NCHRP REPORT 350 TEST 3-11 OF THE TEXAS TYPE T6 BRIDGE RAIL

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Research Project Title: Evaluation and Testing of Bridge Rails and Transitions to NCHRP Report 350 Criteria

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16. Abstract

The Texas Type T6 Bridge Rail was developed under a previous TxDOT study with TTI. The Texas Type T6 was crash tested and evaluated under NCHRP Report 230 guidelines. The two tests performed included one test with a 2041-kg passenger vehicle traveling at 99.0 km/h and 27.5 degrees, and the second was with a 1035-kg passenger vehicle traveling at 93.3 km/h and 14.0 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 T6 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 T6 did not perform satisfactorily. Although the bridge rail contained and redirected the vehicle, some of the anchor bolts pulled out allowing posts to be displaced from the bridge deck. The vehicle rolled onto its left side upon exiting the installation and intruded into adjacent traffic lanes. Exit angle at loss of contact was significantly greater than the 60 percent allowed.

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IMPLEMENTATION RECOMMENDATIONS

No implementable results are contained in this report.

DISCLAIMER

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SUMMARY

The Texas Type T6 Bridge Rail was the second bridge rail selected for full-scale crash testing under this study. This tubular W-beam and steel posts bridge rail was developed under a previous Texas Department of Transportation (TxDOT) study with Texas Transportation Institute (TTI). The Texas Type T6 was crash tested and evaluated under NCHRP Report 230 guidelines. The two tests performed included one test with a 2041-kg passenger vehicle traveling at 99.0 km/h and 27.5 degrees, and the second was with a 1035-kg passenger vehicle traveling at 93.3 km/h and 14.0 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 T6 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 T6 did not perform satisfactorily. Although the bridge rail contained and redirected the vehicle, some of the anchor bolts pulled out allowing posts to be displaced from the bridge deck. The vehicle rolled onto its left side upon exiting the installation and intruded into adjacent traffic lanes. The exit angle at loss of contact was significantly greater than the 60 percent allowed.

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 the *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 pool-funded studies and research projects, FHWA tests some of the most widely used safety appurtenances, including several bridge rails and transitions. However, this testing will not be all-inclusive. Some bridge rails, unique to the Texas Department of Transportation (TxDOT), 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.

Throughout the years, the 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 when 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.

In the first task, 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 of evaluation 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 second bridge rail selected for full-scale crash testing was the Texas Type T6 Bridge Rail. This tubular W-beam and steel post bridge rail was developed under a previous TxDOT study with TTI *(4)*. The Texas Type T6 was crash tested and evaluated under NCHRP Report 230 guidelines *(5)*. The two tests performed included one test with a 2041-kg passenger vehicle traveling at 99.0 km/h and 27.5 degrees, and the second was with a 1035-kg passenger vehicle traveling at 93.3 km/h and 14.0 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 T6 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

Development and testing of the tubular W-beam bridge rail (Texas Type T6) was reported in 1978 *(4)*. This bridge rail performed acceptably in tests with automobiles: a 2041-kg vehicle traveling 99.1 km/h and impacting at 27.5 degrees, and a 1034-kg vehicle traveling 93.3 km/h and impacting at 14 degrees.

Subsequent to this work, the Texas Type T6 Bridge Rail was adopted by TxDOT and has become a popular rail. Since then, NCHRP Report 350 has been adopted for testing and evaluating highway safety appurtenances. On the basis of previous testing, FHWA has designated the Texas Type T6 Bridge Rail as being acceptable for test level 2 of NCHRP Report 350.

A testing program was initiated to determine whether the Texas Type T6 Bridge Rail would perform acceptably at test level 3 of NCHRP Report 350. Results of test 3-11 (a 2000-kg pickup at 100 km/h and 25 degrees) are reported herein.

The Texas Type T6 Bridge Rail consists of a tubular W-beam rail element constructed by welding two standard 12-gage W-beam rail elements together back to back. The rail element is mounted on W 152x13 steel posts spaced at 1.9 m. A breakaway welded connection is provided between the post and the 16-mm thick base plate. The breakaway connection is achieved by welding the tension flange to the base plate with a 10-mm fillet weld and welding the compression flange with two short lengths each 19 mm long.

The Texas Type T6 Bridge Rail was installed on an existing concrete foundation 23 m long. ASTM A36 threaded anchors (22 mm diameter by 152 mm long) with two-component adhesive were used to anchor the posts to the concrete foundation. The bridge rail was terminated at each end with no approach or runout guardrail or other end treatment. Details of the bridge rail are shown in figure 1 and the completed installation is shown in figure 2.

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.

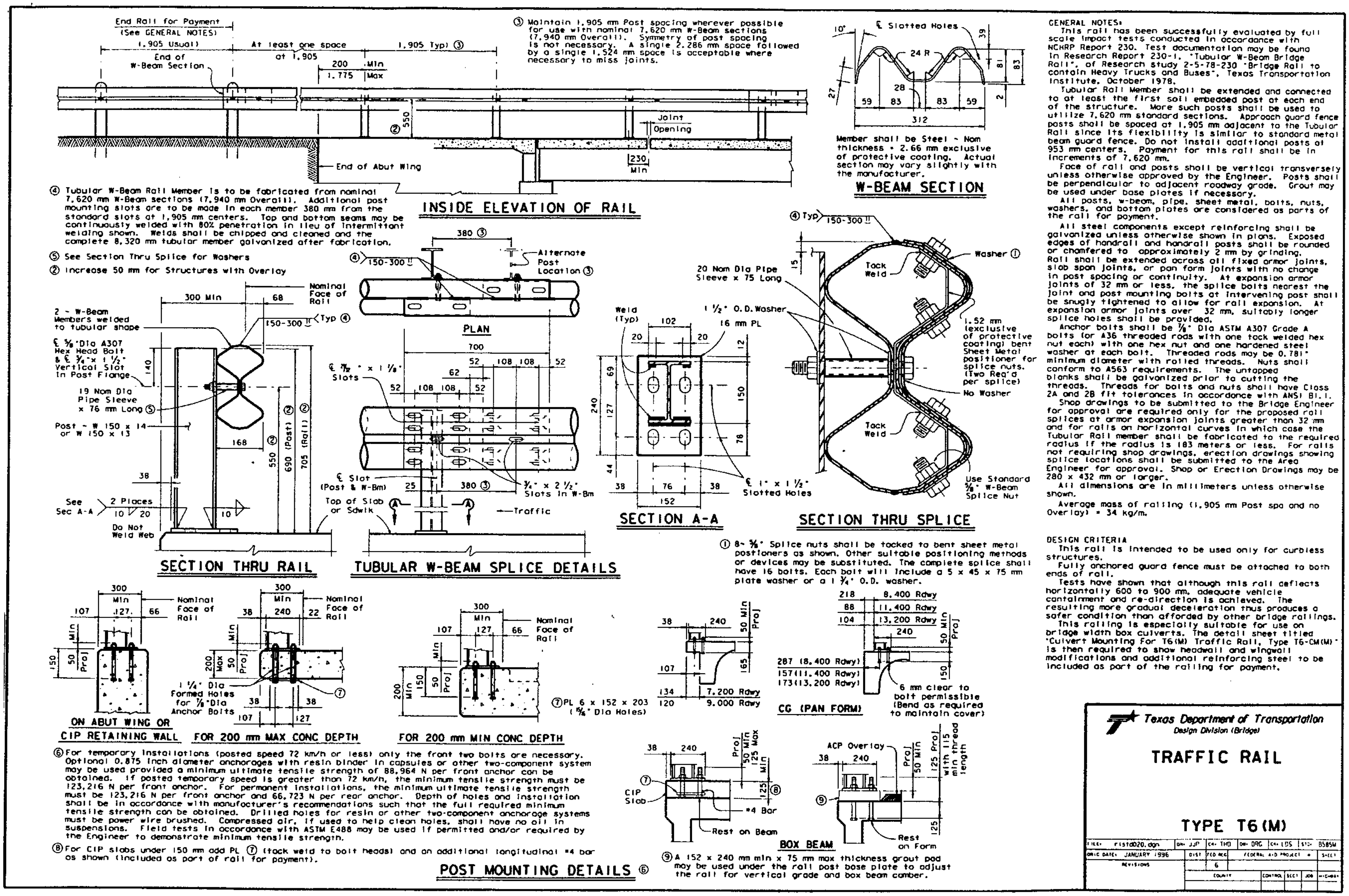


Figure 1. Details of the Texas Type T6 Bridge Rail Installation

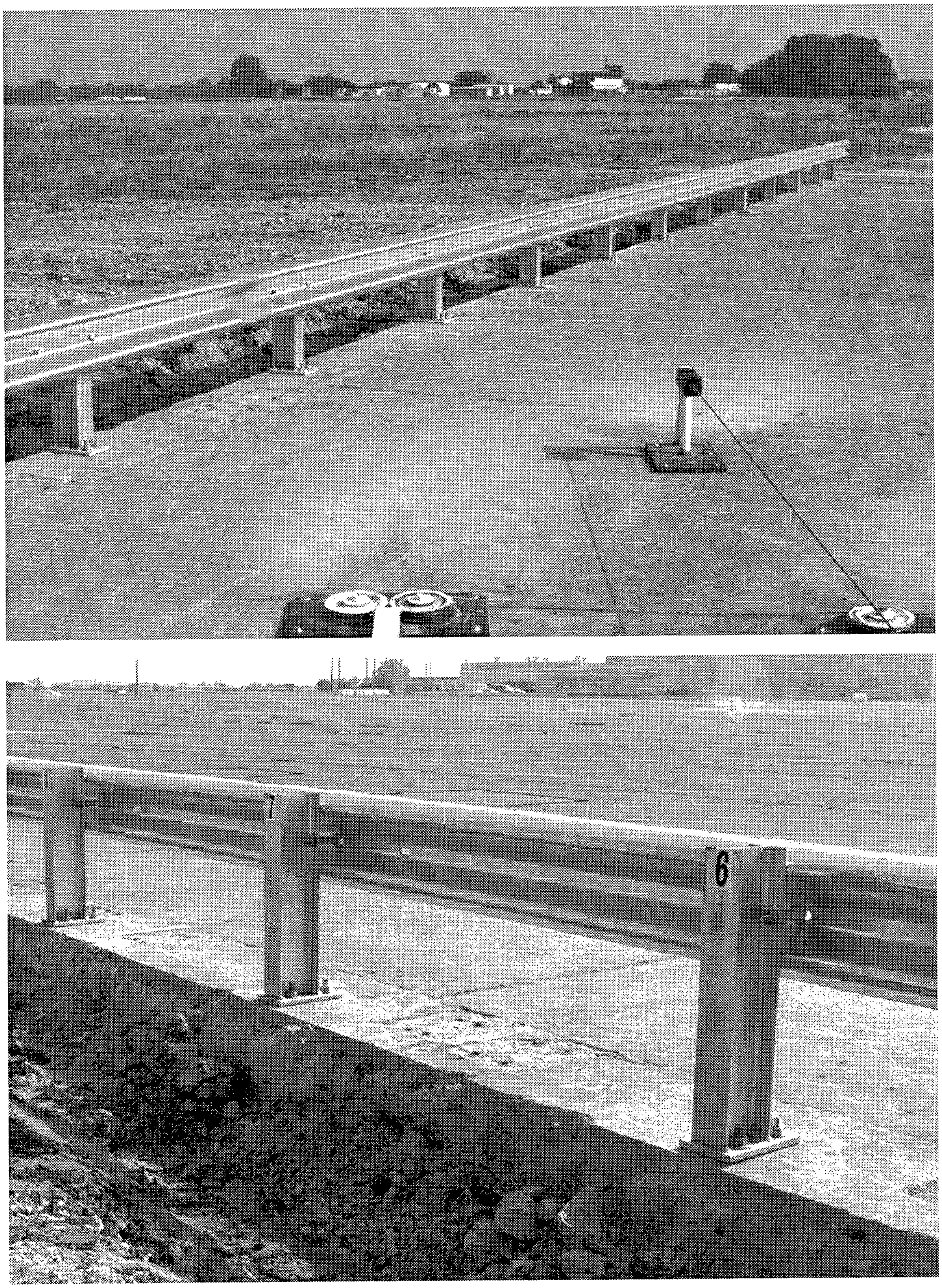


Figure 2. Texas Type T6 Bridge Rail Installation before Test 418048-2

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.

