FULL-SCALE CRASH TESTS
OF HIGH-PERFORMANCE
MEDIAN BARRIER

Prepared for
Office of Research
Federal Highway Administration
U.S. Dept. of Transportation

and

New Jersey Turnpike Authority

Work Order Number Two
Contract DOT-FH-11-9485

by

C.E. Buth
Research Engineer

and

Wanda L. Campise
Research Associate

Texas Transportation Institute
Texas A&M Research Foundation
The Texas A&M University System

August 1982
# TABLE OF CONTENTS

I. INTRODUCTION ............................................................................. 1  

II. TEST BARRIER INSTALLATION ......................................................... 2  

III. TEST NUMBER 4348-1 ................................................................. 6  
    2190-lb/62.6mph/15.0 deg  
    (993kg/100.7 kph/15.0 deg)  
    Vehicle and Instrumentation ......................................................... 6  
    Conduct of Test ........................................................................... 7  
    Test Results .................................................................................. 7  

IV. TEST NUMBER 4348-2 ................................................................. 28  
    80,420 lb/52.8 mph/16.0 deg  
    (36,480 kg/85.0 kph/16.0 deg)  
    Vehicle and Instrumentation ......................................................... 28  
    Conduct of Test ........................................................................... 28  
    Test Results .................................................................................. 29
NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The contents of this report reflect the views of the Texas Transportation Institute, which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Department of Transportation.

This report does not constitute a standard, specification, or regulation.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential to the object of this document.
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plan View of Test Barrier Installation</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Cross Section of Test Barrier Installation</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Detail of Barrier Cross-Section and Steel Reinforcement</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Vehicle Before Test 4348-1</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>Test Vehicle Properties (Test 4348-1)</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>Barrier Before Test 4348-1</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>Barrier After Test 4348-1</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Vehicle After Test 4348-1</td>
<td>13</td>
</tr>
<tr>
<td>9</td>
<td>Summary Sheet for TEst 4348-1</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>Sequential Photographs for Test 4348-1</td>
<td>15</td>
</tr>
<tr>
<td>11</td>
<td>Interior Sequential Photographs for Test 4348-1</td>
<td>17</td>
</tr>
<tr>
<td>12</td>
<td>Vehicle Longitudinal Accelerometer Traces for Test 4348-1</td>
<td>18</td>
</tr>
<tr>
<td>13</td>
<td>Vehicle Lateral Accelerometer Trace for Test 4348-1</td>
<td>19</td>
</tr>
<tr>
<td>14</td>
<td>Vehicle Yaw for Test 4348-1</td>
<td>20</td>
</tr>
<tr>
<td>15</td>
<td>Vehicle Pitch for Test 4348-1</td>
<td>21</td>
</tr>
<tr>
<td>16</td>
<td>Vehicle Roll for Test 4348-1</td>
<td>22</td>
</tr>
<tr>
<td>17</td>
<td>Driver Head Accelerometer Traces for Test 4348-1</td>
<td>23</td>
</tr>
<tr>
<td>18</td>
<td>Driver Chest Accelerometer Traces for Test 4348-1</td>
<td>24</td>
</tr>
<tr>
<td>19</td>
<td>Passenger Head Accelerometer Traces for Test 4348-1</td>
<td>25</td>
</tr>
<tr>
<td>20</td>
<td>Passenger Chest Accelerometer Traces for Test 4348-1</td>
<td>26</td>
</tr>
<tr>
<td>21</td>
<td>Vehicle Before Test 4348-2</td>
<td>30</td>
</tr>
<tr>
<td>22</td>
<td>Test Vehicle Properties (Test 4348-2)</td>
<td>31</td>
</tr>
<tr>
<td>23</td>
<td>Barrier Before Test 4348-2</td>
<td>32</td>
</tr>
<tr>
<td>24</td>
<td>Barrier After Test 4348-2</td>
<td>33</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HIC and GADD Values for Anthropometric Dummies in Test 4348-1</td>
<td>27</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>25</td>
<td>Vehicle After Test 4348-2</td>
<td>34</td>
</tr>
<tr>
<td>26</td>
<td>Summary Sheet for Test 4348-2</td>
<td>35</td>
</tr>
<tr>
<td>27</td>
<td>Sequential Photographs for Test 4348-2</td>
<td>36</td>
</tr>
<tr>
<td>28</td>
<td>Vehicle Longitudinal Accelerometer Trace for Test 4348-2</td>
<td>38</td>
</tr>
<tr>
<td>29</td>
<td>Vehicle Lateral Accelerometer Trace for Test 4348-2</td>
<td>39</td>
</tr>
<tr>
<td>30</td>
<td>Vehicle Yaw for Test 4348-2</td>
<td>40</td>
</tr>
<tr>
<td>31</td>
<td>Vehicle Pitch for Test 4348-2</td>
<td>41</td>
</tr>
<tr>
<td>32</td>
<td>Vehicle Roll for Test 4348-2</td>
<td>42</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

