
CDC	01RYAS4

Impact Speed	61.3 mi/h (98.6 km/h)
Impact Angle	21.0 deg
Exit Speed	44.5 mi/h (71.6 km/h)
Exit Angle	0.6 deg
Vehicle Accelerations at C.G. (Max. 0.050-sec Avg)	
Longitudinal	-10.2 g
Lateral.	+14.0 g
Occupant Impact Velocity	
Longitudinal	23.3 ft/s (7.1 m/s)
Lateral.	25.7 ft/s (7.8 m/s)
Occupant Ridedown Accelerations	
Longitudinal	2.0 g
Lateral.	-9.3 g

FIGURE 7 Summary of results for Test 1179-1.

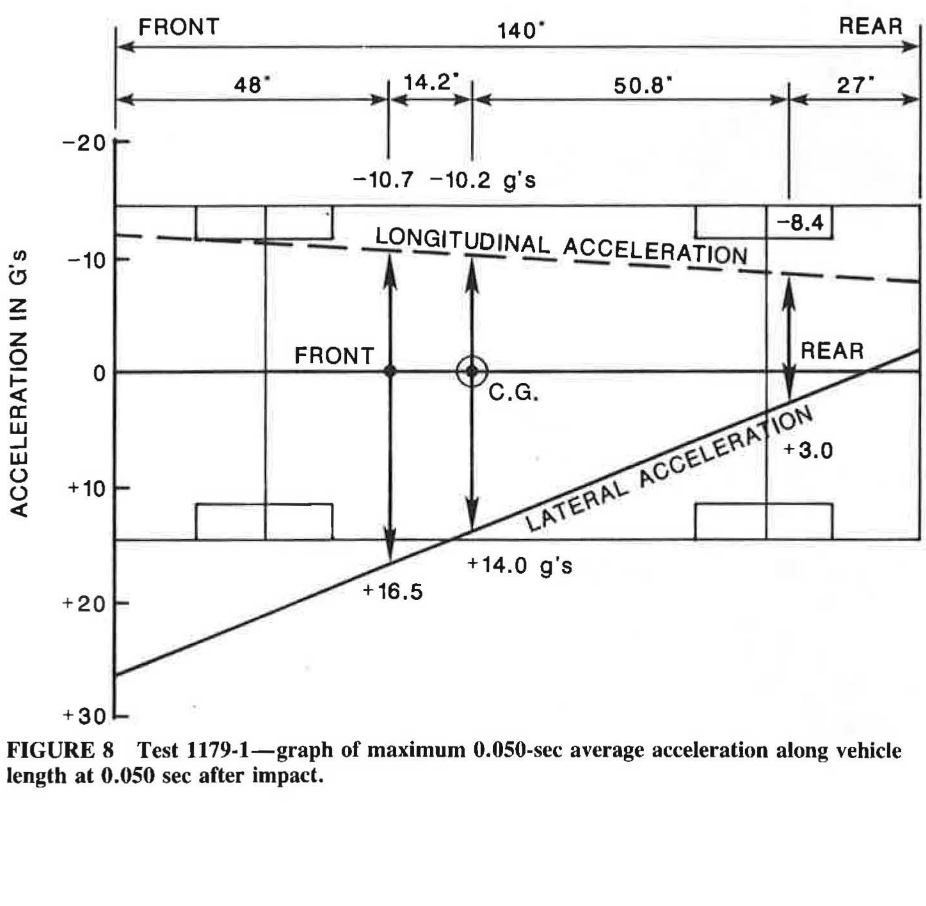


FIGURE 8 Test 1179-1—graph of maximum 0.050-sec average acceleration along vehicle length at 0.050 sec after impact.

FIGURE 9 Vehicle before Test 1179-2.

