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PUBLIC TRANSPORTATION

COOPERATIVE
RESEARCH

BRIDGE RAIL TO RESTRAIN AND REDIRECT 80,000 LB. TRUCKS

in cooperation with the
Department of Transportation
Federal Highway Administration

RESEARCH REPORT 230-4F
STUDY 2-5-78-230
BRIDGE RAIL

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16. Abstract

A standard Texas traffic rail type 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/h), 15° angle impacts. The concrete parapet was increased to 36 in. (91 cm) high, and an elliptical steel rail was mounted on steel posts to increase the rail height to 54 in. (137 cm). One crash test was conducted on the bridge rail. The truck was restrained and smoothly redirected. This test has shown that a simple and economical rail can redirect heavy van type trucks at speeds up to 50 mph (80.5 km/h) and 15° angle impact. The cost of this rail is estimated at about $80 to $90 per foot. Typical passenger car bridge rails in Texas now cost about $25 to $35 per foot.

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BRIDGE RAIL TO RESTRAIN AND REDIRECT 80,000 LB TRUCKS

by

T. J. Hirsch
Research Engineer & Principal Investigator

and

Althea Arnold
Engineering Research Associate

Research Report 230-4F

on

Research Study No. 2-5-78-230
Bridge Rail to Contain Heavy Trucks and Buses

Sponsored by

Texas State Department of Highways and Public Transportation

in cooperation with

The U.S. Department of Transportation
Federal Highway Administration

November 1981

Texas Transportation Institute
Texas A&M University
College Station, Texas

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

KEY WORDS

Bridge Rails, Traffic Barriers, Highway Safety, Trucks, Heavy Vehicles

ACKNOWLEDGMENTS

This research study was conducted under a cooperative program between the Texas Transportation Institute (TTI), the State Department of Highways and Public Transportation (SDHPT) and the Federal Highway Administration (FHWA). Mr. Robert L. Reed (Engineer of Bridge Design, SDHPT) and John J. Panak (Supervising Designing Engineer, SDHPT) were closely involved in all phases of this study.

IMPLEMENTATION STATEMENT

As of the writing of this report none of the findings or conclusions presented have been implemented.

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INTRODUCTION

Current bridge rails are only designed to restrain and redirect passenger cars. Research Report 230-2 (1)* presented an analytical evalulation of Texas bridge rails to contain buses and trucks. Research Report 230-3 (2) presented the results of crash tests on a modified Texas traffic rail type T202 which successfully redirected a 20,000 lb (9,000 kg) school bus and a 32,000 lb (17,400 kg) intercity bus, both at nominally 60 mph (96 km/h) and 15^{o} angle. With the increase in the number and size of large trucks the problem of truck-bridge rail collision is becoming more evident. The bridge rail tested here was selected and designed to restrain and redirect an 80,000 lb (36,287 kg) van type tractor-trailer (3). The design was based on procedures and test data presented in References (1) and (10).

The basic rail selected was a modification of the concrete parapet, Texas traffic rail type C202. The modified C202 rail consists 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 concrete posts are 7 in. (18 cm) thick by 5 ft (1.5 m) long concrete walls with 5 ft (1.5 m) openings. The beam element contains considerable reinforcing steel and provides flexibility, thus minimizing cracking of the concrete when impacted by heavy vehicles. The modified C202 concrete parapet can be placed in long, continuous lengths giving good structural continuity and strength.

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

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*Numbers in parentheses, thus (1), refer to corresponding item in the References.

DESCRIPTION OF BRIDGE RAIL AND DECK MODIFICATIONS

The modified combination rail C202 concrete post/rail has a type C4 steel rail mounted on top. This modified bridge rail makes a combination bridge rail 54 in. (137 cm) high suitable to retain large, 80,000 lb (36,287 kg) van type trucks or tractor-trailers impacting (3) at 15° and 50 mph (80.5 km/h). Drawings of this rail are shown in Figures 1 and 2. Figure 3 contains photographs comparing the size of this combination bridge rail with a Honda Civic, Plymouth, and van type tractor-trailer.

The strength of the standard Texas 7.5 in. (19 cm) thick bridge deck 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 x 7 in. (17.8 cm) thick x 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 thirteen #4 bars (traffic side) and five #4 bars (field side). The thirteen #4 bars contained an 8 in. (20 cm) lap splice on top of the bridge deck which was intended as a breakaway connection.

The concrete rail on top of the post was 13 in. (33 cm) thick by 23 in. (58 cm) high for the entire length of the rail. It contained two sections of square spiral as shown, with ten #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 which requires this type of spiral.

The steel rail on top of the modified C202 concrete rail was the Texas standard type C4 steel rail. It was made from 6 in. (15 cm) diameter standard

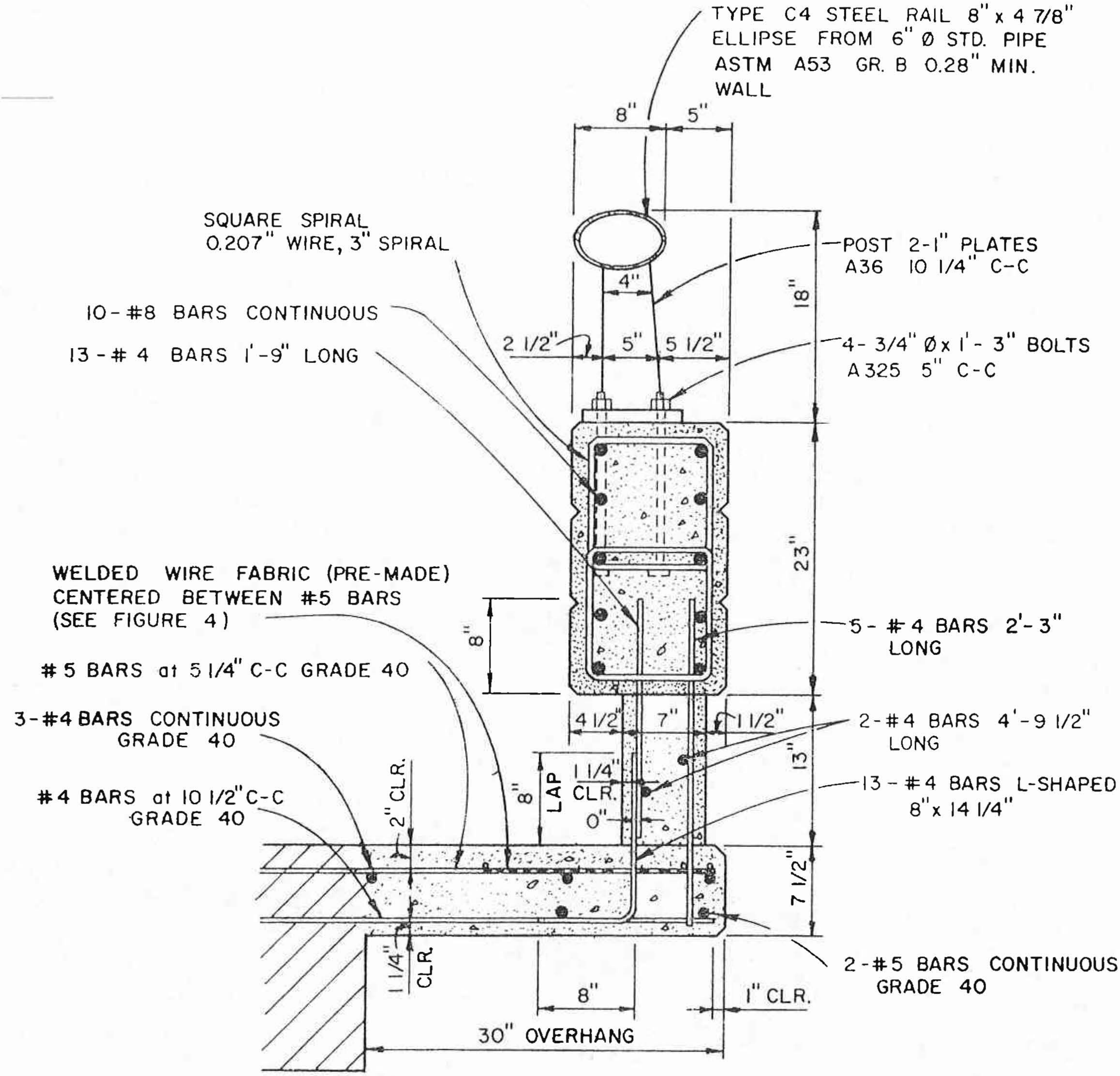


Figure 1. Cross Section of the Modified C202 Bridge Rail.

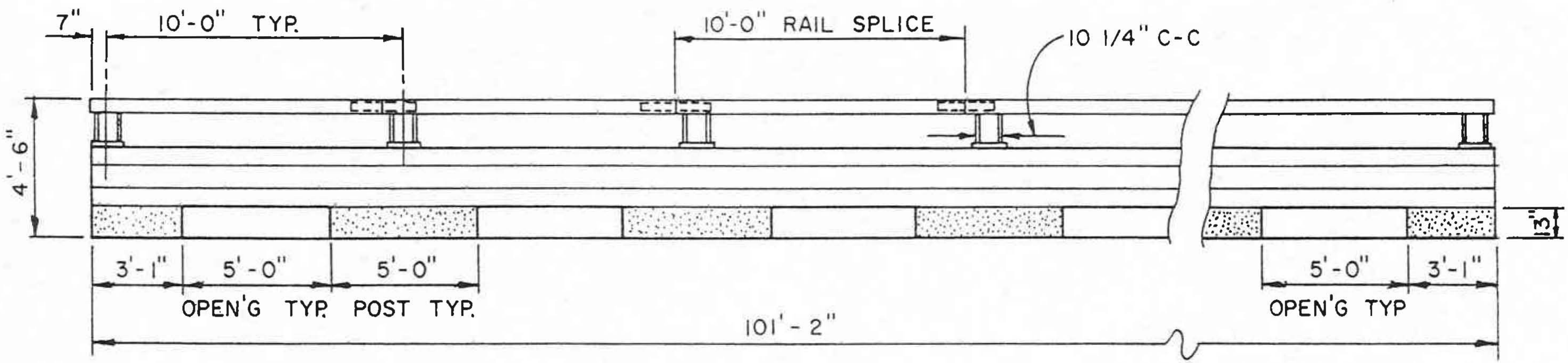
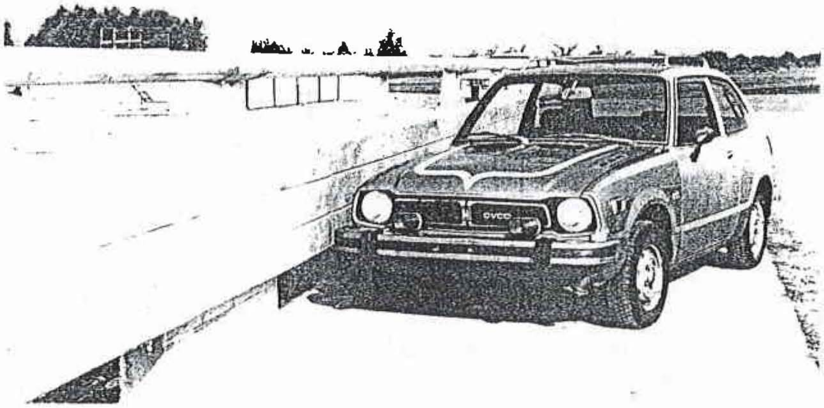
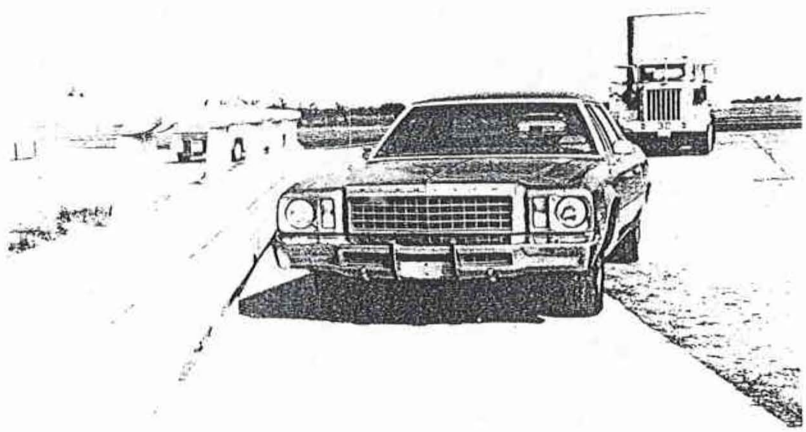


Figure 2. Elevation of the Modified C202 Bridge Rail.



