TEXAS TRANSPORTATION INSTITUTE

TESTING AND EVALUATION OF THE NEW YORK TWO-RAIL CURBLESS AND FOUR-RAIL CURBLESS BRIDGE RAILING AND THE BOX-BEAM TRANSITION

by

C. Eugene Buth, P.E.
Senior Research Engineer

Wanda L. Menges
Associate Research Specialist

and

William F. Williams
Assistant Research Engineer

Contract No. DTFH61-98-C-00056
Report No. 404531-F

Sponsored by
U.S. Department of Transportation
Federal Highway Administration

September 1999

TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A & M UNIVERSITY SYSTEM
COLLEGE STATION, TEXAS

FOREWORD

(COTR TO SUPPLY FOREWORD)

Michael F. Trentacoste
Director, Office of Safety
Research, Development, and Technology

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-99-		

4. Title and Subtitle TESTING AND EVALUATION OF THE NEW YORK TWO-RAIL CURBLESS AND FOUR-RAIL CURBLESS BRIDGE RAILING AND THE BOX-BEAM TRANSITION	5. Report Date September 1999 6. Performing Organization Code
7. Author(s) C. Eugene Buth, Wanda L. Menges, and William F. Williams	8. Performing Organization Report No. 404531-F
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH61-98-C-00056
12. Sponsoring Agency Name and Address Office of Safety Research, Development, and Technology Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296	13. Type of Report and Period Covered Final Report April 1998 - September 1999 14. Sponsoring Agency Code

15. Supplementary Notes

Research Study Title: Evaluation and Crash Testing of New York's Two-Rail and Four-Rail Bridge Rail, and Box Beam Transition

Contracting Officer's Technical Representative (COTR): Charles F. McDevitt - HSR-20

16. Abstract

The objective of this study was to crash test and evaluate the New York Two-Rail Curbless and Four-Rail Curbless Bridge Railings, and the box beam transition. Under the first part of the study, the Two-Rail and Four-Rail bridge railings were evaluated to National Cooperative Highway Research Program (*NCHRP) Report 350* test level 4 (TL-4). To evaluate to TL-4, three full-scale crash tests on the length of need (LON) of the longitudinal barrier, or bridge railing, are required. These include an 820-kg passenger car impacting the critical impact point (CIP) at a nominal impact speed and angle of 100 km/h and 20 degrees, a 2000-kg pickup truck impacting the CIP at a nominal impact speed and angle of 100 km/h and 25 degrees, and an 8000-kg single-unit truck impacting the CIP at a nominal impact speed and angle of 80 km/h and 15 degrees.

After evaluation of the two bridge railings, New York DOT and Federal Highway Administration (FHWA) decided to evaluate a box-beam transition attached to the New York Four-Rail Curbless Bridge Railing. *NCHRP Report 350* test designation 3-21, which is the 2000-kg pickup truck impacting the CIP of the transition at 100 km/h and 25 degrees, was performed on the transition.

This report presents the details and results of all six crash tests performed under this contract.

17. Key Words	18. Distribution Statement
Bridge railing, transition, crash testing, roadside safety, highway safety.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	240	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
EF	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	EC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
EC	Celcius temperature	1.8C+32	Fahrenheit temperature	EF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

Figure No. Page

LIST OF TABLES

I. INTRODUCTION

PROBLEM

Recently, the Federal Highway Administration (FHWA) adopted National Cooperative Highway Research Program (NCHRP) Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, as the official guidelines for performance evaluation of roadside safety hardware.[1] *NCHRP Report 350* specifies the required crash tests for longitudinal barriers, such as bridge railings, and transitions for six performance levels, as well as evaluation criteria for structural adequacy, occupant risk, and post-test vehicle trajectory for each test. The New York Two-Rail Curbless Bridge Railing, the Four-Rail Curbless Bridge Railing and the Box-Beam Transition were required to be evaluated according to the specifications of test level four (TL-4) of *NCHRP Report 350*.

BACKGROUND

Most of the existing roadside safety features were tested according to the previous guidelines contained in *NCHRP Report 230*.[2] FHWA has required that all roadside safety features to be installed under new construction on the National Highway System (NHS) meet the *NCHRP Report 350* performance evaluation guidelines. Implementation of this requirement for breakaway devices, longitudinal barriers (except weak-post W-beam guardrail), crash cushions, and W-beam guardrail terminals on new construction went into effect on October 1, 1998. Guardrail to bridge railing transitions will be required to meet the *NCHRP Report 350* requirements by October 1, 2002. Therefore, it is necessary to test new and/or some existing roadside safety features to evaluate their performance under the new guidelines.

OBJECTIVES

FHWA, in cooperation with New York Department of Transportation (NYDOT), initiated this contract with the objective to crash test and evaluate the New York Two-Rail and Four-Rail Bridge Railings, and the Box-Beam Transition. Under the first part of the study, the Two-Rail Bridge Railing and Four-Rail Bridge Railing were evaluated to *NCHRP Report 350* TL-4. To evaluate to TL-4, three full-scale crash tests on the length of need (LON) of the longitudinal barrier, or bridge railing, are required. These include an 820-kg passenger car impacting the critical impact point (CIP) at a nominal impact speed and angle of 100 km/h and 20 degrees, a 2000-kg pickup truck impacting the CIP at a nominal impact speed and angle of 100 km/h and 25 degrees, and an 8000-kg single-unit truck impacting the CIP at a nominal impact speed and angle of 80 km/h and 15 degrees.

The New York Two-Rail Bridge Railing met all specification for *NCHRP Report 350* test designation 4-10. The New York Two-Rail Curbless Bridge Railing did not meet criteria for D and K of *NCHRP Report 350* test designation 4-11. Separation and deformation of the occupant compartment were judged to have potential for causing serious injury. Damage to the concrete deck at one post location was extensive and required major repairs. It was recommended that the post-to-deck connection be reviewed with the objective of reducing structural damage to the deck. No modifications were made to the deck and *NCHRP Report 350* test designation 4-12 was performed. The New York Two-Rail Bridge Railing met all criteria for *NCHRP Report 350* test designation 4-12.

The New York Four-Rail Curbless Bridge Railing performed acceptably during *NCHRP Report 350* test designations 4-12 and 4-11. The bridge railing geometry of the Four-Rail system was very similar to that of the Two-Rail Curbless Bridge Railing. As the Two-Rail performed acceptably during *NCHRP Report 350* test designation 4-10, this test was not performed on the Four-Rail version.

After evaluation of the two bridge railings, NYDOT and FHWA decided to evaluate a box-beam transition attached to the New York Four-Rail Curbless Bridge Railing. *NCHRP Report 350* test designation 3-21, which is the 2000-kg pickup truck impacting the CIP of the transition at 100 km/h and 25 degrees was performed on this transition. The Box-Beam Transition did not meet occupant risk criterion D and vehicle trajectory criterion K for *NCHRP Report 350* test designation 3-21. Due to the significant amount of overall deformation of the occupant compartment, separation in the floor pan, and partial ejection of the dummy through the door which was pulled open at the hinges, damage to the vehicle was judged to have potential for causing serious injury to occupants. This severe damage resulted from the vehicle snagging on the rail splice joints and bolt heads that protruded after the rail element was partially collapsed.

This report presents the details and results of all six full-scale crash tests performed under this contract. Chapter II presents a brief description of the test facility, details the test conditions, and lists the applicable evaluation criteria. Chapter III presents the details for the three installations tested. Chapters IV, V, and VI present results of the tests and the evaluation assessment of the Two-Rail Curbless Bridge Railing, the Four-Rail Curbless Bridge Railing, and the Box-Beam transition, respectively. Chapter VII briefly summarizes the results of the six tests and offers conclusions.

II. TEST PARAMETERS

TEST FACILITY

The test facilities at the Texas Transportation Institute's (TTI) Proving Ground consist of an 809-hectare complex of research and training facilities situated 16 km northwest of the main campus of Texas A&M University. The site, formerly an air force base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for the placing of the New York Two-Rail and Four-Rail Bridge Railings and the Box-Beam Transition was along a wide expanse of concrete aprons that were originally used as parking aprons for military aircraft. These aprons consist of unreinforced jointed concrete pavement in 3.8-m by 4.6-m blocks (as shown in the adjacent photo) nominally 203 to 305 mm deep. The aprons and runways are about 50 years old and the joints have some displacement, but are otherwise flat and level. The soil was excavated at the edge of the apron, a section of the apron was broken off and sufficient reinforcing bars were added to join to the simulated bridge deck. A 21.98 m section of the New York Two-Rail and Four-Rail Curbless Bridge Railing was installed on the deck. Adjacent to the deck, the New York Box-Beam transition was installed in *NCHRP Report 350* standard soil. Further details of the three installations are presented in Chapter III.

TEST CONDITIONS

According to *NCHRP Report 350*, three tests are required to evaluate longitudinal barriers, such as bridge railings, to test level four (TL-4) and are as described below.

> ***NCHRP Report 350* test designation 4-10**: An 820-kg passenger car impacting the (critical impact point) CIP in the length of need (LON) of the longitudinal barrier at a nominal speed and angle of 100 km/h and 20 degrees. This purpose of this test is evaluate the overall performance of the LON section in general, and occupant risks in particular.
>
> ***NCHRP Report 350* test designation 4-11**: A 2000-kg pickup truck impacting the CIP in the LON of the longitudinal barrier at a nominal speed and angle of 100 km/h and 25 degrees. The test is intended to evaluate the strength of section in containing and redirecting the pickup truck.

***NCHRP Report 350* test designation 4-12**: An 8000-kg single-unit truck impacting the CIP in the LON of the longitudinal barrier at a nominal speed and angle of 80 km/h and 15 degrees. The test is intended to evaluate the strength of section in containing and redirecting the heavy truck.

All three *NCHRP Report 350* TL-4 tests were performed on the New York Two-Rail Curbless Bridge Railing. *NCHRP Report 350* test designations 4-12 and 4-11 were performed on the New York Four-Rail Curbless Bridge Railing. Critical impact points (CIP) chosen for each of these tests were as determined in *NCHRP Report 350* Section 3.4.2. For *NCHRP Report 350* test designation 4-10, the CIP was 1.1 m upstream of the splice/post near one-third point. The CIP for *NCHRP Report 350* test designation 4-11 was 1.3 m upstream of the splice/post near one-third point. And, for *NCHRP Report 350* test designation 4-12, the CIP was 1.5 m upstream of the splice/post near the one-third point.

Also, according to *NCHRP Report 350*, two crash tests are required to evaluate longitudinal barrier transitions to test level three (TL-3) and are as described below.

NCHRP Report 350 test designation 3-20: An 820 kg passenger car impacting the transition at the (critical impact point) CIP at a nominal speed and angle of 100 km/h and 20 degrees. The test is intended to evaluate occupant risk and post-impact trajectory.

NCHRP Report 350 test designation 3-21: A 2000 kg pickup truck impacting the transition at the (critical impact point) CIP at a nominal speed and angle of 100 km/h and 25 degrees. The test is intended to evaluate the strength of the section in containing and redirecting the 2000 kg vehicle.

NCHRP Report 350 test designation 3-21 was performed on the New York Box-Beam Transition. As recommended in *NCHRP Report 350*, the BARRIER VII simulation program was used to determine the CIP for this test. The program indicated the CIP to be 2.0 m upstream from the centerline of the first bridge railing post.

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

EVALUATION CRITERIA

The crash tests performed were 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 tests reported herein:

- **Structural Adequacy**

A. For all tests: *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. For all tests: *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. For tests 4-10, 4-11, and 3-21: *The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.*

G. For test 4-12 only: *It is preferable, although not essential, that the vehicle remain upright during and after the collision.*

H. For test 4-10 only: *Occupant impact velocities should satisfy the following:*

Longitudinal and Lateral Occupant Impact Velocity - m/s	
Preferred	*Maximum*
9	*12*

I. For test 4-10 only: *Occupant ridedown accelerations should satisfy the following:*

Longitudinal and Lateral Occupant Ridedown Accelerations - g's	
Preferred	*Maximum*
15	*20*

- **Vehicle Trajectory**

K. For all tests: *After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

L. For tests 4-11 and 3-21 only: *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. For all tests: *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.*

III. TEST ARTICLES

NEW YORK TWO-RAIL CURBLESS BRIDGE RAILING

The New York Two-Rail Curbless Bridge Railing is a steel-beam and steel-post system on a concrete bridge deck. Texas Transportation Institute (TTI) received a drawing from New York Department of Transportation entitled "Proposed Test Details Steel Bridge Rail Two-Rail." This drawing provided details for construction of the concrete deck installation and fabrication of the Two-Rail Bridge Railing system. Based on these details, TTI prepared drawings for construction of the bridge railing test installation. These drawings are shown as figure 1 in this report.

For this project, a simulated concrete bridge deck cantilever was constructed. The total length of the test installation was 21.98 m. The bridge deck cantilever was 750 mm in width and 300 mm thick. The bridge deck cantilever was constructed immediately adjacent to an existing concrete runway located at the TTI test facility. The concrete deck was anchored to the runway by welding "L"-shaped dowels to existing dowels located in the concrete runway. The specified 28-day compressive strength of the concrete used to construct the deck was 27.6 MPa. Measured compressive strength at one day after the crash test (23 days age) was 27.7 MPa. Prior to constructing the deck, a concrete footing was constructed to provide additional support for the concrete deck. The footing measured 1665 mm in width and 203 mm in depth.

After construction of the footing, form work was constructed for a vertical support wall and the concrete deck cantilever. The vertical support wall and the concrete deck cantilever were cast monolithically. The vertical support wall was 305 mm in width and served to anchor the deck to the existing runway and footing. Two layers of reinforcement were constructed in the deck and extended through the deck into the vertical support wall. The bottom layer of transverse reinforcement was epoxy coated and consisted of #13 bars at 200-mm spacings. The bottom longitudinal reinforcement consisted of four bars on 200-mm spacings. The outer three longitudinal bars were #16 bars and the innermost bar (traffic side) was a #13 bar. The outermost (field side) bottom longitudinal bar was epoxy coated. Longitudinal reinforcement in the vertical support consisted of three #13 uncoated bars on each face.

The top layer of transverse reinforcement consisted of alternating #13 and #19 bars on 100-mm spacings. The transverse bars were hooked using a 90-mm radius. The hook extended an additional 215 mm and lapped the bottom transverse reinforcement. Starting from the field side of the deck toward the traffic side, the longitudinal reinforcement consisted of four #16 bars on 100-mm spacings located beneath the top transverse reinforcement with three #13 bars on 200-mm spacings located above the top transverse reinforcement. All reinforcement used in the top layer was epoxy coated.

The New York Two-Rail Bridge Railing consists of two TS 152x152x4.8 tubes supported by W150x37 posts on 2500-mm spacings. Each post was 790 mm in height and was continuously

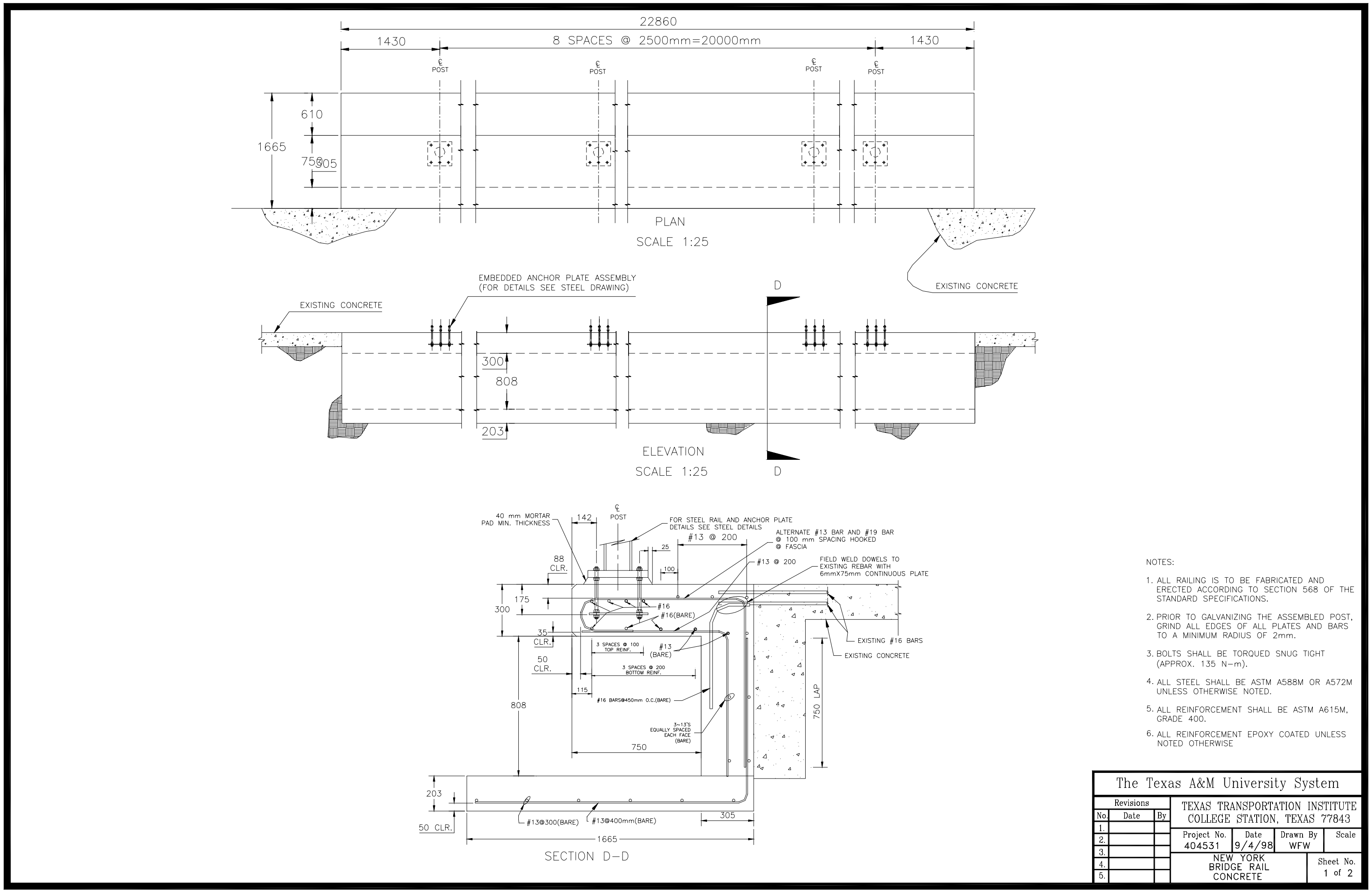


Figure 1. Details of the New York Curbless Two-Rail Bridge Railing for tests 404531-1 through 3.

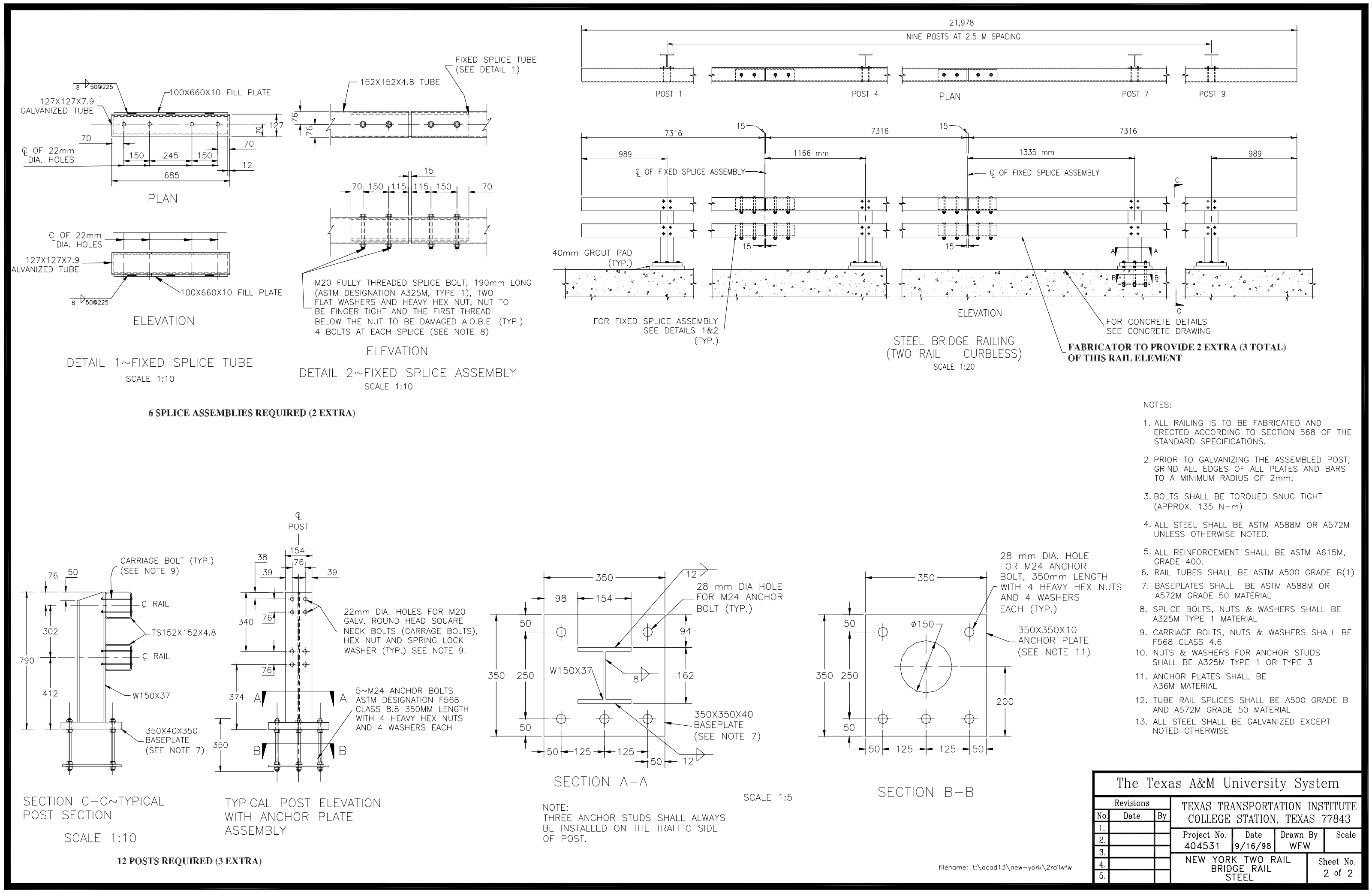


Figure 1. Details of the New York Curbless Two-Rail Bridge Railing for test 404531-1 through 3 (continued).

welded to a 350-mm x 350-mm x 38-mm baseplate with a 12-mm fillet weld. A 40-mm high-strength cementitious grout pad was placed beneath each post. The posts were anchored into the concrete deck using five M24 anchor bolts and 350-mm x 350-mm x 10-mm anchor plates. Three of the five anchor bolts were located on the traffic face of the posts. The anchor plates were embedded into the concrete deck 175 mm from the top surface of the deck. The anchor plates were fabricated using A36 Material. The anchor bolt material met the requirements of specification ASTM F568 Class 8.8. The posts and the baseplates were fabricated using A572M Grade 50 material. The lower rail was located 412 mm from the top of the deck and the upper rail was located 714 mm from the top of the deck. The rails were connected to each post using four M20 galvanized round head square neck (carriage) bolts. The round heads of the bolts were located on the traffic face of the rail and bolted through the rail and the front flange of the post. The rails were spliced together using a fixed internal splice tube fabricated from TS127x127x7.9 tube with two 100-mm x 660-mm x 10-mm plates welded on two sides of the tube. The splice tube was connected to the rail tubes using four M19 x 190-mm bolts. The splice tube bolts met the requirements of ASTM A325 Type 1 material. The bridge rail tubes met the requirements of ASTM A500 Grade B material. The tube rail splices met the requirements of ASTM A500 Grade B and A572M Grade 50 material. For additional information, see figure 1.

The concrete deck was damaged at post 4 during test 404531-2 (*NCHRP Report 350* test designation 4-11) which was performed on October 27, 1998. TTI was instructed by New York Department of Transportation personnel to remove all loose concrete from the damaged area, clean the exposed concrete surface, apply concrete bonding agent to the surface, reset the anchor plate assembly, and patch the damaged area with a comparable strength concrete patch. TTI personnel repaired the area as per these instructions on November 18, 1998. For the single-unit truck test, the impact point was moved away from this damaged area (three posts farther south) with the single-unit truck impacting the rail in the opposite direction from that of the pickup truck test. No cracking or other sign of distress was present around the repaired area before this test.

All material was galvanized except the anchor bolts and anchor plates. The completed installation is shown in figure 2.

NEW YORK FOUR-RAIL CURBLESS BRIDGE RAILING

The New York Four-Rail Curbless Bridge Railing is a steel beam and steel post system on a concrete bridge deck. Texas Transportation Institute (TTI) received a drawing from New York Department of Transportation entitled “Proposed Test Details - Steel Bridge Rail - Two Rail and Four Rail.” These drawings provided details for construction of the concrete deck installation and fabrication of the Four Rail Bridge Railing System. Based on these details, TTI prepared drawings for construction of the bridge railing test installation. These drawings are shown as figure 3 in this report.

Figure 2. New York Two-Rail Curbless Bridge Railing Installation.

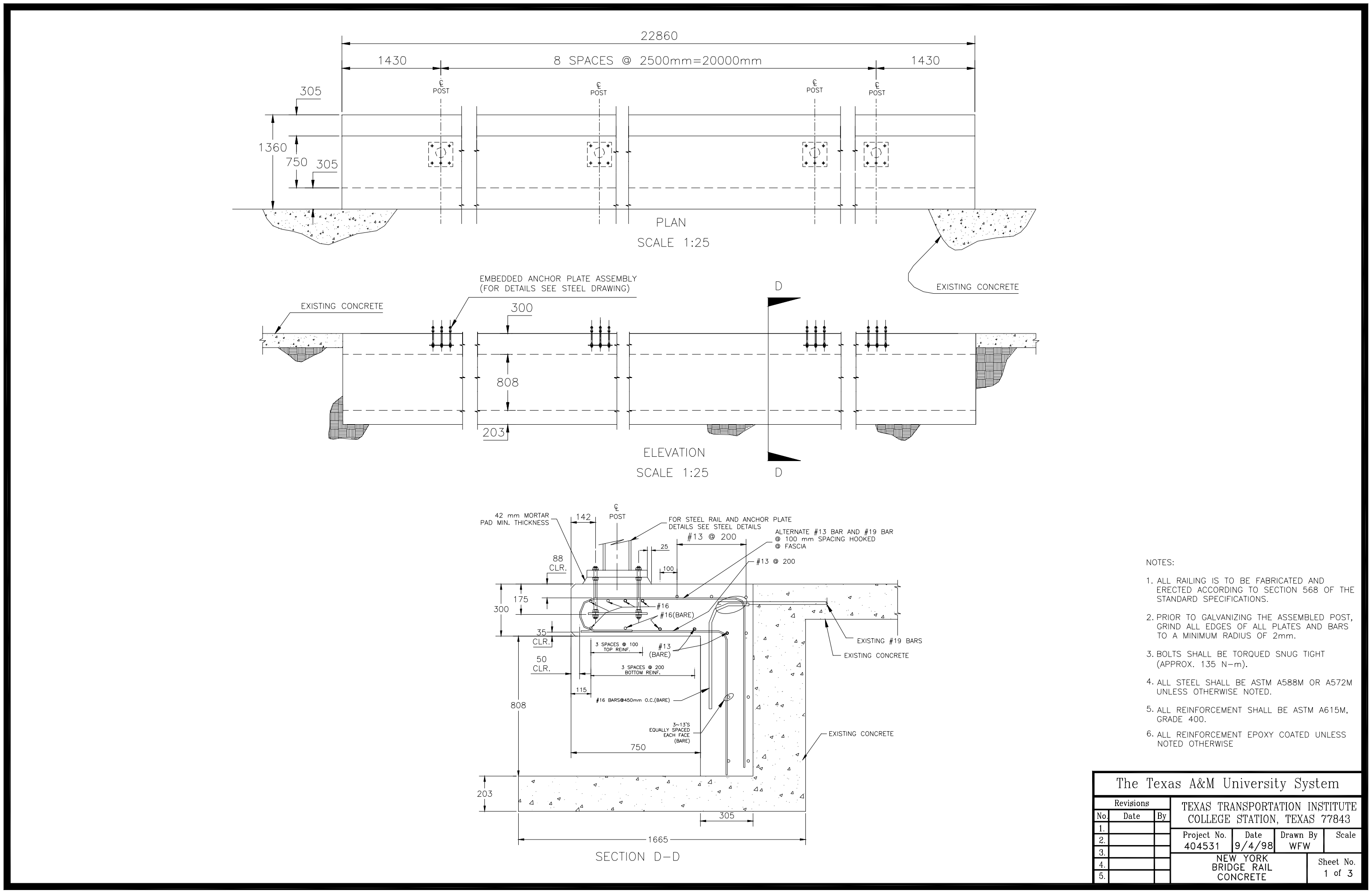


Figure 3. Details of the New York Four-Rail Curbless Bridge Railing used for tests 404531-4 and 6.

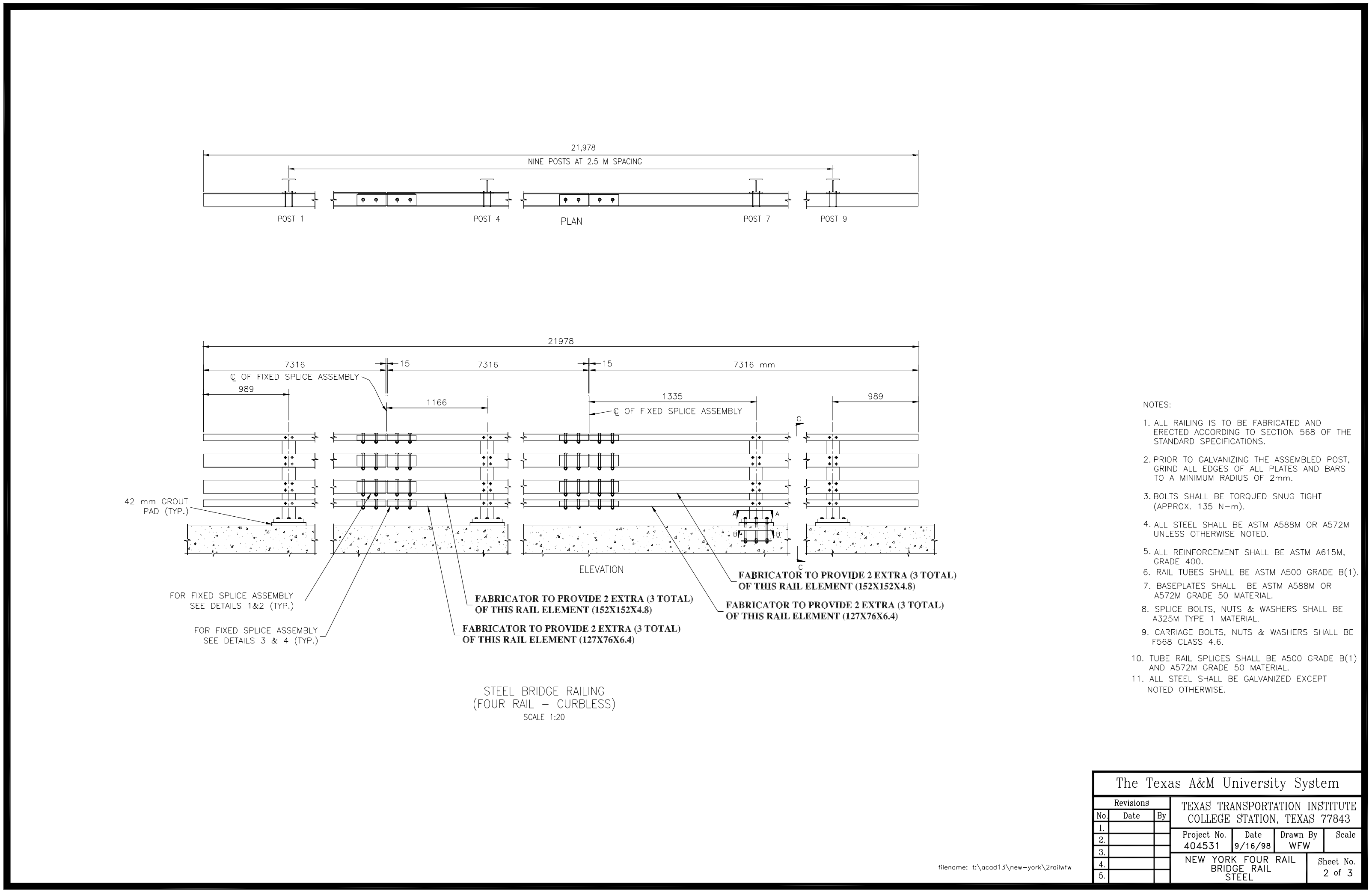


Figure 3. Details of the New York Four-Rail Curbless Bridge Railing used for test 404531-4 and 6 (continued).

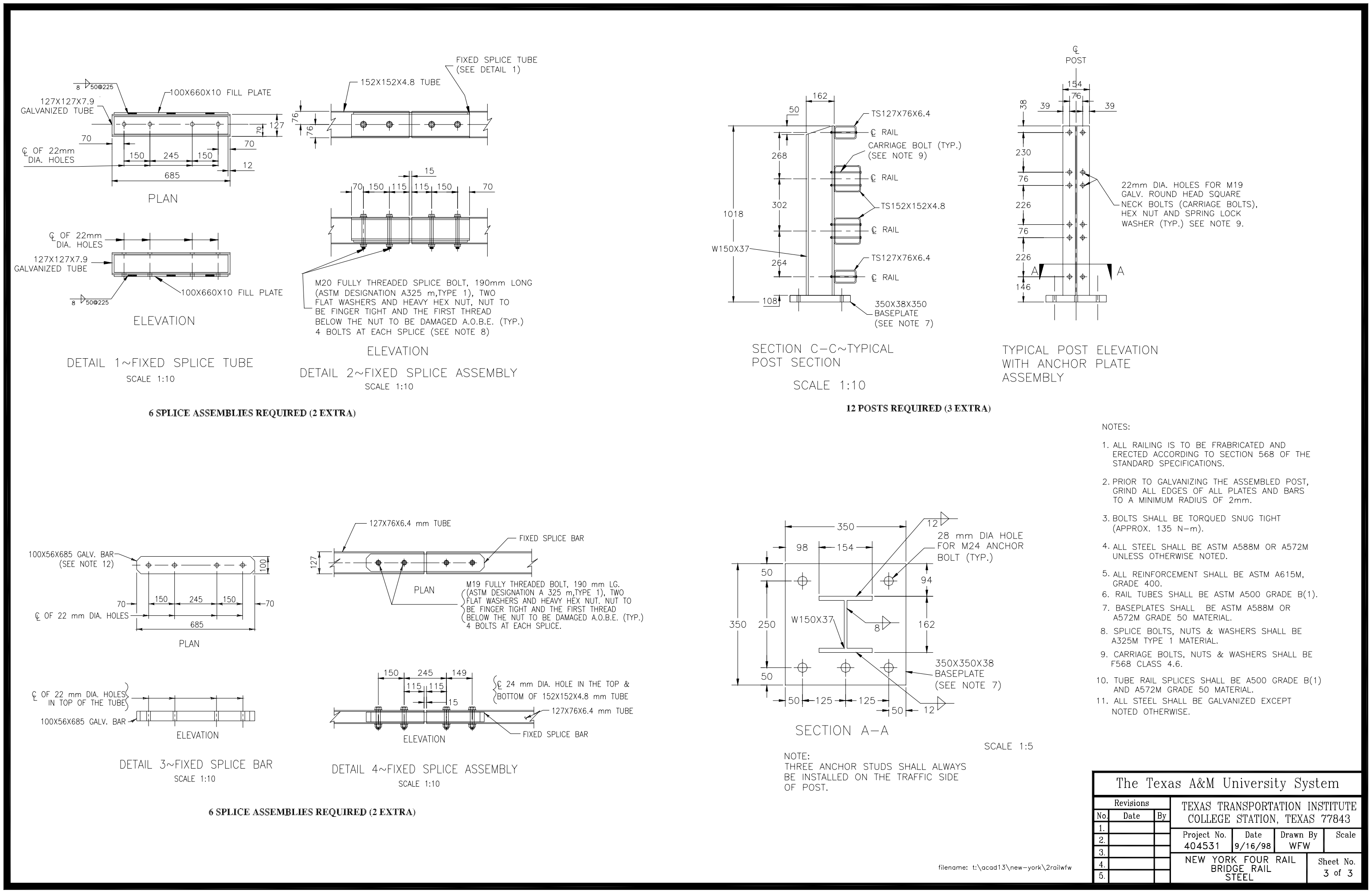


Figure 3. Details of the New York Four-Rail Curbless Bridge Railing used for test 404531-4 and 6 (continued).

For this project, a simulated concrete bridge deck cantilever was constructed. The total length of the test installation was 21.98 m. The bridge deck cantilever was 750 mm in width and 300 mm thick. The bridge deck cantilever was constructed immediately adjacent to an existing concrete runway located at the TTI test facility. The concrete deck was anchored to the runway by welding "L" shaped dowels to existing dowels located in the concrete runway. The specified 28-day compressive strength of the concrete used to construct the deck was 27.6 MPa. The measured 28-day compressive strength was 34.79 MPa. Prior to constructing the deck, a concrete footing was constructed to provide additional support for the concrete deck. The footing measured 1665 mm in width and was 203 mm in depth.

The vertical support wall and the concrete deck cantilever were cast monolithically. The vertical support wall was 305 mm in width and served to anchor the deck to the existing runway. Two layers of reinforcement were constructed in the deck and extended through the deck into the vertical support wall. The bottom layer of transverse reinforcement was epoxy coated and consisted of #13 bars at 200 mm spacings. The bottom longitudinal reinforcement consisted of four bars on 200 mm spacings. The outer three longitudinal bars were #16 bars and the innermost bar (traffic side) was a #13 bar. The outermost (field side) bottom longitudinal bar was epoxy coated. Longitudinal reinforcement in the vertical support consisted of three #13 uncoated bars on each face.

The top layer of transverse reinforcement consisted of alternating #13 and #19 bars on 100 mm spacings. The transverse bars were hooked. The hook extended an additional 215 mm and lapped the bottom transverse reinforcement. Starting from the field side of the deck toward the traffic side, the longitudinal reinforcement consisted of four #16 bars on 100 mm spacings located beneath the top transverse reinforcement with three #13 bars on 200 mm spacings located above the top transverse reinforcement. All reinforcement used in the top layer was epoxy coated.

The New York Four Rail Bridge Railing consists of two TS 152x152x4.8 tubes and two TS 127x76x6.4 tubes supported by W150x37 posts. The posts were located on 2500 mm spacings. The TS 152x152x4.8 tubes were located between the TS 127x76x6.4 tubes. Each post was 1.06 m in height and was continuously welded to a 350 mm x 350 mm x 38 mm baseplate with a 12 mm fillet weld. A 42-mm high-strength cementitious grout pad was placed beneath each post. The posts were anchored into the concrete deck using five M24 anchor bolts and 350 mm x 350 mm x 10 mm anchor plates. Three of the five anchor bolts were located on the traffic face of the posts. The anchor plates were embedded into the concrete deck 175 mm from the top surface of the deck. The anchor plates were fabricated using A36 Material. The anchor bolt material met the requirements of specification ASTM F568 Class 8.8. The posts and the base plates were fabricated using A572M Grade 50 material. The lower rail was located 226 mm from the top of the deck and the upper rail was located 1.06 m from the top of the deck with the middle rail located at 528 mm and 830 mm, respectively. The middle rail were connected to each post using four M20 galvanized round head square neck (carriage) bolts. The upper and lower rails were connected to each post using two M20 galvanized round head square neck (carriage) bolts. The round heads of the bolts were located on the traffic face of the rail and bolted through the rail and the front flange of the post. The middle rails were spliced together using a fixed internal splice tube fabricated from TS127x127x7.9 tube with two 100 mm x 660 mm x 10 mm plates welded on two sides of the tube. The splice tube connected to the rail tubes using four M19 x 190 mm bolts. The upper and lower rails were spliced together using 100x56x900 bars. The splice tube bolts met the requirements of ASTM A325 Type 1 material. The bridge rail tubes met the requirements of ASTM A500 Grade B material. The tube rail splices met the requirements of ASTM A500 Grade B and A572M Grade 50 material. For additional information see figure 3.

The concrete deck was damaged at post 3 during the previous test (*NCHRP Report 350* test designation 4-12) which was performed on March 25, 1999. TTI was instructed by New York Department of Transportation personnel to remove all loose concrete from the damaged area, clean the exposed concrete surface, apply concrete bonding agent to the surface, reset the anchor plate assembly, and patch the damaged area with a comparable strength concrete patch. TTI personnel repaired the area as per these instructtions on April 9, 1999. For the test reported herein, the impact point was moved away from the damaged area (three posts farther north) with the pickup truck impacting the railing in the opposite direction of the previous single-unit truck test. No cracking or other signs of distress were present around the repaired area before or after the test reported herein.

All material was galvanized except the anchor bolts and anchor plates. The completed installation is shown in figure 4.

NEW YORK BOX-BEAM TRANSITION

The New York Box Beam Guide Rail to Steel Rail Transition consists of two steel tubes connected to the New York Standard Four-Rail Bridge Railing Design that transitions into the New York Standard Box Beam Guardrail. Texas Transportation Institute received a drawing from New York Department of Transportation entitled “Proposed Test Details Box Beam Guide Rail to Steel Rail Transition.” TTI purchased a complete transition system, length of need of Guardrail, and Type I end assembly from DI Highway Sign & Structure Corporation, New York. DI Highway manufactures these transitions according to New York Department of Transportation (NYDOT) specifications and supplies these transitions to NYDOT. TTI received a drawing from DI Highway entitled “Steel Bridge Rail to Box Beam Guide Rail Transition, Drawing No. BD-RS4.” These drawings provided details for construction of the transition. Based on these details, TTI prepared drawings for construction of this transition test installation. These drawings are shown as figure 5 in this report.

The test installation consisted of a 10.4 m transition section, 14.7 m length of need of Box Beam Guardrail, and 1.1 m long Type 1 end assembly. The transition is connected to the two middle rails of the four tube bridge rail. The transition tubes are connected with two 900 mm expansion splice tubes. Each tube was connected with four M20 fully threaded bolts that bolted through the tubes and splices. The splice tubes were fabricated from TS 127x127x7.9 tubes with two 100x10x875 fill plates welded to two adjoining sides of the tubes. A 110 mm gap was present between the transition tubes and the bridge rail tubes.

Figure 4. New York Four-Rail Curbless Bridge Railing Installation.

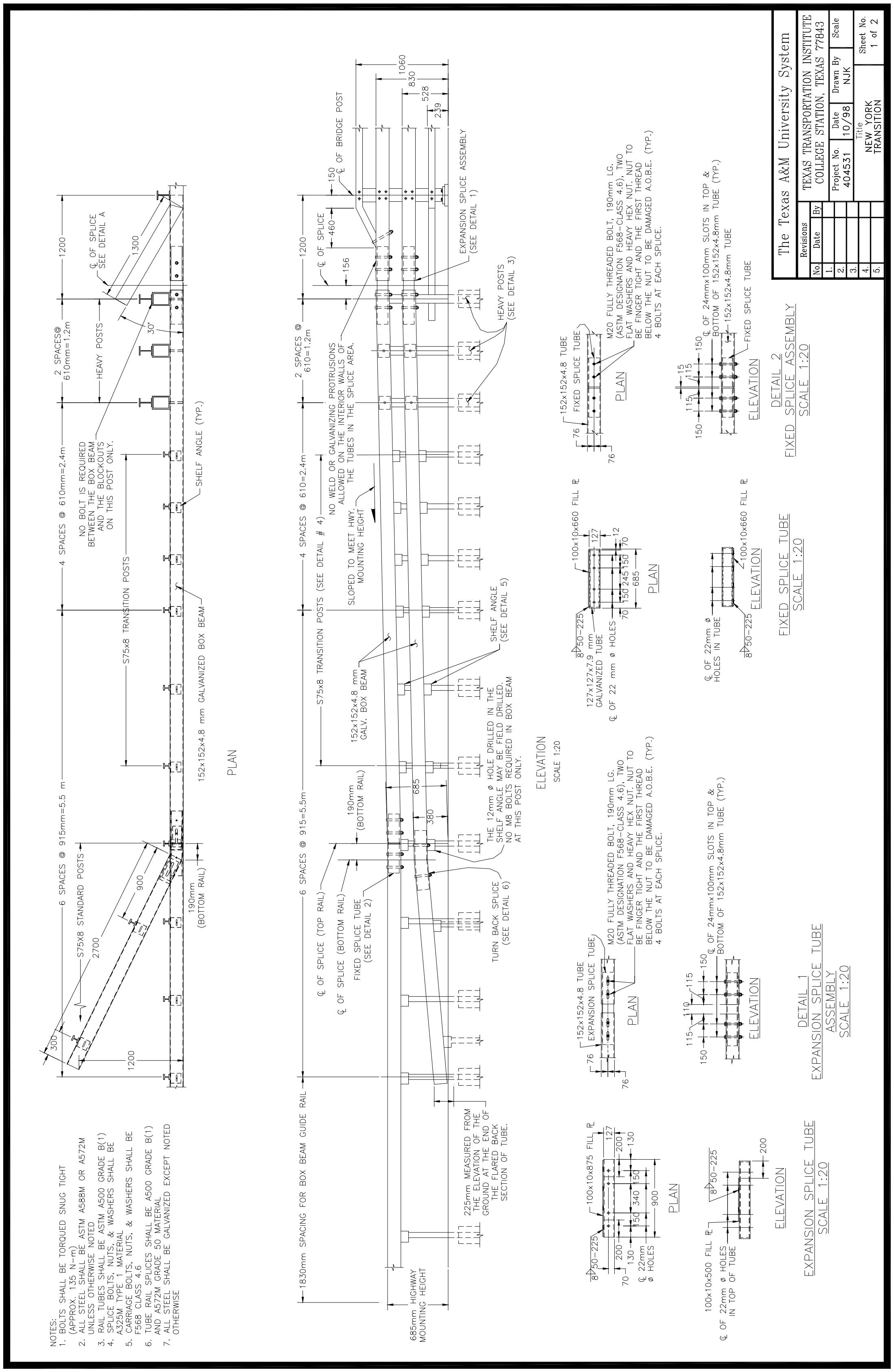


Figure 5. Details of New York Box-Beam Transition.

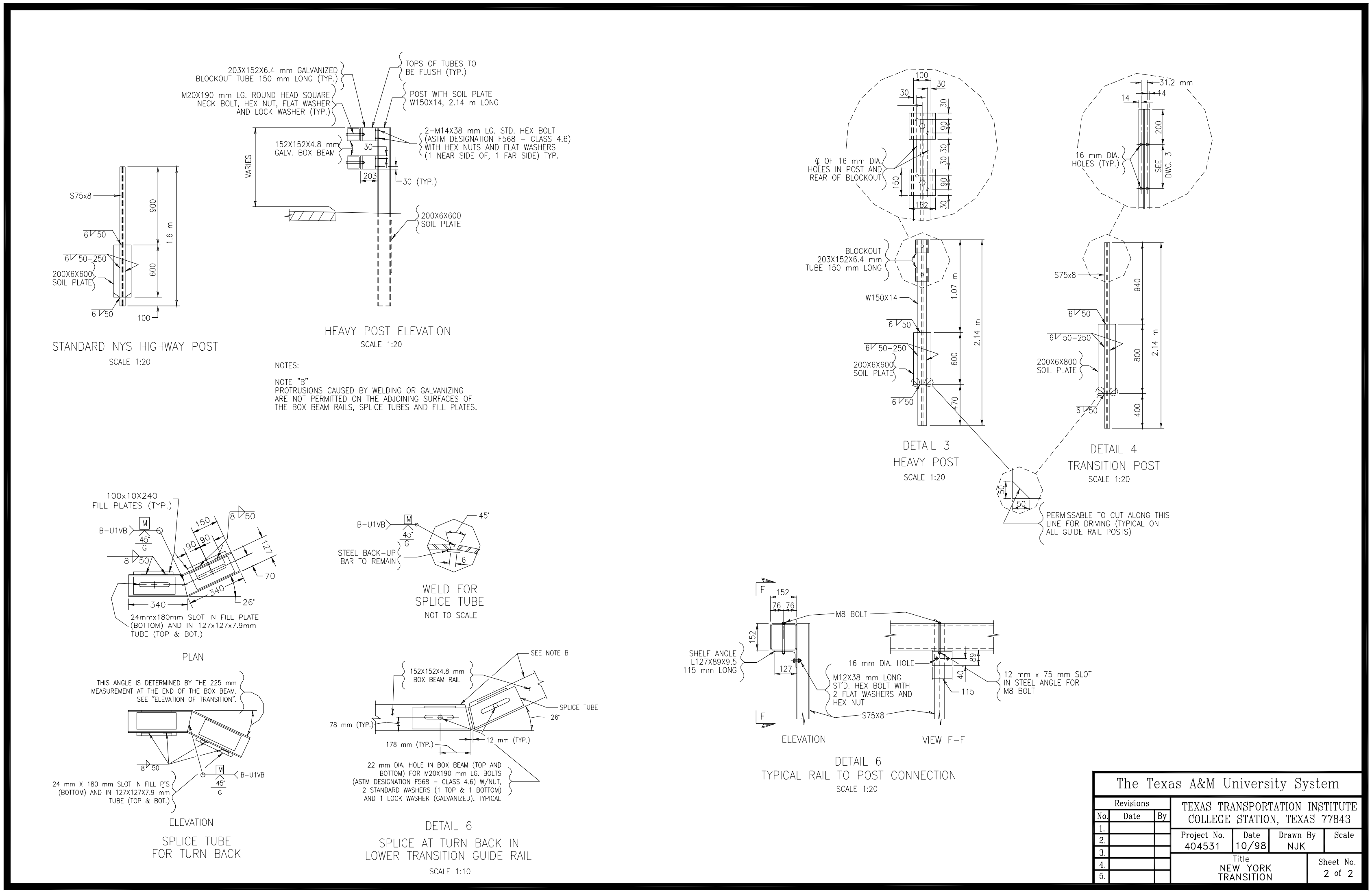


Figure 5. Details of New York Box-Beam Transition (continued).

The top TS 127x76x6.4 rail of the bridge railing extended horizontally beyond the last bridge rail post 150 mm and was sloped downward over a distance of 460 mm. It was connected to the top TS 152x152x4.8 tube with an M20 round head square neck carriage bolt. The bottom TS 127x76x6.4 rail of the bridge railing extended horizontally beyond the last bridge rail post 150 mm and turned behind Post 22 at a 30 degree angle.

The 10.4 m transition consisted of two TS 152x152x4.8 tubes supported by 13 posts. The first transition post (Post No. 22) was located 1245 mm from the last bridge deck post (Post No. 23). The first three posts in the transition away from the bridge deck were W150x14 heavy posts (Nos. 20 to 21) spaced at 610 mm on centers followed by four S75x8 Transition Posts (Nos. 16 to 19) spaced also at 610 mm on centers. The remaining length of transition consisted of six S75x8 Transition Posts (Post Nos. 10 to 15) spaced at 915 mm on centers. TS 203x152x6.4 tubular blockouts were used on the W150x14 heavy posts. The blockouts were connected to posts by two M14x38 mm long standard hex bolts. The blockouts were bolted to the tubes (except Post No. 22) by one M20x190 mm long round head square neck bolt. The remaining transition and box beam guardrail posts were connected to the transition tubular members by L127x89x9.5 shelf angles that connected to the posts with M12x38 mm long standard hex bolts. The transition and box beam tubes were supported by the shelf angles and bolted through the angles using M8 standard hex head bolts.

The top TS 152x152x4.8 transition tube attached to the bridge railing at a height of 830 mm above the deck surface and sloped to meet the box beam guardrail height of 685 at Post No. 13. The Lower TS 152x152x4.8 transition tube attached to the bridge railing at 528 mm above the deck surface and sloped 380 mm above the ground surface at Post No. 13. At Post No. 13, the lower transition tube angled back 26 degrees behind Post Nos. 10 through 12 and sloped downward from this point to the ground surface. Two posts supported the flared back portion of the lower transition tube.

The W150x14 heavy posts used in the transition were 2.14 m in length and utilized 200 mm x 6 mm x 600 mm soil plates attached 470 mm from the bottom of the posts. The S75x8 transition posts used in the installation were also 2.14 m in length and utilized 200 mm x 6 mm x 800 mm soil plates attached 400 mm from the bottom of the posts.

For this test installation, approximately 14.7 m of standard New York Box Beam Guardrail extended beyond the transition. This guardrail system consisted of TS152x152x4.8 box beam with a mounting height of 685 mm. The guardrail was supported by S75x8 Standard New York State Highway Posts 1.6 m in length with 200 mm x 6 mm x 600 mm soil plates attached to each post. The soil plates were located 100 mm from the bottom of the posts. The posts were spaced at 1830 mm on centers. A Standard New York State Type I End Assembly was used to terminate the test installation.

As mentioned earlier, details of the installation are shown in figure 5, and photographs of the completed installation as tested are shown in figure 45.

IV. TESTING OF THE NEW YORK TWO-RAIL CURBLESS BRIDGE RAILING

Three *NCHRP Report 350* TL-4 tests were performed on the New York Two-Rail Bridge Railing.

> ***NCHRP Report 350* test designation 4-10**: An 820-kg passenger car impacting the (critical impact point) CIP in the length of need (LON) of the longitudinal barrier at a nominal speed and angle of 100 km/h and 20 degrees.
>
> ***NCHRP Report 350* test designation 4-11**: A 2000-kg pickup truck impacting the CIP in the LON of the longitudinal barrier at a nominal speed and angle of 100 km/h and 25 degrees.
>
> ***NCHRP Report 350* test designation 4-12**: An 8000-kg single-unit truck impacting the CIP in the LON of the longitudinal barrier at a nominal speed and angle of 80 km/h and 15 degrees.

Details of the construction of the New York Two-Rail Bridge Railing are discussed in Chapter III and shown in figures 1 and 2.

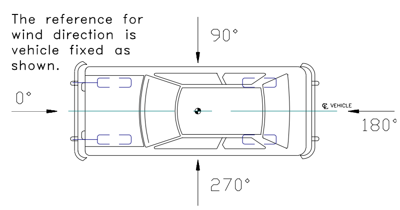
TEST 404531-1 (*NCHRP REPORT 350* TEST DESIGNATION 4-10)

Test Vehicle

A 1993 Ford Festiva, shown in figures 6 and 7, was used for the crash test. Test inertial weight of the vehicle was 820 kg, and its gross static weight was 896 kg. The height to the lower edge of the vehicle front bumper was 395 mm and height to the upper edge of the front bumper was 550 mm. Additional dimensions and information on the vehicle are given in appendix B, figure 53. 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.

Weather Conditions

The crash test was performed the morning of October 23, 1998. A total of 178 mm of rain was recorded 2 days prior to the test, but this did not affect the test as the bridge railing was installed on the concrete deck. No other rainfall occurred during the 10 days prior to the test. Weather conditions at the time of testing were as follows: Wind Speed: 6 km/h; Wind Direction: 200 degrees with respect to the vehicle (vehicle traveling southerly direction); Temperature: 16EC; Relative Humidity: 37 percent.



Impact Description

The vehicle, traveling at 100 km/h, impacted the two-rail bridge railing 1.2 m upstream from post 4, at a 19.1-degree angle. Shortly after impact, the bottom rail showed movement. At 0.010 s, the right front wheel steered left then traveled parallel with the railing. The upper rail moved at 0.012 s. At 0.017 s, the vehicle's right front wheel continued to steer left. Post 4 deformed at 0.019 s. At 0.024 s, the right front wheel canted as the upper part of the tire was pushed down from the lower bridge rail. The vehicle began to redirect at 0.038 s. The right front tire contacted the concrete and metal base of post 4 at 0.056 s, and at 0.066 s, the right front tire contacted post 4. At 0.068 s, the right-side passenger door window shattered, and at 0.097 s, the rear of the vehicle impacted the bridge railing. Traveling at 89.1 km/h, the vehicle was moving parallel to the rail element at 0.113 s. At 0.165 s, the left front tire steered right. At 0.224 s, traveling at 85.3 km/h, the vehicle lost contact with the bridge railing at a 0.8 degree angle. Brakes on the vehicle were applied at 1.4 s, bringing the vehicle to rest 52.7 m downstream from impact and 9.1 m behind the installation. Sequential photographs of the test period are shown in appendix C, figures 59 and 60.

Figure 6. Vehicle/installation geometrics for test 404531-1.

Figure 7. Vehicle before test 404531-1.

Damage to Test Article

Damage to the New York Two-Rail Curbless Bridge Railing is shown in figures 8 and 9. Tire marks were on the baseplate and nuts at impact. No cracks in the deck were noticed after the test. There was cosmetic damage with no measurable deformation of the rail elements. Total length of vehicle contact with the rail element was 3.0 m.

Vehicle Damage

The vehicle sustained structural damage on the front right and right side. The sway bar, A-arm, motor support, and right strut and axle were all severely damaged. The front right portion of the bumper, fan, radiator, hood, tire, and wheel were damaged as shown in figure 10. The right front and rear quarter panels and right door were dented. The left front tire also sustained damage. The roof had a slight buckle on the passenger side. The maximum exterior crush was 190 mm, measured near bumper height on the right side. Maximum deformation of the occupant compartment was 15 mm (2-percent reduction in space) in the right firewall area. The door and the floor pan were deformed. The interior of the vehicle is shown in figure 11. Exterior vehicle crush and occupant compartment measurements are shown in appendix B, tables 11 and 12.

Occupant Risk Factors

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 4.7 m/s at 0.196 s, the highest 0.010-s occupant ridedown acceleration was -2.5 g's from 0.132 to 0.142 s, and the maximum 0.050-s average acceleration was -6.3 g's between 0.034 and 0.084 s. In the lateral direction, the occupant impact velocity was 7.5 m/s at 0.085 s, the highest 0.010-s occupant ridedown acceleration was -11.3 g's from 0.126 to 0.136 s, and the maximum 0.050-s average was -13.9 g's between 0.022 and 0.072 s. These data and other pertinent information from the test are summarized in figure 12. Vehicle angular displacements and accelerations versus time traces are presented in appendix D, figures 71 through 83.

Assessment of Test Results

As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  A. *Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation,*

Figure 8. Vehicle trajectory path after test 404531-1.

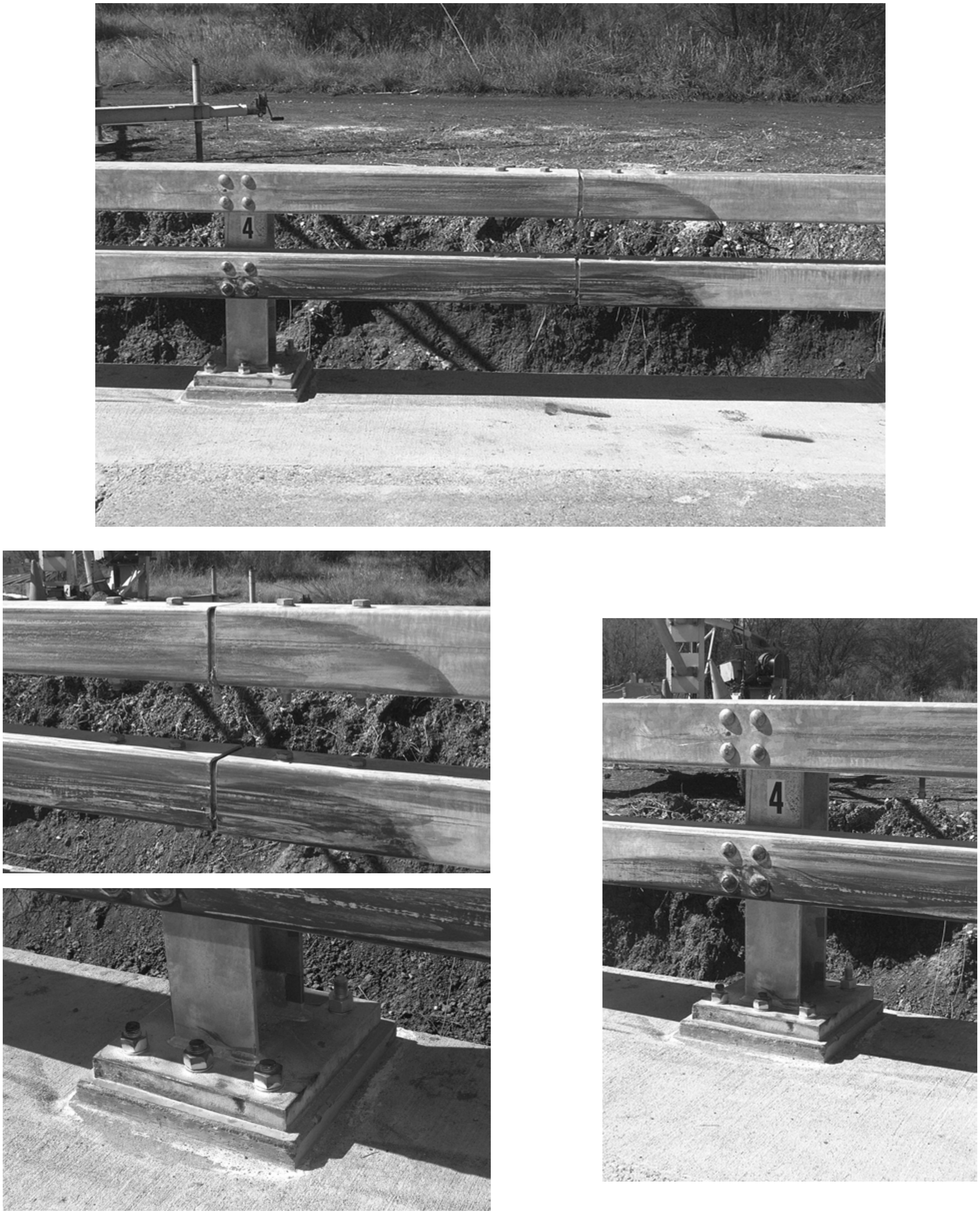


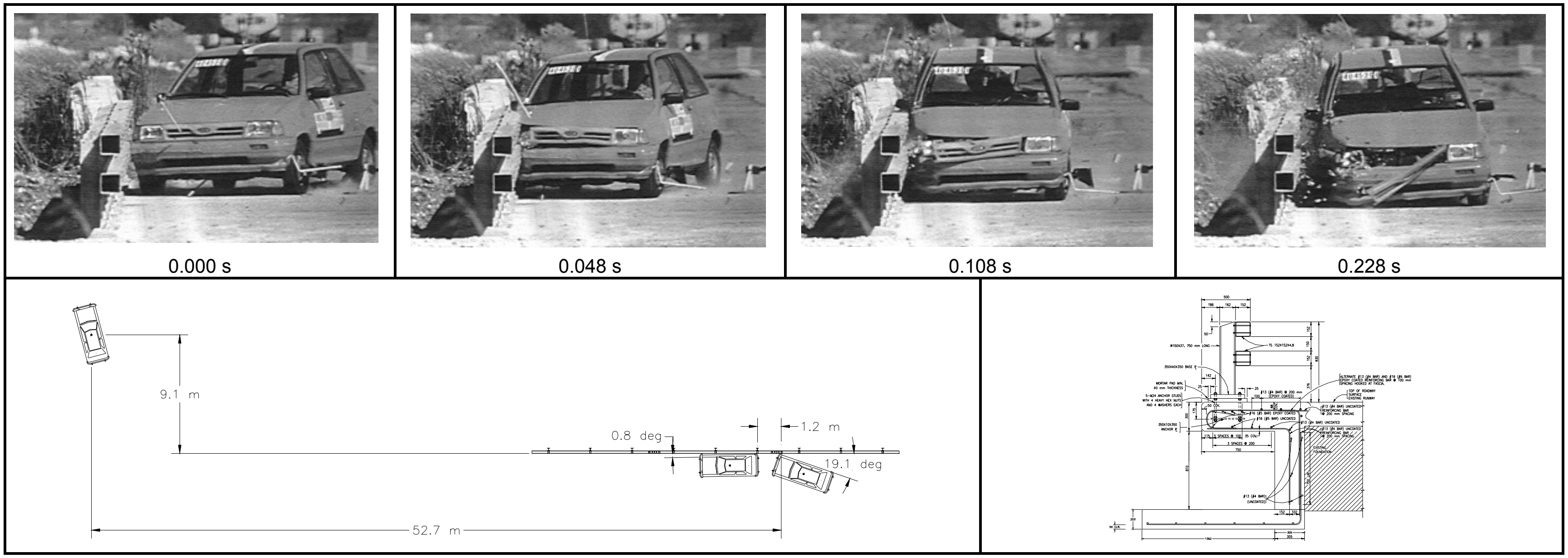
Figure 9. Installation after test 404531-1.

Figure 10. Vehicle after test 404531-1.

Before test

After test

Figure 11. Interior of vehicle for test 404531-1.



General Information	
Test Agency	Texas Transportation Institute
Test No.	404531-1
Date	10/23/98
Test Article	
Type	Bridge Rail
Name or Manufacturer	New York Two-Rail Bridge Railing
Installation Length (m)	22.9
Material or Key Elements	Tubular Steel Rail Elements on Steel Wide-Flange Posts on deck
Soil Type and Condition	Concrete Deck, Dry
Test Vehicle	
Type	Production
Designation	820C
Model	1993 Ford Festiva
Mass (kg)	
Curb	814
Test Inertial	820
Dummy	76
Gross Static	896

Impact Conditions	
Speed (km/h)	99.9
Angle (deg)	19.1
Exit Conditions	
Speed (km/h)	85.3
Angle (deg)	0.8
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	4.7
y-direction	7.5
THIV (km/h)	29.4
Ridedown Accelerations (g's)	
x-direction	-2.5
y-direction	-11.3
PHD (g's)	11.4
ASI	1.62
Max. 0.050-s Average (g's)	
x-direction	-6.3
y-direction	-13.9
z-direction	1.8

Test Article Deflections (m)	
Dynamic	nil
Permanent	nil
Vehicle Damage	
Exterior	
VDS	01RFQ2
CDC	01FREK2 & 01RFEW2
Maximum Exterior Vehicle Crush (mm)	190
Interior	
OCDI	RF0000000
Max. Occ. Compart. Deformation (mm)	15
Post-Impact Behavior	
(during 1.0 s after impact)	
Max. Yaw Angle (deg)	-17
Max. Pitch Angle (deg)	-3
Max. Roll Angle (deg)	-8

Figure 12. Summary of results for test 404531-1, *NCHRP Report 350* test 4-10.

although controlled lateral deflection of the test article is acceptable.

The New York Two-Rail Curbless Bridge Railing contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation.

- **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, and intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

No detached elements, fragments, or other debris from the test article were present to penetrate or to show potential for penetrating the occupant compartment. Minimal deformation occurred to the occupant compartment, 15 mm (2% reduction in space) in the right firewall area

F. *The vehicle should remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

H. *Occupant impact velocities should satisfy the following:*

Longitudinal and Lateral Occupant Impact Velocity - m/s	
Preferred	*Maximum*
9	*12*

Longitudinal occupant impact velocity was 4.7 m/s and lateral occupant impact velocity was 7.5 m/s.

I. *Occupant ridedown accelerations should satisfy the following:*

Longitudinal and Lateral Occupant Ridedown Accelerations - g's	
Preferred	*Maximum*
15	*20*

Longitudinal occupant ridedown acceleration was -2.5 g’s and lateral occupant ridedown acceleration was -11.3 g’s.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes as it came to rest behind the installation

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.*

The exit angle at loss of contact was 0.8 degrees, which was significantly less than 60 percent of the impact angle.

TEST 404531-2 (*NCHRP REPORT 350* TEST DESIGNATION 4-11)

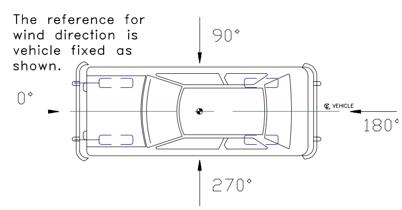
The New York Two-Rail Bridge Railing installation used in the first test was used for this second test, *NCHRP Report 350* test designation 4-11.

Test Vehicle

A 1994 Chevrolet 2500 pickup, shown in figures 13 and 14, was used for the crash test. Test inertia weight of the vehicle was 2000 kg, and its gross static weight was 2075 kg. The height to the lower edge of the vehicle front bumper was 390 mm and to the upper edge of the front bumper was 620 mm. Additional dimensions and information on the vehicle are given in appendix B, figure 54. 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.

