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7. Author(s) C. Eugene Buth, Roger P. Bligh, and Wanda L. Menges		8. Performing Organization Report No. Report 1804-3	
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16. Abstract The Texas Type T411 Bridge Rail is a concrete beam-and-posts system that was developed under a previous Texas Transportation Institute (TTI) study performed for Texas Department of Transportation (TxDOT). The Texas Type T411 was previously crash tested and approved under NCHRP Report 230 guidelines. However, with the adoption of NCHRP Report 350, the bridge rail needed to be reevaluated using the 2000-kg pickup truck. This report presents the details and results of the full-scale crash test on the Texas Type T411 Bridge Rail with the 2000-kg pickup truck traveling at 100 km/h and 25 degrees to evaluate performance at test level three. According to the specifications set for NCHRP Report 350 test designation 3-11, the Texas Type T411 Bridge Rail met all requirements except occupant risk. Significant occupant compartment deformation occurred on the center and right side of the vehicle. This deformation was judged to have the potential to cause serious injury.			
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**NCHRP REPORT 350 TEST 3-11 OF  
THE TEXAS TYPE T411 BRIDGE RAIL**

by

C. Eugene Buth  
Research Engineer  
Texas Transportation Institute

Roger P. Bligh  
Assistant Research Engineer  
Texas Transportation Institute  
and

Wanda L. Menges  
Associate Research Specialist  
Texas Transportation Institute

Letter Report 1804-3  
Research Project Number 0-1804  
Research Project Title: Evaluation and Testing of Bridge Rails  
and Transitions to NCHRP Report 350 Criteria

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The Texas A&M University System  
College Station, Texas 77843-3135



## **IMPLEMENTATION RECOMMENDATIONS**

1. The Texas Type T411 Bridge Rail failed the crash test reported herein for test level 3 (TL-3) of NCHRP Report 350 (1). This would indicate that it should not be used on high-speed facilities where a TL-3 railing is needed.
2. Based on previous testing, FHWA has designated the Texas Type T411 Bridge Rail as being acceptable for TL-2 of NCHRP Report 350. This would indicate that continued use of the Texas Type T411 Bridge Rail is acceptable on low-speed roadways.



## **DISCLAIMER**

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the data. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation, Federal Highway Administration, The Texas A&M University System, or Texas Transportation Institute. This report does not constitute a standard, specification, or regulation, and its contents are not intended for construction, bidding, or permit purposes. In addition, the above listed agencies assume no liability for its contents or use thereof. The names of specific products or manufacturers listed herein do not imply endorsement of those products or manufacturers. The engineer in charge of the project was Mr. C. Eugene Buth, P.E.#27579.

## **ACKNOWLEDGMENT**

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## SUMMARY

The first bridge rail selected for full-scale crash testing under this study was the Texas Type T411 Bridge Rail. This concrete beam and posts bridge rail was developed under a previous TxDOT study with TTI. The Texas Type T411 was crash tested and evaluated under NCHRP Report 230 guidelines. The two tests performed included one test with an 808-kg passenger vehicle traveling at 96.9 km/h and 21.2 degrees, and the second was with a 2043-kg passenger vehicle traveling at 100.1 km/h and 26.0 degrees. The bridge rail performed acceptably during these two tests. However, with the adoption of NCHRP Report 350, the bridge rail needed to be reevaluated using the 2000-kg pickup truck. This report presents the details and results of the full-scale crash test on the Texas Type T411 Bridge Rail with the 2000-kg pickup truck traveling at 100 km/h and 25 degrees to evaluate performance at test level three.

According to the specifications set for NCHRP Report 350 test designation 3-11, the Texas Type T411 met all requirements except occupant risk. Significant occupant compartment deformation that could cause serious injury occurred on the center and right side of the vehicle.



## I. INTRODUCTION

On July 16, 1993, the Federal Highway Administration (FHWA) formally adopted the new performance evaluation guidelines for highway safety features set forth in the National Cooperative Highway Research Program (NCHRP) Report 350 as a "Guide or Reference" document in *Federal Register*, Volume 58, Number 135 (1,2). FHWA has also mandated that, on projects let after October 1998, only highway safety appurtenances that have successfully met the performance evaluation guidelines set forth in NCHRP Report 350 may be used on new construction projects on the National Highway System (NHS).

Changes incorporated into the new NCHRP Report 350 guidelines include new design test vehicles, expanded test matrices, and revised impact conditions. Of most significance was the adoption of a 2000-kg pickup truck as the design test vehicle for structural adequacy tests. This change has necessitated the retesting and reevaluation of the impact performance of many existing roadside safety features. Through various pooled fund studies and research projects, FHWA has tested and continues to test some of the most widely used safety appurtenances, including several bridge rails and transitions. However, this testing will not be all-inclusive. There remain some bridge rails unique to the Texas Department of Transportation (TxDOT) that have not been crash tested to the new NCHRP Report 350 guidelines. Therefore, there is a need for assessing the safety performance of these railings and, if necessary, modifying the designs to meet the requirements of NCHRP Report 350 in order to permit their continued use beyond the October 1998 deadline.

Over the years, Texas Transportation Institute (TTI) and TxDOT have worked jointly on the development, evaluation, and testing of many TxDOT standard bridge rail designs. This cooperative research has resulted in many satisfactory designs with demonstrated impact performances that have been successfully implemented by the Department. This project is an extension of this previous work during which the performance of selected railing and transition designs will be evaluated both analytically and experimentally through full-scale crash testing to assess compliance with the new NCHRP Report 350 performance criteria.

Under the first task of this study, TTI researchers identified all bridge rails and transitions similar to those used in Texas that have already been tested or were scheduled to be tested. The researchers reviewed all previous testing on current TxDOT railing designs and any related tests on other similar designs to document any existing test results that demonstrate acceptability of the railing designs by NCHRP Report 350 standards.

In the second task, TTI researchers presented TxDOT with a list of untested bridge rails and transitions, along with needed testing for these designs. The untested bridge rails and transitions, believed to have long-term usage potential to TxDOT, were selected and prioritized for full scale testing.

During task three, the first step in the evaluation of items to be tested was a simple analysis of strength and geometry in accordance with railing provisions of the American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) code,

supplemented by other information available to the researchers (3).

After all analyses were performed, the first bridge rail selected for full-scale crash testing was the Texas Type T411 Bridge Rail. This concrete beam-and-post bridge rail was developed under a previous TxDOT study with TTI (4). The Texas Type T411 was crash tested and evaluated under NCHRP Report 230 guidelines (5). The two tests performed included one test with an 808-kg passenger vehicle traveling at 96.9 km/h and 21.2 degrees, and the second was with a 2043-kg passenger vehicle traveling at 100.1 km/h and 26.0 degrees. The bridge rail performed acceptably during these two tests. However, with the adoption of NCHRP Report 350, the bridge rail needed to be reevaluated using the 2000-kg pickup truck. This report presents the details and results of the full-scale crash test on the Texas Type T411 Bridge Rail with the 2000-kg pickup truck traveling at 100 km/h and 25 degrees to evaluate performance at test level three.



## II. STUDY APPROACH

### TEST ARTICLE

This bridge rail is constructed of reinforced concrete 813 mm high by 305 mm thick and contains 203 mm wide by 457 mm high openings at 457 mm center-to-center longitudinal spacing. Figures 1 and 2 present a plan view, elevation, and cross section of the T411 rail. The bridge deck is a 203-mm thick, typical Texas bridge slab design in accordance with AASHTO specifications (6).

Figure 3 shows photographs of the 23.1 m bridge rail installation prior to crash testing. The four pilasters are not truly strong posts, as they appear to be. They contain styrofoam blocks 267 mm by 330 mm by 533 mm (void), which means the pilasters are similar in strength to the 203 mm by 457 mm openings. The use of the pilasters is, thus, optional since they do not contribute to the bridge rail strength as built and crash tested.

This bridge rail was designed using a failure mechanism (or yield line) method of analysis (7). The design strength of the concrete was  $f_c = 24.8$  MPa, and the yield strength of reinforcing steel was  $f_y = 413.7$  MPa. The top beam was nominally 178 mm wide and 279 mm thick ( $b = 178$  mm and  $d = 210$  mm), yielding an ultimate moment capacity of 27.9 kN-m. With a moment arm of 0.67 m, each post could resist a lateral load of about 42.3 kN. The failure load would be about 293.1 kN or more. Five posts would crack, and a 2.7 m length of bridge rail would be involved.

Concrete specimens taken from the simulated bridge deck yielded a compressive strength of 33.6 MPa at 28 days of age. The compressive strength of the concrete rail was 35.2 MPa at 28 days of age.

### CRASH TEST CONDITIONS

NCHRP Report 350 requires two tests for test level 3 evaluation of longitudinal barriers:

**NCHRP Report 350 test designation 3-10:** This test involves an 820-kg passenger vehicle (820C) impacting the length-of-need (LON) of the barrier at a nominal speed and angle of 100 km/h and 20 degrees. The purpose of this test is to evaluate the overall performance of the LON section, in general, and occupant risks, in particular.

**NCHRP Report 350 test designation 3-11:** The test involves a 2000-kg pickup truck (2000P) impacting the LON of the barrier at a nominal speed and angle of 100 km/h and 25 degrees. The test is intended to evaluate strength of the section in containing and redirecting the 2000P vehicle.

The small car test required as NCHRP Report 350 test designation 3-10, is the same as the NCHRP Report 230 test S13, which was performed under the original study (4). Test 418048-1 corresponds to NCHRP Report 350 test designation 3-11 and is reported herein.