NOTE: This rail has not been tested with a mini or standard passenger car at this time.



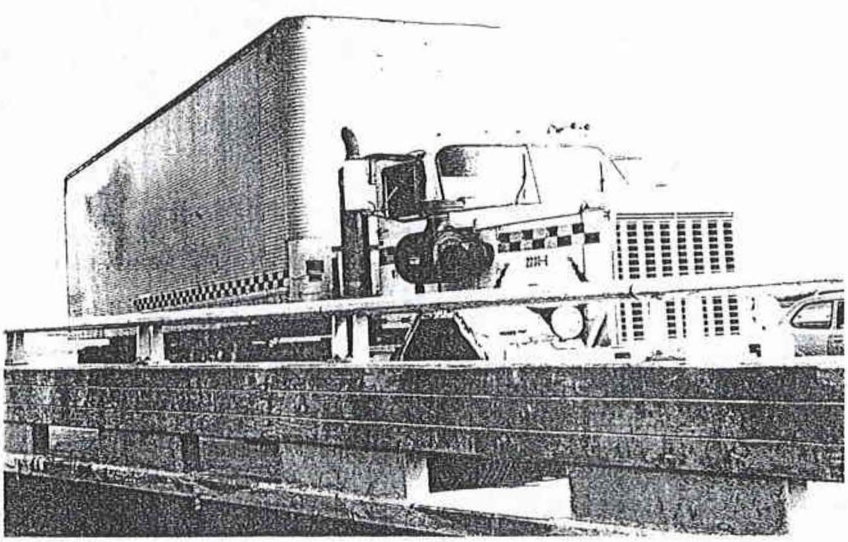


Figure 3. Comparison of Honda, Plymouth, and 80,000 lb Truck with Modified Combination Rail.

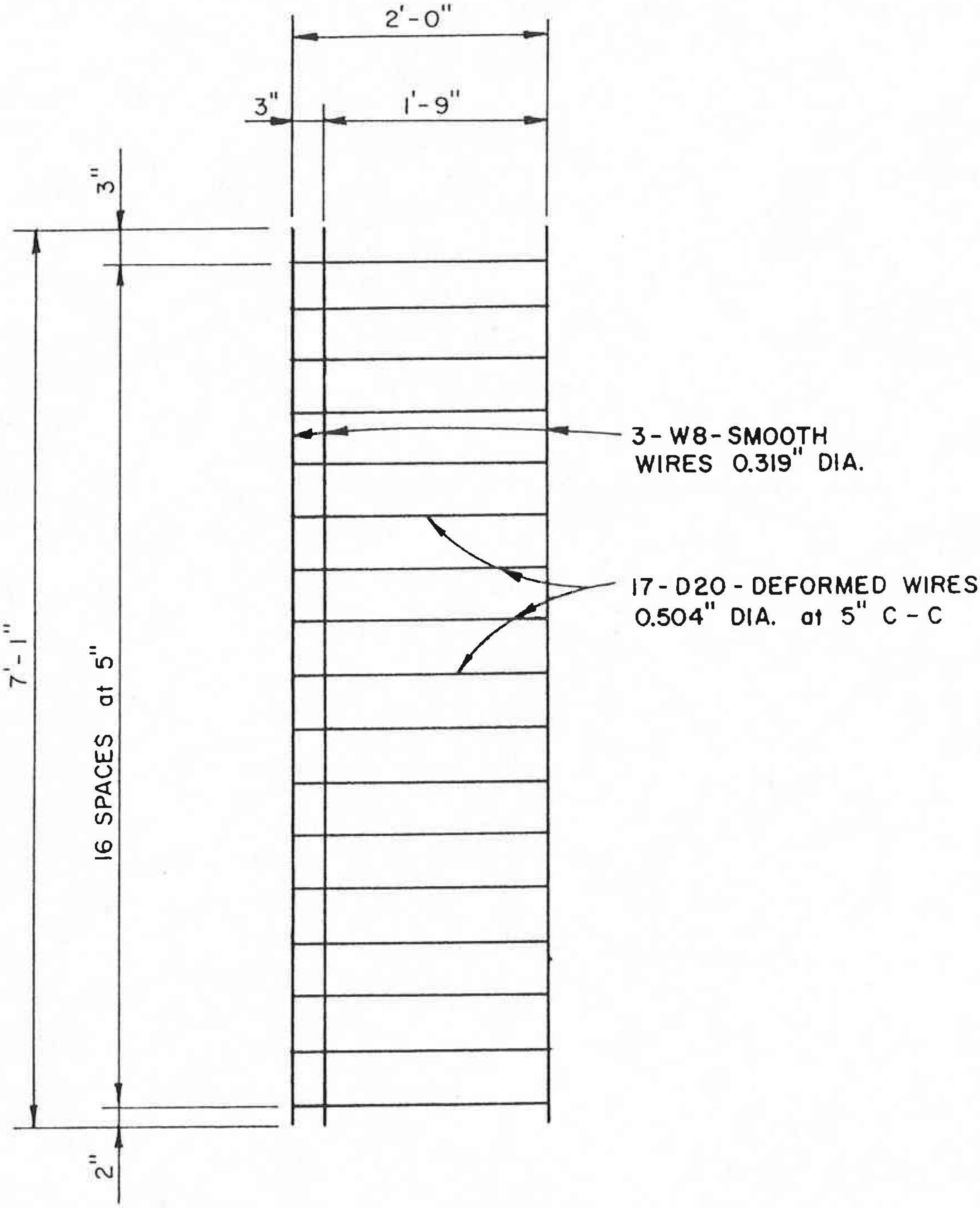


Figure 4. Detail of Special Slab Reinforcement used Under Each Concrete Post.

steel pipe (ASTM A53 Grade B) shaped into an 8 in. x 4-7/8 in. (20 cm x 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 3/4 in. diameter by 15 in. (38 cm) long A325 bolts. 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.

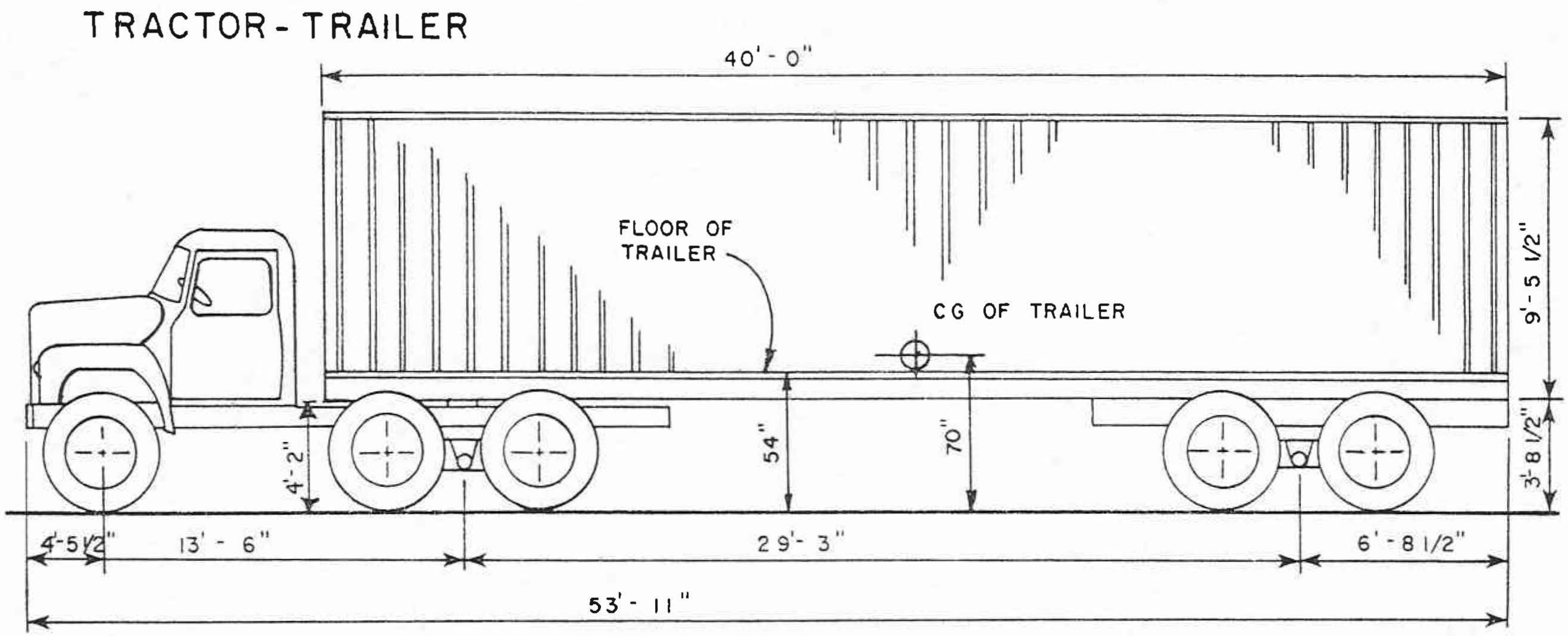
All steel bars in the concrete post and rail were grade 60, including the bent bars that anchor the post to the deck. The deck steel bars were grade 40. The concrete for the deck, post and rail was such that its strength was 3000 psi (2.068 KN/cm^2) at the time of the test.

TRUCK CRASH TEST

This bridge rail system was designed to contain and redirect an 80,000 lb (36,287 kg) van type tractor-trailer. A simulated bridge deck with this rail system was built at the Texas Transportation Institute Proving Grounds and tested with a 1978 Auto Car tractor-trailer ballasted with sand bags to 79,770 lbs (36,184 kg). Drawings showing the dimensions of this vehicle along with loaded and unloaded weights on each axle or pair of axles are shown in Figures 5 and 6. Before and after test photographs of the truck are presented in Figures 7 and 8.

The truck impacted the rail at 49.1 mph (79.0 km/h) and 15^{0} angle. Impact occurred between posts 3 and 4, and the truck was smoothly redirected. Figure 9 shows the bridge rail and test site immediately after test 6. The truck entry and exit path can be seen clearly. The truck sustained damage to the right front and right tandem wheels. The trailer body bulged out slightly on the right side from the shift in load (sand bags). The trailer body was in contact with the upper railing over a length of approximately 40 ft (12 m) as can be seen in Figure 8. This point of contact was centered about 4 in. (10 cm) above the trailer floor which is at 54 in. (137 cm) as shown in Figure 5. A summary of the crash test data is shown in Table 1.

The bridge deck supporting posts 1 through 8 was cracked and damaged, with the major portion of the damage centered around post 4. Test results on another on-going HPR research study has indicated the welded wire fabric shown by Figure 4 did not significantly increase the deck or slab strength. Appendix C shows composite photographs of the traffic and field side of the rail after the test. The cracks in the rail were highlighted with grease pencil for better visibility. Sequential photographs showing the overhead and frontal view of the crash test are shown in Appendix A.