Test 418048-2 corresponds to NCHRP Report 350 test designation 3-11 and is reported herein.

EVALUATION CRITERIA

The crash test performed was evaluated in accordance with 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 to 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 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 (IRIG) tape recorders. For analysis and evaluation of impact performance, the data were played back from the tape machines, filtered with an SAE J211 filter, and digitized using a microcomputer,

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/compartment impact velocities, time of occupant/compartment 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 were then filtered with a 60-Hz digital filter and acceleration versus time curves for the longitudinal, lateral, and vertical directions were plotted using a commercially available software package (Excel 7).

The PLOTANGLE program used 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, and 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 for observation 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

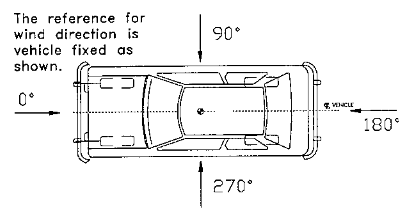
The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable 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 so that the tow vehicle could move away from the test site. A two to one 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, i.e., no steering or braking inputs, and unrestrained. The vehicle remained free-wheeling until the vehicle cleared the immediate area of the test site, at which time the brakes on the vehicle were activated to bring it to a safe and controlled stop.

III. CRASH TEST RESULTS

TEST 418048-2 (NCHRP Report 350 test no. 3-11)

A 1993 Chevrolet 2500 pickup, shown in figures 3 and 4, 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 400 mm and it was 620 mm to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in figure 5. 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 May 7, 1998. No rainfall had occurred for the 10 days prior to the test. Weather conditions at the time of testing were as follows: wind speed: 15 km/h; wind direction: 200 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 27°C; relative humidity: 69 percent.



Test Description

The vehicle, traveling at 99.9 km/h, impacted the Texas Type T6 bridge rail 1170 mm downstream from post 6 at a 26.6 degree angle. At 0.030 s, the left front bumper deformed as it contacted the rail, and post 7 moved. The vehicle redirected at 0.039 s as the it was traveling 73.5 km/h. At 0.043 s, the left front tire contacted post 7 as the post was deforming toward the field. The tire snagged on post 7 and deflated as it was under the rail at 0.078 s. At 0.088 s, post 8 separated from the bridge deck, was thrown to the field side of the rail at 0.125 s, and then bounced back under the rail element. Post 9 separated from the bridge deck at 0.145 s. The vehicle's right front tire lost contact with the ground at 0.170 s. Post 9 was thrown to the field side of the rail at 0.200 s and then bounced back into the traffic lanes. Shortly afterward, the left rear tire contacted the rail near post 9. At 0.256 s the vehicle was parallel with the rail and was traveling at 73.5 km/h. The right rear tire left the ground at 0.263 s, vehicle's nose pitched down and the vehicle rolled counterclockwise. The right front of the vehicle became airborne at 0.375 s. At 0.559 s the vehicle was traveling 61.6 km/h and lost contact with the rail at a 27.8 degree exit angle. Brakes on the vehicle were not applied. The vehicle subsequently came to rest on its left side at 0.725 s and slid to a stop, resting 41.2 m down from impact and 11.4 m in front of the installation. Sequential photographs of the test period are shown in figures 6 and 7.

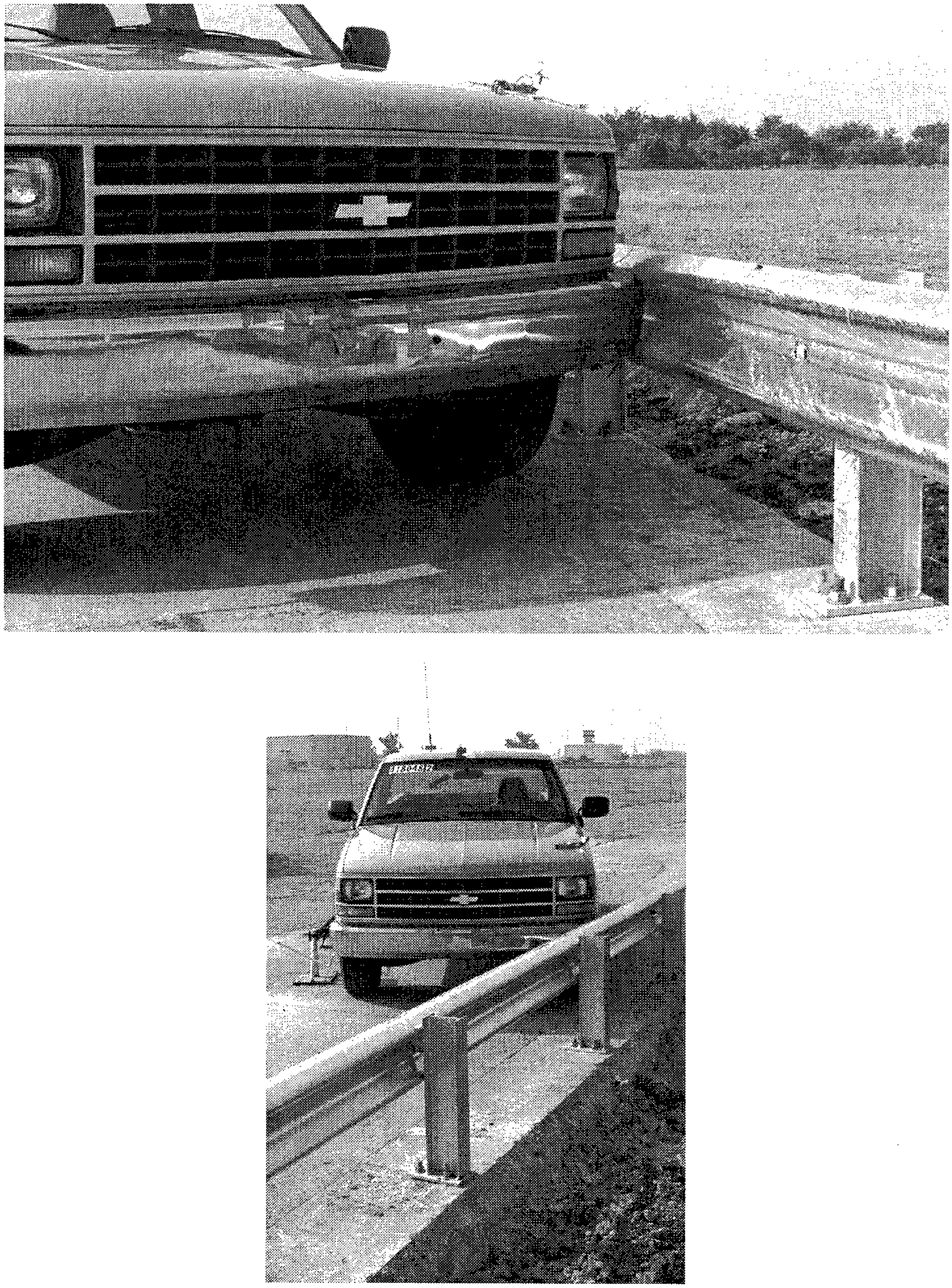


Figure 3. Vehicle/Installation Geometrics for Test 418048-2

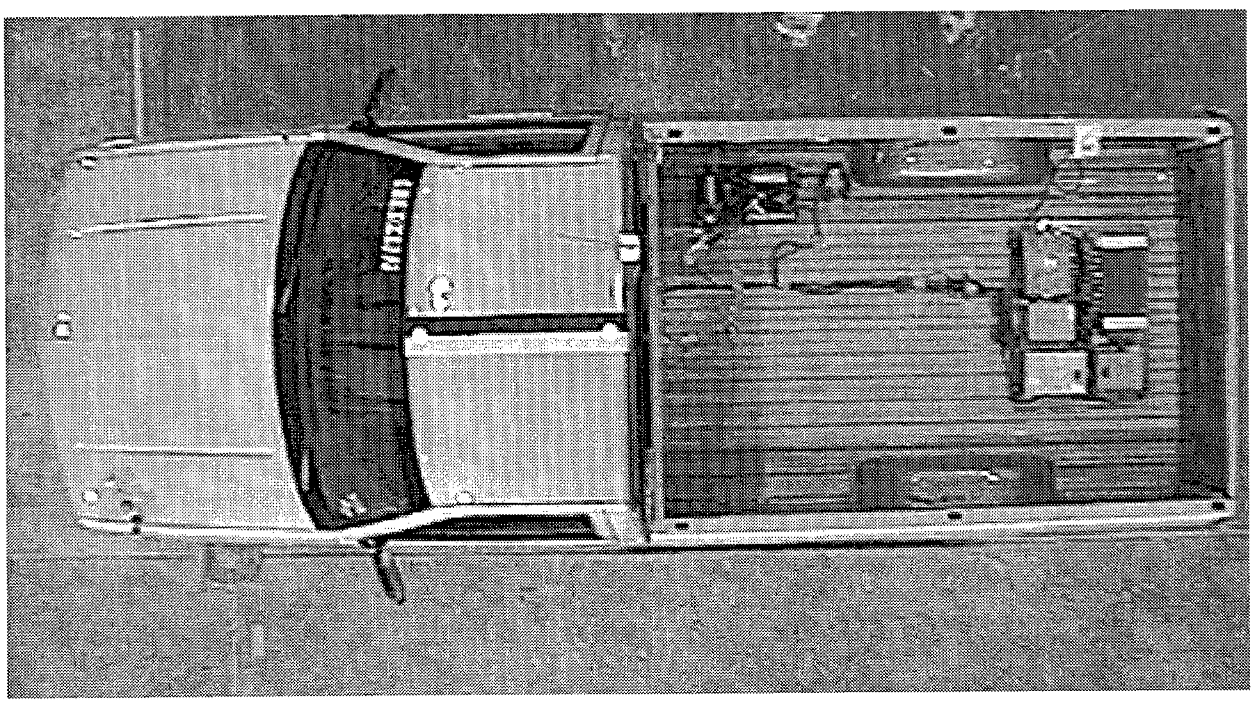


Figure 4. Vehicle before Test 418048-2

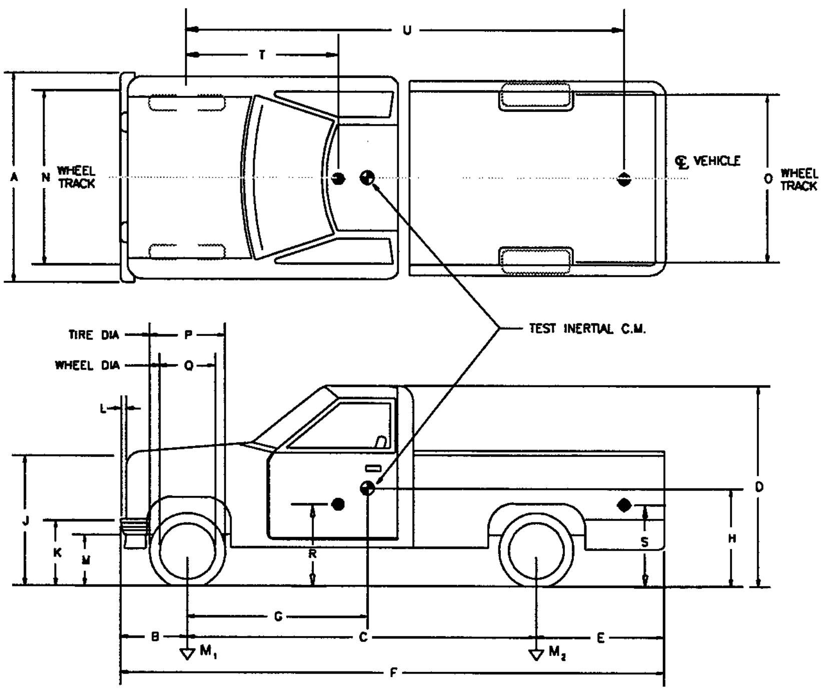
DATE: 5/7/98 TEST NO.: 418048-2 VIN NO.: 1GCFC24K6PZ209046

YEAR: 1993 MAKE: Chevrolet MODEL: 2500 pickup truck

TIRE INFLATION PRESSURE: ______ ODOMETER: 113757 TIRE SIZE: 24575R16

MASS DISTRIBUTION (kg) LF 559 RF 533 LR 456 RR 452

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



● Denotes accelerometer location.