Soil and Weather Conditions

The crash test was performed the morning of October 27, 1998. A total of 178 mm of rain was recorded 6 days prior to the test, but did not affect the test as the bridge railing was installed on the concrete deck. No other rainfall occurred during the 10 days prior to the study. Weather conditions at the time of testing were as follows: Wind Speed: 3 km/h; Wind Direction: 200 degrees with respect to the vehicle (vehicle traveling in southerly direction); Temperature: 25EC; Relative Humidity: 63 percent.



Impact Description

The vehicle, traveling at 101.7 km/h, impacted the two-rail bridge railing 1.3 m upstream from post 4 at a 25.4-degree angle. Shortly after impact, the lower rail element moved. At 0.007 s, the upper rail element deformed, and at 0.017 s, the right front tire contacted the lower bridge rail. By 0.019 s, the front right wheel steered left, and at 0.029 s, the front right tire was parallel with the bridge railing. The front right tire canted and the lower tire and rim traveled under the rail element at 0.034 s. At 0.035 s, the front left wheel steered left, and post 4 moved at 0.039 s. The vehicle began to redirect at 0.041 s. The first visible crack in the deck appeared on the field side of the installation at 0.049 s. At 0.056 s, the front right tire contacted the base of post 4, and at 0.060 s, the front left wheel steered right, toward the bridge railing. By 0.061 s, the front right tire contacted post 4, the concrete on the bridge deck surface in front of post 4 separated from the deck, and more cracks appeared on the field side of the installation. At 0.066 s, the farthest-most crack appeared downstream from post 4 on the field side of the installation. The right front tire deflated at 0.070 s, and the right rear tire contacted the lower rail element and traveled down the railing past post 4 at 0.178 s. Yawed toward the railing, the left

Figure 13. Vehicle/installation geometrics for test 404531-2.

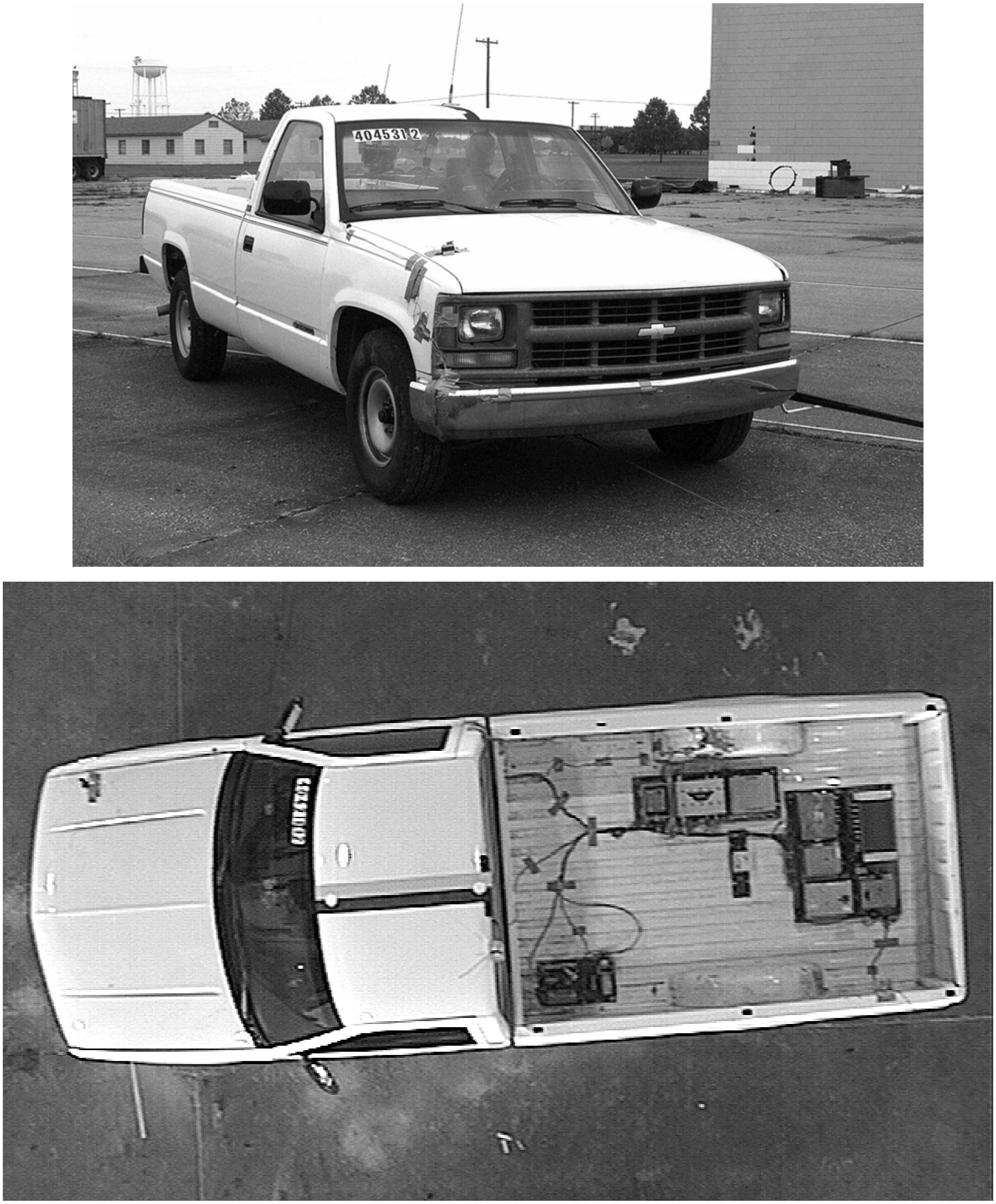


Figure 14. Vehicle before test 404531-2.

rear side of the vehicle impacted the railing. Traveling at 84.2 km/h, the vehicle was parallel with the installation at 0.186 s. The left and right rear tires lost contact with the ground at 0.244 s. At 0.341 s, traveling at 83.4 km/h, the vehicle lost contact with the bridge railing at a 7.4-degree angle. The left and right rear tires returned to the road surface at 0.577 and 0.638 s, respectively. Brakes on the vehicle were applied at 1.6 s, bringing the vehicle to rest 69.3 m downstream and 12.2 m toward the traffic lanes. Sequential photographs of the test period are shown in appendix C, figures 61 and 62.

Damage to Test Article

Damage to the New York Two-Rail Curbless Bridge Railing is shown in figures 15 through 17. Tire marks extended 225 mm behind the rail element at impact and tire marks were on the edges of the front and rear flange on the impact side of post 4, on the front face of the post and on the front anchor bolts. The tubular element in the vicinity of post 4 was partially flattened and the four bolts connecting the lower element were partially pulled out and deformed (see figure 16). Numerous cracks in the concrete deck surrounded post 4 and part of the concrete deck was broken away. After removal of the broken concrete around post 4, the exposed reinforcement did not show any signs of damage (see figure 17). At post 5, tire marks were on the front flange on the impact side of the post and extended 200 mm behind the rail element. Total length of vehicle contact with the rail elements was 3.3 m.

Vehicle Damage

The vehicle sustained structural damage on the front right and the right side. The sway bar, tie rod, right front upper and lower A-arms, upper ball joint, right A-post, drive shaft, and transmission housing were all severely damaged. The front right portion of the bumper, hood, grill, fan, radiator, right front tire, and rim were damaged as shown in figure 18. The windshield was shattered and the right door was deformed outward 150 mm. The right front quarter panel and rear bed were dented. The front end of the vehicle shifted 150 mm to the left. At the rear of the vehicle on the right side, the rear tire and rim sustained damage, the rear axle was pushed back, and the rear U-bolts at the leaf springs were broken. The maximum exterior crush to the front bumper was 470 mm on the front and 340 mm on the right side. The floor pan was separated at the seam just above the upward curve (where the occupant's feet normally rest). The opening in the floor pan at the separation was judged to be wide enough to allow an occupant's foot to become jammed into the opening or go through (see lower photo in figure 19). This result was judged to have a potential for causing serious injury to the occupant. Maximum deformation of the occupant compartment was 199 mm (17.6-percent reduction in space) in the floor pan area and maximum reduction of space was 38.8 percent in the center floor pan to instrument panel area. The interior of the vehicle is shown in figure 19. Exterior vehicle crush and occupant compartment measurements are shown in appendix B, tables 13 and 14.

Figure 15. After-impact trajectory for test 404531-2.

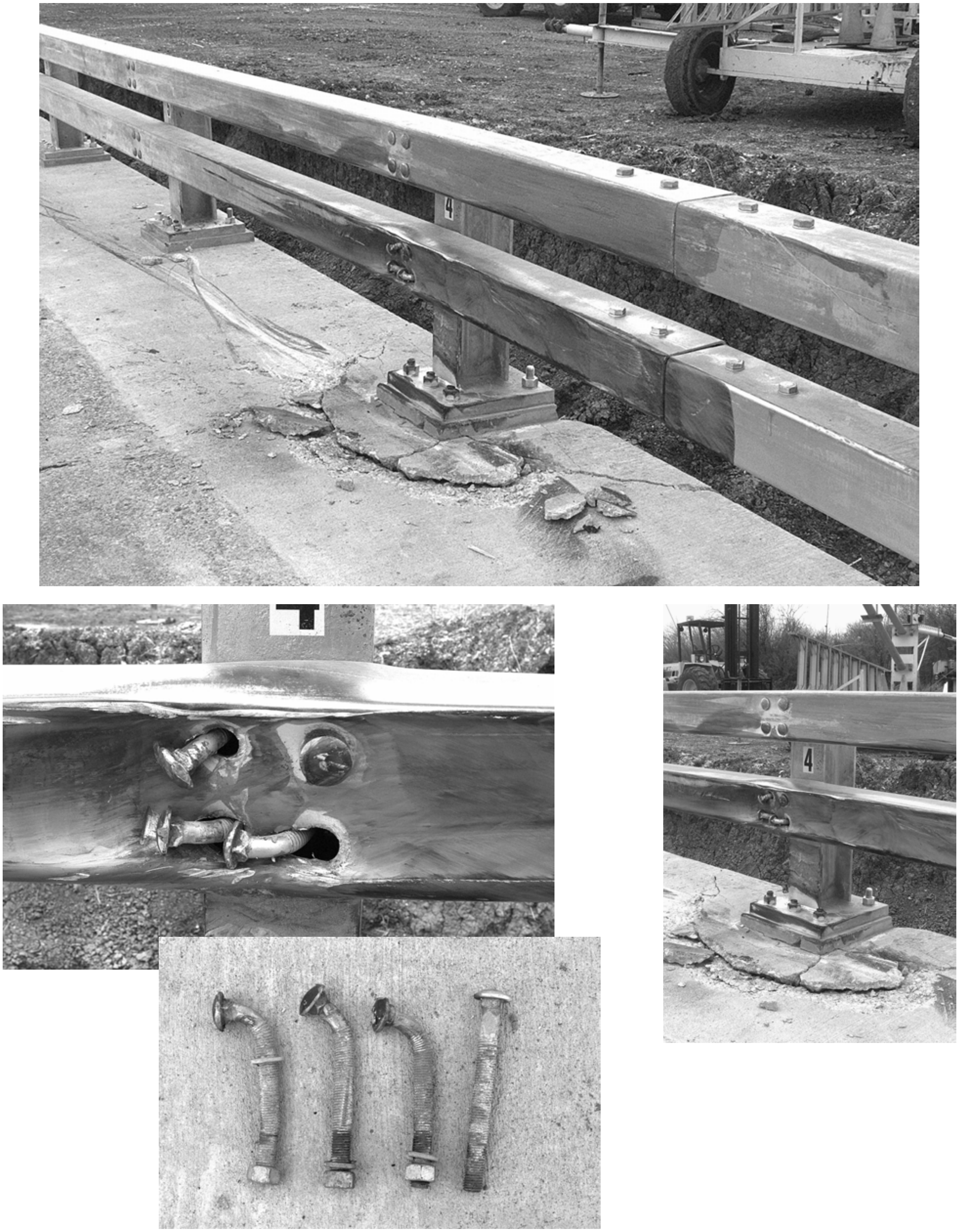


Figure 16. Damage to railing at post 4 after test 404531-2.

After removing concrete

Figure 17. Damage to deck at post 4 after test 404531-2.

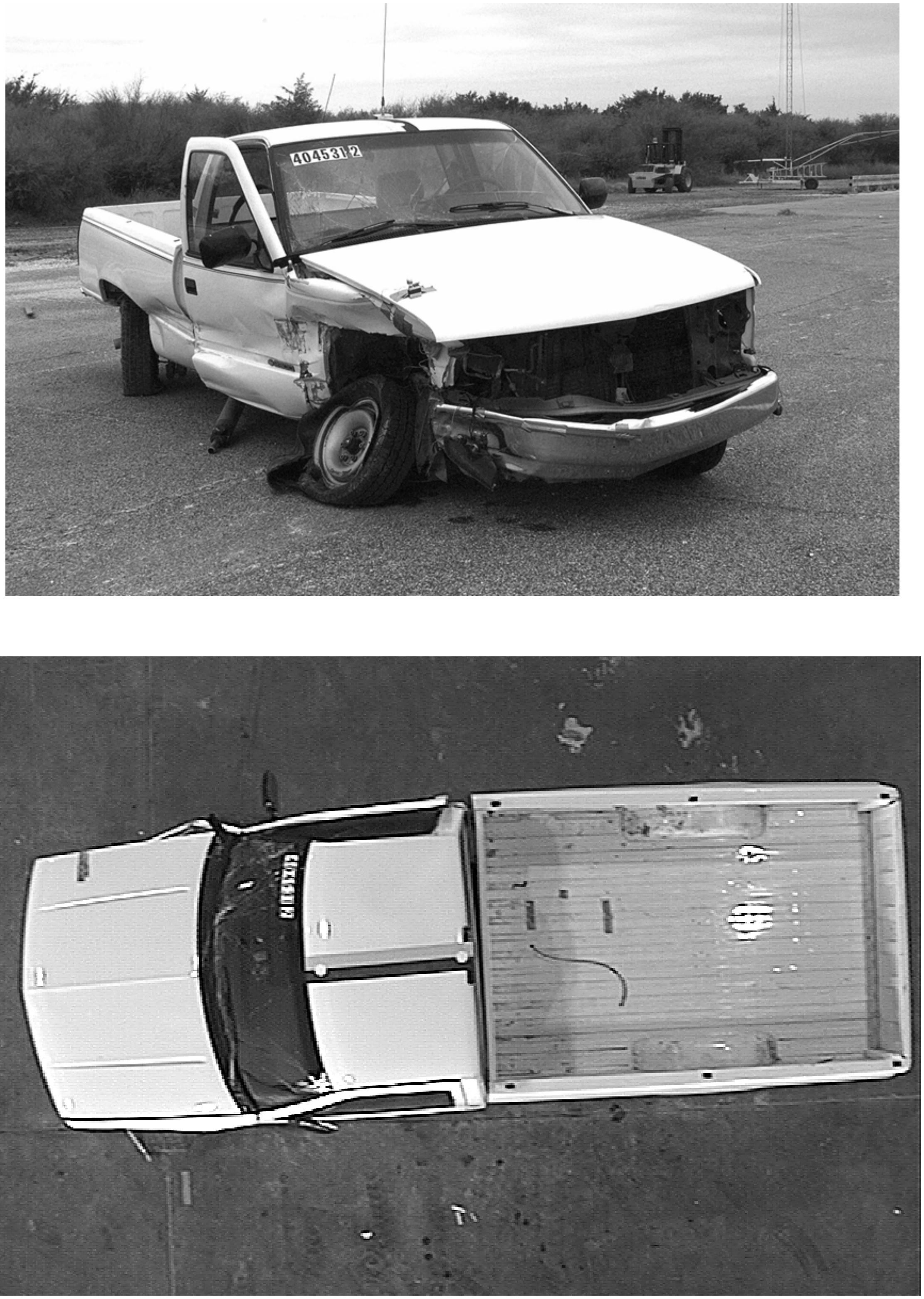


Figure 18. Vehicle after test 404531-2.

Before test

After test

Figure 19. Interior of vehicle for test 404531-2.

Occupant Risk Factors

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 7.1 m/s at 0.160 s, the highest 0.010-s occupant ridedown acceleration was -9.1 g's from 0.104 to 0.114 s, and the maximum 0.050-s average acceleration was -10.1 g's between 0.036 and 0.086 s. In the lateral direction, the occupant impact velocity was 7.2 m/s at 0.098 s, the highest 0.010-s occupant ridedown acceleration was -12.1 g's from 0.131 to 0.141 s, and the maximum 0.050-s average was -12.6 g's between 0.016 and 0.066 s. These data and other pertinent information from the test are summarized in figure 20. Vehicle angular displacements and accelerations versus time traces are presented in appendix D, figures 84 through 97.

Assessment of Test Results

As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **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 New York Two-Rail Curbless Bridge Railing contained and redirected the vehicle. The vehicle did not penetrate, override, or underride the installation.

- **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.*

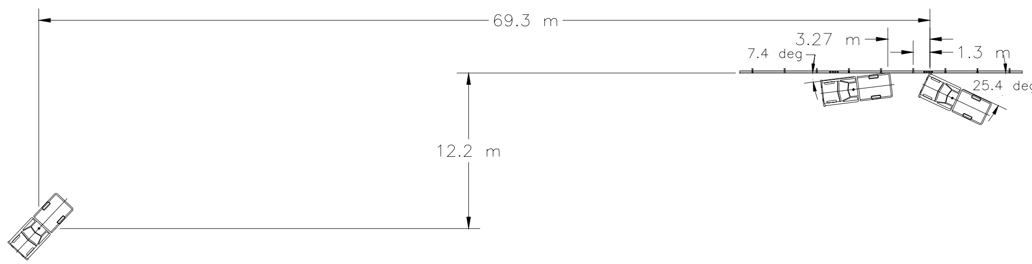
  No detached elements, fragments, or other debris from the test article were present to penetrate or to show the potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. Maximum deformation of the occupant compartment was 199 mm (17.6-percent

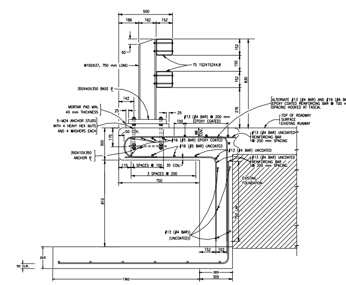
0.000 s

0.097 s

0.193 s

0.387 s





General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 404531-2
- Date 10/27/98

Test Article
- Type . . . . Bridge Railing
- Name . . . . New York 2-Rail Bridge Railing
- Installation Length (m) 22.0
- Material or Key Elements . . Tubular Steel Rail Elements on Steel Wide Flange Posts on deck

Soil Type and Condition . . . . Concrete Deck, Dry

Test Vehicle
- Type . . . . Production
- Designation 2000P
- Model . . . . 1994 Chevrolet 2500 pickup truck
- Mass (kg)
  - Curb 1922
  - Test Inertial 2000
  - Dummy 75
  - Gross Static 2075

Impact Conditions
- Speed (km/h) 101.7
- Angle (deg) 25.4

Exit Conditions
- Speed (km/h) 83.4
- Angle (deg) 7.4

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 7.1
  - y-direction 7.2
- THIV (km/h) 30.3
- Ridedown Accelerations (g's)
  - x-direction . . . . -9.1
  - y-direction . . . . -12.1
- PHD (g's) 13.1
- ASI 1.53
- Max. 0.050-s Average (g's)
  - x-direction . . . . -10.1
  - y-direction . . . . -12.6
  - z-direction . . . . -5.8

Test Article Deflections (m)
- Dynamic 0.05
- Permanent . . . . nil

Vehicle Damage
- Exterior
  - VDS 01RFQ5
  - CDC 01FREK3
- Maximum Exterior @01RYEW3
  - Vehicle Crush (mm) 470
- Interior
  - OCDI RF0214100
- Max. Occ. Compart.
  - Deformation (mm) 199
- Max. Occ. Compart.
  - Reduction of Space (%) . . 38.8

Post-Impact Behavior
- (during 1.0 s after impact)
- Max. Yaw Angle (deg) . . . . . . -32
- Max. Pitch Angle (deg) 6
- Max. Roll Angle (deg) . . . . . . -5

Figure 20. Summary of results for test 404531-2, *NCHRP Report 350* test 4-11.

reduction in space) in the floor pan area and maximum reduction of space was 38.8 percent in the center floor pan to instrument panel area with separation of the floor pan just above the upward curve (where the occupant's feet normally rest).

F. *The vehicle should remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision event.

- **Vehicle Trajectory**

K. *After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

Intrusion into adjacent traffic lanes occurred as the vehicle came to rest 12.2 m toward traffic.

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.*

In the longitudinal direction, the occupant impact velocity was 7.1 m/s and occupant ridedown acceleration was -9.1 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.*

Exit angle at loss of contact was 7.4 degrees, which was less than 60 percent of the impact angle.

TEST 404531-3 (*NCHRP REPORT 350* TEST DESIGNATION 4-12)

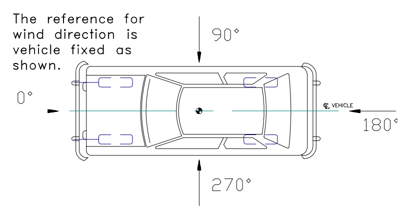
The installation used for this test was used in the previous two tests. The bridge deck was damaged around the fourth post from the end during the second test (with the pickup truck). The bridge deck was repaired as per instructions from New York DOT personnel and, for this test, the impact point was chosen in the opposite direction of the previous tests to avoid the damaged area.

Test Vehicle

A 1984 Chevrolet C70 single-unit truck, shown in figures 21 and 22, was used for the crash test. Test inertia weight of the vehicle was 8000 kg, and its gross static weight was 8000 kg. The height to the lower edge of the vehicle front bumper was 540 mm and to the upper edge of the front bumper was 860 mm. Additional dimensions and information on the vehicle are given in appendix B, figure 55. 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.

Soil and Weather Conditions

The crash test was performed the afternoon of January 13, 1999. No rainfall was recorded for the 10 days prior to the test. Weather conditions at the time of testing were as follows: Wind Speed: 8 km/h; Wind Direction: 5 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 14EC; Relative Humidity: 53 percent.



Impact Description

The 8000 kg single-unit truck impacted the New York Two-Rail Curbless Bridge Railing 1.6 m upstream of post 4. Upon impact, the vehicle was traveling at a speed and angle of 82.6 km/h and 15.5 degrees. Shortly after impact the front bumper of the vehicle shifted back and at 0.016 s the left front tire contacted the rail element. At 0.017 s the rail element moved at the joint and at 0.026 s posts 3 and 4 moved. By 0.028 s, there was noticeable deformation of the rail element and at 0.044 s the left front tire lost contact with the ground. The right front wheel steered toward the railing at 0.056 s and the vehicle began to redirect at 0.079 s. At 0.089 s the front of the vehicle contacted post 4 and at 0.163 s the left front tire returned to the ground. The front of the vehicle contacted post 5 at 0.194 s and the left rear wheel contacted the railing at 0.276 s. At 0.298 s the vehicle was traveling parallel with the railing, and the vehicle was traveling at a speed of 75.2 km/h. The left front tire lost contact with the railing at 0.303 s and the deck around post 4 cracked at 0.307 s. Post 5 moved at 0.322 s and the bottom of the box-van at the left front corner contacted the top of the rail element. As the box-van rode along the top of

Figure 21. Vehicle/installation geometrics for test 404531-3.

Figure 22. Vehicle before test 404531-3.

the railing, the edge caught on the top of post 6 at 0.434 s. The left front tire contacted the rail element again at 0.578 s. At 0.829 s the vehicle lost contact with the bridge railing. Exit angle and speed were not attainable from the overhead camera; however, estimating from the tire marks, the vehicle exited the railing at approximately 2 degrees. Brakes on the vehicle were not applied. The vehicle contacted a second barrier downstream of the bridge railing and subsequently came to rest 42.7 m down from the impact point and in line with the bridge railing (against the second barrier). Sequential photographs of the test period are shown in appendix C, figures 63 and 64.

Damage to Test Article

Damage to the New York Two-Rail Curbless Bridge Railing is shown in figures 23 through 25. The bolts in the base of post 4 were rotated up and the rail element was partially flattened. The bolts in the lower rail element at post 4 were partially pulled out and deformed. The concrete deck around post 4 was structurally damaged. The vehicle was in contact with the bridge railing for 4.33 m. The bottom of the box-van caught the top of post 6, which rotated slightly. The vehicle lost contact, impacted the bridge railing again 400 mm downstream of post 7, and then rode along and off the end of the railing. Maximum dynamic deflection of the rail element was not attainable due to the vehicle size. Maximum permanent deformation was 30 mm.

Vehicle Damage

Damage to the vehicle is shown in figure 26. Structural damage included deformed left front springs, U-bolts and shock bolt. Also damaged were the front bumper, left front quarter panel, left door, left side fuel tank, left front and rear outside wheel rims, and the under side of the box-van on the left front corner. Maximum exterior crush was 230 mm to the left side at the front corner near bumper height. Maximum occupant compartment deformation was 80 mm at the side panel near the driver door. The interior of the vehicle is shown in figure 27.

Occupant Risk Factors

Data from the accelerometer located at the vehicle center of gravity were digitized for informational purposes only and were computed as follows. In the longitudinal direction, the occupant impact velocity was 2.4 m/s at 0.422 s, the highest 0.010-s occupant ridedown acceleration was -2.4 g’s from 0.990 to 1.000 s, and the maximum 0.050-s average acceleration was -1.1 g’s between 0.166 and 0.216 s. In the lateral direction, the occupant impact velocity was 3.1 m/s at 0.183 s, the highest 0.010-s occupant ridedown acceleration was 2.5 g’s from 0.231 to 0.241 s, and the maximum 0.050-s average was 3.1 g’s between 0.000 and 0.050 s. These data and other pertinent information from the test are summarized in figure 28. Vehicle angular displacements and accelerations versus time traces are presented in appendix D, figures 98 through 107.

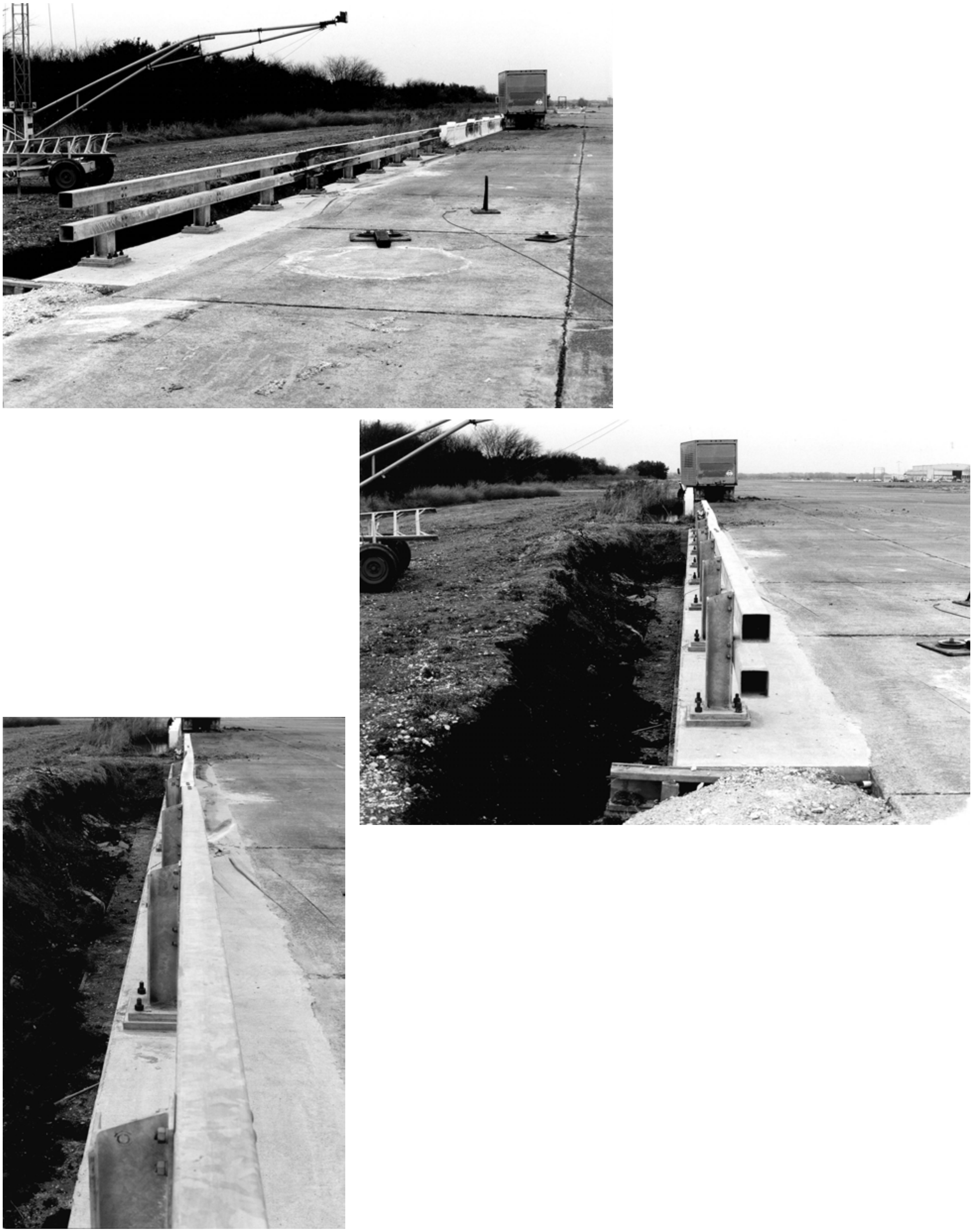


Figure 23. Vehicle trajectory path after test 404531-3.

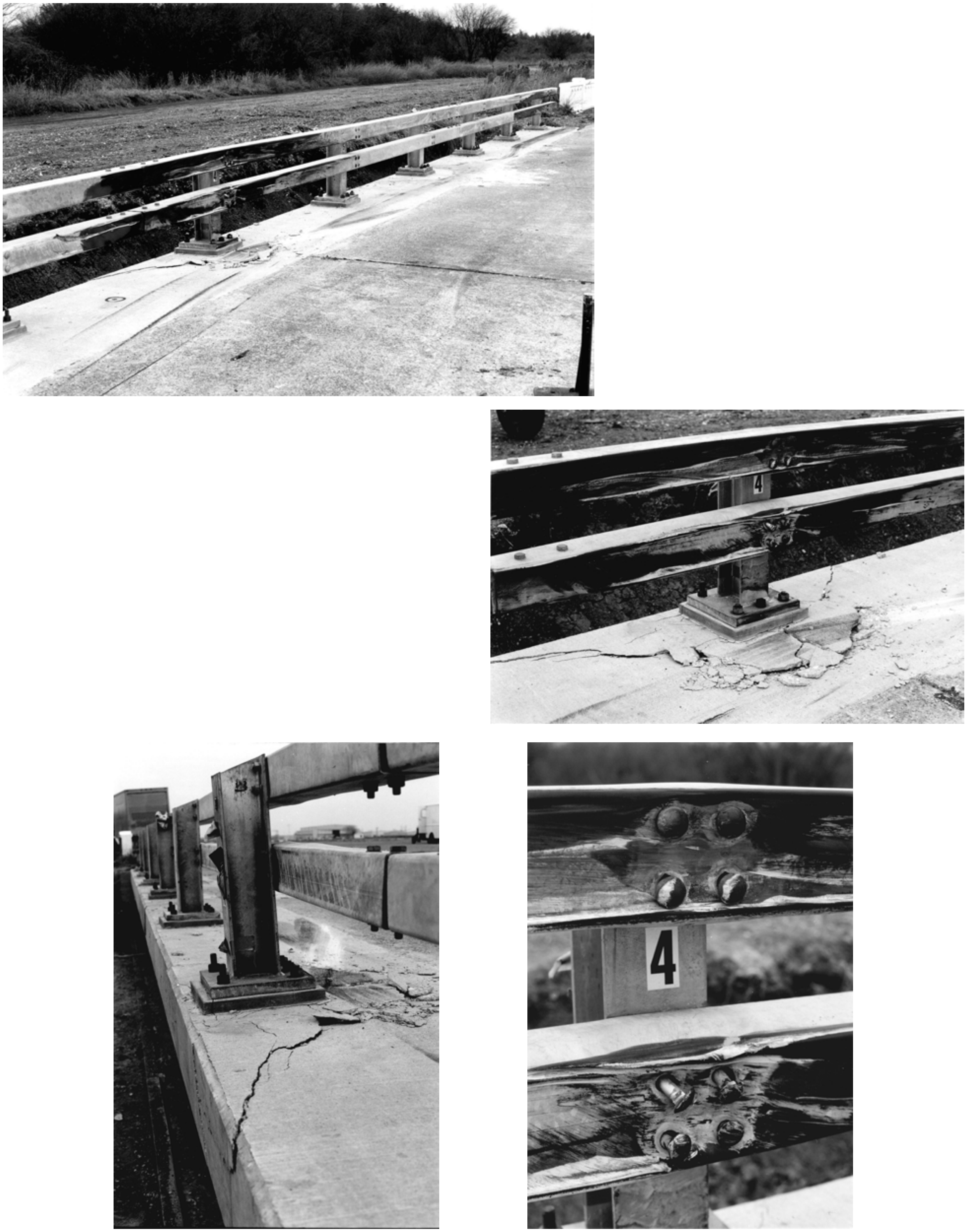


Figure 24. Damage at post 4 after test 404531-3.

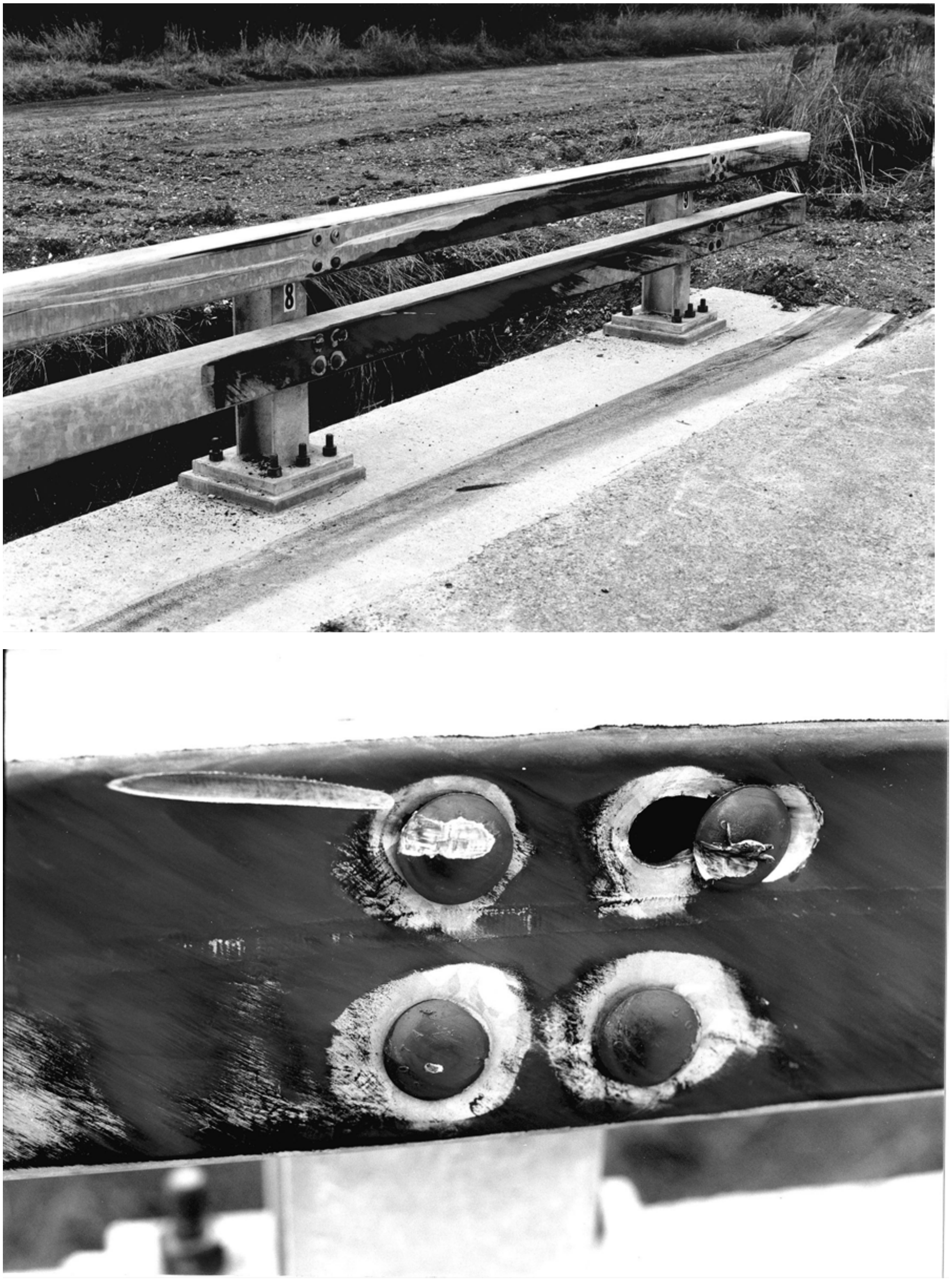


Figure 25. Damage at post 8 after test 404531-3.

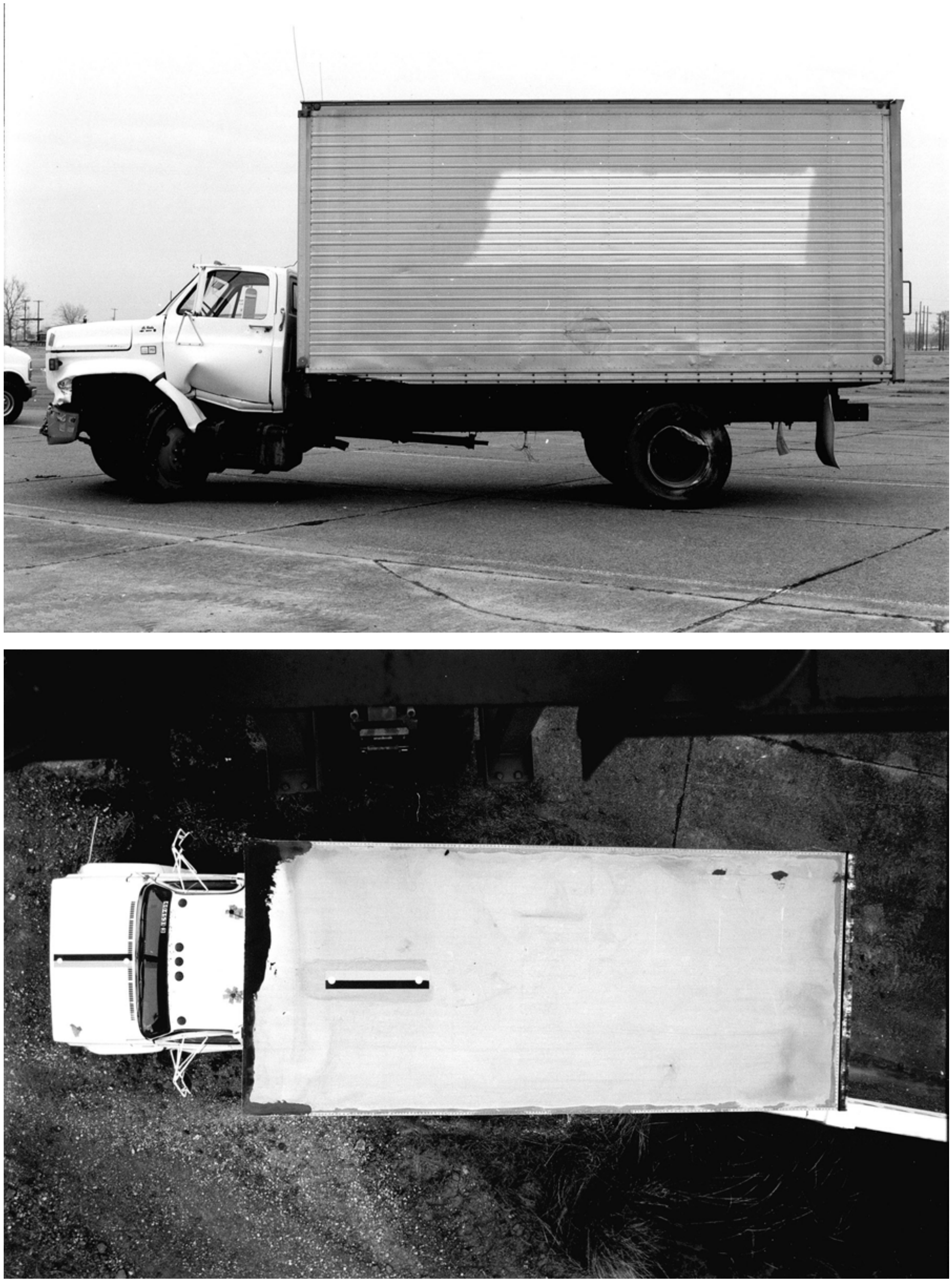
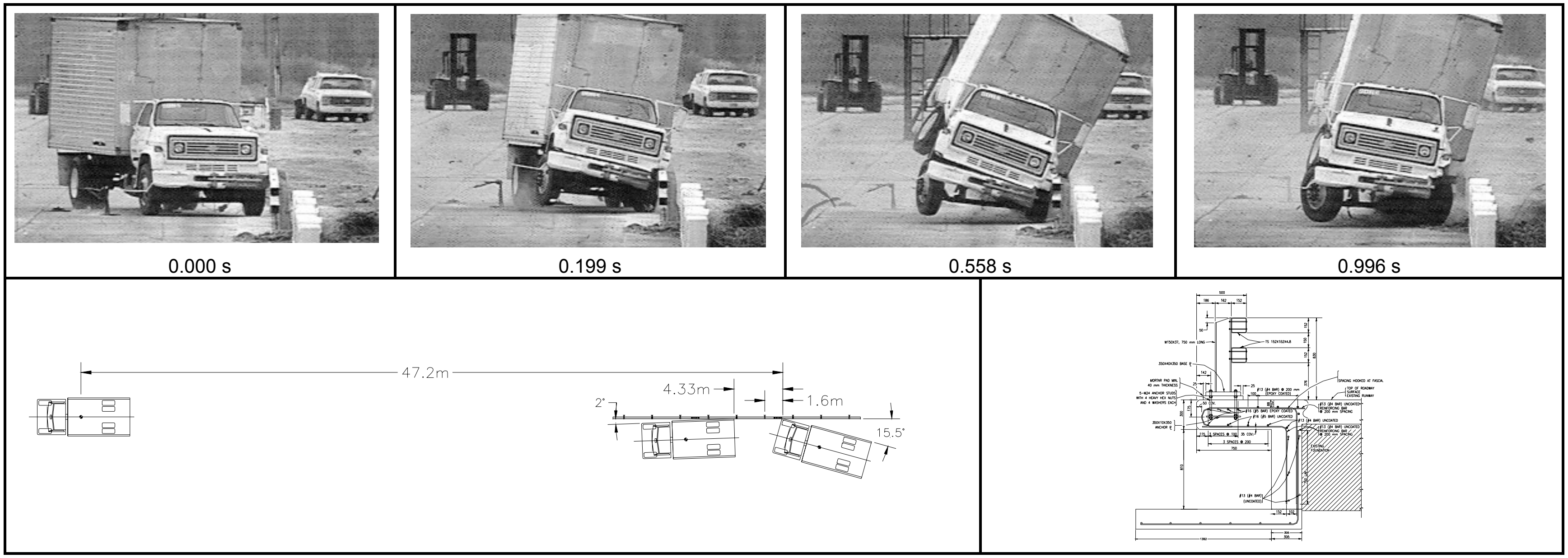


Figure 26. Vehicle after test 404531-3.

Before test

After test

Figure 27. Interior of vehicle for test 404531-3.



General Information	
Test Agency	Texas Transportation Institute
Test No.	404531-3
Date	01/13/99
Test Article	
Type	Bridge Railing
Name	New York 2-Rail Bridge Railing
Installation Length (m)	22.0
Material or Key Elements	Tubular Steel Rail Elements on Steel Wide-Flange Posts on deck
Soil Type and Condition	Concrete Deck, Dry
Test Vehicle	
Type	Production
Designation	8000S
Model	1984 Chevrolet single-unit truck
Mass (kg)	
Curb	5112
Test Inertial	8000
Dummy	No Dummy
Gross Static	8000

Impact Conditions	
Speed (km/h)	82.6
Angle (deg)	15.5
Exit Conditions	
Speed (km/h)	N/A
Angle (deg)	approx. 2
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	3.0
y-direction	2.5
THIV (km/h)	10.2
Ridedown Accelerations (g's)	
x-direction	-2.3
y-direction	5.2
PHD (g's)	5.2
ASI	0.35
Max. 0.050-s Average (g's)	
x-direction	-1.9
y-direction	3.1
z-direction	-2.7

Test Article Deflections (m)	
Dynamic	N/A
Permanent	0.03
Vehicle Damage	
Exterior	
VDS	N/A
CDC	N/A
Maximum Exterior Vehicle Crush (mm)	230
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	80
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	13
Max. Pitch Angle (deg)	-3
Max. Roll Angle (deg)	-14

Figure 28. Summary of results for test 404531-3, *NCHRP Report 350* test 4-12.

Assessment of Test Results

As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **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 New York Two-Rail Curbless Bridge Railing contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation.

- **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.*

  No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, nor to present hazard to others in the area. Maximum occupant compartment deformation was 80 mm in the side panel near the driver door.

  G. *It is preferable, although not essential, that the vehicle remain upright during and after the collision.*

  The vehicle remained upright during and after the collision event.

- **Vehicle Trajectory**

  K. *After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

  The vehicle came to rest 47.2 m down from impact and in line with the face of the bridge railing and would not intrude into adjacent traffic.

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.*

Exit angle at loss of contact was not attainable from the overhead camera. However, according to wheel marks on the deck, the vehicle was traveling at an approximate 2 degree angle.

V. TESTING OF THE NEW YORK FOUR-RAIL CURBLESS BRIDGE RAILING

Two of the three *NCHRP Report 350* TL-4 tests were performed on the New York Four-Rail Curbless Bridge Railing.

> ***NCHRP Report 350* test designation 4-12**: An 8000-kg single-unit truck impacting the CIP in the LON of the longitudinal barrier at a nominal speed and angle of 80 km/h and 15 degrees.

> ***NCHRP Report 350* test designation 4-11**: A 2000-kg pickup truck impacting the CIP in the LON of the longitudinal barrier at a nominal speed and angle of 100 km/h and 25 degrees.

Details of the construction of the New York Four-Rail Curbless Bridge Railing are discussed in Chapter III and shown in figures 3 and 4.

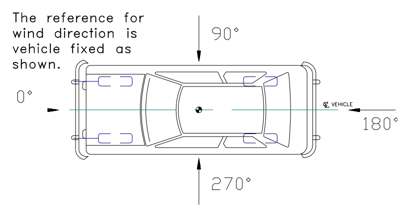
TEST 404531-4 (*NCHRP REPORT 350* TEST DESIGNATION 4-12)

Test Vehicle

A 1984 GMC 7000 single-unit truck, shown in figures 29 and 30, was used for the crash test. Test inertia weight of the vehicle was 8000 kg, and its gross static weight was 8000 kg. The height to the lower edge of the vehicle front bumper was 530 mm and to the upper edge of the front bumper was 820 mm. Additional dimensions and information on the vehicle are given in appendix B, figure 56. 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.

Weather Conditions

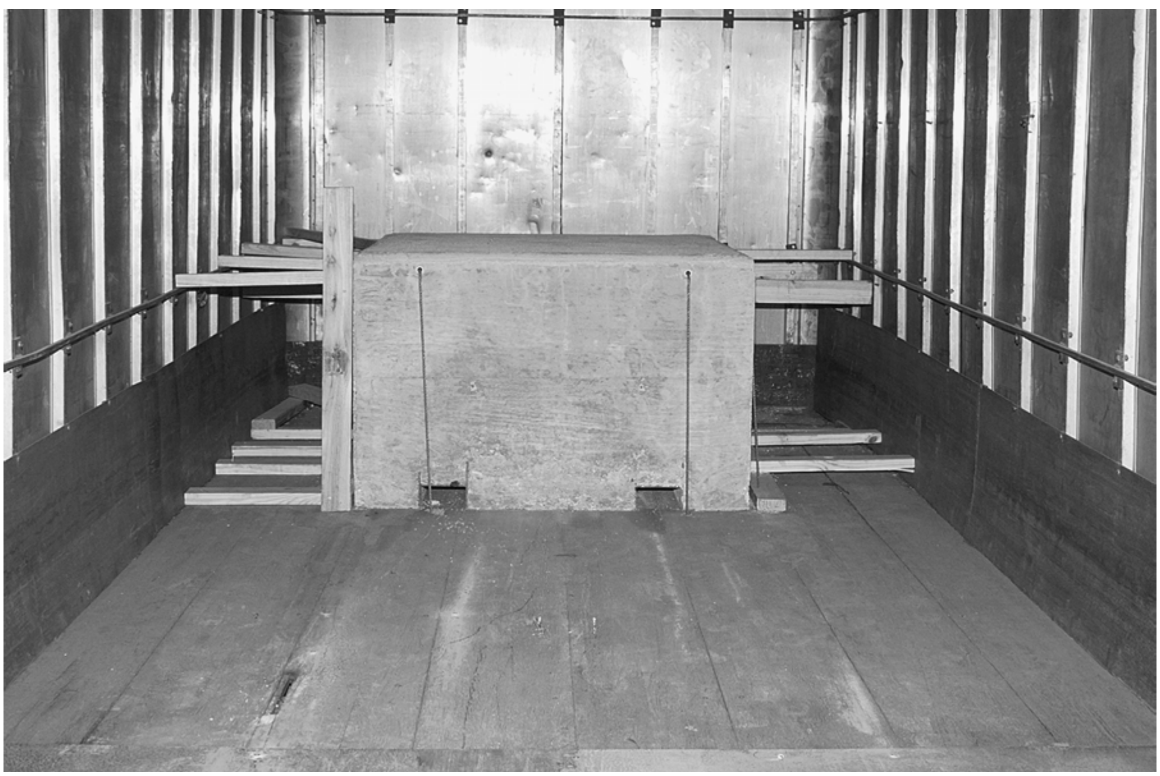
The crash test was performed the morning of March 25, 1999. Six days before the test 36 mm of rainfall was recorded. No other rainfall of significance was recorded during the remaining ten days prior to the test. Weather conditions at the time of testing were as follows: Wind Speed: 21 km/h; Wind Direction: 15 degrees with respect to the vehicle (vehicle was traveling in a northwesterly direction); Temperature: 16EC; Relative Humidity: 73 percent.



Impact Description

The vehicle, traveling at 83.7 km/h, impacted the four-rail bridge railing at post 3, at a 15.5 degree angle. Shortly after impact, the front left quarter panel of the vehicle contacted the rail element. At 0.011 s, the second and third rail elements moved, and at 0.016 s, post 4 moved. By 0.036 s, post 5 moved, and by 0.044 s, the front left tire lost contact with the ground. The vehicle contacted the top rail element at the splice between posts 3 and 4 at 0.050 s. The vehicle began to redirect at 0.097 s. At 0.102 s, the bottom left corner of the box van contacted the top rail element, and at 0.206 s, the front left tire returned to the ground. At 0.215 s the vehicle was traveling parallel with the railing, and the vehicle was traveling at a speed of 80.2 km/h. By 0.237 s, post 3 moved, and by 0.245 s the right rear tires lost contact with the ground. At 0.772 s, traveling at 73.1 km/h, the vehicle lost contact with the bridge railing at an exit angle of 1.4 degrees. The rear and front right tires returned to the ground at 0.859 s and 0.954 s; respectively. At 1.397 s, the hood of the vehicle came open. Brakes on the vehicle were not applied. At 1.403 s, the vehicle contacted a second barrier downstream of the bridge railing and subsequently stopped 57.2 m down from the impact point and 4.8 m behind the test installation. The vehicle came to rest over its separated front axle, which was situated parallel with the longitudinal axis of the vehicle. As the vehicle stopped, the position of the axle caused the vehicle to rock over onto its left side. Sequential photographs of the test period are shown in appendix C, figures 65 and 66.

Figure 29. Vehicle/installation geometrics for test 404531-4.



Interior of vehicle.

Figure 30. Vehicle before test 404531-4.

Damage to Test Article

Damage to the New York Four-Rail Curbless Bridge Railing is shown in figures 31 through 33. The lower TS 152x152x4.8 tube was deformed inward where the vehicle made initial contact. The concrete deck around post 3 and 4 was structurally damaged. The vehicle was in contact with the railing 5.0 m and then again from post 8 to the end of the installation. Maximum dynamic deflection was not attainable due to vehicle blocking the view. Maximum permanent deformation was 10 mm.

Vehicle Damage

The vehicle sustained damage to the left front corner as shown in figures 34 and 35. The front axle, springs, and shocks were separated from the vehicle. The steering arm, rod ends, and left front frame were deformed. Also damaged were the front bumper, hood, grill, fan, radiator, left front quarter panel, left door and step, left front tire and rim, left side of the box, right front quarter panel, and left rear outside tire and rim. The fuel tank straps were loose and the floor pan and firewall were slightly deformed. Maximum exterior crush to the vehicle was 300 mm to the left front corner at bumper height. No measurable deformation occurred to the interior occupant compartment. The interior of the vehicle is shown in figure 36.

Occupant Risk Factors

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 2.7 m/s at 0.350 s, the highest 0.010-s occupant ridedown acceleration was -4.5 g's from 0.985 to 0.995 s, and the maximum 0.050-s average acceleration was -1.7 g's between 0.044 and 0.094 s. In the lateral direction, the occupant impact velocity was 3.7 m/s at 0.185 s, the highest 0.010-s occupant ridedown acceleration was -5.2 g's from 0.285 to 0.295 s, and the maximum 0.050-s average was -4.0 g's between 0.077 and 0.127 s. These data and other pertinent information from the test are summarized in figure 37. Vehicle angular displacements and accelerations versus time traces are presented in appendix D, figures 108 through 117.

Assessment of Test Results

As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  A. *Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation*

Figure 31. Vehicle trajectory path after test 404531-4.

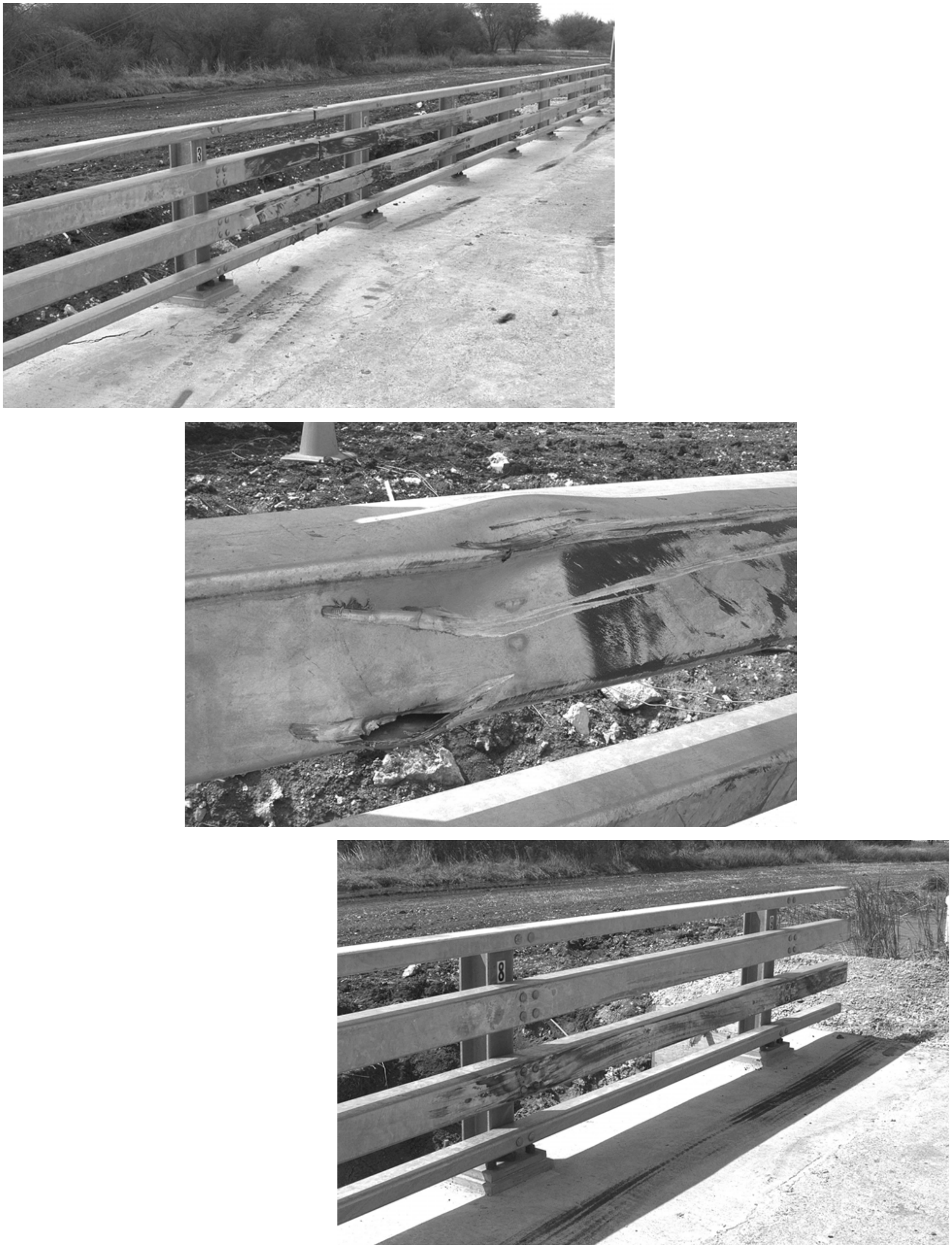


Figure 32. Installation after test 404531-4.

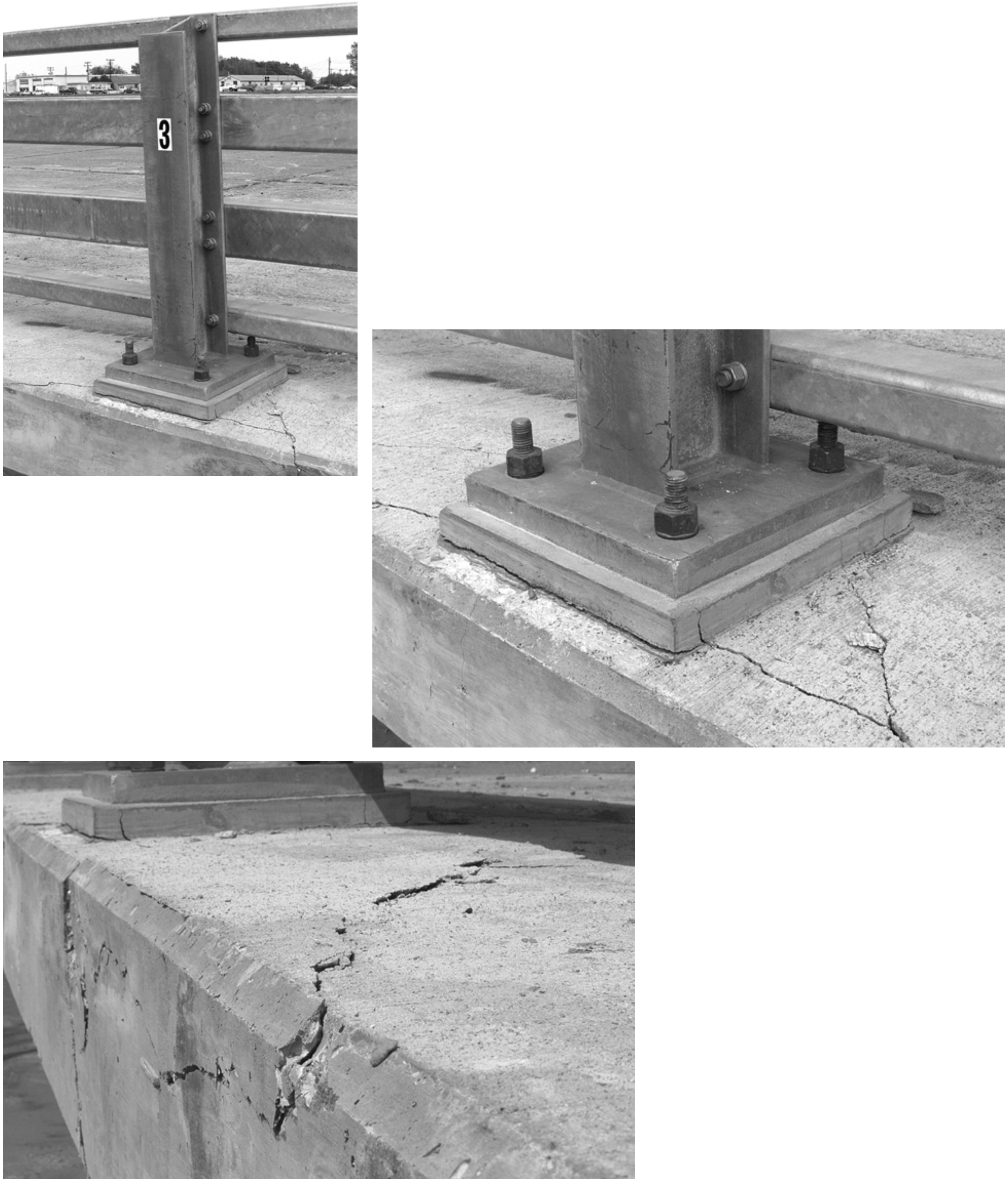


Figure 33. Damage to deck at post 3 after test 404531-4.

Vehicle after being righted.

Figure 34. Vehicle after test 404531-4.

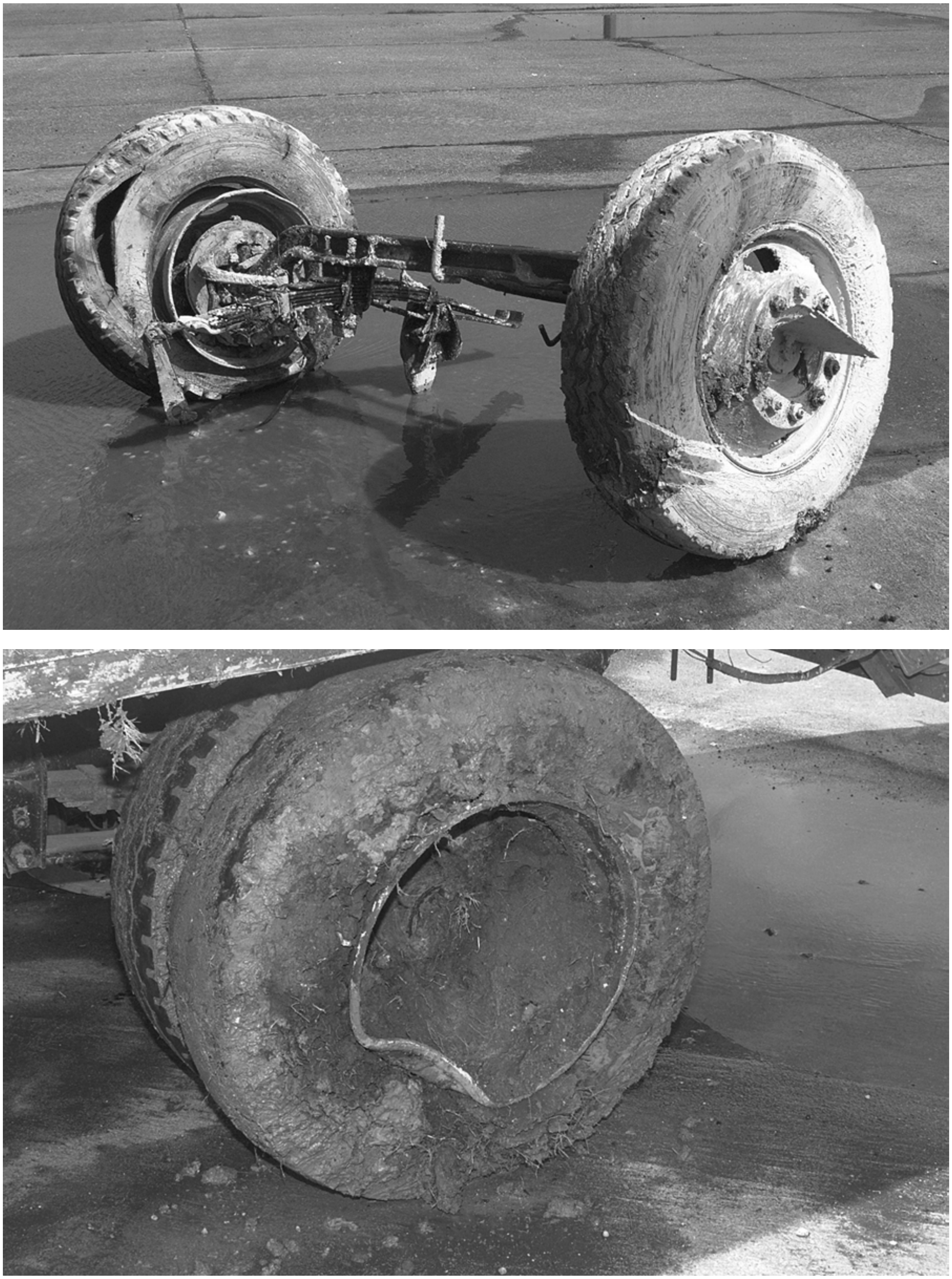


Figure 35. Axle and wheel damage after test 404531-4.

Before test

After test

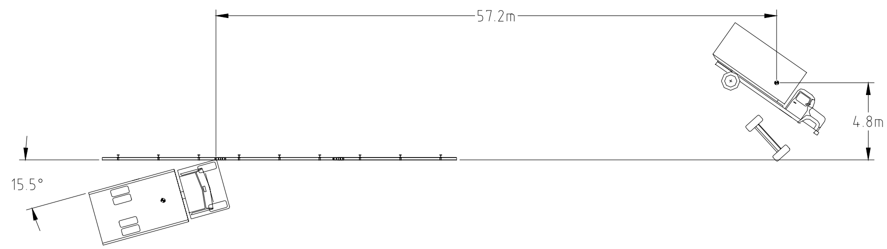
Figure 36. Interior of vehicle for test 404531-4.

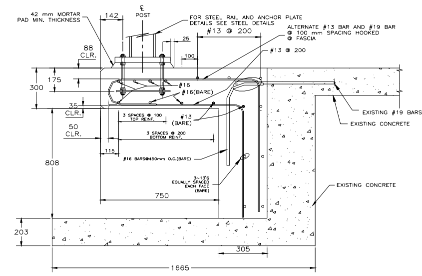
0.000 s

0.095 s

0.261 s

0.474 s





General Information

Test Agency	Texas Transportation Institute
Test No.	404531-4
Date	03/25/99
Test Article	
Type	Bridge Railing
Name or Manufacturer	New York 4-Rail Curbless Bridge Railing
Installation Length (m)	22.0
Material or Key Elements	Tubular Steel Rail Elements on Steel Wide Flange Posts on deck
Soil Type and Condition	Concrete Deck, dry
Test Vehicle	
Type	Production
Designation	8000S
Model	1984 GMC single-unit truck
Mass (kg)	
Curb	5067
Test Inertial	8000
Dummy	No Dummy
Gross Static	8000

Impact Conditions

Speed (km/h)	83.7
Angle (deg)	15.5
Exit Conditions	
Speed (km/h)	73.1
Angle (deg)	1.4
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	2.7
y-direction	3.7
THIV (km/h)	16.7
Ridedown Accelerations (g's)	
x-direction	-4.5
y-direction	-5.2
PHD (g's)	7.5
ASI	0.47
Max. 0.050-s Average (g's)	
x-direction	-1.7
y-direction	-4.0
z-direction	2.2

Test Article Deflections (m)

Dynamic	N/A
Permanent	0.01
Vehicle Damage	
Exterior	
VDS	N/A
CDC	N/A
Maximum Exterior Vehicle Crush (mm)	300
Interior	
OCDI	N/A
Max. Occ. Compart. Deformation (mm)	N/A
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	15
Max. Pitch Angle (deg)	4
Max. Roll Angle (deg)	14

Figure 37. Summary of results for test 404531-4, *NCHRP Report 350* test 4-12.

although controlled lateral deflection of the test article is acceptable.

The New York Four-Rail Curbless Bridge Railing contained and redirected the 8000S vehicle. The vehicle did not penetrate, underride, or override the installation. Minimal lateral deflection occurred; however, the bridge deck was structurally damaged around the posts on either side of impact.