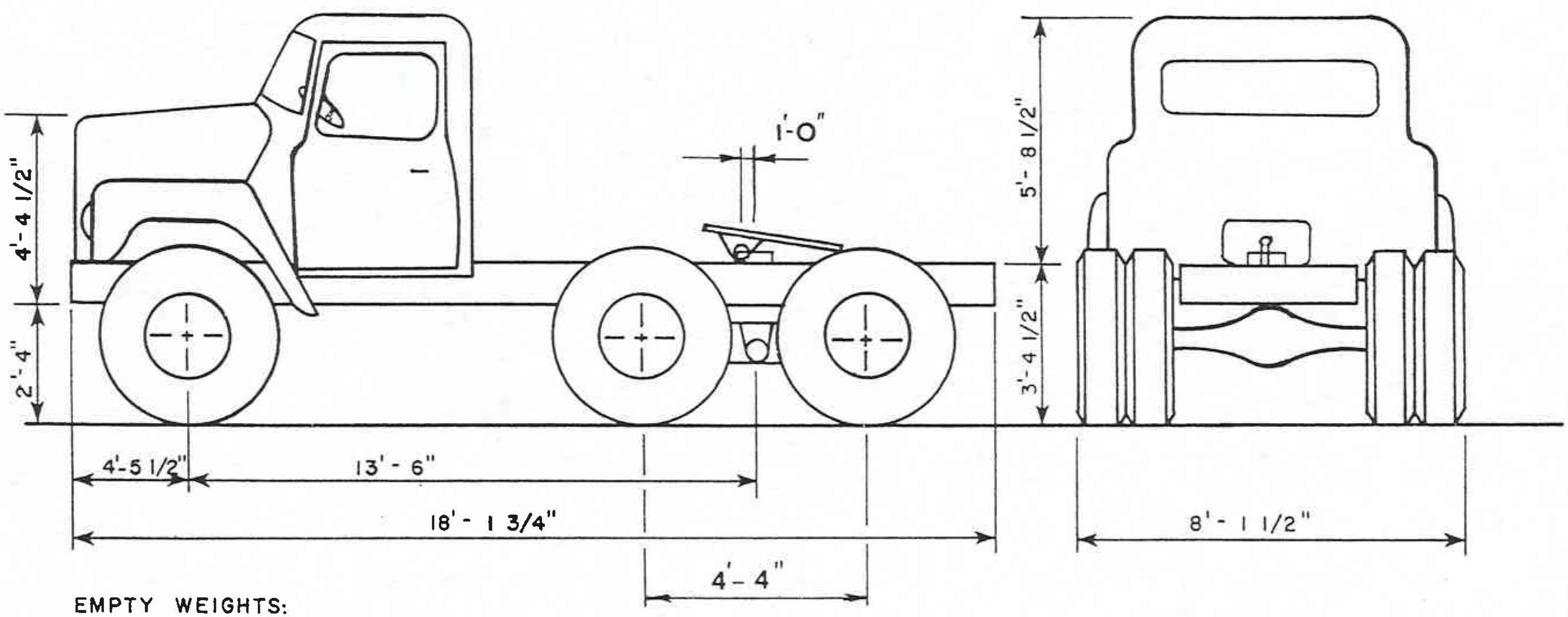


EMPTY WEIGHTS:	
Weight on front axle	10,720 lbs
Weight on center axles	13,070
Weight on rear axles	8,880
Total Empty Weight	32,670 lbs

LOADED WEIGHTS:	
Weight on front axle	11,490 lbs
Weight on center axles	33,760
Weight on rear axles	34,520
Total Loaded Weight	79,770 lbs

Figure 5. Tractor-Trailer Loaded Dimensions, Empty Weights and Loaded Weights.

TRACTOR



EMPTY WEIGHTS:

Weight on front axle	10,320 lbs
Weight on rear axles	8,070
Total Empty Weights	18,390 lbs

Figure 6. Empty Tractor Dimensions and Weights.

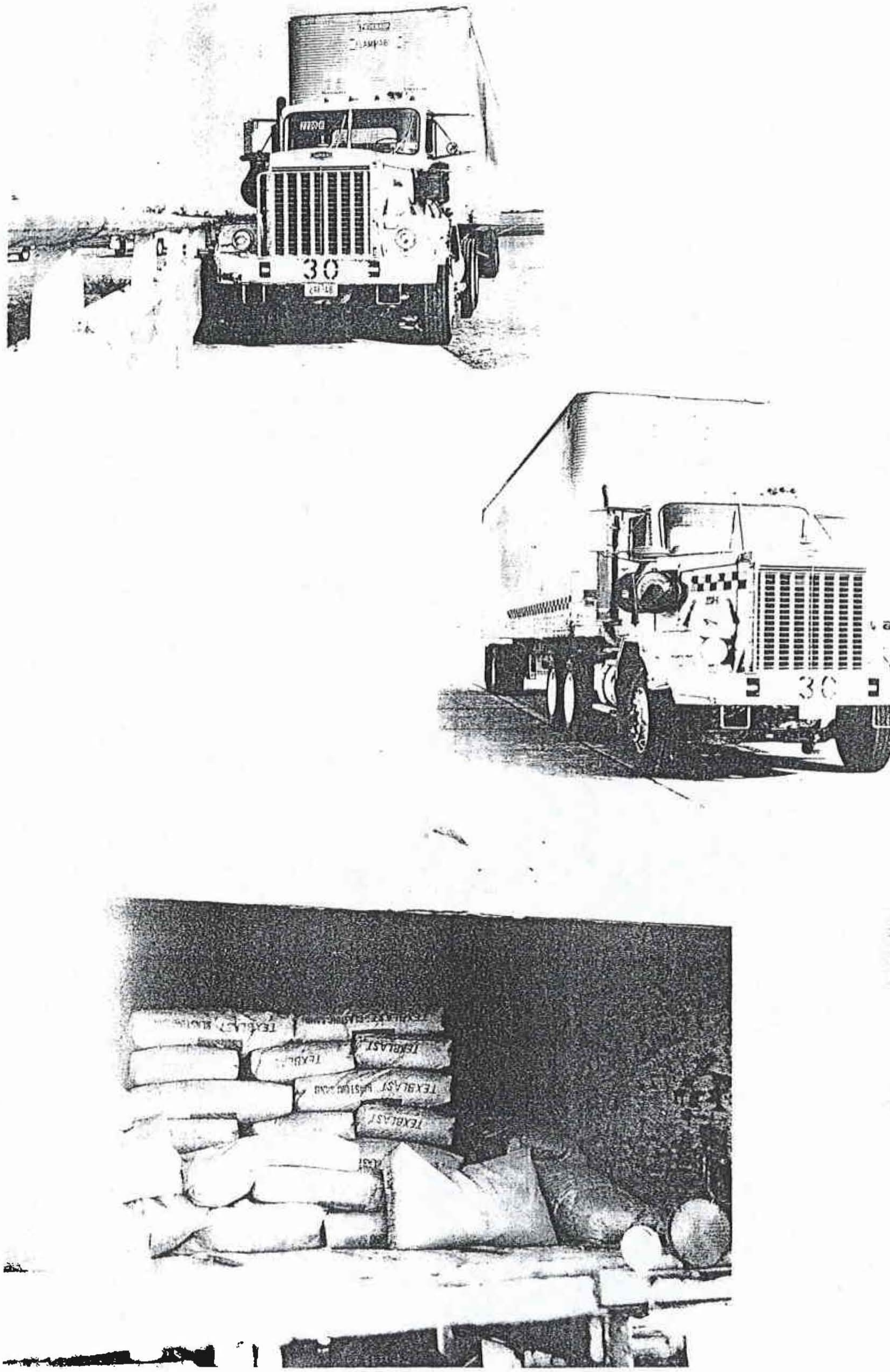


Figure 7. 80,000 lb Truck before Test.

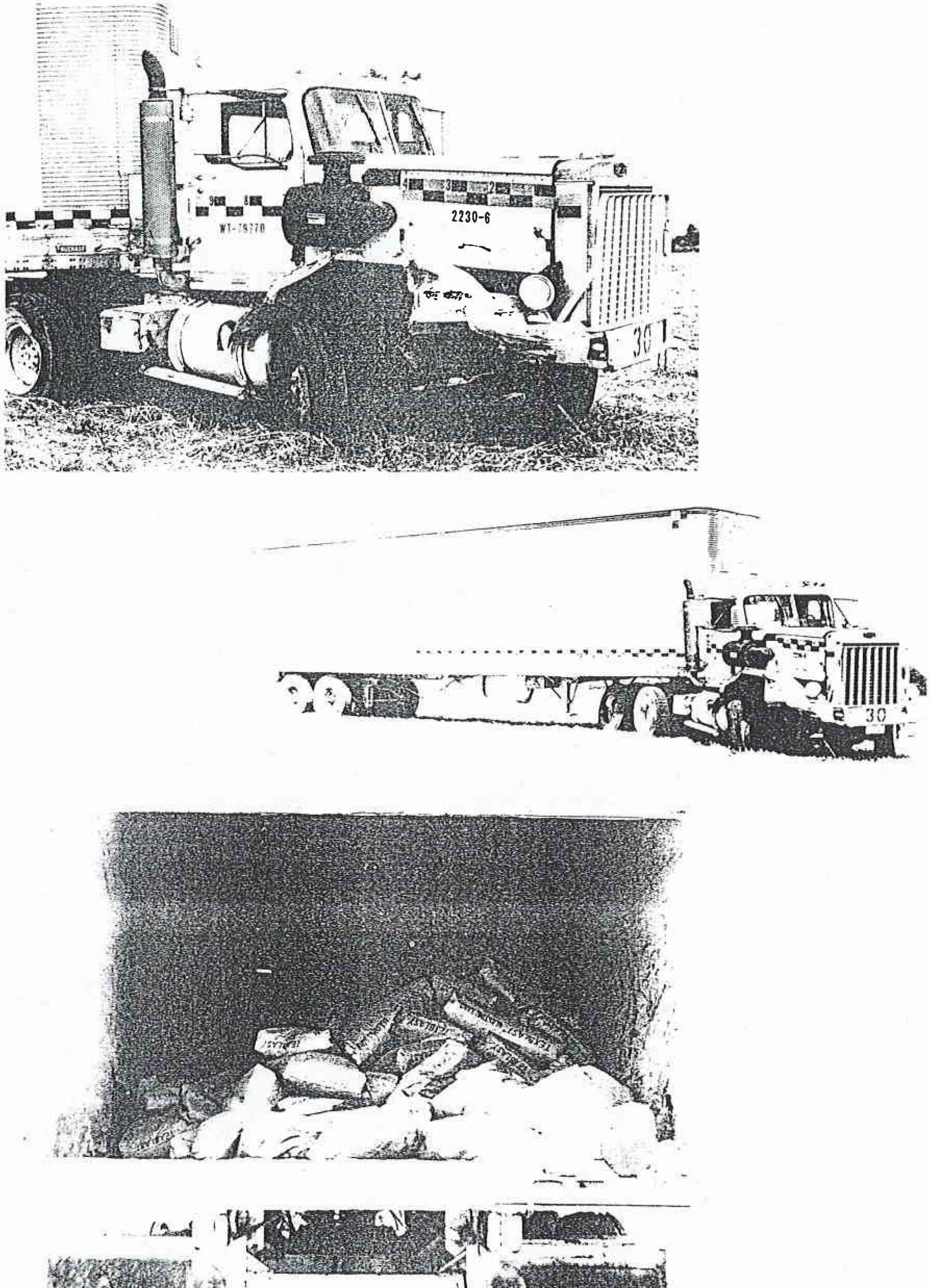


Figure 8. 80,000 lb Truck after Test.

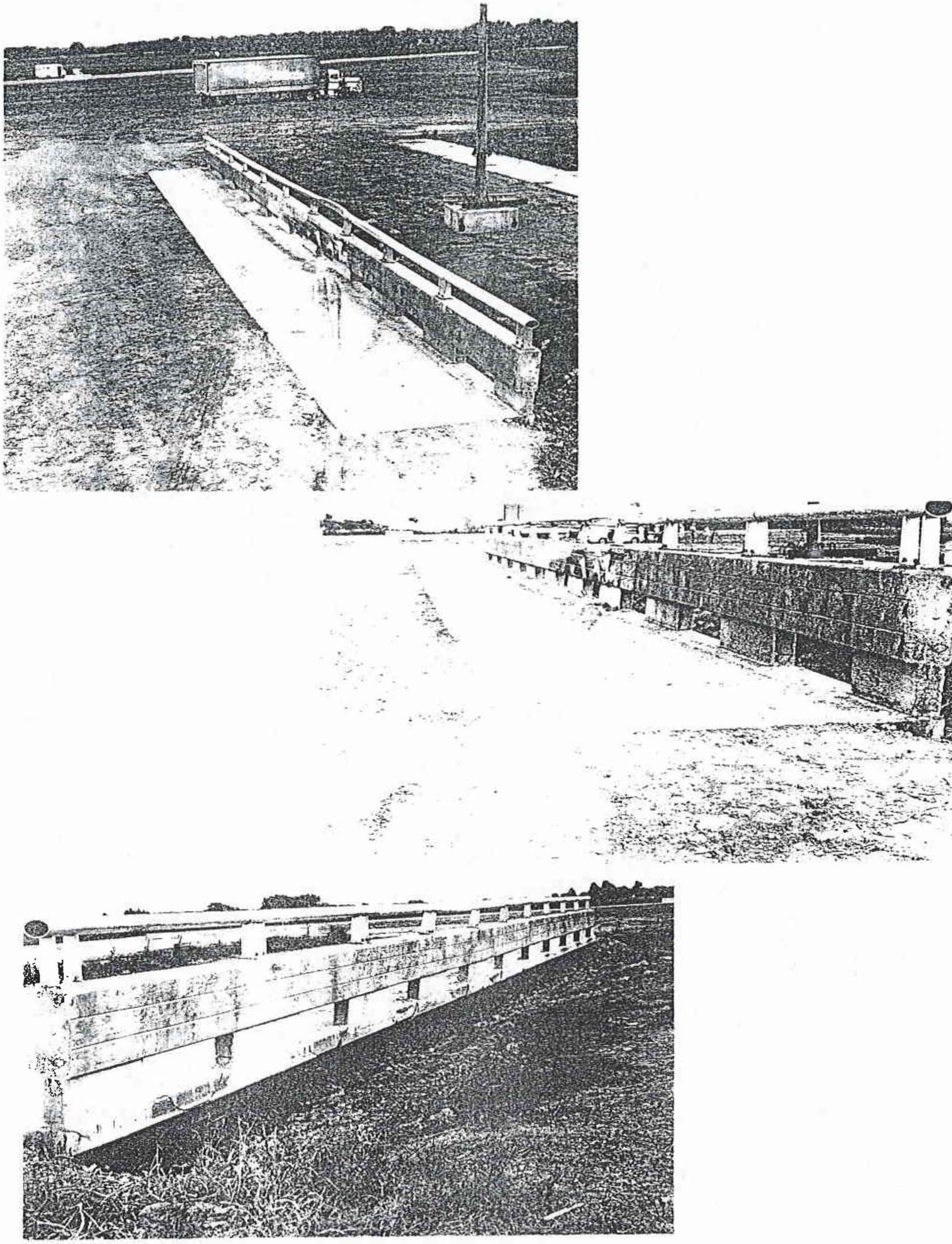


Figure 9. Bridge Rail and Truck after Test.