NOTES: R-90mm TO LT

ENGINE TYPE: 8 CYL

ENGINE CID: 5.7 L

TRANSMISSION TYPE:

X AUTO

_ MANUAL

OPTIONAL EQUIPMENT:

6 LUGS

DUMMY DATA:

TYPE:

MASS:

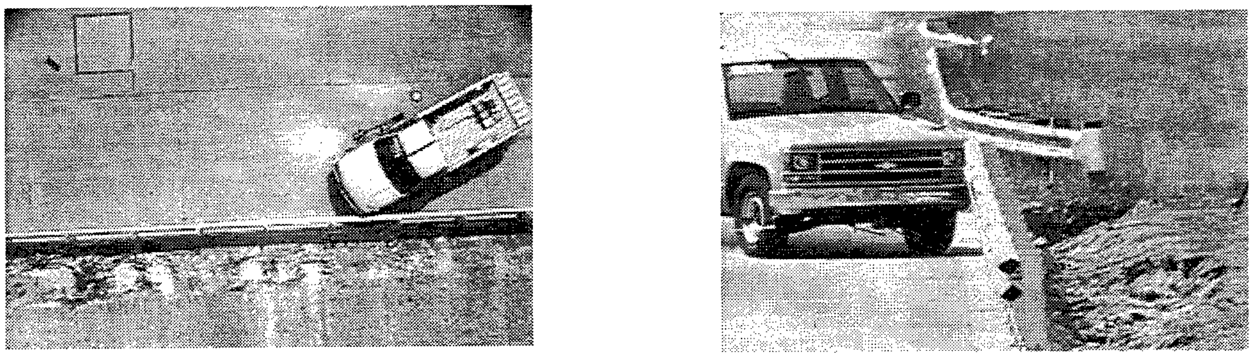
SEAT POSITION:

GEOMETRY – (mm)

A 1860	E 1300	J 1030	N 1585	R 710
B 760	F 5410	K 620	O 1615	S 900
C 3350	G 1520.9	L 60	P 760	T 1490
D 1780	H	M 400	Q 440	U 3990

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	1108	1092	
M_2	769	912	
M_T	1877	2000	

Figure 5. Vehicle Properties for Test 418048-2



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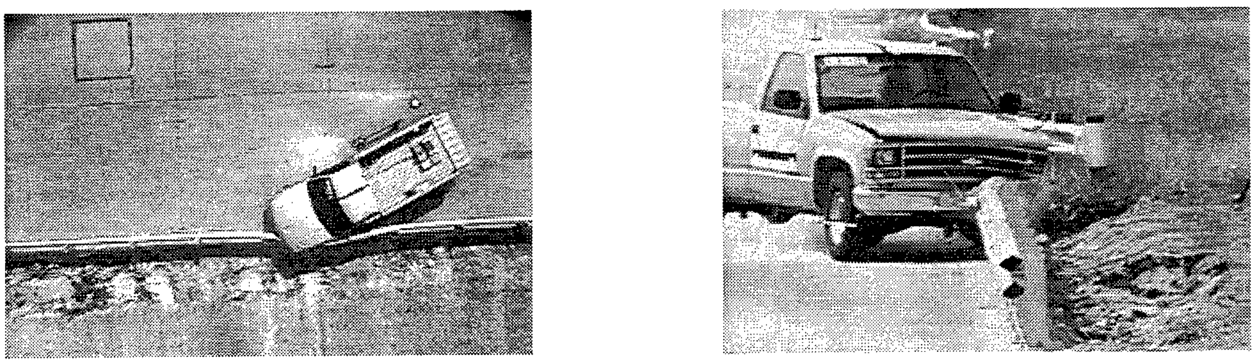

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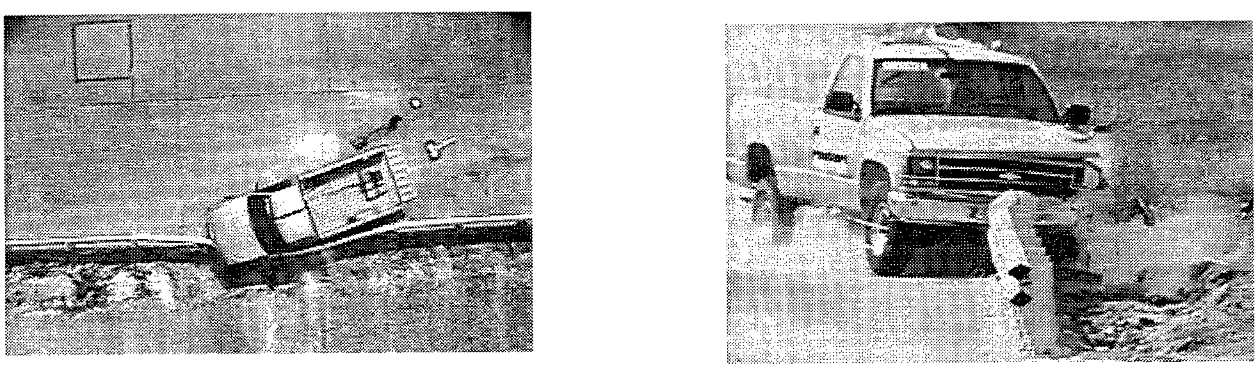

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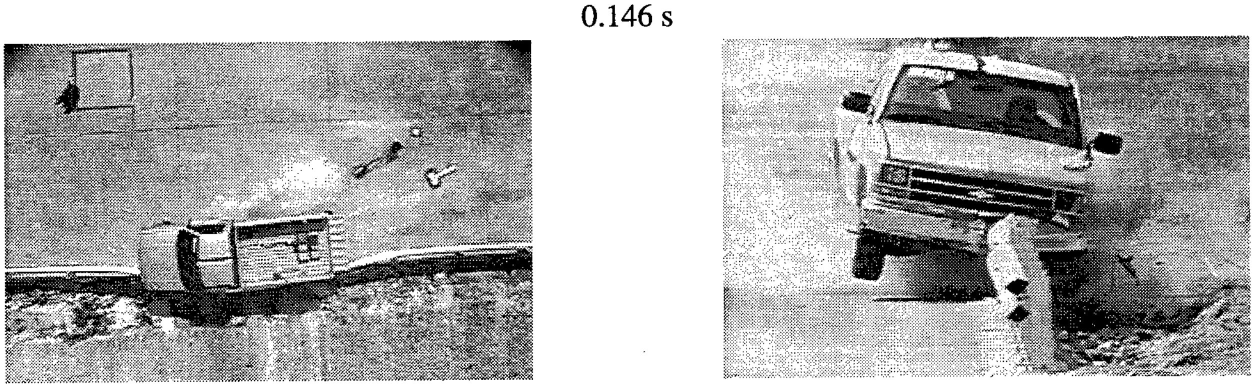

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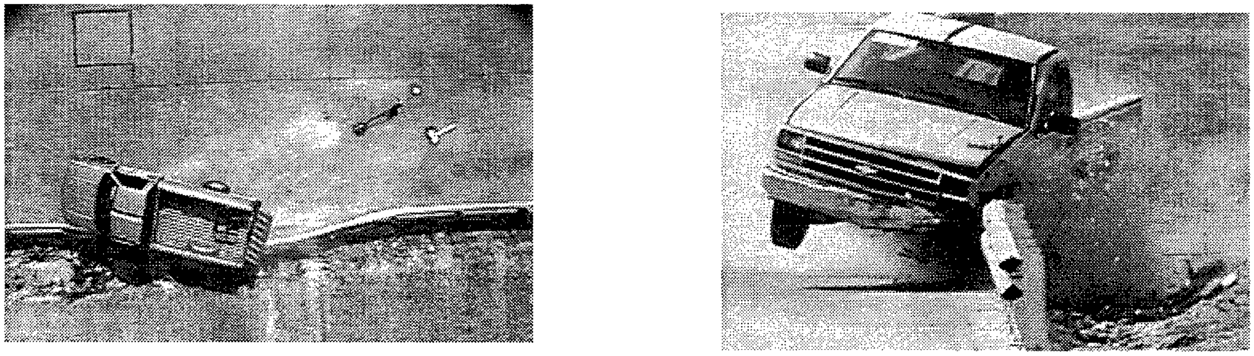
Figure 6. Sequential Photographs for Test 418048-2 (Overhead and Frontal Views)



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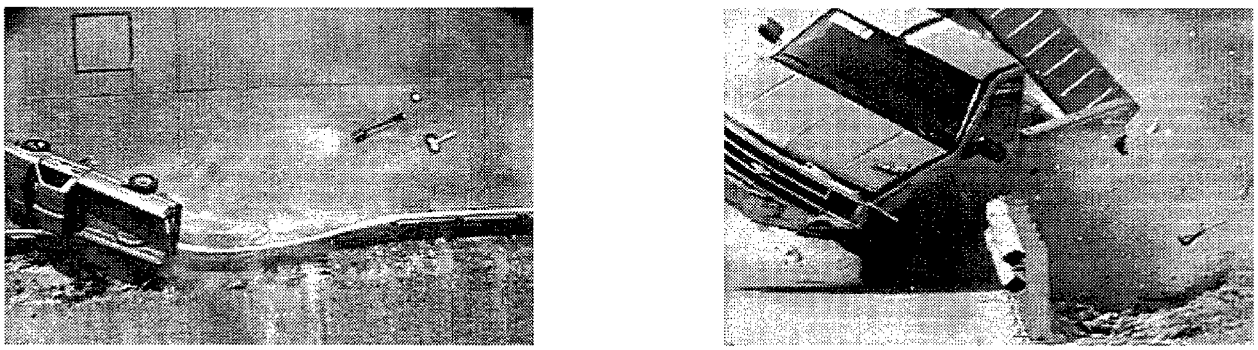

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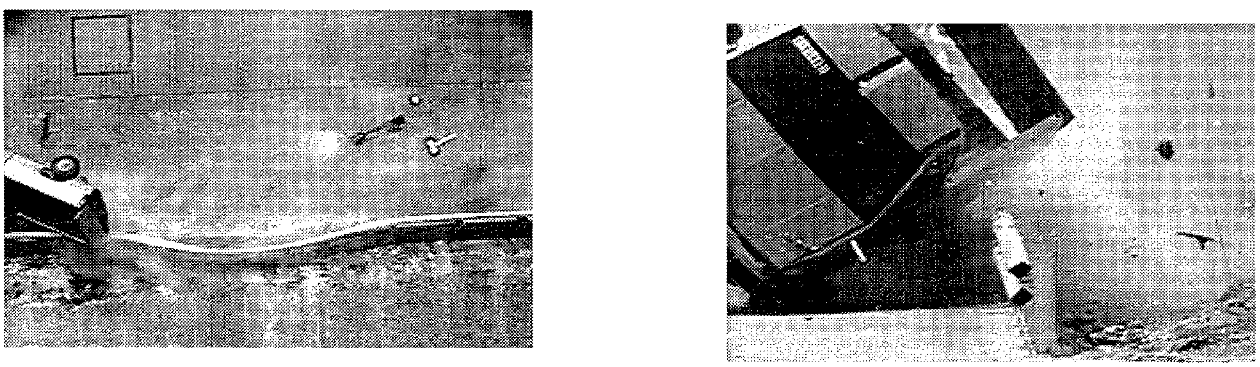