- **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.*

No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. No deformation of the occupant compartment occurred.

G. *It is preferable, although not essential, that the vehicle remain upright during and after the collision.*

The 8000S vehicle remained upright and stable during and immediately after the impact. The front axle was separated from the vehicle and as the vehicle came to rest, the axle was under the vehicle in a parallel direction along the length of the vehicle. The vehicle leaned and then rolled onto its left side after coming to a complete stop.

- **Vehicle Trajectory**

K. *After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes as it came to rest in line and slightly behind the installation.

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.*

The exit angle at loss of contact was 1.4 degrees which was 9 percent of the impact angle.

TEST 404531-6 (*NCHRP REPORT 350* TEST DESIGNATION 4-11)

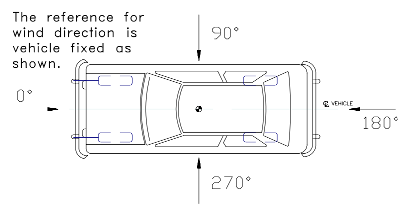
The installation used for this test was used in a previous test with a single-unit truck. The bridge deck was damaged around the third and fourth post from the end in the previous test. The bridge deck was repaired as per instructions from New York DOT personnel and, for this test, the impact point was chosen in the opposite direction of the previous test to avoid the damaged area.

Test Vehicle

A 1994 Chevrolet 2500 pickup truck, shown in figures 38 and 39, was used for the crash test. Test inertia weight of the vehicle was 2000 kg, and its gross static weight was 2076 kg. The height to the lower edge of the vehicle front bumper was 390 mm and to the upper edge of the front bumper was 610 mm. Additional dimensions and information on the vehicle are given in appendix B, figure 57. 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.

Weather Conditions

The crash test was performed the morning of March 29, 1999. The day before and four days before the test 5 mm of rainfall was recorded for each day and ten days before the test 36 mm was recorded. Weather conditions at the time of testing were as follows: Wind Speed: 13 km/h; Wind Direction: 155 degrees with respect to the vehicle (vehicle was traveling southwesterly direction); Temperature: 15EC; Relative Humidity: 90 percent.



Impact Description

The 2000P truck impacted the New York Four-Rail Curbless Bridge Railing 1.4 m upstream from post 6. Upon impact, the vehicle was traveling at a speed and angle of 100.3 km/h and 25.1 degrees. At 0.028 s, post 6 moved, and at 0.041 s, the vehicle began to redirect. The first visible cracks in the deck appeared on the field side of the installation at 0.052 s. By 0.062 s, the passenger side window of the vehicle shattered, and by 0.131 s, the left front tire lost contact with the ground. The rear of the vehicle contacted the rail element at 0.174 s. Traveling at 87.3 km/h, the vehicle was traveling parallel to the test installation at 0.175 s. At 0.263 s, traveling at 94.6 km/h, the vehicle lost contact with the bridge railing at a 4.3 degree angle. The left front tire returned to the ground at 0.282 s. As the vehicle exited the railing, it was tracking straight forward. Brakes on the vehicle were applied at 1.4 seconds, and the vehicle yawed clockwise and lightly contacted a protective barrier. The vehicle rolled back and subsequently came to rest 70 m downstream and 5.5 m toward traffic lanes. Sequential photographs of the test period are shown in appendix C, figures 67 and 68.

Figure 38. Vehicle/installation geometrics for test 404531-6.

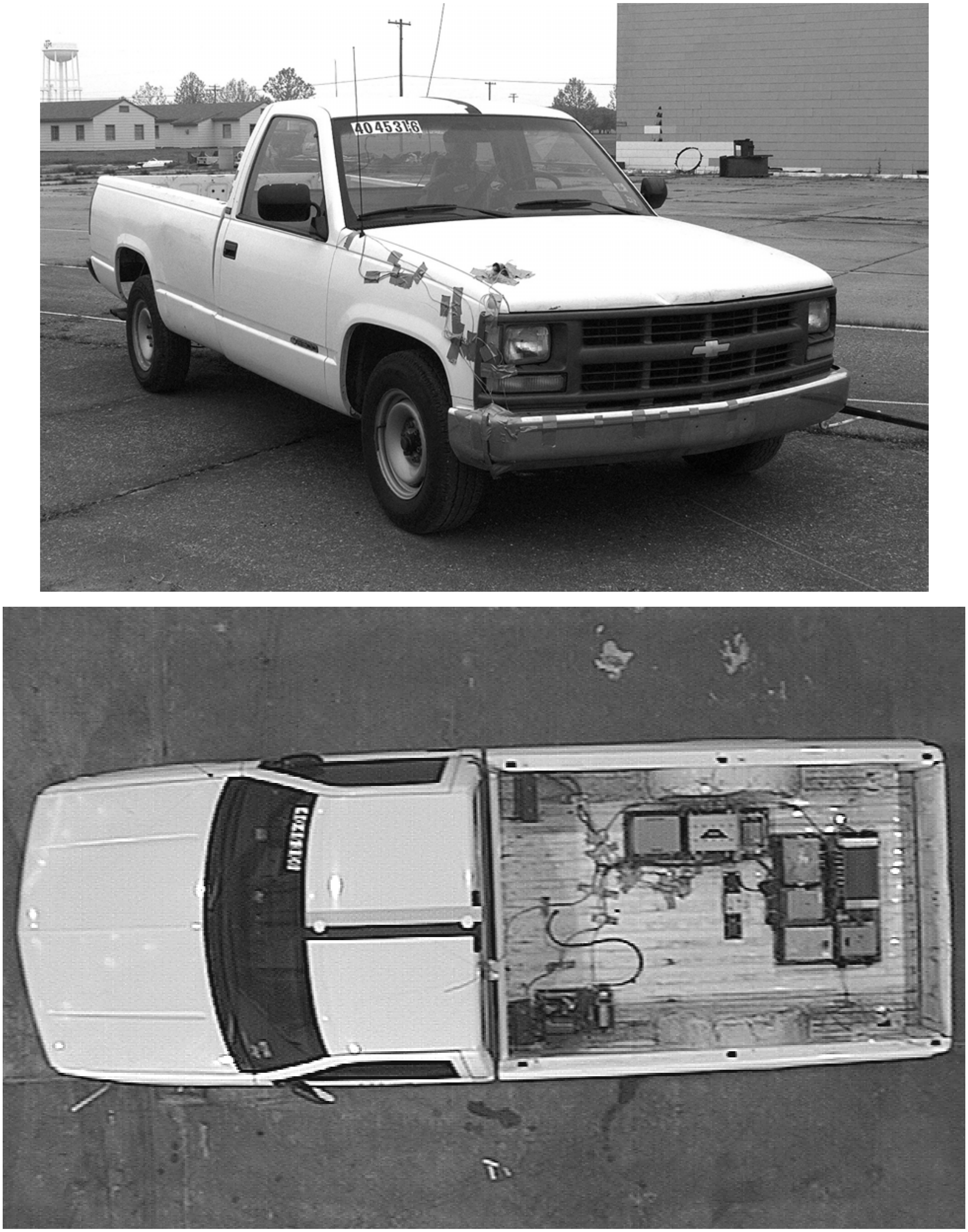


Figure 39. Vehicle before test 404531-6.

Damage to Test Article

Damage to the New York Four-Rail Curbless Bridge Railing is shown in figures 40 and 41. The bolts in the lower, wider rail element at post 6 were partially pulled out and deformed and the rail element was deformed inward. Cracks in the concrete bridge deck radiated toward the rear of the deck from the rear bolts at the base of post 7. The concrete deck around post 6 was structurally damaged. Length of contact of the vehicle with the rail element was 3.47 m. Maximum dynamic deflection of the rail element was 100 mm and maximum permanent deformation was 55 mm at post 6.

Vehicle Damage

The 2000P vehicle was damaged as shown in figure 42. Structural damage was sustained by the right side upper and lower A-arms, rod ends, idler arm, stabilizer bar, engine supports, transmission supports and the right front frame. Also damaged were the front bumper, hood, grill, fan, radiator, radiator supports, right front quarter panel, right door and window glass, right side of the bed, and right front tire and rim. The windshield was shattered and the A and B pillars deformed. The floor pan and fire wall were deformed. Maximum exterior crush to the vehicle was 410 mm at the right front corner at bumper height. Maximum occupant compartment deformation was 65 mm (6 percent reduction in space) in the floor pan area. Also of note, the female end of the seat belt attachment broke apart allowing the seat belt to come loose. The interior of the vehicle is shown in figure 43. Exterior vehicle crush and occupant compartment measurements are shown in appendix B, tables 15 and 16.

Occupant Risk Factors

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, occupant impact velocity was 6.7 m/s at 0.162 s, maximum 0.010-s ridedown acceleration was -10.1 g's from 0.092 to 0.102 s, and the maximum 0.050-s average was -8.4 g's between 0.046 and 0.096 s. For informational purposes, in the lateral direction, the occupant impact velocity was 8.2 m/s at 0.092 s, the highest 0.010-s occupant ridedown acceleration was -14.6 g's from 0.202 to 0.212 s, and the maximum 0.050-s average was -14.1 g's between 0.027 and 0.077 s. These data and other information pertinent to the test are presented in figure 44. Vehicle angular displacements and accelerations versus time traces are shown in appendix D, figures 118 through 131.

Figure 40. Vehicle trajectory path after test 404531-6.

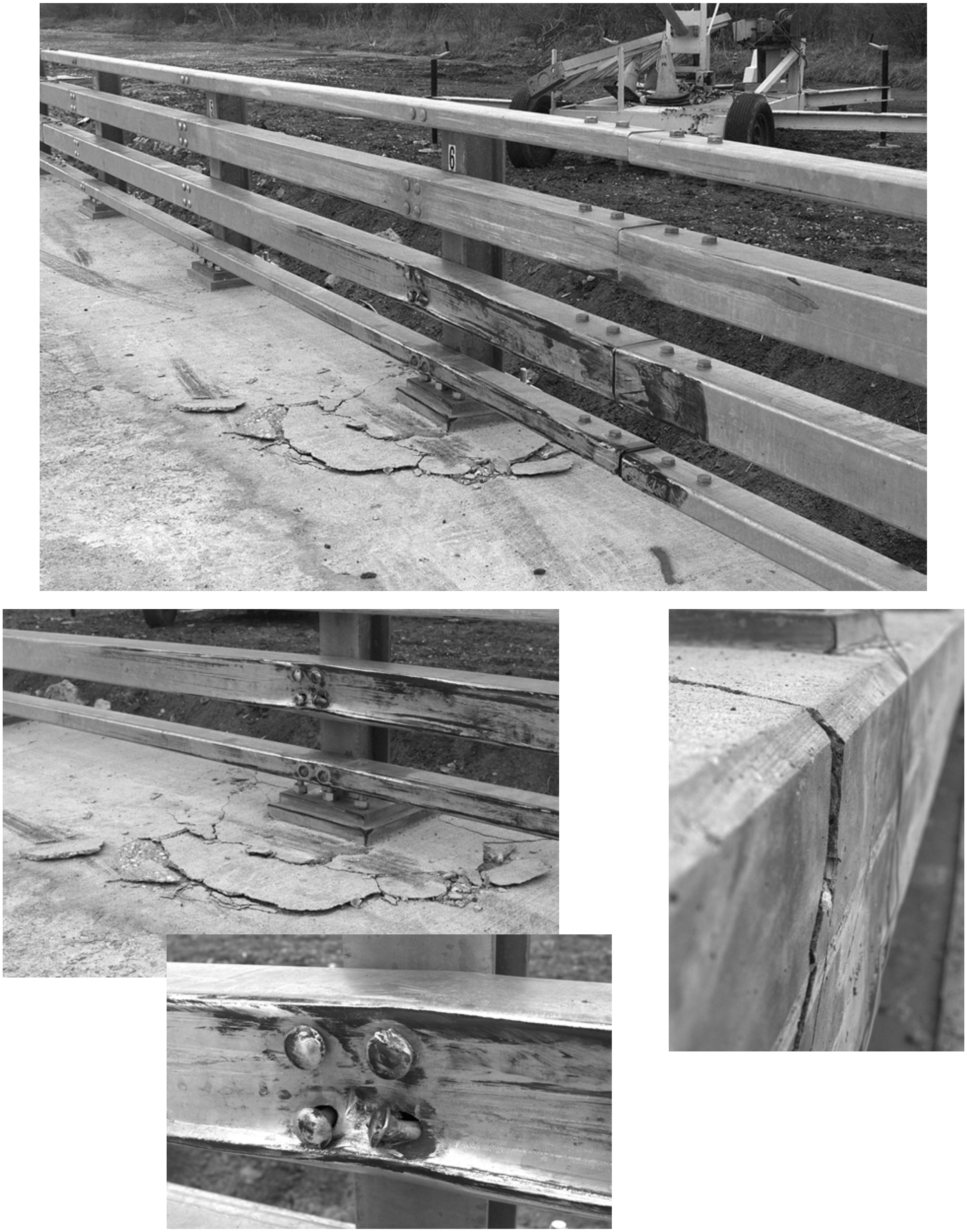
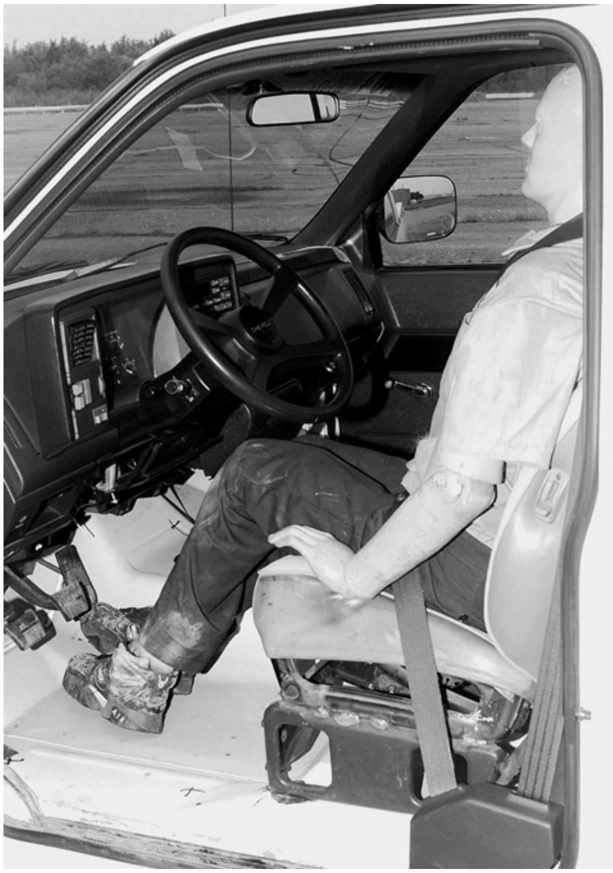


Figure 41. Installation after test 404531-6.

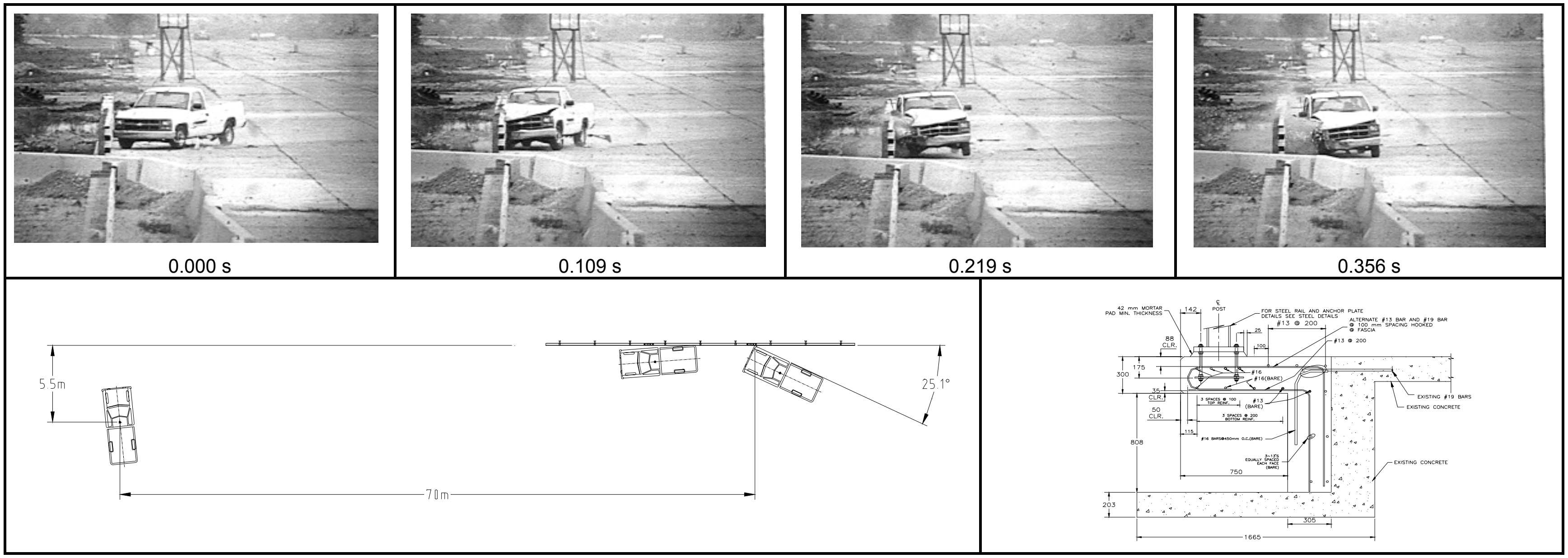
Figure 42. Vehicle after test 404531-6.



Before test

After test

Figure 43. Interior of vehicle for test 404531-6.



General Information
- Test Agency .... Texas Transportation Institute
- Test No. 404531-6
- Date 03/29/99

Test Article
- Type .... Bridge Railing
- Name or Manufacturer .... New York 4-RailCurbless Bridge Railing
- Installation Length (m) 22.0
- Material or Key Elements .. Tubular Steel Rail Elements on Steel Wide Flange Posts on deck

Soil Type and Condition .... Concrete deck, dry

Test Vehicle
- Type .... Production
- Designation 2000P
- Model .... 1994 Chevrolet 2500 pickup truck
- Mass (kg)
  - Curb 1895
  - Test Inertial 2000
  - Dummy 76
  - Gross Static 2076

Impact Conditions
- Speed (km/h) 100.3
- Angle (deg) 25.1

Exit Conditions
- Speed (km/h) 94.5
- Angle (deg) 4.3

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 6.7
  - y-direction 8.2
- THIV (km/h) 32.4
- Ridedown Accelerations (g's)
  - x-direction .... -10.1
  - y-direction .... -14.6
- PHD (g's) 19.0
- ASI 1.76
- Max. 0.050-s Average (g's)
  - x-direction .... -8.4
  - y-direction .... -14.1
  - z-direction .... -5.7

Test Article Deflections (m)
- Dynamic 0.10
- Permanent 0.06

Vehicle Damage
- Exterior
  - VDS 01RFQ4
  - CDC .... 01FREK3 &01RYEW3
- Maximum Exterior
  - Vehicle Crush (mm) 410
- Interior
  - OCDI RF01140001
- Max. Occ. Compart.
  - Deformation (mm) 65

Post-Impact Behavior
(during 1.0 s after impact)
- Max. Yaw Angle (deg) ...... -28
- Max. Pitch Angle (deg) 6
- Max. Roll Angle (deg) ...... -4

Figure 44. Summary of results for test 404531-6, *NCHRP Report 350* test 4-11.

Assessment of Test Results

As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **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 New York Four-Rail Curbless Bridge Railing contained and redirected the 2000P vehicle. The vehicle did not penetrate, underride, or override the installation. Minimal lateral deflection occurred (100 mm), however, the concrete bridge deck was structurally damaged around the post just upstream of impact.

- **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.*

No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. Maximum occupant compartment deformation was 65 mm (6 percent reduction of space) in the floor pan area. This deformation would not cause serious injury to occupants.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.*

The vehicle remained upright and stable during and after the impact period.

- **Vehicle Trajectory**

K. *After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

Due to asymmetrical brake application, the vehicle did intrude into adjacent traffic lanes as it came to rest 70 m down from impact and 5.5 m toward 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.*

Longitudinal occupant impact velocity was 6.7 m/s and longitudinal ridedown acceleration was -10.1 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.*

Exit angle at loss of contact with the installation was 4.3 degrees which was 17 percent of the impact angle.

VI. TESTING OF THE NEW YORK BOX-BEAM TRANSITION

One of the two *NCHRP Report 350* TL-3 tests were performed on the New York Box-Beam Transition.

> **NCHRP Report 350 test designation 3-21**: A 2000 kg pickup truck impacting the transition at the (critical impact point) CIP at a nominal speed and angle of 100 km/h and 25 degrees.

Details of the construction of the New York Box-Beam Transition are discussed in Chapter III and shown in figures 5 and 45.

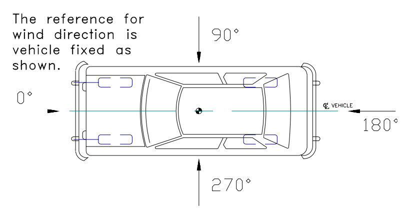
TEST 404531-7 (*NCHRP REPORT 350* TEST DESIGNATION 3-21)

Test Vehicle

A 1995 Chevrolet 2500 pickup truck, shown in figures 45 and 46, was used for the crash test. Test inertia weight of the vehicle was 2000 kg, and its gross static weight was 2076 kg. The height to the lower edge of the vehicle front bumper was 370 mm and to the upper edge of the front bumper was 585 mm. Additional dimensions and information on the vehicle are given in appendix B, figure 58. 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.

Soil and Weather Conditions

The crash test was performed the morning of May 5, 1999. Nine days prior to the test 28 mm of rainfall was recorded. No other rainfall of significance was recorded during the remaining ten days prior to the test. Moisture content was 8.2 percent, 7.6 percent, and 7.4 percent at posts 22, 20, and 18, respectively. Weather conditions at the time of testing were as follows: Wind Speed: 3 km/h; Wind Direction: 20 degrees with respect to the vehicle (vehicle was traveling in a northwesterly direction); Temperature: 29EC; Relative Humidity: 27 percent.



Impact Description

The 2000P vehicle, while traveling at a speed of 98.6 km/h, impacted the transition at 2.0 m upstream of post 23 (the first bridge railing post) at an angle of 25.3 degrees. Shortly after impact posts 21, 22, and 23 moved and at 0.012 s post 19 moved. At 0.022 s the left front tire contacted the lower rail of the transition and caused the wheel to steer away from the railing. The front of the vehicle was at post 22 at 0.027 s and the right front wheel steered away from the railing at 0.033 s. At 0.035 s the left front tire was traveling parallel with the rail element and at 0.037 s the tire began to ride under the rail element. The vehicle began to redirect and post 23 moved at 0.037 s. The left front tire snagged on post 22 at 0.060 s and lost contact with the post at 0.072 s. At this time the right front wheel steered forward. At 0.074 s the front of the vehicle was at post 23. The vehicle contacted the bridge rail element at 0.081 s and the windshield cracked at 0.084 s. At 0.087 s the hinged edge of the driver's door snagged on post 22 and the door glass shattered. The driver's door deformed at 0.090 s and the door opened at the hinges at 0.098 s. At 0.112 s the right front tire lost contact with the ground and at 0.125 s the left front tire deflated after contacting the base plate bolt at post 23. The front bumper of the vehicle lost contact with the bridge rail element at 0.152 s and the right rear tire lost contact with the ground at 0.184 s. At 0.197 s the left front tire lost contact with the rail element, at 0.201 s the front of the vehicle was at post 24, and at 0.202 s the left front tire lost contact with the ground. The left

Figure 45. Vehicle/installation geometrics for test 404531-7.

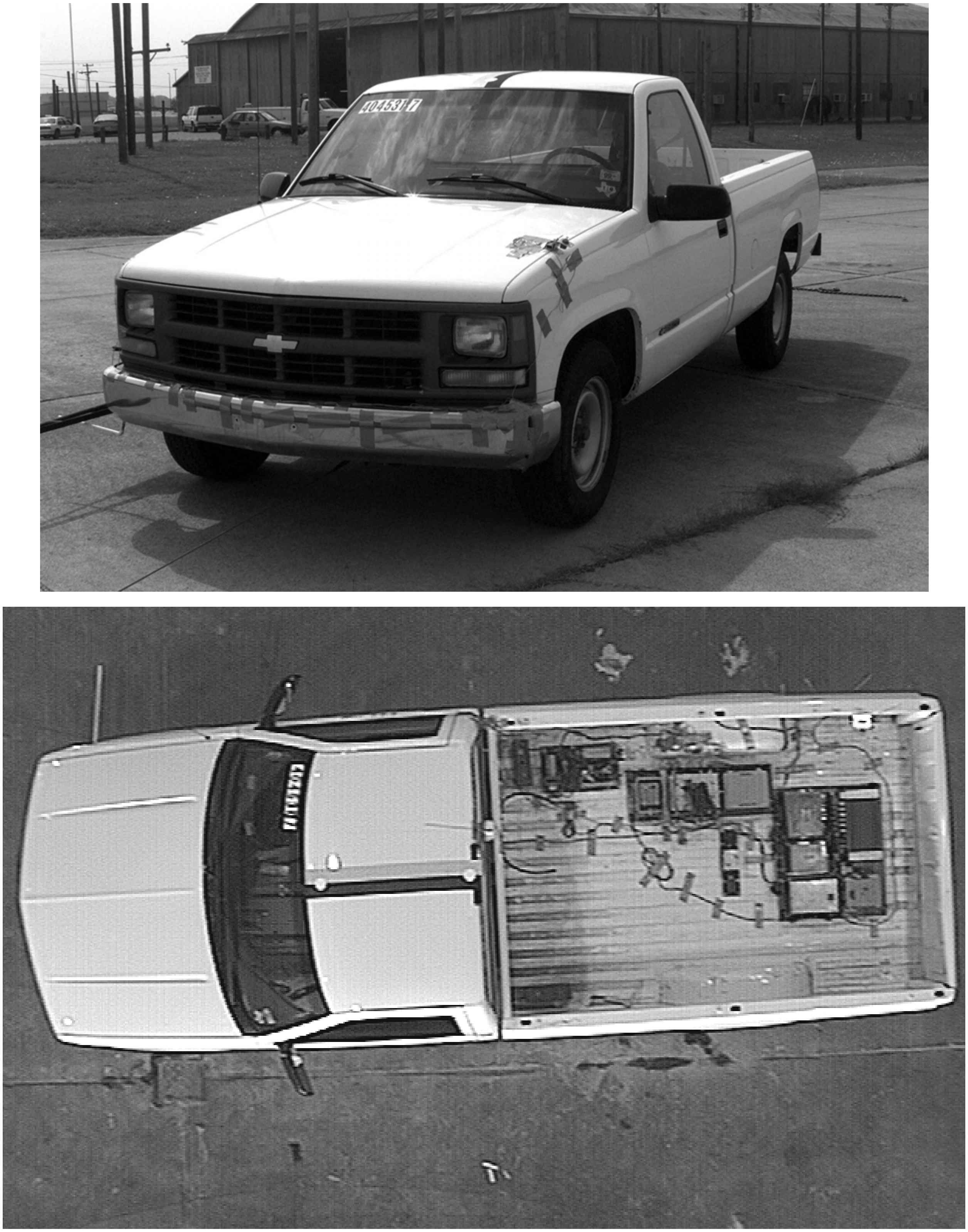


Figure 46. Vehicle before test 404531-7.

rear tire lost contact with the ground at 0.215 s and the front of the vehicle lost contact with the rail element at 0.236 s. At 0.240 s, the vehicle was traveling parallel with the bridge railing at a speed of 69.6 km/h and at 0.244 s the rear of the vehicle contacted the bridge rail element. The left rear tire lost contact with the bridge rail element at 0.355 s and the vehicle lost contact with the bridge railing at 0.393 s. At this time the vehicle was traveling at a speed of 65.3 km/h and an exit angle of 7.6 degrees. Between 0.416 s and 0.575 s all four tires returned to the ground. At 0.800 s the left leg of the dummy protruded out of the cab of the pickup allowing the foot to drag the ground until 0.843 s. Brakes on the vehicle were applied at 2.1 s after impact. The vehicle slowly yawed clockwise and subsequently came to rest 54.9 m down from impact and 19.1 m toward traffic lanes. As the vehicle stopped, the dummy's left leg was fully protruding out of the cab with the foot resting on the concrete pavement and the right leg partially out of the cab. Sequential photographs of the test period are shown in appendix C, figures 69 and 70.

Damage to Test Article

Damage to the New York Four-Rail Curbless Bridge Railing Transition is shown in figures 47 and 48. Tire marks were on the face of the lower three tubes on the transition and the bridge railing for a total of 4.22 m. The lip of the rail splice joint between posts 22 and 23 (first bridge railing posts) was pulled up and the lower bolts on the third tube from the top on post 23 were partially pulled out in the area where the tube was partially collapsed. Tire marks on the bridge deck extended 470 mm behind the rail elements. Cracks in the deck radiated outward from the bolts of the base plate at post 23. Maximum permanent deformation of the rail elements was 65 mm between the transition and the bridge railing.

Vehicle Damage

The 2000P vehicle was severely damaged as shown in figure 49. Structural damage included a deformed left front frame rail, broken left upper ball joint, deformed upper A-arm and deformed A-pillar and B-pillar. The front end was shifted 200 mm to the right. The windshield was shattered and the roof was buckled. The window glass in the driver side door was broken out, the side mirror pulled off and the driver side door was pulled open 220 mm at the hinges. Also damaged was the front bumper, grill, left headlight, radiator, master cylinder, brake booster, hood, left front tire and rim, left front quarter panel, left rear quarter panel, left rear tire and rim, and rear bumper. Maximum exterior crush to the vehicle was 470 mm to the frontal plane at the left corner and 510 mm to the left side plane at the front corner. The floor pan was deformed and separated with an opening 370 mm long by 60 mm wide near the area where the occupant's feet rest. The firewall and instrument panel were deformed . Deformations into the occupant compartment were as follows: 158 mm (18%) in the instrument panel area; 131 mm (12%) in the floor pan area; 95 mm (7%) in the firewall area; and 51 mm (32%) in the instrument panel to floor pan area. Photographs of the interior of the vehicle are shown in figures 50 and 51. Exterior vehicle crush and occupant compartment measurements are shown in appendix B, tables 17 and 18.

Figure 47. Vehicle trajectory path after test 404531-7.

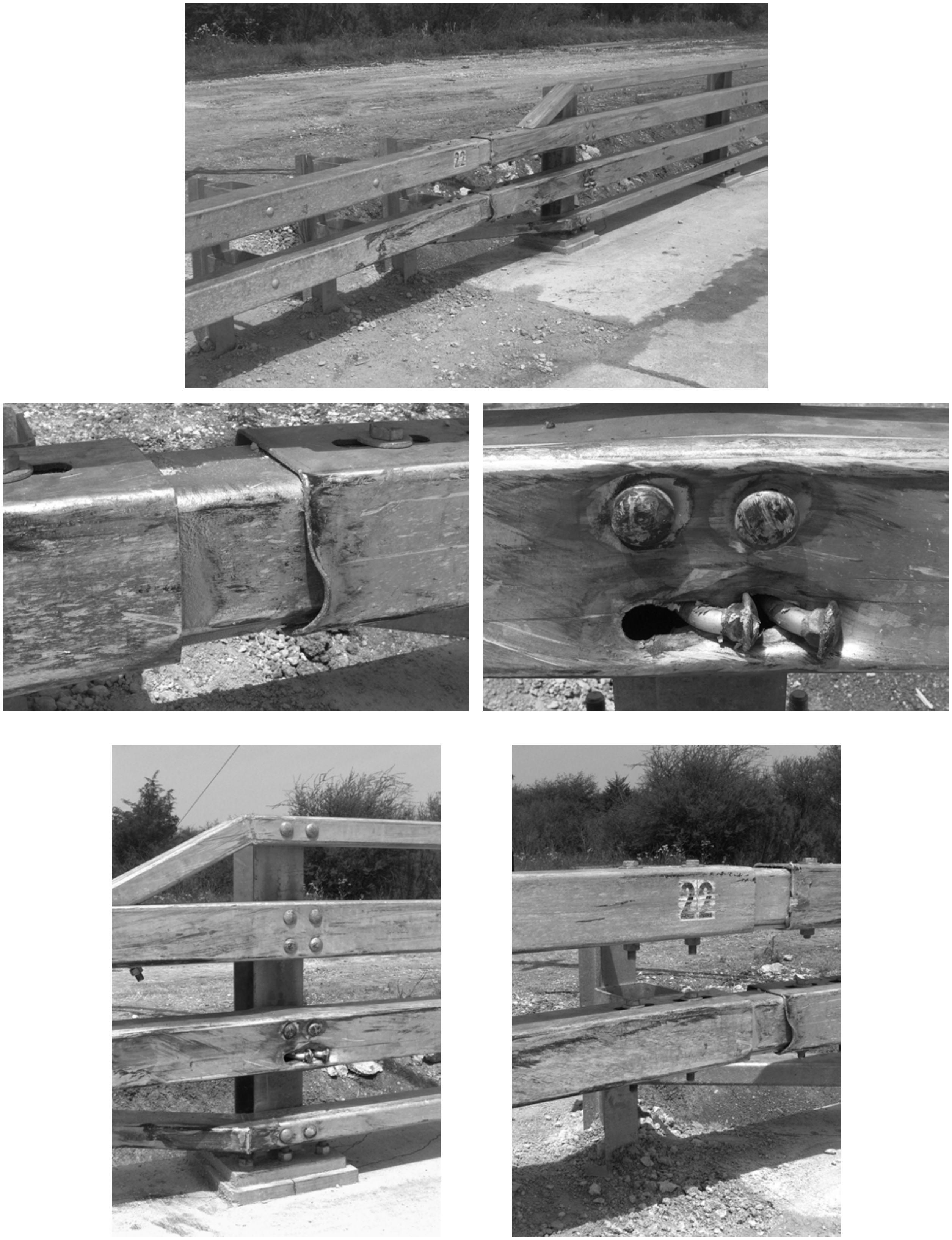


Figure 48. Installation after test 404531-7.

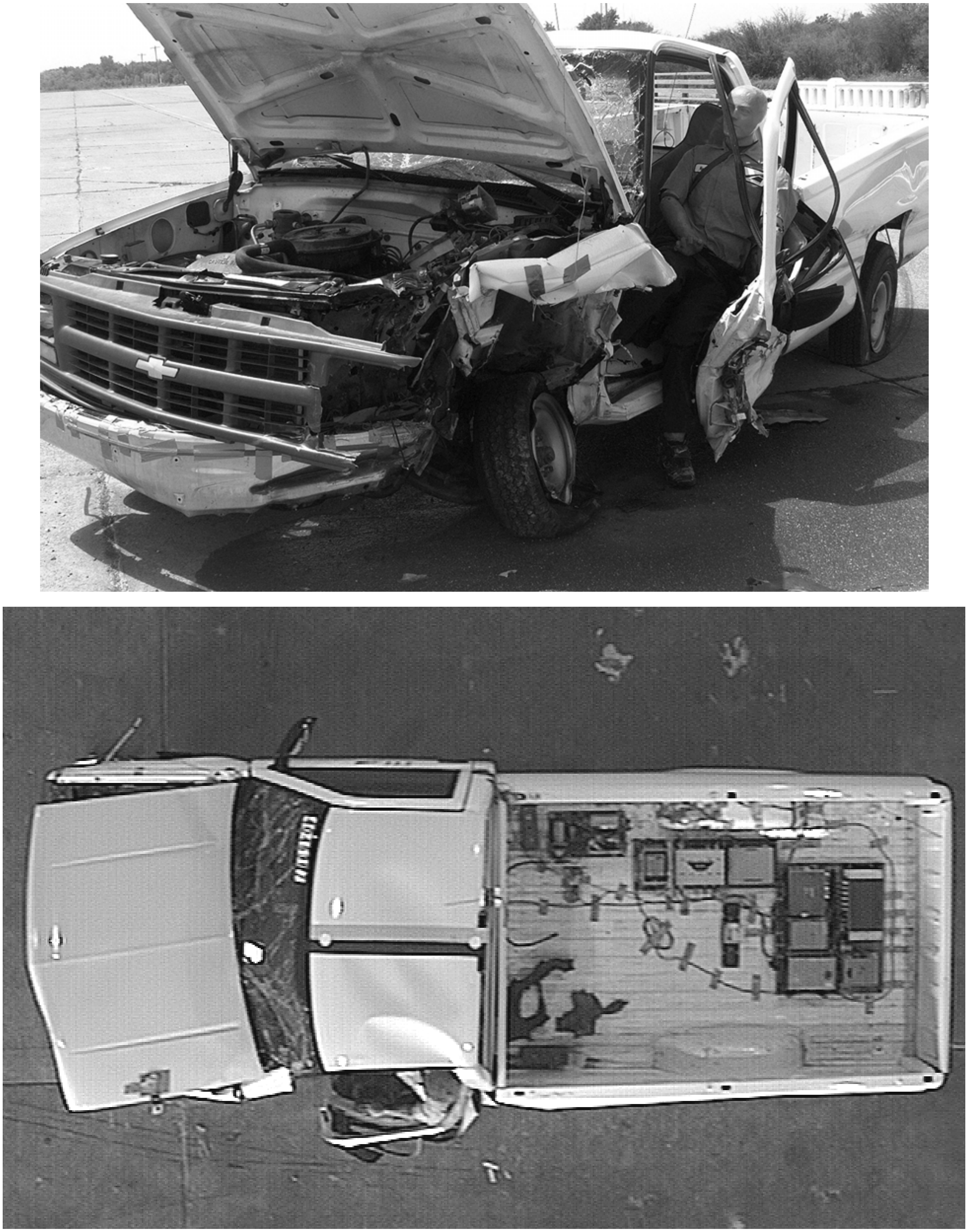


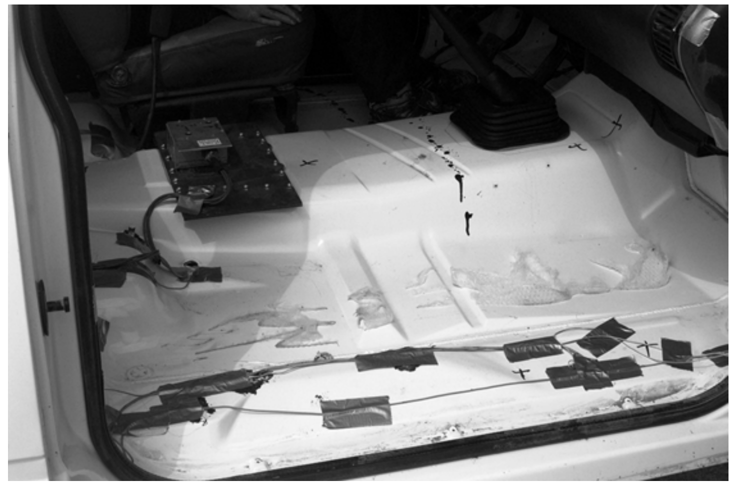
Figure 49. Vehicle after test 404531-7.

Before test

After test

Figure 50. Interior of vehicle for test 404531-7.

Before test



After test

Figure 51. Floor pan of vehicle for test 404531-7.

Occupant Risk Factors

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, occupant impact velocity was 9.2 m/s at 0.145 s, maximum 0.010-s ridedown acceleration was -11.4 g's from 0.118 to 0.128 s, and the maximum 0.050-s average was -12.2 g's between 0.056 and 0.106 s. In the lateral direction, the occupant impact velocity was 7.3 m/s at 0.100 s, the highest 0.010-s occupant ridedown acceleration was 8.9 g's from 0.101 to 0.111 s, and the maximum 0.050-s average was 13.4 g's between 0.026 and 0.076 s. These data and other information pertinent to the test are presented in figure 52. Vehicle angular displacements and accelerations versus time traces are shown in appendix D, figures 132 through 145.

Assessment of Test Results

As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

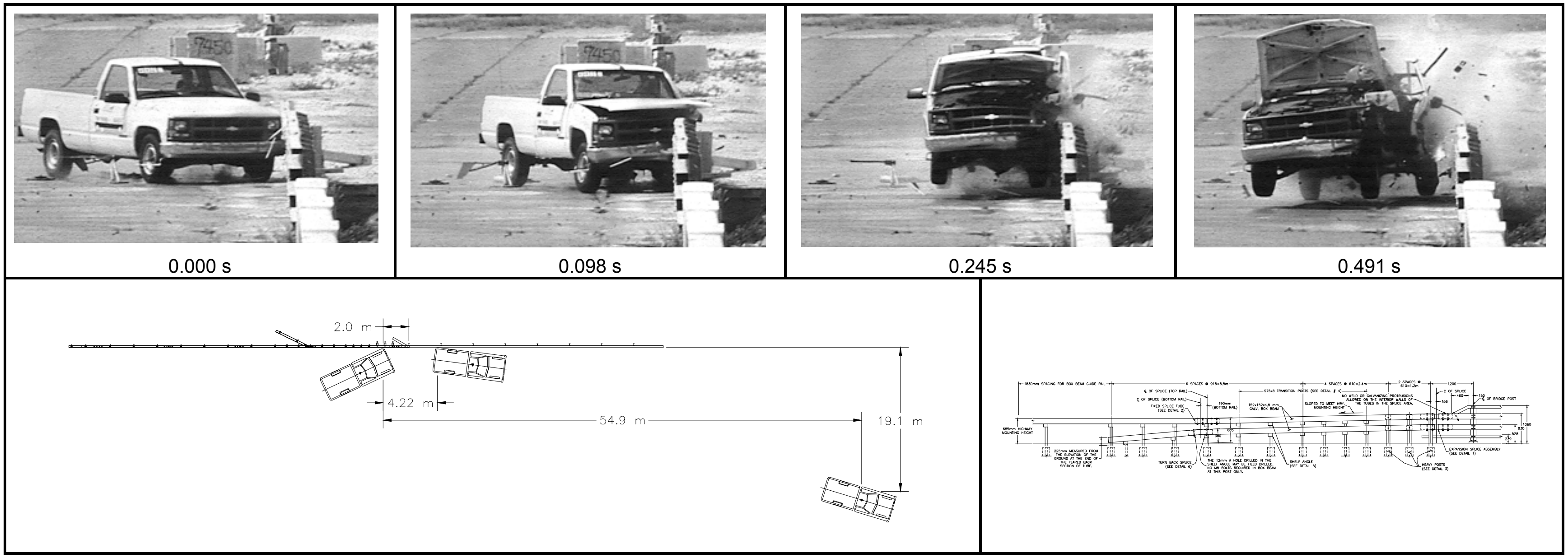
  A. *Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*

  The New York Four-Rail Bridge Railing Transition contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum permanent deformation was 65 mm.

- **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.*

  No detached elements, fragments or other debris were present to penetrate or to show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. However, the occupant



General Information

Test Agency	Texas Transportation Institute
Test No.	404531-7
Date	05/05/99
Test Article	
Type	Transition
Name	New York 4-Railing Transition
Installation Length (m)	22.0
Material or Key Elements	Tubular Steel Rail Elements on Steel Wide Flange Posts
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1995 Chevrolet 2500 Cheyenne pickup truck
Mass (kg)	
Curb	1959
Test Inertial	2000
Dummy	76
Gross Static	2076

Impact Conditions

Speed (km/h)	98.6
Angle (deg)	25.3
Exit Conditions	
Speed (km/h)	65.3
Angle (deg)	7.6
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	9.2
y-direction	7.3
THIV (km/h)	34.4
Ridedown Accelerations (g's)	
x-direction	-11.4
y-direction	8.9
PHD (g's)	19.8
ASI	1.85
Max. 0.050-s Average (g's)	
x-direction	-12.2
y-direction	13.4
z-direction	-8.4

Test Article Deflections (m)

Dynamic	nil
Permanent	65
Vehicle Damage	
Exterior	
VDS	11LFQ7
CDC	11LFEK3 & 11LEW3
Maximum Exterior Vehicle Crush (mm)	510
Interior	
OCDI	LF21140001
Max. Occ. Compart. Deformation (mm)	158
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	43
Max. Pitch Angle (deg)	3
Max. Roll Angle (deg)	-5

Figure 52. Summary of results for test 404531-7, *NCHRP Report 350* test 3-21.

compartment sustained deformation in almost all directions: 158 mm (18%) in the instrument panel area; 131 mm (12%) in the floor pan area; 95 mm (7%) in the firewall area; and 51 mm (32%) in the instrument panel to floor pan area. The floor pan separated with an opening 370 mm long by 60 mm wide near the area where the occupant's feet rest. The driver door of the vehicle was torn from the cab at the hinges allowing the leg of the dummy to protrude out of the vehicle. Due to the significant amount of overall deformation, separation in the floor pan, and partial ejection of the dummy, these damages were judged to have potential for causing serious injury to occupants.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.*

The 2000P vehicle remained upright during and after the collision period.

- **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 19.1 m toward 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.*

Longitudinal occupant impact velocity was 9.2 m/s and longitudinal occupant ridedown acceleration was -11.4 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.*

Exit angle at loss of contact was 7.6 degrees which was 30 percent of the impact angle.

VII. SUMMARY AND CONCLUSIONS

SUMMARY OF FINDINGS

New-York Two-Rail Curbless Bridge Railing

The New York Two-Rail Curbless Bridge Railing contained and redirected the vehicle during *NCHRP Report 350* test designation 4-10. The vehicle did not penetrate, underride, or override the installation. No detached elements, fragments or other debris were present to penetrate or to show potential for penetrating the occupant compartment, nor to present an undue hazard to other traffic. Maximum deformation of the occupant compartment was 15 mm (2% reduction of space) in the right firewall area. The vehicle remained upright during and after the collision period. Occupant risk facts were within the limits specified in *NCHRP Report 350*. No intrusion into adjacent traffic lanes occurred after the vehicle lost contact with the bridge railing as the vehicle came to rest behind the installation. Exit angle at loss of contact was 0.8 degrees, which was less than 60 percent of the impact angle.

During *NCHRP Report 350* test designation 4-11, the New York Two-Rail Curbless Bridge Railing contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation. No detached elements, fragments or other debris were present to penetrate nor to show potential for penetrating the occupant compartment, nor to present an undue hazard to others in the area. Maximum deformation of the occupant compartment was 199 mm (17.6 percent reduction of space) in the floor pan area and maximum reduction of space was 38.8 percent in the center floor pan to instrument panel area with separation of the floor pan just above the upward curve (where the occupant's feet normally rest). The opening in the floor pan at the separation was judged to be wide enough to allow an occupant's foot to become jammed into the opening or go through (see lower photo in figure 11). The vehicle remained upright during and after the collision period. Intrusion into adjacent traffic lanes occurred as the vehicle came to rest 12.2 m toward traffic. Longitudinal occupant impact velocity was 7.2 m/s and longitudinal occupant ridedown was -12.1 g's. Exit angle at loss of contact was 7.4 degrees which was less than 60 percent of the impact angle.

The New York Two-Rail Curbless Bridge Railing contained and redirected the vehicle during *NCHRP Report 350* test designation 4-12. The vehicle did not penetrate, underride, or override the installation. No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, nor to present hazard to others in the area. Maximum occupant compartment deformation was 80 mm in the side panel near the driver door. The vehicle remained upright during and after the collision event. The vehicle came to rest 47.2 m down from impact and in line with the face of the bridge railing and would not intrude into adjacent traffic. Exit angle at loss of contact was estimated to be 2 degrees.

New-York Four-Rail Curbless Bridge Railing

The New York Four-Rail Curbless Bridge Railing contained and redirected the 8000S vehicle during *NCHRP Report 350* test designation 4-12. The vehicle did not penetrate, underride, or override the installation. Minimal lateral deflection occurred; however, the bridge deck was structurally damaged around the posts on either side of impact. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. No deformation of the occupant compartment occurred. The 8000S vehicle remained upright and stable during and immediately after the impact. The front axle was separated from the vehicle and as the vehicle came to rest the axle was under the vehicle in a parallel direction along the length of the vehicle. The vehicle leaned and then rolled onto its left side after coming to a complete stop. The vehicle did not intrude into adjacent traffic lanes as it came to rest in line and slightly behind the installation. The exit angle at loss of contact was 1.4 degrees which was 9 percent of the impact angle.

During *NCHRP Report 350* test designation 4-11, the New York Four-Rail Curbless Bridge Railing contained and redirected the 2000P vehicle. The vehicle did not penetrate, underride, or override the installation. Minimal lateral deflection occurred; however, the concrete bridge deck was structurally damaged around the post just upstream of impact. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. Maximum occupant compartment deformation was 65 mm (6 percent reduction of space) in the floor pan area. The vehicle remained upright and stable during and after the impact period. The vehicle did intrude into adjacent traffic lanes as it came to rest 70 m down from impact and 5.5 m toward traffic lanes. Longitudinal occupant impact velocity was 6.7 m/s and longitudinal ridedown acceleration was -10.1 g's. Exit angle at loss of contact with the installation was 4.3 degrees which was 17 percent of the impact angle.

New-York Box-Beam Transition

The New York Box-Beam Transition contained and redirected the 2000P vehicle during *NCHRP Report 350* test designation 3-21. The vehicle did not penetrate, underride, or override the installation. Maximum permanent deformation was 65 mm. No detached elements, fragments or other debris were present to penetrate or to show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. However, the vehicle sustained deformation in almost all directions: 158 mm (18%) in the instrument panel area; 131 mm (12%) in the floor pan area; 95 mm (7%) in the firewall area; and 51 mm (32%) in the instrument panel to floor pan area. The floor pan separated with an opening 370 mm long by 60 mm wide near the area where the occupant's feet rest. The door of the vehicle was torn from the cab at the hinges allowing the leg of the dummy to protrude out of the vehicle. The 2000P vehicle remained upright during and after the collision period. The vehicle did intrude into adjacent traffic lanes as it came to rest 19.1 m toward traffic lanes. Longitudinal occupant impact velocity was 9.2 m/s and longitudinal occupant ridedown acceleration was -11.4 g's. Exit angle at loss of contact was 7.6 degrees which was 30 percent of the impact angle.

CONCLUSIONS

New-York Two-Rail Curbless Bridge Railing

The New York Two-Rail Curbless Bridge Railing met all requirements specified for *NCHRP Report 350* test designation 4-10, as shown in table 1.

The New York Two-Rail Curbless Bridge Railing did not meet criteria for D and K of *NCHRP Report 350* test designation 4-11, as shown in table 2. As stated previously, the separation and deformation of the occupant compartment was judged to have potential for causing serious injury (criterion D). The vehicle came to rest 12.2 m toward traffic lanes which would intrude into adjacent traffic lanes (criterion K); however this criterion is preferable, not required. Damage to the concrete deck at one post location was extensive and required major repairs. It was recommended that the post-to-deck connection be reviewed with the objective of reducing structural damage to the deck. It is also recommended that consideration be given to increasing the thickness of the tubular rails from 4.8 mm to 6.4 mm in order to minimize flattening of the rails and snagging on the carriage bolts.

Prior to the third test, the deck was repaired with no modifications to the post-to-deck connection. The New York Two-Rail Curbless Bridge Railing met all criteria for test *NCHRP Report 350* test designation 4-12, as shown in table 3.

New-York Four-Rail Curbless Bridge Railing

As shown in table 4, the New York Four-Rail Curbless Bridge Railing met all criteria specified for *NCHRP Report 350* test designation 4-12. The New York Four-Rail Curbless Bridge Railing also met the required criteria specified for test *NCHRP Report 350* test designation 4-11, as shown in table 5.

New-York Box-Beam Transition

The New York Box-Beam Transition did not meet occupant risk criterion D and vehicle trajectory criterion K for *NCHRP Report 350* test designation 3-21, as shown in table 6. Due to the significant amount of overall deformation of the occupant compartment, separation in the floor pan, and partial ejection of the dummy through the door which was pulled open at the hinges, overall damage to the vehicle was judged to have potential for causing serious injury to occupants. This severe damage resulted from the vehicle snagging on the rail splice joints and bolt heads that protruded after the rail element was partially collapsed.

Table 1. Performance evaluation summary for test 404531-1, *NCHRP Report 350* test 4-10.

Test Agency: Texas Transportation Institute | Test No.: 404531-1 | Test Date: 10/23/98

<table>
<tr><th>NCHRP Report 350 Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td><u>Structural Adequacy</u>
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.</td><td>The New York Two-Rail Curbless Bridge Railing contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation</td><td>Pass</td></tr>
<tr><td><u>Occupant Risk</u>
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.</td><td>No detached elements, fragments, or other debris were present to penetrate nor to show potential for penetrating the occupant compartment, nor to present an undue hazard to other traffic. Maximum deformation of the occupant compartment was 15 mm (2% reduction in space) in the right firewall area.</td><td>Pass</td></tr>
<tr><td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.</td><td>The vehicle remained upright during the after the collision period.</td><td>Pass</td></tr>
<tr><td>H. Occupant impact velocities should satisfy the following:
<table><tr><th colspan="3">Occupant Velocity Limits (m/s)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and lateral</td><td>9</td><td>12</td></tr></table></td><td>Longitudinal occupant impact velocity = 4.7 m/s
Lateral occupant impact velocity = 7.5 m/s</td><td>Pass</td></tr>
<tr><td>I. Occupant ridedown accelerations should satisfy the following:
<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits (g's)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and lateral</td><td>15</td><td>20</td></tr></table></td><td>Longitudinal ridedown acceleration = -2.5 g’s
Lateral ridedown acceleration = -11.3 g’s</td><td>Pass</td></tr>
<tr><td><u>Vehicle Trajectory</u>
K. After collision, it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.</td><td>No intrusion occurred after the vehicle lost contact with the bridge rail</td><td>Pass</td></tr>
<tr><td>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.</td><td>Exit angle at loss of contact was 0.8 degrees which was less than 60 percent of the impact angle.</td><td>Pass</td></tr>
</table>

*Criterion K and M are preferable, not required.

Table 2. Performance evaluation summary for test 404531-2, *NCHRP Report 350* test 4-11.

Test Agency: Texas Transportation Institute | Test No.: 404531-2 | Test Date: 10/27/98

NCHRP Report 350 Evaluation Criteria	Test Results	Assessment
<u>Structural Adequacy</u> 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 New York Two-Rail Bridge Rail contained and redirected the vehicle. The vehicle did not penetrate, underride, or override the installation	Pass
<u>Occupant Risk</u> 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.	No detached elements, fragments, or other debris were present to penetrate nor to show potential for penetrating the occupant compartment, nor to present an undue hazard to other traffic. Maximum deformation of the occupant compartment was 199 mm (17.6 percent reduction in space) in the floor pan area and maximum reduction of space was 38.8 percent in the center floor pan to instrument panel area. The floor pan separated creating an opening in the vicinity of the occupant's feet. The resulting damage to the occupant compartment was judged to have potential for causing serious injury.	Fail
F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.	The vehicle remained upright during the after the collision period.	Pass
<u>Vehicle Trajectory</u> K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	Intrusion into adjacent traffic lanes occurred as the vehicle came to rest 12.2 m toward traffic.	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 7.2 m/s and longitudinal occupant ridedown was -12.1 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.	Exit angle at loss of contact was 7.4 degrees which was less than 60 percent of the impact angle.	Pass*

*Criterion preferable, not required.

Table 3. Performance evaluation summary for test 404531-3, *NCHRP Report 350* test 4-12.

Test Agency: Texas Transportation Institute | Test No.: 404531-3 | Test Date: 01/13/99

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 New York Two-Rail Curbless 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.	No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, nor to present hazard to others in the area. Maximum occupant compartment deformation was 80 mm in the side panel near the driver door.	Pass
G. It is preferable, although not essential, that the vehicle remain upright during and after collision.	The vehicle remained upright during and after the collision event.	Pass*
Vehicle Trajectory K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	The vehicle came to rest 47.2 m down from impact and in line with the face of the bridge rail.	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.	Exit angle at loss of contact was estimated at approximately 2 degrees.	Pass*

*Criteria G, K, and M are preferable, not required.

Table 4. Performance evaluation summary for test 404531-4, *NCHRP Report 350* test 4-12.

Test Agency: Texas Transportation Institute | Test No.: 404531-4 | Test Date: 03/25/99

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 New York Four-Rail Curbless Bridge Rail contained and redirected the 8000S vehicle. The vehicle did not penetrate, underride, or override the installation. Minimal lateral deflection occurred.	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.	No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. No deformation of the occupant compartment occurred.	Pass
G. It is preferable, although not essential, that the vehicle remain upright during and after collision.	The 8000S vehicle remained upright and stable during and immediately after the impact. The vehicle leaned and then rolled onto its left side after coming to a complete stop.	Pass*
Vehicle Trajectory K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	The vehicle did not intrude into adjacent traffic lanes as it came to rest in line and slightly behind the installation.	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 was 1.4 degrees which was 9 percent of the impact angle.	Pass*

*Criterion G, K, and M are preferable, not required.

Table 5. Performance evaluation summary for test 404531-6, *NCHRP Report 350* test 4-11.

Test Agency: Texas Transportation Institute | Test No.: 404531-6 | Test Date: 03/29/99

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 New York Four-Rail Curbless Bridge Rail contained and redirected the 2000P vehicle. The vehicle did not penetrate, underride, or override the installation. Minimal lateral deflection occurred.	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.	No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. Maximum occupant compartment deformation was 65 mm (6 percent reduction of space) in the floor pan area.	Pass
F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.	The vehicle remained upright and stable during and after the impact period.	Pass
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 70 m down from impact and 5.5 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 6.7 m/s and longitudinal ridedown acceleration was -10.1 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.	Exit angle at loss of contact with the installation was 4.3 degrees which was 17 percent of the impact angle.	Pass*

*Criterion K and M are preferable, not required.

Table 6. Performance evaluation summary for test 404531-7, *NCHRP Report 350* test 3-21.

Test Agency: Texas Transportation Institute | Test No.: 404531-7 | Test Date: 05/05/99

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 New York Box-Beam Transition contained and redirected the 2000P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum permanent deformation was 65 mm.	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.	No detached elements, fragments, or other debris were present to penetrate or to show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. However, the occupant compartment sustained deformation in almost all directions: 158 mm (18%) in the instrument panel area; 131 mm (12%) in the floor pan area; 95 mm (7%) in the firewall area; and 51 mm (32%) in the instrument panel to floor pan area. The floor pan separated with an opening 370 mm long by 60 mm wide near the area where the occupant’s feet rest. The door of the vehicle was torn from the cab at the hinges allowing the dummy to be partially ejected from the vehicle.	Fail
F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.	The vehicle remained upright during and after the collision period.	Pass
Vehicle Trajectory K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	The 2000P vehicle did intrude into adjacent traffic lanes as it came to rest 19.1 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 9.2 m/s and longitudinal occupant ridedown acceleration was -11.4 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.	Exit angle at loss of contact was 7.6 degrees which was 30 percent of the impact angle.	Pass*

*Criterion K and M are preferable, not required.

APPENDIX A. CRASH TEST PROCEDURES AND DATA ANALYSIS

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 820C and 2000P test vehicles were instrumented with five uniaxial accelerometers mounted in the following locations: (1) center top surface of the instrument panel; (2) inside end of right front wheel spindle; (3) inside end of left front wheel spindle; (4) top of engine block; and (5) bottom of engine block. The exact location of each accelerometer was measured and is reported in tables 7 through 10. These accelerometers were ENDEVCO Model 7264A low-mass piezoresistive accelerometers with a ±2000-g range.

On-board data acquisition is provided by a 16-channel Prosig P4010 system. Each analog channel has integral signal conditioning, fixed-frequency anti-alias filtering, and a programmable transducer bridge power supply. Each P4010 four-channel POD contains one Mb of battery-backed memory allowing for more than 13 s of storage at a maximum of 10,000 samples per second per channel. All channels are synchronized by a common external clock. The accuracy of this system is ±0.1%.

In addition, all test vehicles were 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 8000S vehicles also were instrumented with a biaxial accelerometer in the cab of the vehicle. These accelerometers were ENDEVCO Model 2262CA, piezoresistive accelerometers with a ±100-g range.

The accelerometers are strain-gage type with a linear millivolt output proportional to acceleration. Rate-of-turn transducers are solid state, gas flow units designed for high g service. Signal conditioners and amplifiers in the test vehicle increase the low-level signals to a ±2.5-Volt maximum level. The signal conditioners also provide the capability of an R-Cal or shunt calibration for the accelerometers and a precision voltage calibration for the rate transducers. The electronic signals from the accelerometers and rate transducers are transmitted to a base station by means of a 15-channel, constant bandwidth, Inter-Range Instrumentation Group (IRIG),
FM/FM telemetry link for recording on magnetic tape and for display on a real-time strip chart. Calibration signals from the test vehicle are recorded minutes before the test and also immediately afterwards. A crystal-controlled time reference signal is simultaneously recorded with the data. Pressure-sensitive switches on the bumper of the impacting vehicle are 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 produces an “event” mark on the data record to establish the exact instant of contact with the installation.

Table 7. Locations of vehicle accelerometers for test 404531-1.

Location	X (mm) (distance from front axle)	Y (mm) (distance from centerline)	Z (mm) (distance from ground)	Data Axis
Instrument panel	0	0	0	+X
Right front wheel spindle	+60	+700	-220	-Y
Left front wheel spindle	+60	-700	-220	+X
Top of engine block	+170	0	-755	+X
Bottom of engine block	+170	+25	-300	+X
Vehicle c.g.	-900	0	-390	+X,+Y,+Z
Vehicle rear axle	-2420	-180	-480	+X,+Y

Reference point: X=0 at front axle Y=0 at centerline Z=0 at ground
Sign convention: +X=forward +Y=right +Z=down

Table 8. Locations of vehicle accelerometers for test 404531-2.

Location	X (mm) (distance from front axle)	Y (mm) (distance from centerline)	Z (mm) (distance from ground)	Data Axis
Instrument panel	-660	0	1235	+X
Right front wheel spindle	0	+720	-365	-Y
Left front wheel spindle	0	-720	-365	+X
Top of engine block	+80	0	-875	+X
Bottom of engine block	-310	0	-340	+X
Vehicle c.g.	-1460	0	-695	+X,+Y,+Z
Vehicle rear axle	-3350	0	-840	+X,+Y,+Z

*Reference point: X=0 at front axle Y=0 at centerline Z=0 at ground
Sign convention: +X=forward +Y=right +Z=down

Table 9. Locations of vehicle accelerometers for test 404531-6.

Location	X (mm) (distance from front axle)	Y (mm) (distance from centerline)	Z (mm) (distance from ground)	Data Axis
Instrument panel	-695	0	-1220	+X
Right front wheel spindle	0	+700	-360	-Y
Left front wheel spindle	0	-700	-360	+X
Top of engine block	+75	+70	-880	+X
Bottom of engine block	-300	-76	-350	+X
Vehicle c.g.	-1480	0	-650	+X,+Y,+Z
Vehicle rear axle	-3340	0	-840	+X,+Y,+Z

*Reference point:	X=0 at front axle	Y=0 at centerline	Z=0 at ground
Sign convention:	+X=forward	+Y=right	+Z=down

Table 10. Locations of vehicle accelerometers for test 404531-7.

Location	X (mm) (distance from front axle)	Y (mm) (distance from centerline)	Z (mm) (distance from ground)	Data Axis
Instrument panel	-810	0	-1330	+X
Right front wheel spindle	+690	0	340	+X
Left front wheel spindle	-690	0	340	+Y
Top of engine block	+170	-70	-880	+X
Bottom of engine block	-380	0	-305	+X
Vehicle c.g.	-1480	0	-680	+X,+Y,+Z
Vehicle rear axle	-3350	0	-810	+X,+Y,+Z

*Reference point:	X=0 at front axle	Y=0 at centerline	Z=0 at ground
Sign convention:	+X=forward	+Y=right	+Z=down

The multiplex of data channels transmitted on one radio frequency is received at the data acquisition station, and demultiplexed onto separate tracks of a 28-track (IRIG) tape recorder. After the test, the data are played back from the tape machine, filtered with SAE J211 filters, and digitized using a microcomputer, at 2000 samples per second per channel, for analysis and evaluation of impact performance.

All accelerometers are calibrated annually by the Society of Automotive Engineers ((SAE) J211 *4.6.1*) by means of an ENDEVCO 2901, precision primary vibration standard. This device, along with its support instruments, is returned to the factory annually for a National Institute of Standards and Technology (NIST) traceable calibration. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel, per SAE J211. Calibrations and evaluations will be made any time a data channel is suspected of any anomalies.

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).

The PLOTANGLE program used the digitized data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0002-s intervals and then instructed 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

An Alderson Research Laboratories Hybrid II, 50th-percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver's position of the vehicle. The dummy was not instrumented.

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 16-mm movie cine, a BetaCam, a VHS-format video camera and recorder, and still cameras were used to record and document the condition 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.

APPENDIX B. TEST VEHICLE PROPERTIES AND INFORMATION

DATE: 10-23-98 TEST NO.: 404531-1 VIN NO.: KWJPT06H1P6107226

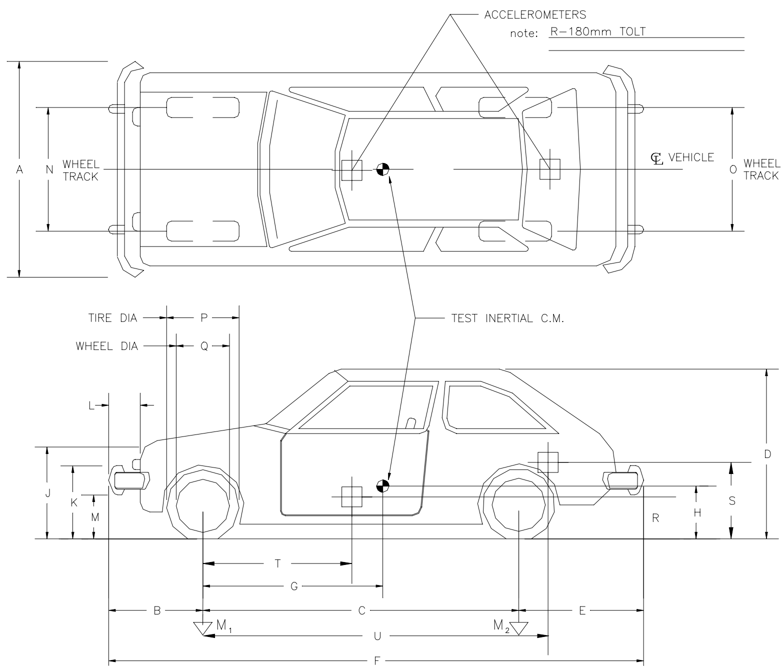
YEAR: 1993 MAKE: FORD MODEL: FESTIVA

TIRE INFLATION PRESSURE: ______ ODOMETER: 85031 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: ____ Minor Damage Charged to Project: ______

MASS DISTRIBUTION (kg) LF 259 RF 251 LR 153 RR 157

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 4 CYL.

ENGINE CID: 1.3L

TRANSMISSION TYPE:

__ AUTO

X MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY – (mm)

A	1500	E	550	J	760	N	1405	R	390
B	640	F	3490	K	550	O	1400	S	480
C	2300	G	869.5	L	120	P	540	T	900
D	1450	H		M	395	Q	330	U	2420

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	530	510	548
M_2	284	310	348
M_T	814	820	896

Figure 53. Vehicle properties for test 404531-1.

Table 11. Exterior crush measurements for test 404531-1.

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________ Corner shift: A1 ________ A2 ________ End shift at frame (CDC) (check one) < 4 inches ________ $ 4 inches ________	Bowing: B1 ____ X1 ____ B2 ____ X2 ____ 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	600	150	520	0	10	25	25	90	150	+470
2	Above front wheel well	600	190	1200	0	40	80	120	160	190	+1040

[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).

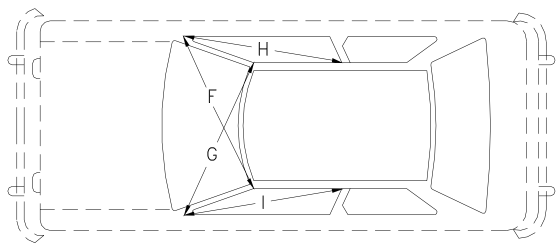
***Measure and document on the vehicle diagram the location of the maximum crush.

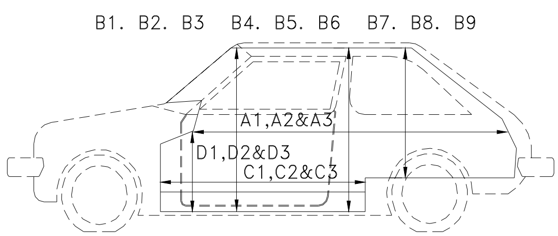
Note: Use as many lines/columns as necessary to describe each damage profile.