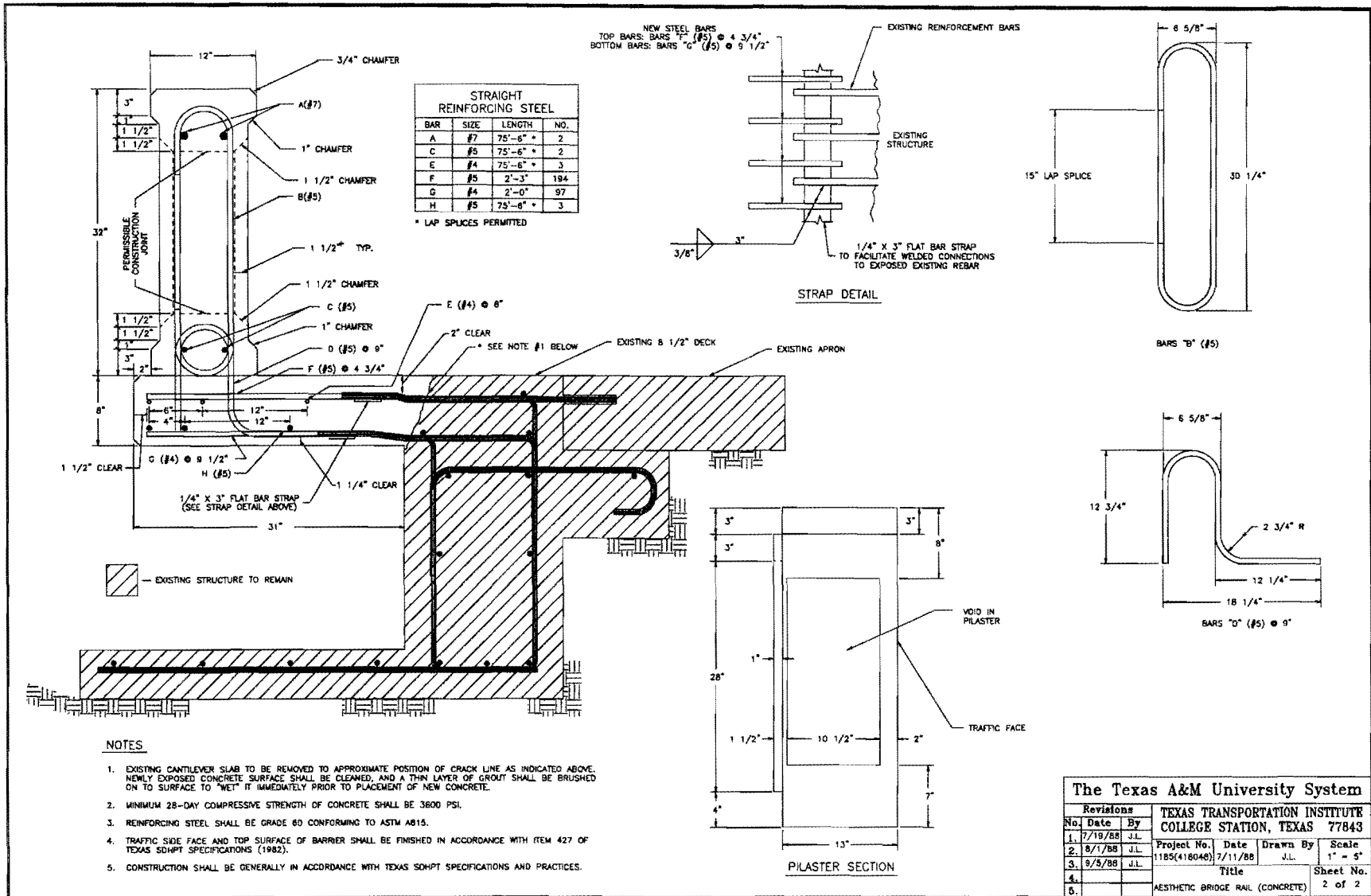
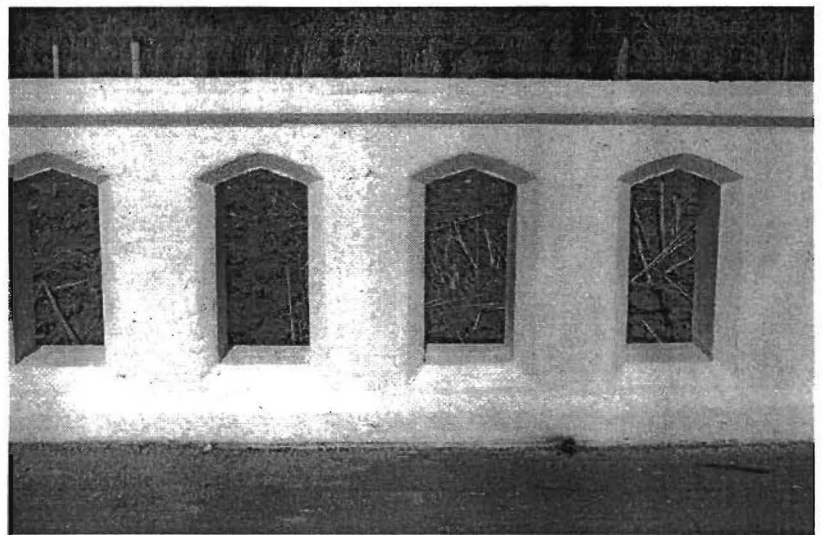
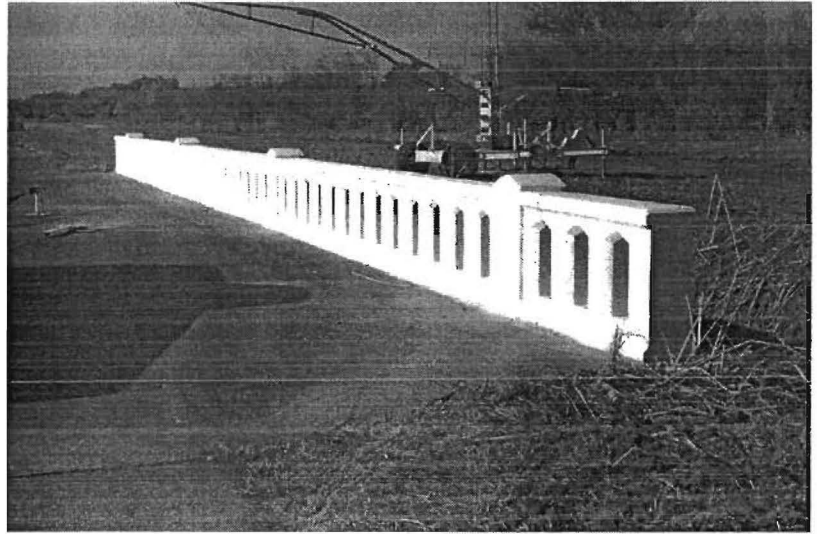


Figure 2. Details of the Texas Type T411 Bridge Rail -- Cross Section

The Texas A&M University System				
Revisions				
No.	Date	By	TEXAS TRANSPORTATION INSTITUTE COLLEGE STATION, TEXAS 77843	
1.	7/19/88	J.L.	Project No.	Date
2.	8/1/88	J.L.	1185(418048)	7/11/88
3.	9/5/88	J.L.	Title	
4.			Sheet No.	
5.			AESTHETIC BRIDGE RAIL (CONCRETE) 2 of 2	



**Figure 3. Texas Type T411 Bridge Railing Installation before Test 418048-1**

## EVALUATION CRITERIA

The crash test performed and reported herein was evaluated in accordance with the criteria presented in NCHRP Report 350. As stated in NCHRP Report 350, "Safety performance of a highway appurtenance cannot be measured directly but can be judged on the basis of three factors: structural adequacy, occupant risk, and vehicle trajectory after collision." Accordingly, the following safety evaluation criteria from table 5.1 of NCHRP Report 350 were used to evaluate the crash test reported herein:

- **Structural Adequacy**
  - A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation, although controlled lateral deflection of the test article is acceptable.
- **Occupant Risk**
  - D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.
  - F. The vehicle should remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.
- **Vehicle Trajectory**
  - K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.
  - L. The occupant impact velocity in the longitudinal direction should not exceed 12 m/s, and the occupant ridedown acceleration in the longitudinal direction should not exceed 20 g's.
  - M. The exit angle from the test article preferably should be less than 60 percent of the test impact angle, measured at time of vehicle loss of contact with the test device.

## **CRASH TEST AND DATA ANALYSIS PROCEDURES**

The crash test and data analysis procedures were in accordance with guidelines presented in NCHRP Report 350. Brief descriptions of these procedures are presented as follows.

### **Electronic Instrumentation and Data Processing**

The test vehicle was instrumented with three solid-state, angular-rate transducers to measure roll, pitch, and yaw rates; a triaxial accelerometer near the vehicle center of gravity to measure longitudinal, lateral, and vertical acceleration levels; and a back-up biaxial accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. The accelerometers were strain-gauge type with a linear millivolt output proportional to acceleration.

The electronic signals from the accelerometers and transducers were transmitted to a base station by means of a constant bandwidth FM/FM telemetry link for recording on magnetic tape and for display on a real-time strip chart. Calibration signals were recorded before and after the test, and an accurate time reference signal was simultaneously recorded with the data. Pressure sensitive switches on the bumper of the impacting vehicle were actuated just prior to impact by wooden dowels to indicate the elapsed time over a known distance to provide a measurement of impact velocity. The initial contact also produced an "event" mark on the data record to establish the exact instant of contact with the installation.

The multiplex of data channels, transmitted on one radio frequency, was received at the data acquisition station and demultiplexed into separate tracks of Inter-Range Instrumentation Group (I.R.I.G.) tape recorders. After the test, the data were played back from the tape machines, filtered with an SAE J211 filter, and digitized using a microcomputer for analysis and evaluation of impact performance.

The digitized data were then processed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions on the functions of these two computer programs are provided as follows.

The DIGITIZE program uses digitized data from vehicle-mounted linear accelerometers to compute occupant/compartments impact velocities, time of occupant/compartments impact after vehicle impact, and the highest 10-ms average ridedown acceleration. The DIGITIZE program also calculates a vehicle impact velocity and the change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are then filtered with a 60-Hz digital filter. Acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using a commercially available software package (Excel).

The PLOTANGLE program uses the digitized data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.00067-s intervals and then instructs a plotter to draw a reproducible plot: yaw, pitch, and roll versus time. These displacements are in

reference to the vehicle-fixed coordinate system, with the initial position and orientation of the vehicle-fixed coordinate system being that which existed at initial impact.

### **Anthropomorphic Dummy Instrumentation**

Use of a dummy in the 2000P vehicle is optional, according to NCHRP Report 350; there was no dummy used in the tests with the 2000P vehicle.

### **Photographic Instrumentation and Data Processing**

Photographic coverage of the test included three high-speed cameras: one overhead with a field of view perpendicular to the ground and directly over the impact point; one placed behind the installation at an angle; and a third placed to have a field of view parallel to and aligned with the installation at the downstream end. A flash bulb activated by pressure sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked Motion Analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A Betacam, a VHS-format video camera and recorder, and still cameras were used to record and document conditions of the test vehicle and installation before and after the test.