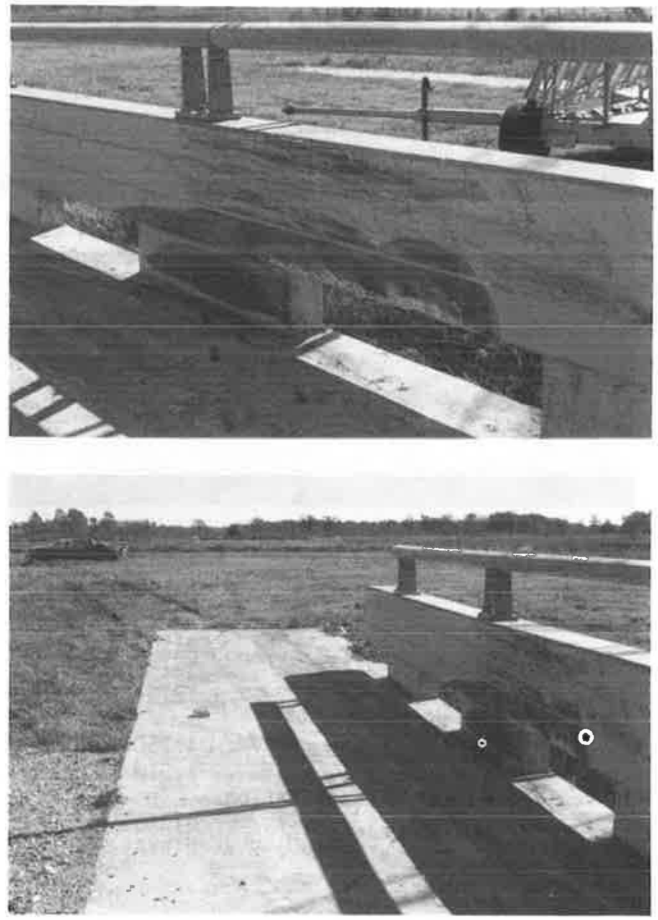


FIGURE 11 Bridge rail after Test 1179-2.

FIGURE 10 Vehicle after Test 1179-2.

sented in Figure 14, which shows a plot of the maximum 0.050-sec average accelerations along the vehicle length at 0.075 sec after impact. This is when the maximum lateral vehicle acceleration at the center of gravity occurred.

The vehicle and barrier met all of the safety evaluation criteria required by *NCHRP Report 230* (*5*) and the *Guide Specifications for Bridge Railings* (*6*).

DISCUSSION OF RESULTS

The Honda Civic test was *NCHRP Report 230* Test S13 and the Cadillac test was Test 10. For a beam-and-post system, *NCHRP Report 230* calls for the impact point to be at mid-span for both tests. However, to determine if the front wheel or hood will contact the posts, *NCHRP Report 230* suggests using a more vulnerable impact location. This was done in the two tests. The impact point was moved 2.0 ft and 2.5 ft, respectively, further upstream of the midspan location and the critical post.

The Honda Civic struck 4.5 ft upstream of the leading edge of the concrete post, and the wheel did contact the post. The damage to the wheel and suspension was moderate, but the wheel was still rolling after impact. The vehicle trajectory was excellent with a departure angle of only 0.6 degree, and the vehicle would not have returned to the traffic lanes. This test