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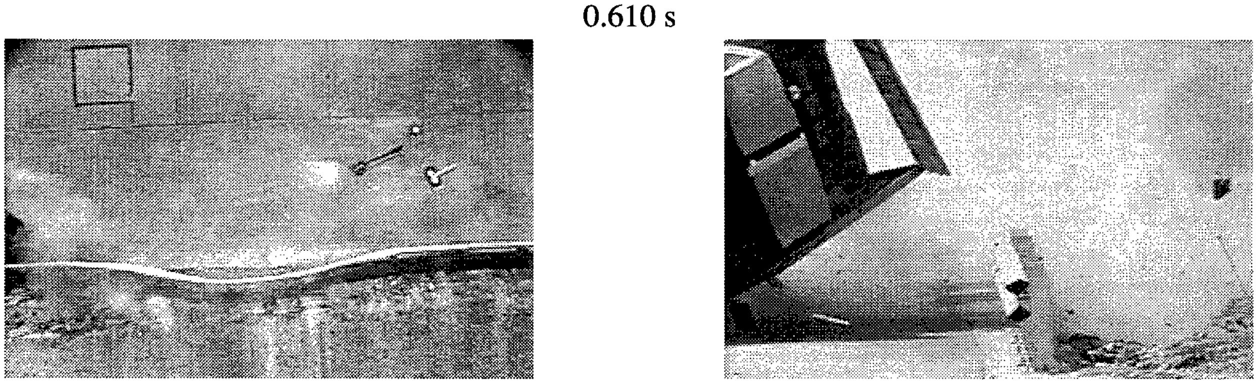

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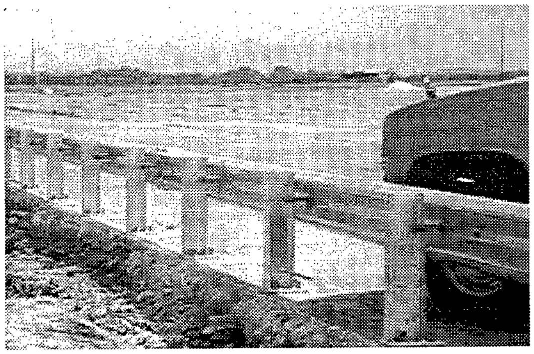
Figure 6. Sequential Photographs for Test 418048-2
(Overhead and Frontal Views) (continued)



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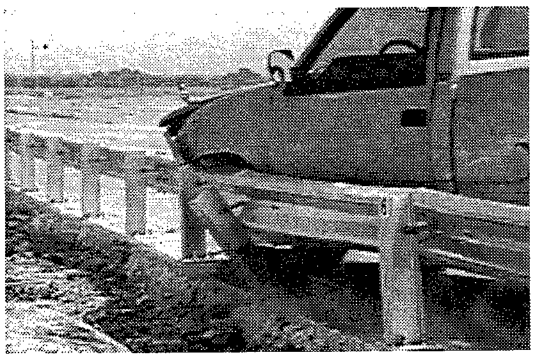

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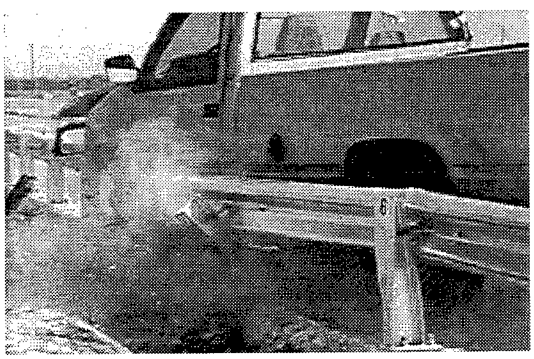

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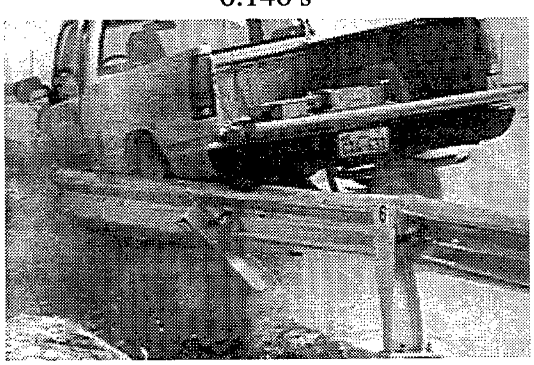

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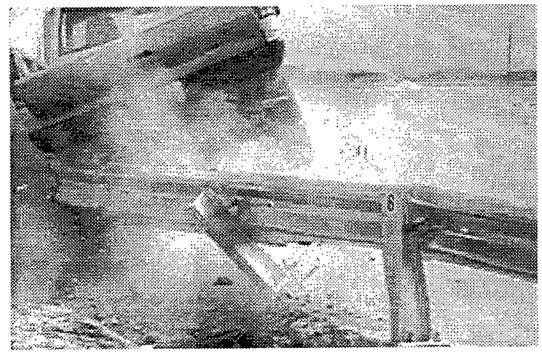

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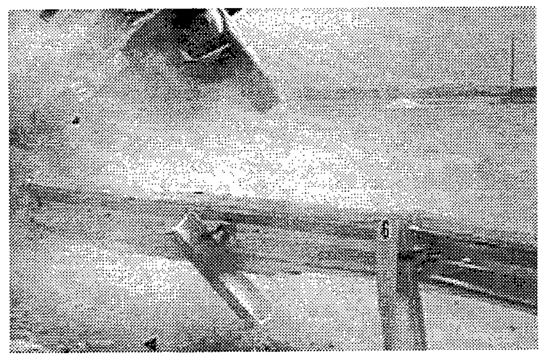

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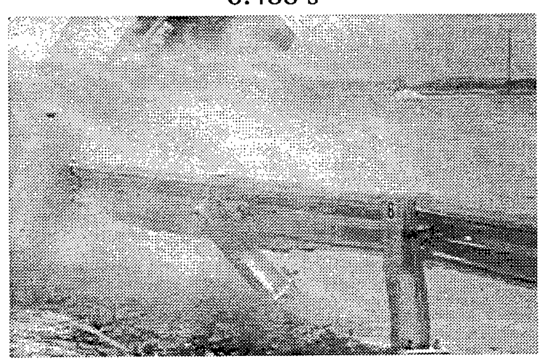

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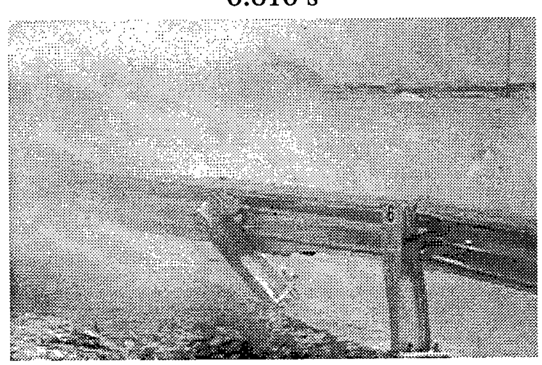


0.781 s

Figure 7. Sequential Photographs for Test 418048-2 (Rear View)

Damage to Test Installation

Damage to the Texas Type T6 Bridge Rail can be seen in figures 8 and 9. Posts 8 and 9 were pulled from the bridge deck. Post 8 was laying in front of the rail at post 15 and post 9 was laying 26 m down from its original position and 31 m toward traffic. Posts 7 and 10 were pulled up but were still partially attached to the bridge deck. Posts 1 through 6, 10, 11, 13, 15, and 17 were rotated. The tubular W-beam was flattened slightly around post 10. Maximum dynamic deflection of the rail element during the test was 0.82 m and maximum permanent deflection after the test was 0.43 m.

Vehicle Damage

The vehicle after impact with the bridge rail is shown in figures 11 and 12. Structural damage to the vehicle included deformation of the left front of the frame, stabilizer bar, upper and lower left arms, rods, and Pittman arm. The bumper, hood, grill, radiator, left front and rear quarter panels, left door and window, and the left front tire and wheel also received damage. Maximum crush to the vehicle was 570 mm at the top of the front bumper on the left side. Maximum occupant compartment deformation was 20 mm (6.5 percent reduction in space) in the floor pan area. These measurements were taken at points of reference taken prior to the test. The interior of the vehicle is shown in figure 13. Exterior crush and occupant compartment measurements are shown in tables 1 and 2.

Occupant Risk Values

Data from the tri-axial accelerometer, located at the vehicle center of gravity, were digitized to compute occupant impact velocity and ridedown accelerations. The occupant impact velocity and ridedown accelerations in the longitudinal axis only are required from these data for evaluation of criterion L of NCHRP Report 350. In the longitudinal direction, the occupant impact velocity was 7.7 m/s at 0.173 s, the highest 0.010-s occupant ridedown acceleration was -11.0 g's from 0.151 to 0.161 s, and the maximum 0.050-s average acceleration -7.3 g's between 0.051 and 0.101 s. In the lateral direction, the occupant impact velocity was 5.4 m/s at 0.134 s, the highest 0.010-s occupant ridedown acceleration was 9.7 g's from 0.159 to 0.169 s, and the maximum 0.050-s average was 5.8 g's between 0.072 and 0.122 s. These data and other pertinent information from the test are summarized in figure 14. Vehicle angular displacements are displayed in figure 15. Vehicular accelerations versus time traces are presented in figures 16 through 18.