### **Test Vehicle Propulsion and Guidance**

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2 to 1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time brakes on the vehicle were activated to bring it to a safe and controlled stop.



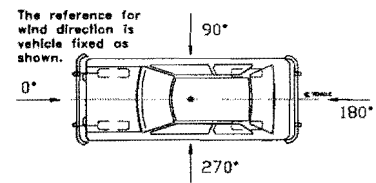


### III. CRASH TEST RESULTS

#### TEST 418048-1 (NCHRP Report 350 Test No. 3-11)

A 1993 Chevrolet 2500 pickup truck, shown in figures 4 and 5, was used for the crash test. Test inertia weight of the vehicle was 2000 kg, and its gross static weight was 2000 kg. The height to the lower edge of the vehicle bumper was 410 mm, and it was 630 mm to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in figure 6. 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 test was performed the morning of April 20, 1998. No rainfall occurred during the ten days prior to the test. Weather conditions during the time of the test were as follows: Wind speed: 13 km/h; wind direction: 350 degrees with respect to the vehicle (vehicle was traveling in a south/southwesterly direction); temperature: 22 °C; relative humidity: 39 percent.



#### Test Description

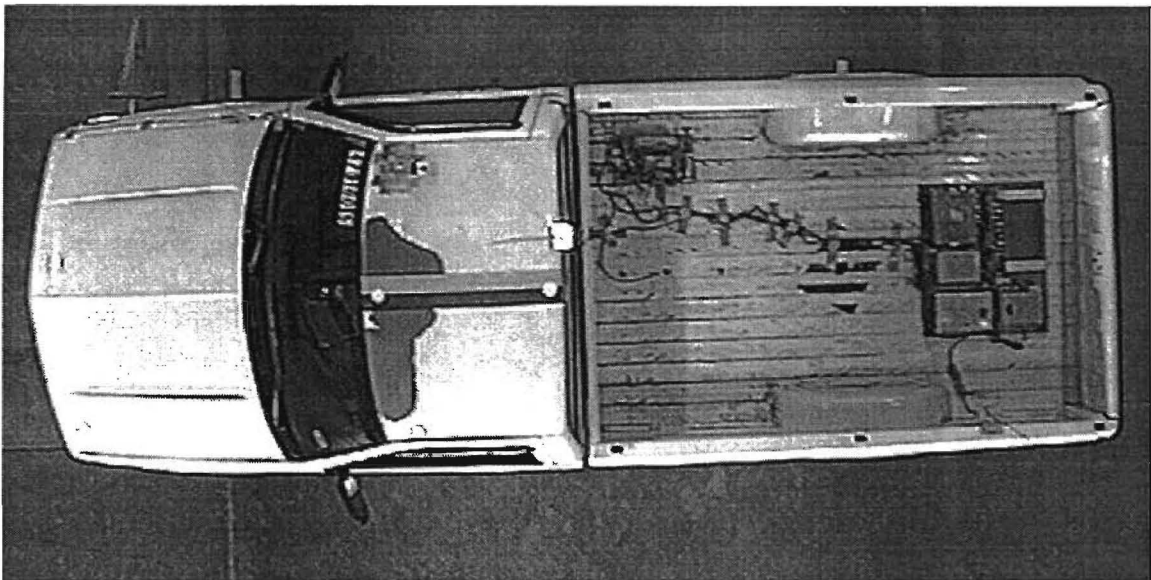
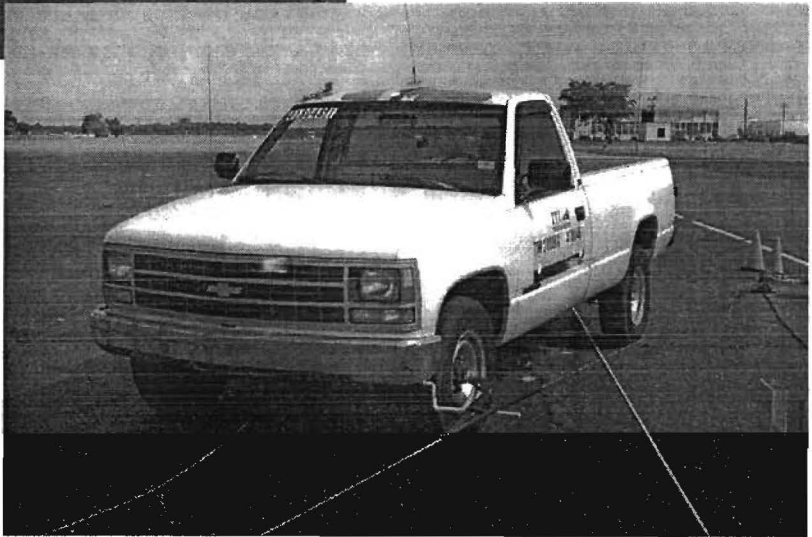
The vehicle, traveling at 101.3 km/h, impacted the Texas Type T411 bridge rail at 24.9 degrees, 11.6 m down from the end of the installation. Shortly after impact, the right front wheel steered away from the bridge rail, and then at 0.032 s, the tire entered the opening just down from impact. The left front wheel steered toward the rail at 0.040 s, and the right door deformed at 0.052 s. Redirection of the vehicle began at 0.052 s. At 0.062 s, stress cracks appeared in the windshield, and at 0.075 s the right door glass shattered. The rear of the vehicle contacted the bridge rail at 0.254 s. At 0.263 s, the vehicle was traveling parallel with the bridge rail at a speed of 69.7 km/h. The vehicle remained in contact with the bridge rail for a distance of 3.7 m and lost contact with the bridge rail at 0.392 s. As the vehicle exited the rail, it was traveling at a speed of 69.5 km/h and an exit angle of 11.5 deg. Brakes on the vehicle were applied 2.0 s after impact. The vehicle subsequently came to rest 44.2 m down from impact and 3.6 m behind the installation. Sequential photographs of the test period are shown in figures 7 and 8.

#### Damage to Test Installation

Damage to the Texas Type T411 bridge rail is shown in figures 9 and 10. Most of the damage was cosmetic, consisting of tire marks and scuffs. Tire marks extended 45 mm into the first window up from impact, 230 mm into the second, 70 mm into the third, 52 mm into the fourth, 25 mm into the fifth, and 40 mm into the sixth. A hairline stress crack occurred 390 mm down from impact. The edge of the concrete on the large pilaster upstream of impact was spalled. The vehicle was in contact with the bridge rail a total of 3.7 m.



**Figure 4. Vehicle/Installation Geometrics for Test 418048-1**



**Figure 5. Vehicle before Test 418048-1**

DATE: 4-20-98 TEST NO.: 418048-1 VIN NO.: 1GCGC24K6PE195144  
 YEAR: 1993 MAKE: CHEVY MODEL: 2500 P/U  
 TIRE INFLATION PRESSURE: \_\_\_\_\_ ODOMETER: 101631 TIRE SIZE: LT24575R16

MASS DISTRIBUTION (kg) LF 552 RF 536 LR 450 RR 462

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:  
 \_\_\_\_\_  
 \_\_\_\_\_

● Denotes accelerometer location.  
 NOTES: \_\_\_\_\_  
 \_\_\_\_\_

ENGINE TYPE: 8 CYL  
 ENGINE CID: 5.7 L  
 TRANSMISSION TYPE:  
 \_\_\_\_\_ AUTO  
 \_\_\_\_\_  MANUAL

OPTIONAL EQUIPMENT:  
8 LUGS  
 \_\_\_\_\_  
 \_\_\_\_\_

DUMMY DATA:  
 TYPE: \_\_\_\_\_  
 MASS: \_\_\_\_\_  
 SEAT POSITION: \_\_\_\_\_

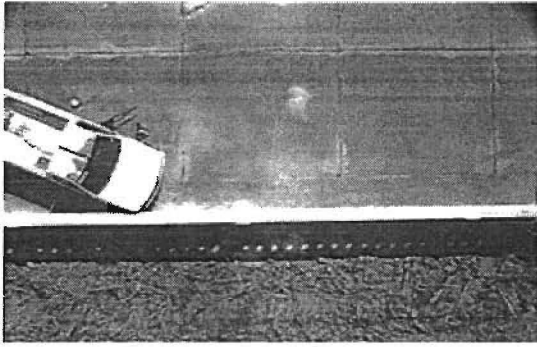
**GEOMETRY - (mm)**

A	<u>1860</u>	E	<u>1260</u>	J	<u>1020</u>	N	<u>1610</u>	R	<u>710</u>
B	<u>770</u>	F	<u>5380</u>	K	<u>630</u>	O	<u>1625</u>	S	<u>930</u>
C	<u>3350</u>	G	<u>1527.6</u>	L	<u>60</u>	P	<u>745</u>	T	<u>1480</u>
D	<u>1840</u>	H	_____	M	<u>410</u>	Q	<u>445</u>	U	<u>4050</u>

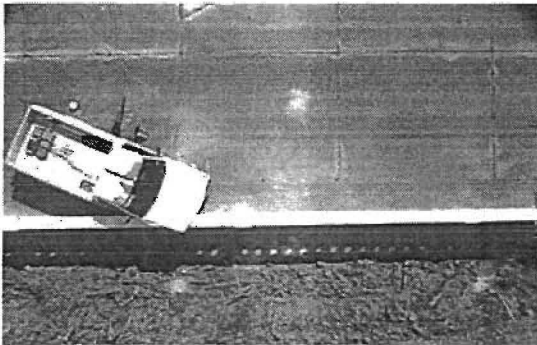
  

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M <sub>1</sub>	<u>1166</u>	<u>1088</u>	_____
M <sub>2</sub>	<u>976</u>	<u>912</u>	_____
M <sub>T</sub>	<u>2142</u>	<u>2000</u>	_____

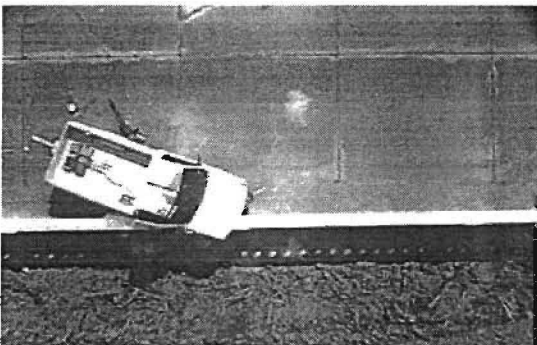
**Figure 6. Vehicle Properties for Test 418048-1**