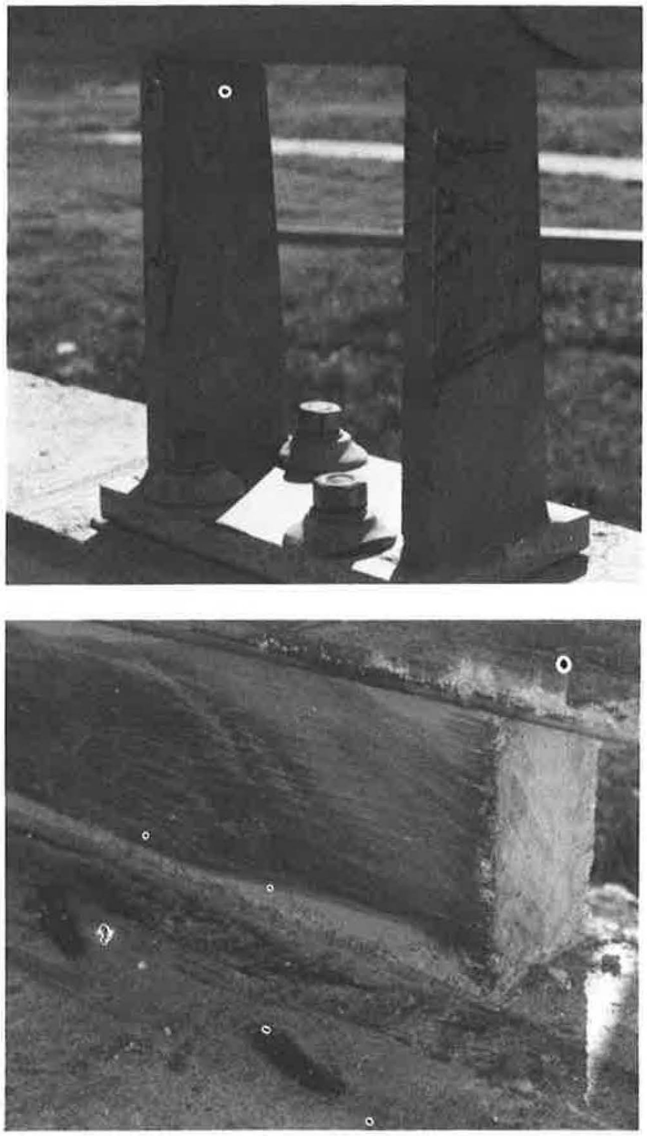


FIGURE 12 Damage to upper and lower Post 11 after Test 1179-2.

was successful and met the evaluation criteria of *NCHRP Report 230*.

The Cadillac struck 5 ft upstream of the leading edge of the concrete post and 7 ft upstream of the leading edge of the steel post. The Cadillac wheel did not contact the concrete post, and the damage to the wheel and suspension was moderate. The wheel was still rolling after impact, and the vehicle trajectory was good with a departure angle of only 2.0 degrees. The hood contacted the steel post and was severely damaged. The hood pushed the right front windshield inward several inches but it did not intrude into the passenger compartment. Consequently, the Cadillac test was judged successful.

Late-model vehicles in the 4,500-lb class are difficult to obtain. The car used was a 1979 model with a large hood that protruded 16 in. over the top of the concrete parapet. Similar vehicles (1977 Plymouths) used in tests reported elsewhere (*7*) had hoods that protruded 14 in. (Test OBR-2) and 12 in. (Test NCBR-2) over the bridge rails. Such vehicles are not representative of modern passenger cars, which have much smaller and differently shaped hoods. The older passenger car hoods extended to within 1 or 2 in. of the outside edge of the car. Modern, smaller hoods terminate 6 to 8 in. inside the outside car edge and are usually shielded by the fenders. A classic example of this is the 1,800-lb Honda Civic used in *NCHRP Report 230* Test S13 (see Figure 6 of *NCHRP Report 230*). Contact between hood and posts has never been observed in tests with this vehicle.

NCHRP Report 230 recommends that the impact position be midway between the posts for longitudinal barriers. In this study the impact positions were selected to be as severe as possible. This was done in order to provide test data on railing geometrics that would help refine the geometrics design guidelines presented by AASHTO (*6*).

Other crash test agencies have almost never moved the impact point far enough upstream of the leading edge of the posts to permit maximum underride of the wheel or override of the hood to achieve this level of interaction (*7*). The vehicle and barrier met the evaluation criteria required by *NCHRP Report 230*.

SUMMARY AND CONCLUSIONS

A standard Texas traffic rail, C202, was modified by increasing its height and strengthened so that it could restrain and redirect an 80,000-lb truck. The modified C202 rail consisted of a concrete beam element 13 in. (33 cm) wide and 23 in. (58 cm) deep, mounted 36 in. (91 cm) high on concrete posts located at 10-ft (3.0-m) center-to-center spacing. The posts were concrete walls 7 in. (19 cm) thick × 5 ft (1.5 m) long with 5-ft (1.5-m) openings between each post. To increase the effective height of the bridge rail, a standard C4 steel rail was mounted on top of the concrete rail.