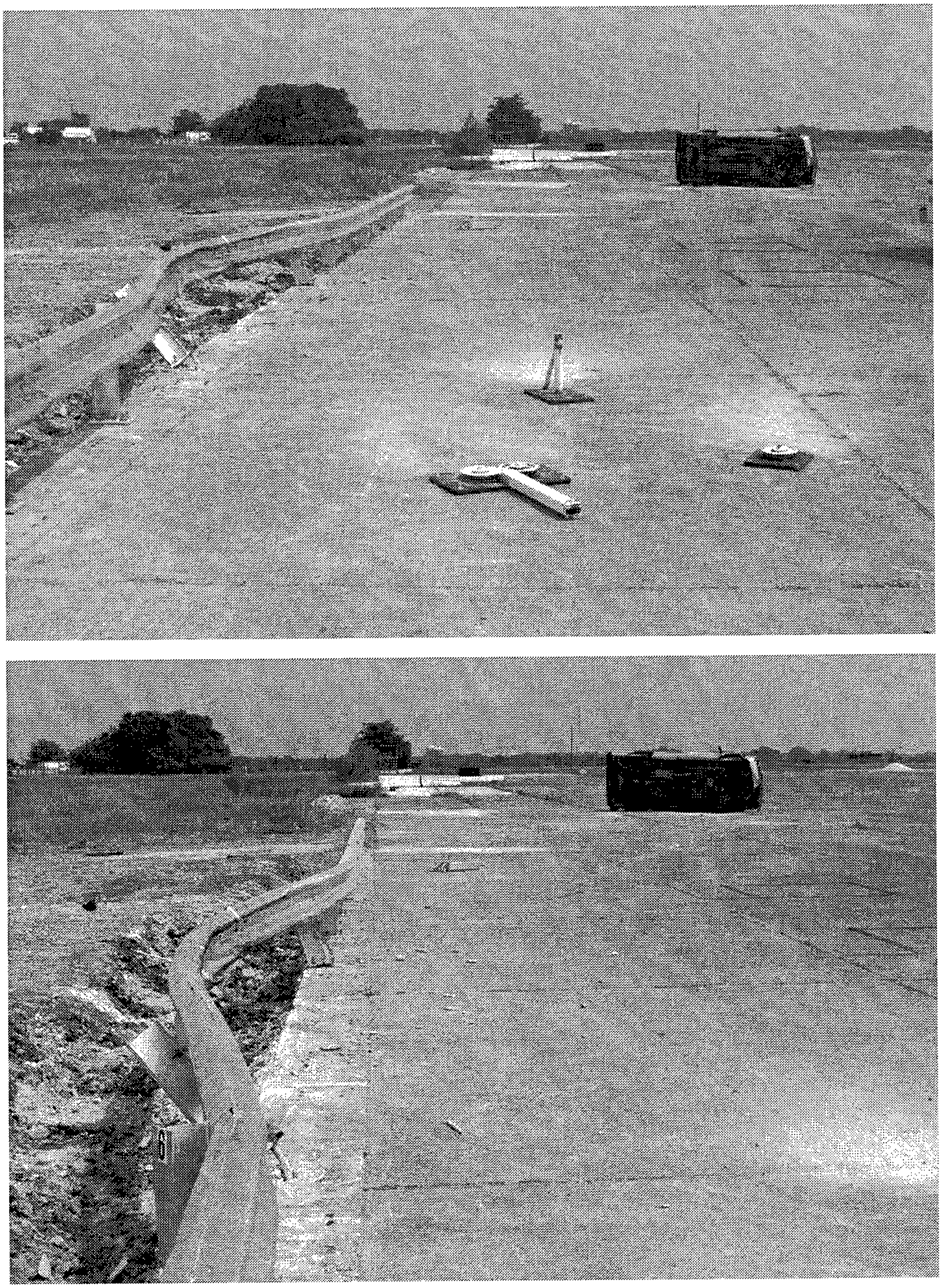


Figure 8. After Impact Trajectory for Test 418048-2

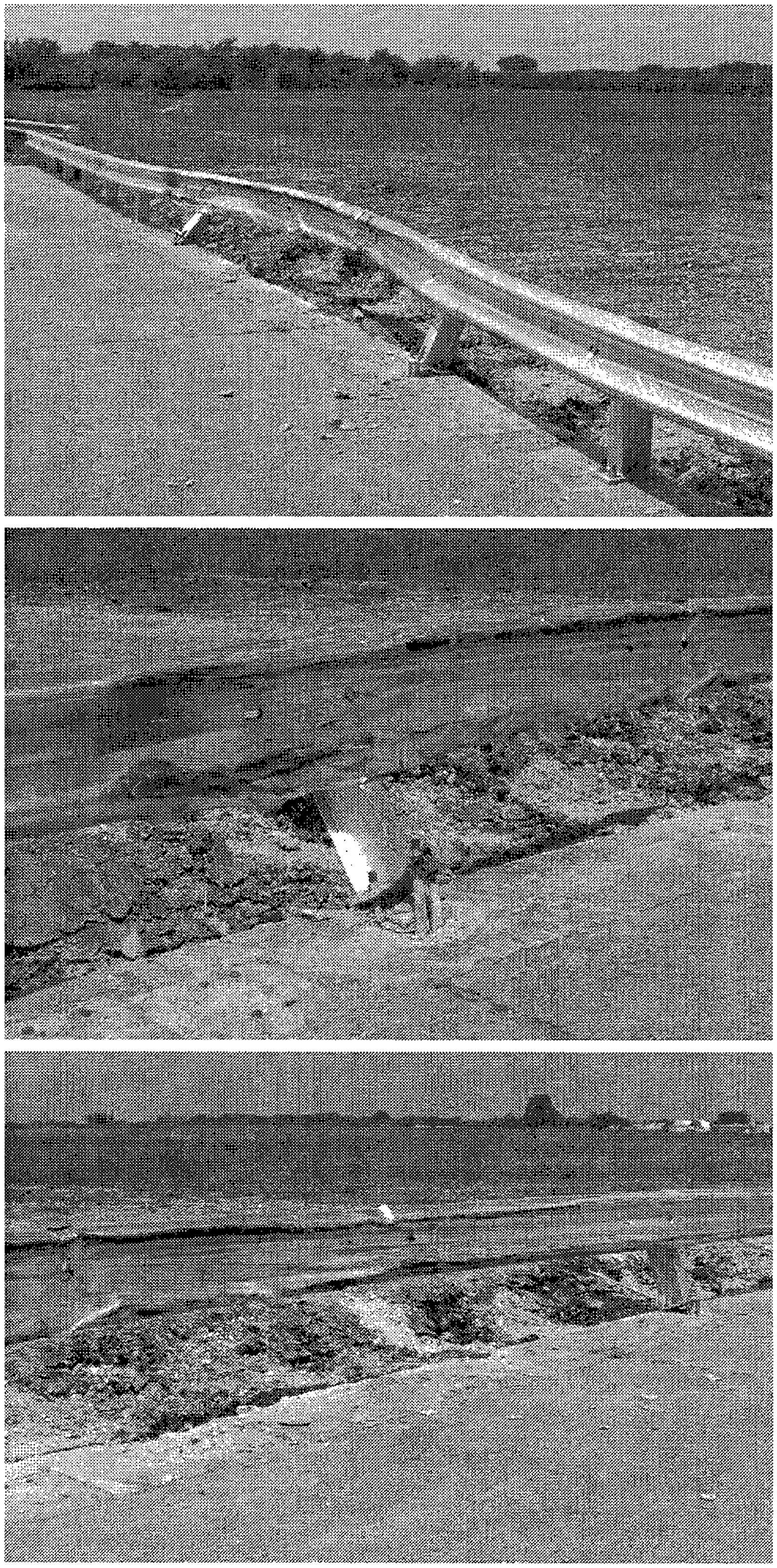
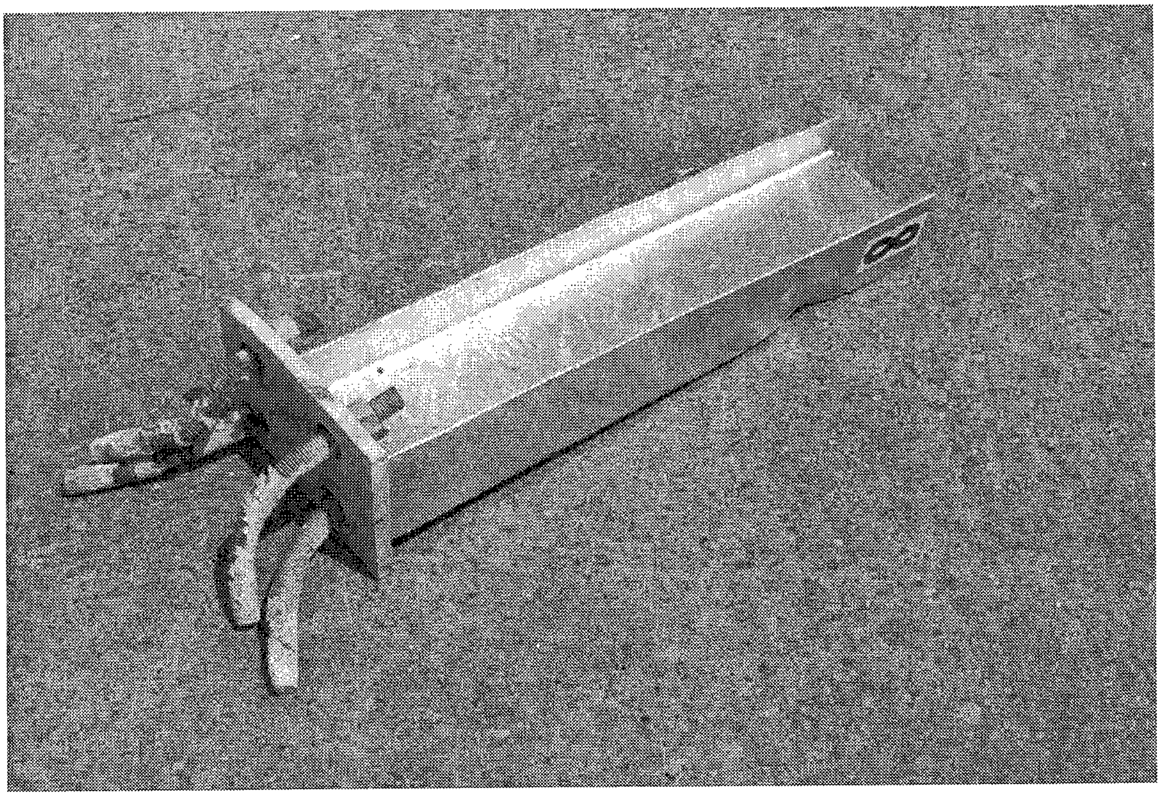
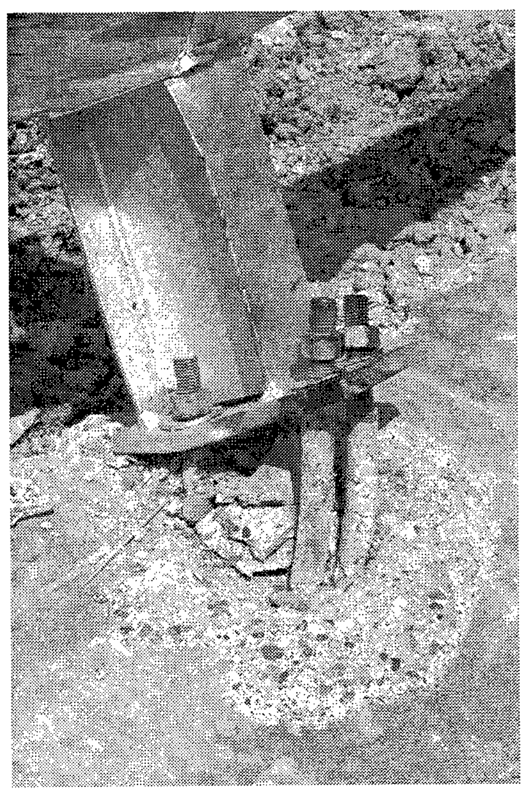