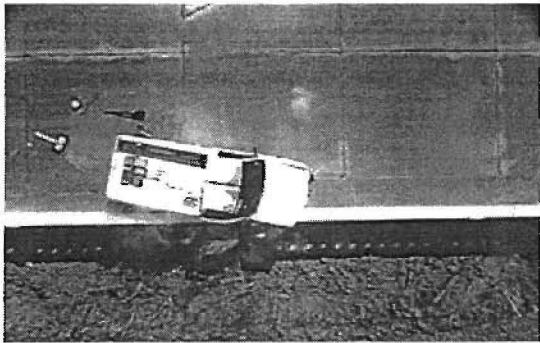
0.000 s



0.050 s



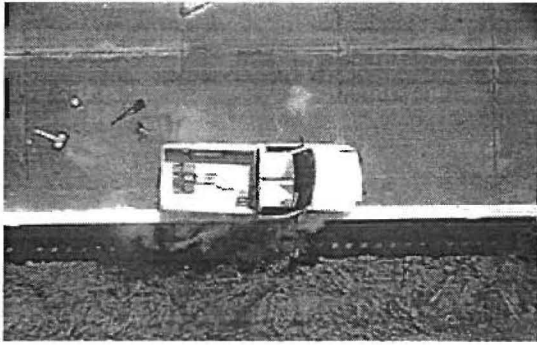
0.100 s



0.174 s

**Figure 7. Sequential Photographs for Test 418048-1  
(Overhead and Frontal Views)**

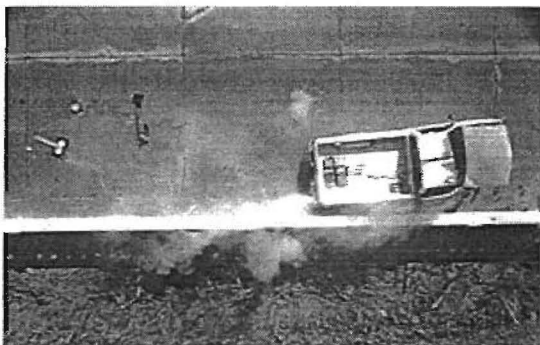




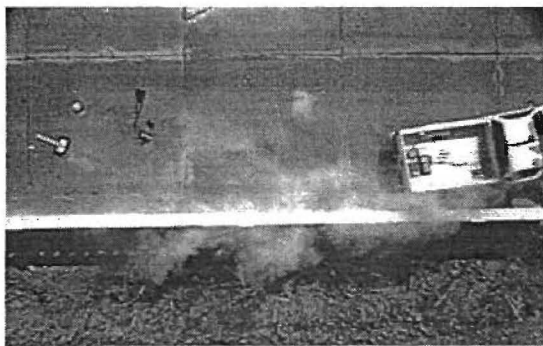
0.248 s



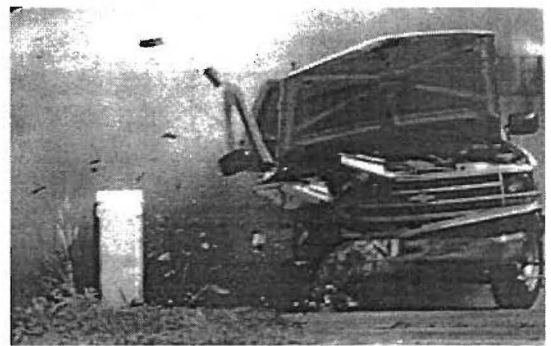
0.347 s



0.471 s



0.596 s



**Figure 7. Sequential Photographs for Test 418048-1  
(Overhead and Frontal Views) (continued)**



0.000 s



0.248 s



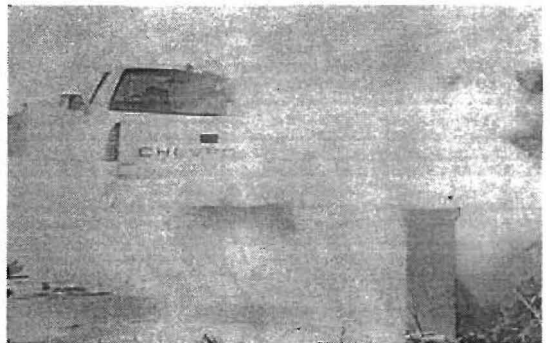
0.050 s



0.347 s



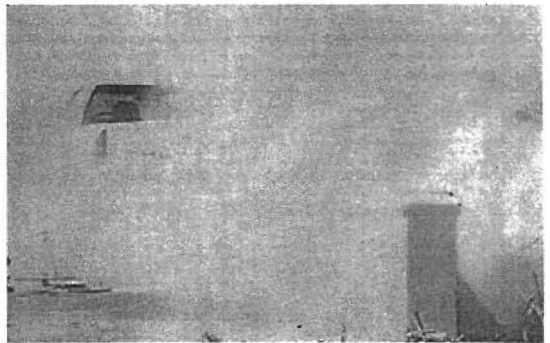
0.100 s



0.471 s

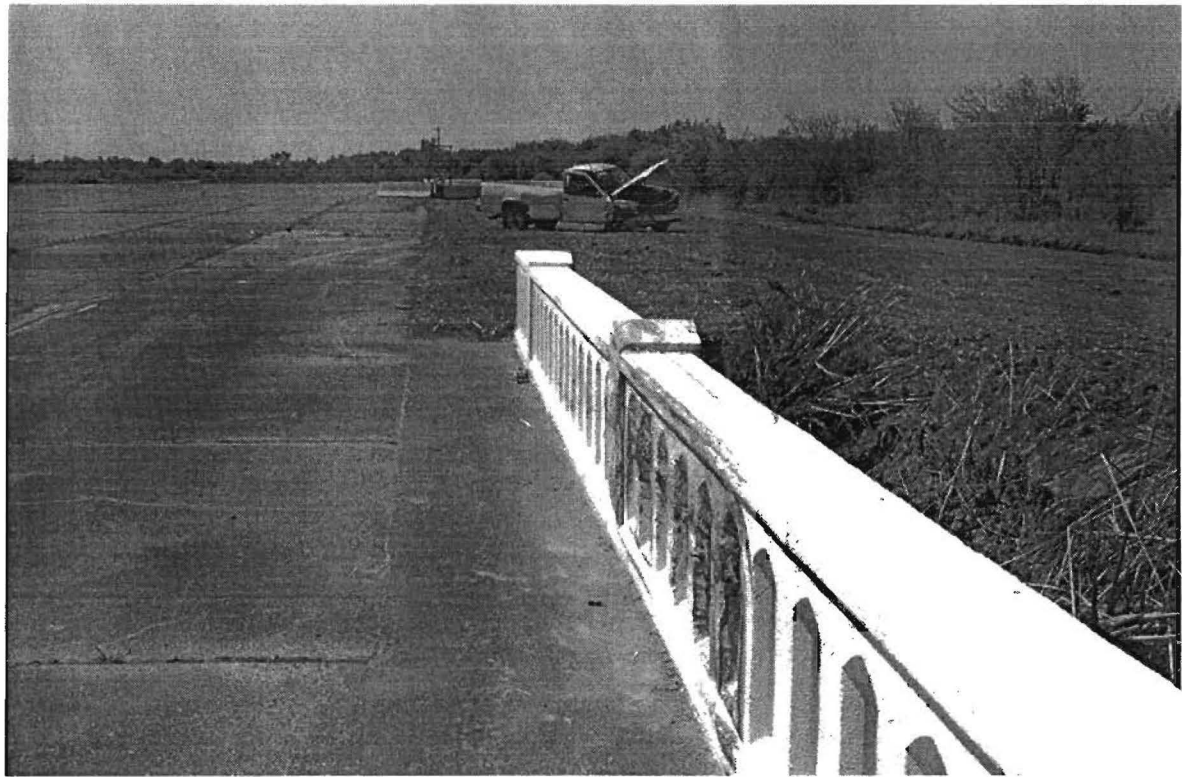
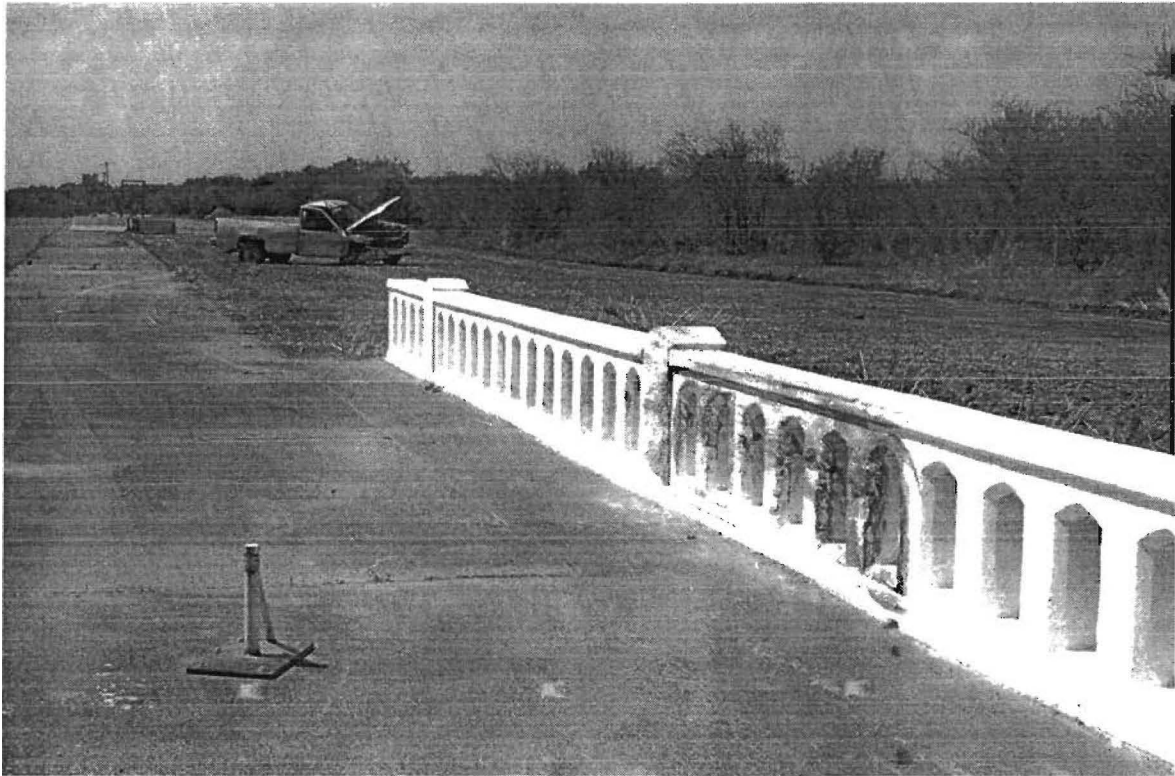