Table 1. Summary and Results of Crash Tests.

TEST NUMBER	6
VEHICLE DATA	Tractor-Trailer (Van Type) 1978 Auto Car
MASS - kg (lb)	36,184 (79,770)
SPEED - km/hr (mph)	79.0 (49.1)
FILM DATA	
Angle - degrees	
Impact	15°
Departure	
Truck	6.3°
Trailer	2.5°
Roll, max.	
Truck	6.0°
Trailer	16.5°
Time to parallel - sec	0.6
Barrier Displacement - cm (in.)	
Concrete Rail	3.8 (1.5)
Steel Rail	30.5 (12)
Distance to Parallel - m (ft)	
Longitudinal	11.3 (35.6)
Lateral	0.65 (2.05)
ACCELEROMETER DATA (located over tractor tandem axles)	
100 hz lo-pass max. flat filter	
Max. Avg. 0.050 Sec Acceleration	
Longitudinal, g's	-1.68
Lateral, g's	5.94
Resultant, g's	6.28
Peak Acceleration	
Longitudinal, g's	21.55
Lateral, g's	19.03
Resultant, g's	31.03

The truck was equipped with roll, pitch, and yaw rate gyro's and x, y, and z accelerometers located above the tractor tandem wheels. Graphs of the filtered data from this instrumentation are presented in Appendix B.

Other data were gathered on the truck during the test. Maximum roll of the tractor tandem axles was 6^{0} from the roll rate gyros and of the trailer 16.5^{0} from the high-speed film. From the accelerometers, the longitudinal, lateral, and resultant maximum average 0.050 sec accelerations were -1.68, 5.94, and 6.28, respectively.

DISCUSSION OF RESULTS

NCHRP Report 230 (3) recommends the following criteria for test S20 (80,000 lb/50 mph/15 deg):

1. "Test article shall smoothly redirect the vehicle; the vehicle shall not penetrate or go over the installation."
2. "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."

According to these criteria the test was a success. The bridge rail contained and smoothly redirected the truck. The bridge rail also remained intact.

Impact severity as defined by the occupant flail space approach was also computed from the accelerometer data. The recommended threshold values for the flail space evaluation are 40 fps and 30 fps for the longitudinal and lateral occupant impact velocity, and 20 g's for the highest 10 msec average after contact. The computed values for this test were well below these recommended values. The longitudinal impact velocity was 7.6 fps, and the highest 10 msec average acceleration after impact was 1.2 g's. The lateral impact velocity was 18.3 fps, and the highest 10 msec average acceleration was 3.3 g's.

The design intent of the upper C4 rail centered at 51.5 in. (131 cm) was to allow the relatively hard trailer floor to strike this rail and thus provide a resistance to overturning by the trailer. The trailer actually impacted this rail at about 6 in. (15 cm) above the centroid of the floor system and thus was in the relatively soft sheet metal portion of the trailer body. Some of the 16.5° roll angle of the trailer was thus due to this softer impact and some was due to the early fracture of the cast steel washers on the anchor bolts.

SUMMARY AND CONCLUSIONS

A standard Texas traffic rail type C202 was modified by increasing its height and strengthened so that it could restrain and redirect an 80,000 lb van type truck or tractor-trailer. 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 concrete posts were 7 in. (18 cm) thick by 5 ft (1.5 m) long concrete walls with 5 ft (1.5 m) openings between each post. To increase the effective height of the bridge rail, a standard type C4 steel rail was mounted on top of the concrete rail.

The crash test was conducted on this bridge rail with a 79,770 lb (36,184 kg) van type tractor-trailer impacting the rail at 49.1 mph (79.0 km/h) and 15^{o}. The vehicle was smoothly redirected. Damage to the truck and rail was moderate.

One significant conclusion that can be deduced from this test is that the upper rail centered at 51.5 in. (131 cm) would have probably performed better had it been lower and if the post anchorage cast steel washers had not prematurely shattered. The trailer roll angle (16.5^{o}) would probably have been smaller. Part of the trailer roll angle was due to the rail contacting the soft body sheet metal. Had the upper rail posts been stiffer and if the rail had contacted the trailer floor as was the design intent, the trailer roll angle would hve been reduced. Thus, some believe that a better location for the upper rail would have been about 51 in. (130 cm) high rather than the 54 in. (137 cm) height used. Another Texas standard rail, the T4, has posts that are stronger than the C4 posts and if it were used in lieu of the C4, the height would become 51 in. (130 cm).

Since many tractor-trailer combinations with long loads use flatbed trailers with no body, it is further recommended that the standard T4 rail be used for the upper rail element of this system. It is further recommended that conventional hardened steel washers be used at the post anchorages.

This test has shown that a bridge rail can be built on standard concrete decks to contain large van type trucks and redirect them without rollover.

The cost of this heavy truck bridge rail is estimated at about $80 to $90 per linear foot. The cost of typical metal or concrete bridge rails now in use in Texas is about $25 to $35 per linear foot.

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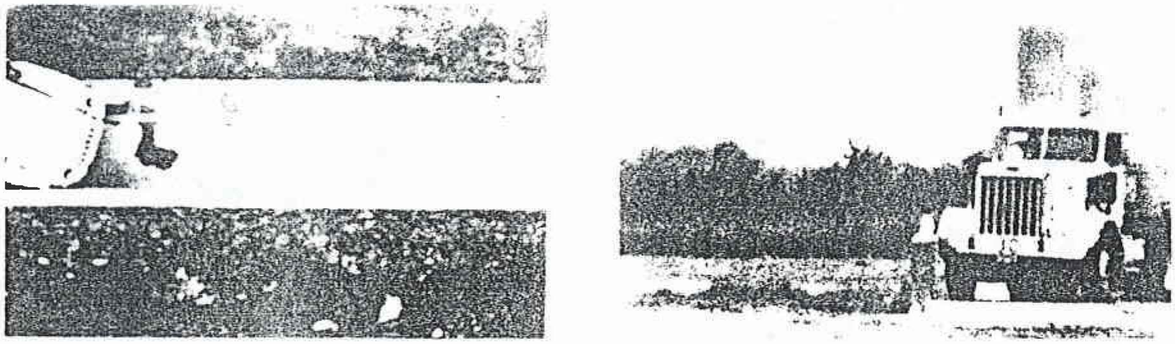
APPENDIX A

SEQUENTIAL PHOTOGRAPHS OF TEST 6



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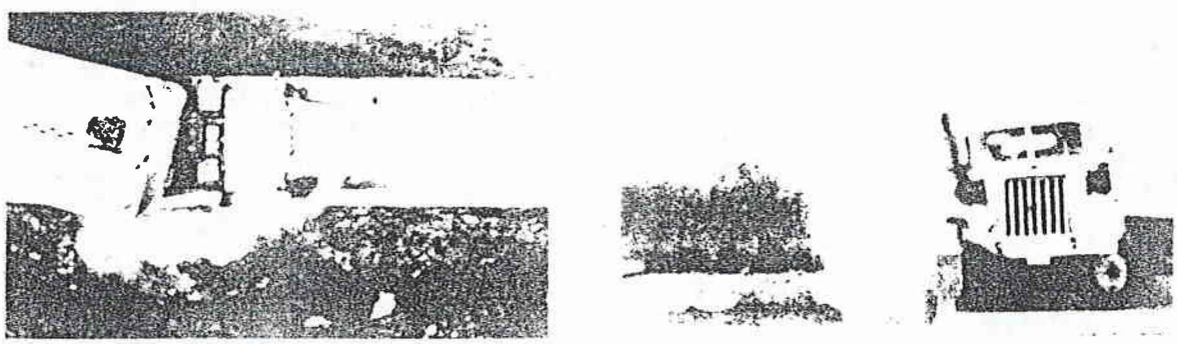

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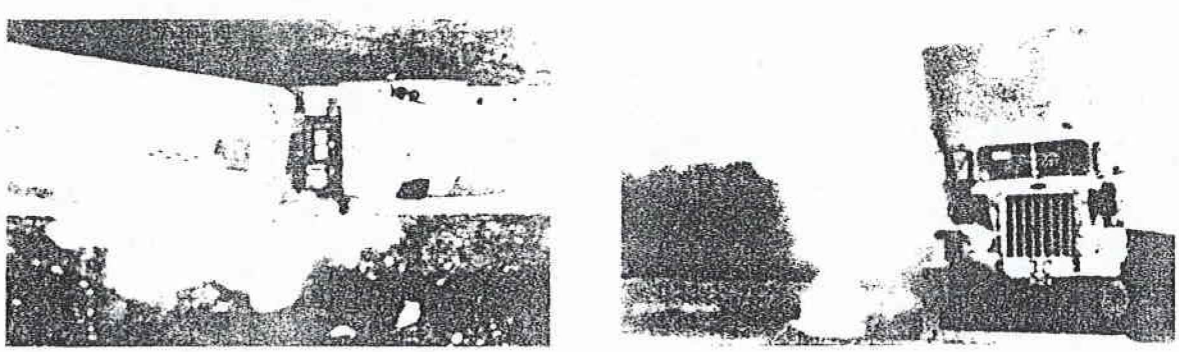
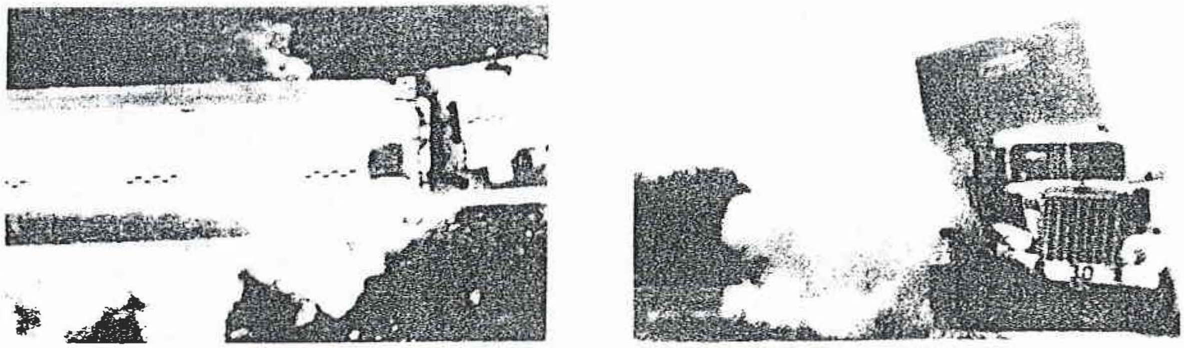


0.391 sec.

Figure A1. Sequential Photographs of Test.