Figure 9. Installation after Test 418048-2

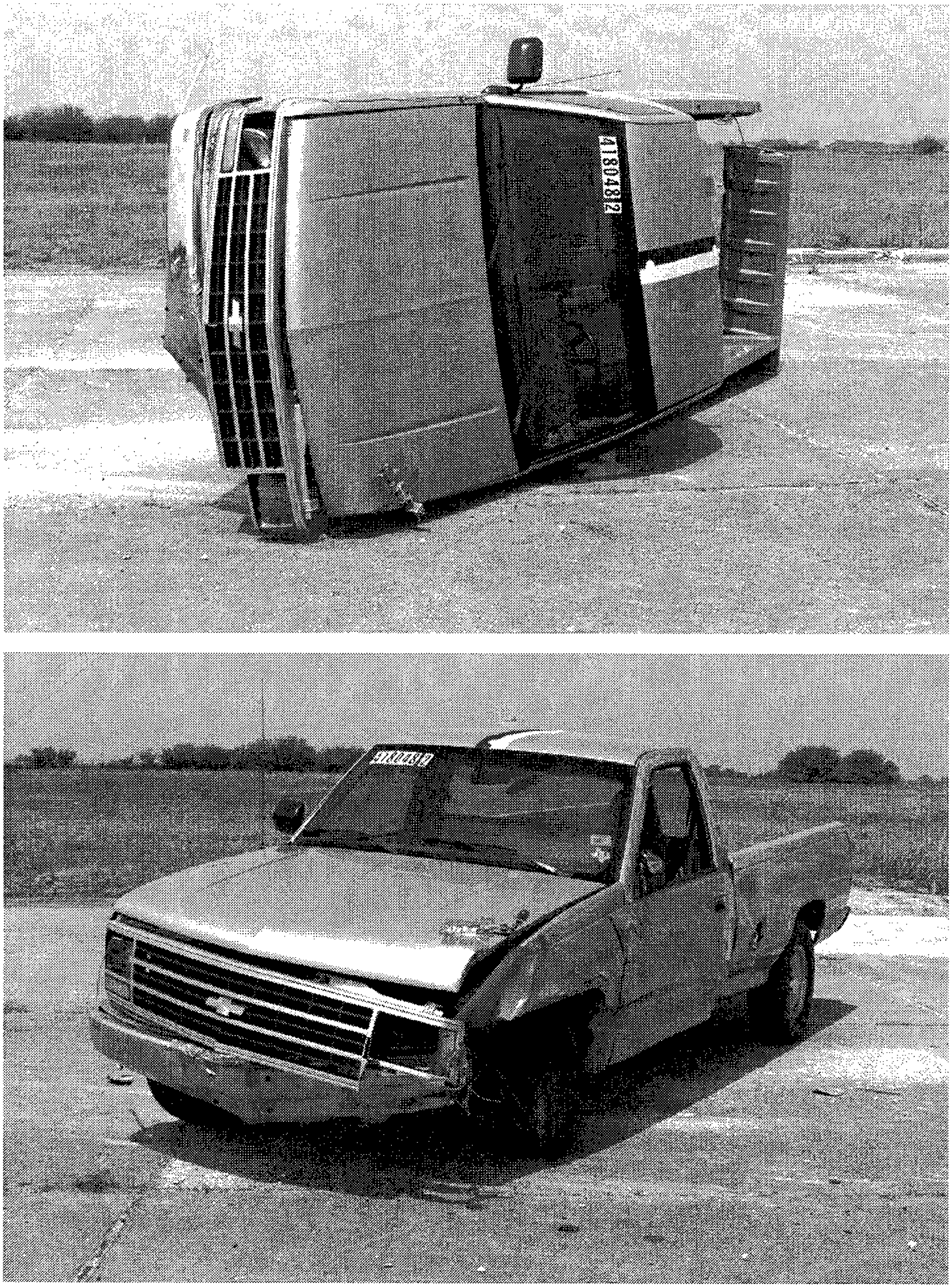


Post 8



Post 10

Figure 10. Damage at Posts 8 and 10 after Test 418048-2



After being uprighted

Figure 11. Vehicle after Test 418048-2

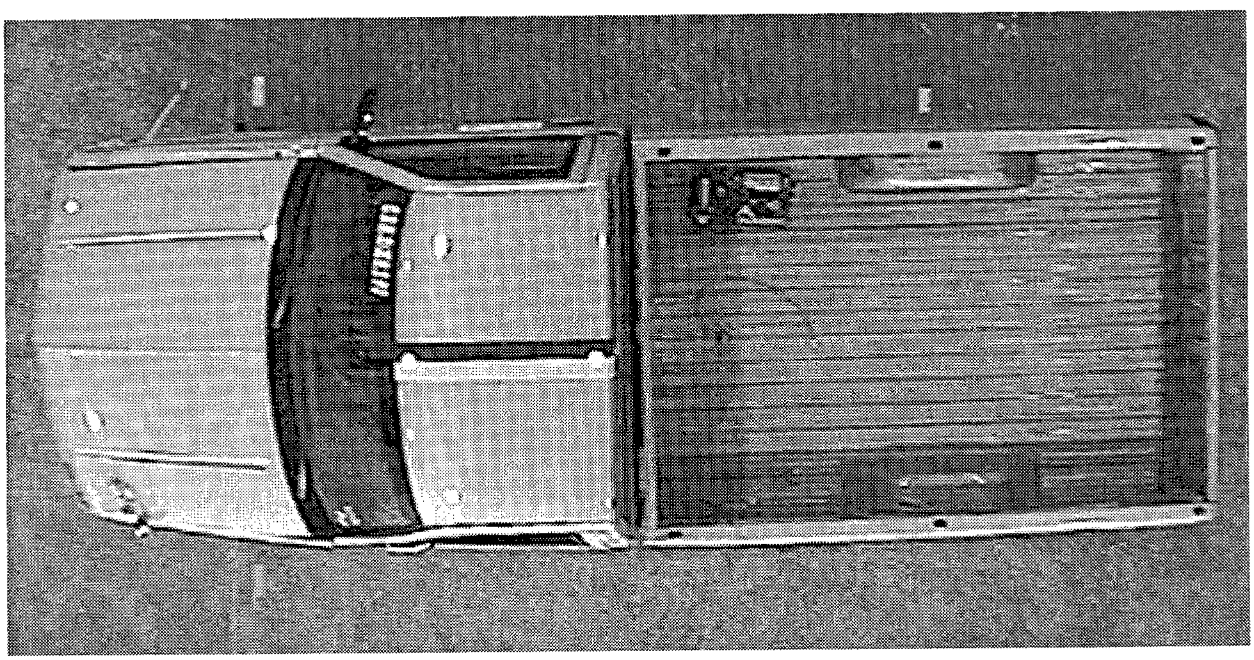
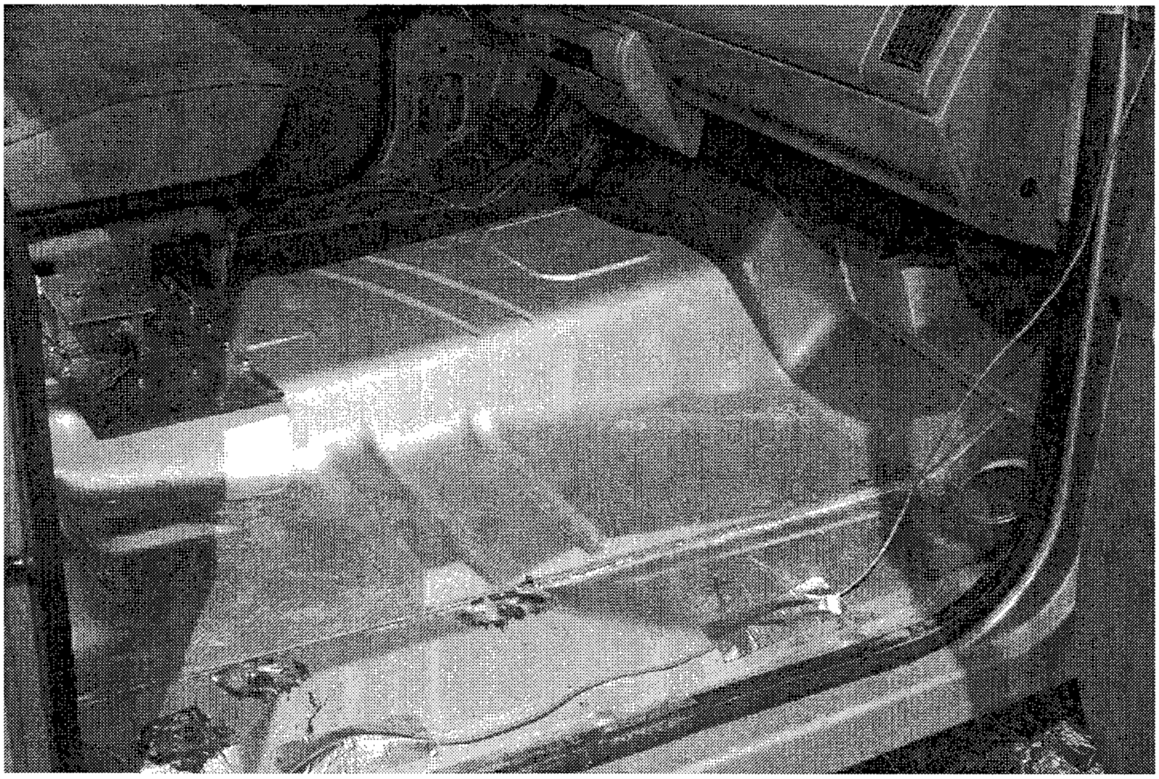


Figure 12. Vehicle Damage after Test 418048-2



Before test ↗ After test ↘

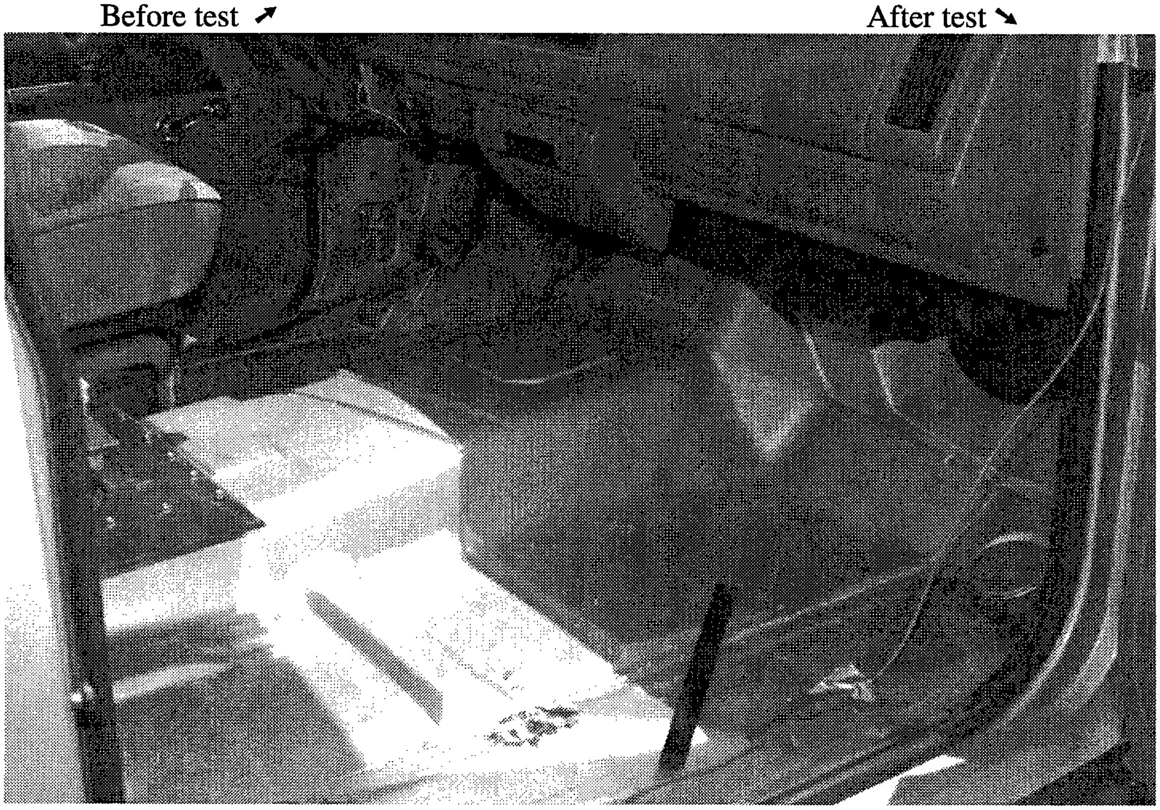


Figure 13. Interior of Vehicle for Test 418048-2

Table 1. Exterior Crush Measurements for Test 418048-2

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 ____ X1 ____
Corner shift: A1 _	B2 ____ X2 ____
A2 _______	
End shift at frame (CDC) (check one) < 4 inches ________ ≥ 4 inches ________	Bowing constant $\frac{X1 + X2}{2} =$ _____

Note: Measure C1 to C6 from Driver to Passenger side in Front or Rear impacts–
Rear to Front in Side impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width ** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Top front bumper	900	570	700	570	430	300	150	60	0	-350
2	610 mm above ground	900	400	3200	90	70	30	100	N/A	400	+400