0.174 s



0.596 s

**Figure 8. Sequential Photographs for Test 418048-1  
(Rear View)**



**Figure 9. After Impact Trajectory for Test 418048-1**



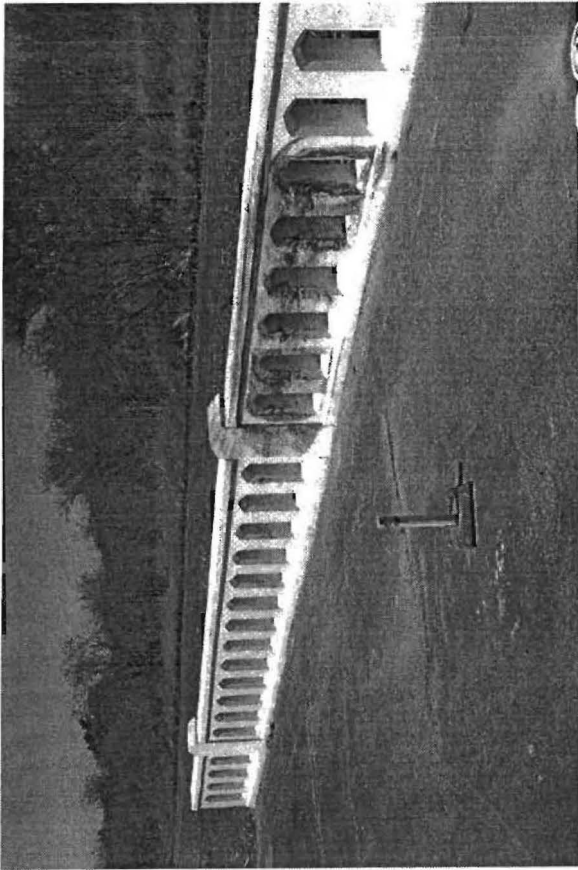
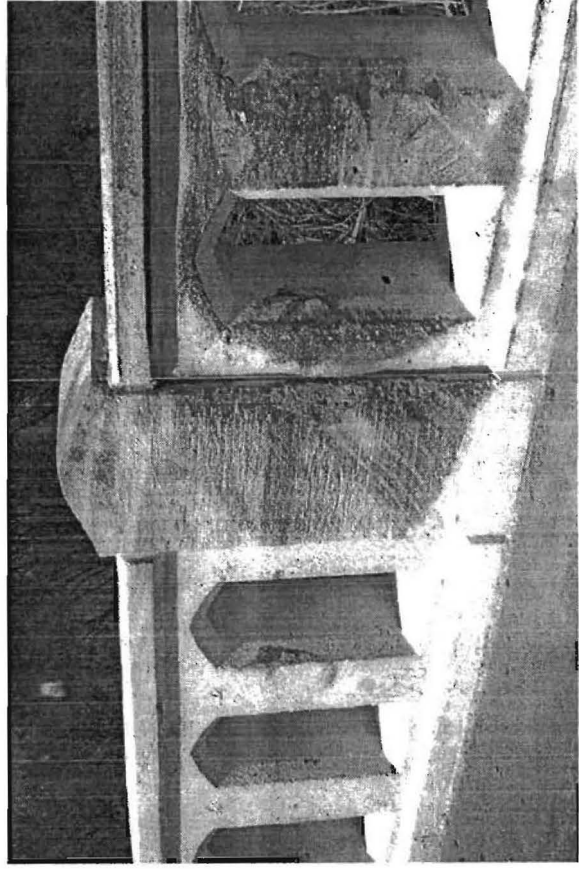
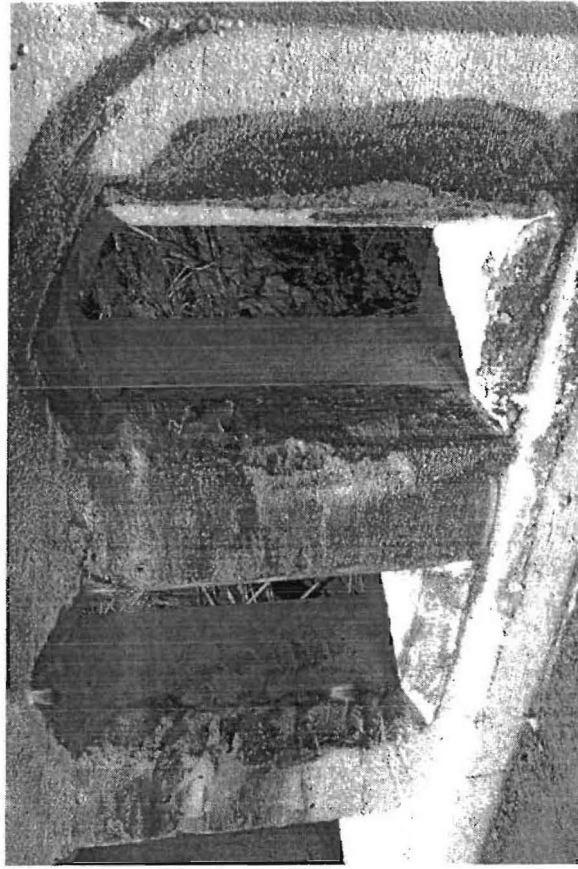


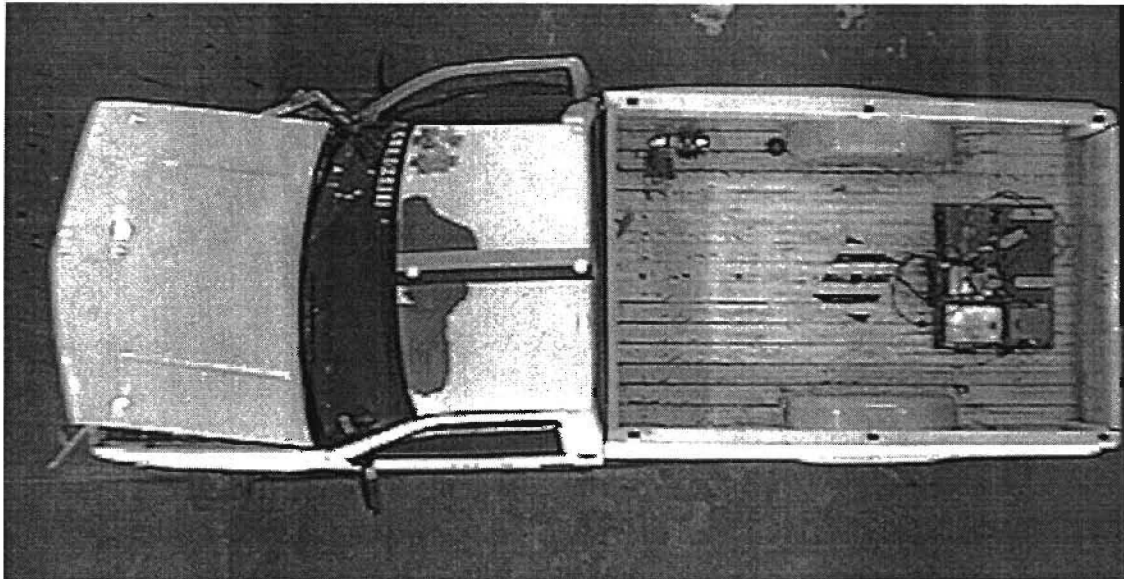
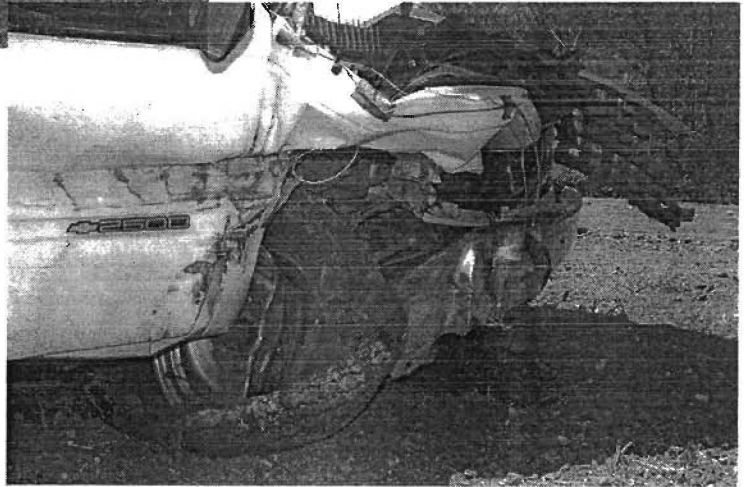
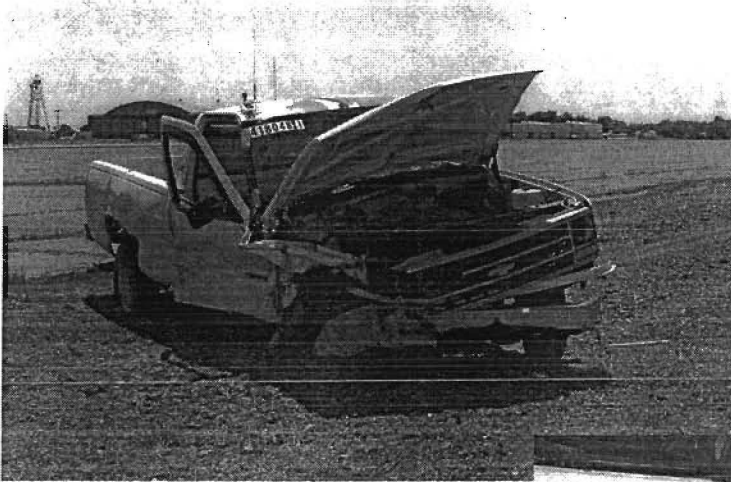
Figure 10. Installation after Test 418048-1