As reported in Research Report 230-4F (*1*) and Hirsch (*2*), a crash test was conducted on this bridge rail with a 79,770-lb (36 184-kg) tractor-trailer striking the rail at 49.1 mph (79.0 km/hr) at a 15-degree angle. The vehicle was smoothly redirected. Damage to the truck and rail was moderate.

This high-performance bridge rail has now been successfully crash-tested with a 1,918-lb car traveling at 61.3 mph and striking at a 21-degree angle and also with a 4,400-lb car traveling at 59.4 mph and striking at a 25.9-degree angle. The results of both tests met the evaluation criteria in *NCHRP Report 230*. The test with the Cadillac sedan was more critical than a test with a 5,400-lb pickup truck traveling at 60 mph and striking at an angle of 20 degrees. Therefore, the barrier is also considered to meet the requirements for Performance Level 3 in the new AASHTO *Guide Specifications for Bridge Railings* (*6*).

For new construction, consideration should be given to forming a 2-in. chamfer on the traffic side edge of the post. This will further reduce the potential for wheels snagging on the posts.

ACKNOWLEDGMENTS

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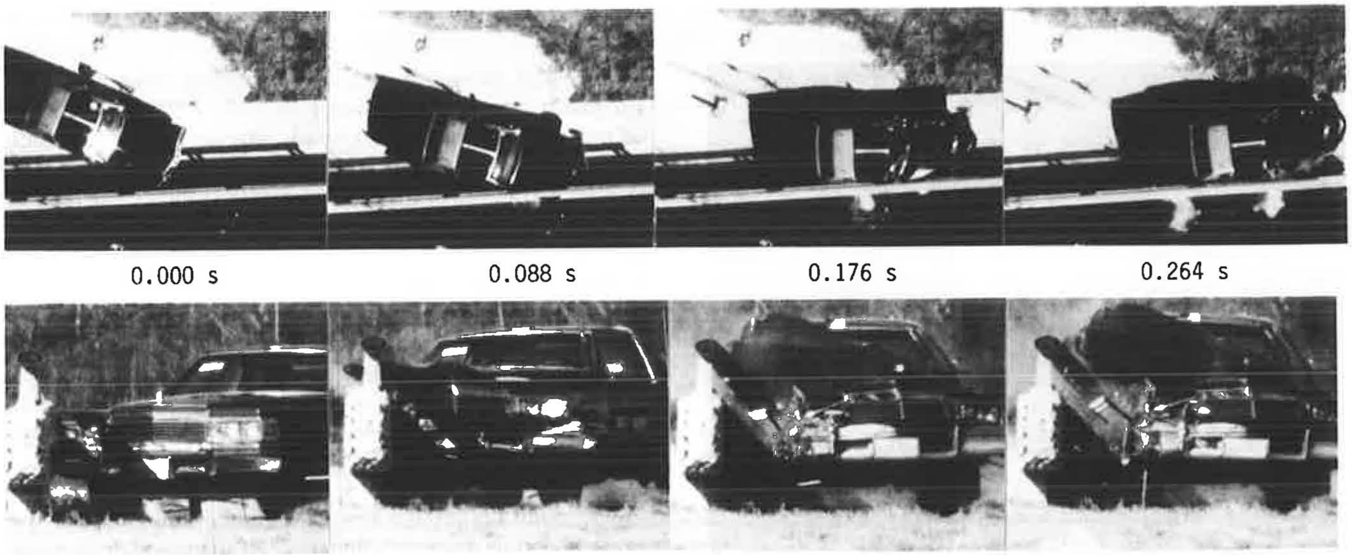

Test No	1179-2
Date.	12/01/87
Test Installation	C202 Bridge Rail with C4 Steel Rail
Length of Installation. . . .	101 ft (31 m)
Vehicle	1979 Cadillac
Vehicle Weight	
Test Inertia.	4,400 lb (1,998 kg)
Vehicle Damage Classification	
TAD	01RFQ6
CDC	01RYAS4