This documents the performance of two full-scale crash tests on a proposed high-performance median barrier.

The proposed design was a concrete median barrier, patterned after the popular New Jersey Safety Shape, with a total height of 42 in. A test barrier installation was subjected to two full-scale crash tests - one with a Honda sedan at 62.6 mph and 15.0 deg, the other with a van type tractor/trailer at 52.8 mph and 16.0 deg. The tractor/trailer was loaded with sandbags to a total weight of 80,420 lbs.

The objective of the tractor/trailer test was to determine the degree of containment that the proposed barrier would provide for this vehicle. The objective of the small car test was to determine whether an adequately safe redirection for this vehicle would be provided.
II. TEST BARRIER INSTALLATION

A 250-ft long segment of the proposed barrier along with part of an anticipated highway cross-section surface was constructed for testing (Figure 1). The barrier was cast-in-place with construction joints at the third points. Reinforcing steel was continuous across the construction joints and grout was applied to the face of the cross-section of each previous pour to provide bonding between it and the subsequent pour. A paved transition between the highway cross-section and the approach runway was constructed. A cross-section of the test installation is shown in Figure 2, and a detail of the barrier cross-section and steel reinforcement is shown in Figure 3. The design required 4000 psi concrete and grade 60 reinforcing steel. Nine concrete cylinder tests gave an average compressive strength at 4,360 psi.
Figure 1: Plan View of Test Barrier Installation.
Figure 2. Cross Section of Test Barrier Installation.

Traffic Lane Shoulder Median

12' - 0"

5' - 0"

8' - 0"

8' - 0"

2" H.M.A.C.

1.0% Slope

2" H.M.A.C.

8.0% Slope

3" H.M.A.C.

2.0% Slope

3" H.M.A.C.

Compacted Crushed Limestone Base

Special Subgrade Material
Figure 3. Detail of Barrier Cross-Section and Steel Reinforcement.
Vehicle and Instrumentation

The test vehicle was a 1978 Honda Civic shown in Figures 4 and 5. Gross static mass of the vehicle was 2190 lbs and the test inertia mass was 1860 lbs.

The vehicle was equipped with triaxial accelerometers mounted near the center of gravity. Yaw, pitch, and roll were sensed by on-board gyroscopic instruments. The electronic signals were telemetered to a base station for recording on magnetic tape and display on real-time strip chart. Provision was made for the transmission of calibration signals before and after the test, and an accurate time reference signal was simultaneously recorded with the data.

Tape switches near the impact area were actuated by the vehicle to indicate elapsed time over a known distance to provide a quick check of impact speed, and the initial contact switch also produced an "event" mark on the data record to establish the instant of impact.

High-speed motion pictures were obtained from various locations, including an overhead view, to document the events and provide a time-displacement history. Film and electronic data were synchronized through a visual/electronic event signal at initial contact.

Two anthropometric dummies (Alderson Hybrid II) were seated in the front seat position of the vehicle. Both were instrumented with triaxial accelerometers in head and chest. The passenger dummy was
restrained with the standard lab belt and shoulder harness while the
driver dummy was unrestrained.

Conduct of Test

The vehicle was directed into the barrier at an approach angle of
15.0 deg and a speed of 100.7 kph (62.6 mph) using a cable guidance and
reverse to a mechanism. The transmission was in neutral, the steering
wheel was free and the vehicle was released to be unrestrained at
impact. The impact point was approximately 26 m (85 ft) from the
upstream end of the barrier.

