**Title and Subtitle**

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

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**Report Abstract**

A standard Texas traffic rail type T5 concrete safety shape was modified to increase its height and strength to restrain and redirect an 80,000 lb (36,300 kg) tank type tractor-trailer under 50 mph (80.5 km/h), 15° angle impacts. The concrete parapet was increased to 48 in. (122 cm) high, and a 16 in. (41 cm) x 21 in. (53 cm) concrete beam was mounted on concrete posts to increase the total rail height to 90 in. (229 cm). One crash test was conducted on the bridge rail. The truck was restrained and smoothly redirected. This test has shown that a rail can redirect heavy tank type trucks at speeds up to 50 mph (80.5 km/h) and 15° angle impact. The type T5 concrete safety shape uses about 2.6 cubic ft. of concrete per ft. of length and costs about $35 per ft. of length. This new bridge rail used about 7.6 cubic ft. of concrete per ft. of length and should cost about $120 per ft. of length.

**Keywords**

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

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BRIDGE RAIL TO RESTRRAIN AND REDIRECT 80,000 LB. TANK TRUCKS

by

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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 necessarily reflect the official view 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

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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. With the increase in the number and size of large trucks the problem of truck-bridge rail collisions is becoming more evident. The bridge rail tested here was selected and designed to restrain and redirect an 80,000 lb. (36,287 kg) tank type tractor-trailer, as shown in Figure 5. The design was based on data presented in References 1, 2, 3, 11, and 12.

The basic rail selected was a modification of the concrete parapet, Texas traffic rail type T5. The modified T5 rail consists of a concrete safety shaped parapet 48 in. (122 cm) high and a concrete beam element 16 in. (41 cm) wide and 21 in. (53 cm) deep, mounted 90 in. (229 cm) high on concrete posts on top of the parapet. The concrete posts are 8 in. (20 cm) thick by 5 ft. (1.5 m) long concrete walls located at 10 ft. (3 m) center to center spacing. This produces 5 ft. (1.5 m) openings 21 in. (53 cm) high. The beam element contains considerable reinforcing steel, providing both flexibility and strength, thus minimizing cracking of the concrete and permanent deflection of the rail when impacted by heavy vehicles. The modified T5 concrete parapet can be placed in long, continuous lengths giving good structural continuity and strength. The bridge deck immediately below the concrete parapet was increased to 12 in. (4.7 cm) in thickness to minimize cracking when the bridge rail is impacted by a heavy vehicle.
DESIGN TECHNIQUE

Earlier tests have shown that the principal concern in the containment and redirection of large trucks should be the tandem axles of the tractor. A relatively small part of the total kinetic energy is expended in the redirection of the front axle of the tractor and the rear tandem axles of the trailer had an even smaller impact with the traffic rails tested in the past. Knowing that the total loaded weight on the tandem axles of the tractor would be approximately 34,000 lb. (15,436 kg) (see Fig. 5), it was assumed that 10,000 lb. (4540 kg) of this load would be dead load and would probably be transferred to the rail through the wheels and the axles. The remaining 24,000 lb. (10,896 kg) would be live load and would be transferred to the rail through the tank trailer.

Accelerometer data from past tests indicated that the tandem axles of the tractor would be subjected to a 50 msec average lateral acceleration of about 6 g's. Therefore, design impact forces of 60,000 lb. (27,240 kg) (10,000 lb X 6 g's) applied at a height of 21 in. (53 cm) and 144,000 lb. (65,376 kg) (24,000 lb X 6 g's) applied at a height of 84 in. (213 cm) were used to design the rail using yield line or failure mode reinforced concrete design methods. These procedures are outlined in Research Report 230-2 "Analytical Evaluation of Texas Bridge Rails to Contain Buses and Trucks"(1).*

*Numbers in parentheses, thus (1), refer to corresponding items in the references.
DESCRIPTION OF THE BRIDGE RAIL AND DECK MODIFICATIONS

The modified T5 rail has a 16 in. (41 cm) thick, 21 in. (53 cm) tall concrete beam mounted on top. This modified bridge rail makes a combination bridge rail 90 in. (229 cm) tall suitable to retain large 80,000 lb. (36,287 kg) tank type trucks or tractor-trailers impacting at 15\(^\circ\) and 50 mph (80.5 km/h). Drawings of this rail are shown in Figures 1, 2, and 3. Figure 4 contains photographs comparing the size of this bridge rail with a Ford Thunderbird, and the tank-type tractor trailer. The bridge rail was constructed on a 14\(^\circ\) curve and the deck had a super elevation of 0.055 ft. per ft. (0.055 m per m). The rail was mounted vertically.

The concrete parapet was basically a standard Texas type T5 traffic rail which was heightened to 48 in. (122 cm) and thickened to 11 in. (28 cm) at the top and 20.5 in. (52 cm) at the bottom. It was anchored to the bridge deck by #6 stirrups spaced at 8 in. (20 cm) as shown, with ten #8 bars along the length of the rail.