## **Vehicle Damage**

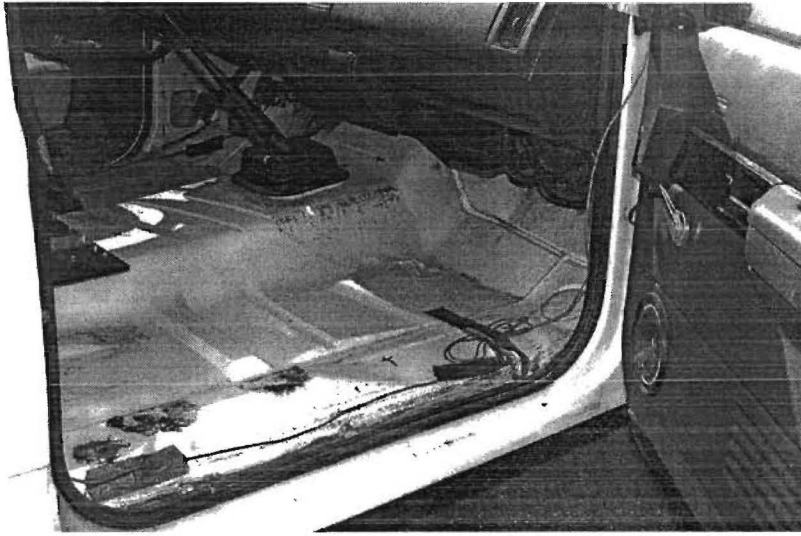
The vehicle after impact with the Texas Type T411 bridge rail is shown in figure 11. Structural damage to the vehicle included deformation of the right front of the frame, right front spindle, A-arms, rod ends, idler arm, right side engine support, and the firewall and floor pan. The A-pillar on the right side was deformed, and the windshield shattered. The bumper, hood, grill, fan, radiator, right front and rear quarter panels, right door and window, and the right front and rear wheels also received damage. Maximum crush to the vehicle was 1040 mm at the front right corner at bumper height. Maximum measurable occupant compartment deformation was 117 mm (8.5 percent reduction in space) in the right side firewall area, and a maximum reduction of 9.7 percent occurred in the occupant compartment at floor pan area. These measurements were taken at points of reference taken prior to the test and do not accurately represent the maximum deformations. As can be seen in figure 12, considerable deformation occurred to the passenger side of the occupant compartment. The floor pan was separated at the seams in several places. An accurate measurement was not attainable. Exterior crush and occupant compartment measurements are shown in tables 1 and 2.

## **Occupant Risk Values**

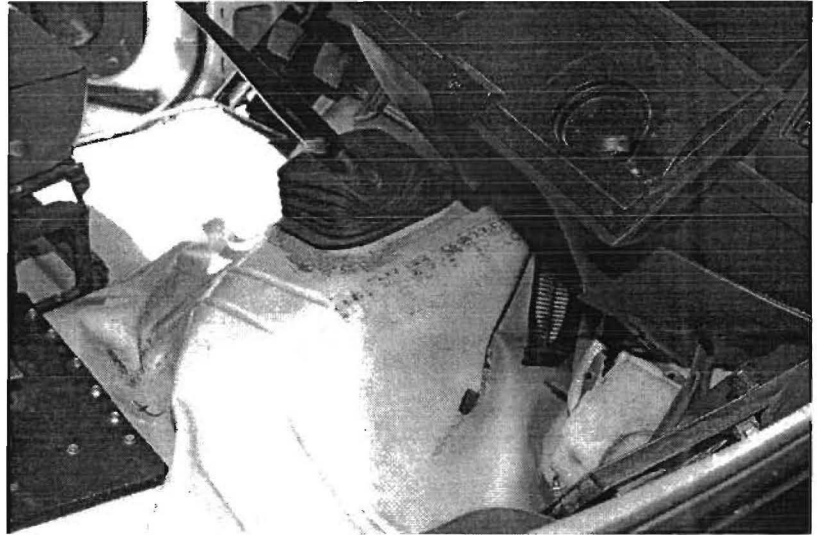
Data from the accelerometer located at the vehicle center of gravity were digitized for evaluation of occupant risk and were computed as follows. In the longitudinal direction, the occupant impact velocity was 9.5 m/s at 0.140 s; the highest 0.010-s occupant ridedown acceleration was -11.3 g's from 0.109 to 0.119 s, and the maximum 0.050-s average acceleration was -11.5 g's between 0.070 and 0.120 s. In the lateral direction, the occupant impact velocity was 7.0 m/s at 0.109 s; the highest 0.010-s occupant ridedown acceleration was -9.2 g's from 0.284 to 0.294 s, and the maximum 0.050-s average was -10.9 g's between 0.049 and 0.099 s. Figure 13 summarizes these data and other pertinent information from the test. Figure 14 displays vehicle angular displacements. Figures 15 and 16 present vehicular accelerations versus time traces.



**Figure 11. Vehicle after Test 418048-1**



Before test



After test



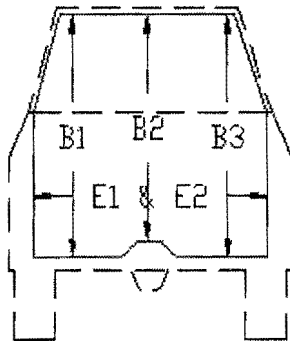
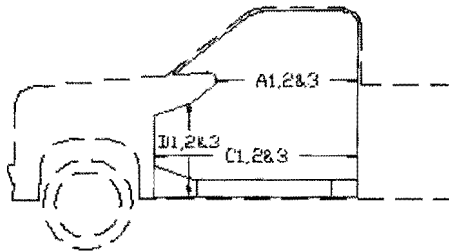
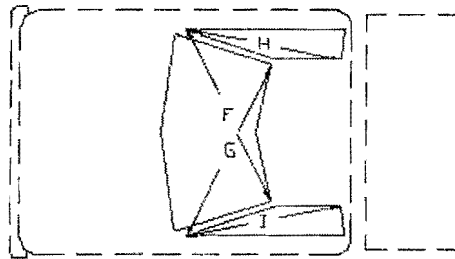
**Figure 12. Interior of Vehicle for Test 418048-1**



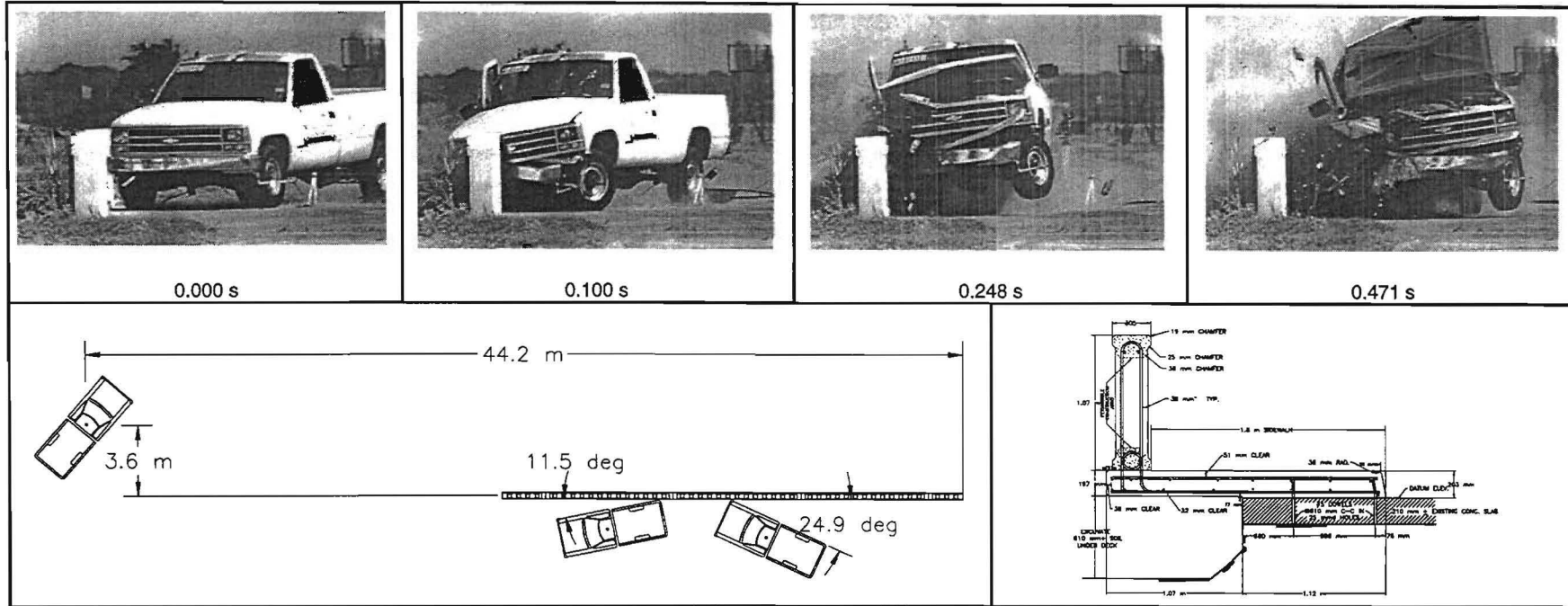
**Table 2. Occupant Compartment Measurements for Test 418048-1**

# Truck

## Occupant Compartment Deformation



	BEFORE	AFTER
A1	1040	1048
A2	1083	1040
A3	1044	977
B1	1080	1080
B2	1047	1140
B3	1072	1060
C1	1373	1373
C2	1250	1165
C3	1372	1255
D1	306	324
D2	155	140
D3	315	290
E1	1600	1645
E2	1595	1616
F	1475	1445
G	1475	1475
H	900	865
I	900	900