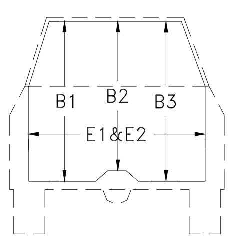
Table 12. Occupant compartment measurements for test 404531-1.

Small Car

Occupant Compartment Deformation







	BEFORE	AFTER
A1	1548	1548
A2	2032	2032
A3	1550	1550
B1	995	995
B2	934	934
B3	1058	1053
B4	970	970
B5	973	973
B6	970	970
B7	860	860
B8	847	847
B9	838	838
C1	629	629
C2	625	625
C3	635	620
D1	327	327
D2	225	225
D3	330	337
E1	1252	1257
E2	1245	1260
F	1190	1190
G	1190	1185
H	900	895
I	900	900

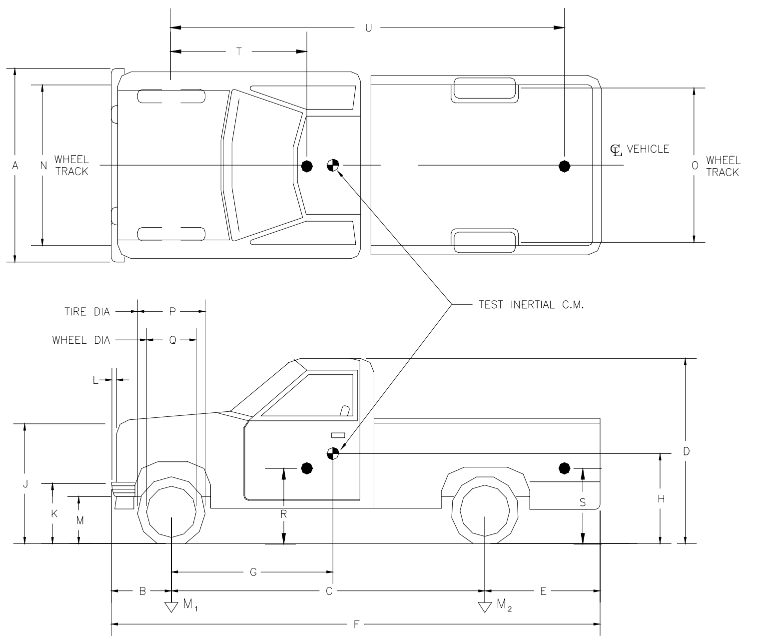
DATE: 10-27-98 TEST NO.: 404531-2 VIN NO.: 1GCFC24K2RE139524

YEAR: 1994 MAKE: CHEVY MODEL: 2500 P/U

TIRE INFLATION PRESSURE: ______ ODOMETER: 137364 TIRE SIZE: LT 245 75R16

MASS DISTRIBUTION (kg) LF 558 RF 517 LR 466 RR 459

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



● Denotes accelerometer location.

NOTES: ______

ENGINE TYPE: 8 CYL.

ENGINE CID: 5.7L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

6 LUGS

DUMMY DATA:

TYPE: ______

MASS: ______

SEAT POSITION: ______

GEOMETRY - (mm)

A	1870	E	1300	J	103	N	1600	R	660
B	770	F	5420	K	620	O	1625	S	860
C	3350	G	1549.4	L	80	P	770	T	1490
D	1760	H		M	390	Q	445	U	3350

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	1100	1075	1118
M_2	822	925	957
M_T	1922	2000	2075

Figure 54. Vehicle properties for test 404531-2.

Table 13. Exterior crush measurements for test 404531-2.

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	**Side Damage**
Undeformed end width ________ Corner shift: A1 ________ A2 ________ End shift at frame (CDC) (check one) < 4 inches ________ $ 4 inches ________	Bowing: B1 ____ X1 ____ B2 ____ X2 ____ 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	At front bumper	800	470	600	0	50	105	180	310	470	+300
2	Above front bumper	800	340	1120	130	190	220	260	320	340	+1480

[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.

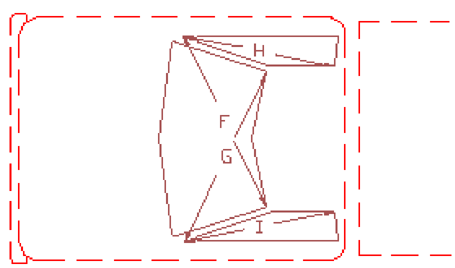
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

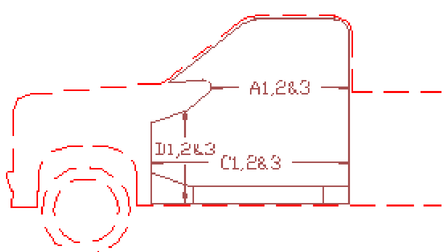
***Measure and document on the vehicle diagram the location of the maximum crush.
Note: Use as many lines/columns as necessary to describe each damage profile.

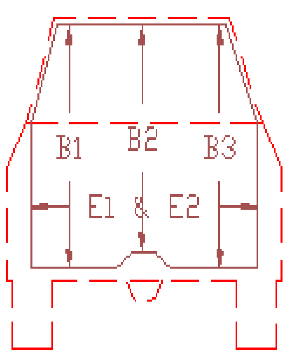
Table 14. Occupant compartment measurements for test 404531-2.

Truck

Occupant Compartment Deformation







	BEFORE	AFTER
A1	1030	1045
A2	1082	1070
A3	1045	1025
B1	1075	1075
B2	1054	935
B3	1090	1131
C1	1374	1374
C2	1262	1230
C3	1372	1325
D1	306	312
D2	98	60
D3	310	420
E1	1591	1575
E2	1589	1595
F	1475	1450
G	1475	1465
H	900	870
I	900	900
Maximum floor pan to roof	1129	930
Maximum lateral deformation near occupants feet	1520	1390

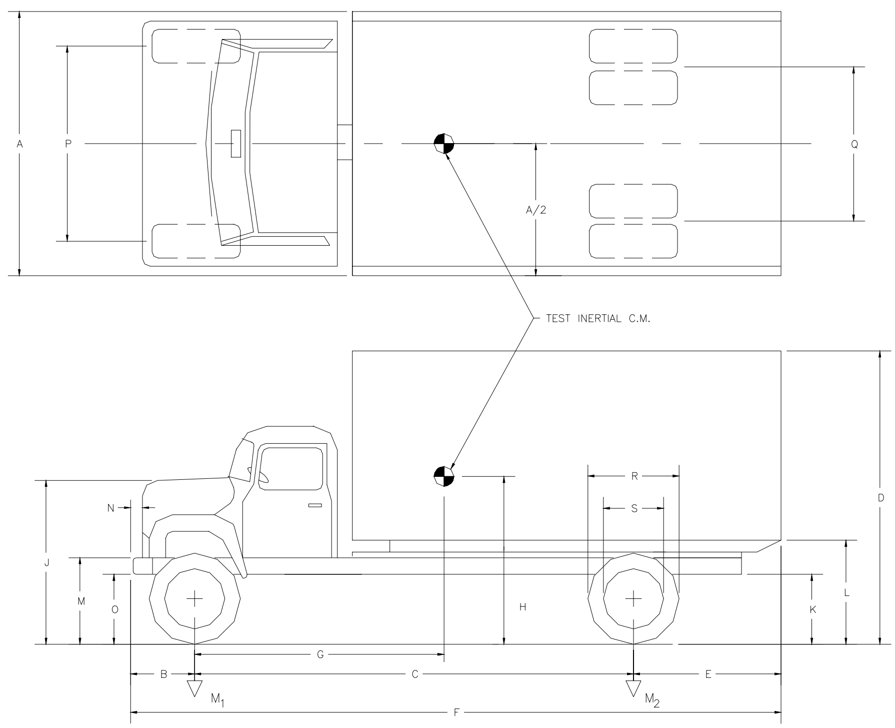
DATE: 1/13/99 TEST NO.: 404531-3 VIN NO.: 1GBL7D1B9EV123663

MODEL: 70 YEAR: 1984 ODOMETER: 70184 TIRE SIZE: 11R22.5

MAKE: CHEVY

MASS DISTRIBUTION (kg) LF 1610 RF 1560 LR 2381 RR 2449

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



GEOMETRY–(mm)

A 2440	D 3785	G 3151.6	K 765	N 90	Q 1810
B 760	E 2240	H 1242.8	L 1302	O 540	R 1045
C 5220	F 8220	J 1645	M 860	P 2000	S 595

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	2209	3170	
M_2	2903	4830	
M_T	5112	8000	

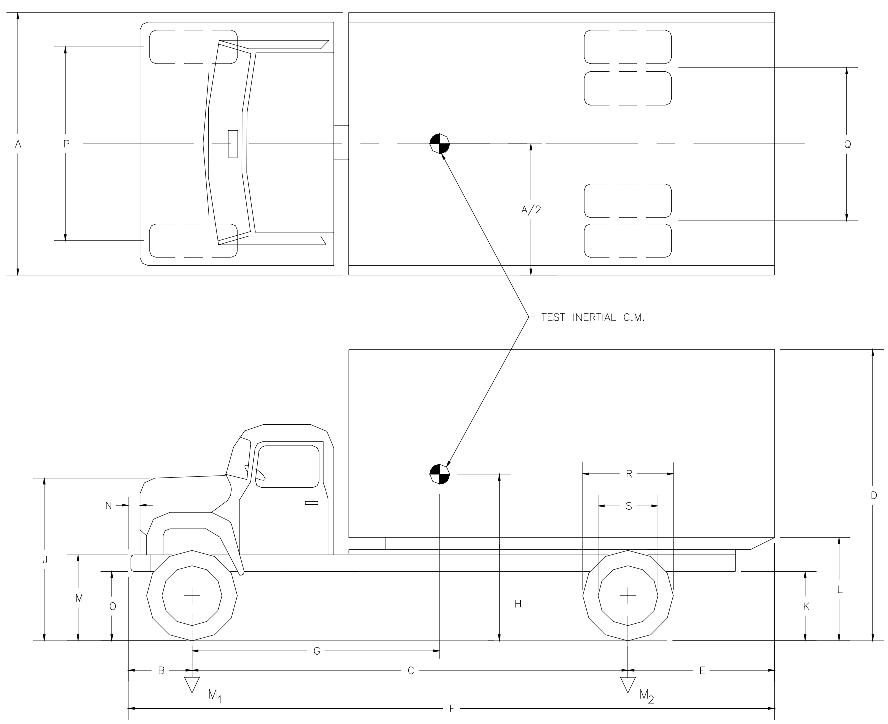
Figure 55. Vehicle properties for test 404531-3.

DATE: 03-25-99 TEST NO.: 404531-4 VIN NO.: IGCJ70183EV525051

YEAR: 1984 MAKE: GMC ODOMETER: 102295 TIRE SIZE: 11R22.5

MASS DISTRIBUTION (kg) LF 1528 RF 1678 LR 2472 RR 2322

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



GEOMETRY–(mm)

A 2430	D 3450	G 3095.1	K 790	N 90	Q 1800
B 790	E 2240	H 1237	L 1270	O 530	R 1030
C 5165	F 8195	J 1585	M 820	P 1920	S 595

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	2105	3206	
M_2	2962	4794	
M_T	5067	8000	

Figure 56. Vehicle properties for test 404531-4.

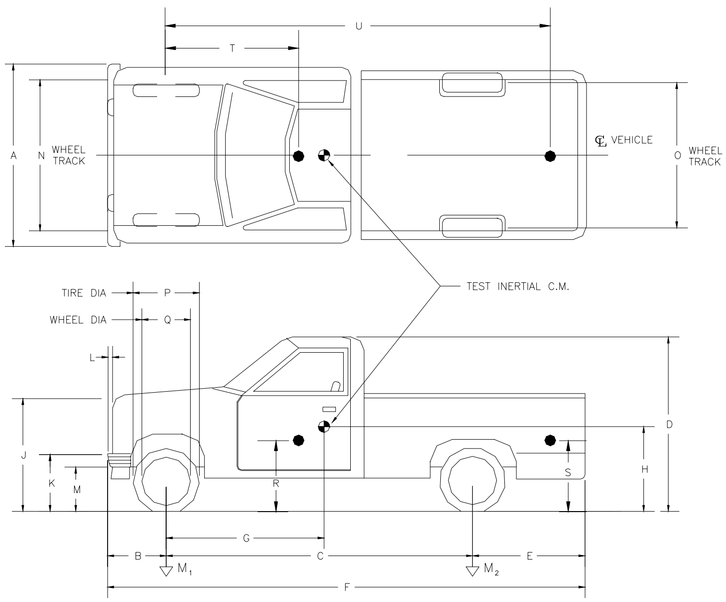
DATE: 03/29/99 TEST NO.: 404531-6 VIN NO.: 1GCFC24K9RE136541

YEAR: 1994 MAKE: CHEVY MODEL: 2500 P/U

TIRE INFLATION PRESSURE: ______ ODOMETER: 246074 TIRE SIZE: LT 225 75/R16

MASS DISTRIBUTION (kg) LF 559 RF 524 LR 457 RR 460

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



● Denotes accelerometer location.

NOTES: R–100mm TO LT

ENGINE TYPE: 8 CYL

ENGINE CID: 5.7 L

TRANSMISSION TYPE:

__ AUTO

X MANUAL

OPTIONAL EQUIPMENT:

6 LUGS

DUMMY DATA:

TYPE: ______

MASS: ______

SEAT POSITION: ______

GEOMETRY – (mm)

A	1860	E	1310	J	1020	N	1570	R	670
B	770	F	5425	K	610	O	1615	S	860
C	3345	G	1533.7	L	65	P	730	T	1500
D	1780	H		M	390	Q	445	U	4000

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	1104	1083	1127
M_2	791	917	949
M_T	1895	2000	2076

Figure 57. Vehicle properties for test 404531-6.

Table 15. Exterior crush measurements for test 404531-6.

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	**Side Damage**
Undeformed end width ________ Corner shift: A1 ________ A2 ________ End shift at frame (CDC) (check one) < 4 inches ________ $ 4 inches ________	Bowing: B1 ____ X1 ____ B2 ____ X2 ____ Bowing constant 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		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width ** (CDC)	Max*** Crush								
1	Front bumper	1050	-410	650	+30	-60	-140	-300	-310	-410	+325
2	760 mm above ground	1050	410	-1030	-170	-220	-240	-300	-410	-410	+1470

[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.

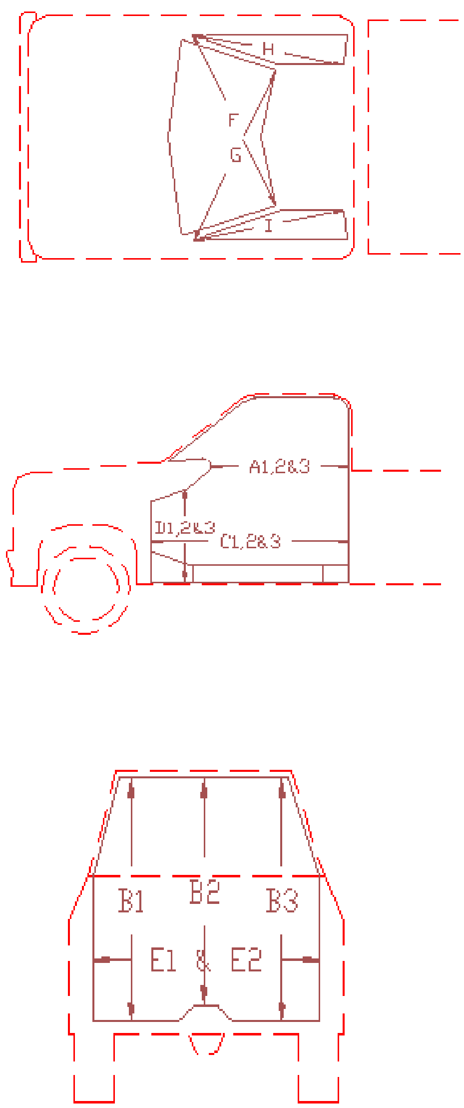
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 16. Occupant compartment measurements for test 404531-6.

Truck

Occupant Compartment Deformation



	BEFORE	AFTER
A1	1037	1044
A2	1085	1080
A3	1045	1024
B1	1070	1077
B2	1067 1067	1132 995
B3	1087	1118
C1	1380	1380
C2	1258	1212
C3	1373	1360
D1	312	312
D2	100	65
D3	310	310
E1	1597	1645
E2	1600	1635
F	1475	1455
G	1475	1475
H	800	790
I	800	800
J	1524	1462

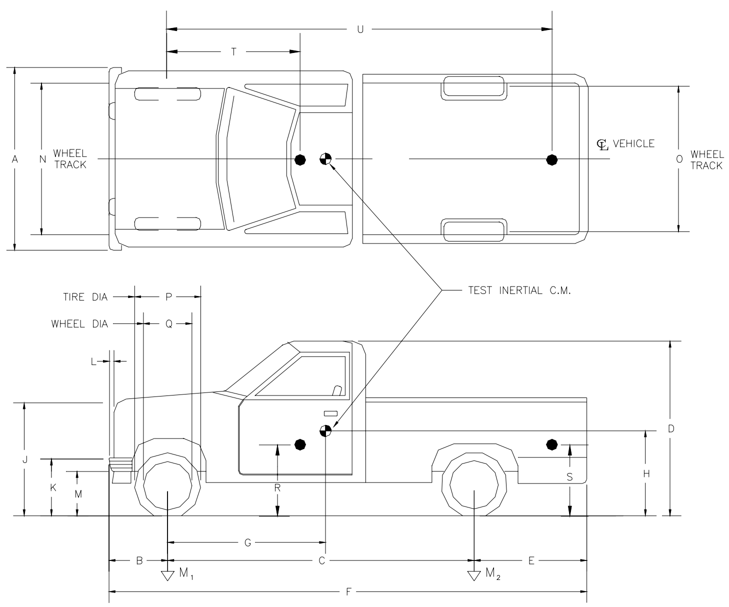
DATE: 05/05/99 TEST NO.: 404531-7 VIN NO.: 1GCFC24K6SZ278859

YEAR: 1995 MAKE: CHEVY MODEL: 2500 P/U

TIRE INFLATION PRESSURE: ______ ODOMETER: 149827 TIRE SIZE: LT 225 75/R16

MASS DISTRIBUTION (kg) LF 570 RF 553 LR 432 RR 445

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



● Denotes accelerometer location.

NOTES: R-100mm TO LT

ENGINE TYPE: 8 CYL

ENGINE CID: 5.7 L

TRANSMISSION TYPE:

__ AUTO
X MANUAL

OPTIONAL EQUIPMENT:

6 LUGS

DUMMY DATA:

TYPE:

MASS:

SEAT POSITION:

GEOMETRY – (mm)

A 1840	E 1320	J 1020	N 1600	R 680
B 860	F 5530	K 585	O 1620	S 870
C 3350	G 1469	L 65	P 740	T 1480
D 1790	H	M 370	Q 445	U 4000

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	1138	1123	1166
M_2	821	877	910
M_T	1959	2000	2076

Figure 58. Vehicle properties for test 404531-7.

Table 17. Exterior crush measurements for test 404531-7.

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width _________ Corner shift: A1 ________ A2 ________ End shift at frame (CDC) (check one) < 4 inches ________ $ 4 inches ________	Bowing: B1 ____ X1 ____ B2 ____ X2 ____ Bowing constant 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	Front bumper	1060	470	640	-470	-320	-230	-150	-70	-0	-320
2	Top front wheel well	1060	510	1440	-510	-410	-330	-330	+220	+200	+340

[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.

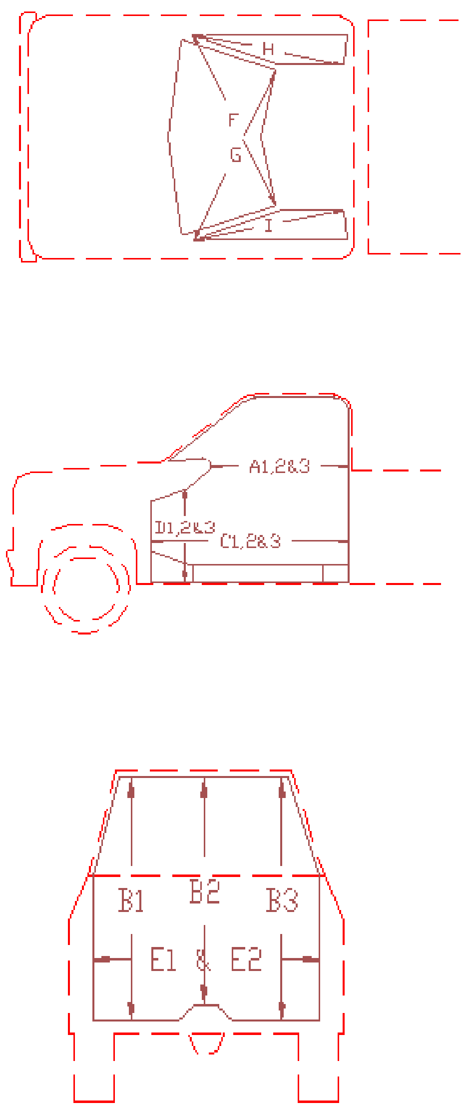
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 18. Occupant compartment measurements for test 404531-7.

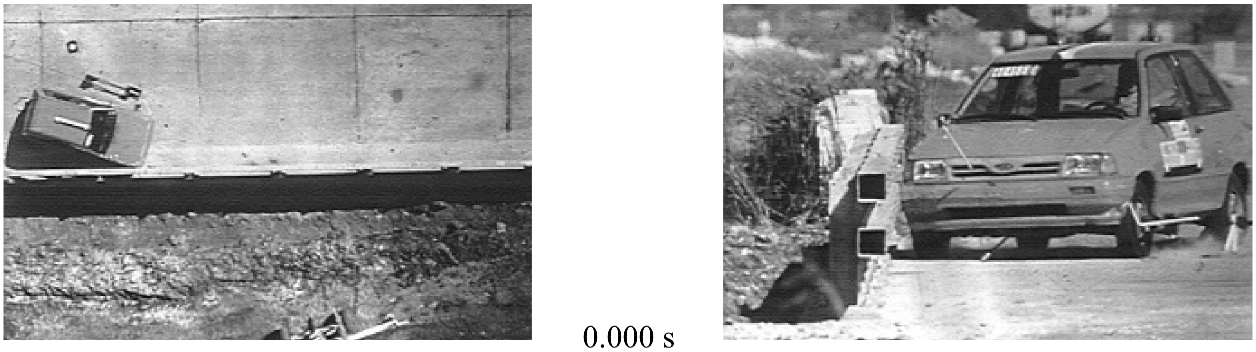
Truck

Occupant Compartment Deformation

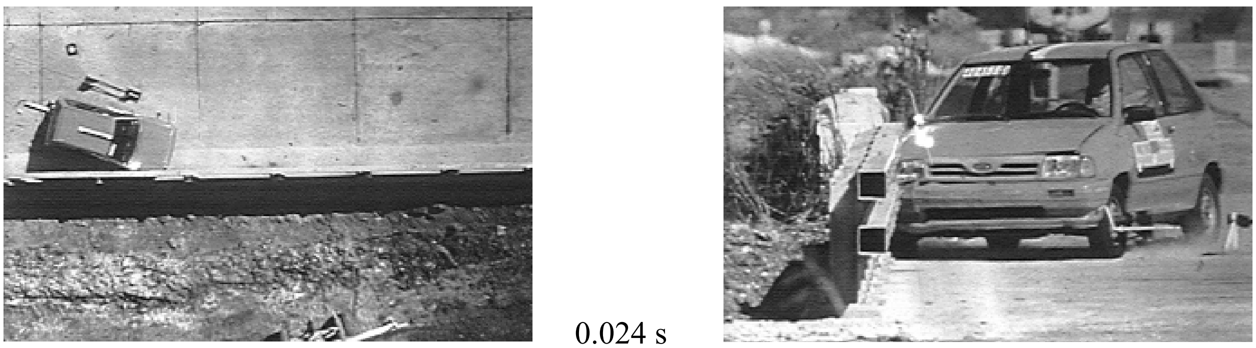


	BEFORE	AFTER
A1	871	713
A2	911	860
A3	910	915
B1	1077	1126
B2	1071	940
B3	1073	1073
C1	1380	1285
C2	1262	1235
C3	1370	1370
D1	320	290
D2	161	110
D3	315	340
E1	1800	2200
E2	1820	2220
F	1460	1425
G	1460	1420
H	900	885
I	900	810
J	1520	1420

APPENDIX C. SEQUENTIAL PHOTOGRAPHS



0.000 s

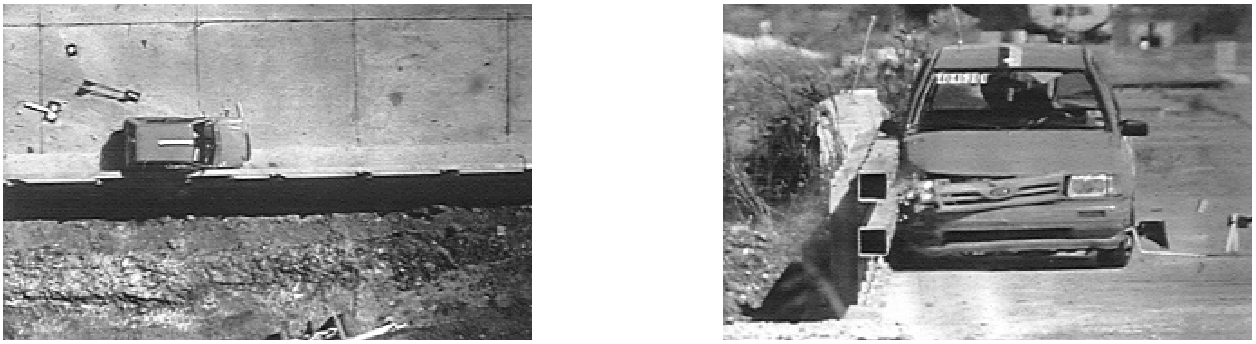


0.024 s

0.048 s

0.072 s

Figure 59. Sequential photographs for test 404531-1 (overhead and frontal views).



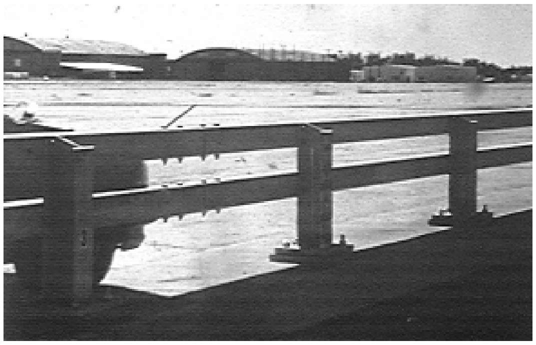
0.108 s

0.156 s

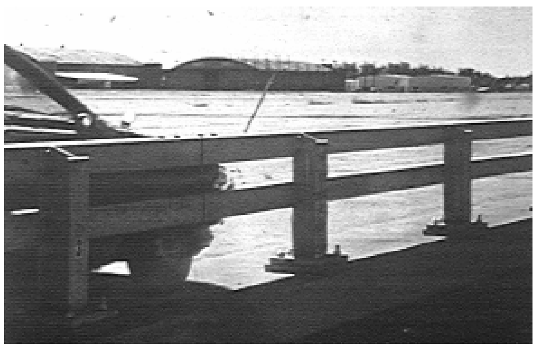
0.228 s

0.349 s

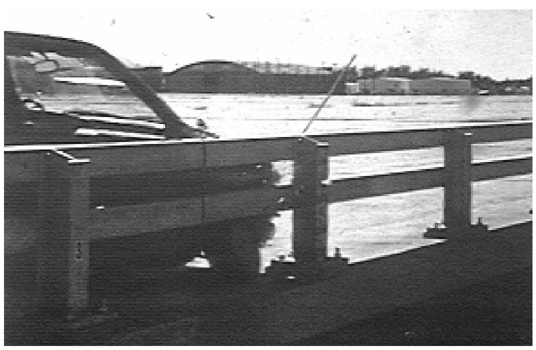
Figure 59. Sequential photographs for test 404531-1
(overhead and frontal views) (continued).



0.000 s



0.024 s

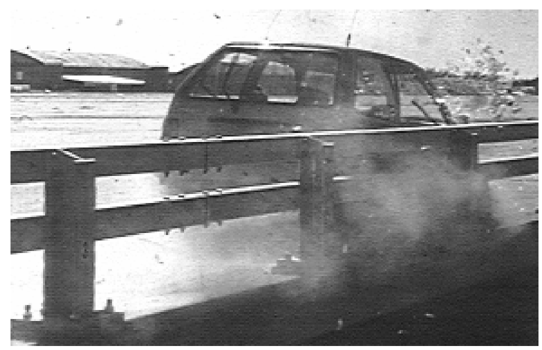


0.048 s

0.072 s

0.108 s

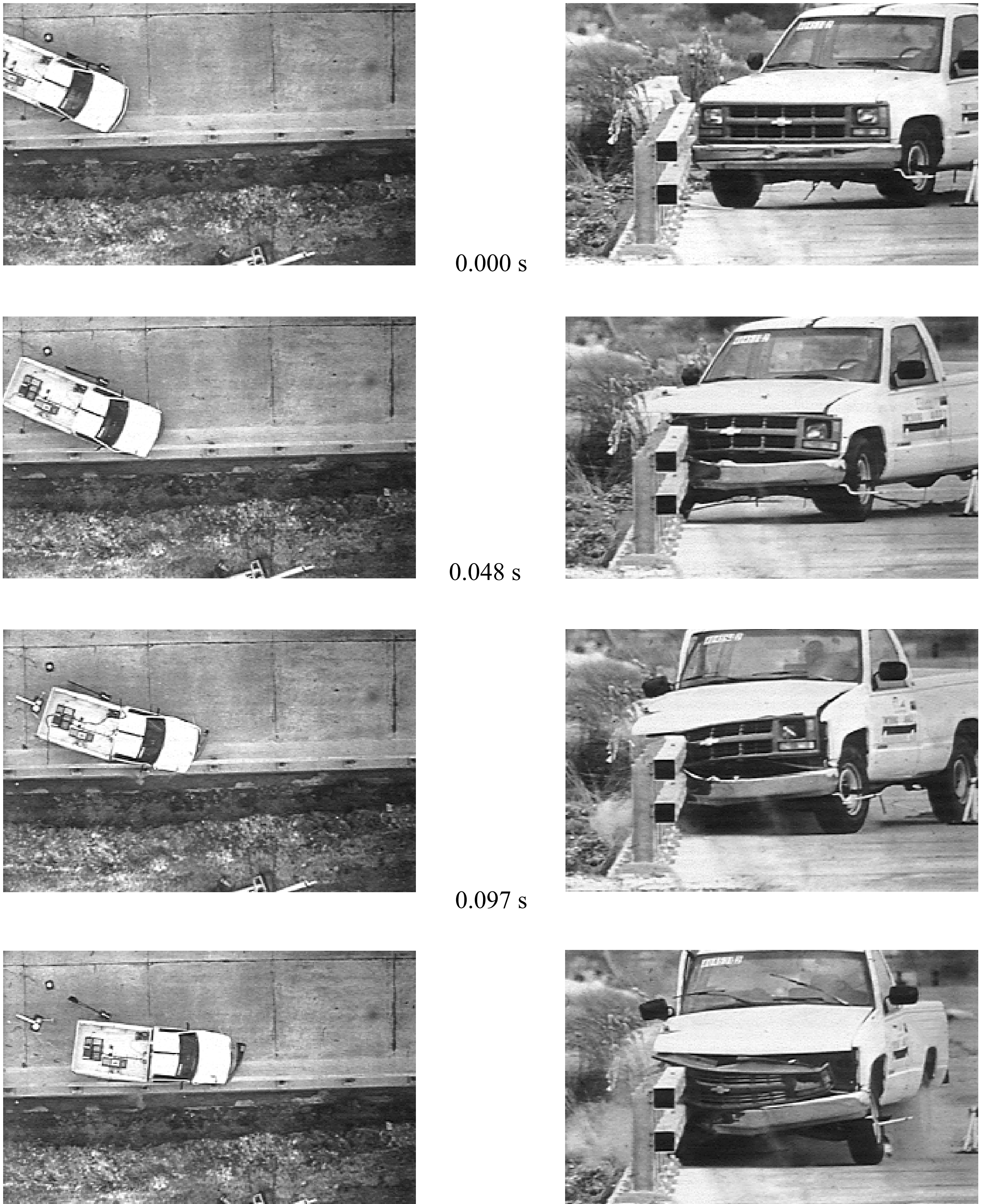
0.156 s



0.228 s

0.349 s

Figure 60. Sequential photographs for test 404531-1
(rear view).



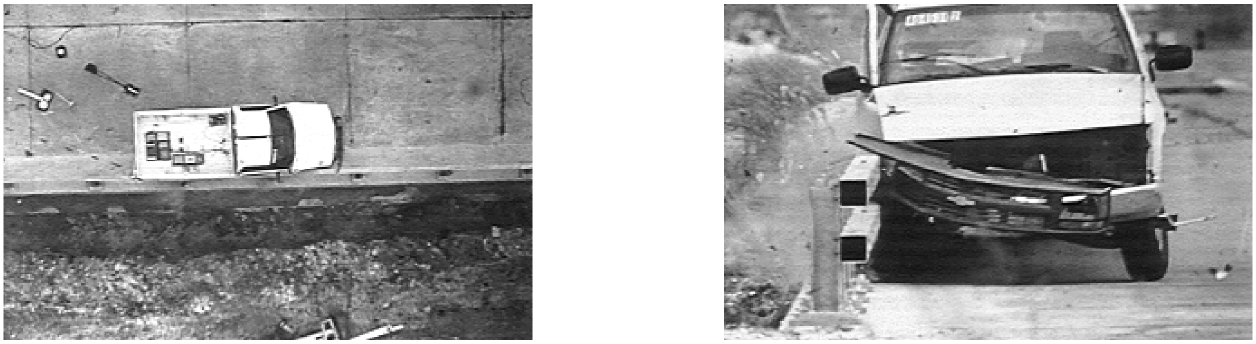
0.000 s

0.048 s

0.097 s

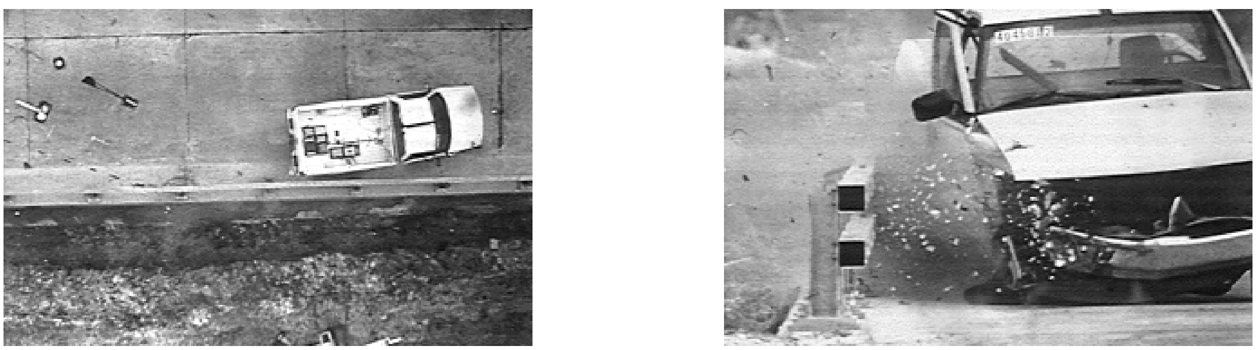
0.145 s

Figure 61. Sequential photographs for test 404531-2
(overhead and frontal views).

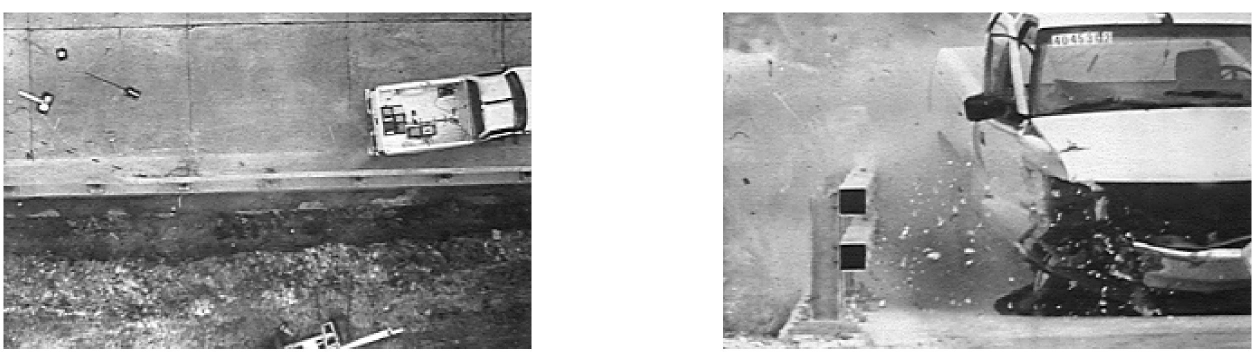


0.193 s

0.266 s

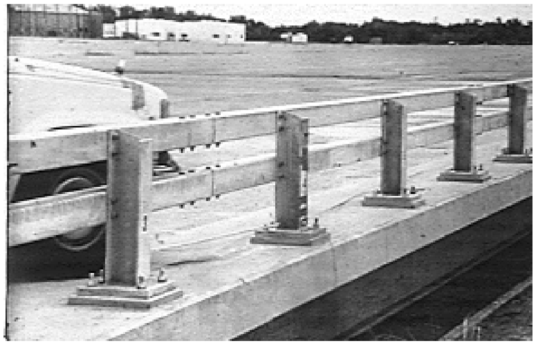


0.387 s

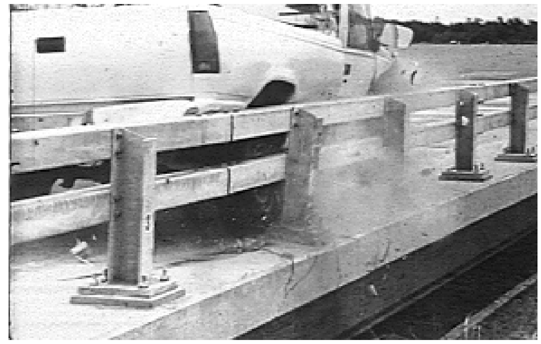


0.483 s

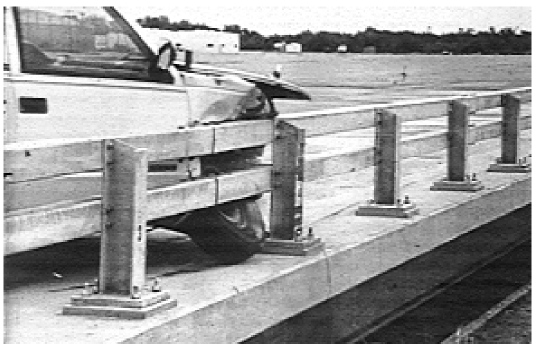
Figure 61. Sequential photographs for test 404531-2
(overhead and frontal views) (continued).



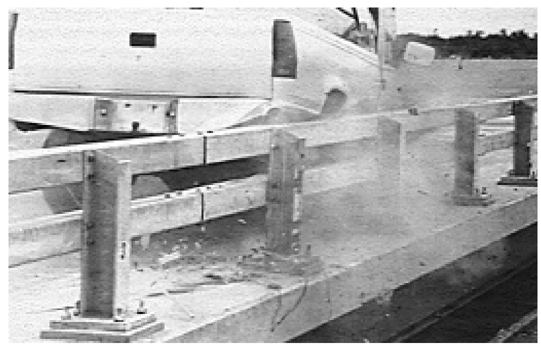
0.000 s



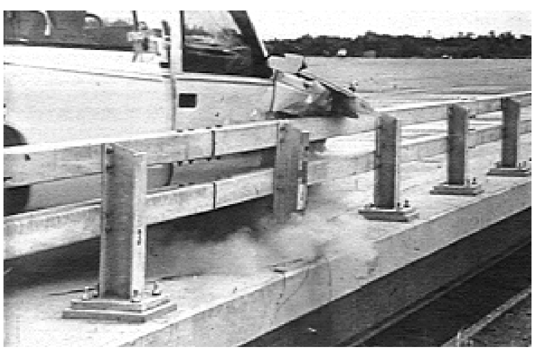
0.193 s



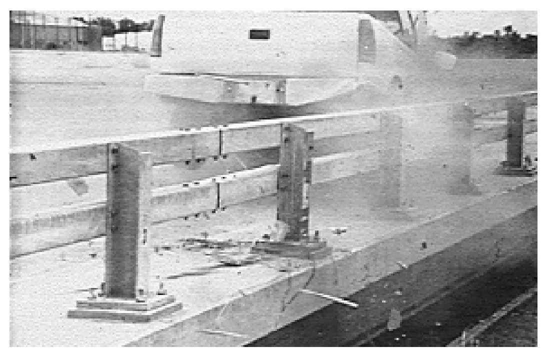
0.048 s



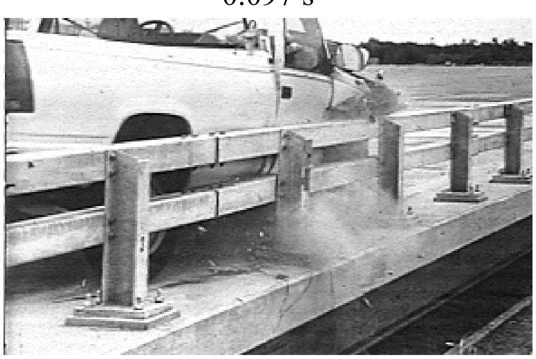
0.266 s



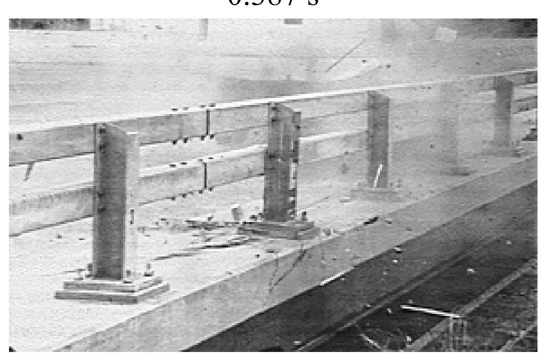
0.097 s



0.387 s



0.145 s



0.483 s

Figure 62. Sequential photographs for test 404531-2
(rear view).

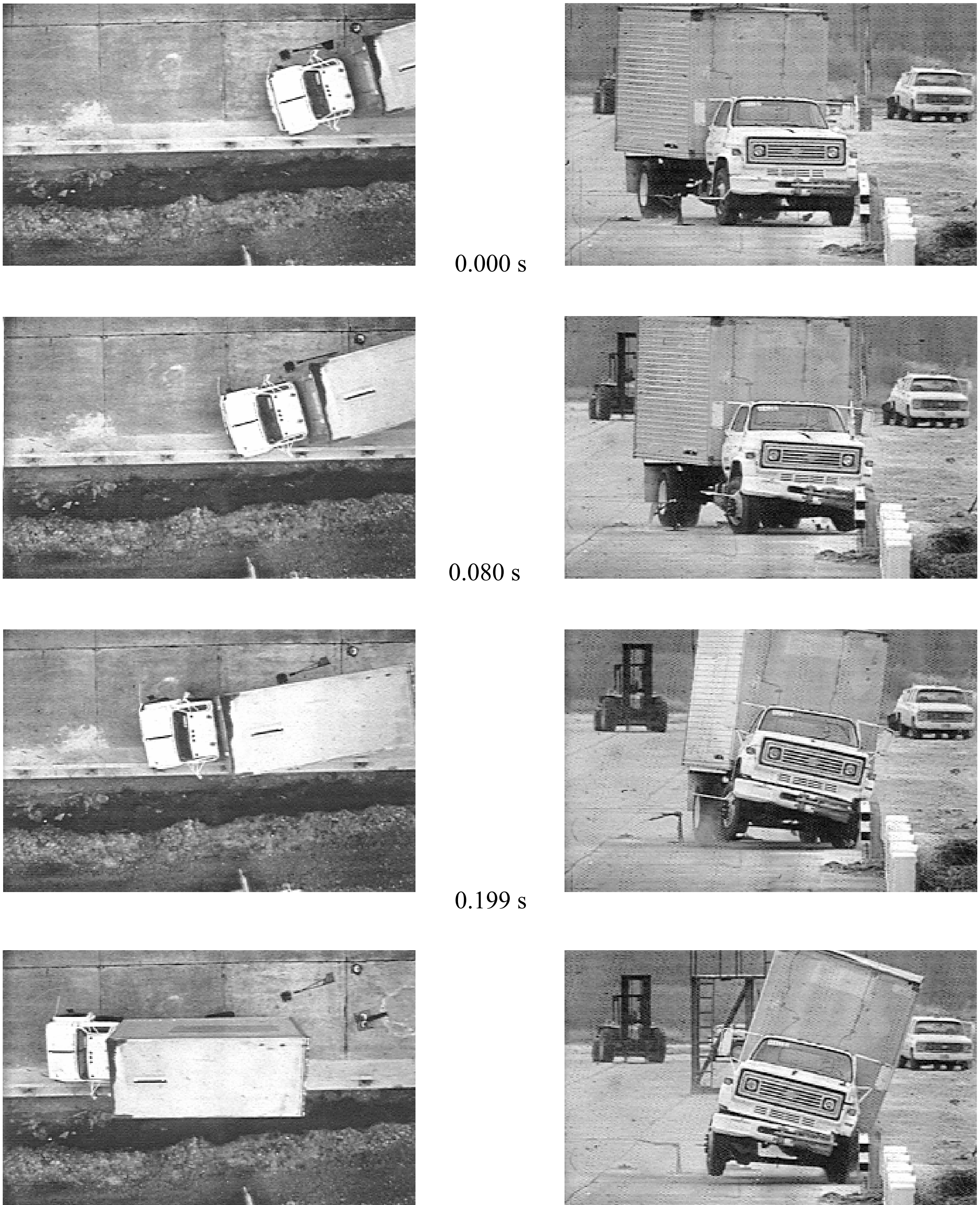
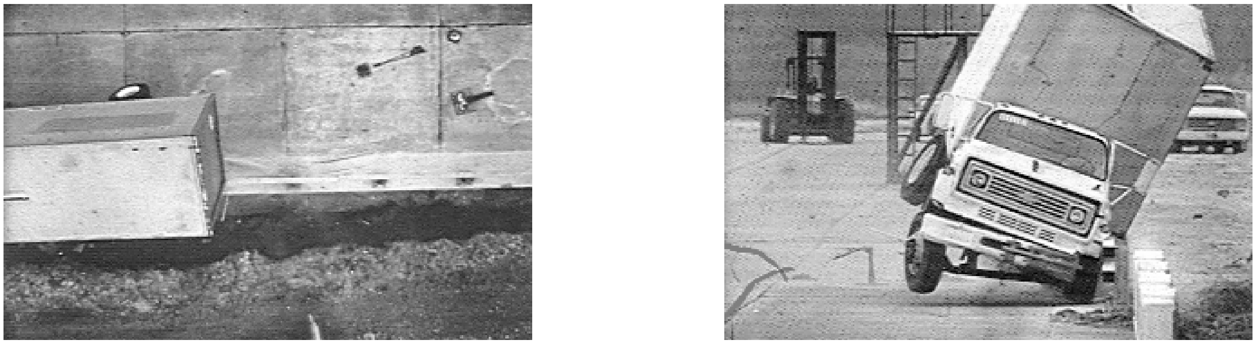
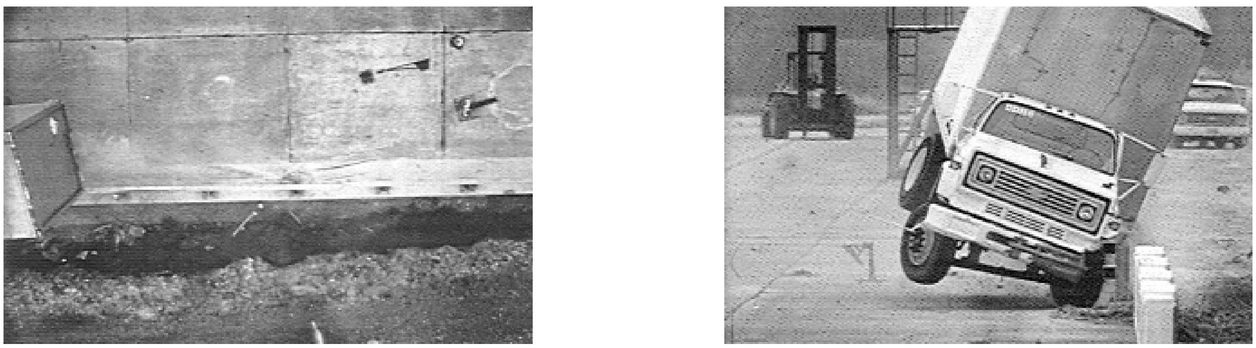


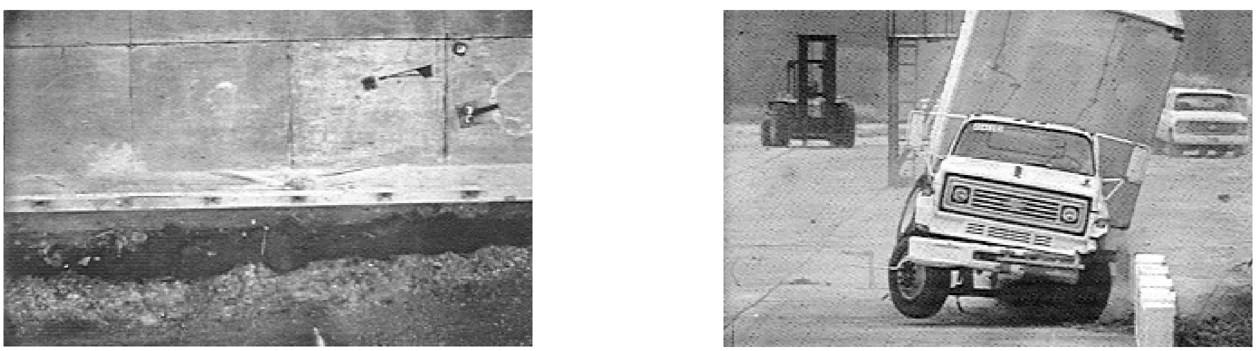
Figure 63. Sequential photographs for test 404531-3
(overhead and frontal views).



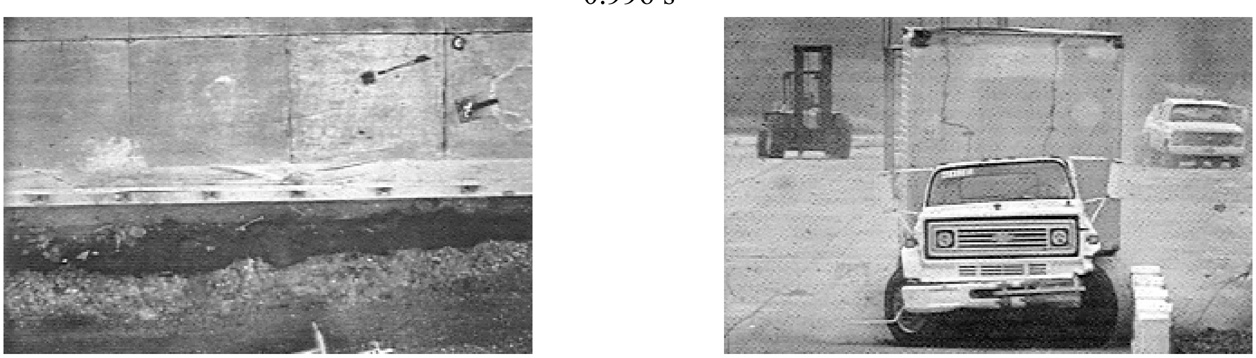
0.558 s



0.757 s

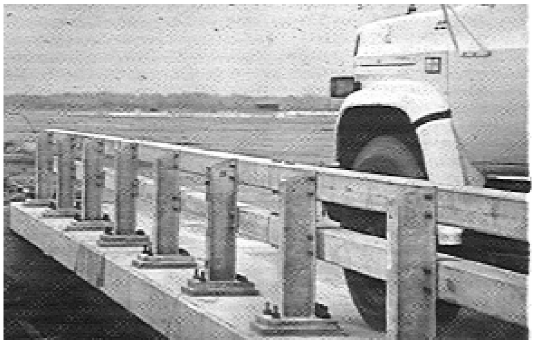


0.996 s

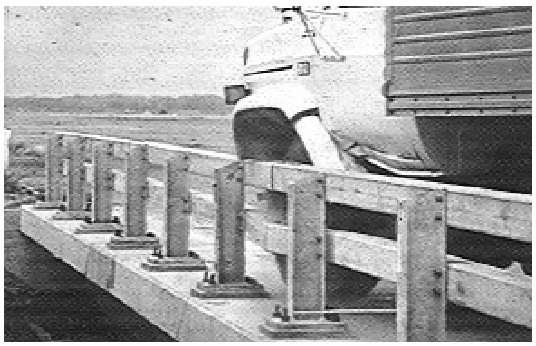


1.275 s

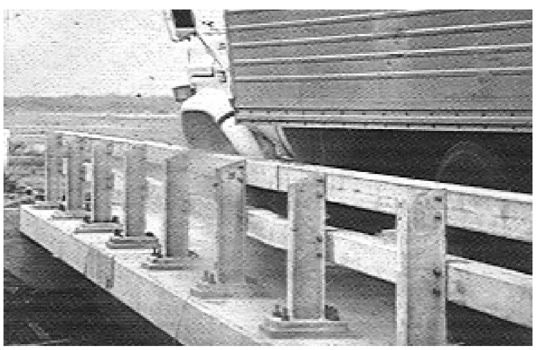
Figure 63. Sequential photographs for test 404531-3
(overhead and frontal views) (continued).



0.000 s

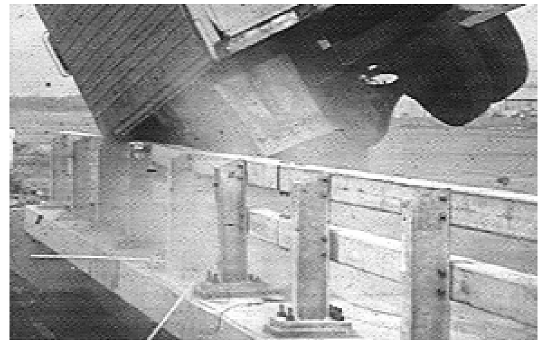


0.080 s

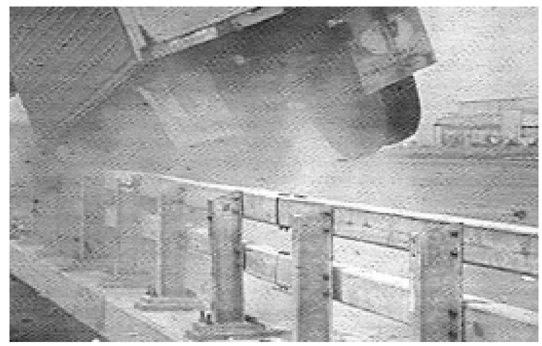


0.199 s

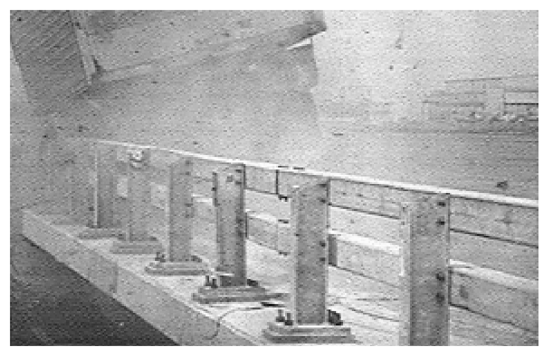
0.359 s



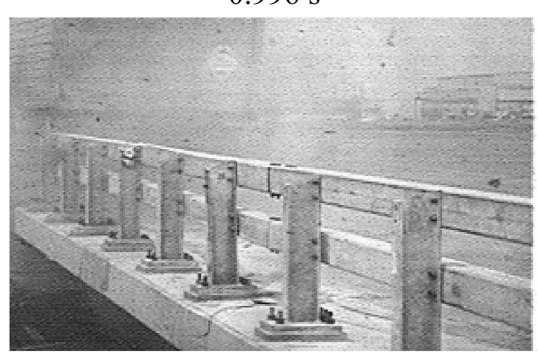
0.558 s



0.757 s



0.996 s



1.275 s

Figure 64. Sequential photographs for test 404531-3
(rear view).

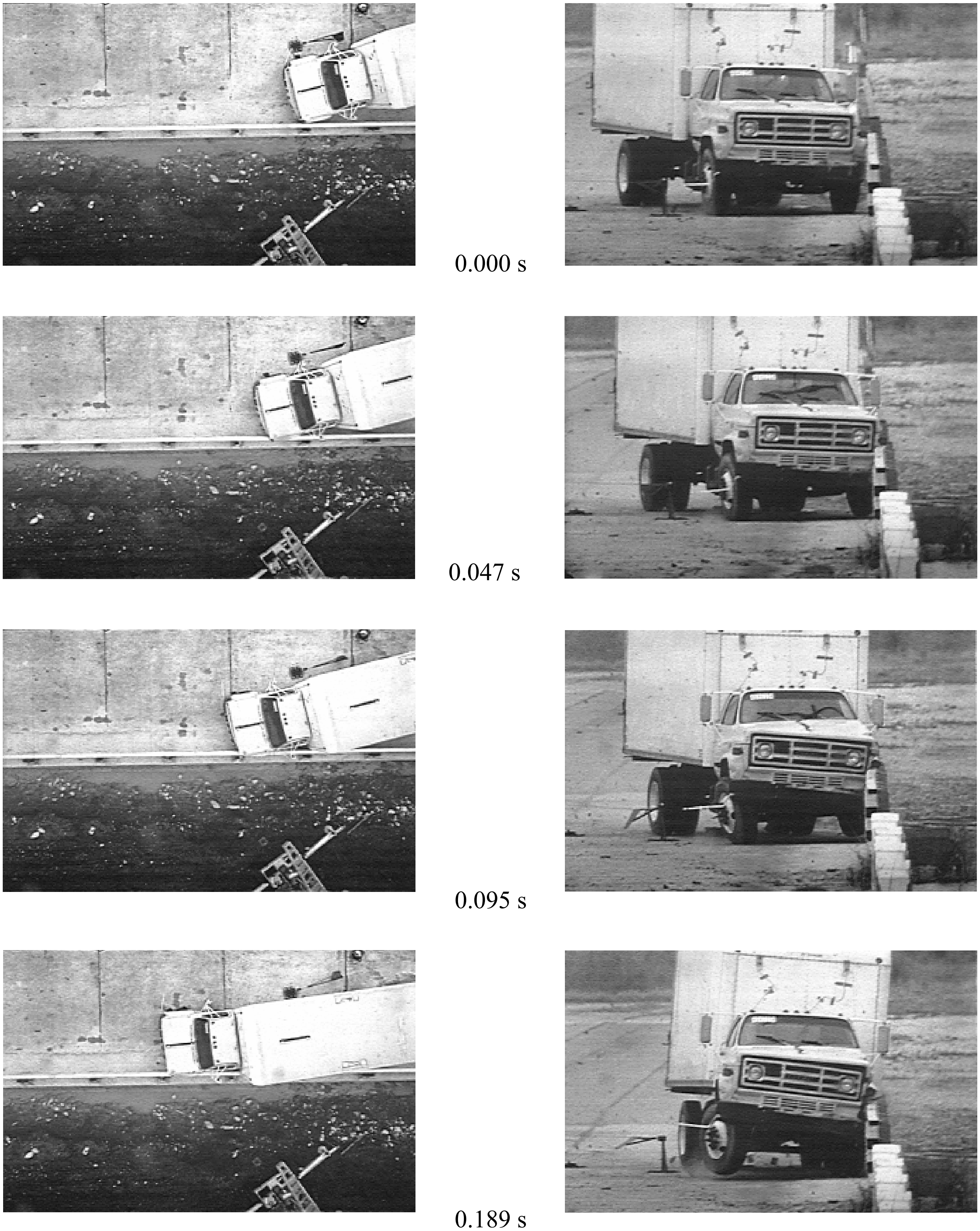
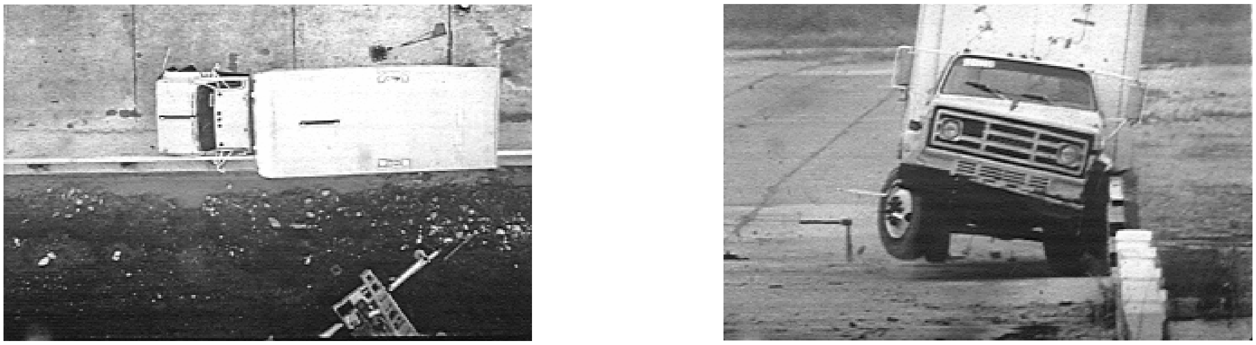
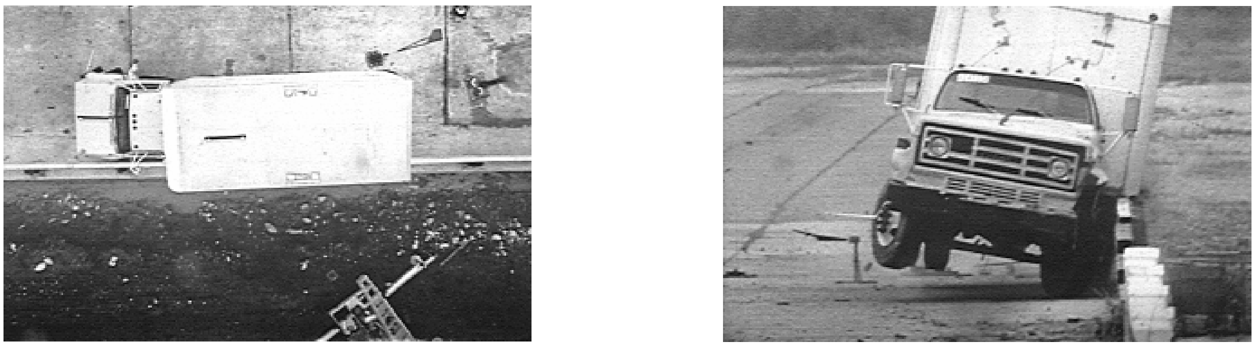


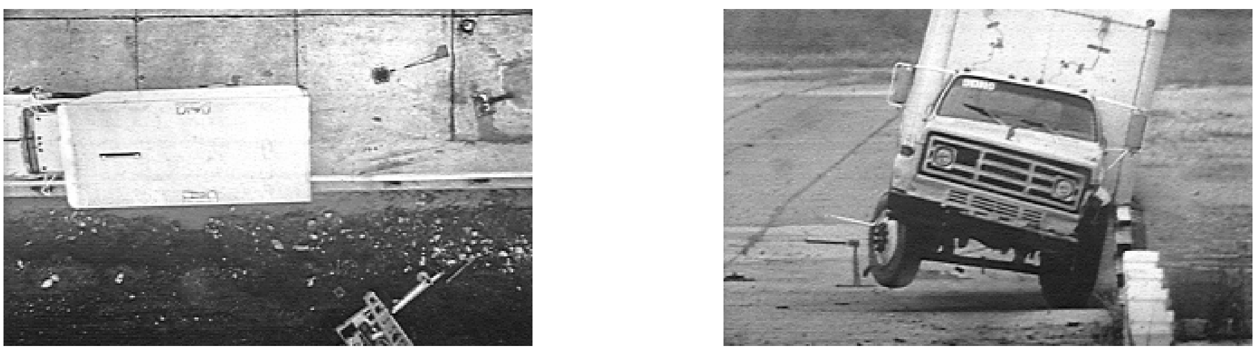
Figure 65. Sequential photographs for test 404531-4 (overhead and frontal views).



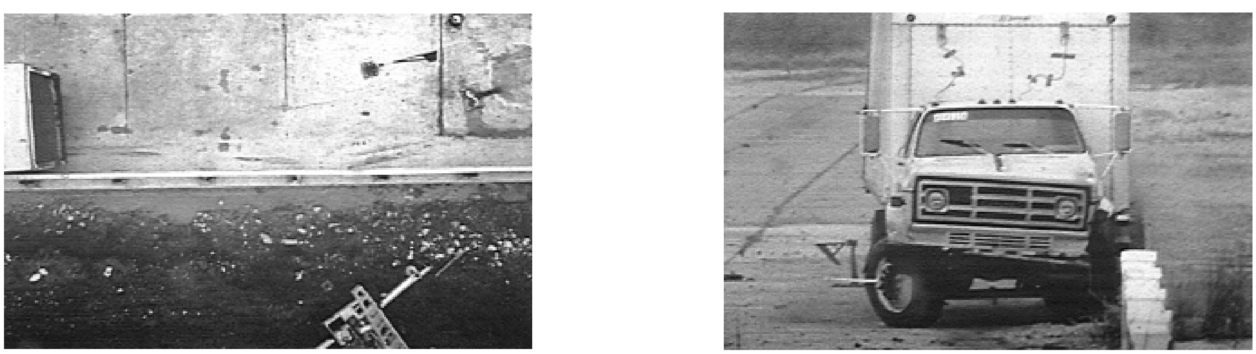
0.261 s



0.355 s

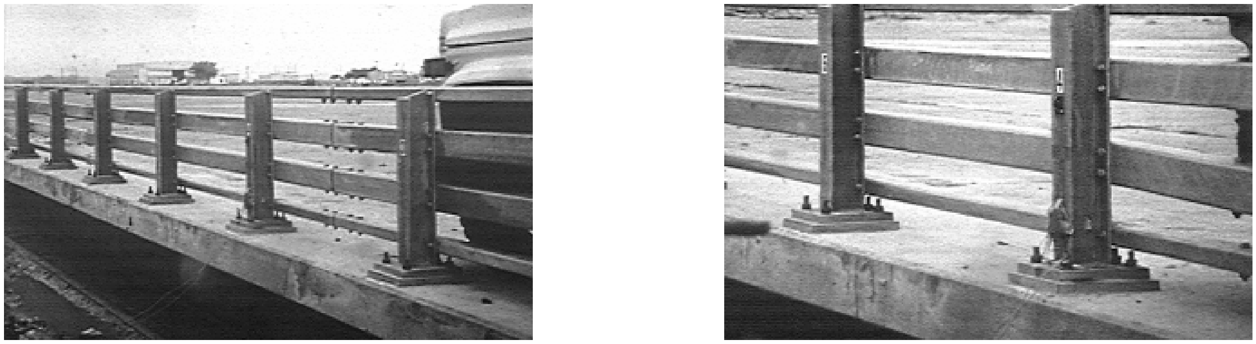


0.474 s

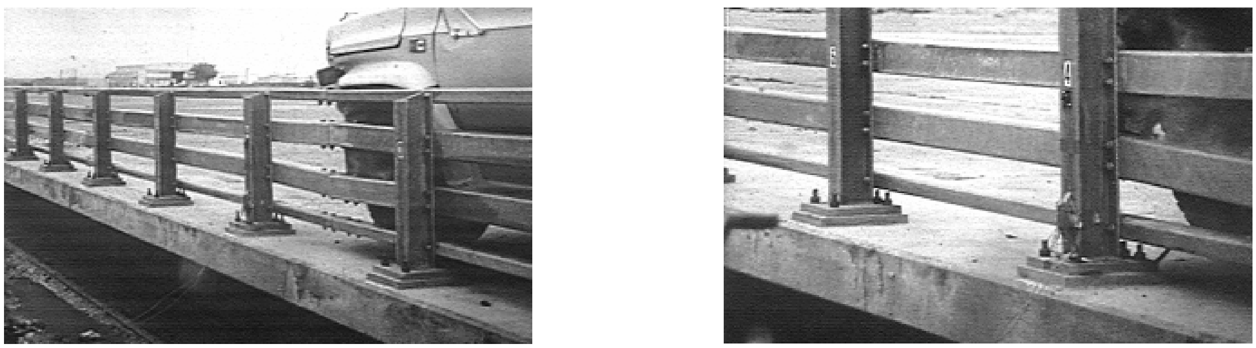


0.772 s

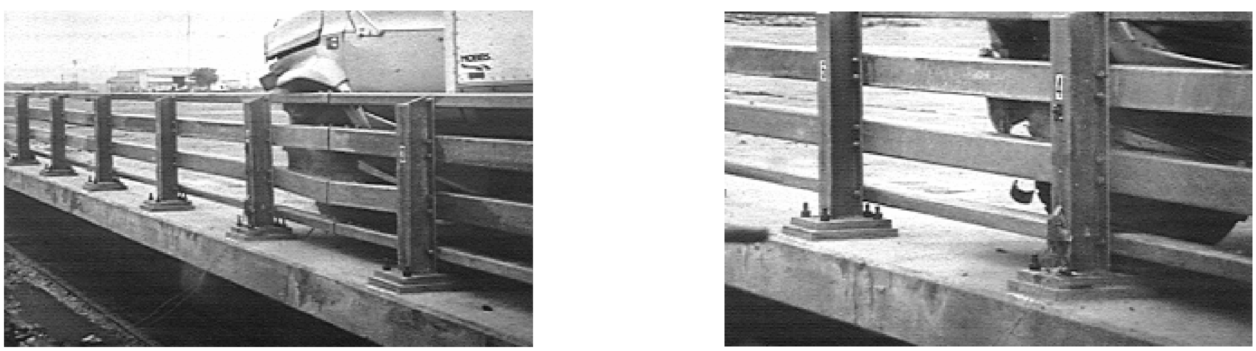
Figure 65. Sequential photographs for test 404531-4
(overhead and frontal views) (continued).