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

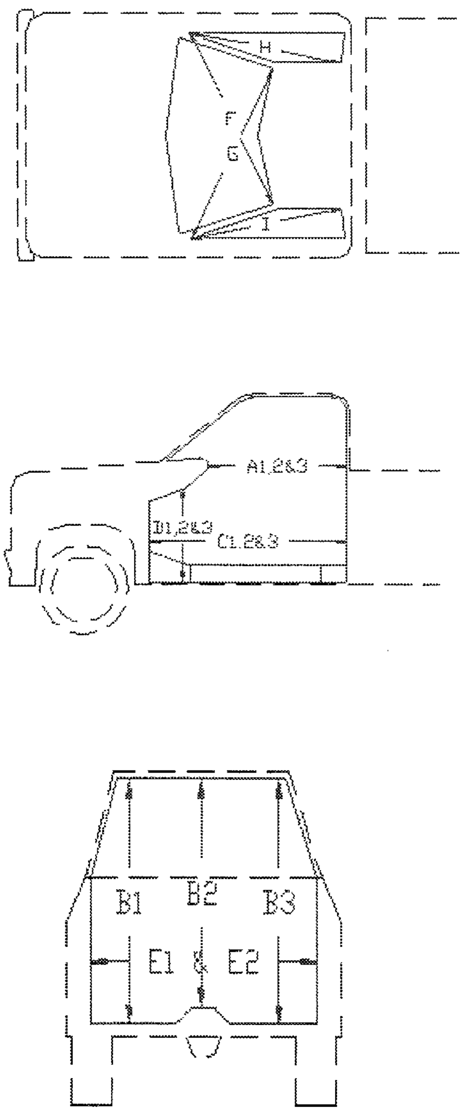
***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

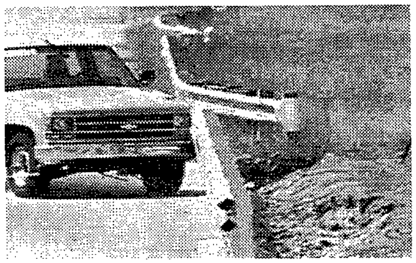
Table 2. Occupant Compartment Measurements for Test 418048-2

Truck

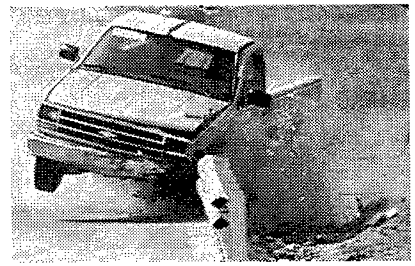
Occupant Compartment Deformation

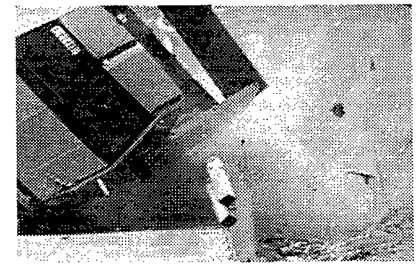


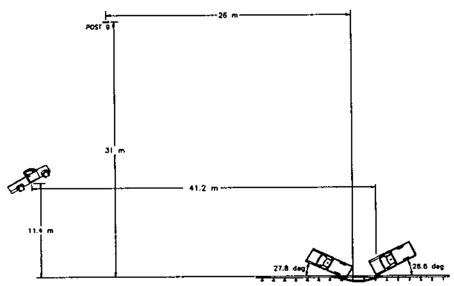
	BEFORE	AFTER
A1	1037	1037
A2	1084	1084
A3	1041	1041
B1	1078	1060
B2	1041	1030
B3	1080	1080
C1	1373	1355
C2	1233	1233
C3	1375	1375
D1	310	290
D2	97	90
D3	312	312
E1	1592	1582
E2	1595	1580
F	1475	1475
G	1475	1475
H	900	900
I	900	900

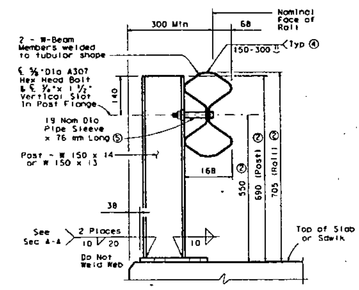

0.000 s


0.146 s


0.366 s


0.610 s





General Information	
Test Agency	Texas Transportation Institute
Test No.	418048-2
Date	05/07/98
Test Article	
Type	Bridge Railing
Name	Texas Type T6
Installation Length (m)	23
Material or Key Elements	Tubular W-Beam on W6x9 Steel Posts
Soil Type and Condition	Existing Deck, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1993 Chevrolet 2500 pickup
Mass (kg)	
Curb	1877
Test Inertial	2000
Dummy	No dummy
Gross Static	2000

Impact Conditions	
Speed (km/h)	99.9
Angle (deg)	26.6
Exit Conditions	
Speed (km/h)	61.6
Angle (deg)	27.8
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	7.7
y-direction	5.4
THIV (km/h)	26.8
Ridedown Accelerations (g's)	
x-direction	-11.0
y-direction	9.7
PHD (g's)	12.1
ASI	0.9
Max. 0.050-s Average (g's)	
x-direction	-7.3
y-direction	5.8
z-direction	3.9

Test Article Deflections (m)	
Dynamic	0.82
Permanent	0.43
Vehicle Damage	
Exterior	
VDS	11LFQ4
CDC	11FLEK3 &11LYEW3
Maximum Exterior Vehicle Crush (mm)	570
Interior	
OCDI	LS0001000
Max. Occ. Compart. Deformation (mm)	20
Post-Impact Behavior	
(during 1.0 s after impact)	
Max. Yaw Angle (deg)	52
Max. Pitch Angle (deg)	-9
Max. Roll Angle (deg)	-92