Test Results

Figures 6 and 7 show the barrier before and after the test and
Figure 8 shows the vehicle after the test. A summary of data is
presented in Figure 9, and exterior and interior sequential photographs
are shown in Figures 10 and 11.

Approximately 0.048 sec after impact the vehicle began riding up
the barrier wall. The vehicle became completely airborne at 0.157 sec
and remained so as it exited the barrier at 0.355 sec at a yaw angle of
5.0 degrees relative to the barrier and speed of 91.3 kph (56.8 mph).
The left front wheel touched the asphalt at 0.622 sec, dug into the
asphalt, and the vehicle rolled laterally and came to rest upright.

The barrier sustained tire markings and scrapings. The vehicle
suffered considerable damage, mostly to the left front quarter and to
the windshield. Both front tires and the left rear were deflated. Also,
these three rims were damaged.

Accelerometer traces are shown in Figures 12 through 13. The
maximum 0.050 sec average longitudinal and lateral accelerations were
-4.6 and -8.3 g's, respectively. Yaw, pitch, and roll curves are presented in Figures 14 through 16.

NCHRP Report 230 describes occupant risk evaluation criteria and places limits on these for acceptable performance for tests conducted at 15 deg impact angles. These values follow. The occupant/compartment impact velocity in the longitudinal direction was 3.8 m/s (12.4 fps) and 5.2 m/s (17.1 fps) in the lateral direction. The maximum 0.010 sec average longitudinal and lateral occupant ridedown accelerations were -2.3 g's and -7.9 g's, respectively. Acceleration plots for the dummies are shown in Figures 17 through 20, and HIC and GADD values are presented in Table 1.
Figure 4. Vehicle Before Test 4348-1.
Test Inertia Mass: 1860 lb
Dummy Mass: 330 lb
Loose Ballast Mass 0 lb
Gross Static Mass: 2190 lb
Wheel Diameter: 21.5 in.
Bumper Height: 15.5 in. to bottom
19.5 in. to top

Figure 5. Test Vehicle Properties (Test 4348-1).
Figure 6. Barrier Before Test 4348-1.
Figure 7. Barrier After Test 4348-1.
Figure 8. Vehicle After Test 4348-1.
Figure 9. Summary Sheet for Test 4348-1.
Figure 10. Sequential Photographs for Test 4348-1
(Vehicle subsequently rolled.)

Figure 10. Sequential Photographs for Test 4348-1 (continued)
Figure 11. Interior Sequential Photographs for Test 4348-1
Figure 12. Vehicle Longitudinal Accelerometer Trace for Test 4348-1.
Figure 13. Vehicle Lateral Accelerometer Trace for Test 4348-1.
Figure 14. Vehicle Yaw for Test 4348-1.
Figure 15. Vehicle Pitch for Test 4348-1.
Figure 16. Vehicle Roll for Test 4348-1.
Figure 18. Driver Chest Accelerometer Traces for Test 4348-1.
Figure 19. Passenger Head Accelerometer Traces for Test 4348-1.
Figure 20. Passenger Chest Accelerometer Traces for Test 4348-1.
Table 1. HIC and GADD Values for Anthropometric Dummies in Test 4348-1.

<table>
<thead>
<tr>
<th>Location</th>
<th>HIC</th>
<th>Between</th>
<th>Highest 0.003 sec sustained acceleration exceeds:</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRIVER HEAD</td>
<td>28</td>
<td>0.056 and 0.168 sec.</td>
<td>25</td>
<td>0.083</td>
<td>0.086</td>
</tr>
<tr>
<td>DRIVER CHEST</td>
<td>25</td>
<td>0.000 and 0.398 sec.</td>
<td>14</td>
<td>0.074</td>
<td>0.077</td>
</tr>
<tr>
<td>PASSENGER HEAD</td>
<td>144</td>
<td>0.134 and 0.142 sec.</td>
<td>49</td>
<td>0.136</td>
<td>0.139</td>
</tr>
<tr>
<td>PASSENGER CHEST</td>
<td>27</td>
<td>0.000 and 0.398 sec.</td>
<td>13</td>
<td>0.178</td>
<td>0.181</td>
</tr>
</tbody>
</table>
IV. TEST NUMBER 4348-2
80,420 lb/52.8 mph/16.0 deg
(36,480 kg/85.0 kph/16.0 deg)

Vehicle and Instrumentation

The test vehicle was a 5-axle tractor/trailer consisting of 1978 auto/car/tractor with an automatic transmission and 40-ft trailmobile van as shown in Figures 21 and 22. Empty weight of the unit was 30,800 lbs and the trailer was loaded with sandbags so that the gross static mass of the vehicle was 80,420 lbs. The sandbags were placed on wooden pallets so that the center of gravity of the sand bags would be near mid-height of the cargo box (Figures 21). Gross weights of the axles are shown in Figure 22.