The concrete post was 21 in. (53 cm) high, 8 in. (20 cm) thick and 60 in. (152 cm) long with a 60 in. (152 cm) open space between each post. Each concrete post was anchored to the concrete rail by means of sixteen #7 bars (eight traffic side and eight field side).

The concrete beam on top of the posts was 16 in. (41 cm) thick and 21 in. (53 cm) high for the entire length of the rail. It contained #3 standard closed stirrups spaced at 8 in. (20 cm) center-to-center as shown, with ten #8 bars along the length of
Figure 1. Cross Section of the Modified T5 Bridge Rail and Modified Bridge Deck.
Figure 3. Plan View of Modified T5 Bridge Rail, Modified Bridge Deck, and Pier System.
Figure 4. Comparison of Thunderbird and 80,000 lb Tank Truck with Modified Rail
the beam.

The strength of the standard Texas 7 in. (18 cm) thick bridge deck was increased in many ways. The dimensions and reinforcement pattern of the standard bridge deck were essentially maintained throughout except in the cantilever portion of the deck. These changes are detailed in Figure 1. The length of the cantilever portion was decreased from 30 in. (76 cm) to 18 in. (46 cm) and the thickness was increased to 12 in. (30.5 cm). The size of the upper transverse bars was increased from #5's to #7's, while the standard 5 in. (12.7 cm) spacing was retained. The size of the lower transverse bars was increased from #4's to #6's, while the standard spacing of 10 in. (25.4 cm) was, again, retained. The size of the upper and lower longitudinal bars was increased to #6's from #4's and #5's, respectively, while the spacing was increased from 12 in. (30.5 cm) to 17.5 in. (44.5 cm).

All reinforcing bars used in both the bridge deck and the rail had a minimum yield strength of 60 ksi (41.4 kN/cm^2). A graph of the compressive strengths of the concrete used in the various components of this rail can be seen in Figure D1. It should be noted that all of the 28-day compressive strengths were well above the minimum specified strength of 3600 psi (0.25 kN/cm^2).
This bridge rail system was designed to contain and redirect an 80,000 lb. (36,287 kg) tank type tractor-trailer. A simulated bridge deck with this rail system was built at the Texas Transportation Institute Proving Grounds and tested with a 1980 Kenworth tractor-trailer ballasted with water to 80,120 lbs. (36,384 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 51.4 mph (82.7 km/h) and 15° angle. Impact occurred at the beginning of post 5, and the truck was smoothly redirected. Figure 9 shows the bridge rail and test site immediately after the test. The truck entry and exit path can be seen clearly. The truck sustained damage to the right front and right tandem wheels. The cab of the truck remained intact and received minimal damage. The trailer body was dented by the impact with the upper beam but did not rupture. The trailer was punctured, however, by the exhaust stack of the truck immediately following impact. A summary of the crash test data is shown in Table 1.

The bridge deck supporting the rail was not significantly damaged. It was determined from the overhead film that the upper beam was deflected a maximum of 4 in. (10.2 cm) and sustained a permanent deflection of 0.64 in. (1.6 cm). Appendix C shows composite photographs of the traffic and field side of the rail after the test. The cracks in the rail are clearly visible.
Figure 5. Tractor-Trailer Loaded Dimensions, Empty Weights, and Loaded Weights.
EMPTY WEIGHTS

Weight on front axle:  
Left 5,390  
Right 5,200
Total 10,590

Weight on rear axles:  
L F 2,040  
R F 2,040
Total 4,080

L R 1,960  
R R 1,990
Total 3,950

Total Empty Weights
TOTAL 18,620

Figure 6. Empty Tractor Dimensions and Weights.
Figure 8. 80,000 lb Tank Truck after Test
Figure 5. Bridge Rail Before and after Test
Table 1. Summary and Results of Crash Tests.