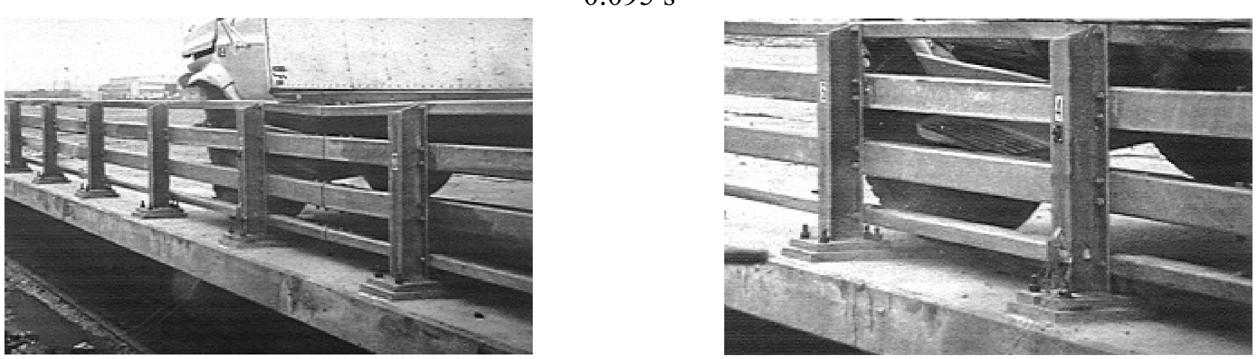
0.000 s



0.047 s

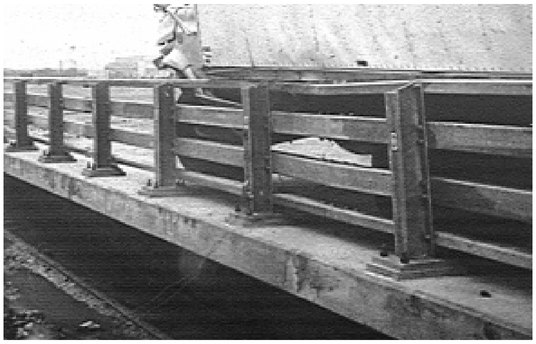
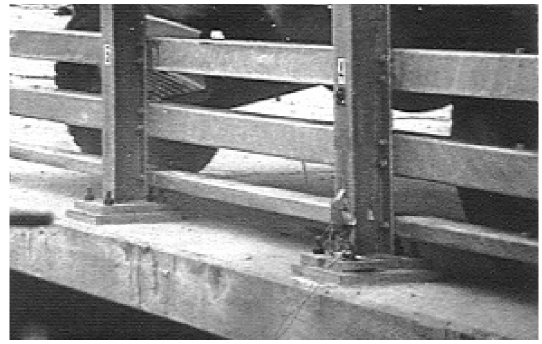


0.095 s

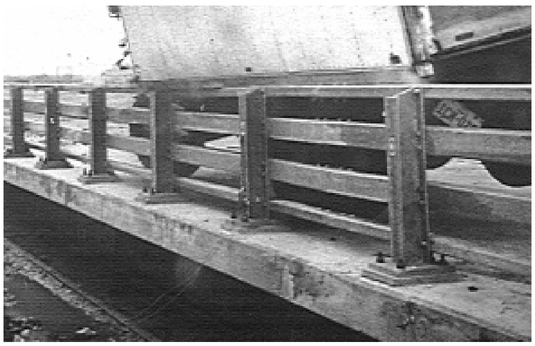
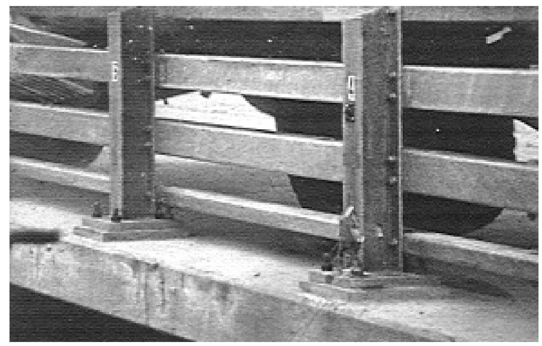


0.189 s

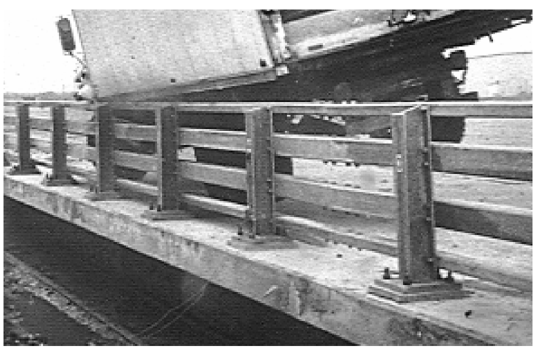
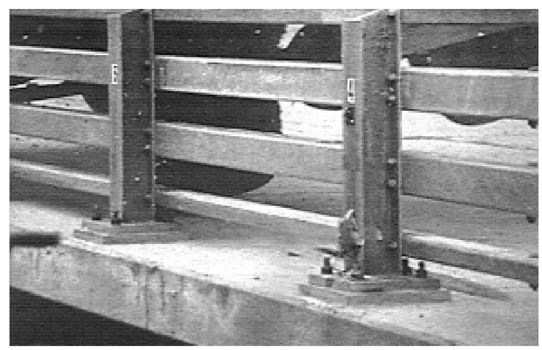
Figure 66. Sequential photographs for test 404531-4
(rear views).

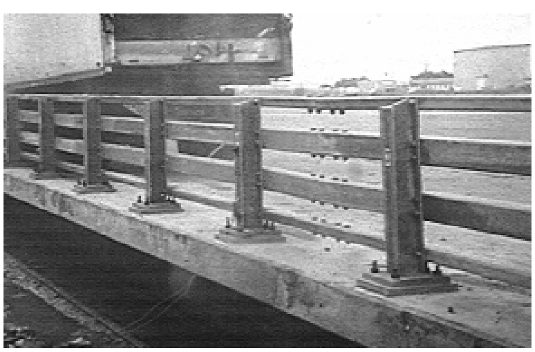
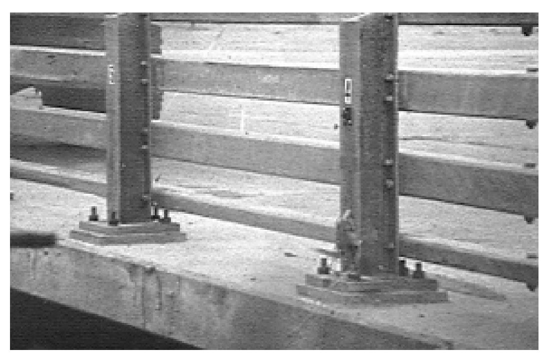
0.261 s

0.355 s

0.474 s

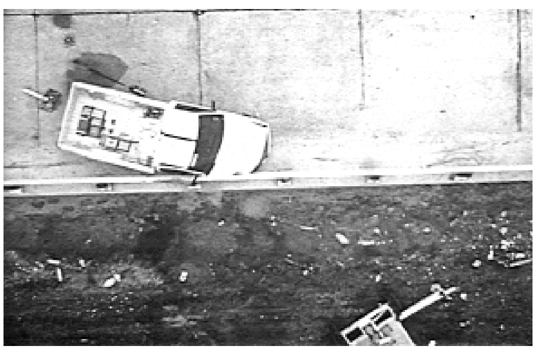



0.772 s

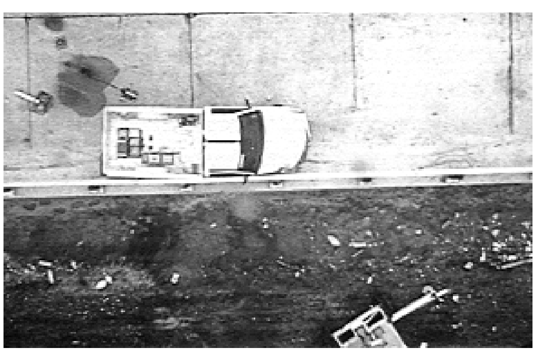
Figure 66. Sequential photographs for test 404531-4
(rear views) (continued).


0.000 s


0.055 s

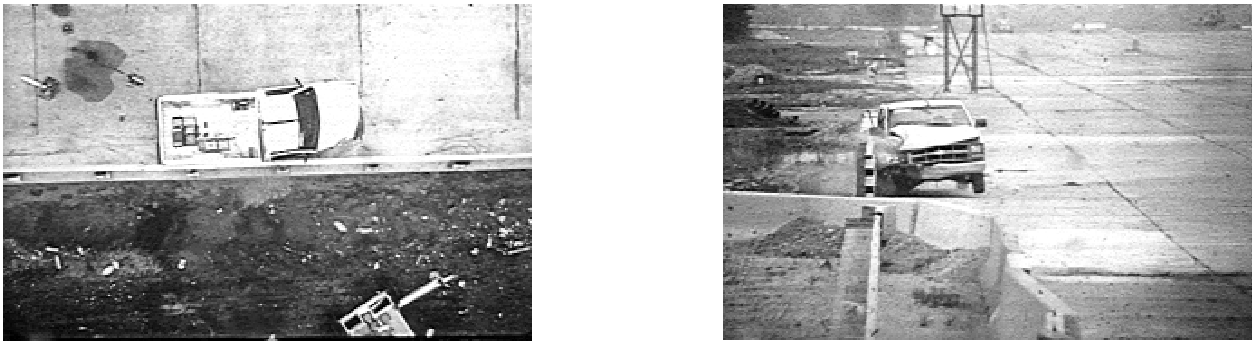



0.109 s



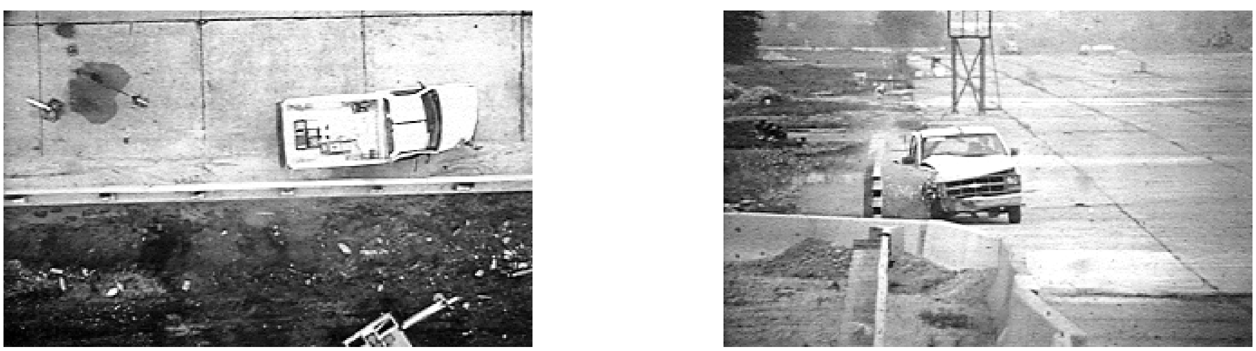

0.164 s

Figure 67. Sequential photographs for test 404531-6 (overhead and frontal views).



0.219 s

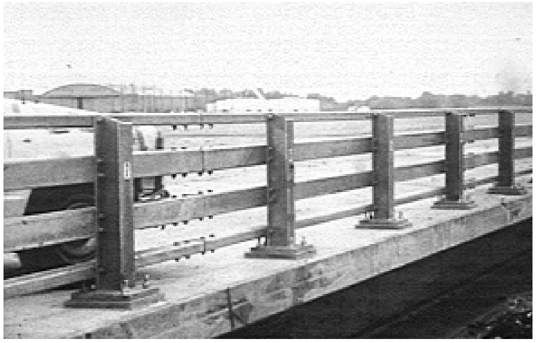
0.274 s



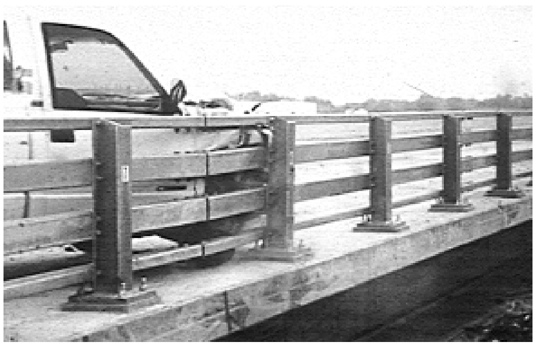
0.356 s

0.492 s

Figure 67. Sequential photographs for test 404531-6 (overhead and frontal views) (continued).

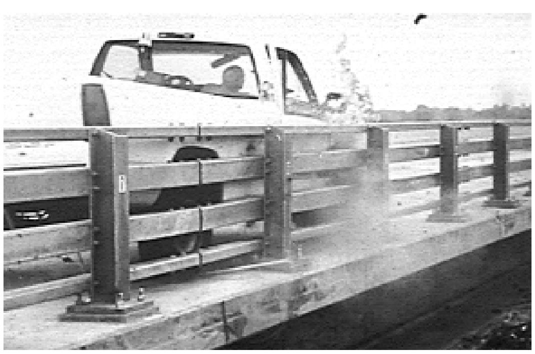


0.000 s

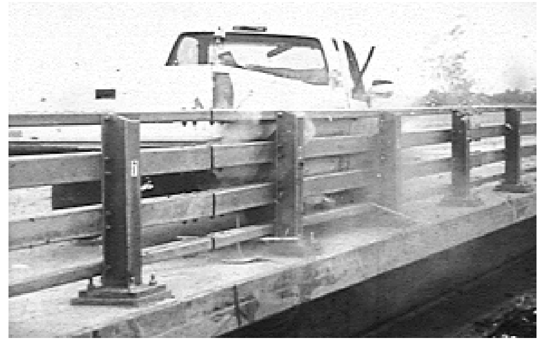


0.055 s

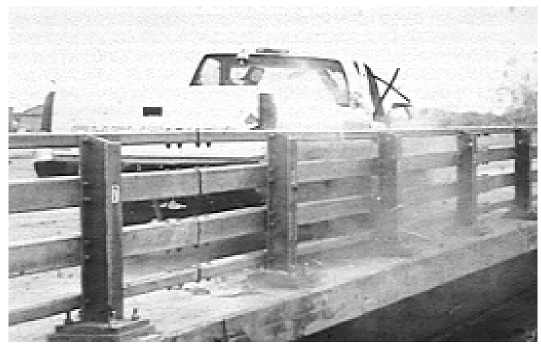
0.109 s



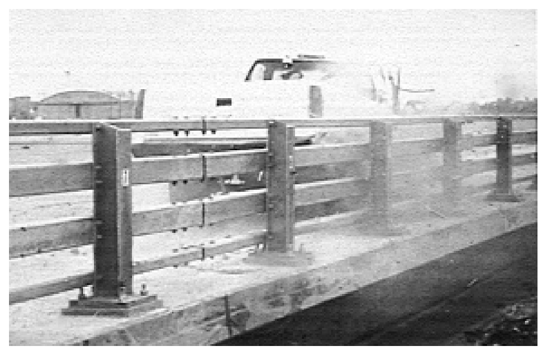
0.164 s



0.219 s



0.274 s



0.356 s

0.492 s

Figure 68. Sequential photographs for test 404531-6
(rear view).

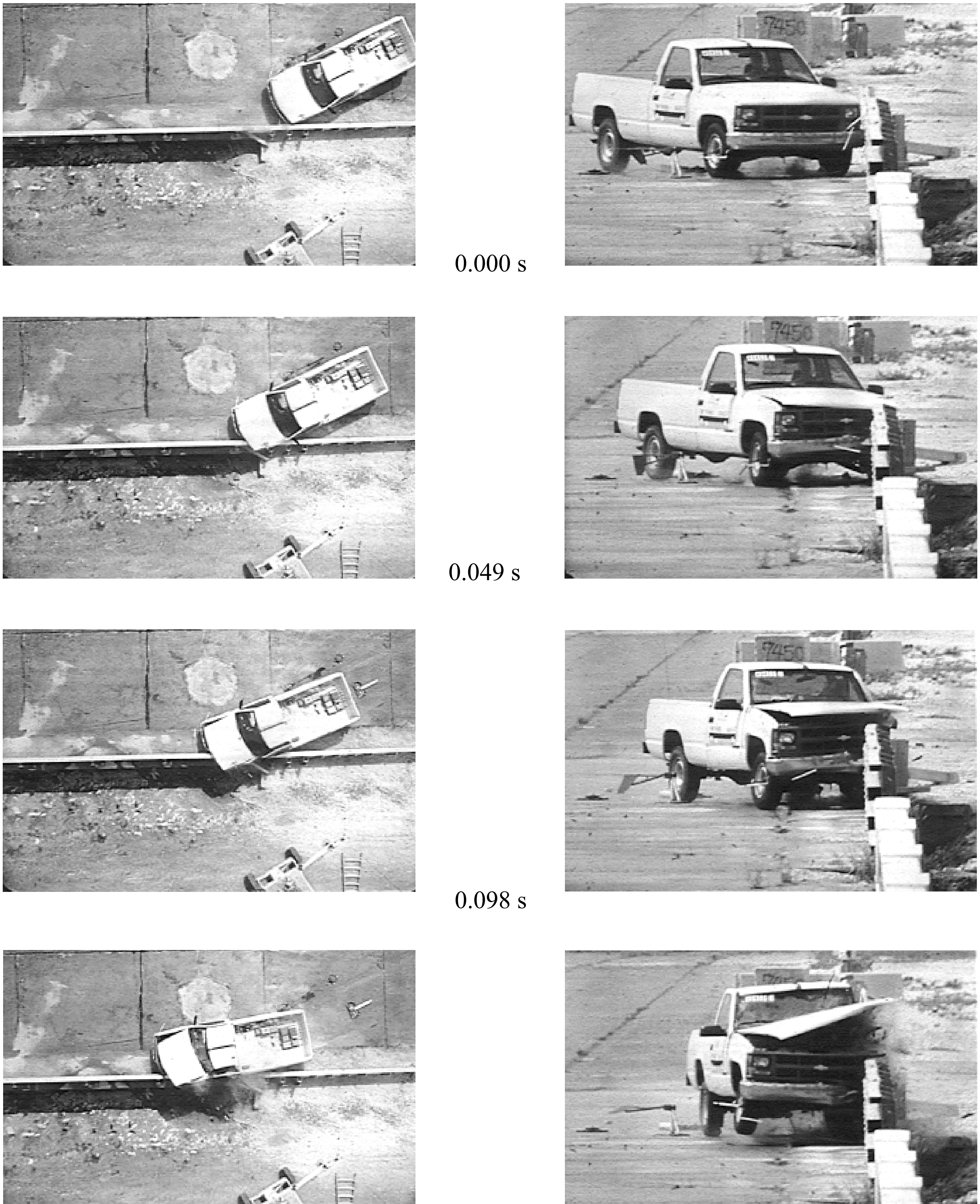
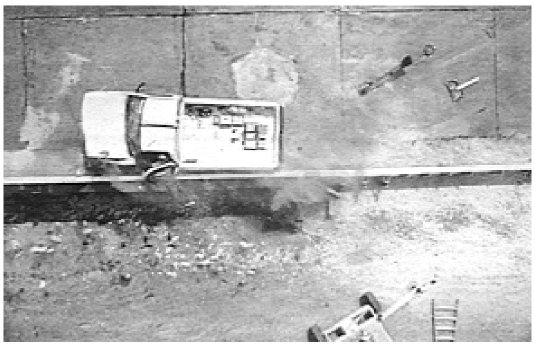
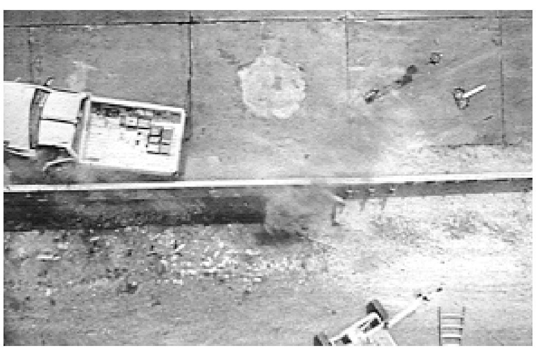


Figure 69. Sequential photographs for test 404531-7
(overhead and frontal views).


0.245 s




0.343 s




0.491 s


0.687 s

Figure 69. Sequential photographs for test 404531-7
(overhead and frontal views) (continued).

0.000 s

0.049 s

0.098 s

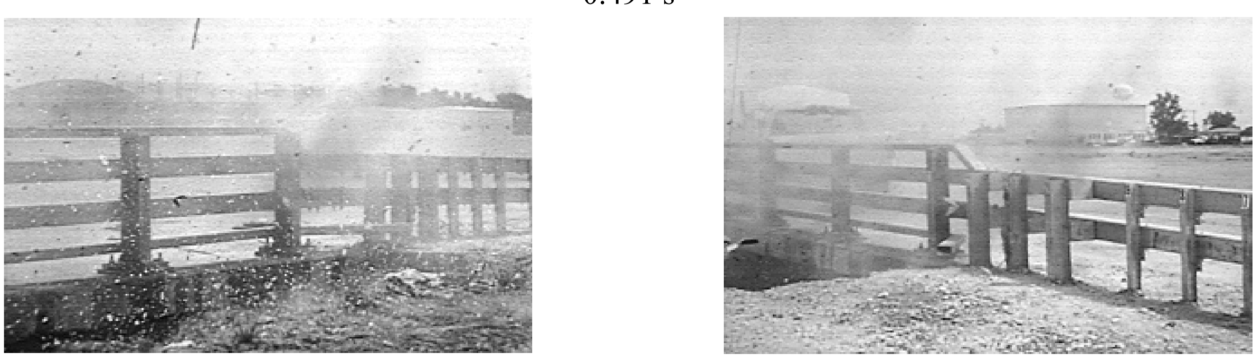
0.172 s

Figure 70. Sequential photographs for test 404531-7
(rear views).

0.245 s

0.343 s

0.491 s



0.687 s

Figure 70. Sequential photographs for test 404531-7 (rear views) (continued).

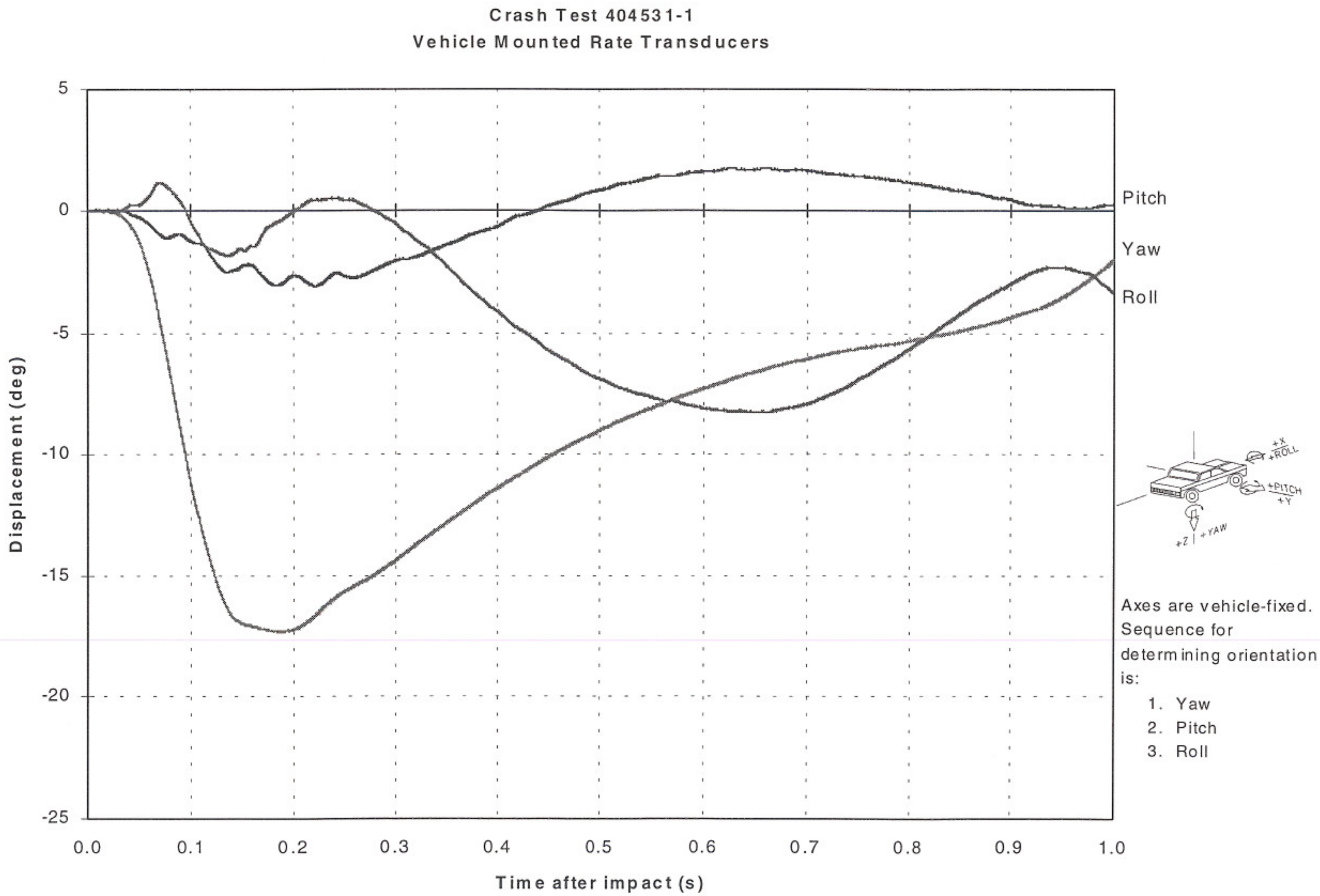


Figure 71. Vehicular angular displacements for test 404531-1.

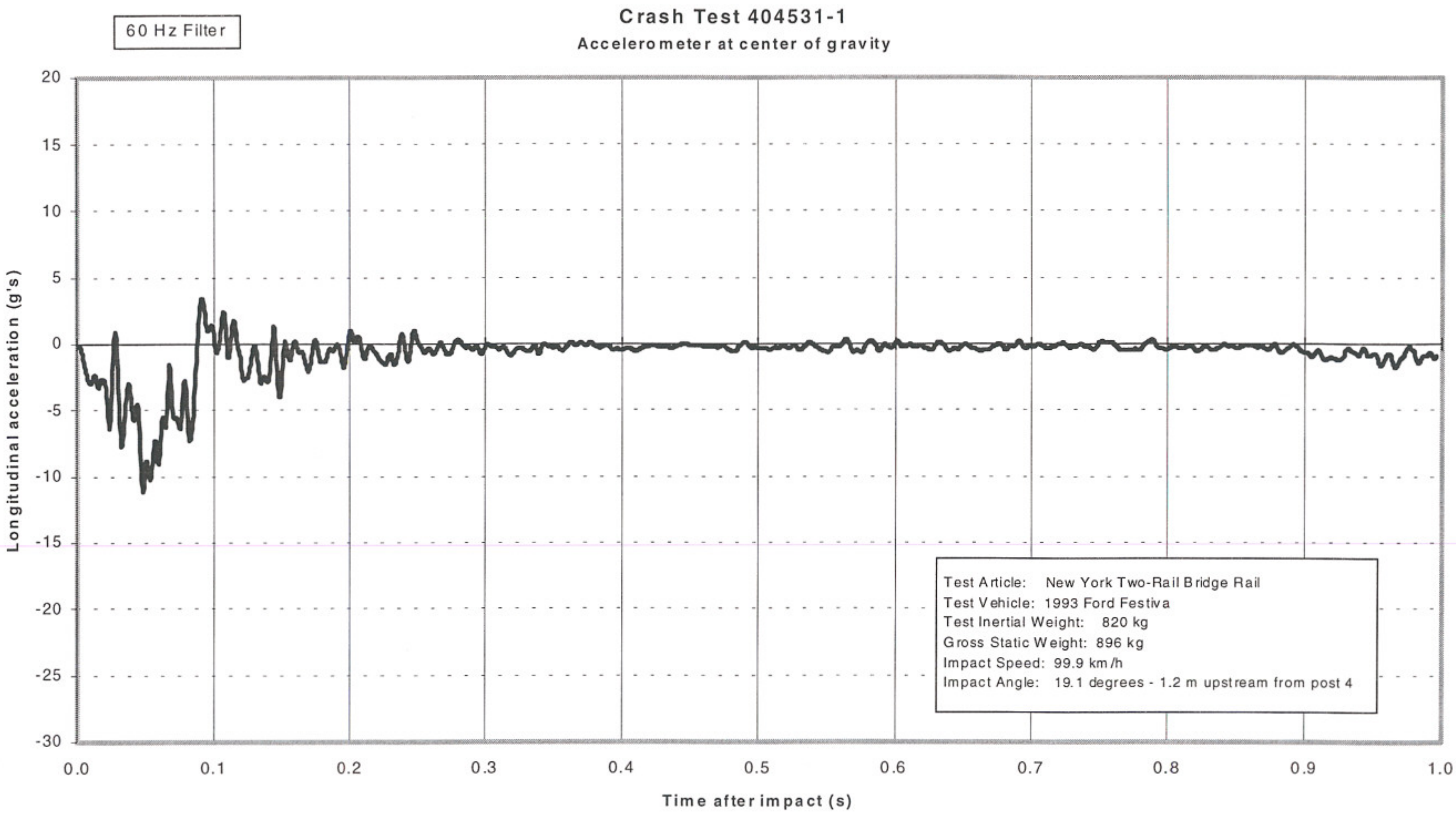


Figure 72. Vehicle longitudinal accelerometer trace for test 404531-1 (accelerometer located at center of gravity).

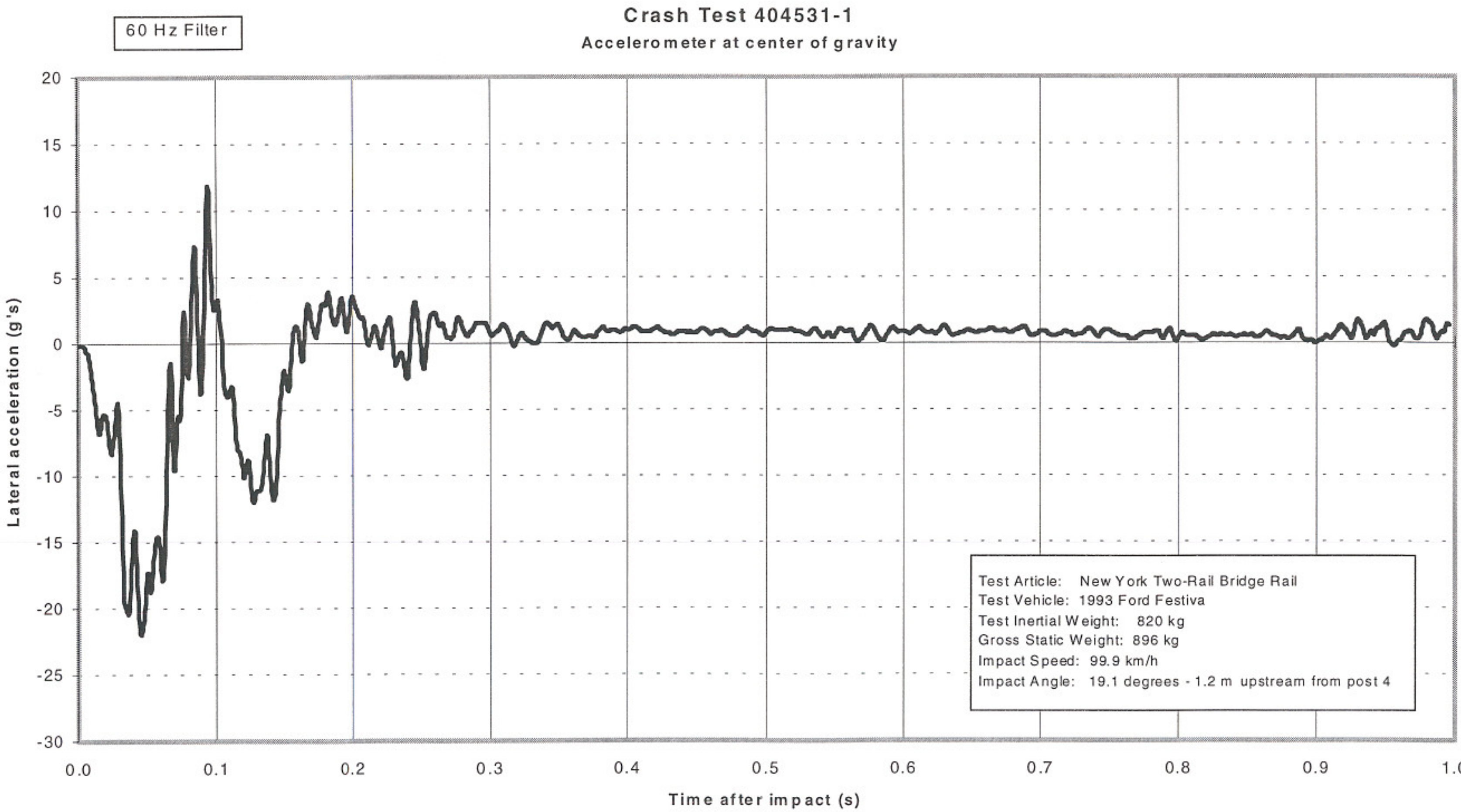


Figure 73. Vehicle lateral accelerometer trace for test 404531-1
(accelerometer located at center of gravity).

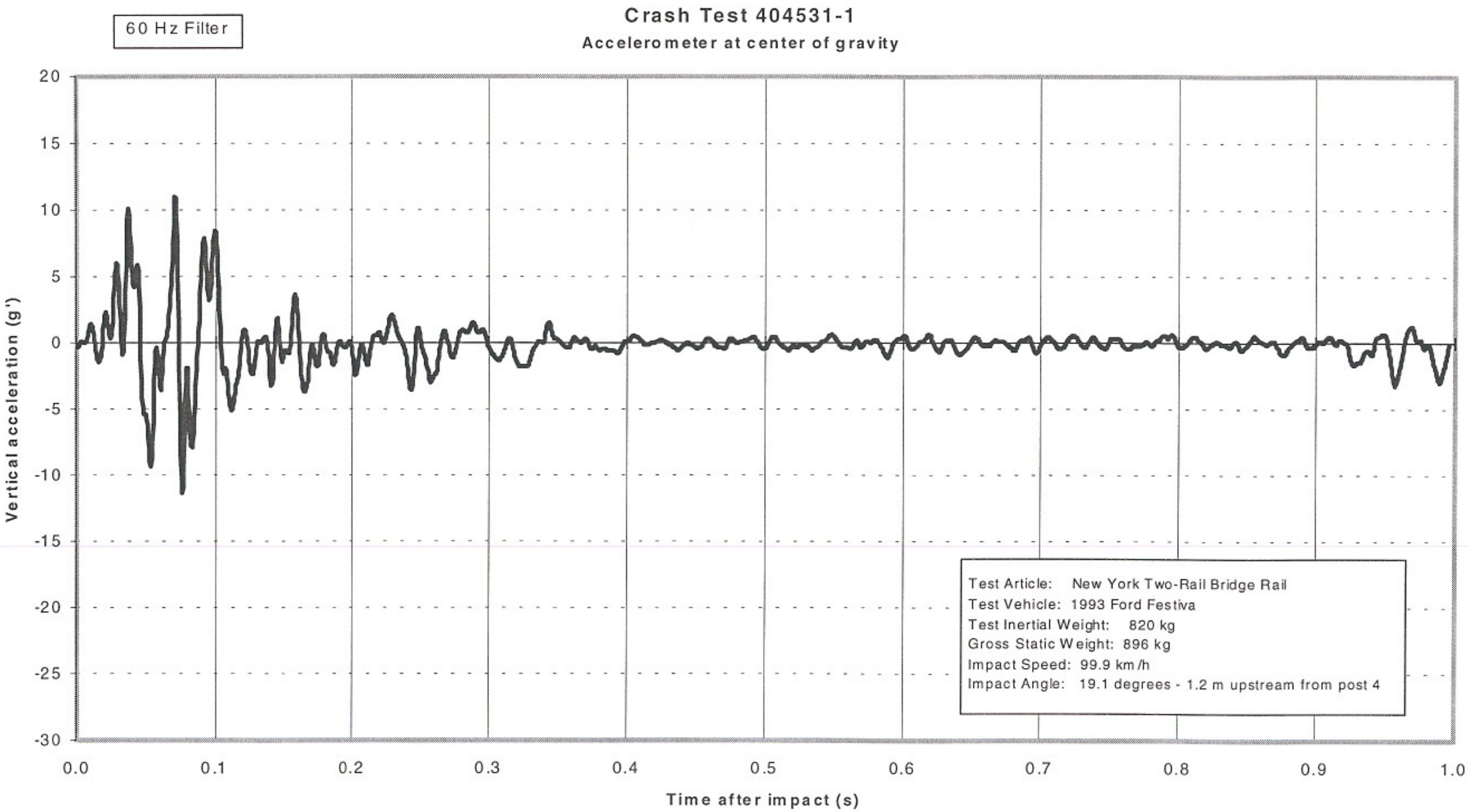


Figure 74. Vehicle vertical accelerometer trace for test 404531-1
(accelerometer located at center of gravity).

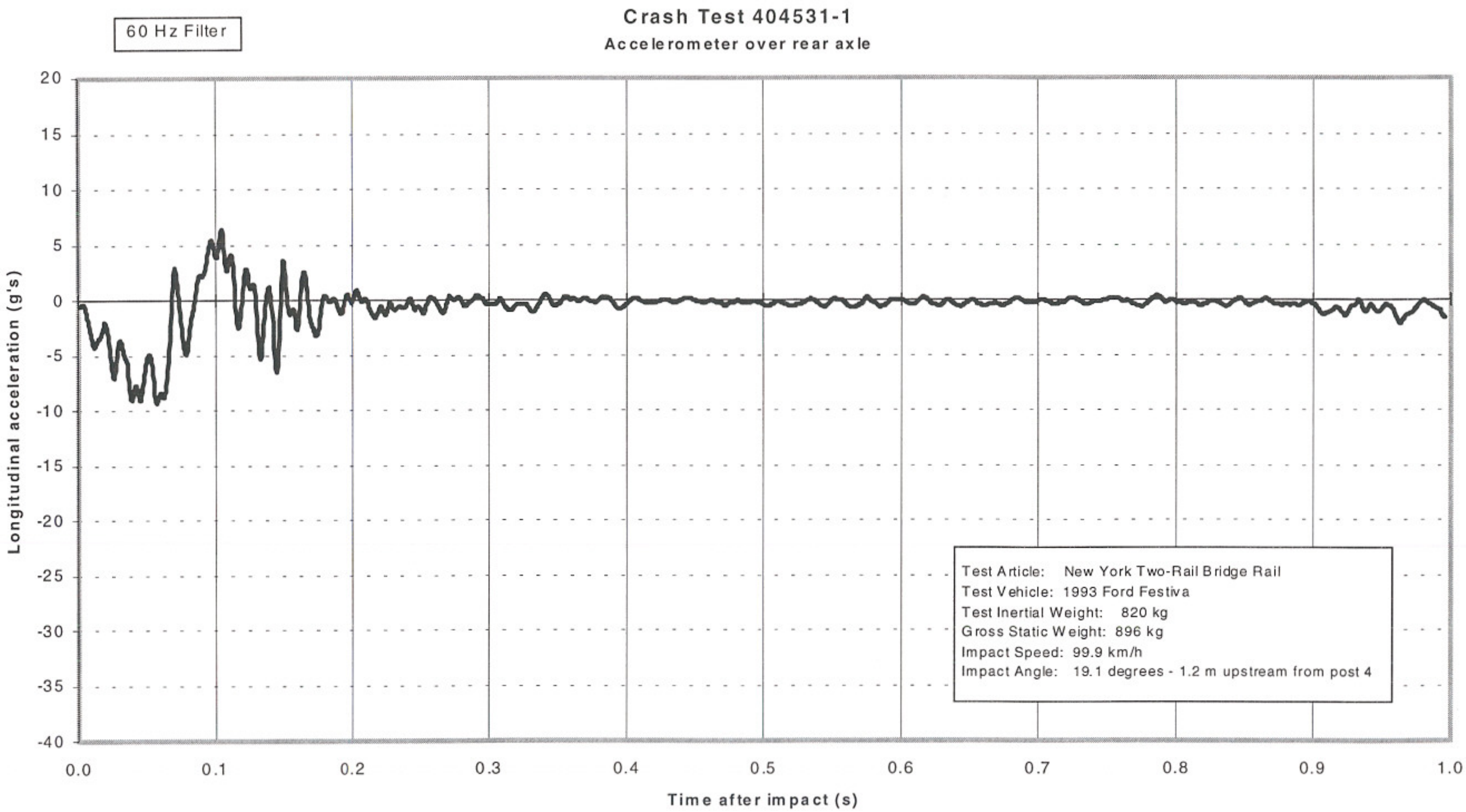


Figure 75. Vehicle longitudinal accelerometer trace for test 404531-1
(accelerometer located over rear axle).

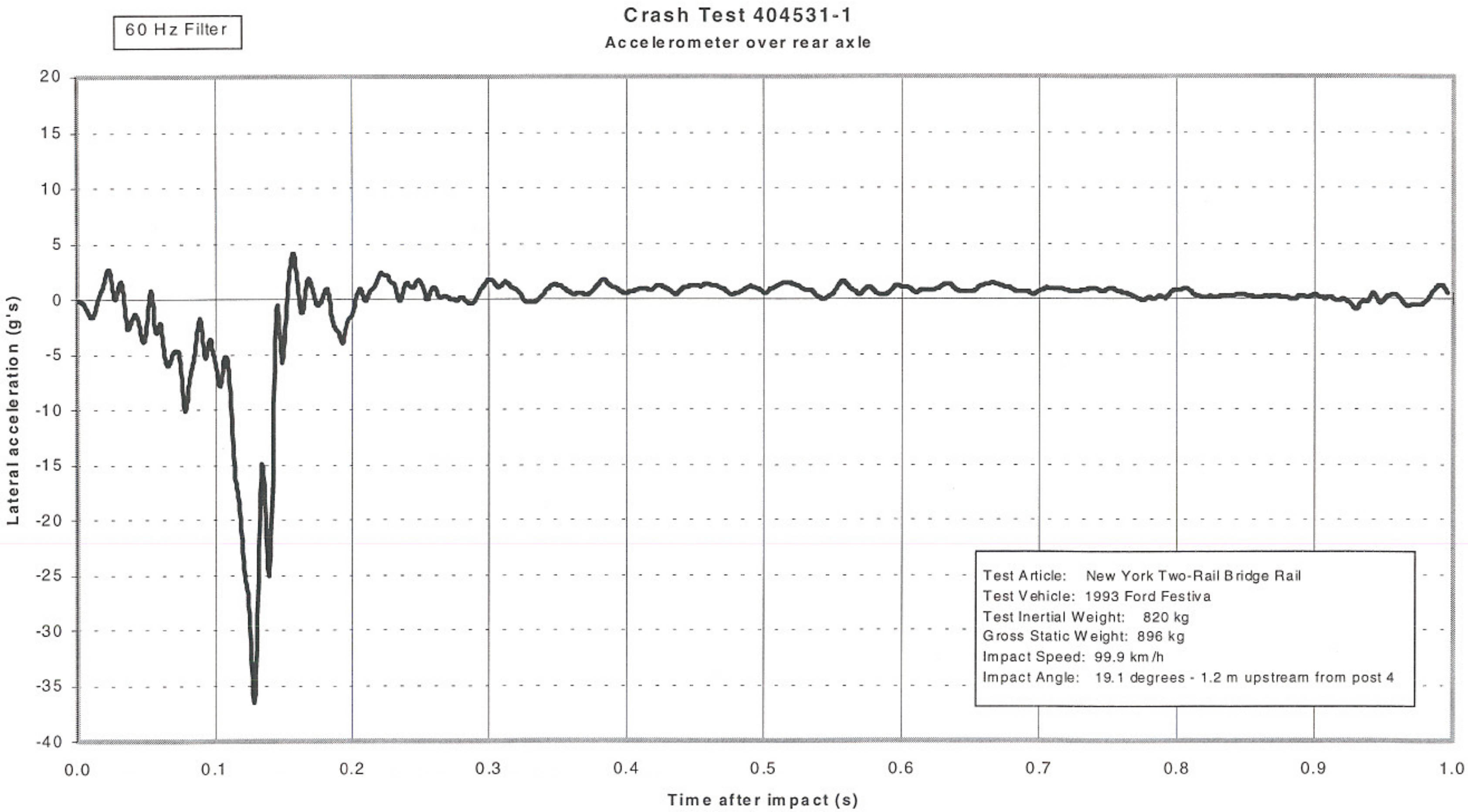


Figure 76. Vehicle lateral accelerometer trace for test 404531-1 (accelerometer located over rear axle).

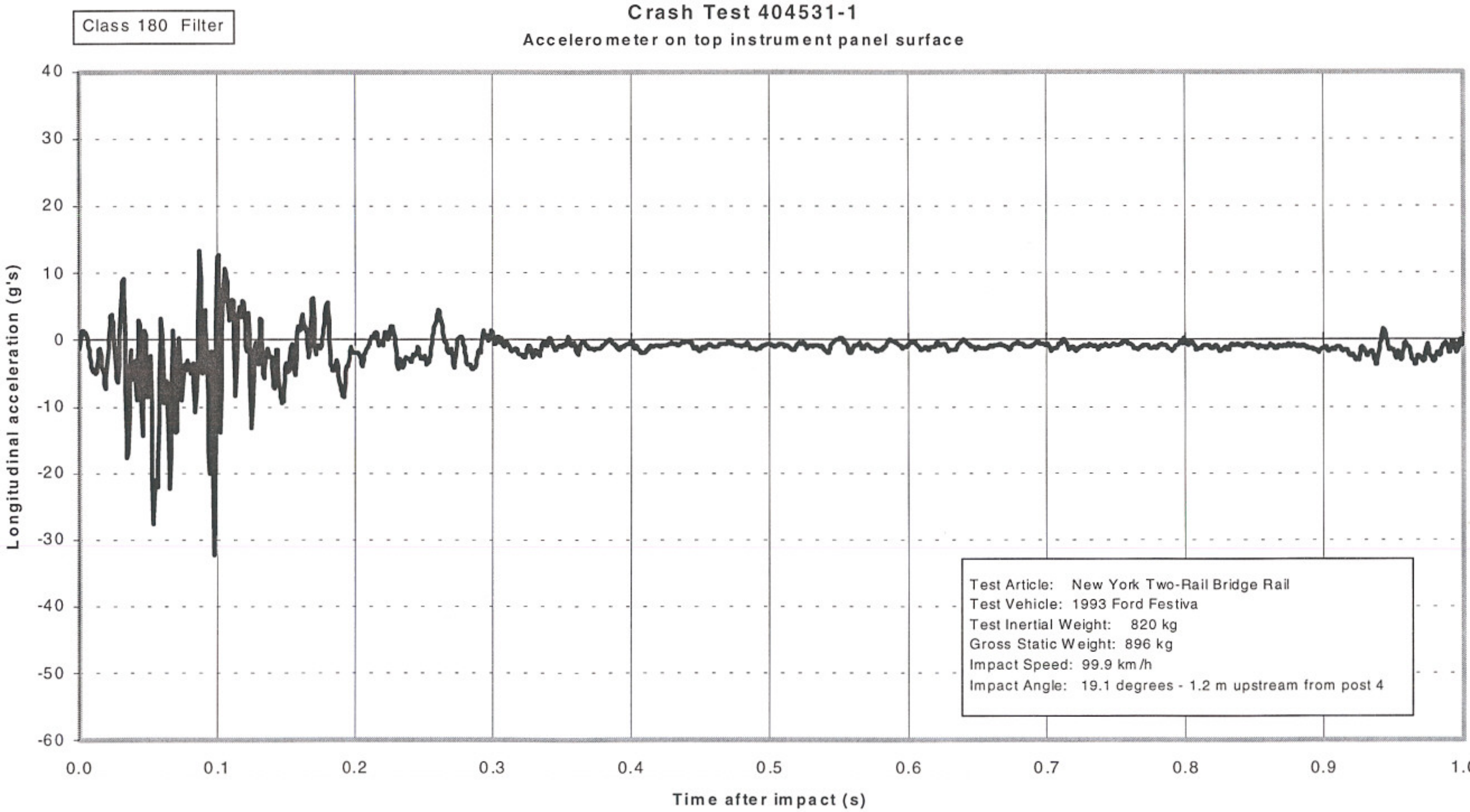


Figure 77. Vehicle longitudinal accelerometer trace for test 404531-1 (accelerometer located on top surface of instrument panel).

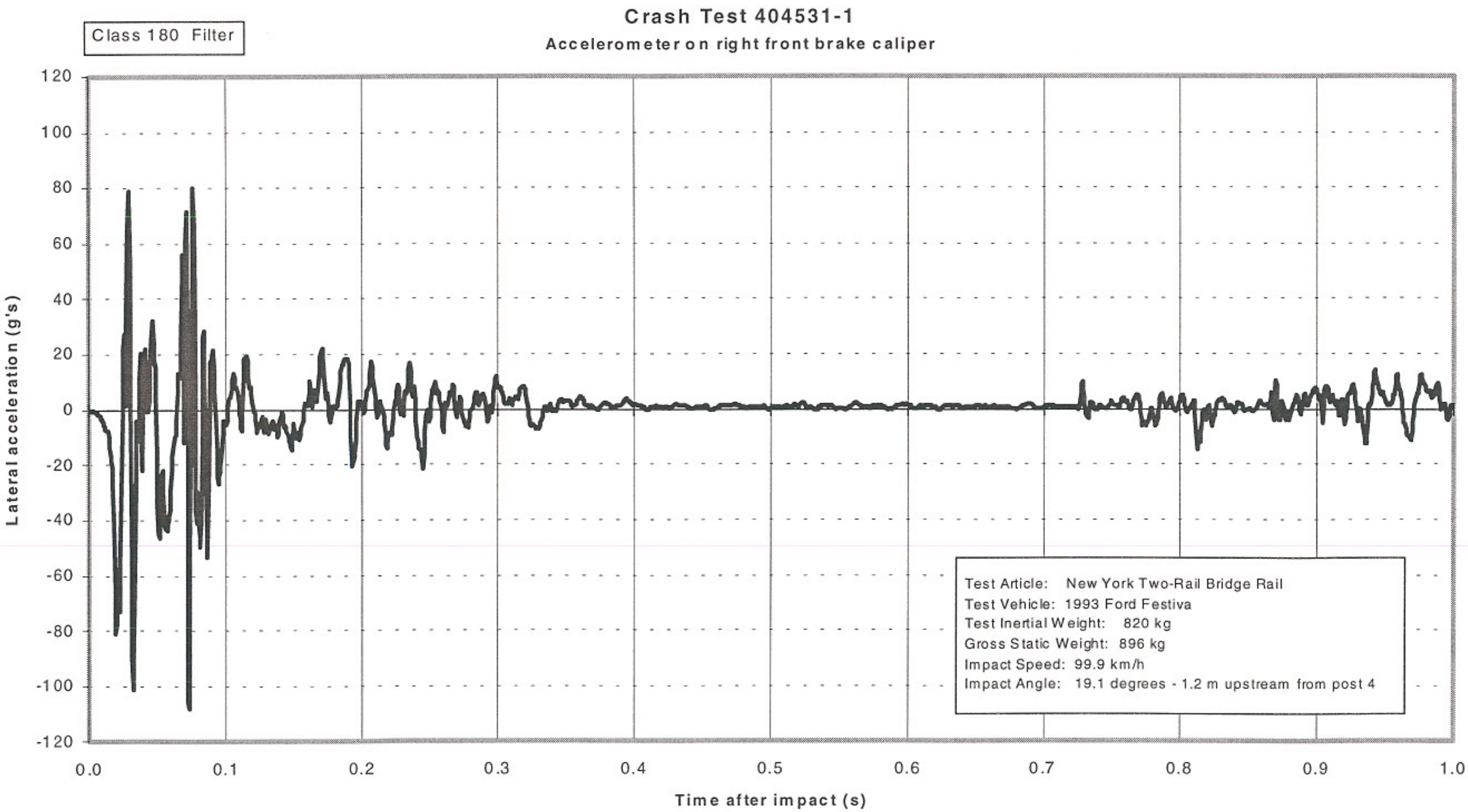


Figure 78. Vehicle lateral accelerometer trace for test 404531-1
(accelerometer located on right front brake caliper).

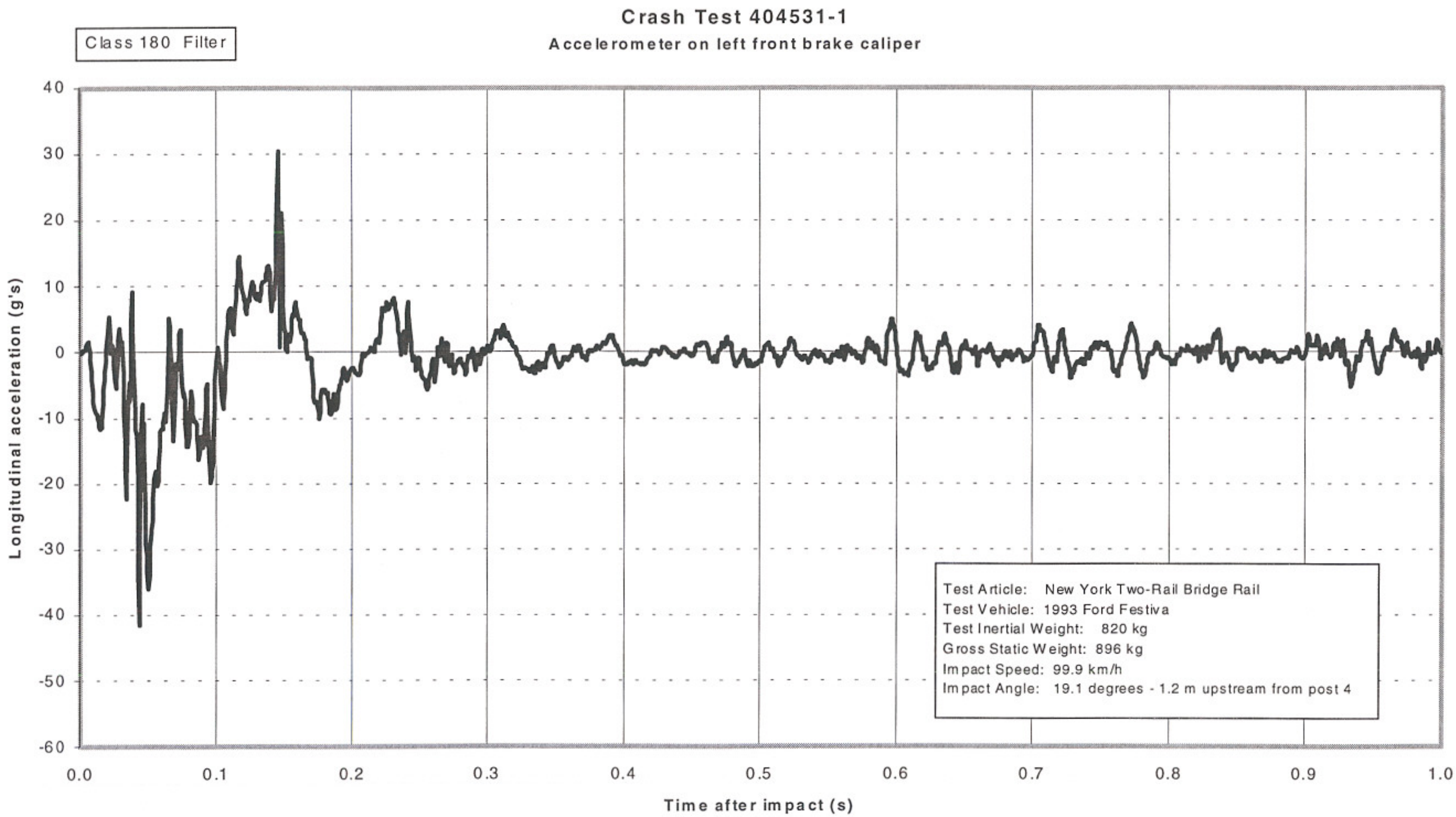


Figure 79. Vehicle longitudinal accelerometer trace for test 404531-1
(accelerometer located on left front brake caliper).

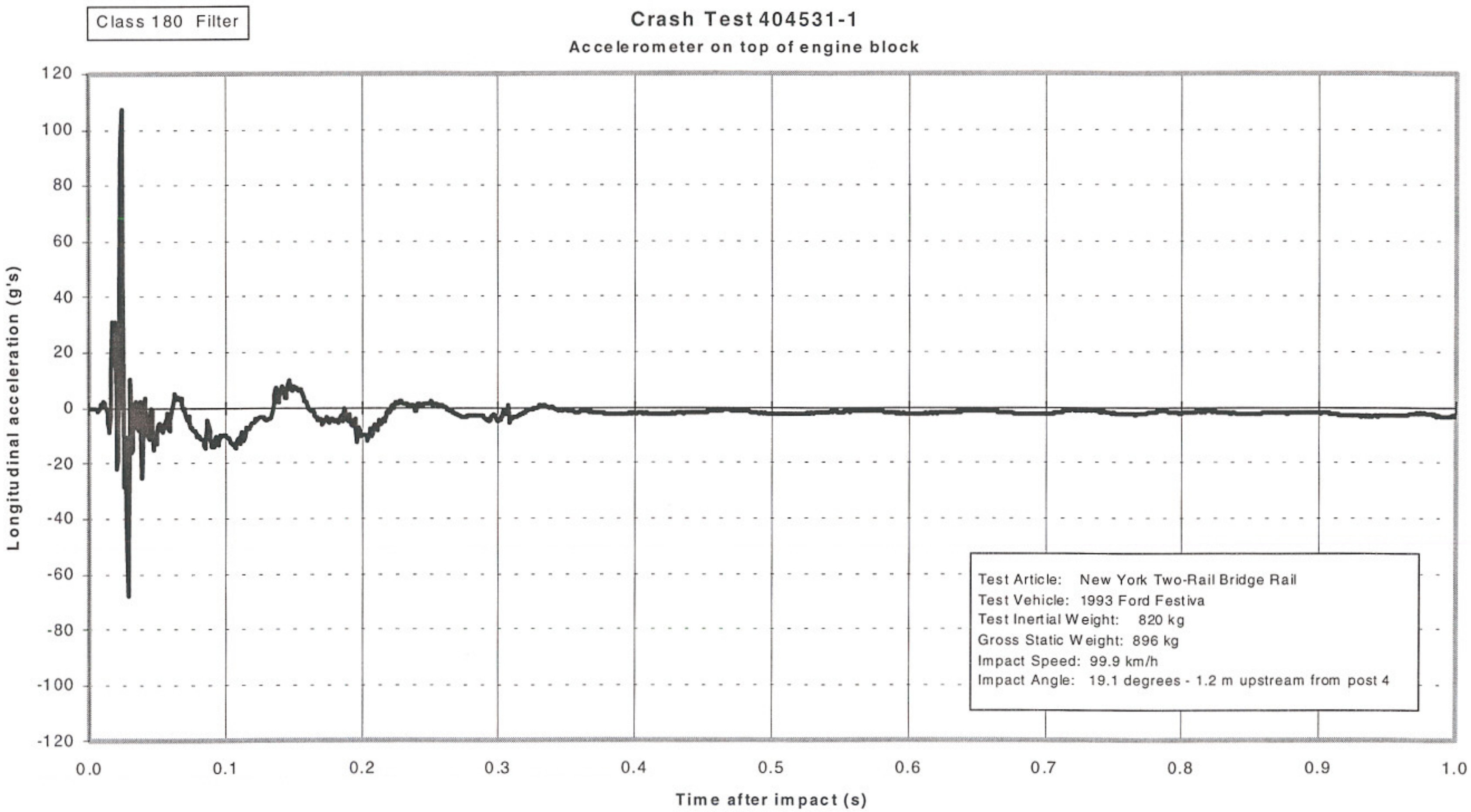


Figure 80. Vehicle longitudinal accelerometer trace for test 404531-1
(accelerometer located on top of engine block).

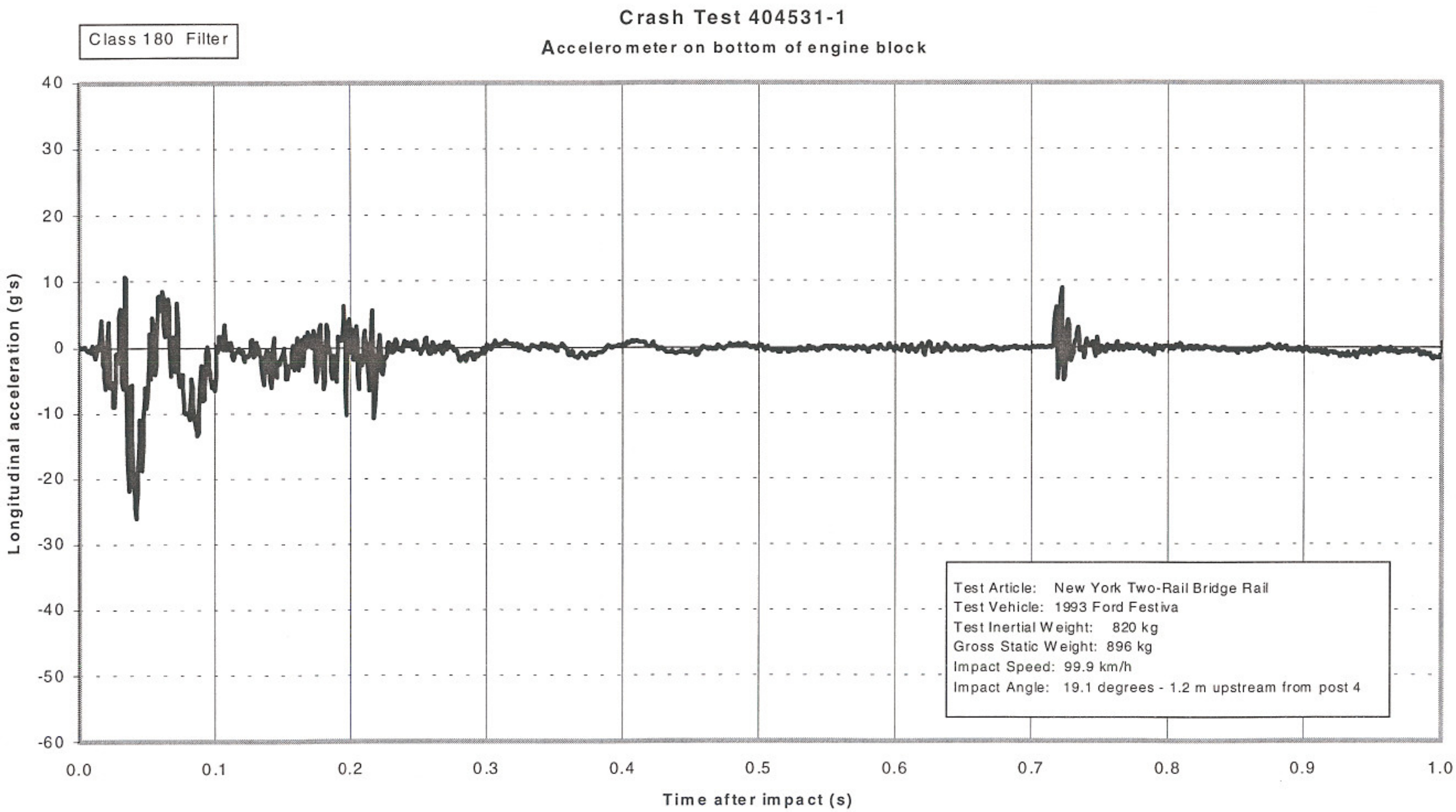


Figure 81. Vehicle longitudinal accelerometer trace for test 404531-1 (accelerometer located on bottom of engine block).

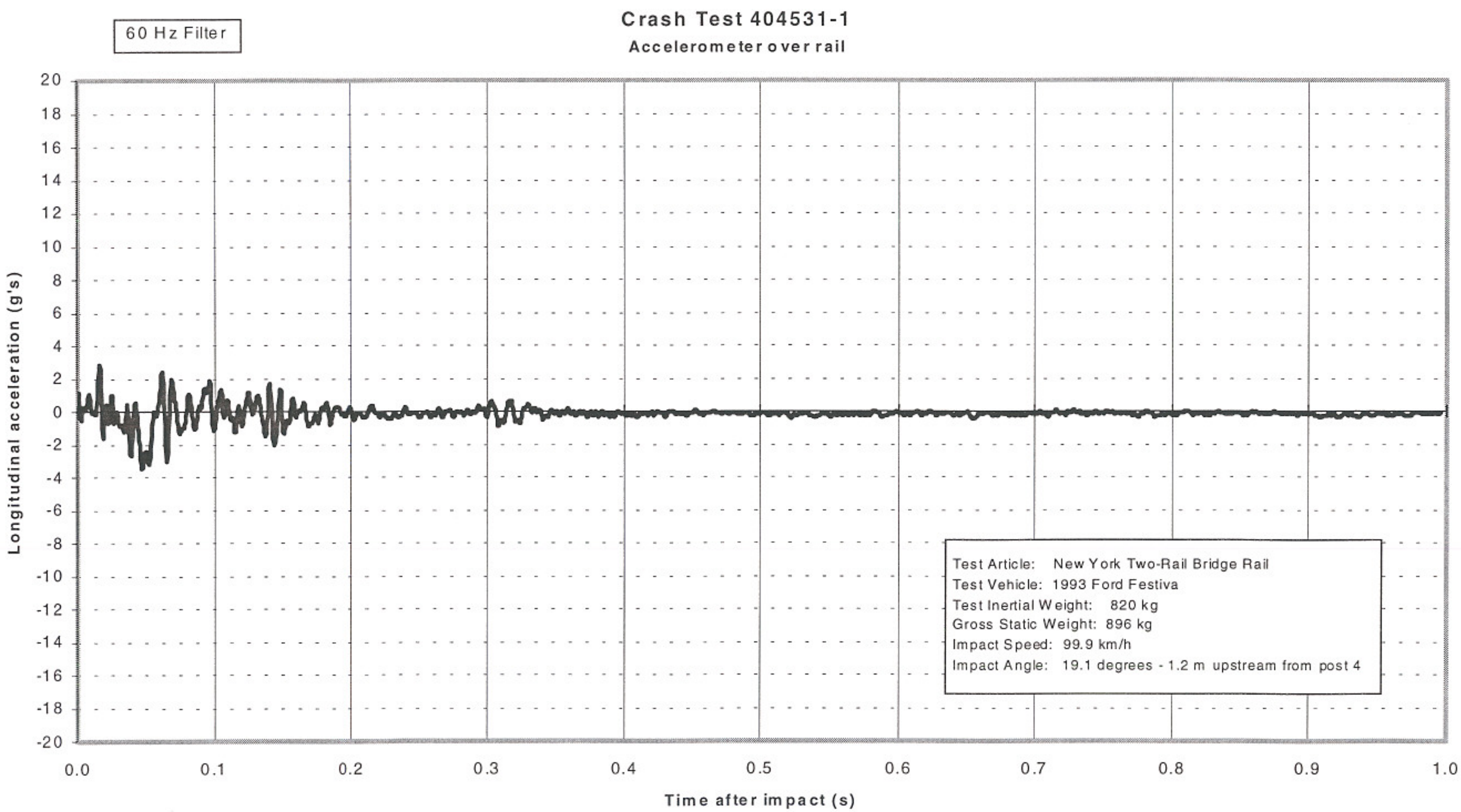


Figure 82. Bridge railing longitudinal accelerometer trace for test 404531-1 (accelerometer located over bridge railing at post 4).