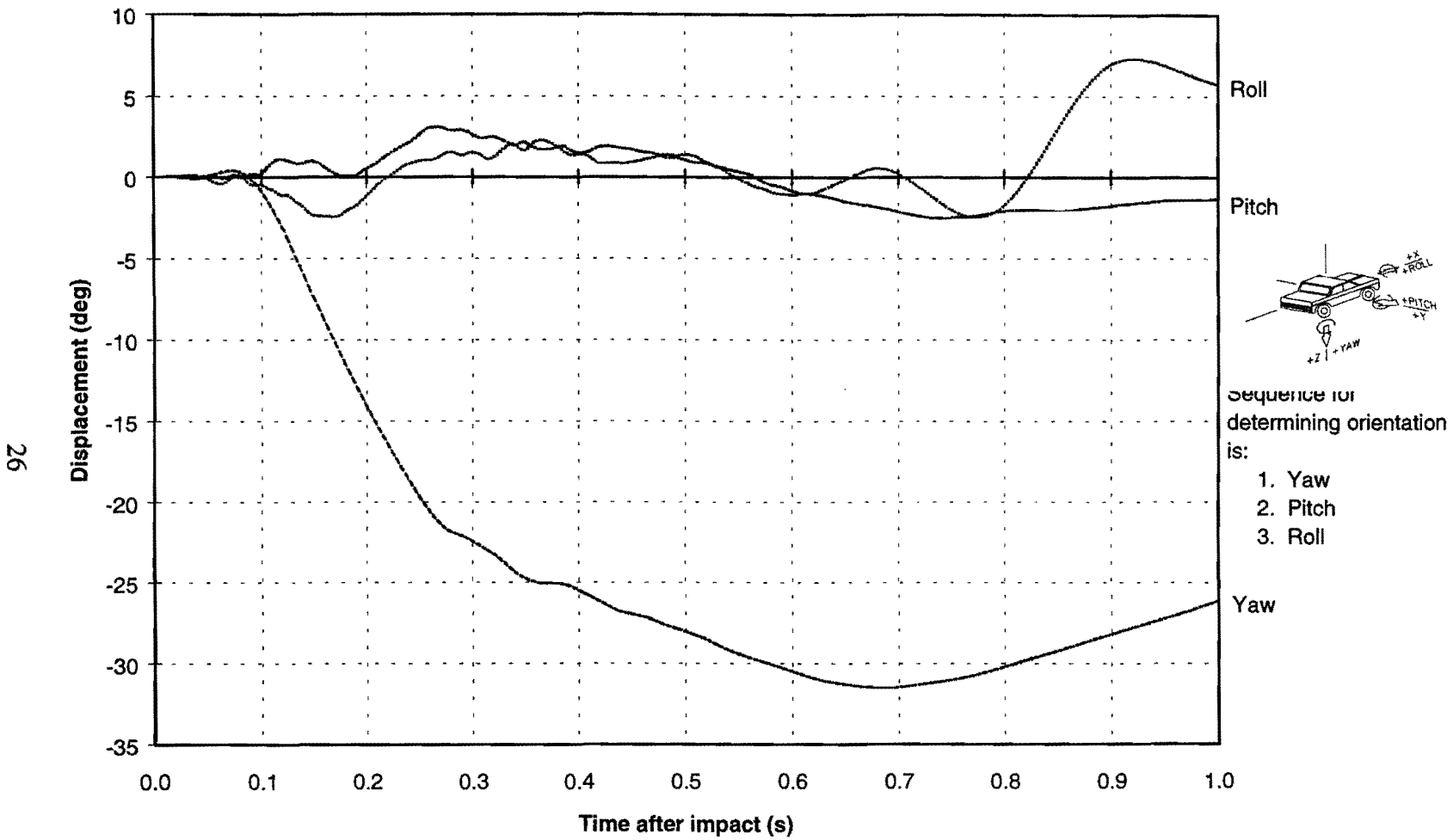
25

<b>General Information</b>		<b>Impact Conditions</b>		<b>Test Article Deflections (m)</b>	
Test Agency .....	Texas Transportation Institute	Speed (km/h) .....	101.3	Dynamic .....	nil
Test No. ....	418048-1	Angle (deg) .....	24.9	Permanent .....	nil
Date .....	04/20/98	<b>Exit Conditions</b>		<b>Vehicle Damage</b>	
<b>Test Article</b>		Speed (km/h) .....	69.5	<b>Exterior</b>	
Type .....	Bridge Rail	Angle (deg) .....	11.5	VDS .....	01FR6
Name or Manufacturer .....	Texas Type T411	<b>Occupant Risk Values</b>		CDC .....	01FREW6
Installation Length (m) .....	23.1	Impact Velocity (m/s)		<b>Maximum Exterior</b>	
Material or Key Elements .....	Concrete Beam and Posts	x-direction .....	9.5	Vehicle Crush (mm) .....	1040
Soil Type and Condition .....	Concrete deck, dry	THIV (km/h) .....	37.4	<b>Interior</b>	
<b>Test Vehicle</b>		Ridedown Accelerations (g's)		OCDI .....	FS1012000
Type .....	Production	x-direction .....	-11.7	<b>Max. Occ. Compart.</b>	
Designation .....	2000P	y-direction .....	-9.2	Deformation (mm) .....	117
Model .....	1993 Chevrolet pickup truck	PHD (g's) .....	15.4	<b>Post-Impact Behavior</b>	
Mass (kg) Curb .....	2142	ASI .....	1.4	(during 1.0 s after impact)	
Test Inertial .....	2000	Max. 0.050-s Average (g's)		Max. Yaw Angle (deg) .....	-32
Dummy .....	No dummy	x-direction .....	-11.5	Max. Pitch Angle (deg) .....	3
Gross Static .....	2000	y-direction .....	-10.9	Max. Roll Angle (deg) .....	7
		z-direction .....	5.0		