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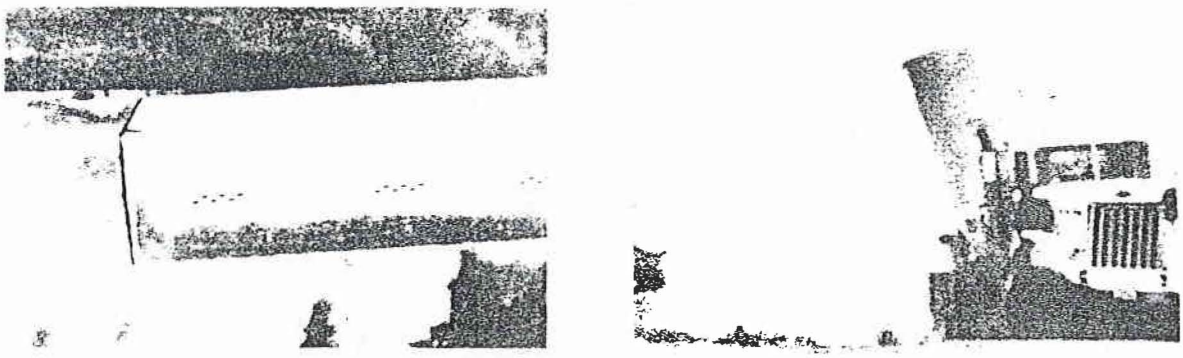

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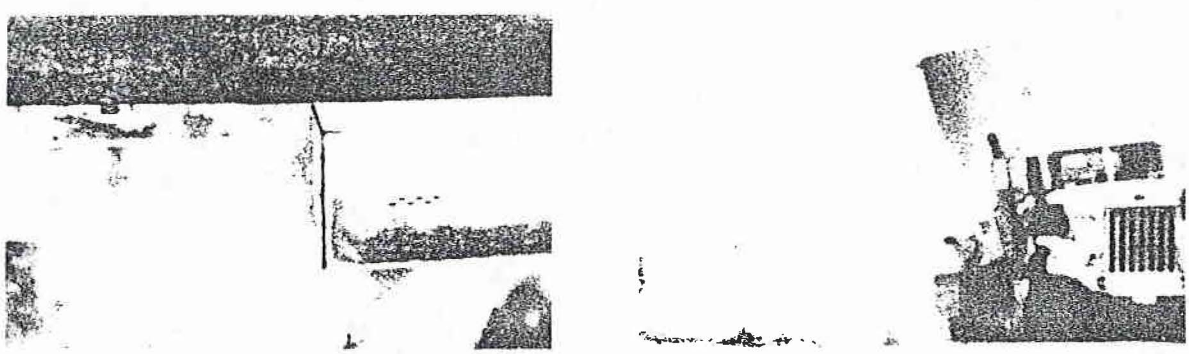

1.096 sec.

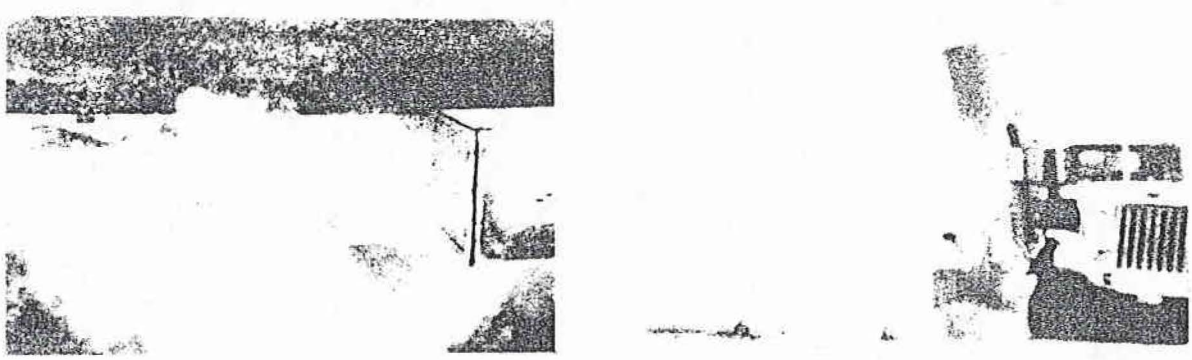

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Figure A1. Sequential Photographs of Test. (continued)

APPENDIX B

ELECTRONIC ACCELEROMETER, ROLL, PITCH AND YAW DATA

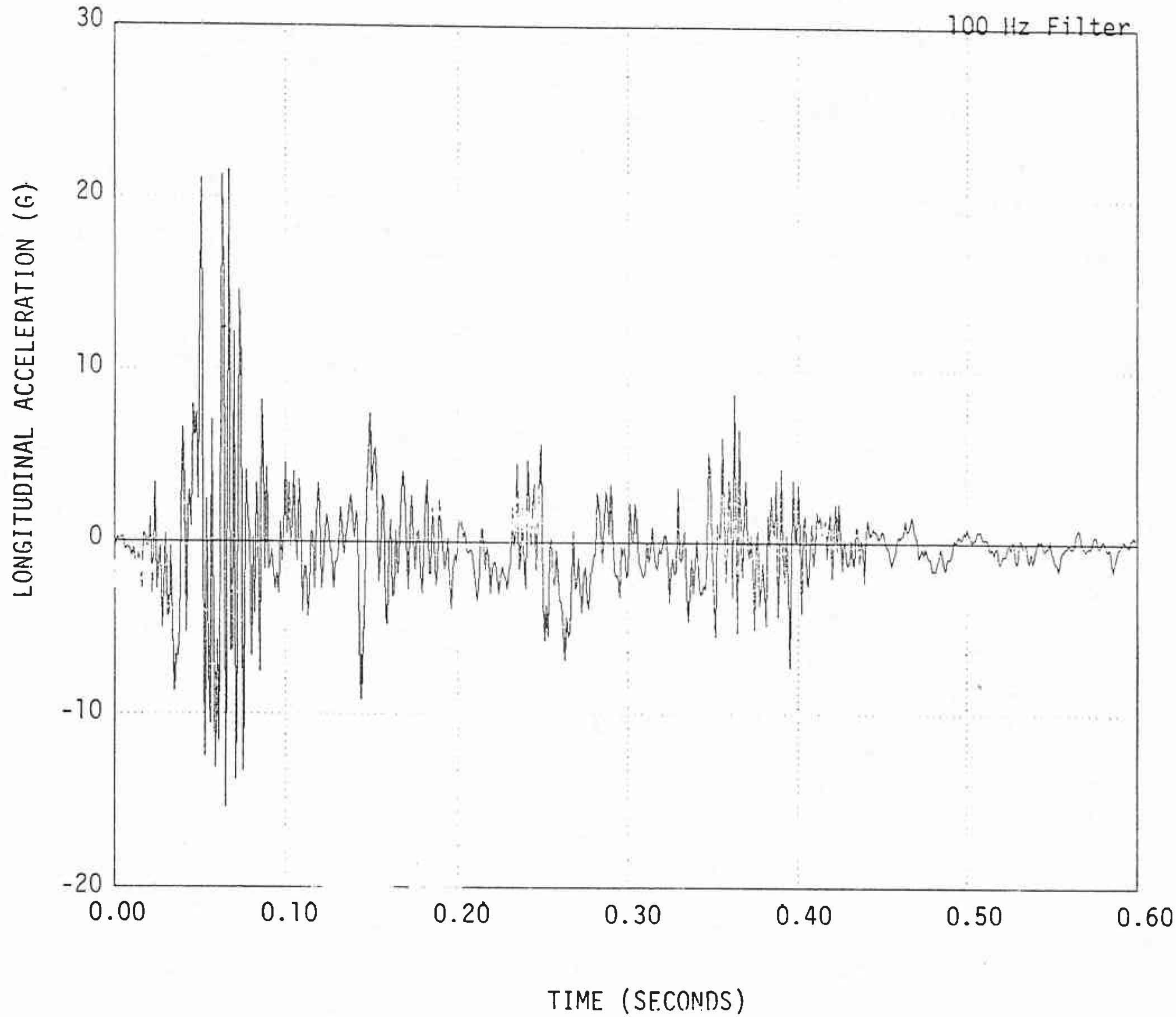

Figure B1. Vehicle Longitudinal Acceleration.

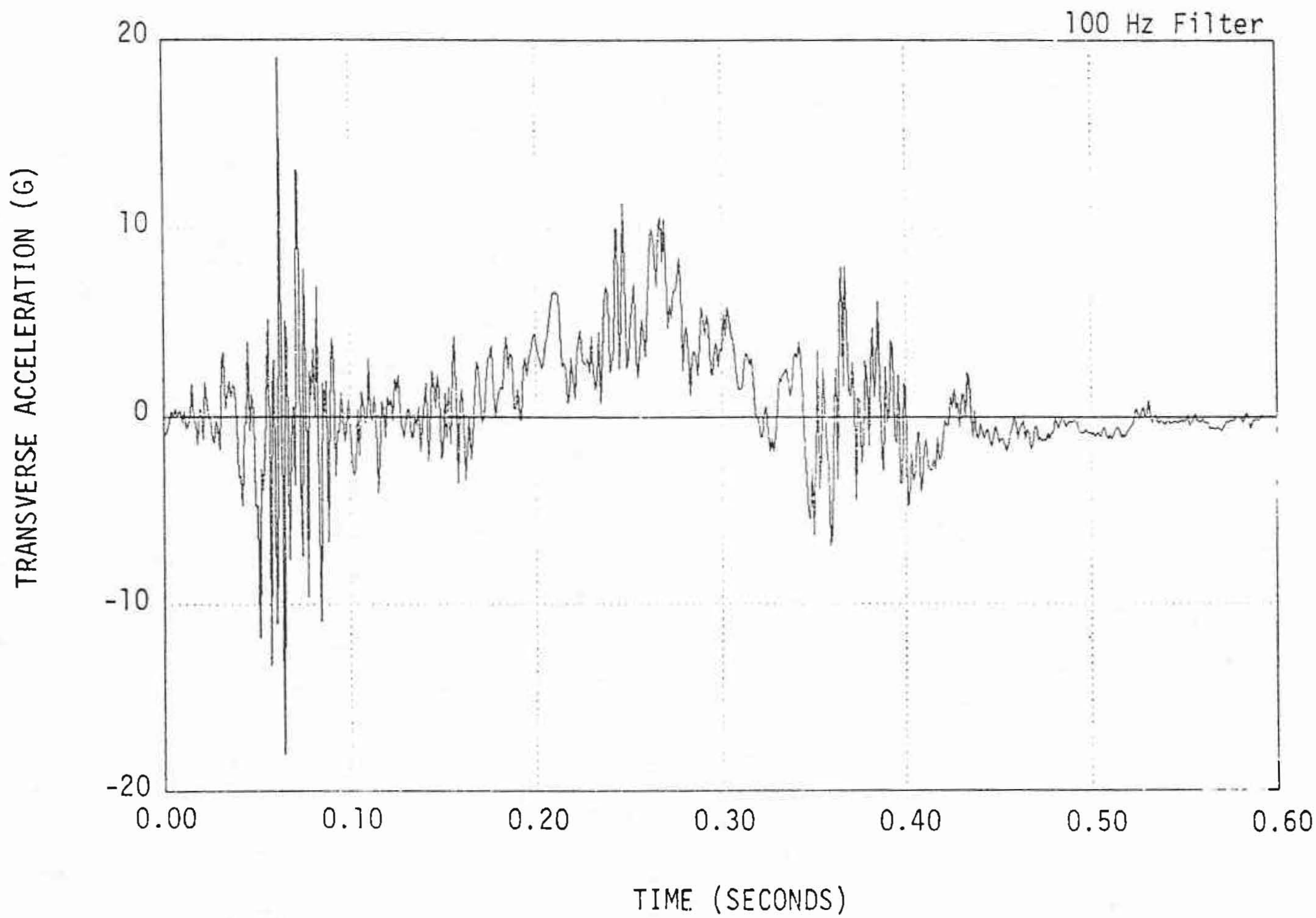

Figure B2. Vehicle Transverse Acceleration.