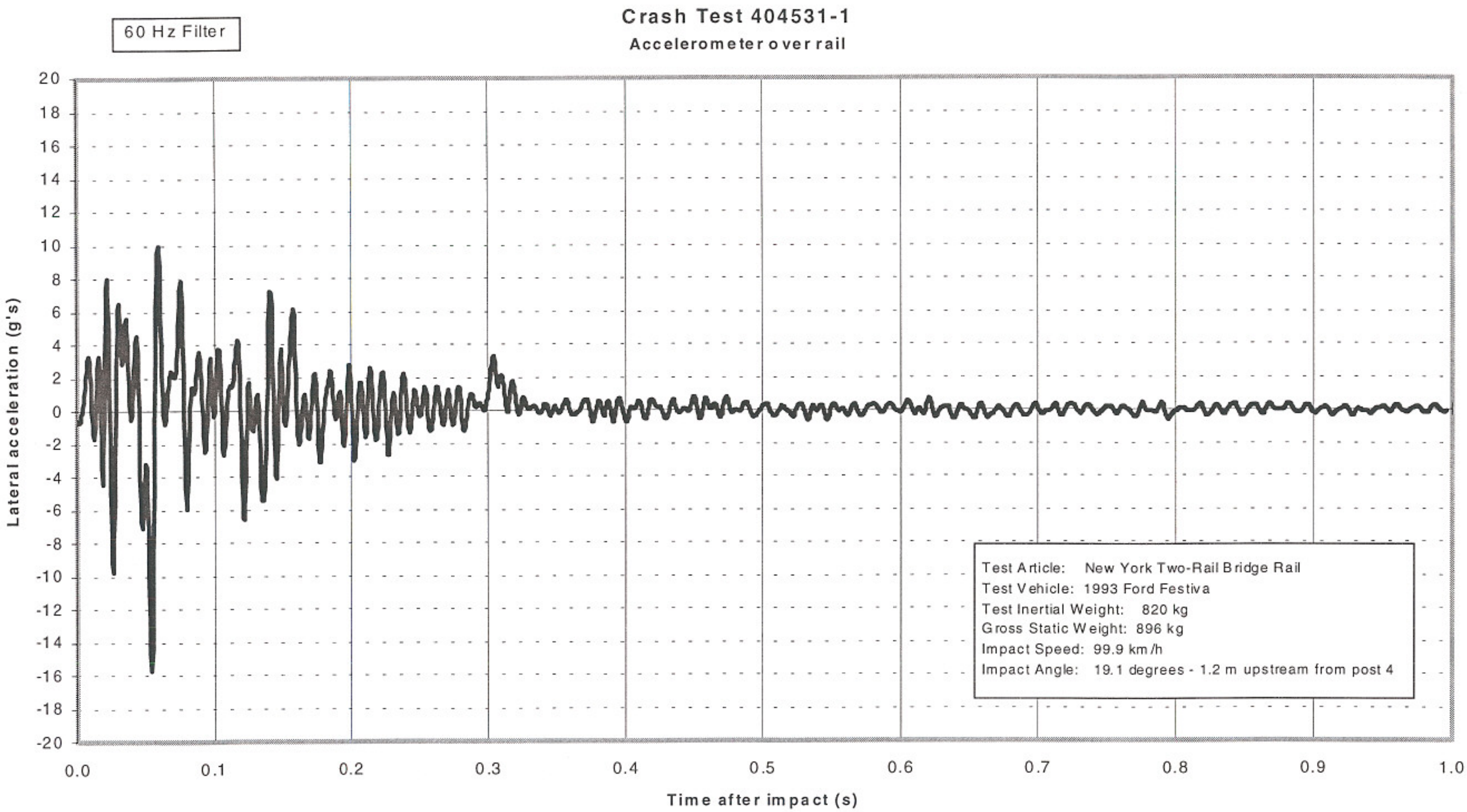


Figure 83. Bridge railing lateral accelerometer trace for test 404531-1 (accelerometer located over bridge railing at post 4).

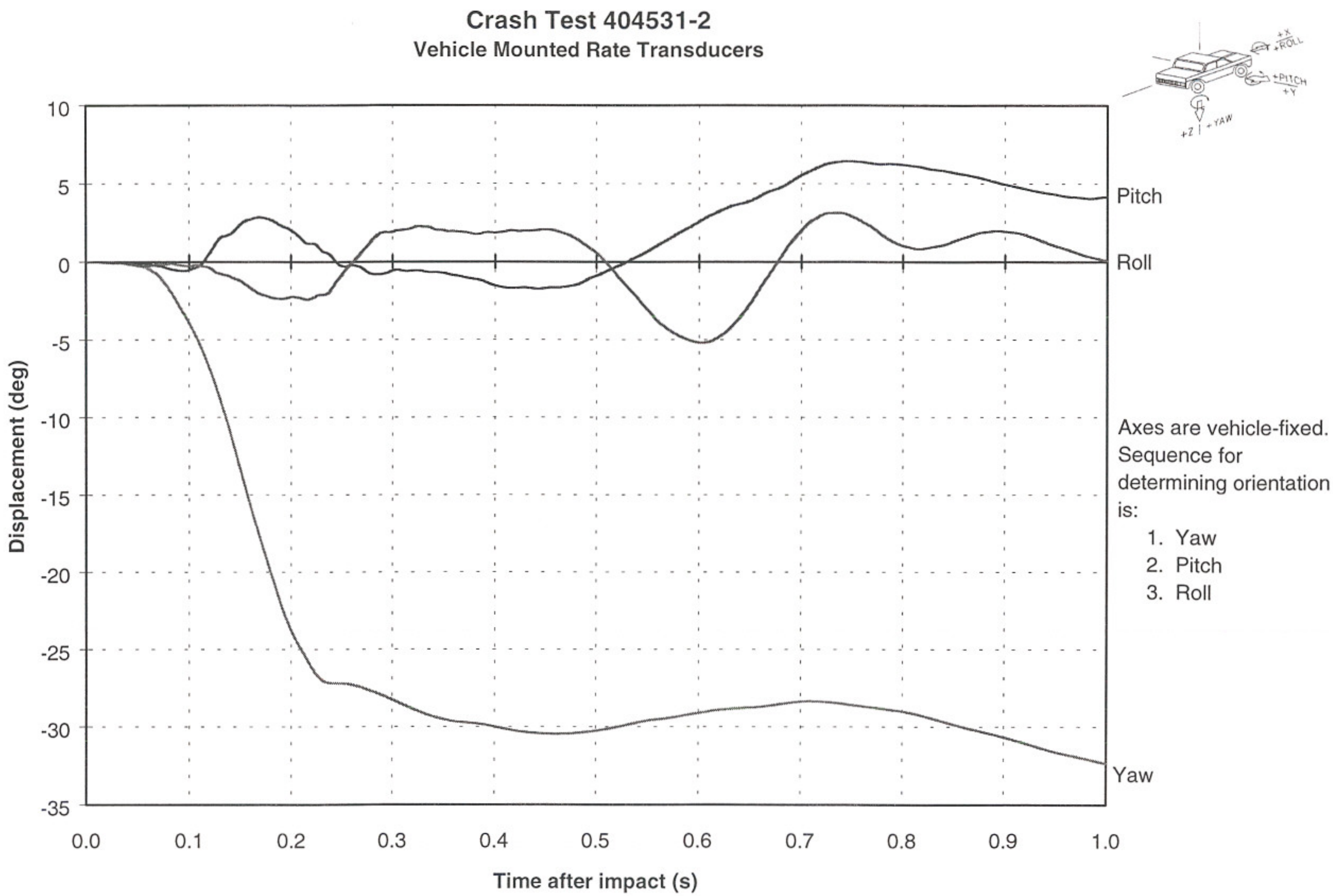


Figure 84. Vehicular angular displacements for test 404531-2.

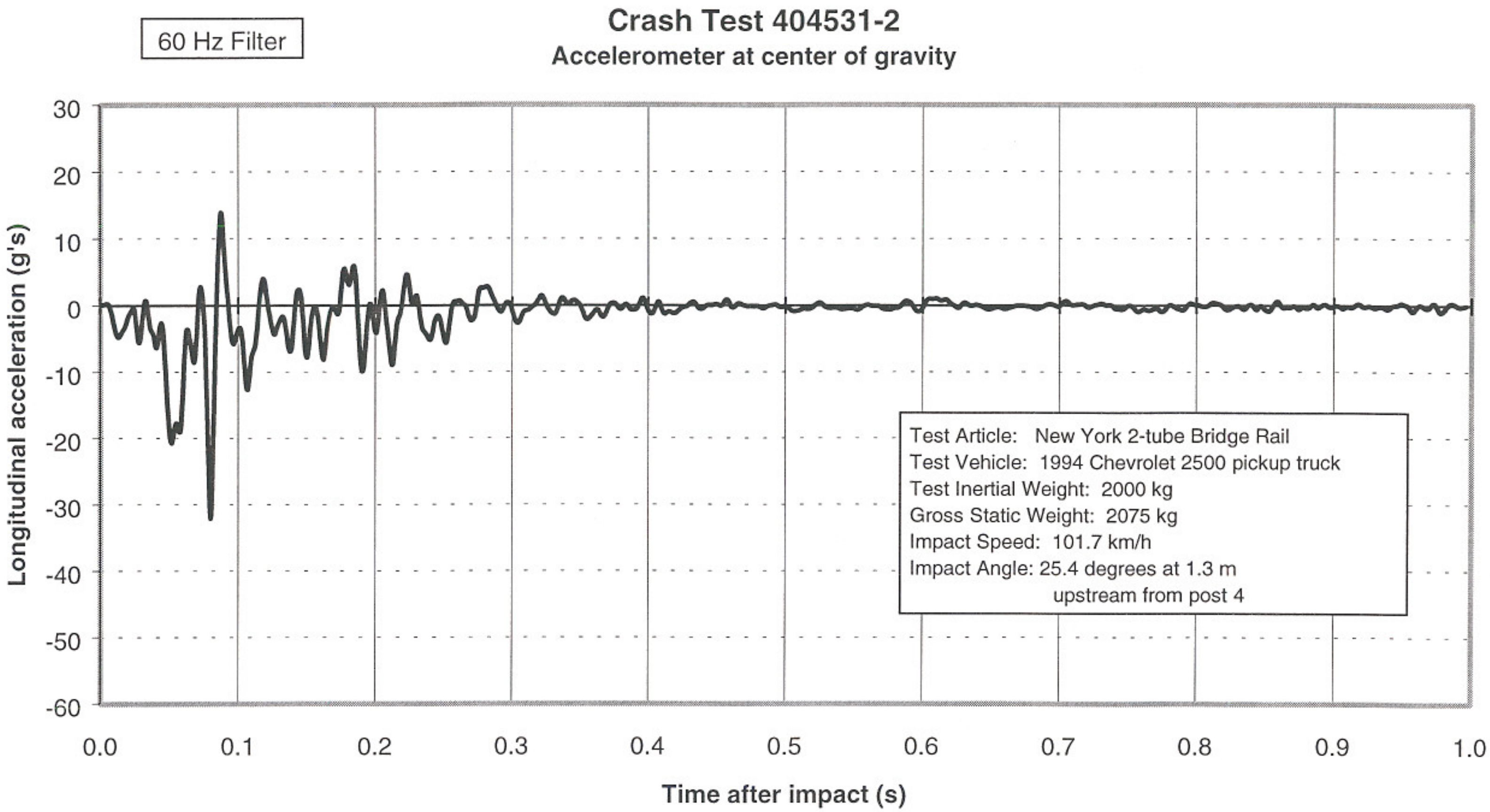


Figure 85. Vehicle longitudinal accelerometer trace for test 404531-2
(accelerometer located at center of gravity).

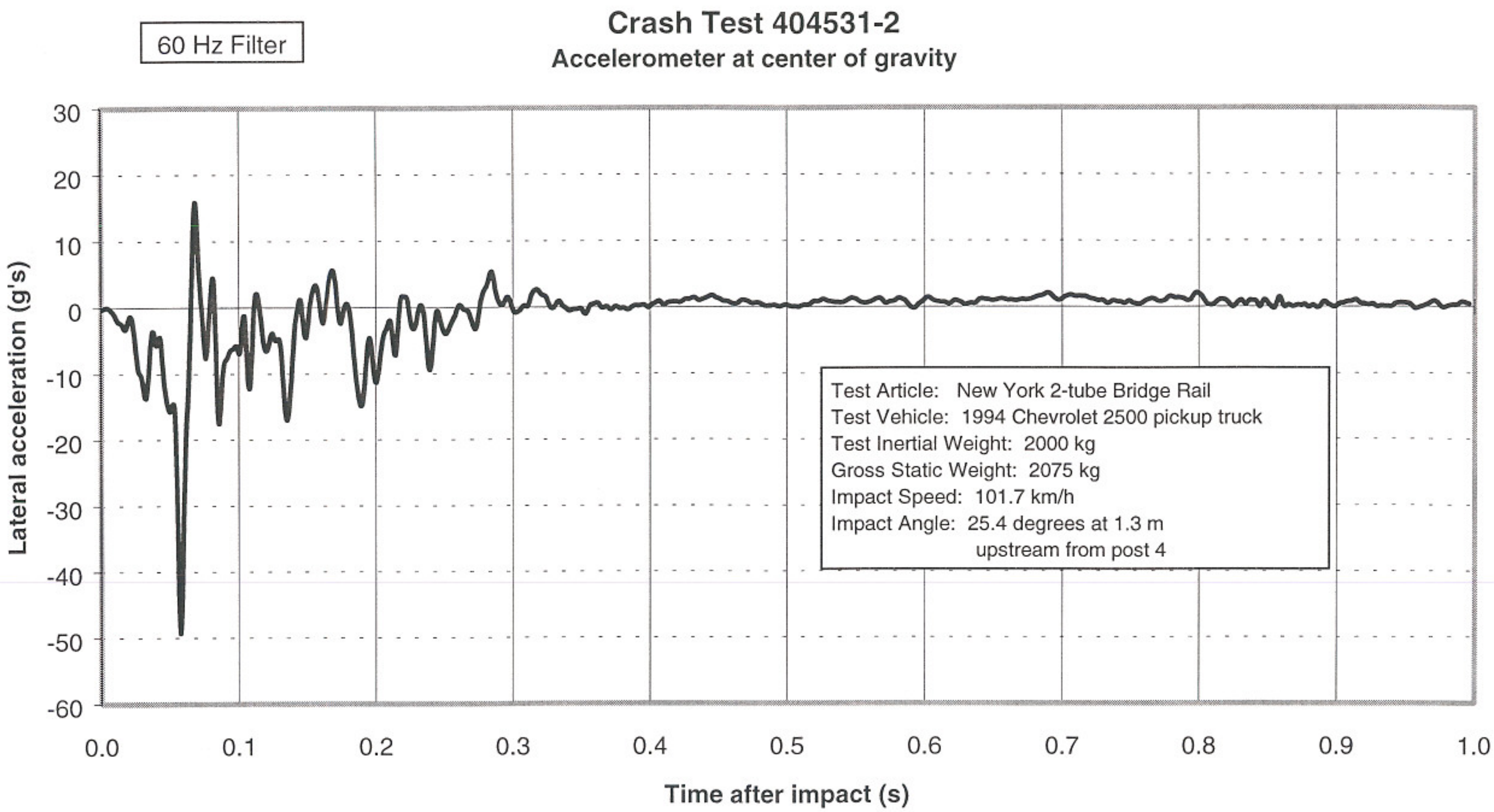


Figure 86. Vehicle lateral accelerometer trace for test 404531-2 (accelerometer located at center of gravity).

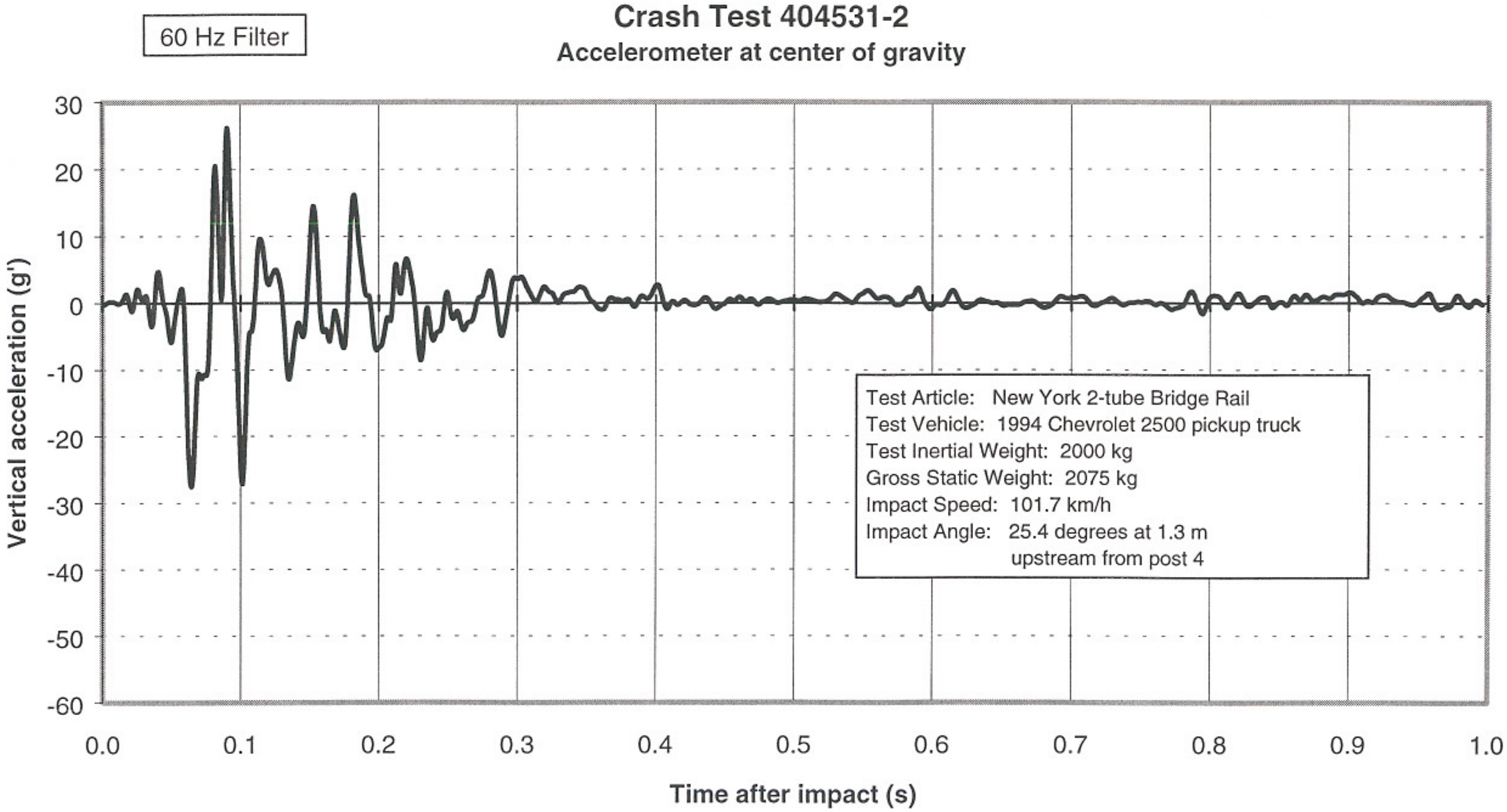


Figure 87. Vehicle vertical accelerometer trace for test 404531-2
(accelerometer located at center of gravity).

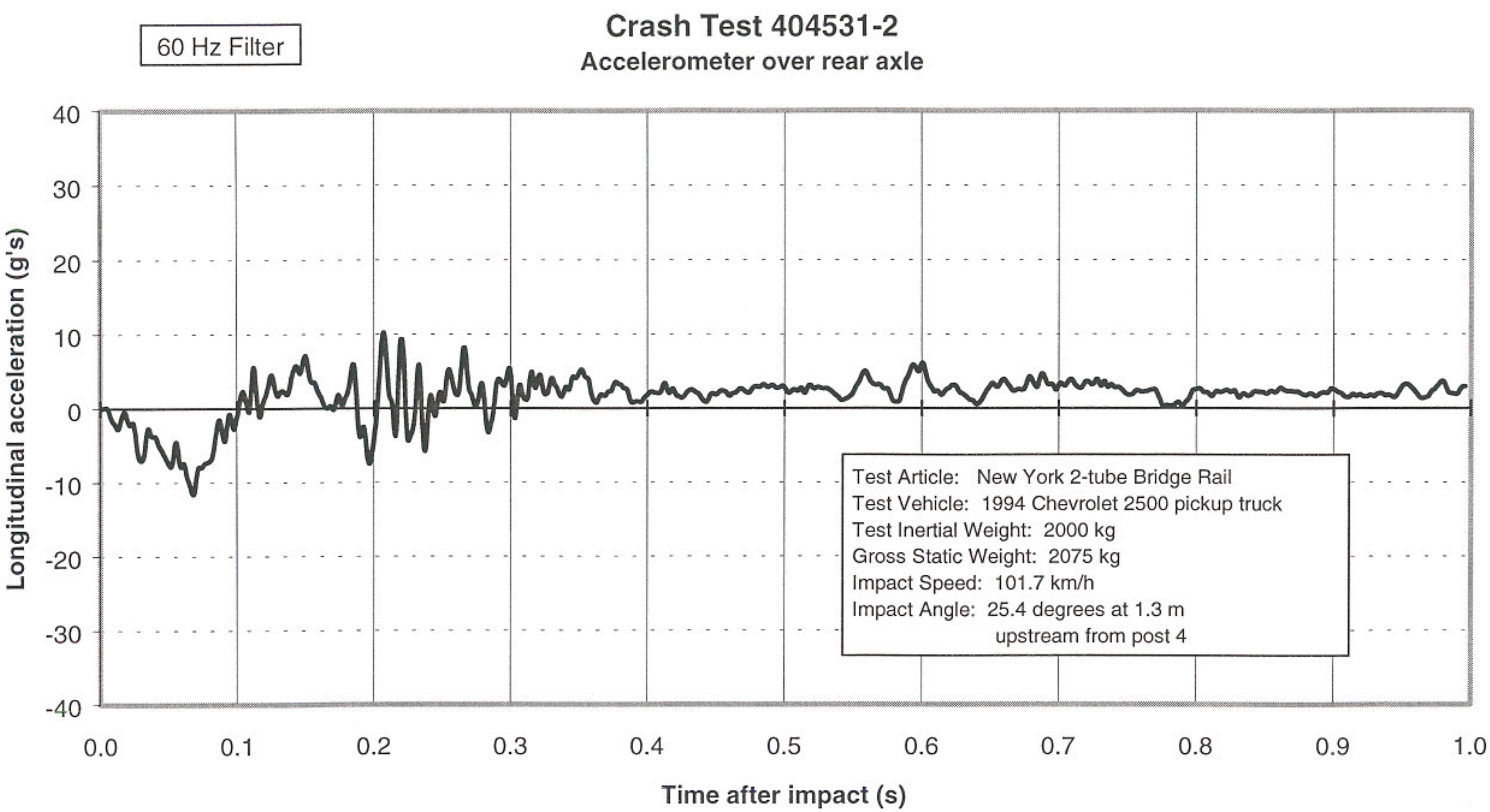


Figure 88. Vehicle longitudinal accelerometer trace for test 404531-2
(accelerometer located over rear axle).

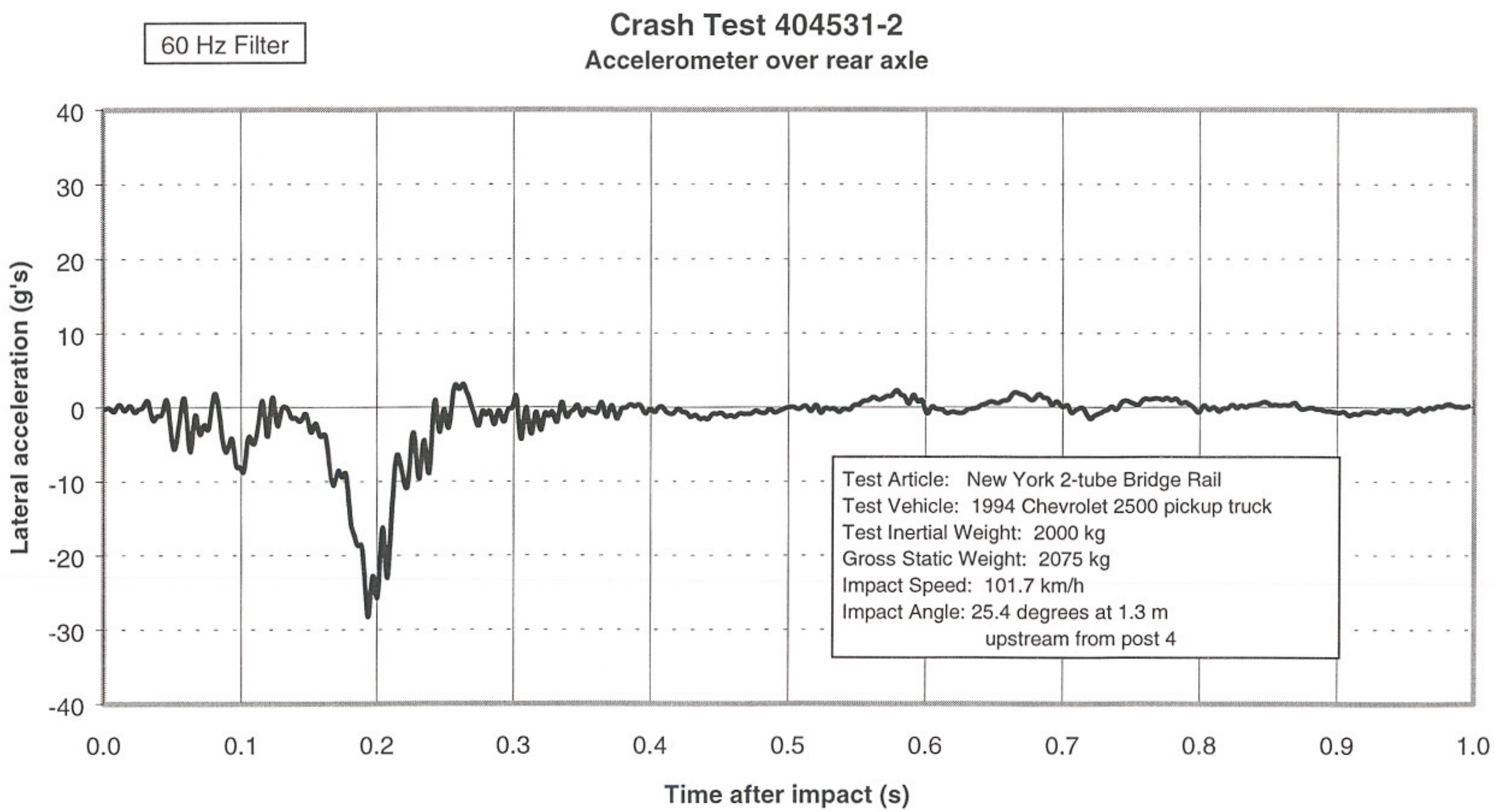


Figure 89. Vehicle lateral accelerometer trace for test 404531-2
(accelerometer located over rear axle).

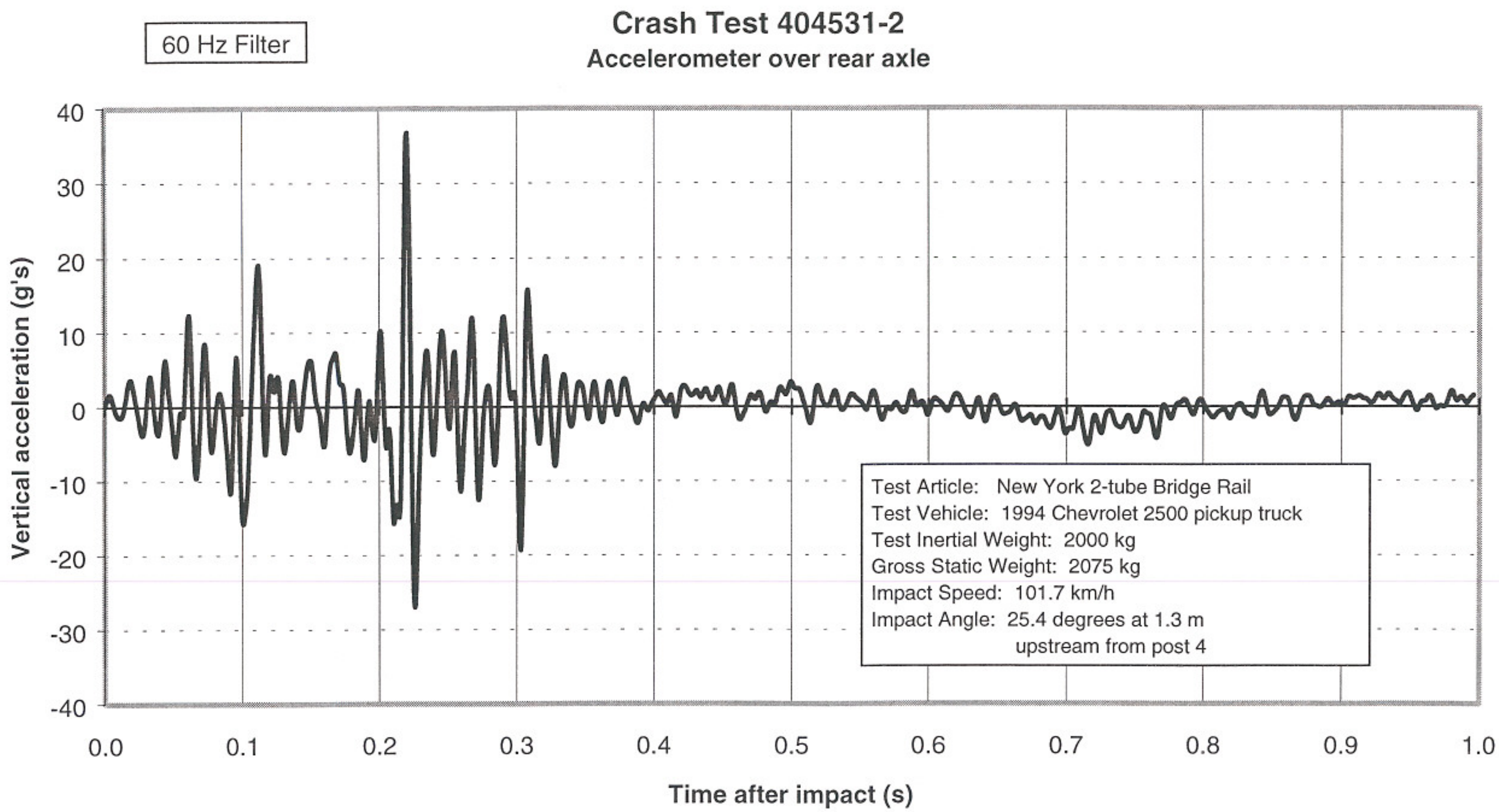


Figure 90. Vehicle vertical accelerometer trace for test 404531-2 (accelerometer located over rear axle).

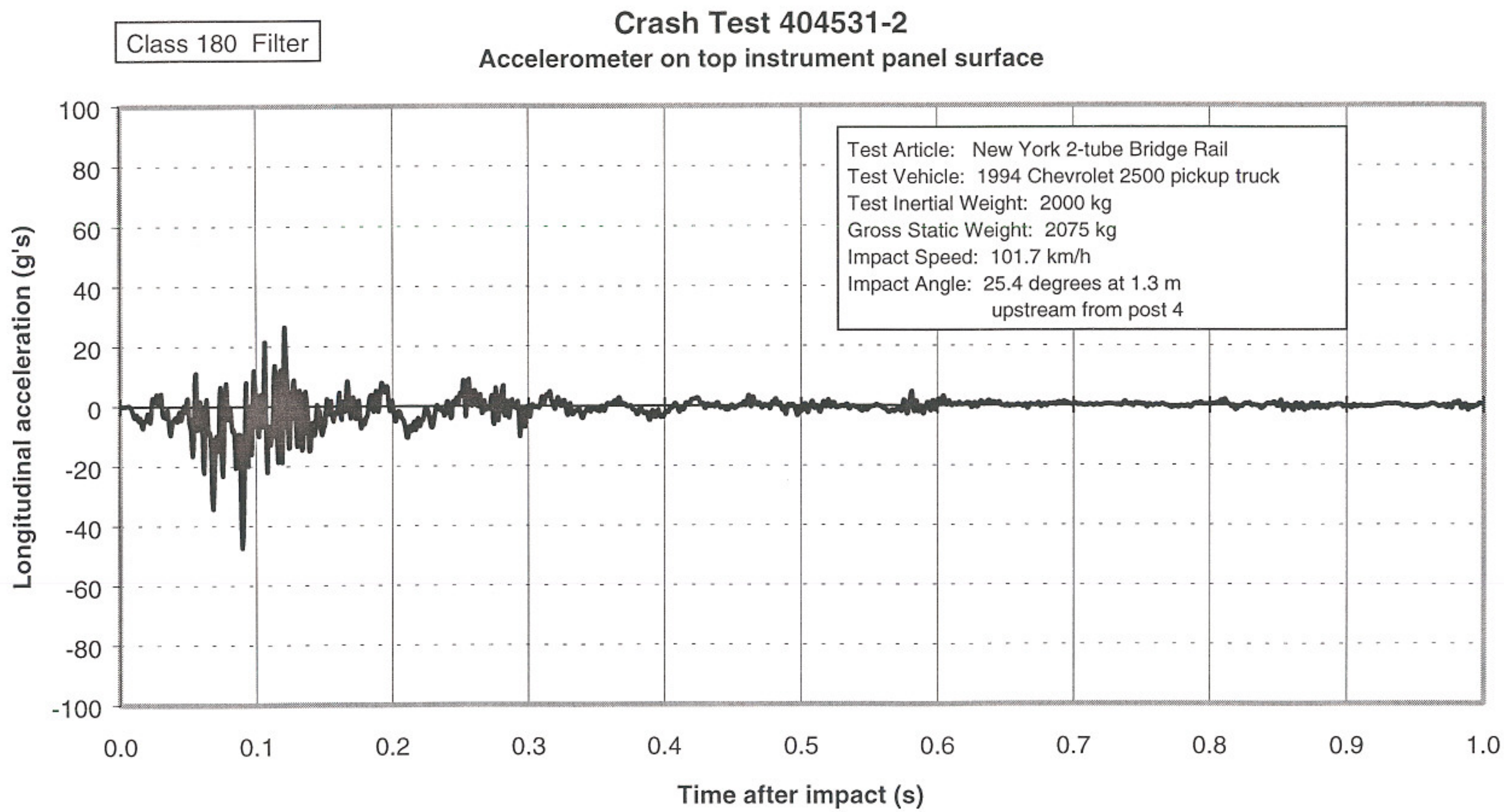


Figure 91. Vehicle longitudinal accelerometer trace for test 404531-2 (accelerometer located on top surface of instrument panel).

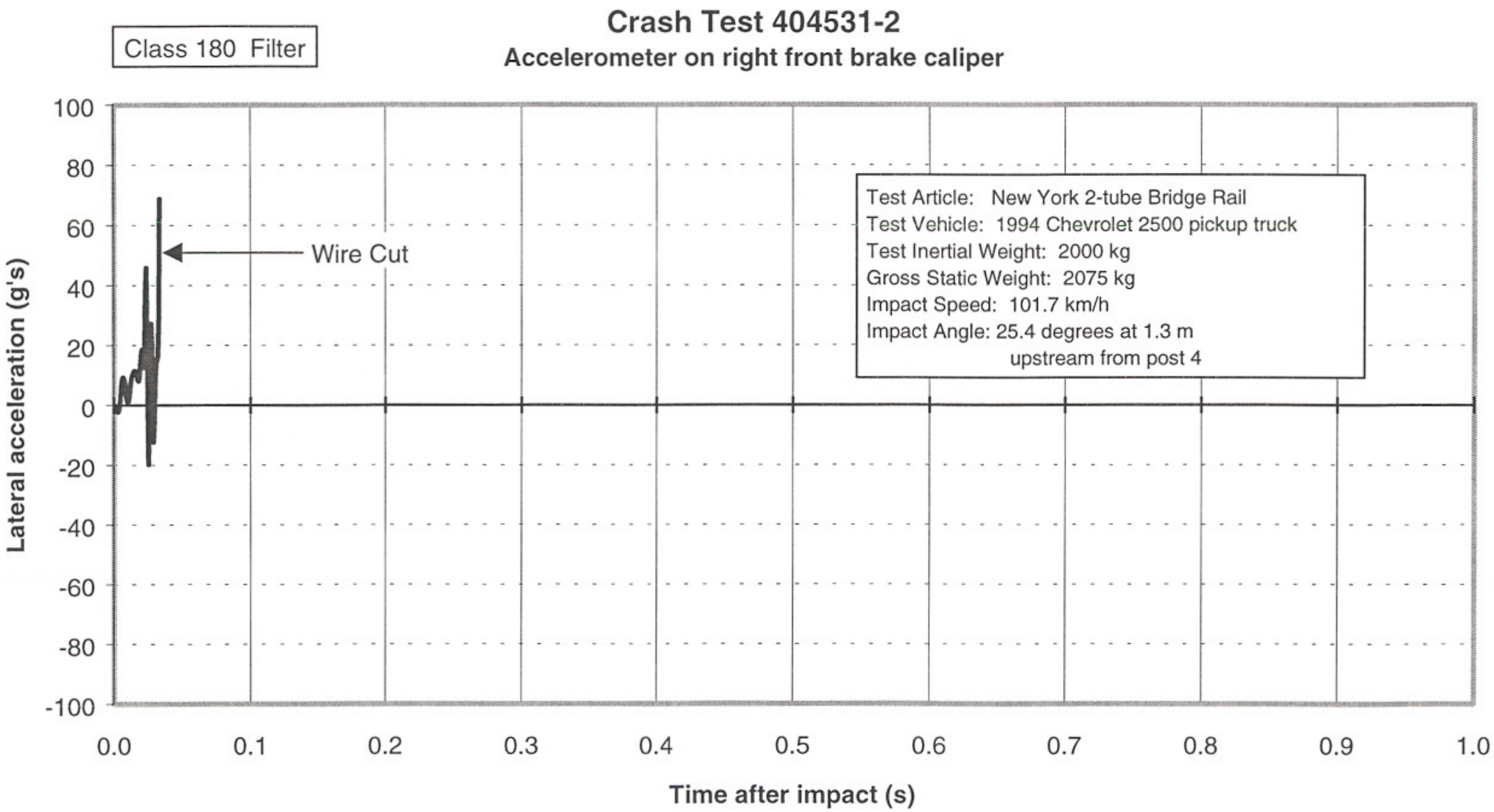


Figure 92. Vehicle lateral accelerometer trace for test 404531-2 (accelerometer located on right front brake caliper).

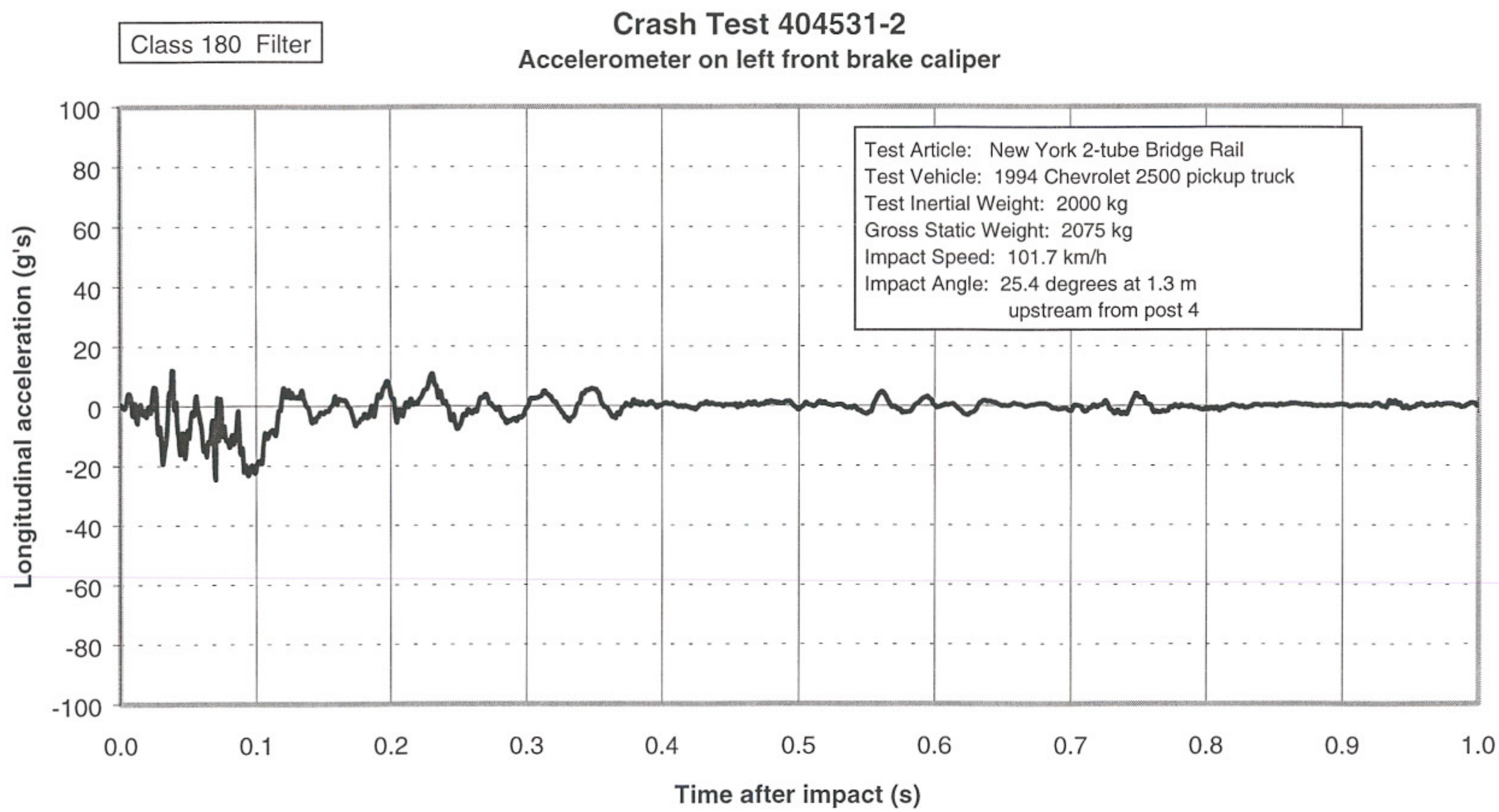


Figure 93. Vehicle longitudinal accelerometer trace for test 404531-2
(accelerometer located on left front brake caliper).

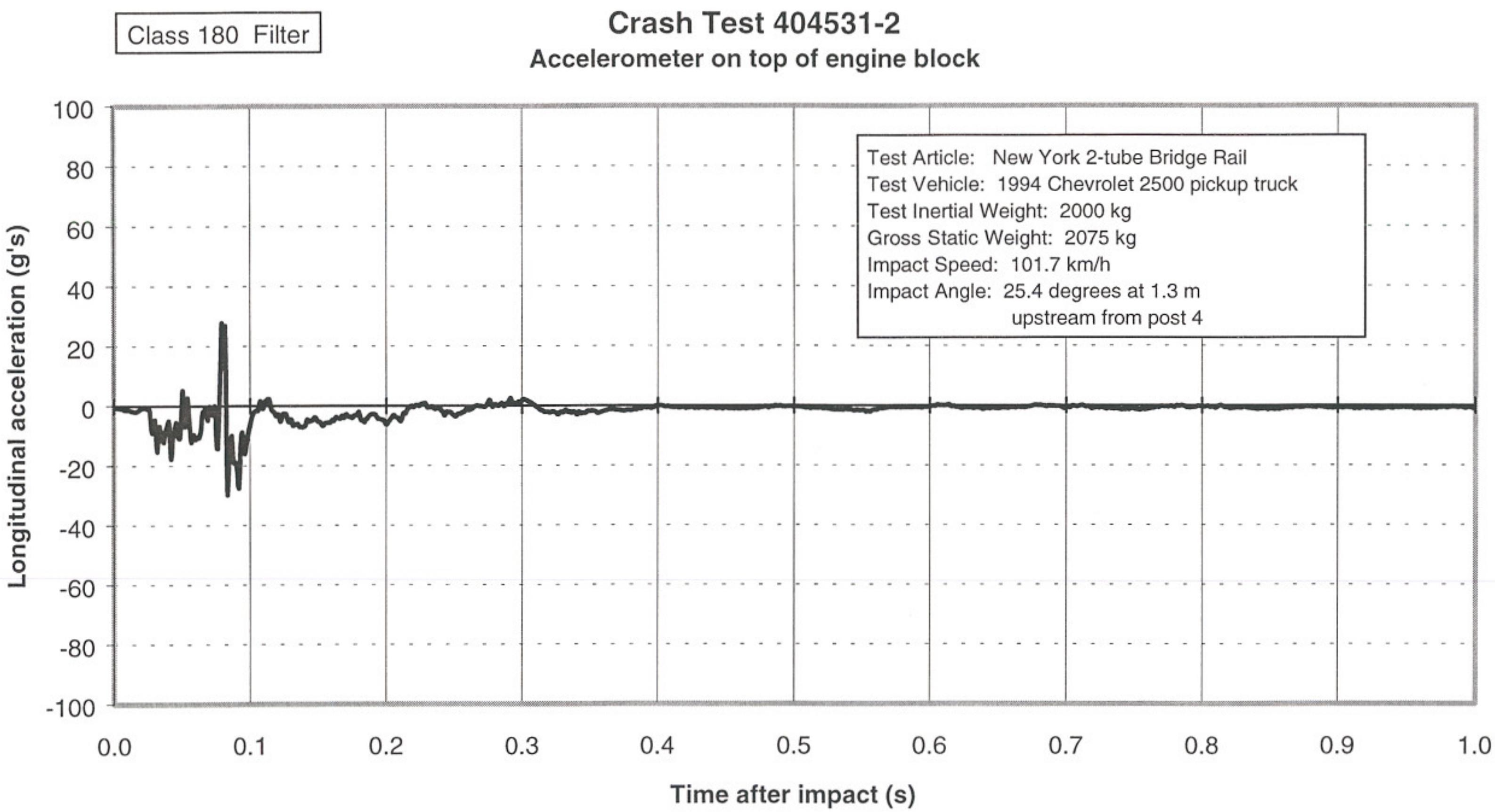


Figure 94. Vehicle longitudinal accelerometer trace for test 404531-2 (accelerometer located on top of engine block).

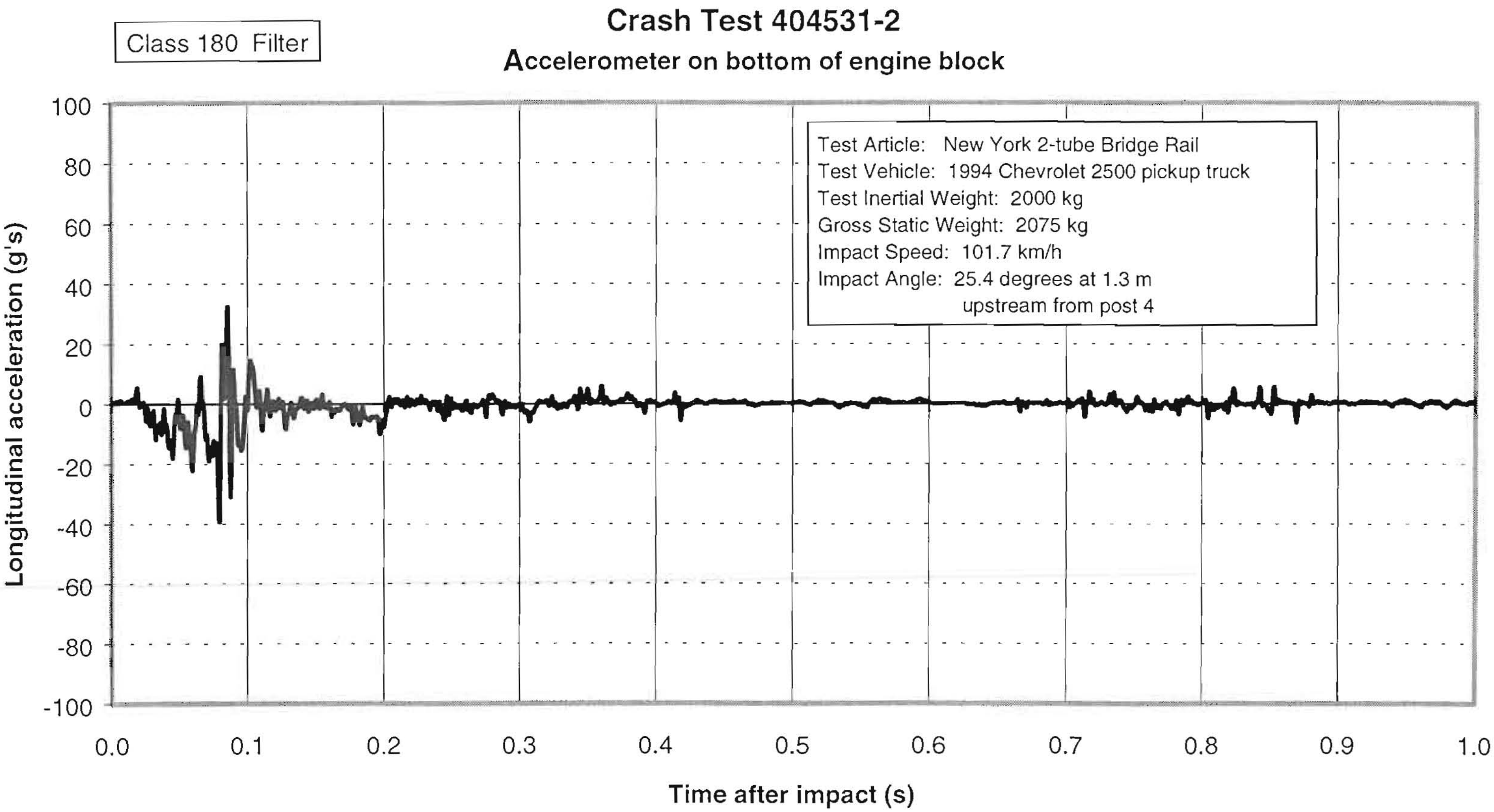


Figure 95. Vehicle longitudinal accelerometer trace for test 404531-2 (accelerometer located on bottom of engine block).

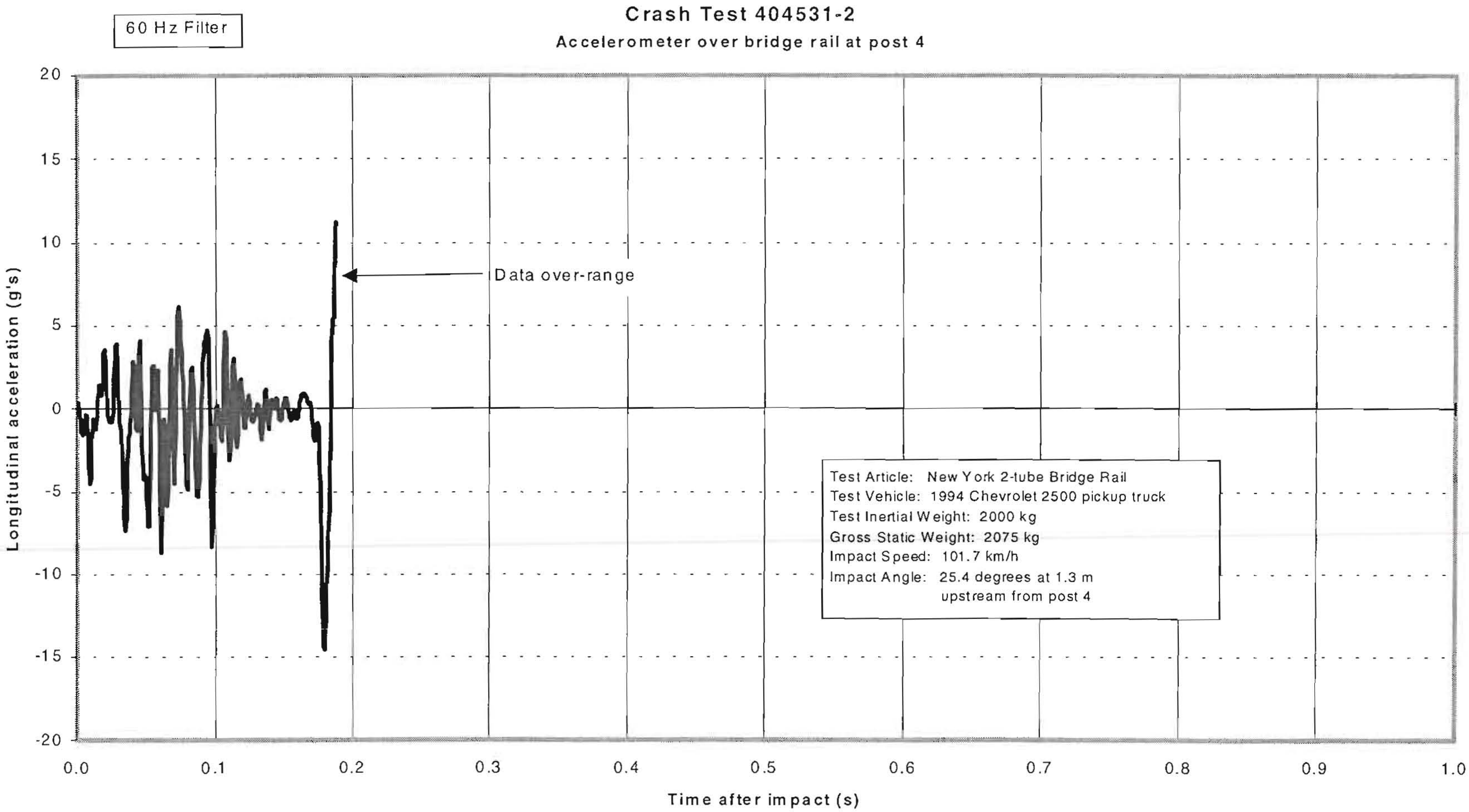


Figure 96. Bridge railing longitudinal accelerometer trace for test 404531-2 (accelerometer located over bridge railing at post 4).

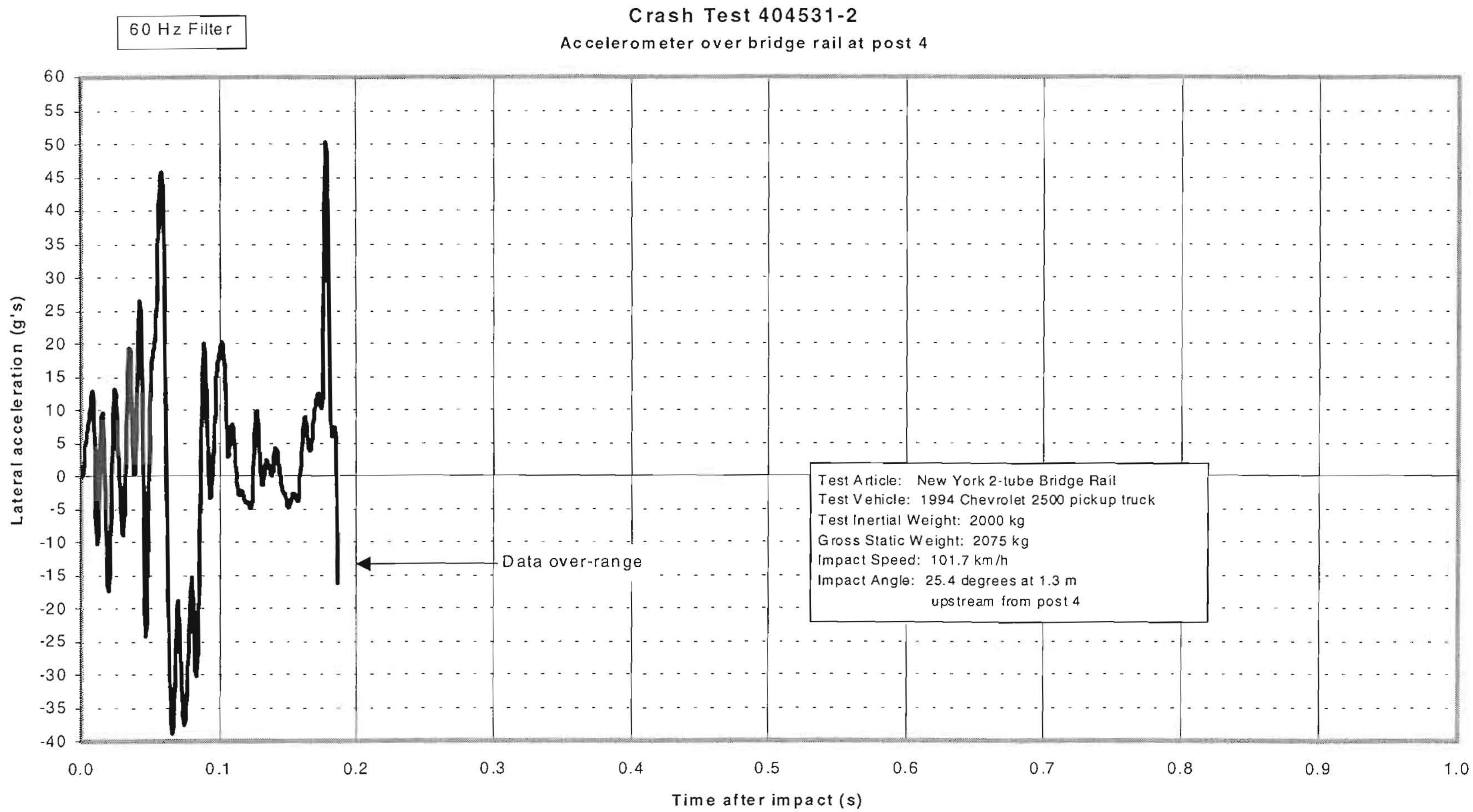


Figure 97. Bridge railing lateral accelerometer trace for test 404531-2
(accelerometer located over bridge railing at post 4).

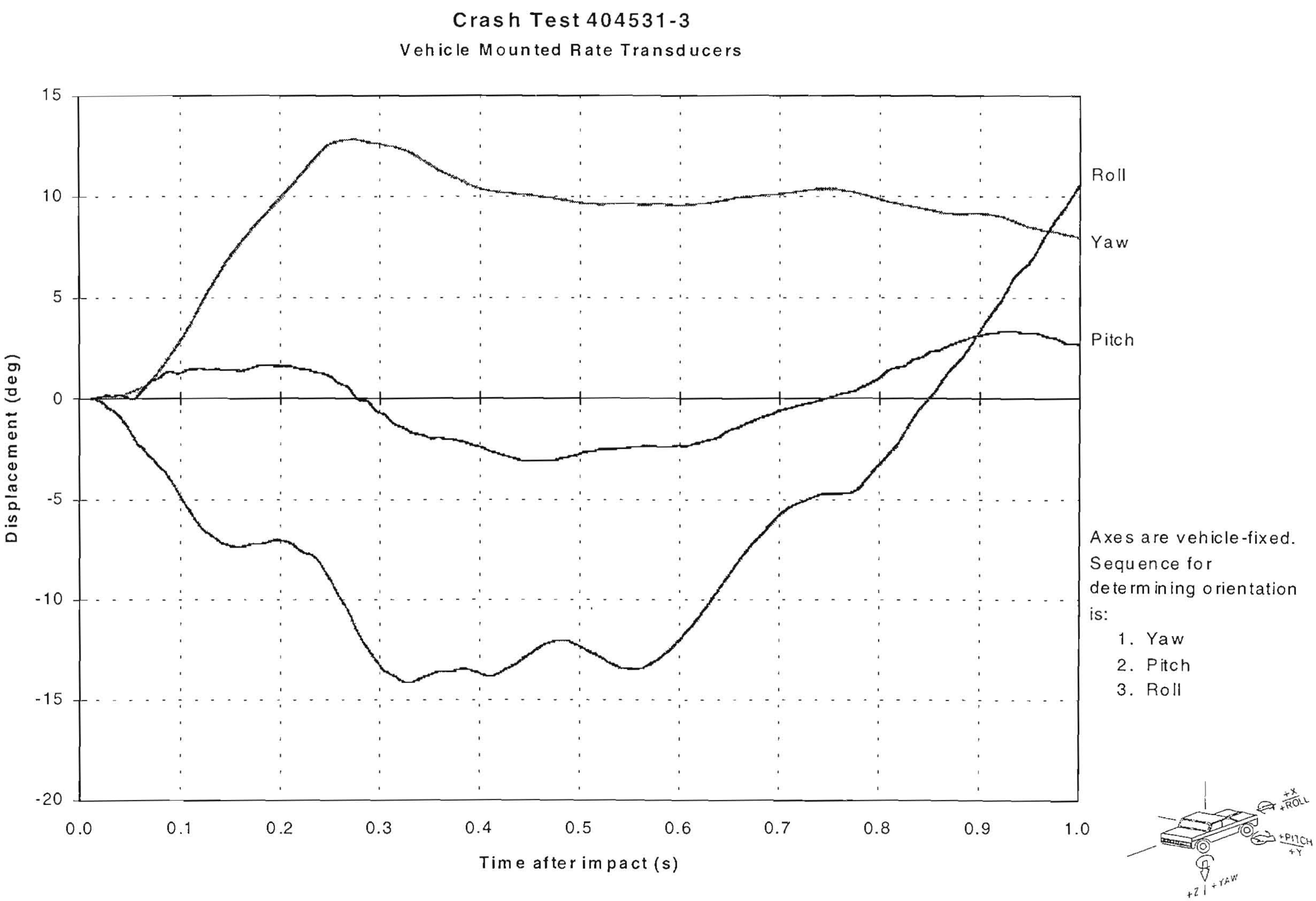


Figure 98. Vehicular angular displacements for test 404531-3.

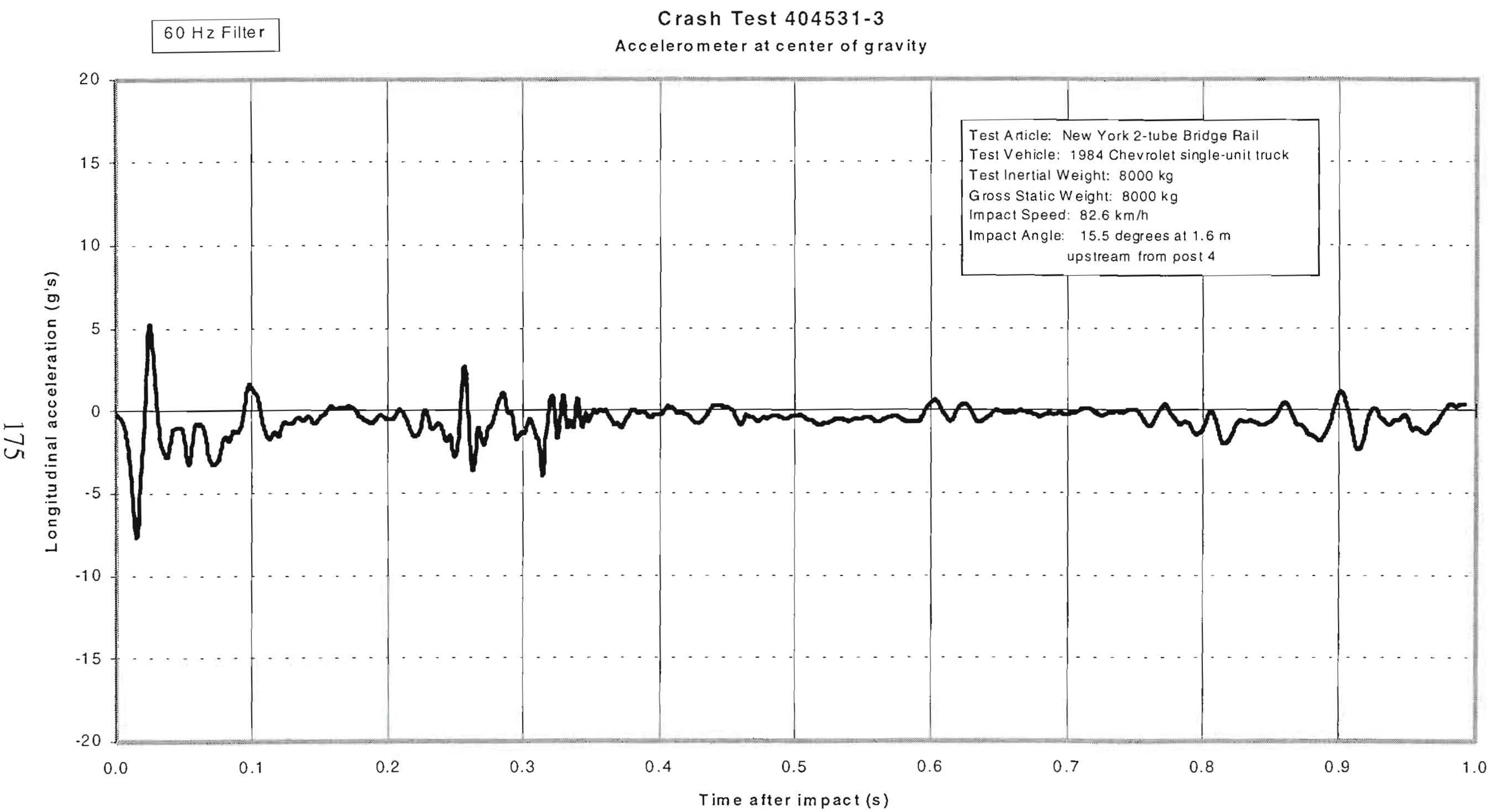


Figure 99. Vehicle longitudinal accelerometer trace for test 404531-3 (accelerometer located at center of gravity).

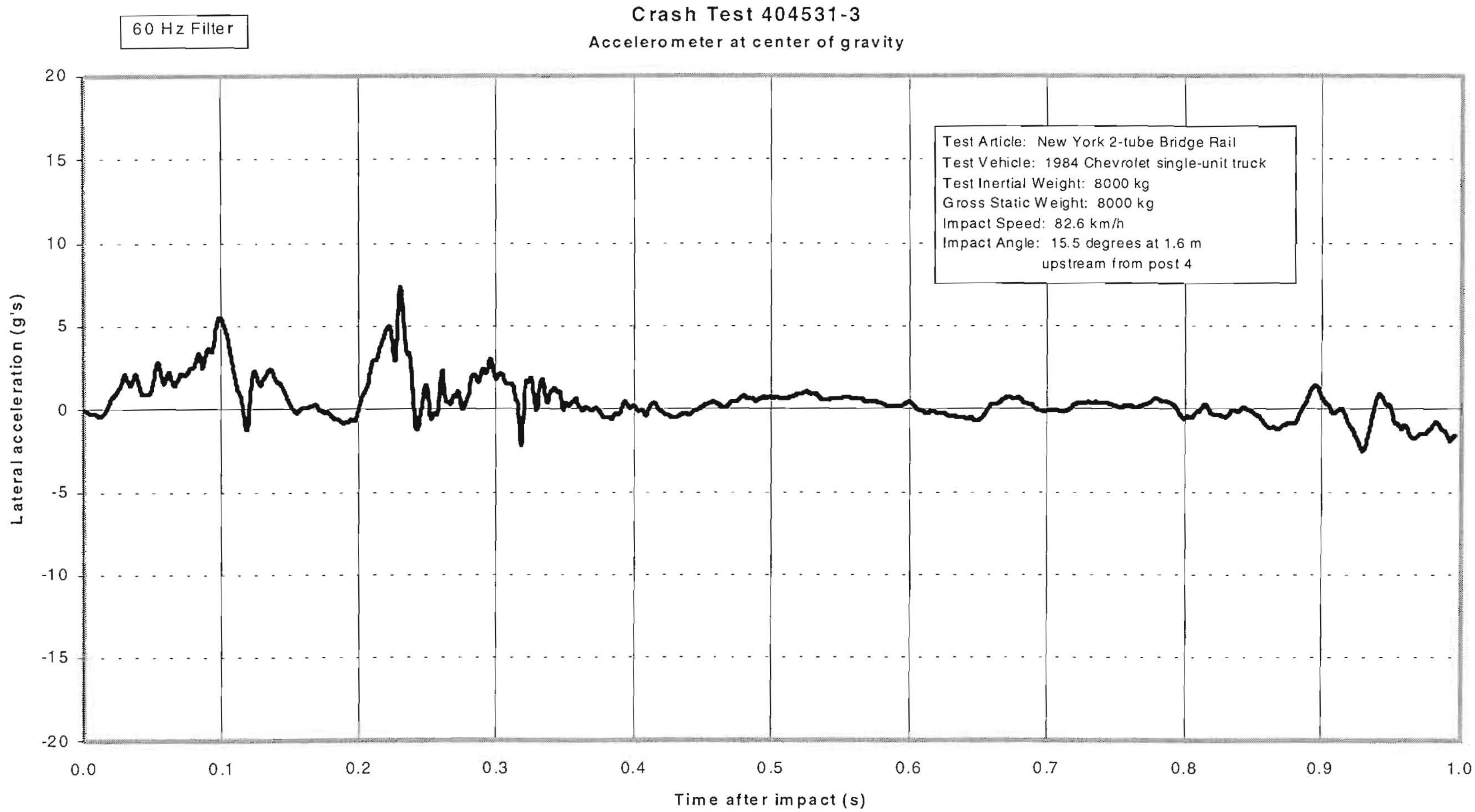


Figure 100. Vehicle lateral accelerometer trace for test 404531-3 (accelerometer located at center of gravity).