Figure 14. Summary of Results for Test 418048-2, NCHRP Report 350 Test 3-11

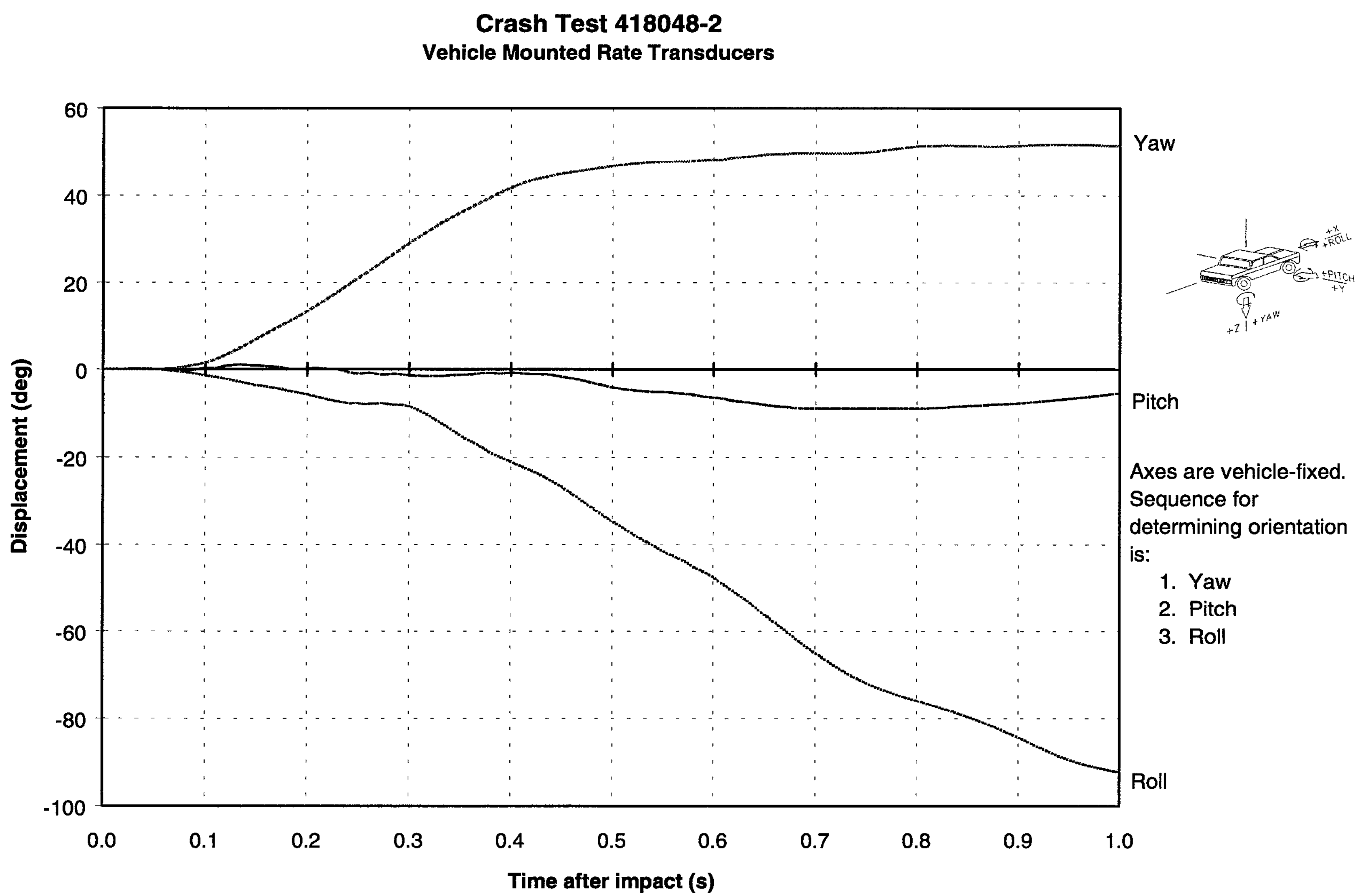


Figure 15. Vehicle Angular Displacements for Test 418048-2

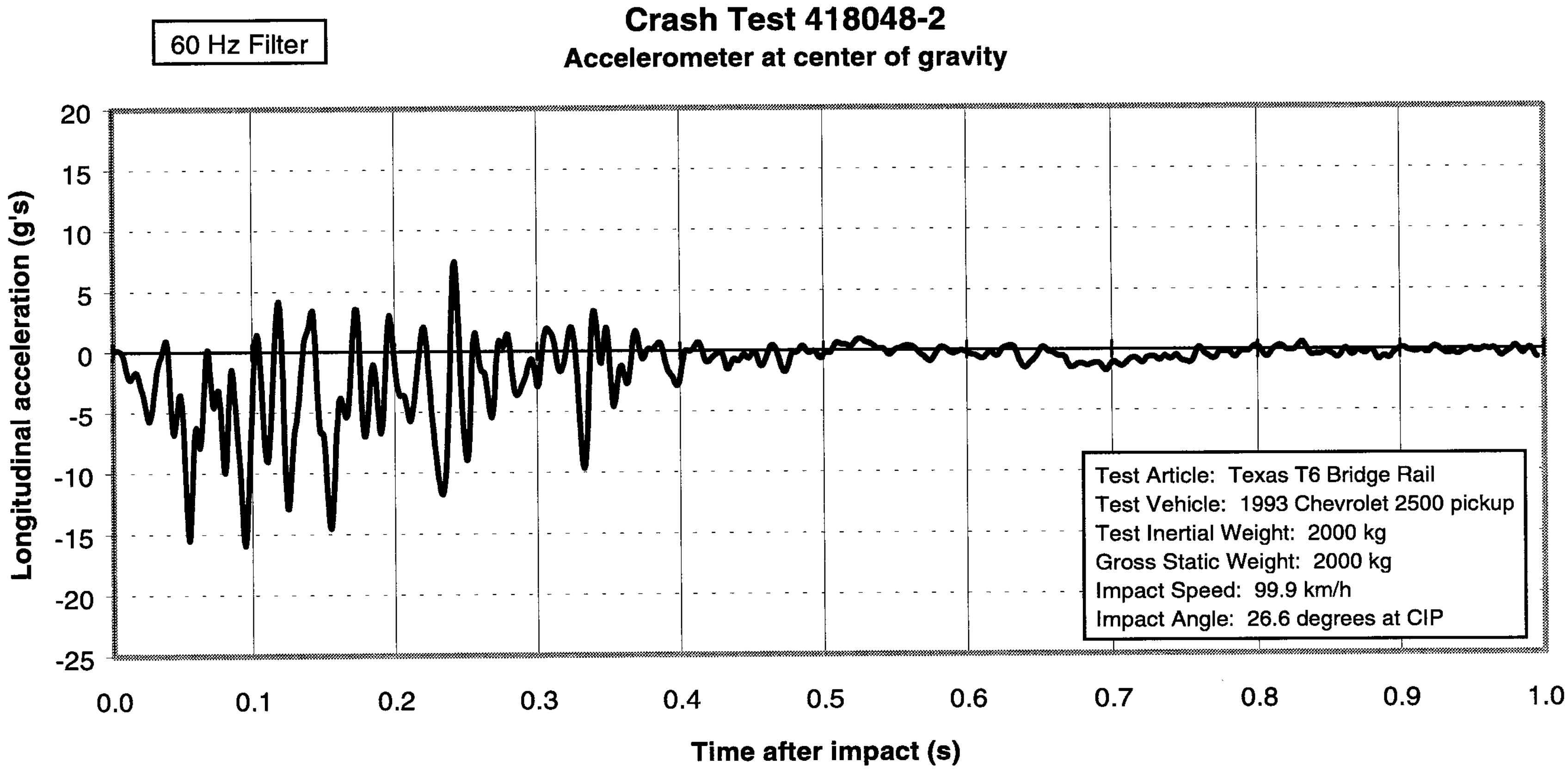


Figure 16. Vehicle Longitudinal Accelerometer Trace for Test 418048-2

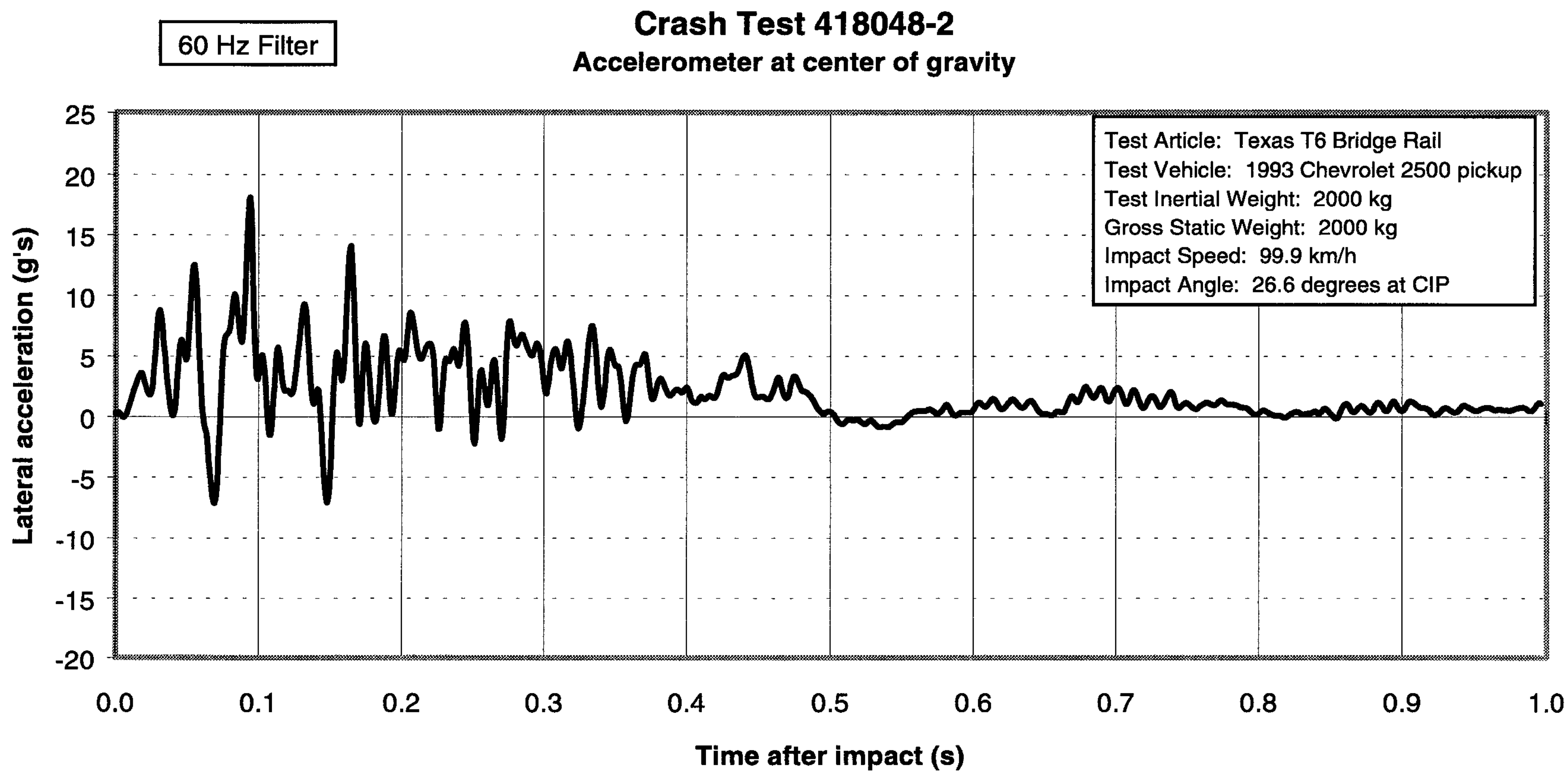


Figure 17. Vehicle Lateral Accelerometer Traces for Test 418048-2

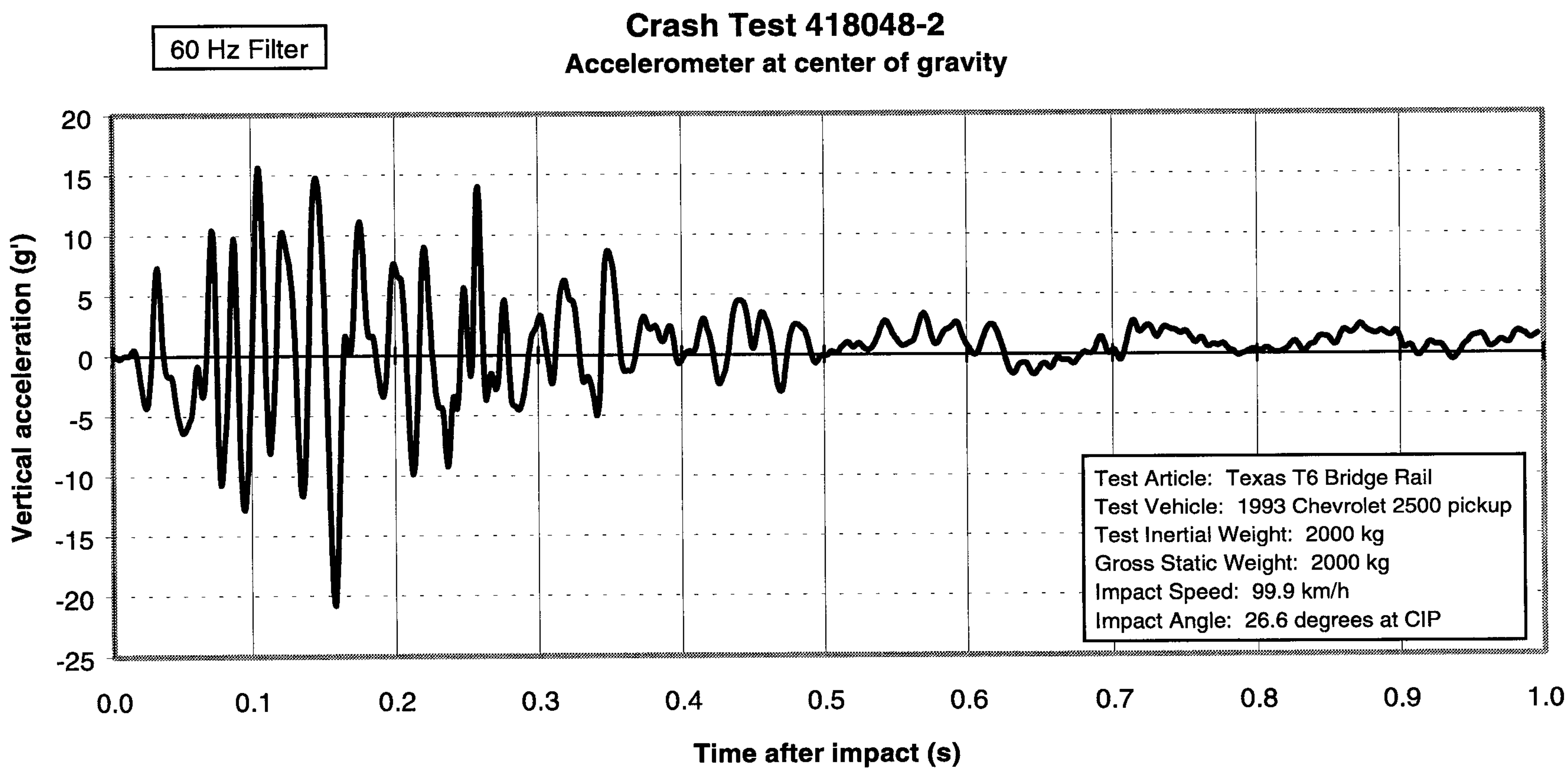


Figure 18. Vehicle Vertical Accelerometer Trace for Test 418048-2

IV. SUMMARY OF FINDINGS AND CONCLUSIONS

SUMMARY OF FINDINGS

The Texas Type T6 Bridge Rail contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation. Detached post 9 was 26 m down and 31 m toward traffic lanes. Although the post did not penetrate nor show potential to penetrate the occupant compartment, it may present undue hazard to others in the area. Maximum occupant compartment deformation was 20 mm (6.9% reduction of space) in the floor pan area. As the vehicle exited the installation it was rolling counterclockwise and subsequently rolled onto it left side. The vehicle did intrude into adjacent traffic lanes as it came to rest on its side 11 m toward traffic lanes. Longitudinal occupant impact velocity was 7.7 m/s and longitudinal occupant ridedown was -11.0 g's. The exit angle at loss of contact with the bridge rail was 27.8 degrees, which was significantly more than 60 percent of the impact angle.

CONCLUSIONS

The Texas Type T6 Bridge Rail did not perform acceptably according to specifications of NCHRP Report 350. The vehicle rolled as it lost contact with the bridge rail and intruded into adjacent traffic lanes. The exit angle was significantly more than allowed and there were detached elements from the installation that may pose an undue hazard to other traffic, pedestrians, or personnel in the area.

Table 3. Performance Evaluation Summary for Test 418048-2, NCHRP Report 350 Test 3-11

Test Agency: Texas Transportation Institute — Test No.: 418048-2 — Test Date: 05/07/98

NCHRP Report 350 Evaluation Criteria	Test Results	Assessment
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.	The Texas Type T6 Bridge Rail contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation.	Pass
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. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.	Detached post 9 was found 26 m down and 31 m toward traffic lanes. Although the post did not penetrate nor show potential to penetrate the occupant compartment, it may present undue hazard to others in the area. Maximum occupant compartment deformation was 20 mm (6.9% reduction of space) in the floor pan area.	Marginal
F. The vehicle should remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.	As the vehicle exited the installation it was rolling counterclockwise and subsequently rolled onto it left side.	Fail
Vehicle Trajectory		
K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	The vehicle did intrude into adjacent traffic lanes as it came to rest on its side 11 m toward traffic lanes.	Fail*
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.	Longitudinal occupant impact velocity was 7.7 m/s and longitudinal occupant ridedown was -11.0 g's.	Pass
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.	The exit angle at loss of contact with the bridge rail was 27.8 degrees, which was significantly more than 60 percent of the impact angle.	Fail*

*Criterion preferable, not required.

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, John J. Panak, and C. E. Buth, *Tubular W-Beam Bridge Rail*, Research Report 230-1 of Research Study 2-5-78-230 for the Texas State Department of Highways and Public Transportation, Texas Transportation Institute, The Texas A&M University System, College Station, Texas, October 1978.

5. J. D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*, NCHRP Report 230, Transportation Research Board, Washington, D.C., 1980.