Instrumentation placed on the tractor consisted of longitudinal and lateral accelerometers; yaw, pitch and roll rate transducers; and control equipment for remotely driving the unit. No instrumentation was installed on the trailer.

Conduct of Test

The vehicle was directed into the barrier at an approach angle of 16.0 deg and a speed of 85.0 kph (52.8 mph) using a radio control unit. The radio unit remotely operated the steering and throttle up to a point just prior to impact. At this point, steering control was released and the engine was turned off. The impact point was approximately 26 m (85 ft) from the upstream end of the barrier.
Test Results

Before and after photographs of the barrier and test vehicle are presented in Figures 21 through 25. A summary of data is shown in Figure 26 and sequential photographs in Figure 27.

The front of the tractor began climbing the wall approximately 0.088 sec after impact. At 0.339 the tractor started descending toward the asphalt. The front of the tractor returned to the surface at 0.503 sec and the trailer began pulling the rear of the tractor up and into the barrier. As the trailer continued to collide with the barrier, the rear of the trailer rolled onto and over the barrier. The tractor and front of the trailer remained on the original side of the barrier. The rear of the trailer crossed the barrier by a maximum distance of approximately 16 ft. The tractor-trailer slid along the barrier, dropped off the end and came to rest on its side as shown in Figure 25.

The barrier received tire markings and gouging. There was no measurable deflection in the barrier during or after the test. The left front tire of the tractor came off the rim. The entire left side of the cab was severely damaged and the trailer came apart spilling the sandbags.

Accelerometer traces are shown in Figures 28 and 29. The maximum 0.050 sec average longitudinal acceleration of the tractor was -2.3 g's and in the lateral direction was -11.4 g's. Yaw, pitch and roll curves for the tractor are presented in Figures 30 through 32.
Figure 21. Vehicle Before Test 4348-2.
Figure 22. Test Vehicle Properties (Test 4348-2).
Figure 23. Barrier Before Test 4348-2.
Figure 24. Barrier After Test 4348-2.
Figure 25. Vehicle After Test 4348-2.
<table>
<thead>
<tr>
<th>Test No.</th>
<th>Impact Speed</th>
<th>Impact Angle</th>
<th>Vehicle Accelerations (Max. 0.050 sec Avg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4348-2</td>
<td>85.0 kph (52.8 mph)</td>
<td>16.0 deg</td>
<td>Longitudinal: -2.3 g</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Continuous Modified Safety Shape</th>
<th>Lateral: -11.4 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-14-82</td>
<td>Safety Shape</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rail</th>
<th>Vehicle</th>
<th>Dummy Restraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Modified Safety Shape</td>
<td>Autocar Tractor-Trailer</td>
<td>Driver (only) Lap Belt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length of Installation</th>
<th>Vehicle Weight</th>
<th>Test Inertia</th>
<th>Gross Static</th>
</tr>
</thead>
<tbody>
<tr>
<td>76.0 m (250.0 ft)</td>
<td>13,971 kg (30,800 lb)</td>
<td>36,479 kg (80,420 lb)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 26. Summary Sheet for Test 4348-2.
Figure 27. Sequential Photographs for Test 4348-2.
Figure 27. Sequential Photographs for Test 4348-2 (continued).
Figure 28. Longitudinal Accelerometer Trace for Test 4348-2.
Figure 29. Lateral Accelerometer Trace for Test 4348-2.
Figure 30. Vehicle Yaw for Test 4348-2.
Figure 31. Vehicle Pitch for Test 4348-2.
Figure 32. Vehicle Roll for Test 4348-2.

Trailer rolled onto barrier. Vehicle came to rest on its left side.