Figure 13. Summary of Results for Test 418048-1

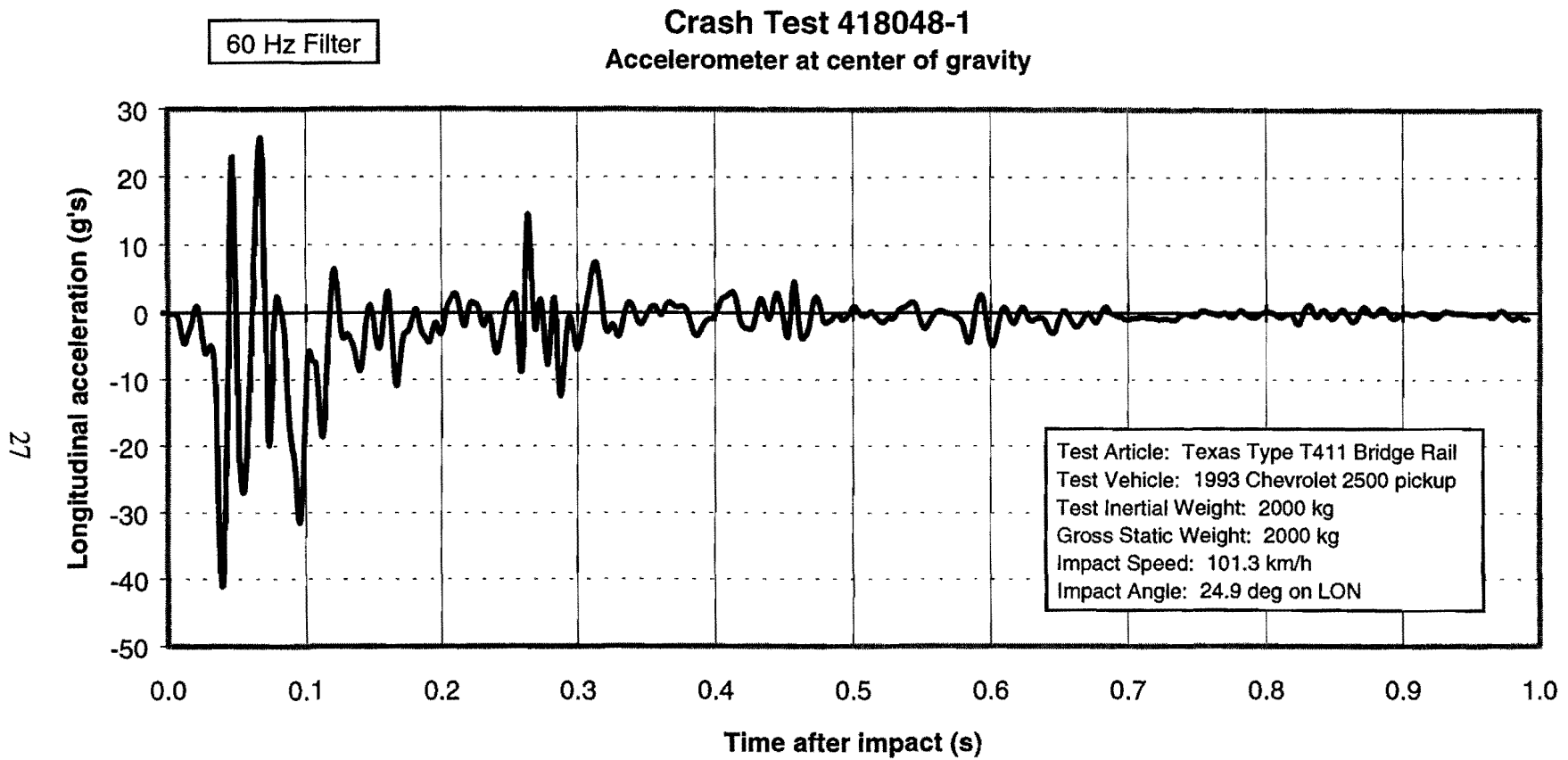


**Crash Test 418048-1**  
**Vehicle Mounted Rate Transducers**



**Figure 14. Vehicle Angular Displacements for Test 418048-1**





**Figure 15. Vehicle Longitudinal Accelerometer Trace for Test 418048-1**

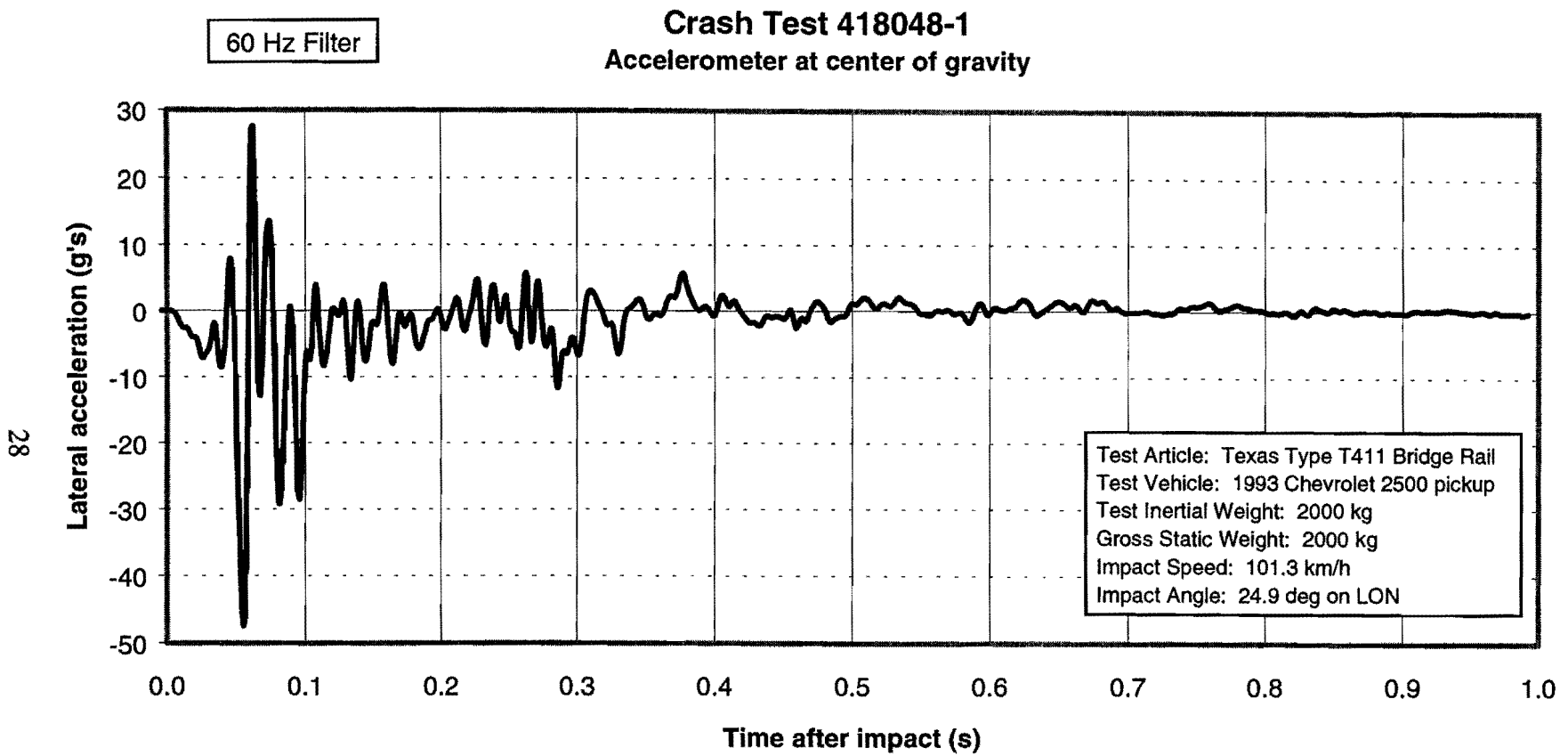
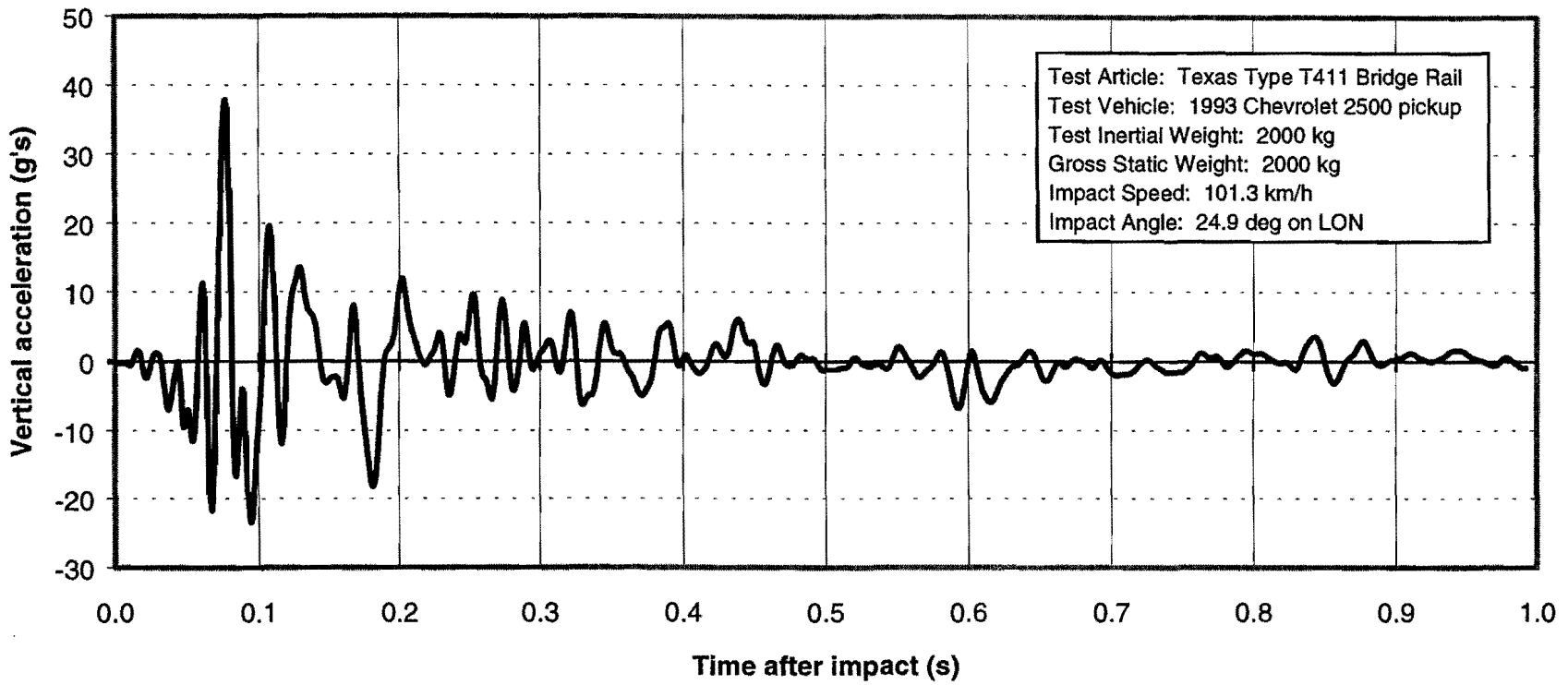


Figure 16. Vehicle Lateral Accelerometer Traces for Test 418048-1

**Crash Test 418048-1**  
**Accelerometer at center of gravity**

60 Hz Filter



**Figure 17. Vehicle Vertical Accelerometer Trace for Test 418048-1**



## **IV. SUMMARY OF FINDINGS AND CONCLUSIONS**

### **SUMMARY OF FINDINGS**

The Texas Type T411 Bridge Rail contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the bridge rail. No detached element, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. An accurate measurement of the maximum deformation could not be attained. However, it was concluded that the damage and deformation which occurred within the occupant compartment could cause serious injury to the lower extremities of occupants. The vehicle remained upright during and after the collision period and did not intrude into adjacent traffic lanes. Occupant risk factors were within the limit specified in NCHRP Report 350, as can be seen in table 3. Exit angle at loss of contact with the bridge rail was 11.5 deg, which was less than 60 percent of the impact angle of 24.9 deg.

### **CONCLUSIONS**

According to the specifications set for NCHRP Report 350 test designation 3-11, the Texas Type T411 met all requirements, except occupant risk. Significant occupant compartment deformation occurred on the center and right side of the vehicle, which was judged to have the potential to cause serious injury.

**Table 3. Performance Evaluation Summary for Test 418048-1, NCHRP Report 350 Test 3-11**

Test Agency: Texas Transportation Institute

Test No.: 418048-1

Test Date: 4/20/98

NCHRP Report 350 Evaluation Criteria	Test Results	Assessment
<p><u>Structural Adequacy</u></p> <p>A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underide, or override the installation, although controlled lateral deflection of the test article is acceptable.</p>	<p>The Texas Type T411 Bridge Rail contained and redirected the vehicle. The vehicle did not penetrate, underide, or override the bridge rail.</p>	<p>Pass</p>
<p><u>Occupant Risk</u></p> <p>D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</p>	<p>No detached element, fragments or other debris were present to penetrate or to show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. An accurate measurement of the maximum deformation could not be attained. However, it was concluded that the damage and deformation which occurred within the occupant compartment could cause serious injury to the lower extremities of occupants.</p>	<p>Fail</p>
<p>F. The vehicle should remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.</p>	<p>The vehicle remained upright during and after the collision period.</p>	<p>Pass</p>
<p><u>Vehicle Trajectory</u></p>		
<p>K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.</p>	<p>The vehicle did not intrude into adjacent traffic lanes.</p>	<p>Pass</p>
<p>L. The occupant impact velocity in the longitudinal direction should not exceed 12 m/s, and the occupant ridedown acceleration in the longitudinal direction should not exceed 20 g's.</p>	<p>Longitudinal occupant impact velocity was 9.5 m/s, and maximum 0.010-s longitudinal occupant ridedown was -11.3 g's.</p>	<p>Pass</p>
<p>M. The exit angle from the test article preferably should be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.</p>	<p>Exit angle at loss of contact with the bridge rail was 11.5 deg, which was less than 60 percent of the impact angle of 24.9 deg.</p>	<p>Pass</p>

## REFERENCES

1. Dwight A. Horne, *Crash Testing of Bridge Railings*, FHWA Memorandum, May 30, 1997.
2. H. E. Ross, Jr., D. L. Sicking, R. A. Zimmer, and J. D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, NCHRP Report 350, Transportation Research Board, Washington, D.C., 1993.
3. *AASHTO LRFD Bridge Design Specifications*, Customary U.S. Units First Edition, American Association of State Highway and Transportation Officials, Washington, D.C., 1994.
4. T. J. Hirsch, C. E. Buth, Wanda Campise, and D. Kakerka, *Aesthetically Pleasing Concrete Beam and Posts Bridge Rail - Texas Type T411*, Research Report 1185-1, Texas Transportation Institute, Texas A&M University, College Station, Texas, March 1989.
5. J. D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*, NCHRP Report 230, Transportation Research Board, Washington, D.C., 1980.
6. *Standard Specifications for Highway Bridges*, Twelfth Edition, American Association of State Highway and Transportation Officials, Washington, D.C., 1977.
7. T. J. Hirsch, *Analytical Evaluation of Texas Bridge Rails to Contain Buses and Trucks*, Research Report 230-2, Texas Transportation Institute, Texas A&M University, February 1986.