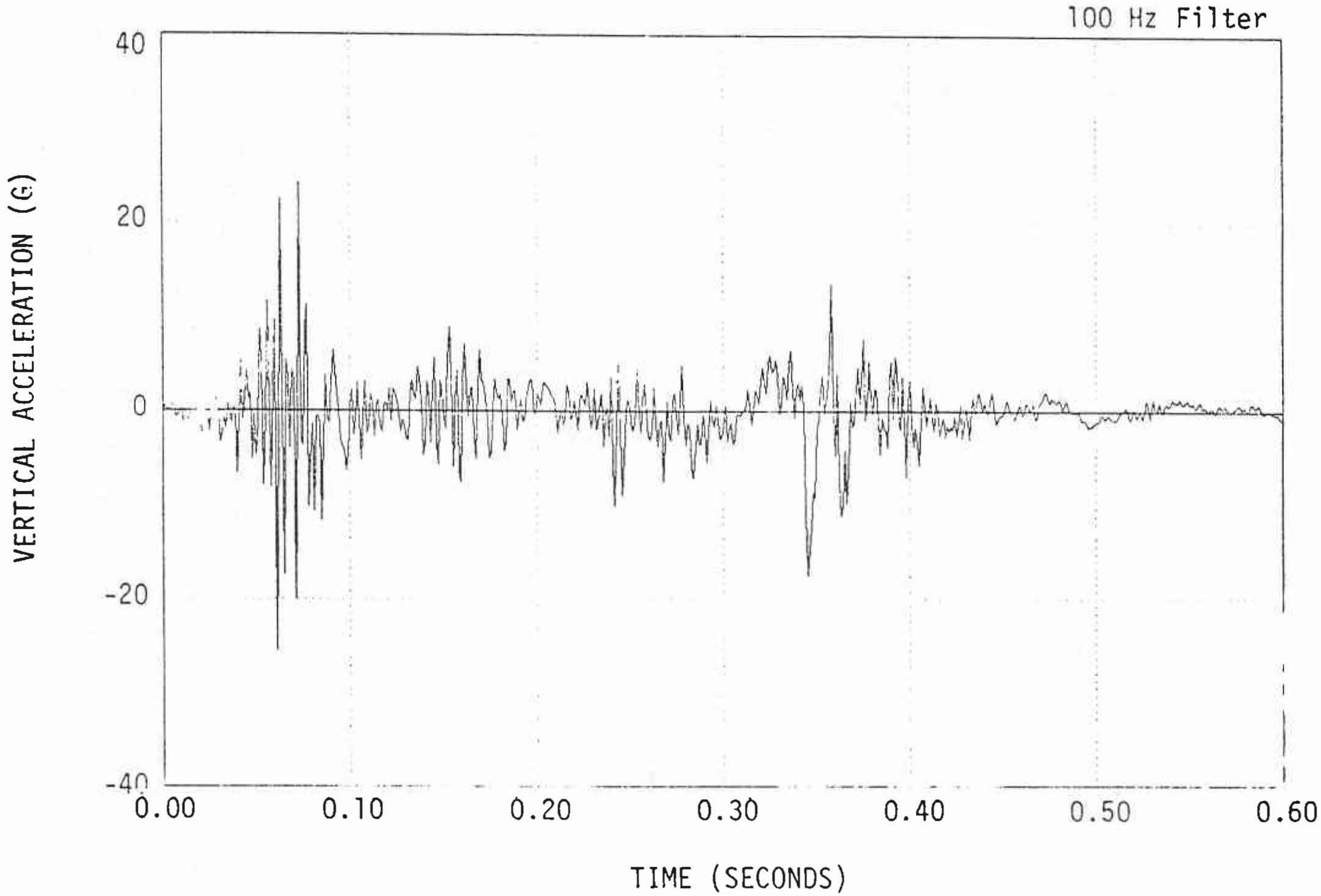

Figure B3. Vehicle Vertical Acceleration.

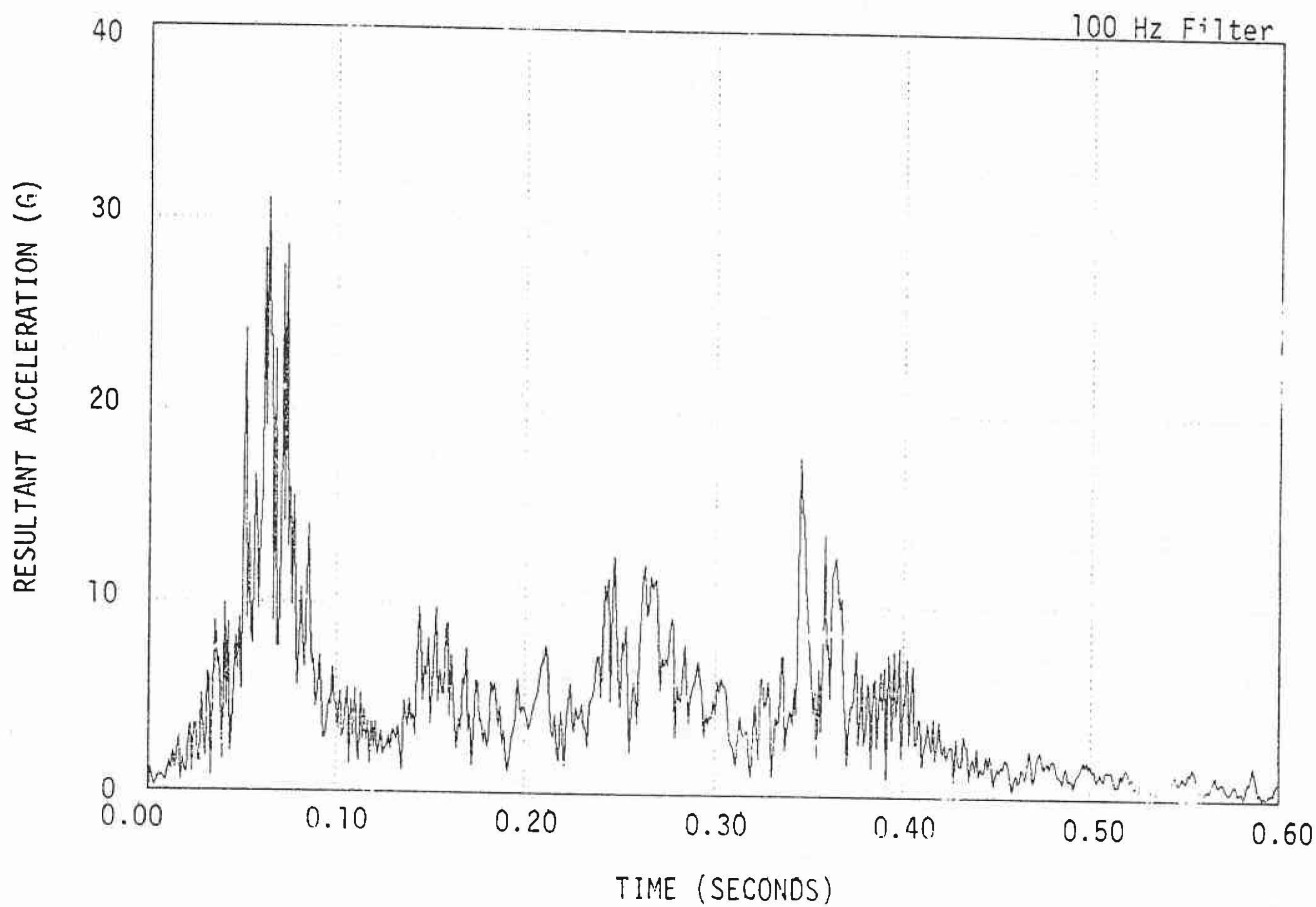

Figure B4. Vehicle Resultant Acceleration.

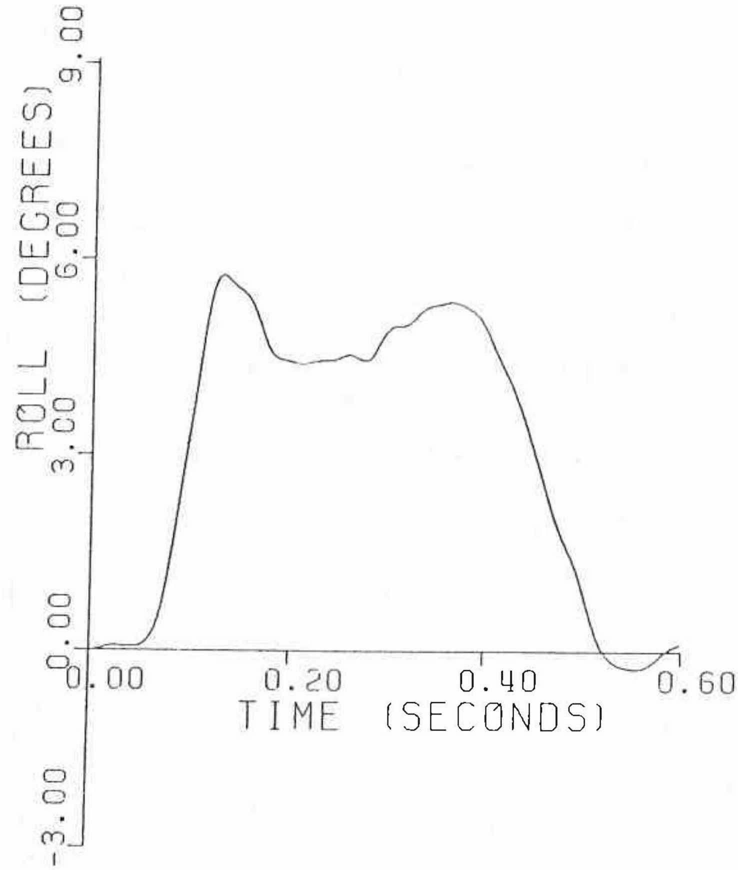

Figure B5. Roll versus Time.

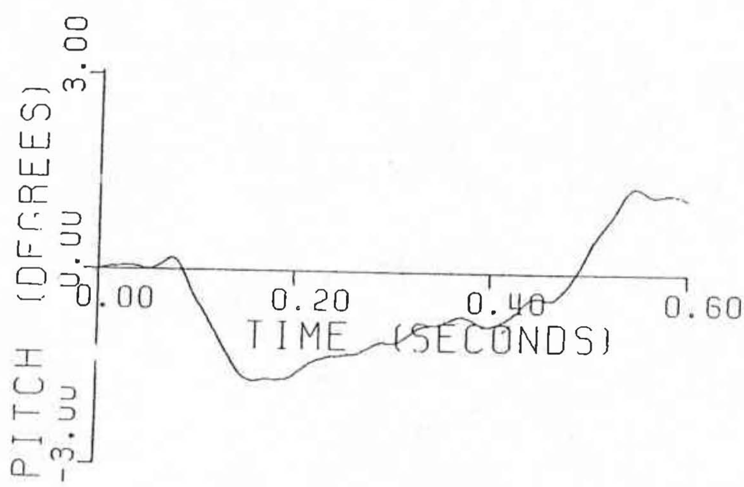

Figure B6. Pitch versus Time.

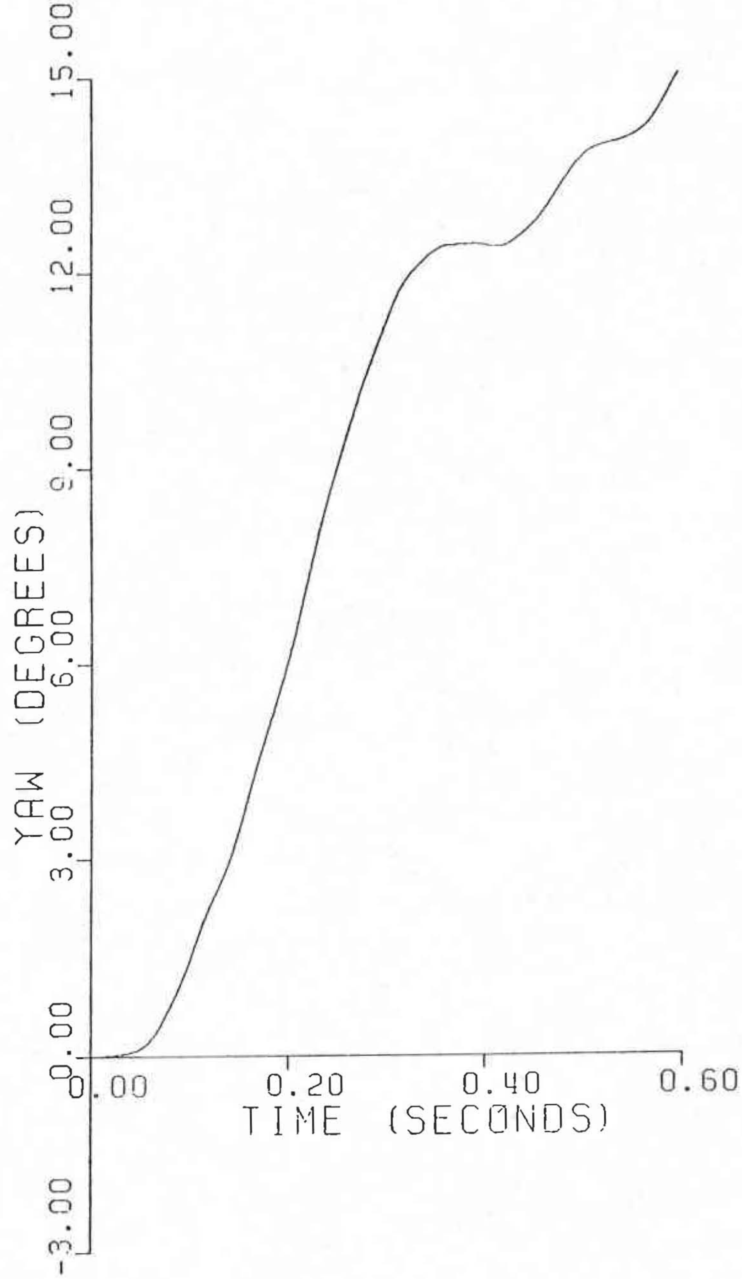

Figure B7. Yaw versus Time.