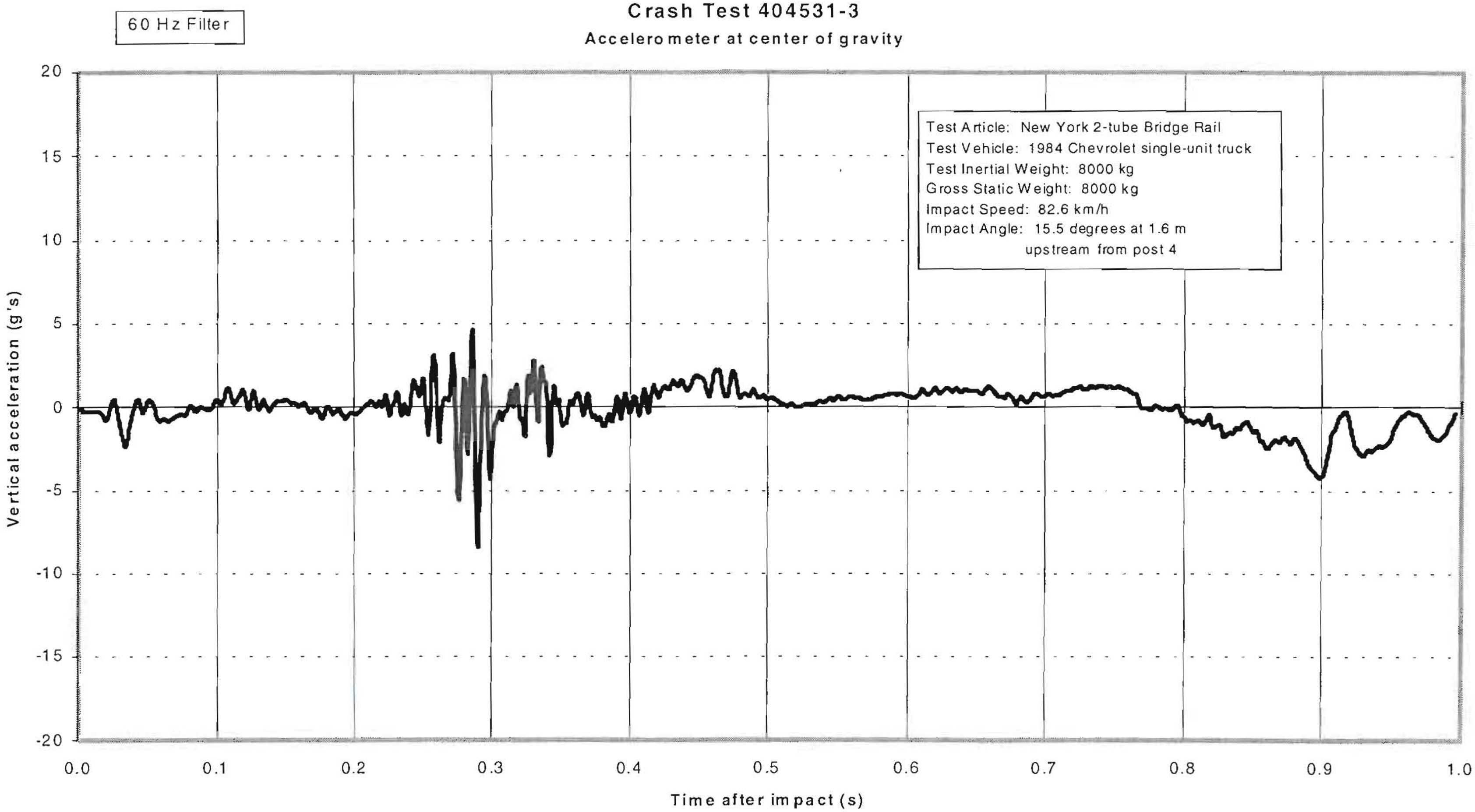


Figure 101. Vehicle vertical accelerometer trace for test 404531-3 (accelerometer located at center of gravity).

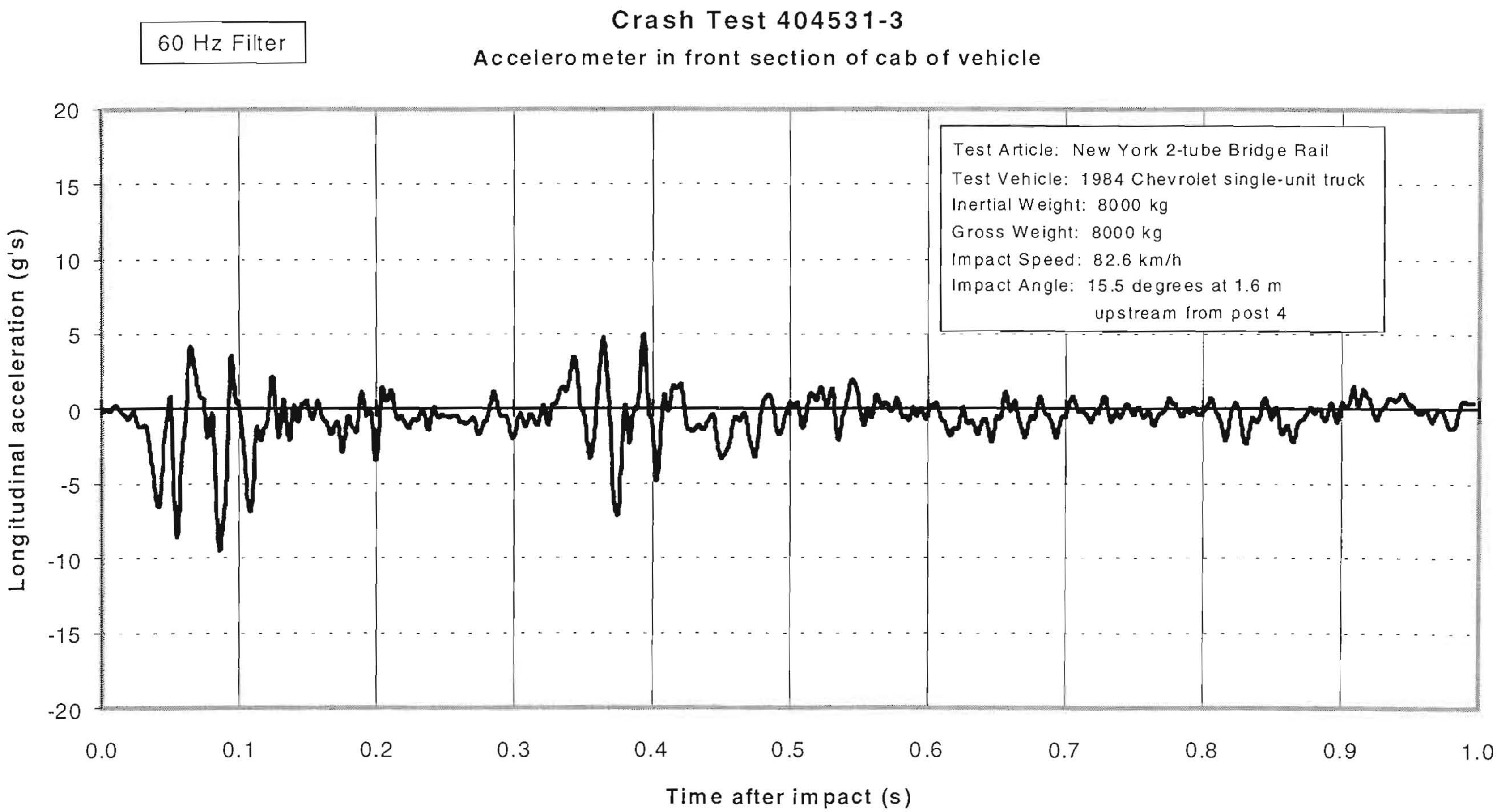


Figure 102. Vehicle longitudinal accelerometer trace for test 404531-3 (accelerometer located in front cab).

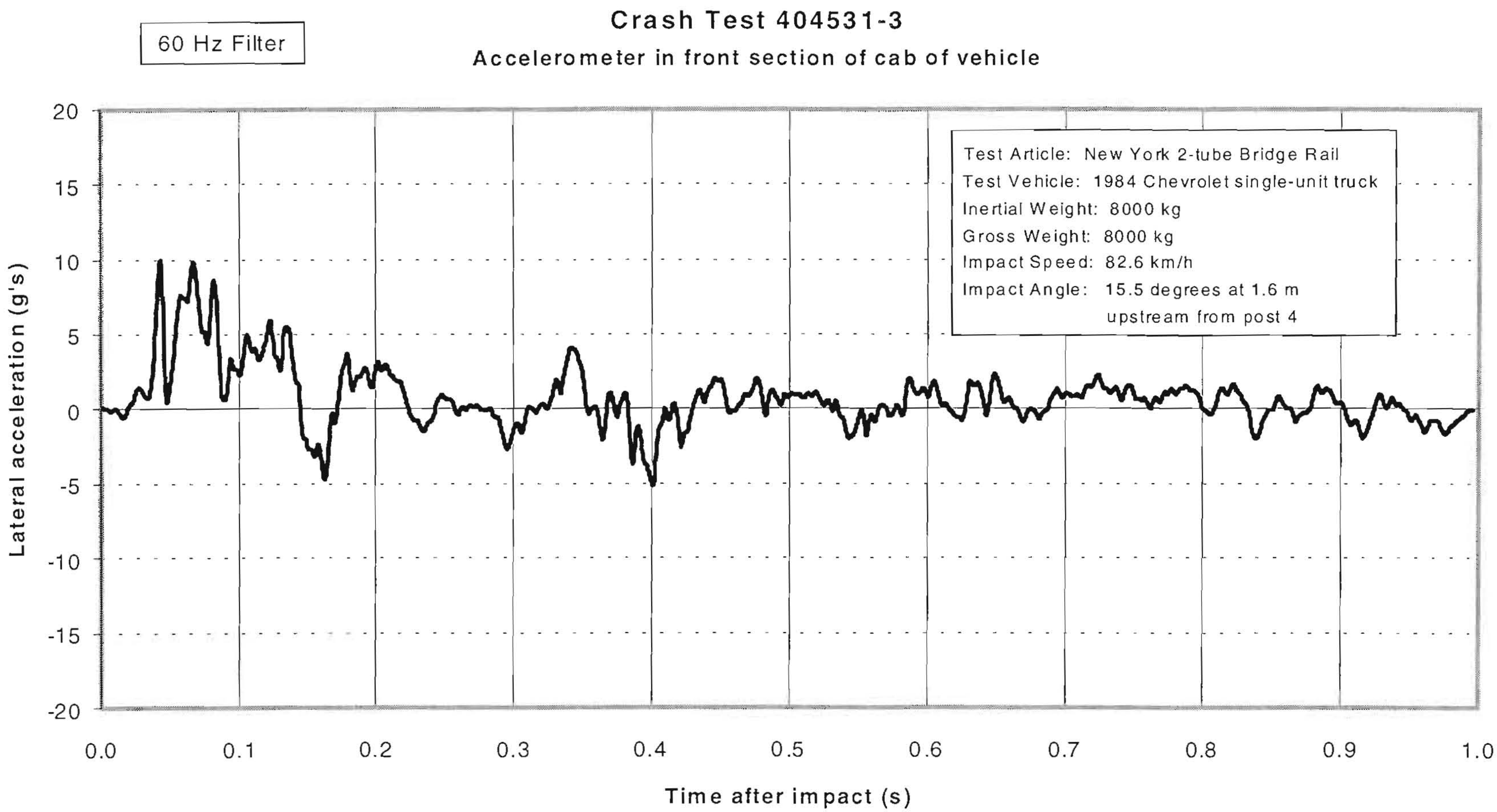


Figure 103. Vehicle lateral accelerometer trace for test 404531-3 (accelerometer located in front cab).

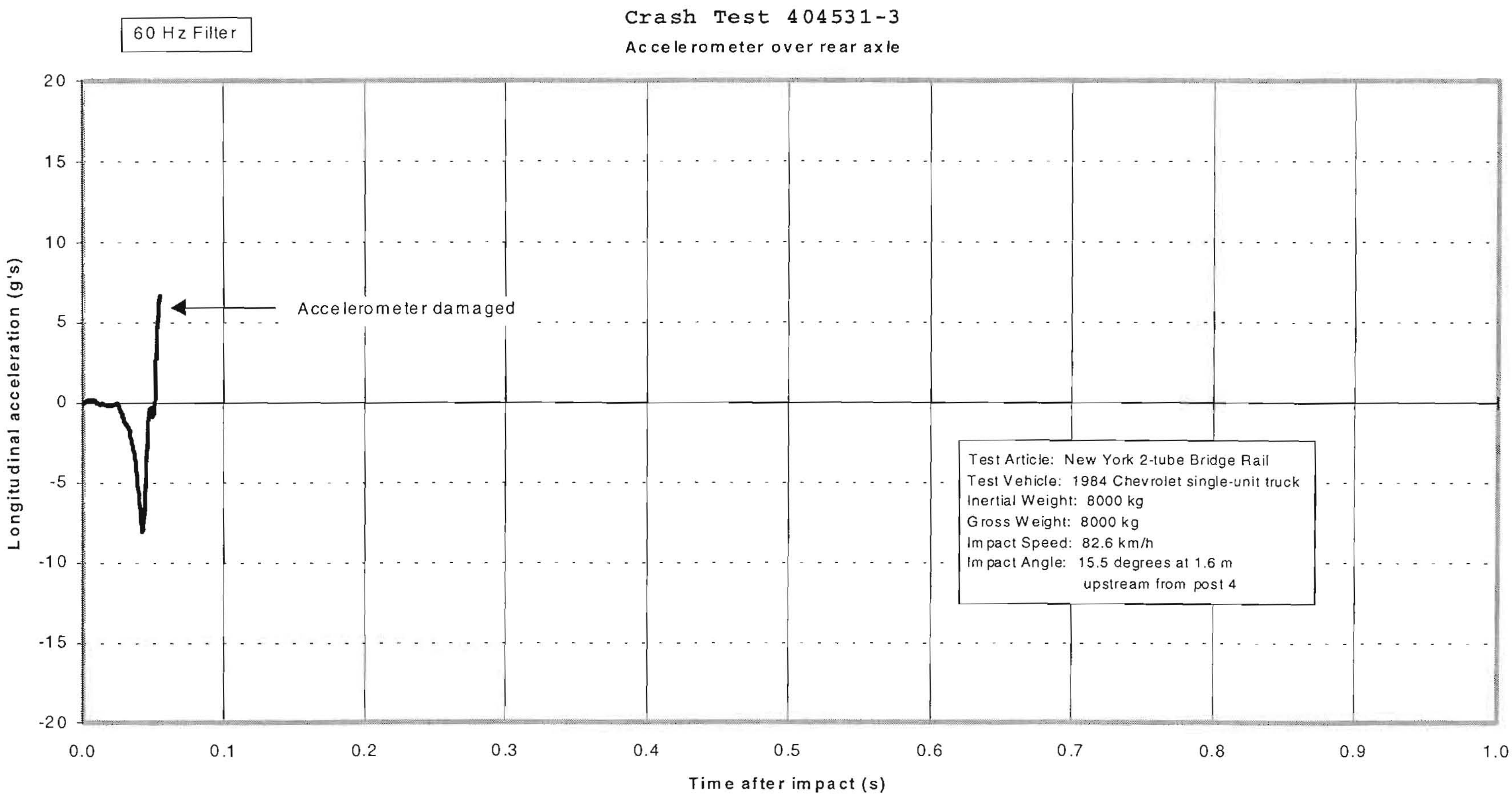


Figure 104. Vehicle longitudinal accelerometer trace for test 404531-3
(accelerometer located in rear of box-van).

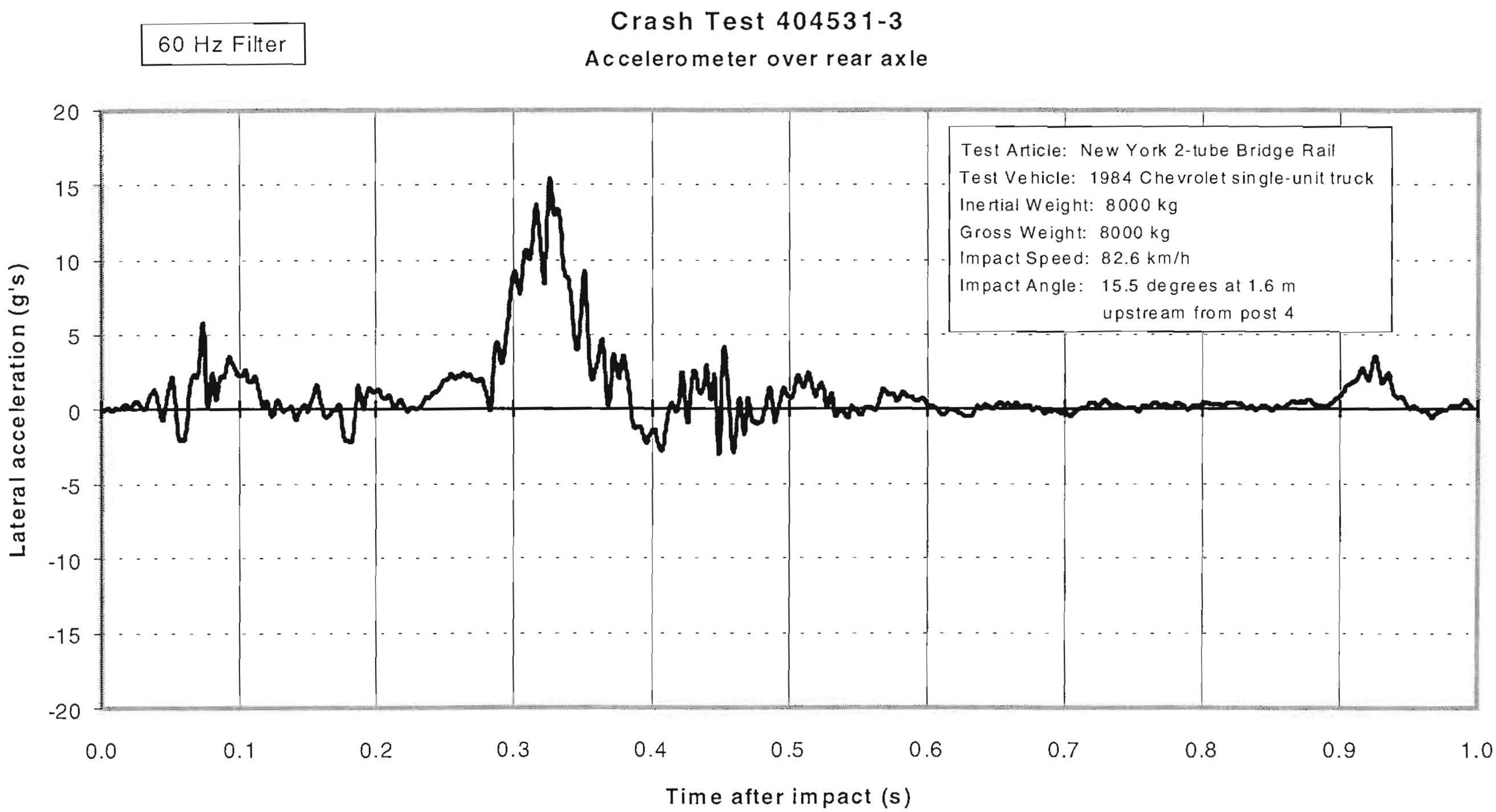


Figure 105. Vehicle lateral accelerometer trace for test 404531-3
(accelerometer located in rear of box-van).

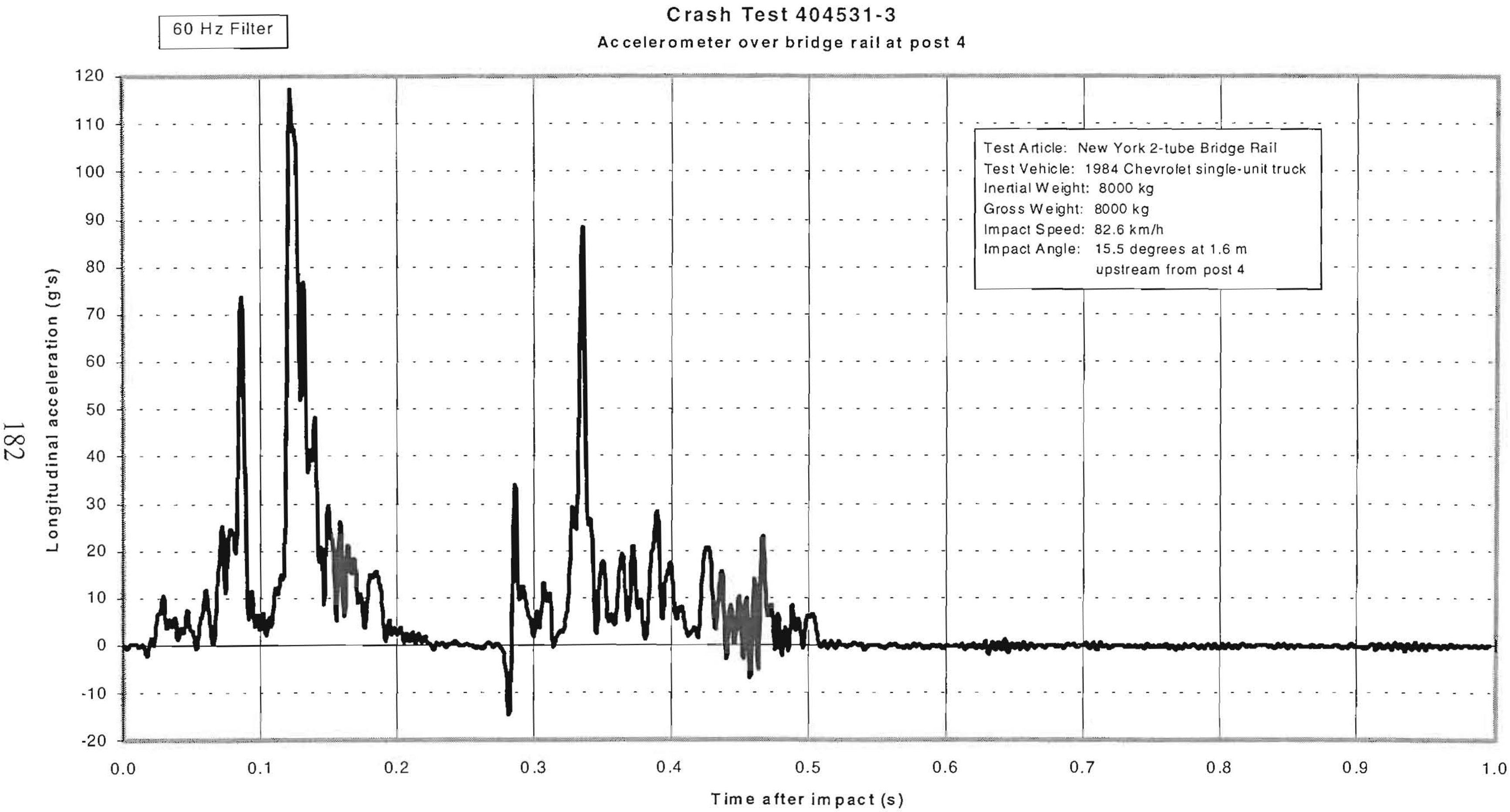


Figure 106. Vehicle longitudinal accelerometer trace for test 404531-3
(accelerometer located on post 4).

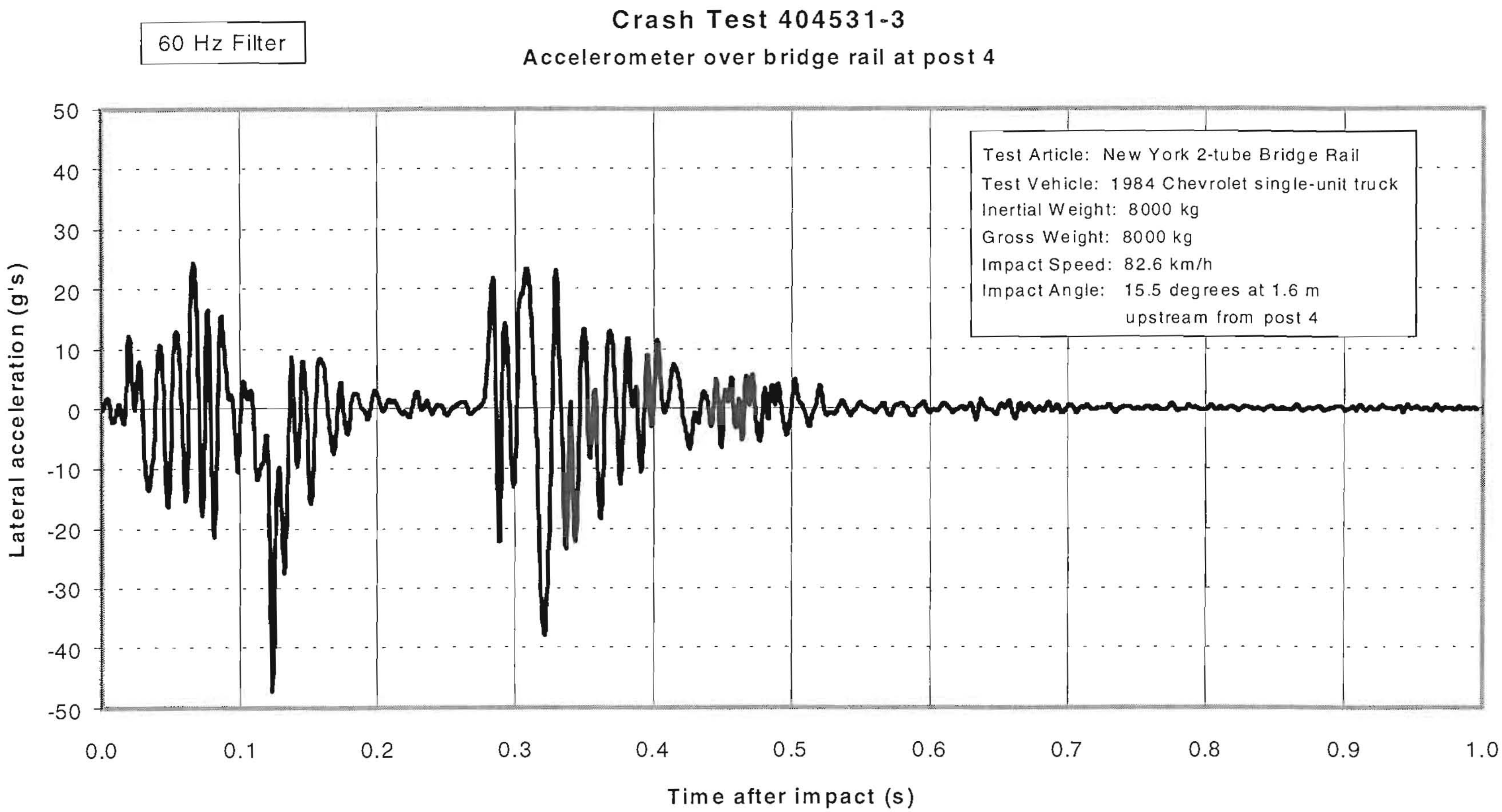


Figure 107. Vehicle lateral accelerometer trace for test 404531-3 (accelerometer located on post 4).

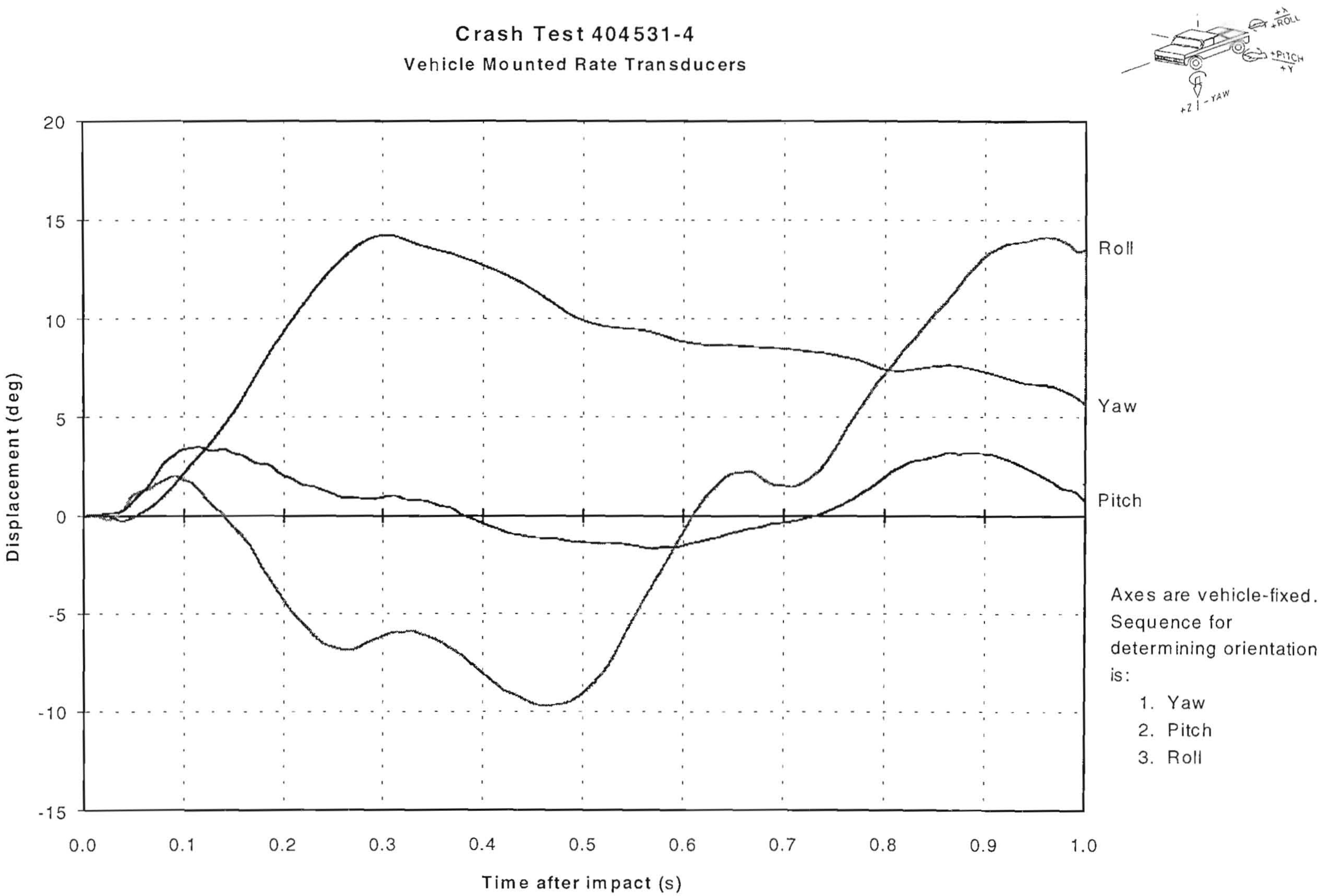


Figure 108. Vehicular angular displacements for test 404531-4.

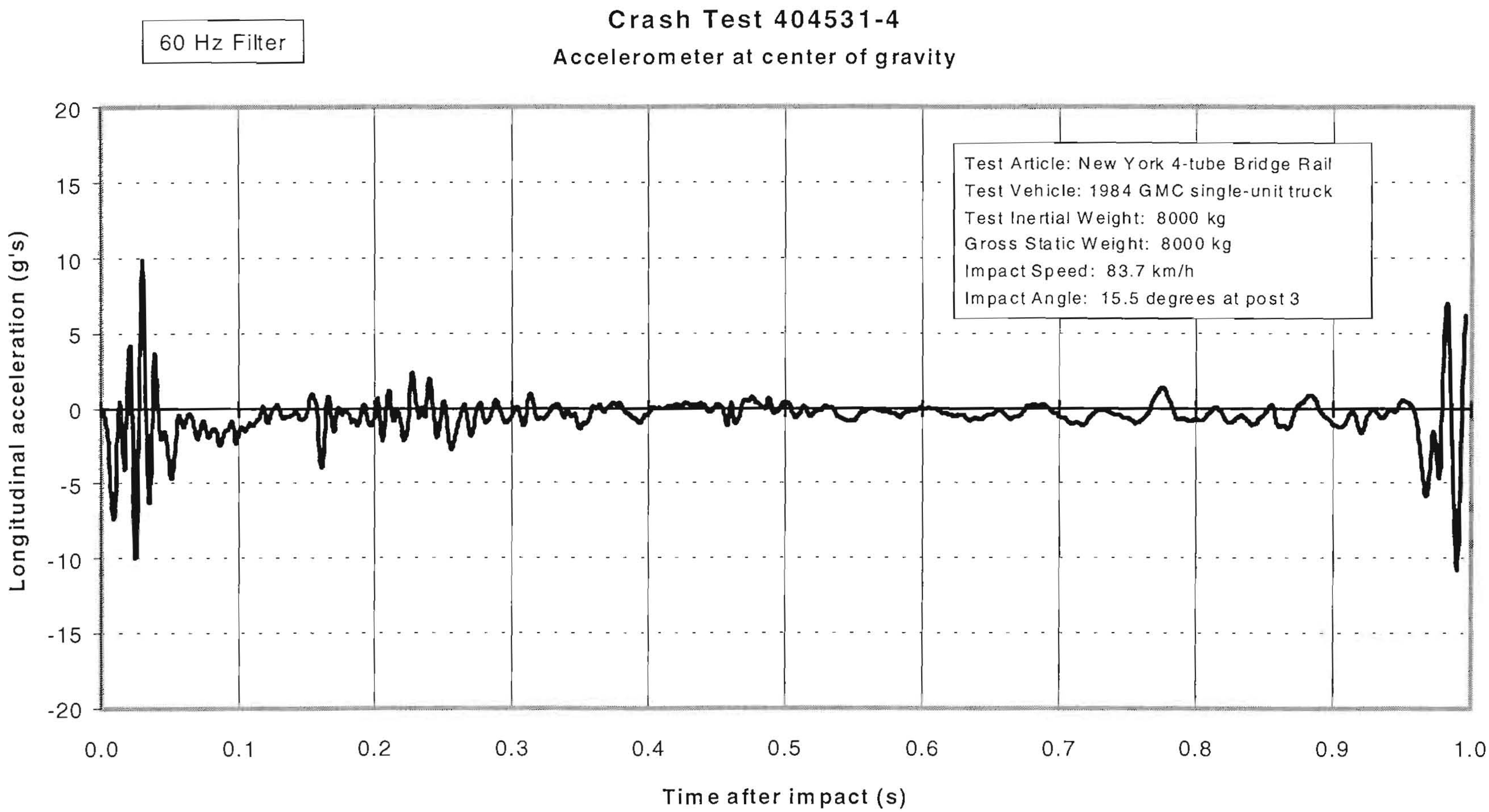


Figure 109. Vehicle longitudinal accelerometer trace for test 404531-4 (accelerometer located at center of gravity).

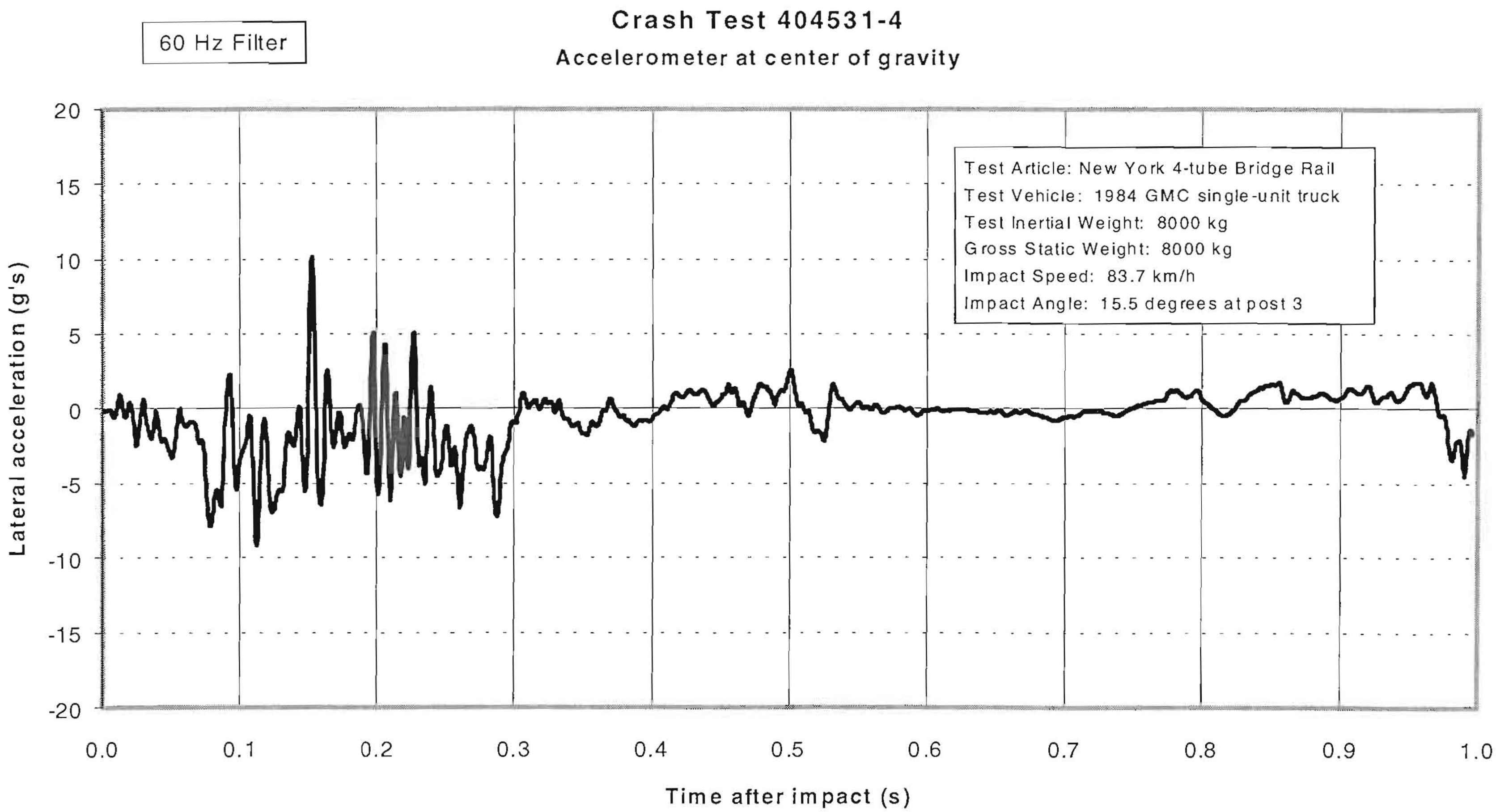


Figure 110. Vehicle lateral accelerometer trace for test 404531-4
(accelerometer located at center of gravity).

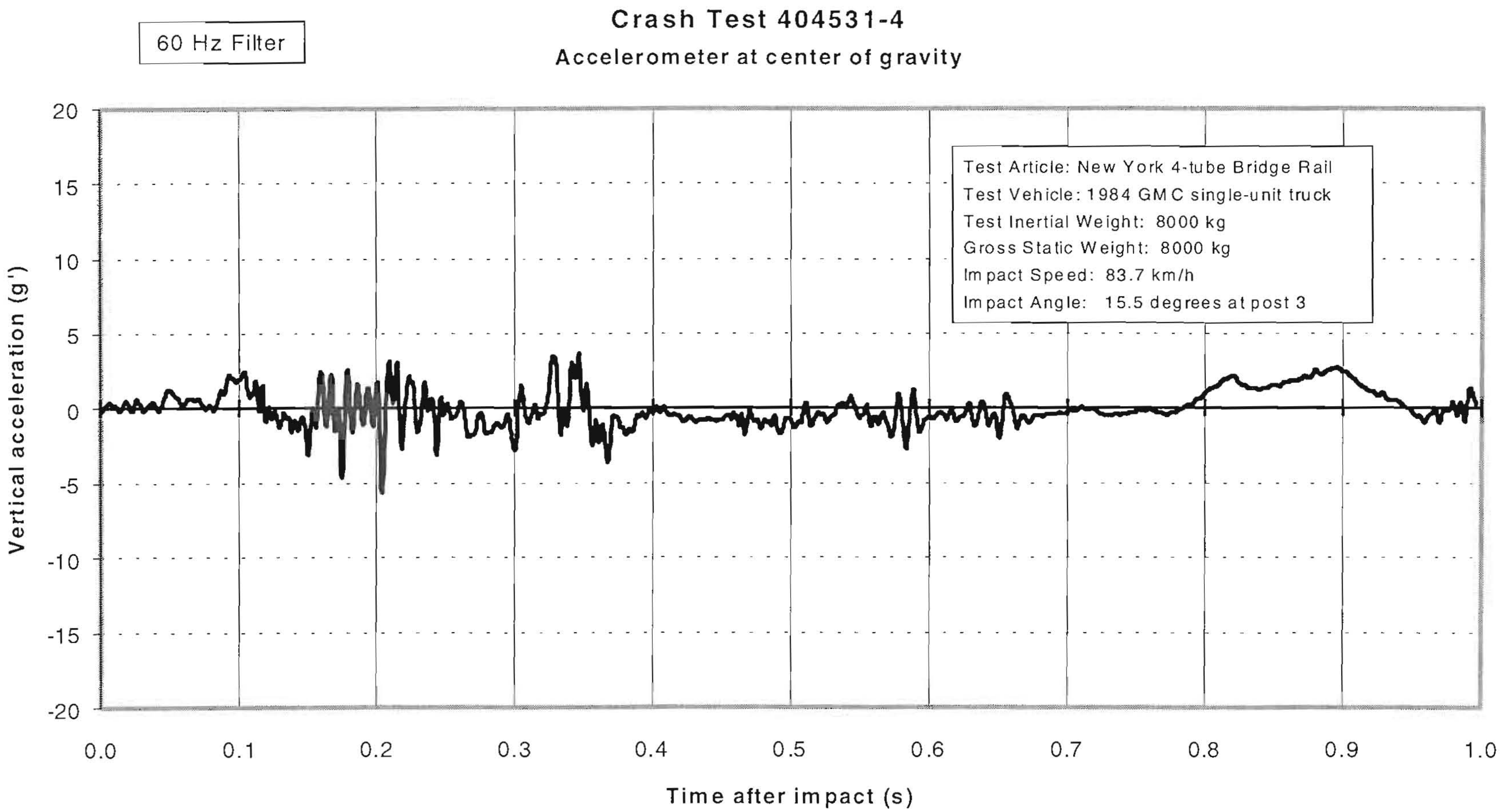


Figure 111. Vehicle vertical accelerometer trace for test 404531-4
(accelerometer located at center of gravity).

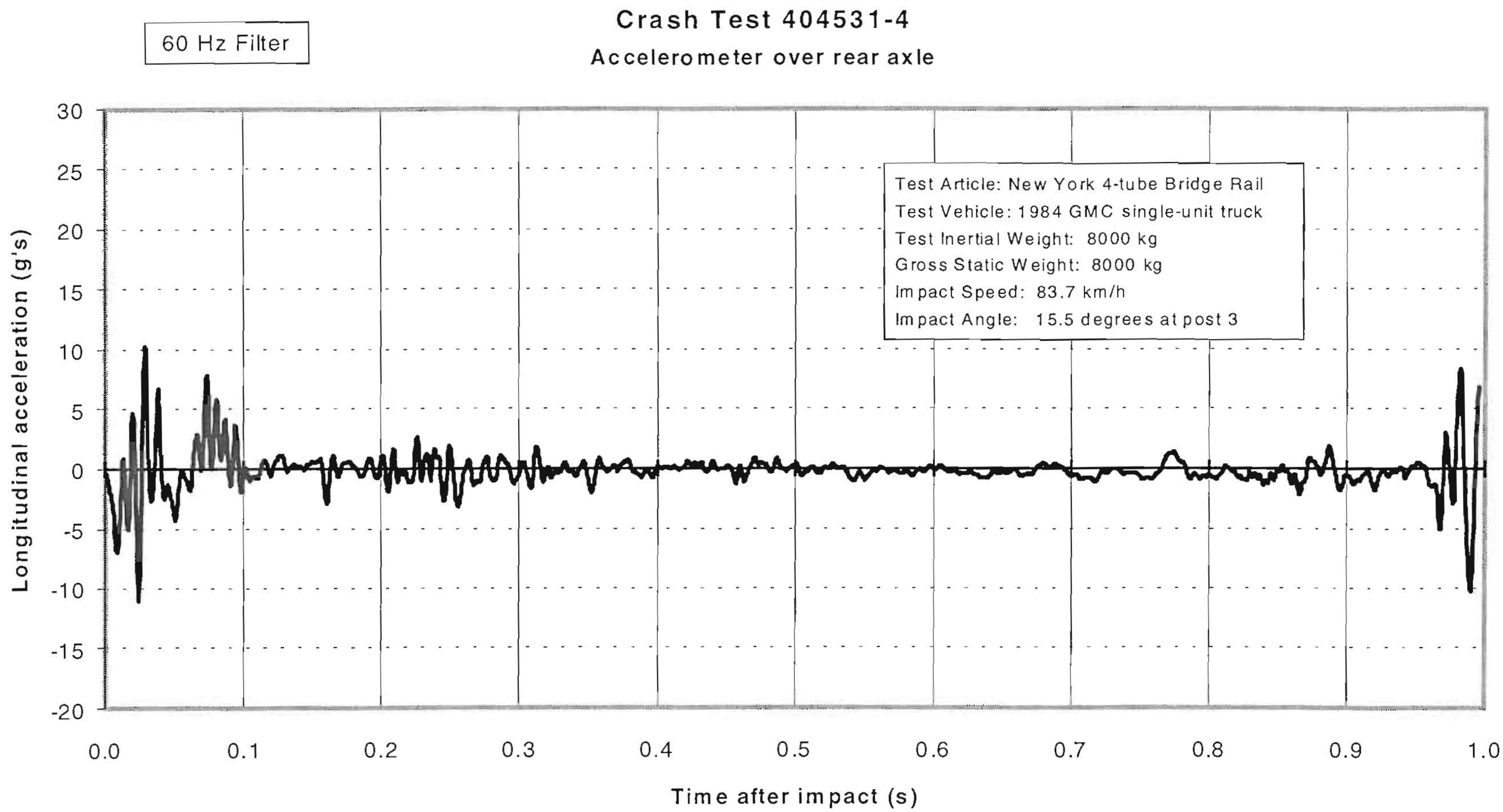


Figure 112. Vehicle longitudinal accelerometer trace for test 404531-4
(accelerometer located over rear axle).

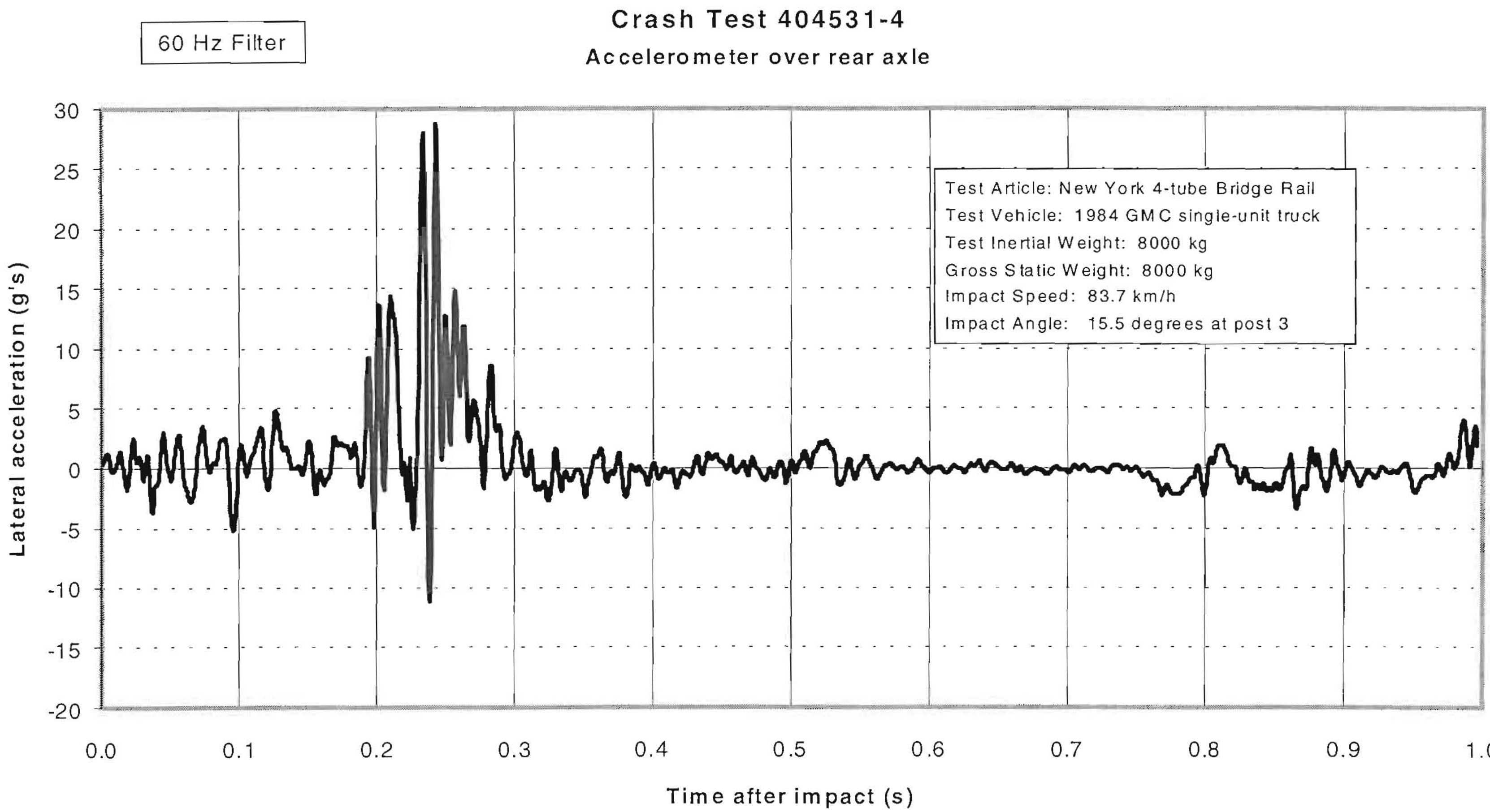


Figure 113. Vehicle lateral accelerometer trace for test 404531-4 (accelerometer located over rear axle).

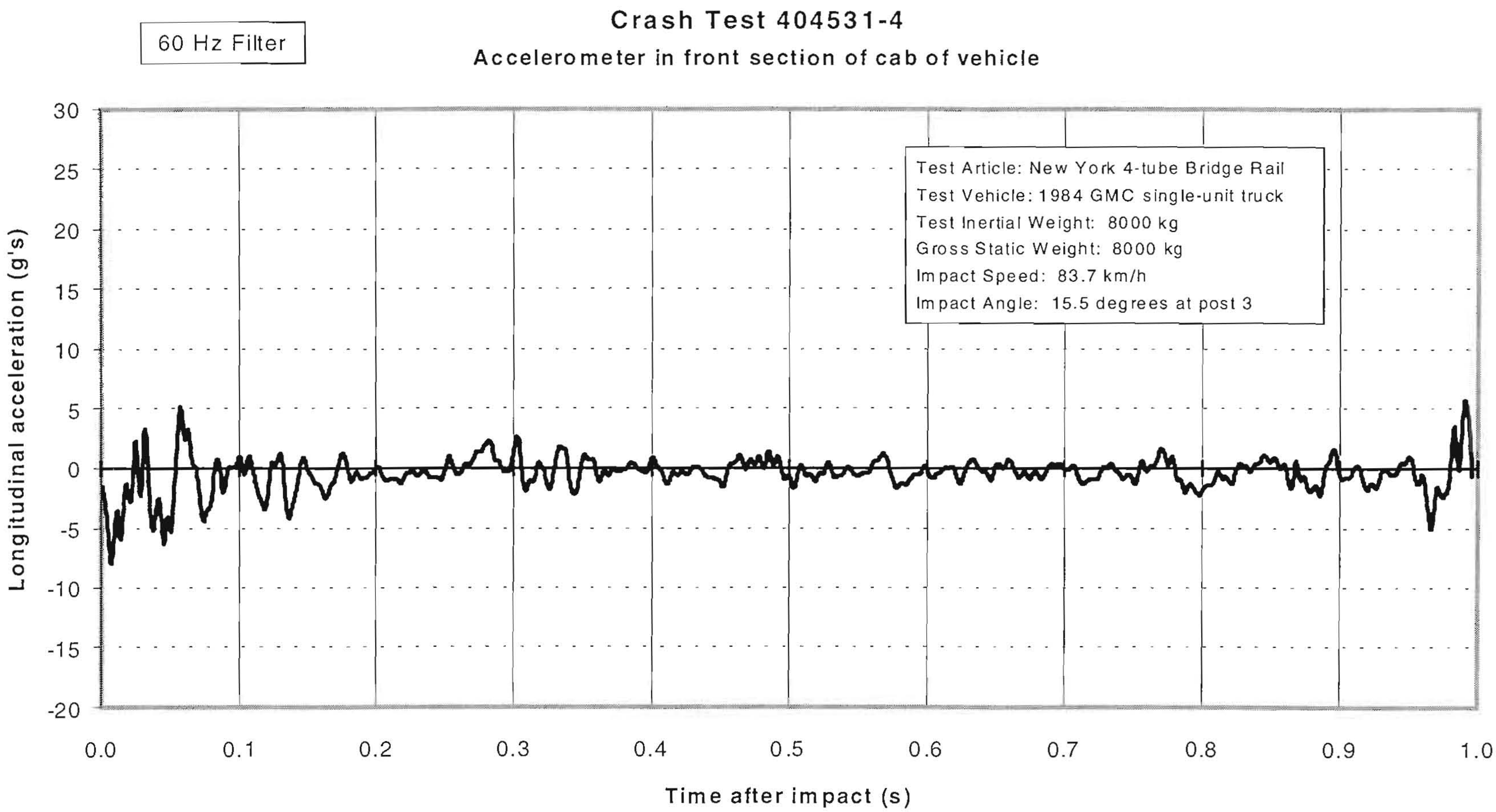


Figure 114. Vehicle longitudinal accelerometer trace for test 404531-4
(accelerometer located in cab of vehicle).

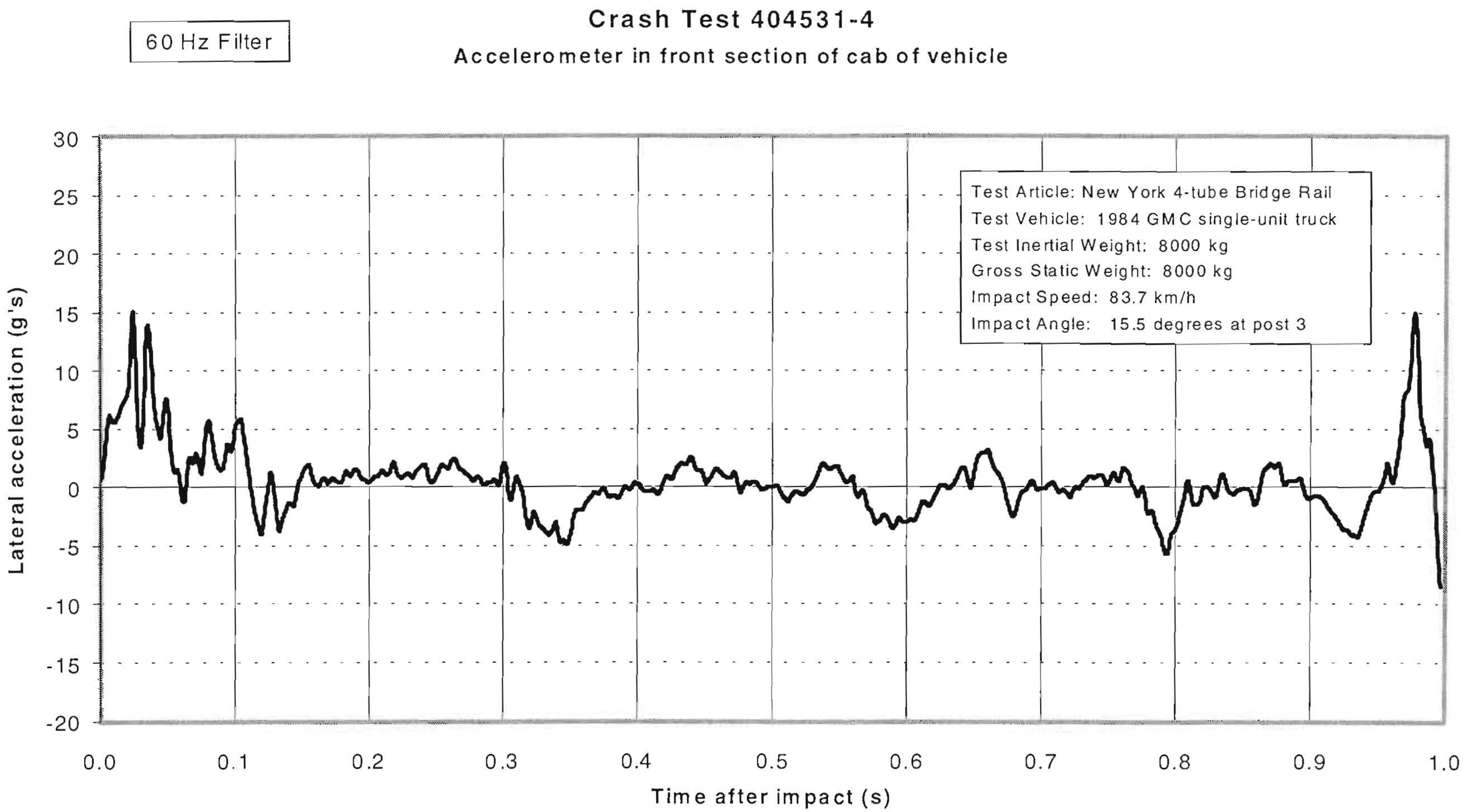


Figure 115. Vehicle lateral accelerometer trace for test 404531-4 (accelerometer located in cab of vehicle).

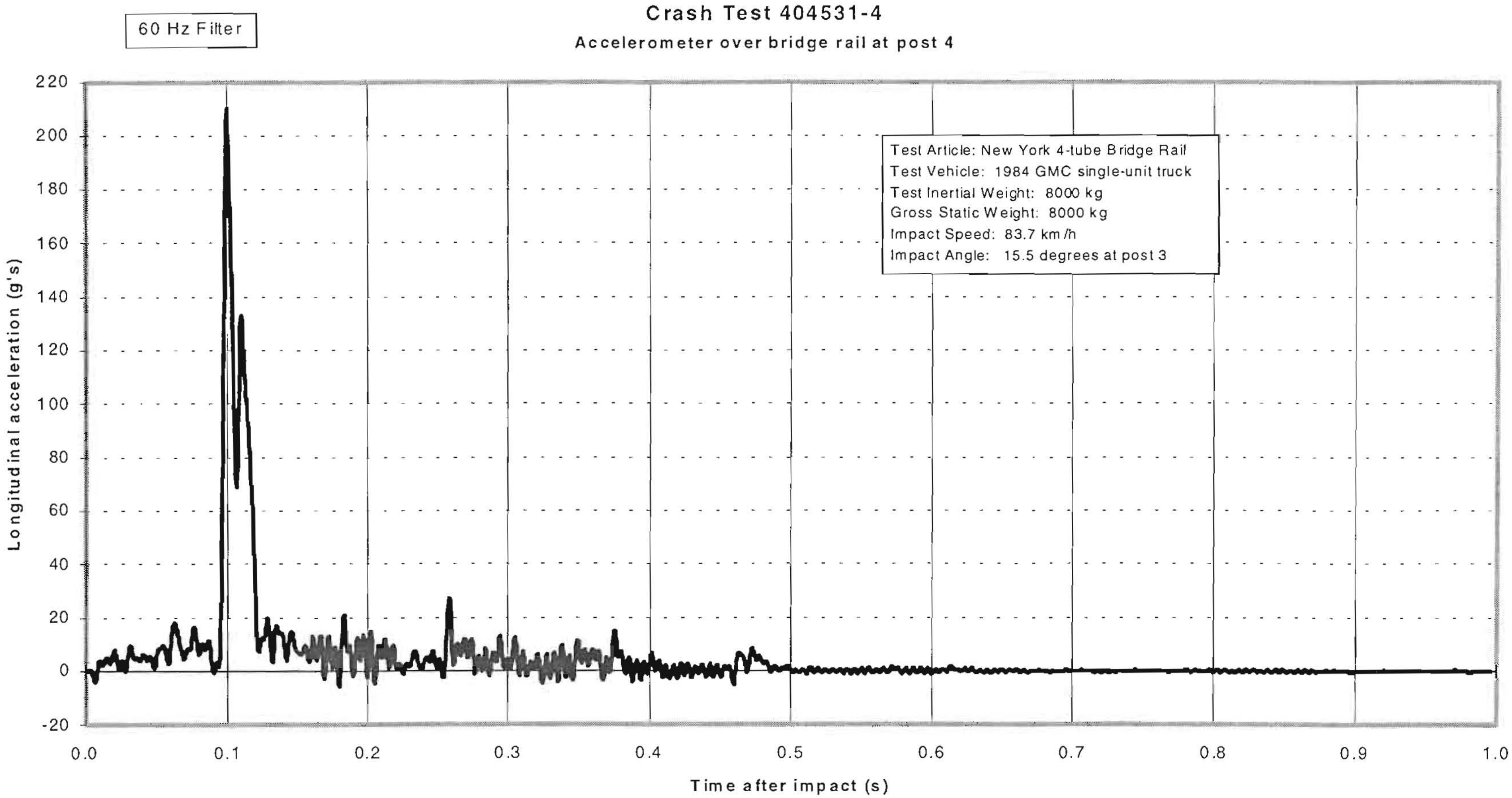


Figure 116. Bridge railing longitudinal accelerometer trace for test 404531-4 (accelerometer located over bridge railing at post 4).

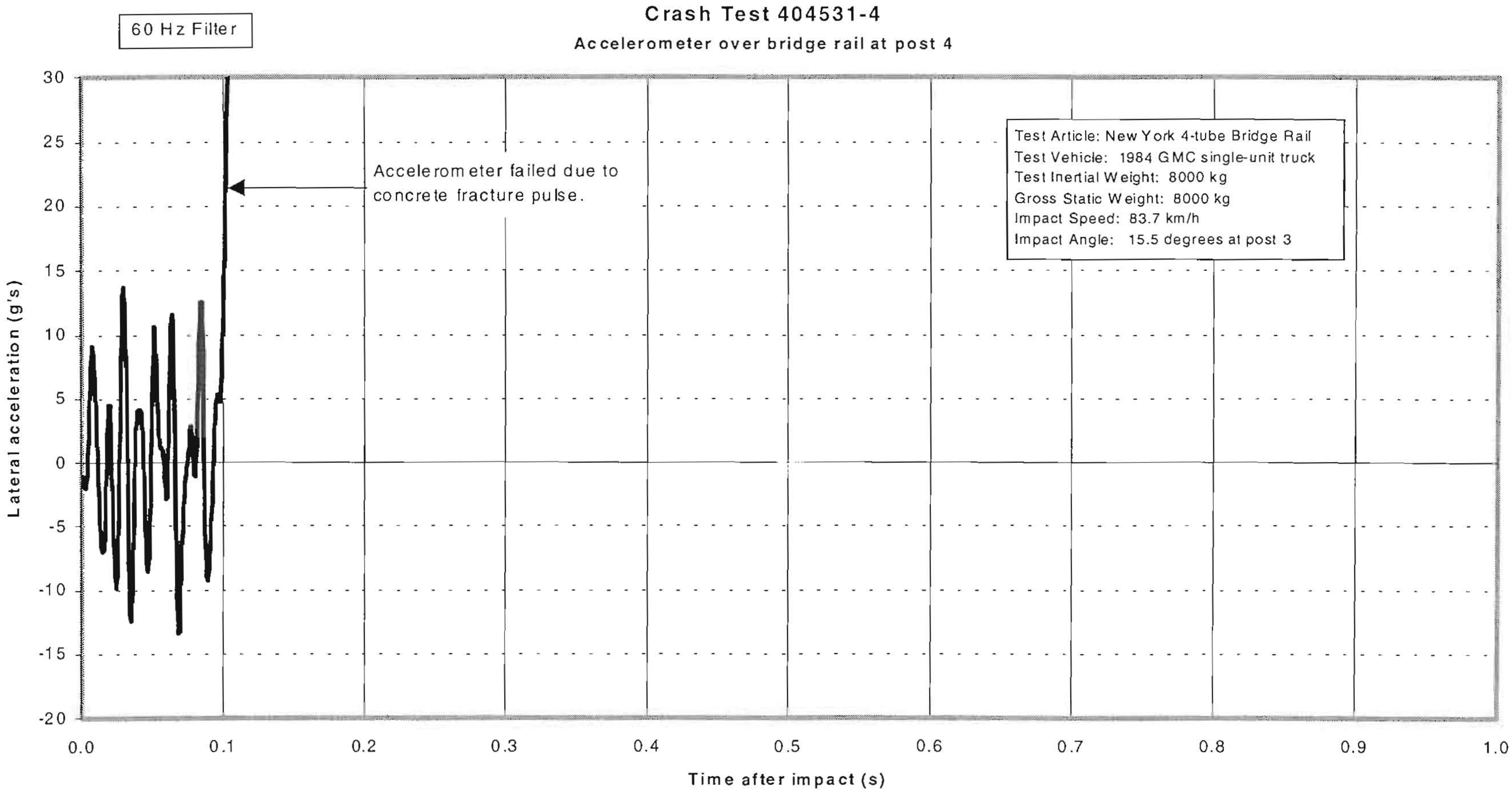


Figure 117. Bridge railing lateral accelerometer trace for test 404531-4 (accelerometer located over bridge railing at post 4).