<table>
<thead>
<tr>
<th>TEST NUMBER</th>
<th>1</th>
</tr>
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<tbody>
<tr>
<td>VEHICLE DATA</td>
<td>Tractor-Trailer (Tank Type) 1980 Kenworth</td>
</tr>
<tr>
<td>MASS - kg (lb)</td>
<td>36,384 (80,120)</td>
</tr>
<tr>
<td>SPEED - km/hr (mph)</td>
<td>82.7 (51.4)</td>
</tr>
<tr>
<td>FILM DATA</td>
<td></td>
</tr>
<tr>
<td>Angle - degrees</td>
<td></td>
</tr>
<tr>
<td>Impact</td>
<td>$15^\circ$</td>
</tr>
<tr>
<td>Roll, max.</td>
<td></td>
</tr>
<tr>
<td>Truck</td>
<td>$17^\circ$</td>
</tr>
<tr>
<td>Trailer</td>
<td>$15^\circ$</td>
</tr>
<tr>
<td>Barrier Displacement - cm (in.)</td>
<td>10.2 (4.0)</td>
</tr>
<tr>
<td>ACCELEROMETER DATA (located over tractor tandem axles)</td>
<td></td>
</tr>
<tr>
<td>100 Hz lo-pass max. flat filter</td>
<td></td>
</tr>
<tr>
<td>Max. Avg. 0.050 Sec Acceleration</td>
<td></td>
</tr>
<tr>
<td>Longitudinal, g's</td>
<td>-1.77</td>
</tr>
<tr>
<td>Lateral, g's</td>
<td>5.54</td>
</tr>
<tr>
<td>Resultant, g's</td>
<td>5.57</td>
</tr>
<tr>
<td>Peak Acceleration</td>
<td></td>
</tr>
<tr>
<td>Longitudinal, g's</td>
<td>10.49</td>
</tr>
<tr>
<td>Lateral, g's</td>
<td>18.56</td>
</tr>
<tr>
<td>Resultant, g's</td>
<td>22.65</td>
</tr>
</tbody>
</table>
Sequential photographs showing the overhead and frontal view of the crash test are shown in Appendix A.

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 positive roll of the tractor tandem axles was 17° from the roll rate gyro's and the trailer approximately 15° from the high-speed film. From the accelerometers, the longitudinal, lateral, and resultant maximum average 0.050 sec accelerations were -1.77, 5.54, and 5.57, 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 and remained totally intact while doing so.

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 respectively, for the longitudinal and lateral occupant impact velocity, and 20 g's for the highest 10 msec average deceleration after contact. The computed values for this test were well below these recommended values. The longitudinal occupant impact velocity was 7.2 fps, and the highest 10 msec average occupant acceleration after contact was -1.83 g's. The lateral occupant impact velocity was 8.03 fps, and the highest 10 msec average acceleration was 11.16 g's.

The design intent of the upper concrete beam centered at 79.5 in. (202 cm) was to allow the tank trailer to strike this beam and thus provide a resistance to overturning by the trailer.
SUMMARY AND CONCLUSIONS

A standard Texas traffic rail type T5 concrete safety shape was modified by increasing its height and strength so that it could restrain and redirect an 80,000 lb. (36,287 kg) tank type truck or tractor-trailer. The concrete parapet was increased to 48 in. (122 cm) high and a concrete beam element 16 in. (41 cm) wide and 21 in. (53 cm) deep, was mounted 90 in. (229 cm) high on concrete posts located at 10 ft. (3.0 m) center-to-center spacing. The concrete posts were 8 in. (20 cm) thick by 5 ft. (1.5 m) long concrete walls with 5 ft. (1.5 m) openings between each post. The rail was constructed vertically on a 14° curve with the deck super elevated 0.055 ft. per ft. (0.055 m per m).

The crash test was conducted on this bridge rail with an 80,120 lb. (36,384 kg) tank type tractor-trailer impacting the rail at 51.4 mph (82.7 km/h) and at an impact angle of 16°. The vehicle was smoothly redirected. Damage to the truck was moderate and damage to the rail was minimal.

This test has shown that a bridge rail can be built on slightly modified standard bridge deck to contain large tank type tractor-trailer trucks and redirect them without rollover.

The cross-sectional area of this modified rail is approximately 7.6 cubic ft. per ft. as compared with approximately 2.6 cubic ft. per ft. for a standard Texas traffic rail type T5. The approximate cost of this modified rail would be about $125 per linear foot, while a standard Texas traffic rail type T5 normally costs about $35 per linear foot.
REFERENCES


APPENDIX A

SEQUENTIAL PHOTOGRAPHS OF CRASH TEST
Figure A1. Sequential Photographs for Test 2911-1.
Figure A2. Sequential Photographs for Test 2911-1. (Continued)
APPENDIX B

ELECTRIC ACCELEROMETER, ROLL, PITCH
AND YAW DATA
Figure B1. Vehicle Longitudinal Accelerometer Trace for Test 2911-1.
Figure B2. Vehicle Lateral Accelerometer Trace for Test 2911-1.
Figure B3. Vehicle Vertical Accelerometer Trace for Test 2911-1.
Figure B4. Trailer Lateral Accelerometer Trace for Test 2911-1.
Axes are vehicle fixed. Sequence for determining orientation is:
1. Yaw
2. Pitch
3. Roll

Figure B5. Vehicle Angular Displacements for Test 2911-1.
APPENDIX C

POST AND RAIL CRACK PATTERNS
4 ft. (1.2 m) Downstream from Impact

19 ft. (5.8 m) Downstream from Impact

Figure C1. Crack Patterns on Traffic Side of the Rail After Test
Figure C2. Crack Patterns on Top of the Beam After the Test
Figure C3. Crack Patterns on Field Side of the Rail After Test
APPENDIX D

CONCRETE STRENGTHS
Figure D1. Concrete Compressive Strength of Various System Components.