APPENDIX C

POST AND RAIL CRACK PATTERNS

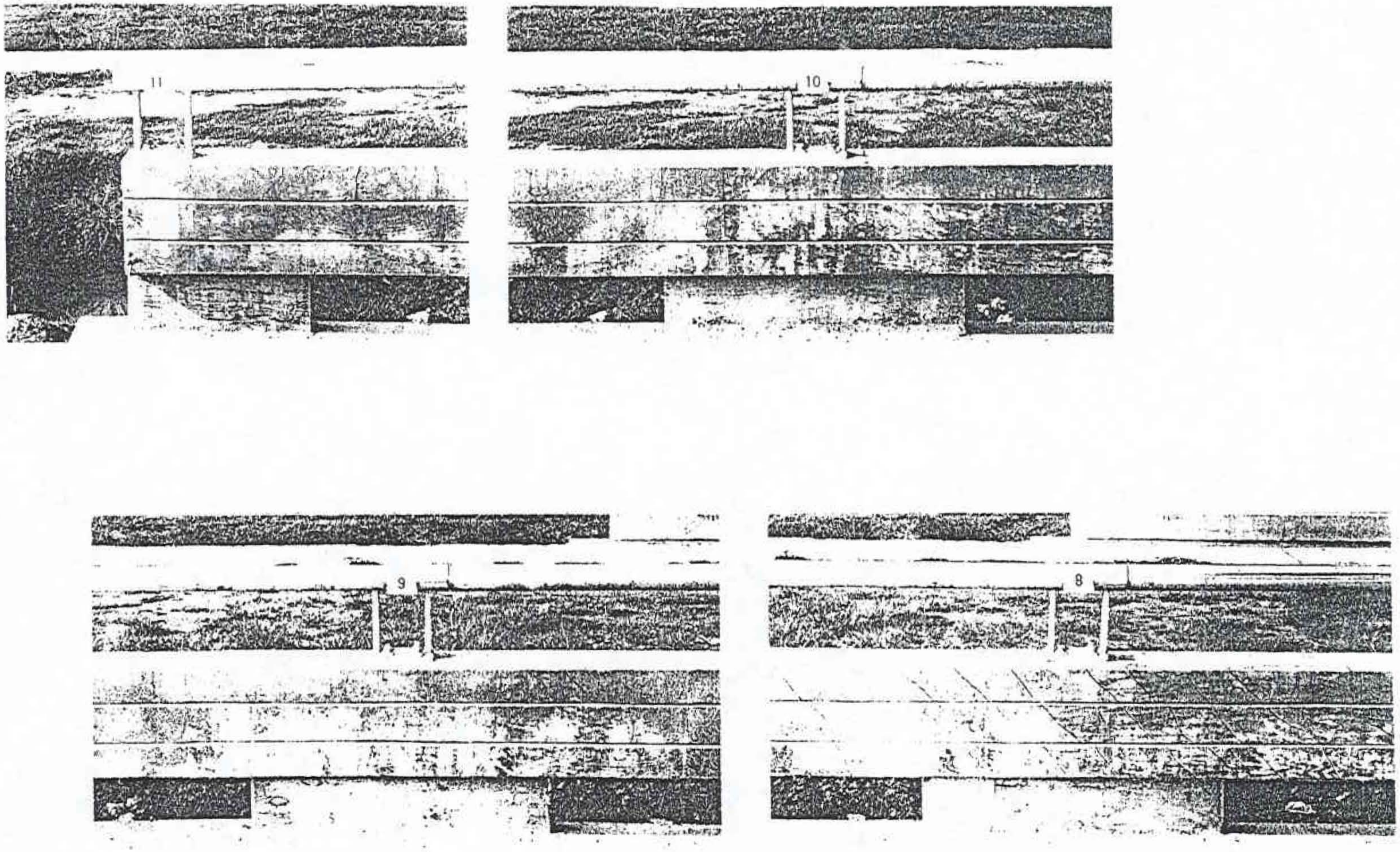

Figure C1. Crack Patterns on Traffic Side of the Rail After Test.

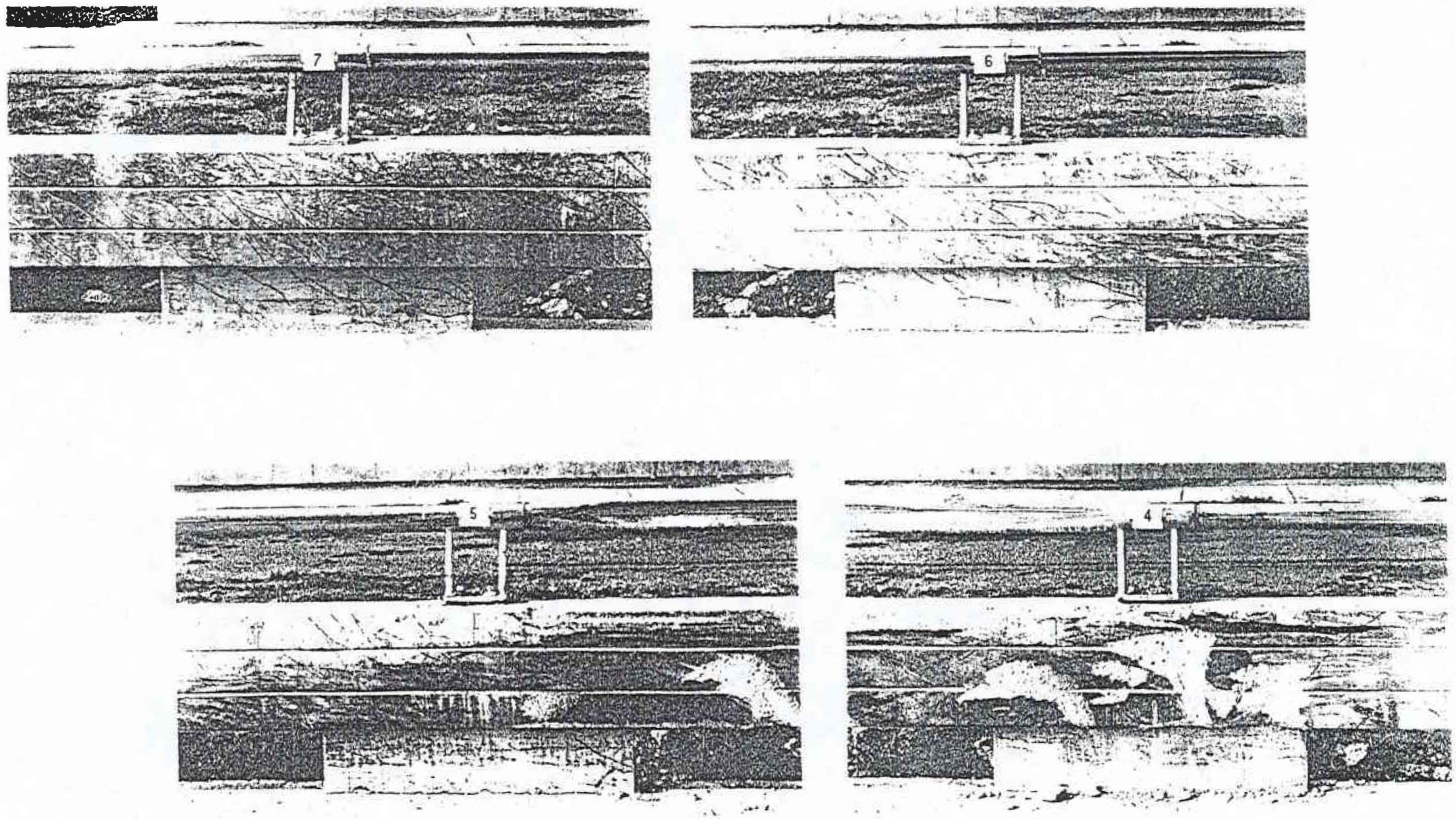

Figure C1. Crack Patterns on Traffic Side of the Rail After Test. (continued)

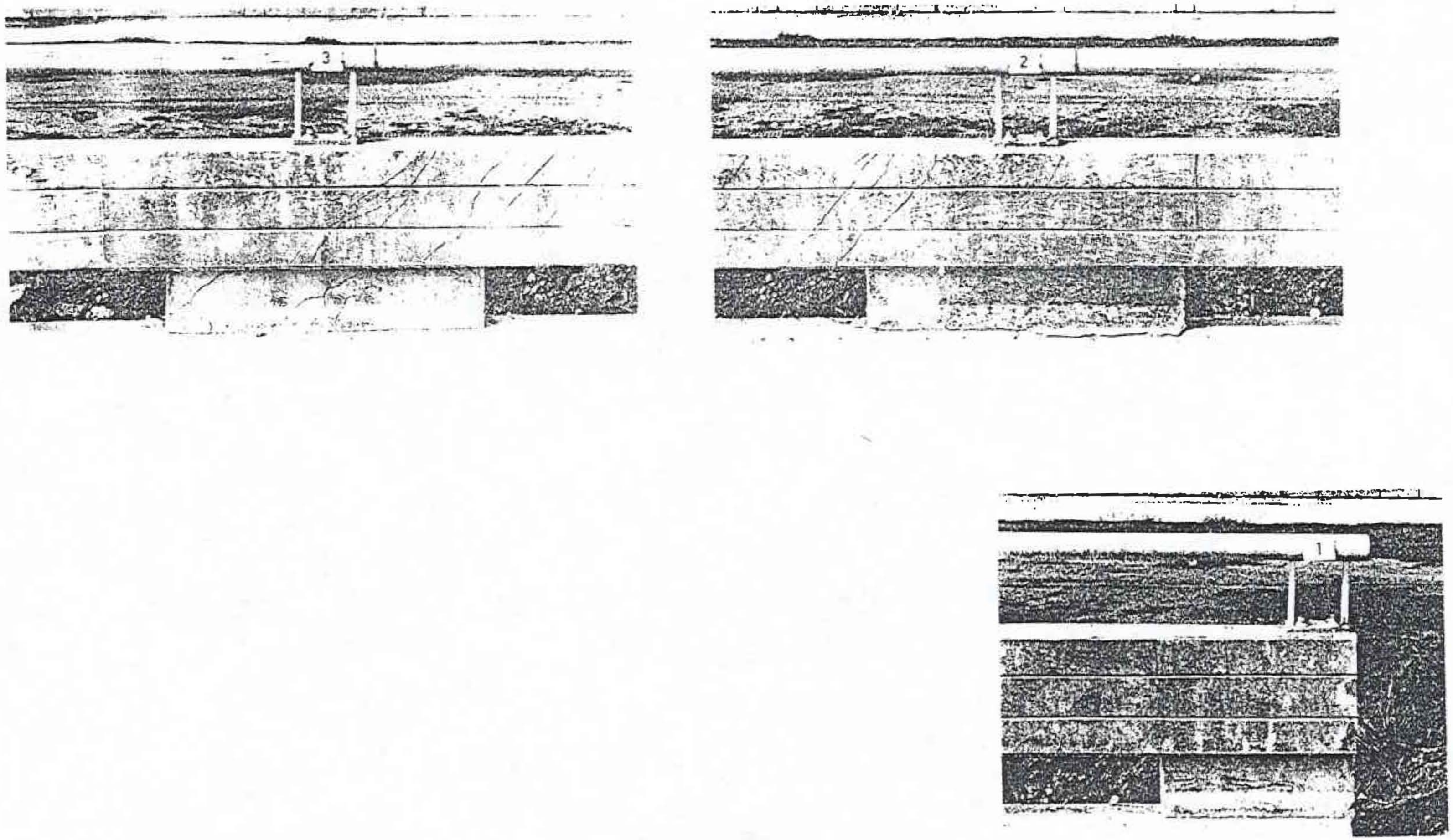

Figure C1. Crack Patterns on Traffic Side of the Rail After Test. (continued)