Impact Speed	59.4 mi/h (95.6 km/h)
Impact Angle	25.9 deg
Exit Speed	44.5 mi/h (71.6 km/h)
Exit Angle	2.0 deg
Vehicle Accelerations at C.G. (Max. 0.050-sec Avg)	
Longitudinal	-9.7 g
Lateral.	+14.3 g
Occupant Impact Velocity	
Longitudinal	23.9 ft/s (7.3 m/s)
Lateral.	27.3 ft/s (8.3 m/s)
Occupant Ridedown Accelerations	
Longitudinal	-4.9 g
Lateral.	-16.7 g

FIGURE 13 Summary of results for Test 1179-2.

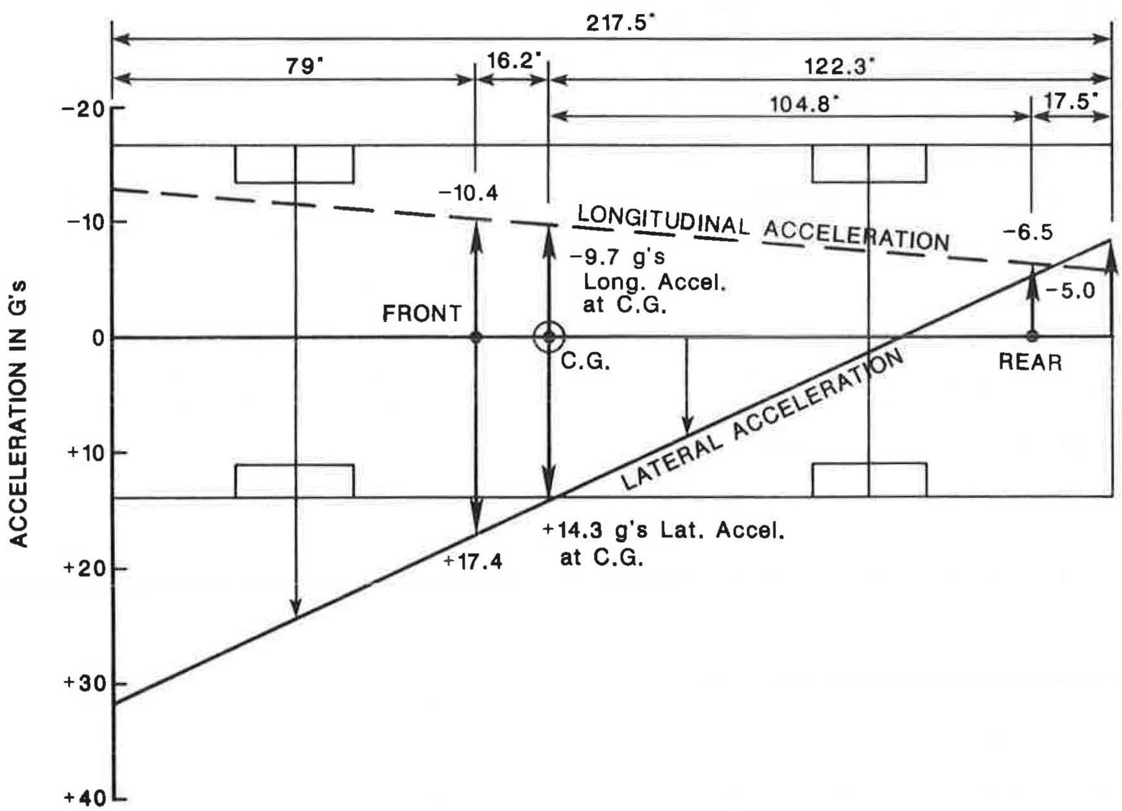

FIGURE 14 Test 1179-2—graph of maximum 0.050-sec average acceleration along vehicle length at 0.075 sec after impact.

and the Federal Highway Administration. Dean Van Landuyt and John J. Panak, both of the SDHPT, were closely involved in all phases of this study.

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