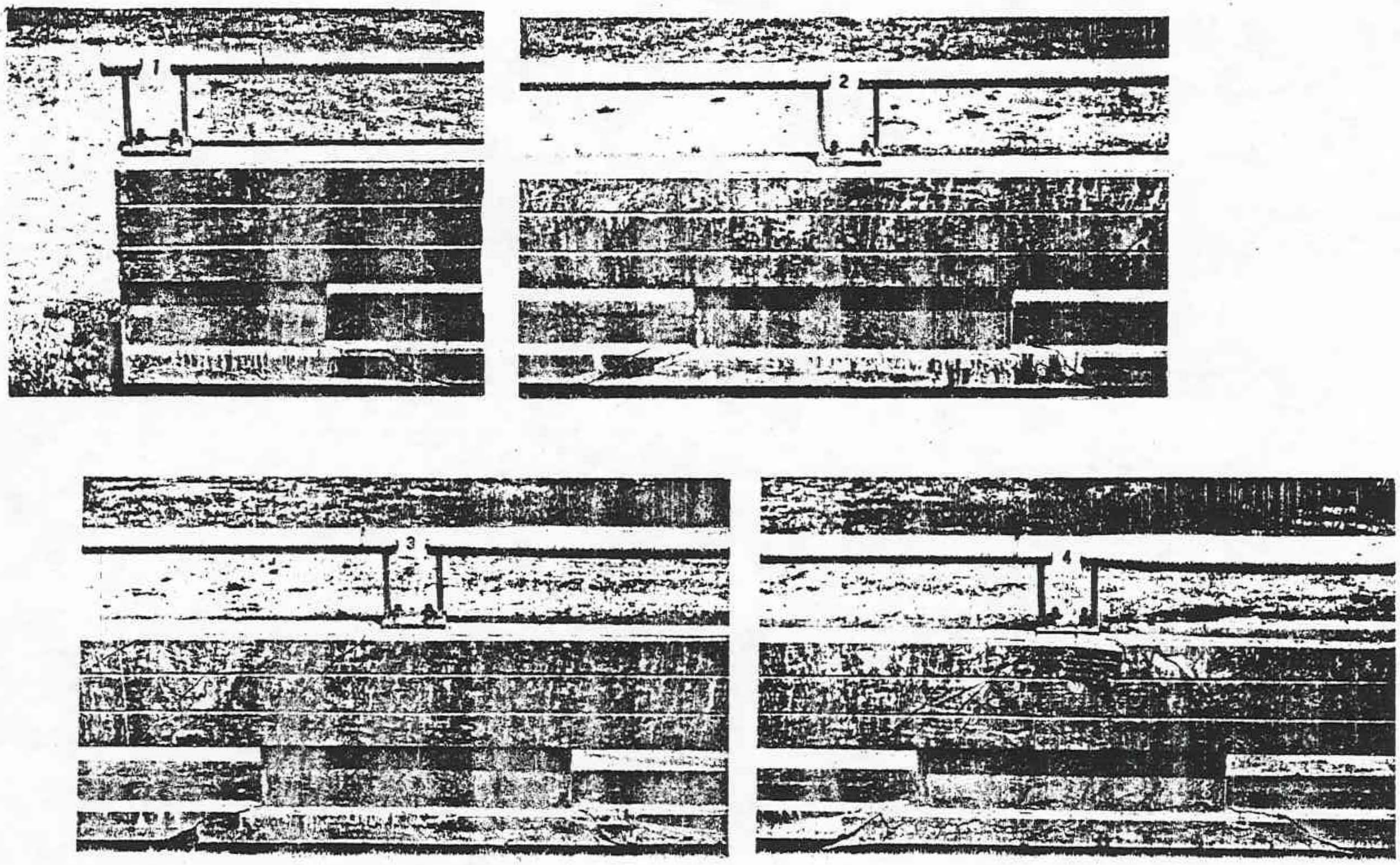

Figure C2. Crack Patterns on Field Side of the Rail After Test.

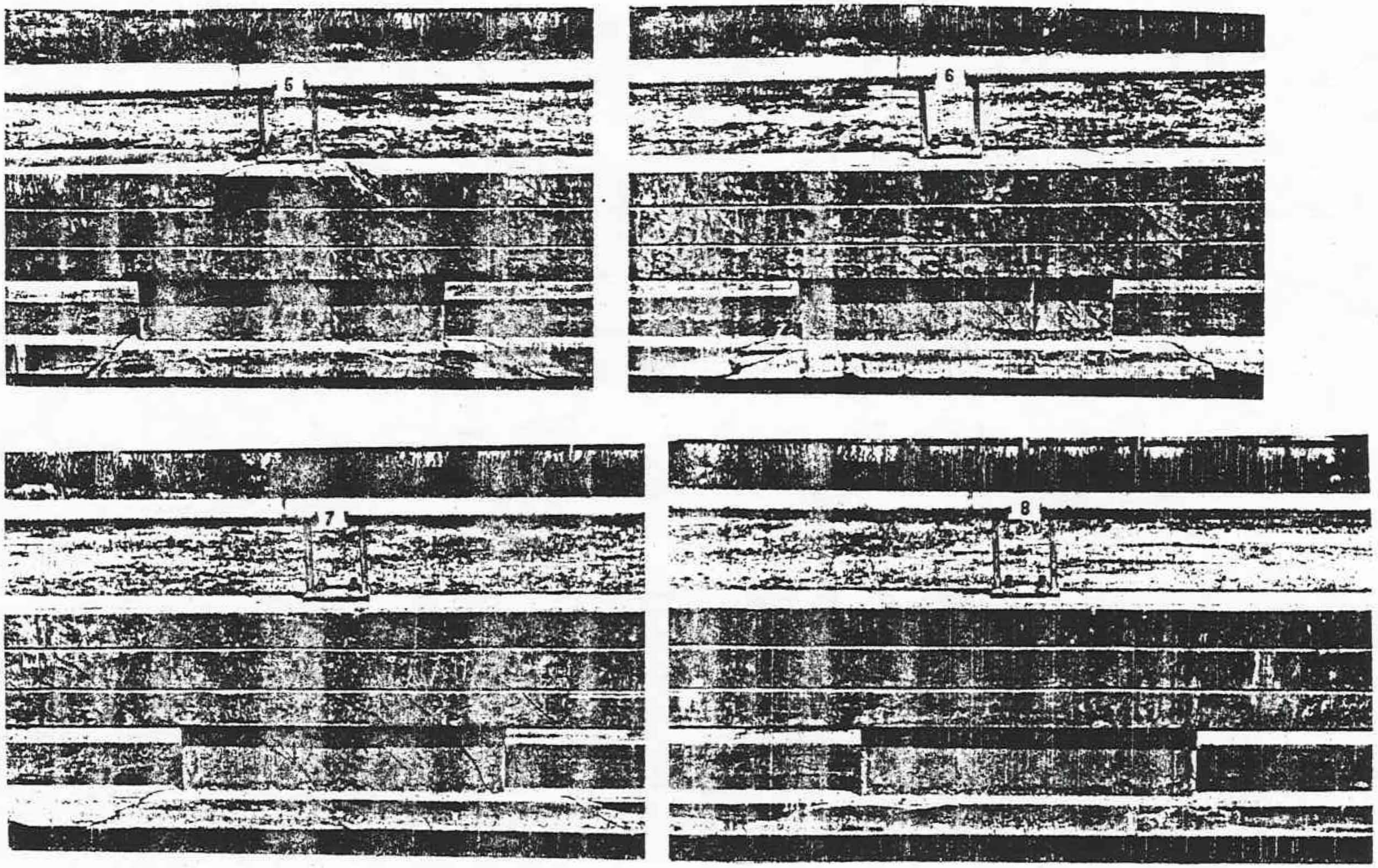

Figure C2. Crack Patterns on Field Side of the Rail After Test. (continued)

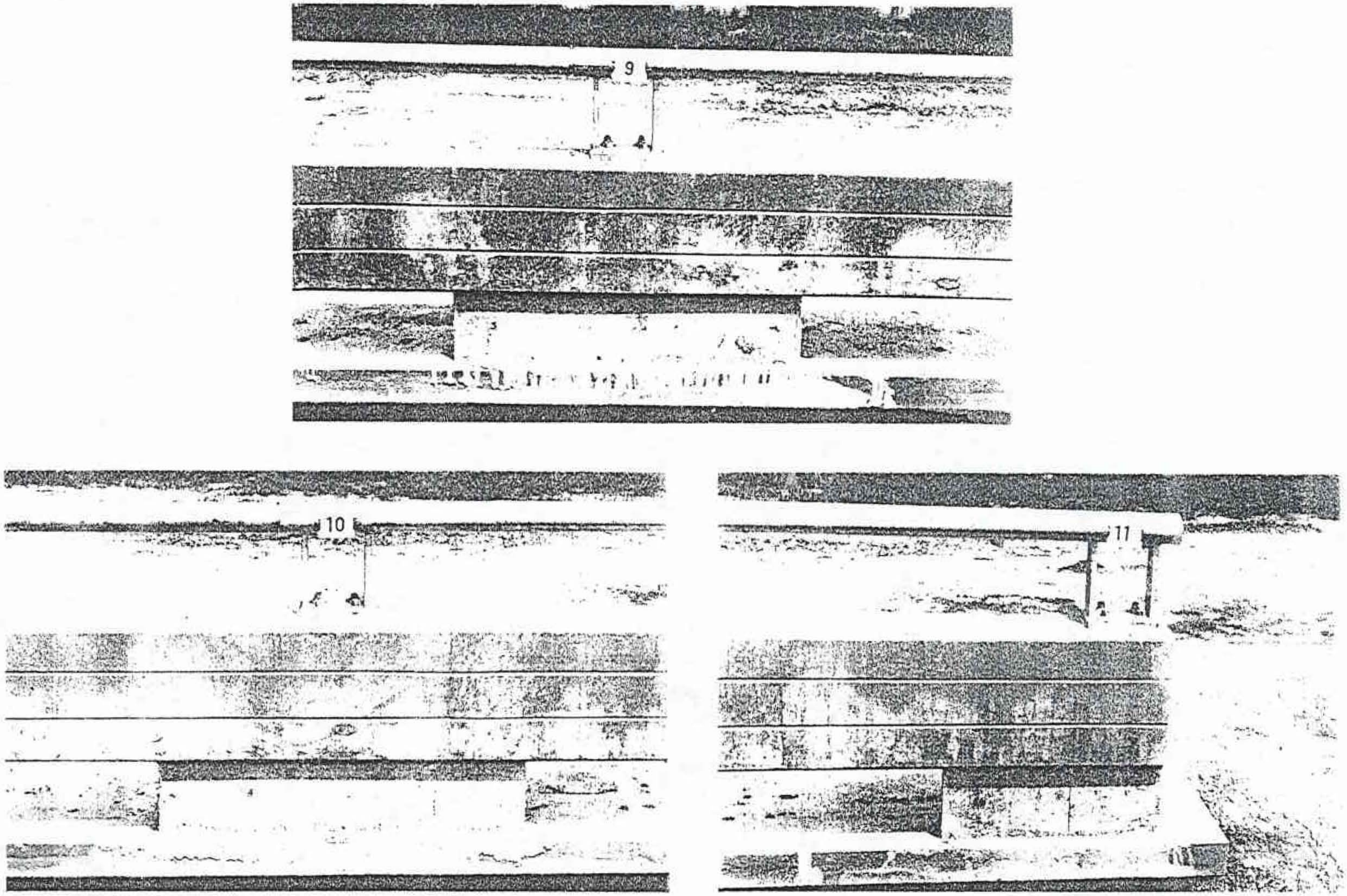

Figure C2. Crack Patterns on Field Side of the Rail After Test. (continued)