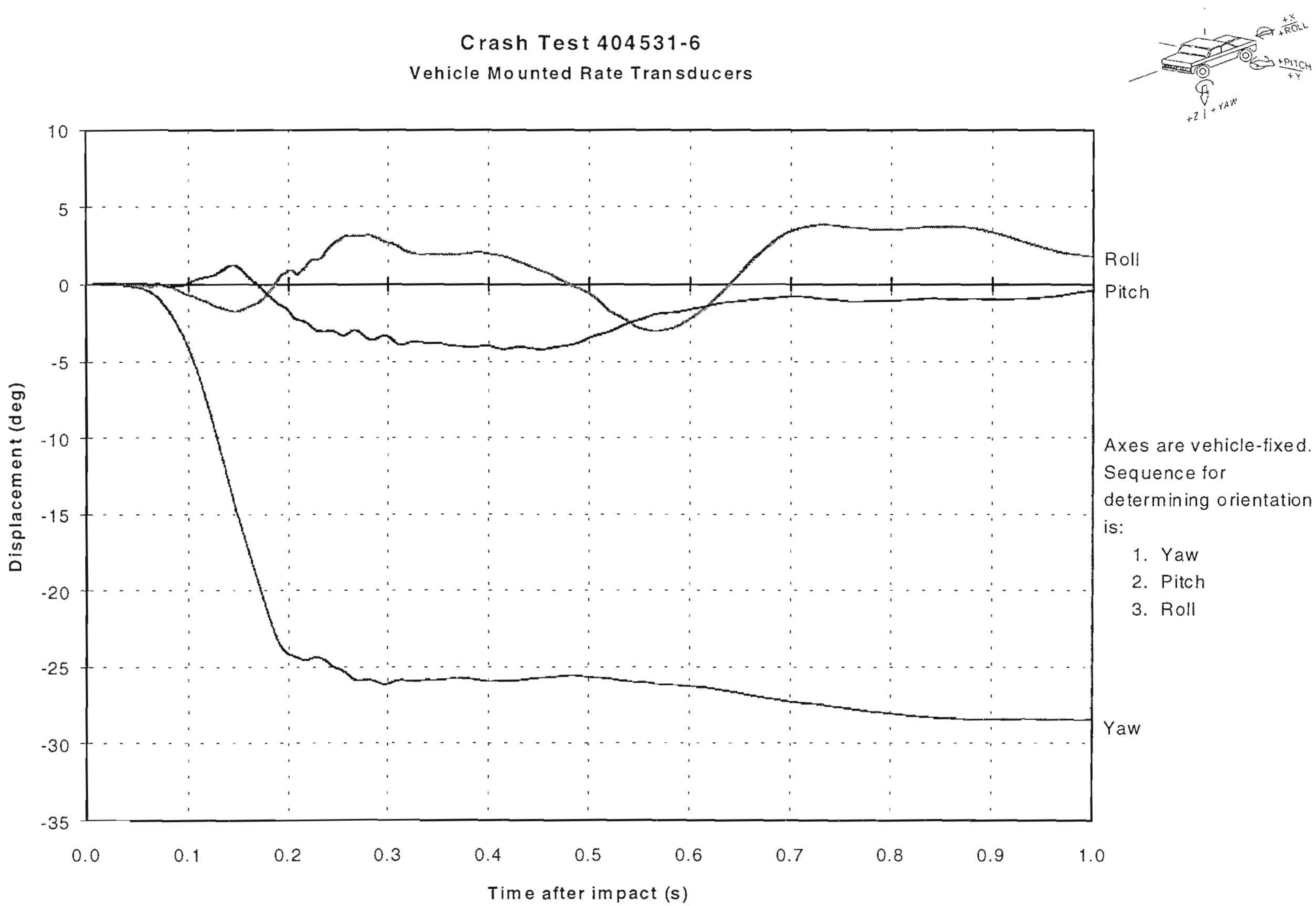


Figure 118. Vehicular angular displacements for test 404531-6.

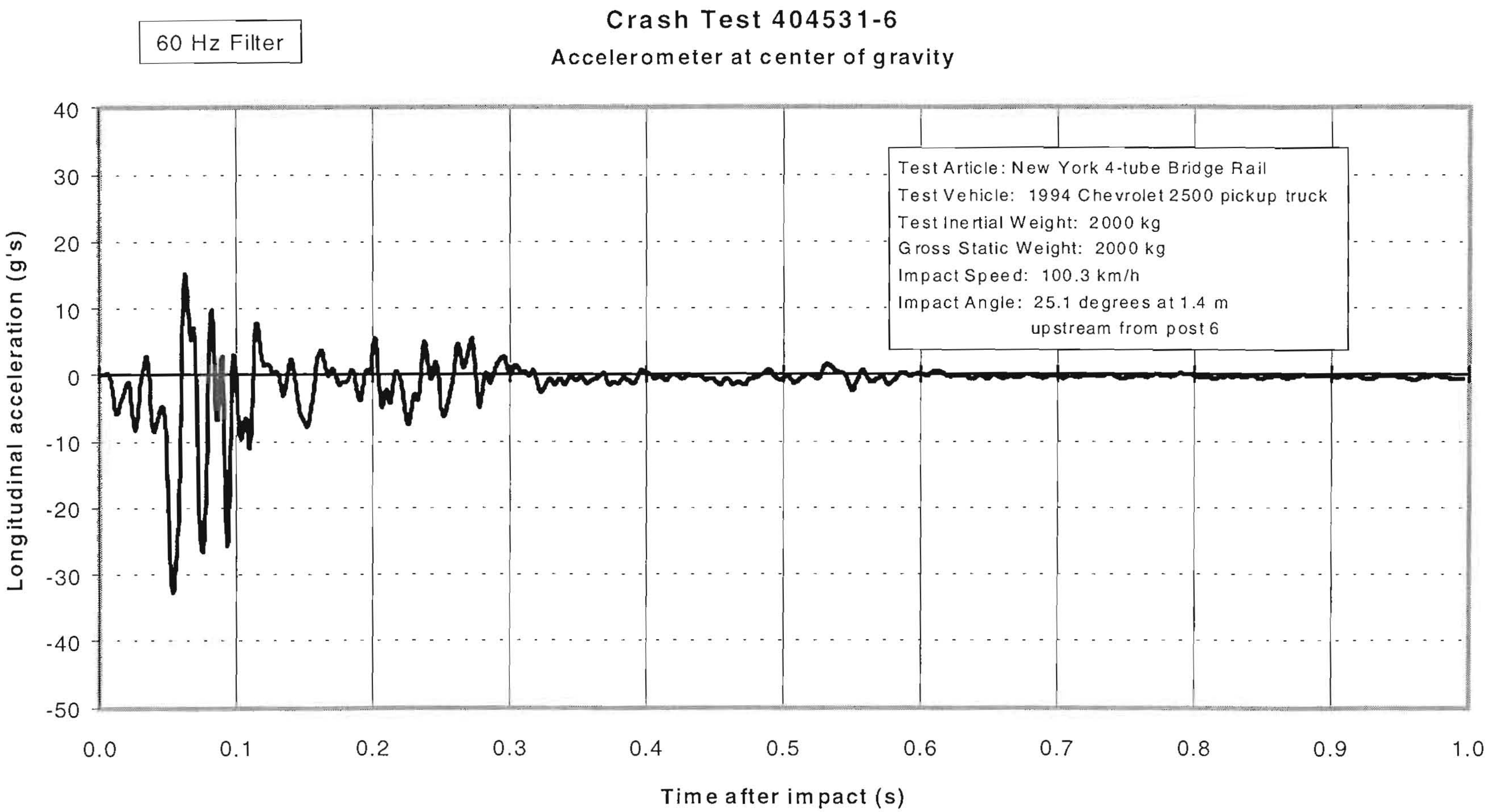


Figure 119. Vehicle longitudinal accelerometer trace for test 404531-6 (accelerometer located at center of gravity).

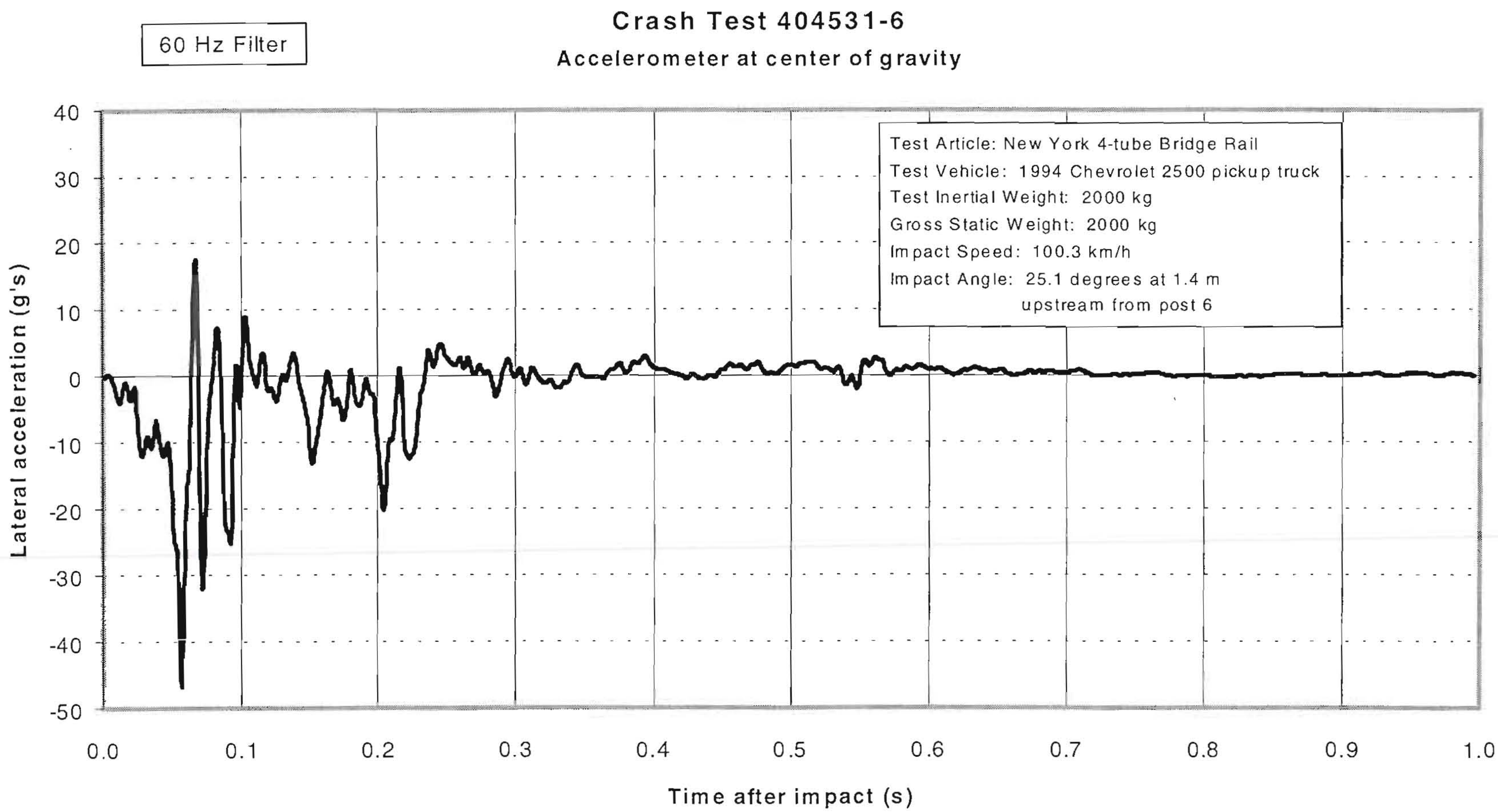


Figure 120. Vehicle lateral accelerometer trace for test 404531-6
(accelerometer located at center of gravity).

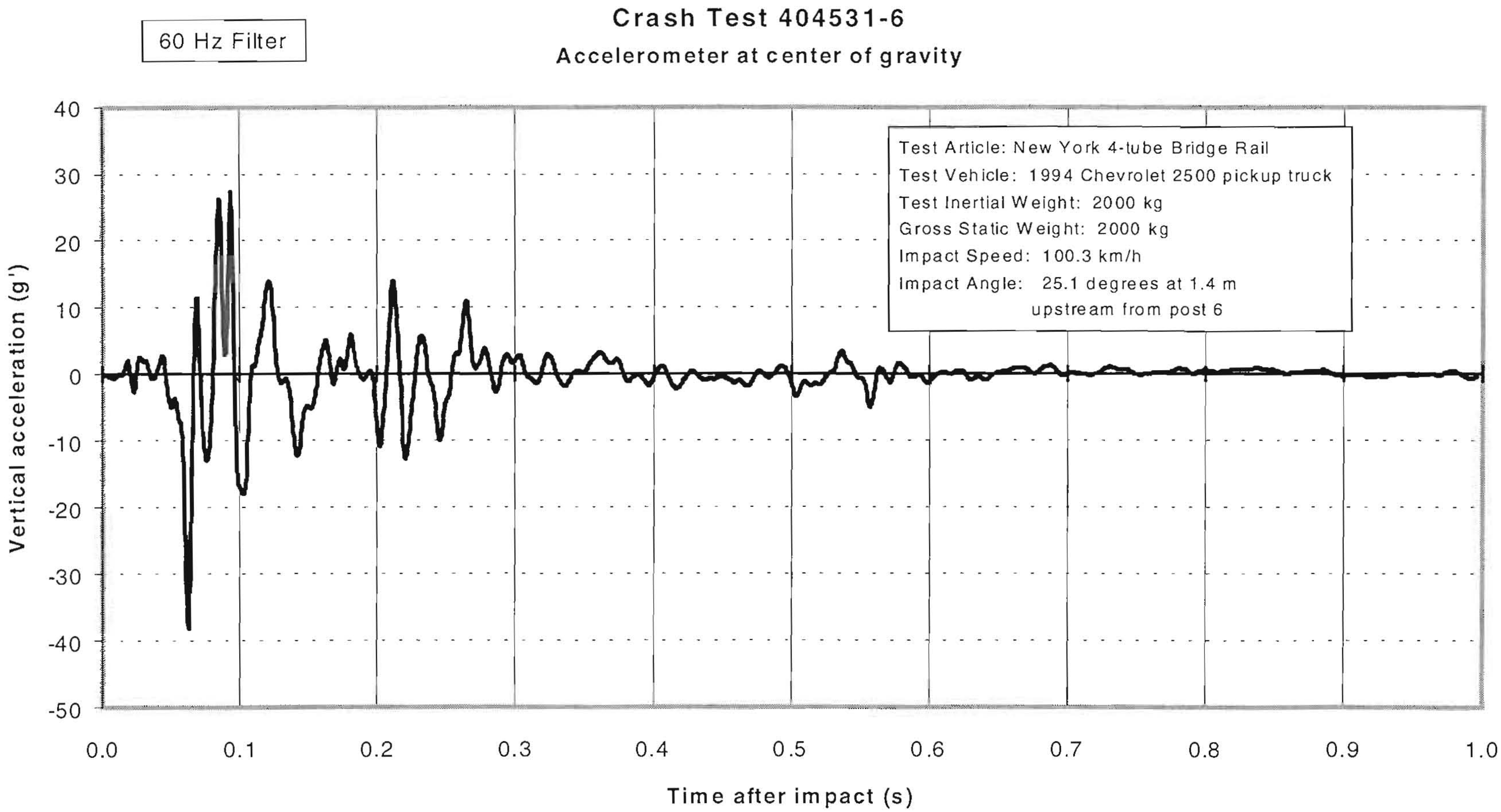


Figure 121. Vehicle vertical accelerometer trace for test 404531-6 (accelerometer located at center of gravity).

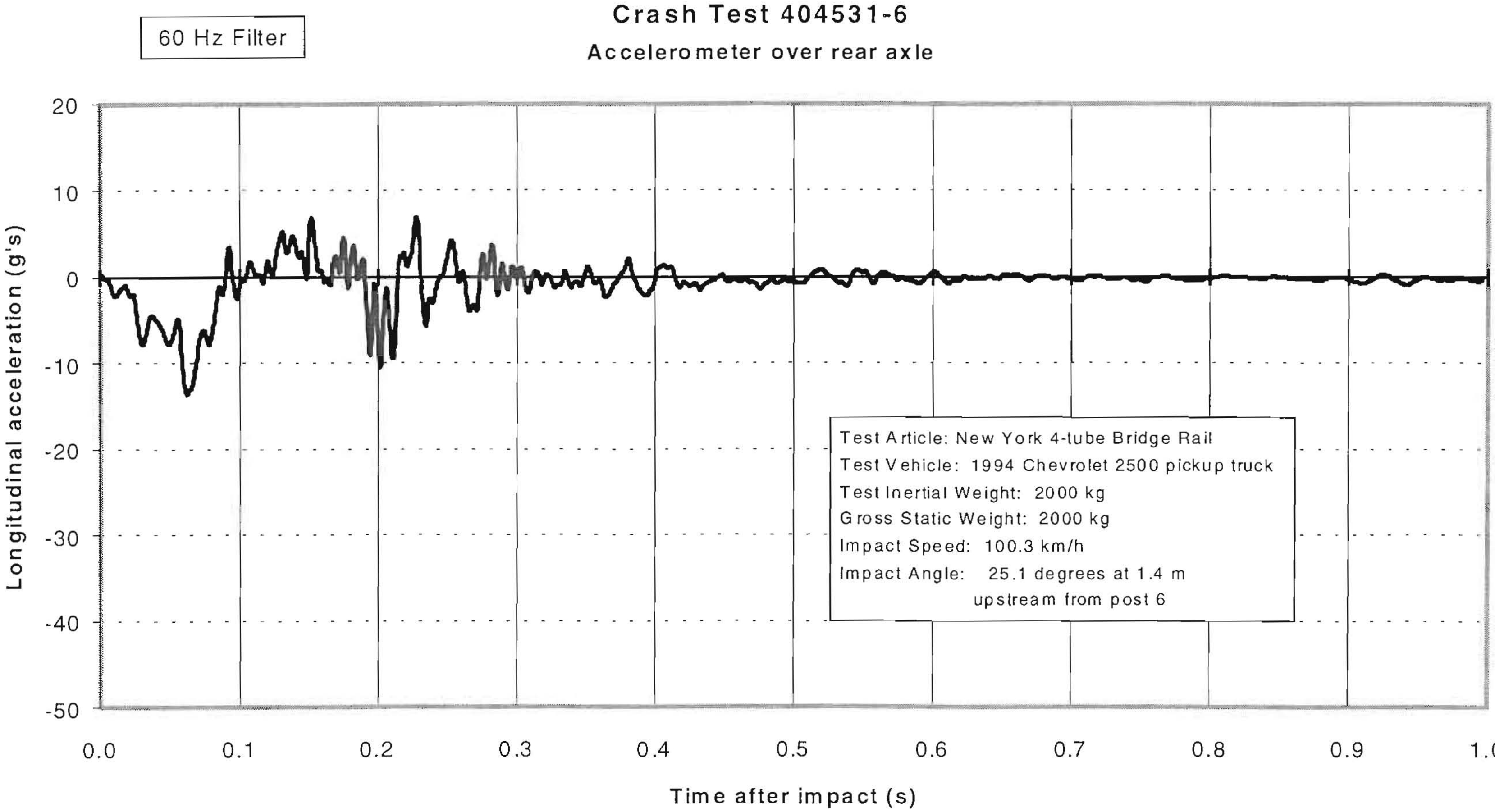


Figure 122. Vehicle longitudinal accelerometer trace for test 404531-6 (accelerometer located over rear axle).

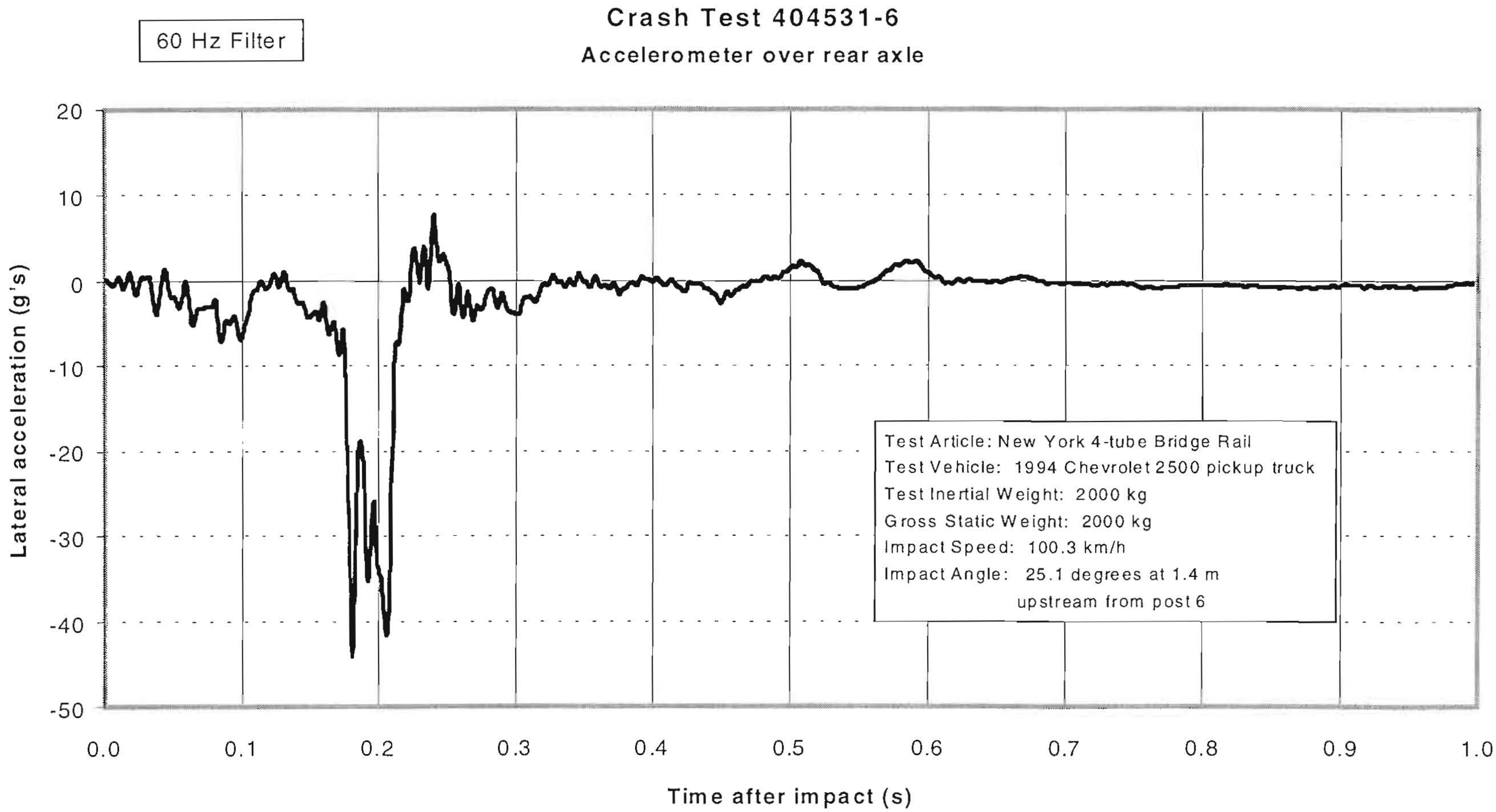


Figure 123. Vehicle lateral accelerometer trace for test 404531-6
(accelerometer located over rear axle).

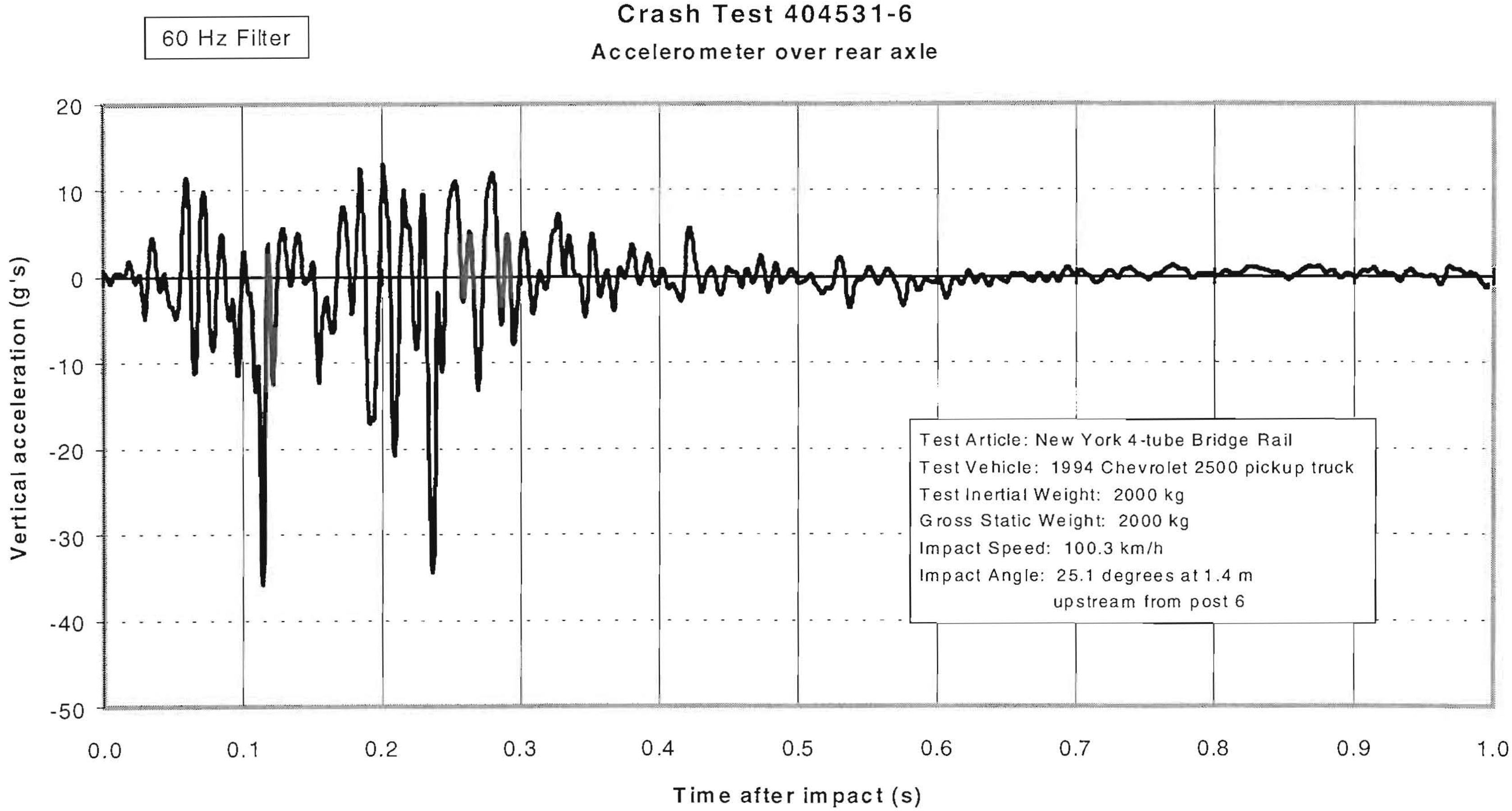


Figure 124. Vehicle vertical accelerometer trace for test 404531-6
(accelerometer located over rear axle).

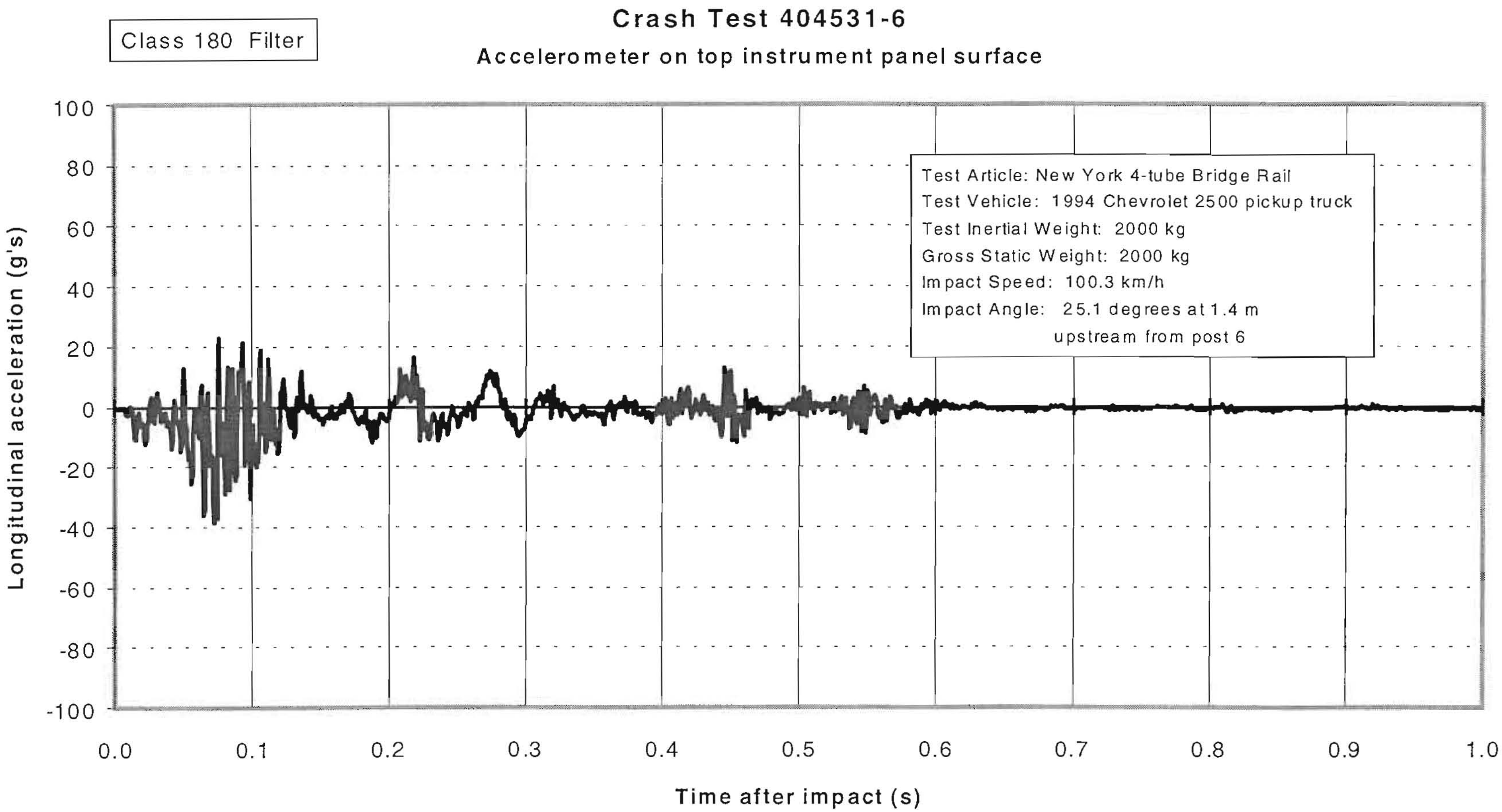


Figure 125. Vehicle longitudinal accelerometer trace for test 404531-6
(accelerometer located on top surface of instrument panel).

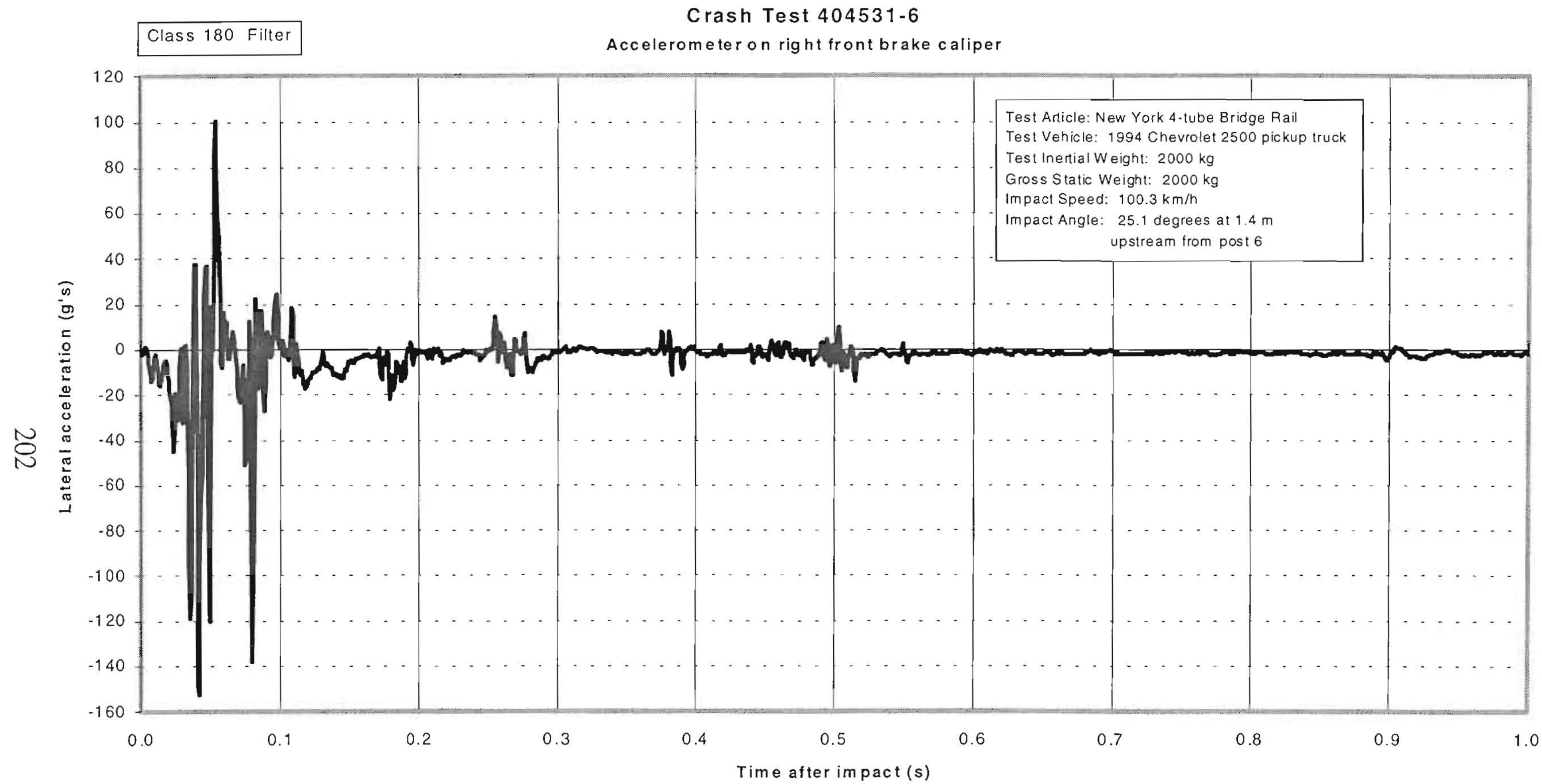


Figure 126. Vehicle lateral accelerometer trace for test 404531-6 (accelerometer located on right front brake caliper).

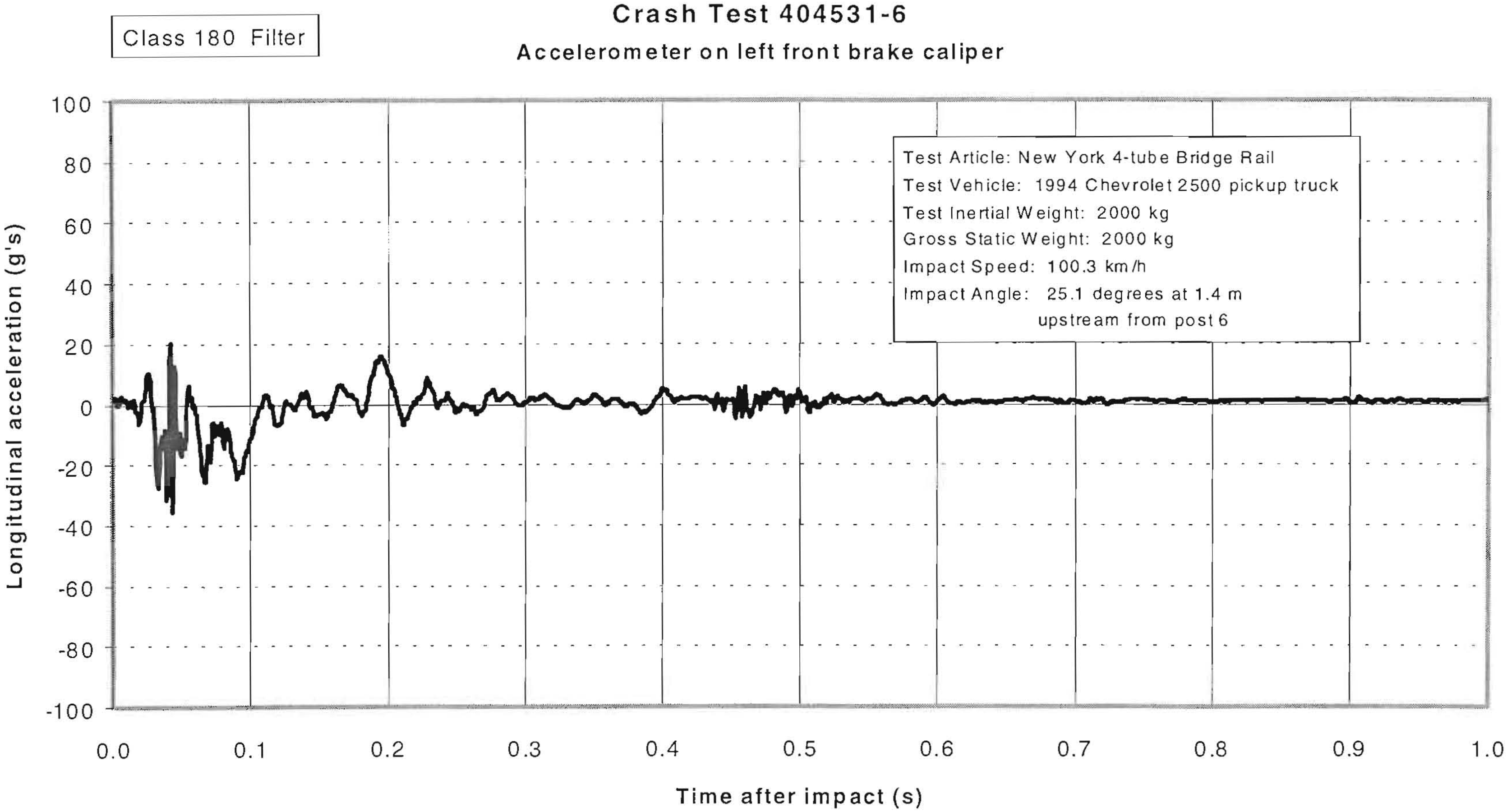


Figure 127. Vehicle longitudinal accelerometer trace for test 404531-6
(accelerometer located on left front brake caliper).

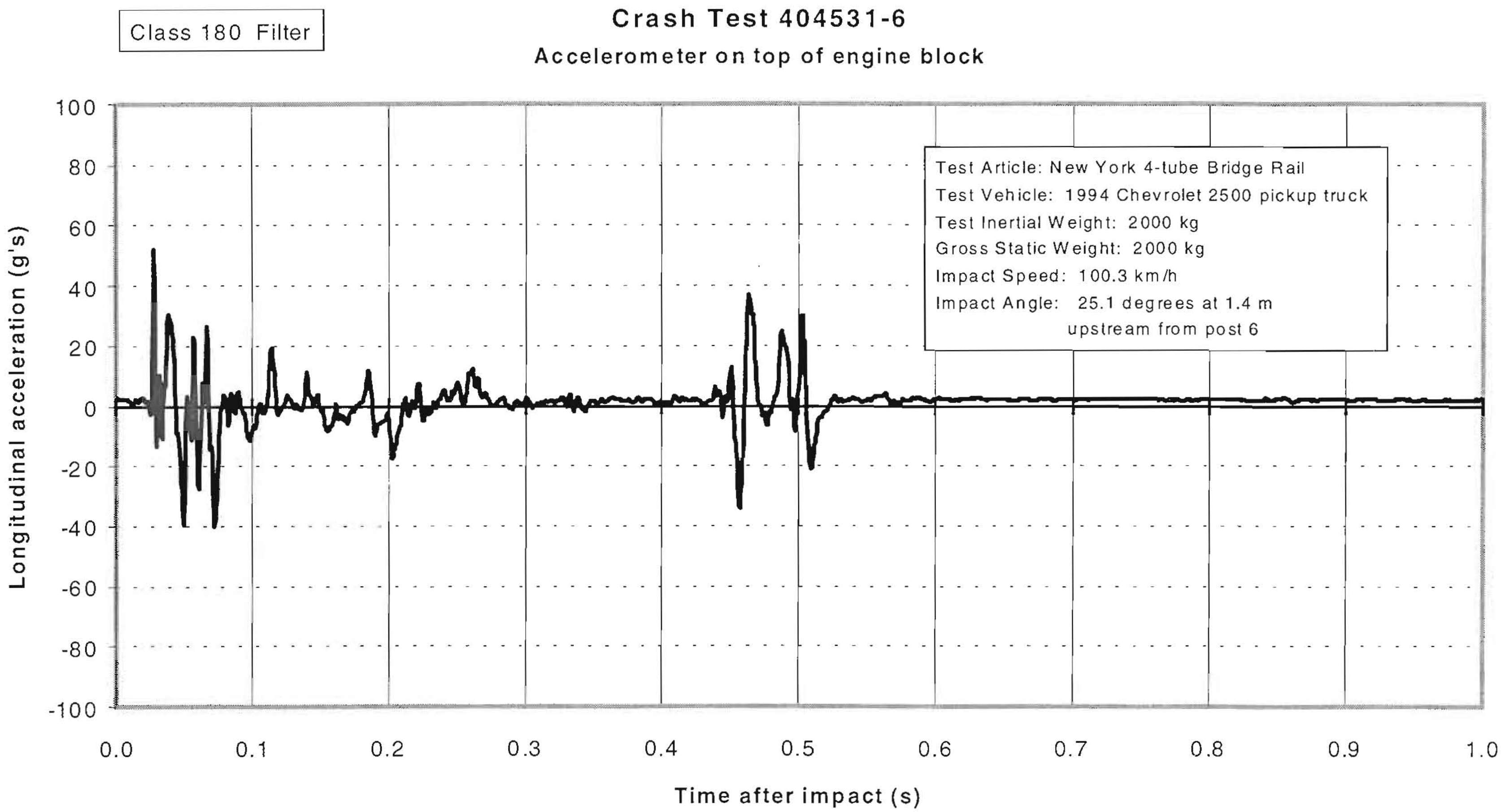


Figure 128. Vehicle longitudinal accelerometer trace for test 404531-6 (accelerometer located on top of engine block).

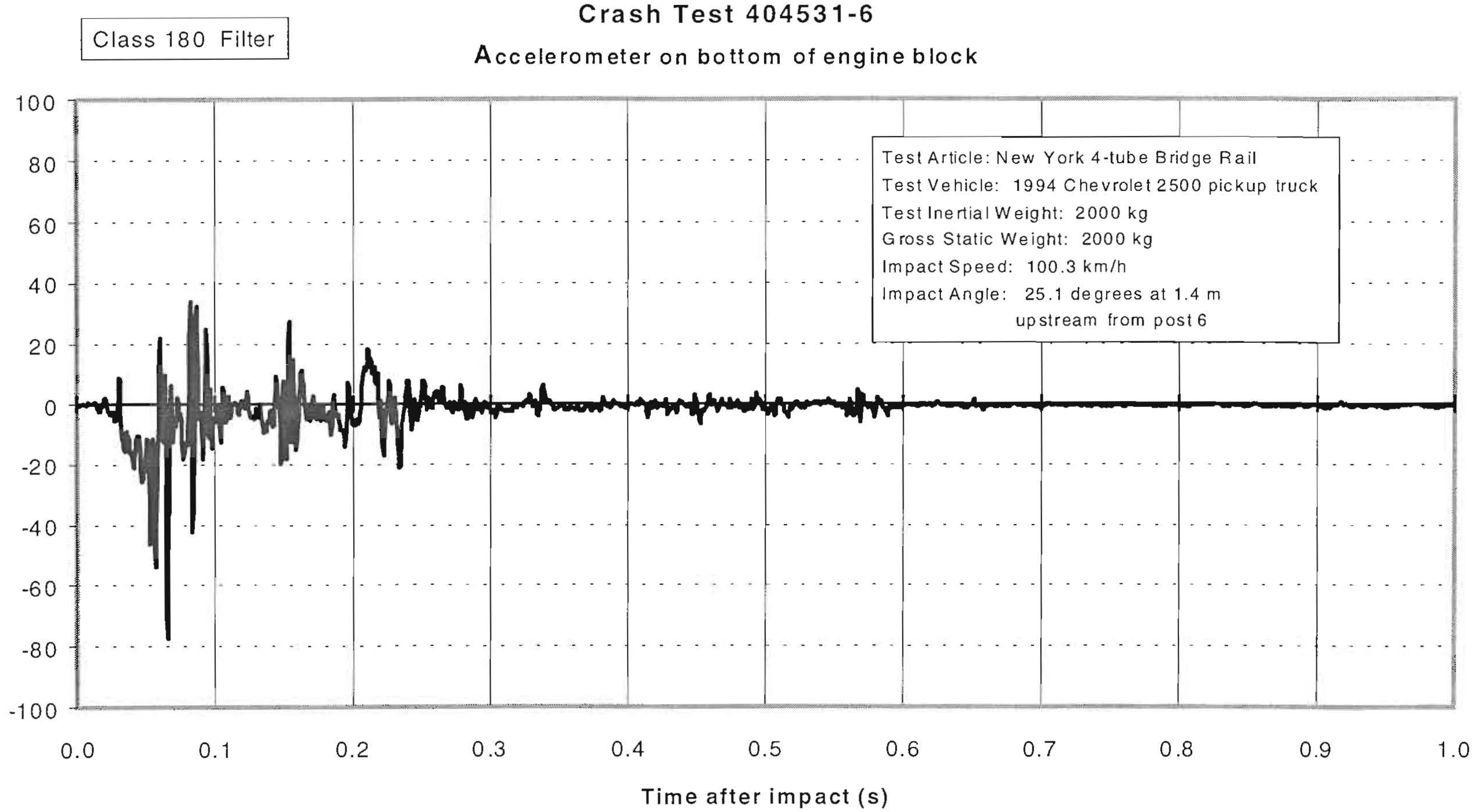


Figure 129. Vehicle longitudinal accelerometer trace for test 404531-6 (accelerometer located on bottom of engine block).

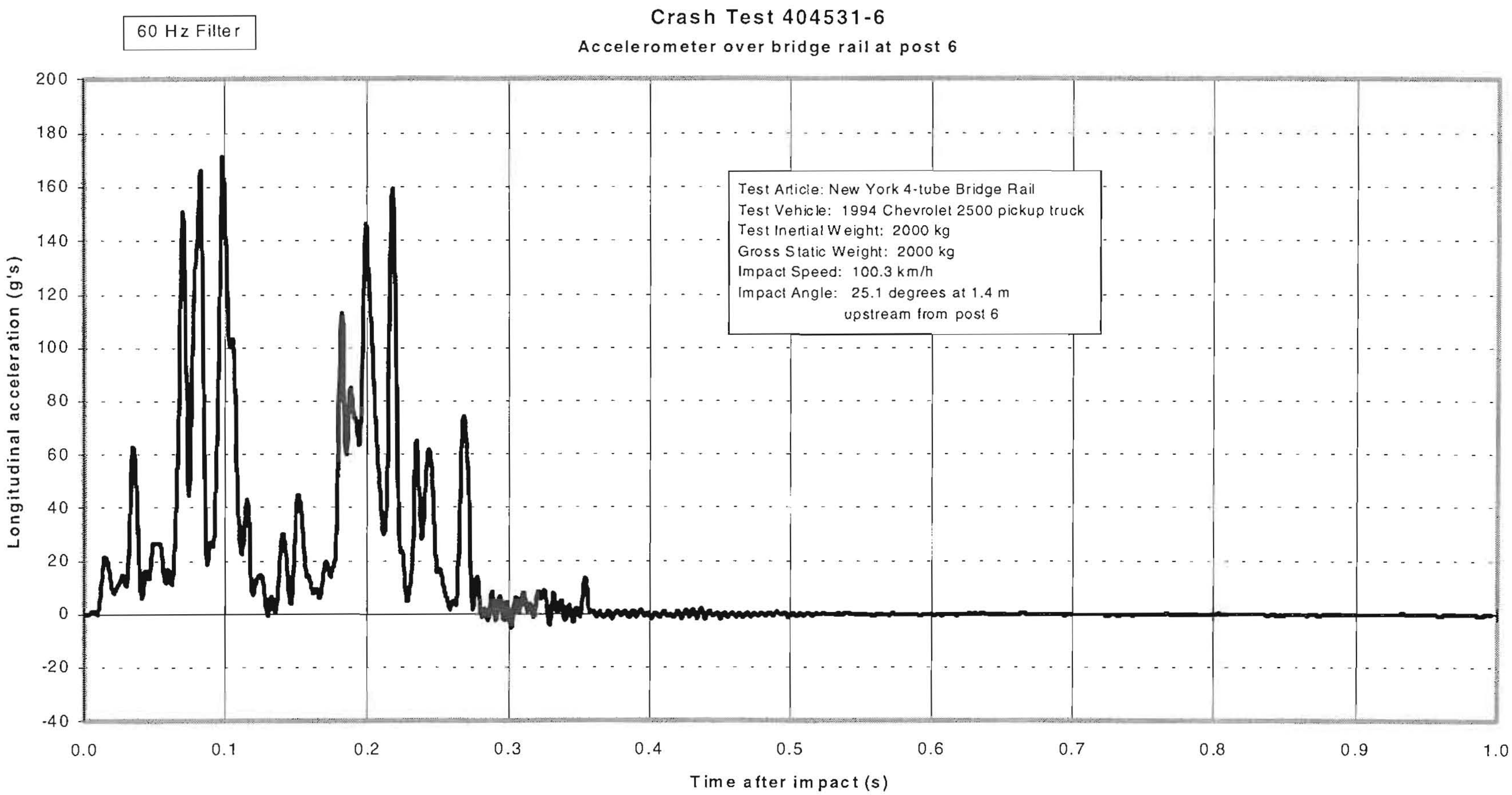


Figure 130. Bridge railing longitudinal accelerometer trace for test 404531-6 (accelerometer located over bridge railing at post 6).

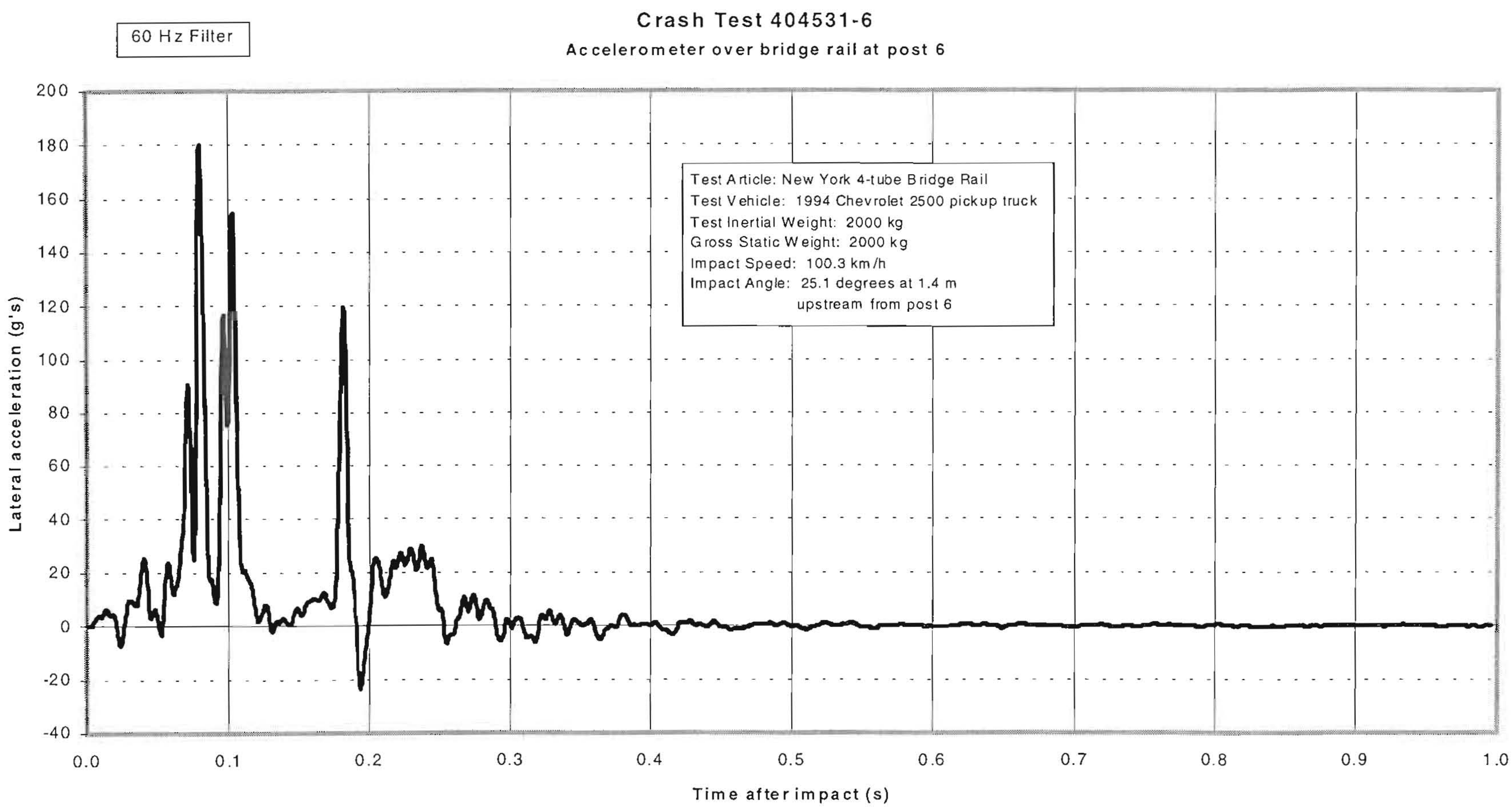


Figure 131. Bridge railing lateral accelerometer trace for test 404531-6 (accelerometer located over bridge railing at post 6).

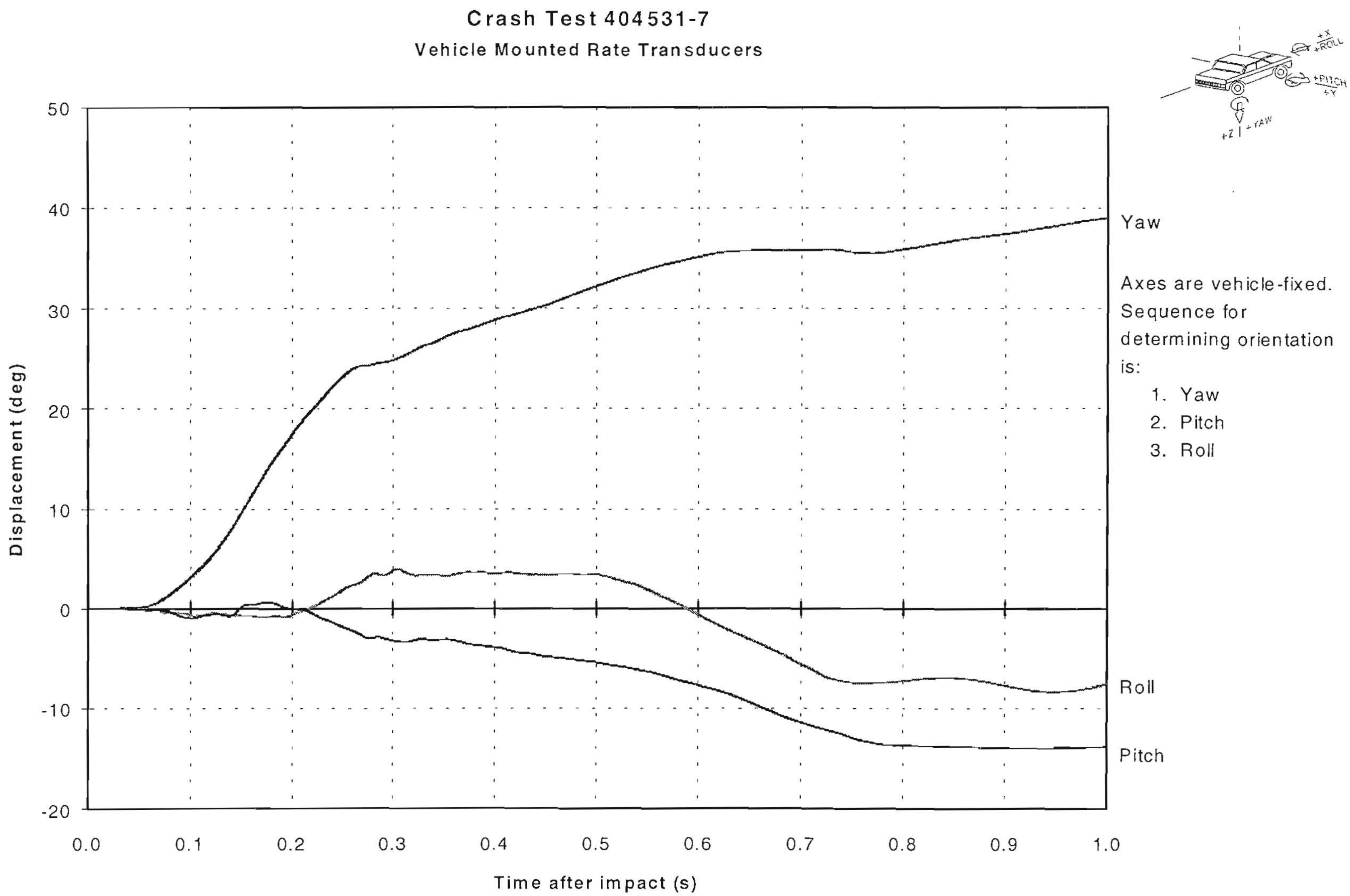


Figure 132. Vehicular angular displacements for test 404531-7.

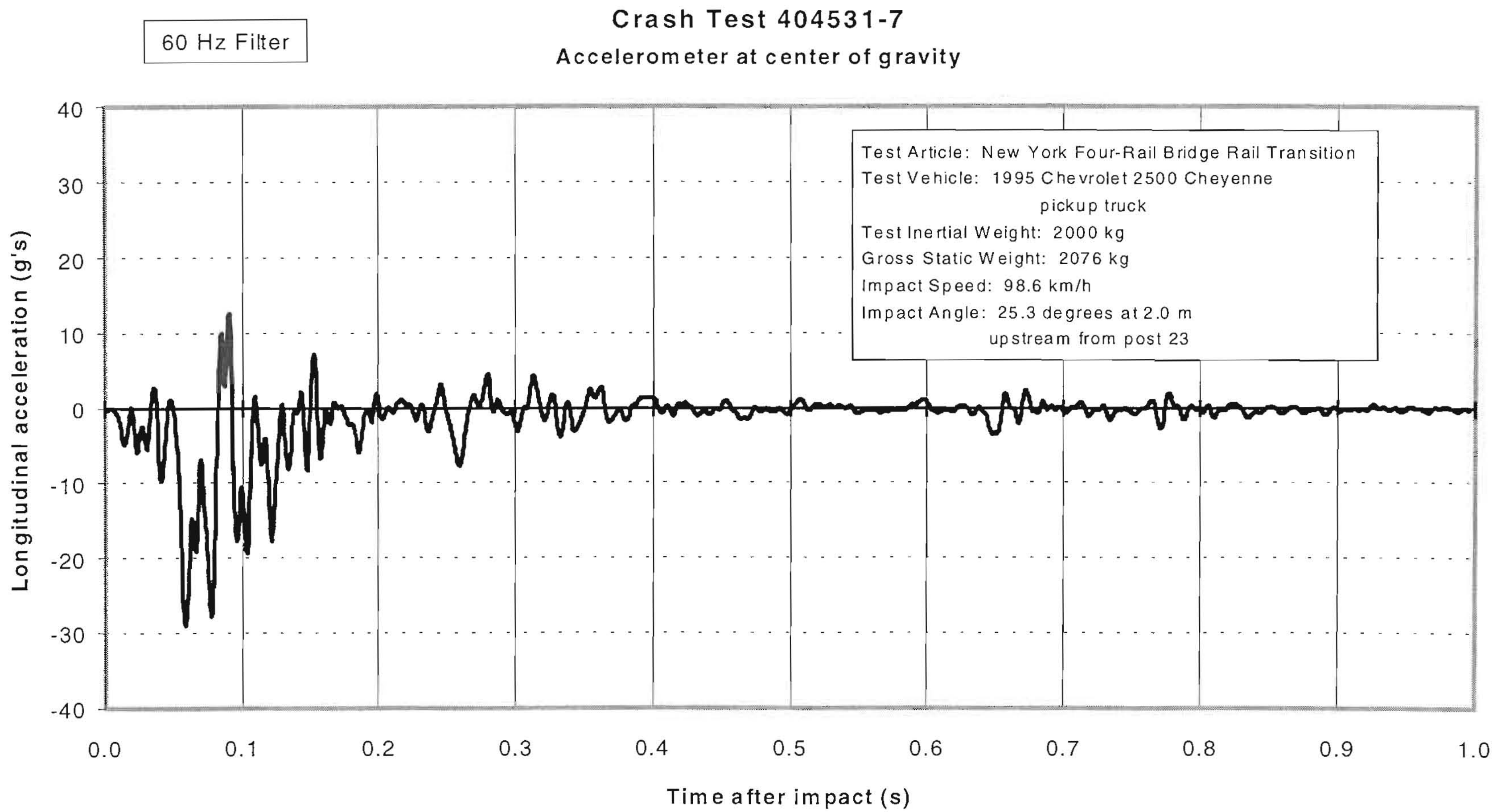


Figure 133. Vehicle longitudinal accelerometer trace for test 404531-7
(accelerometer located at center of gravity).

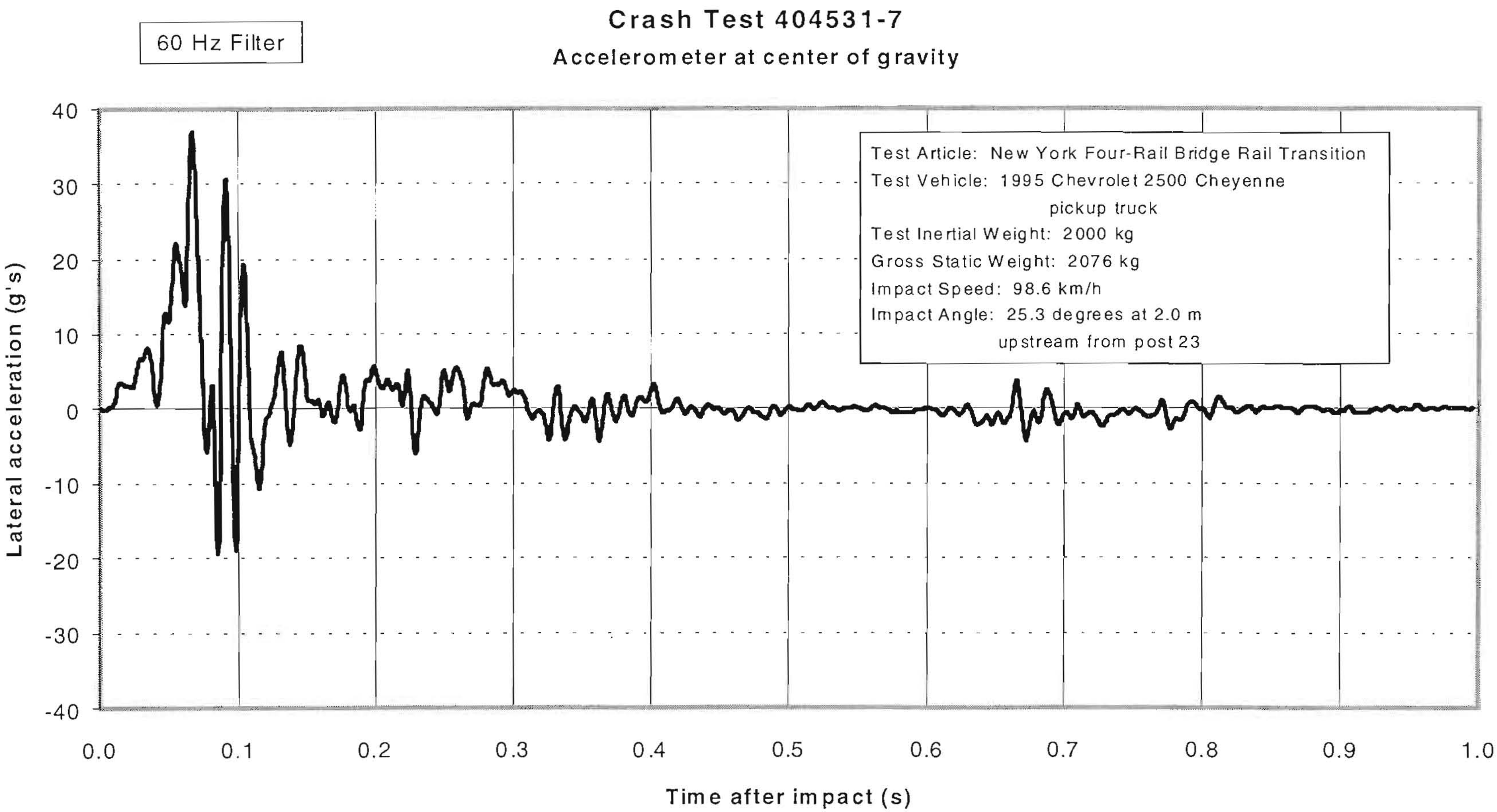


Figure 134. Vehicle lateral accelerometer trace for test 404531-7
(accelerometer located at center of gravity).

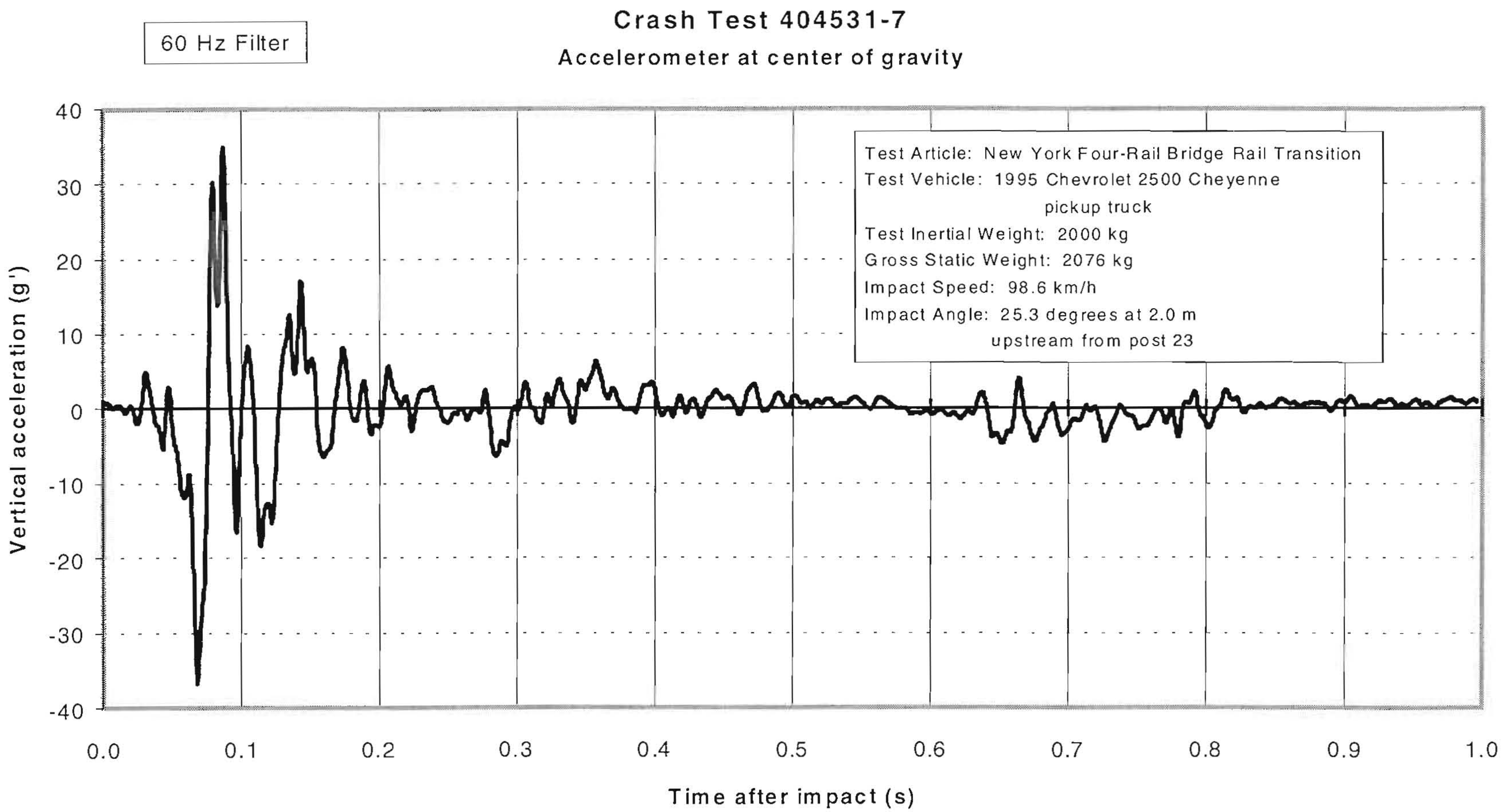


Figure 135. Vehicle vertical accelerometer trace for test 404531-7 (accelerometer located at center of gravity).

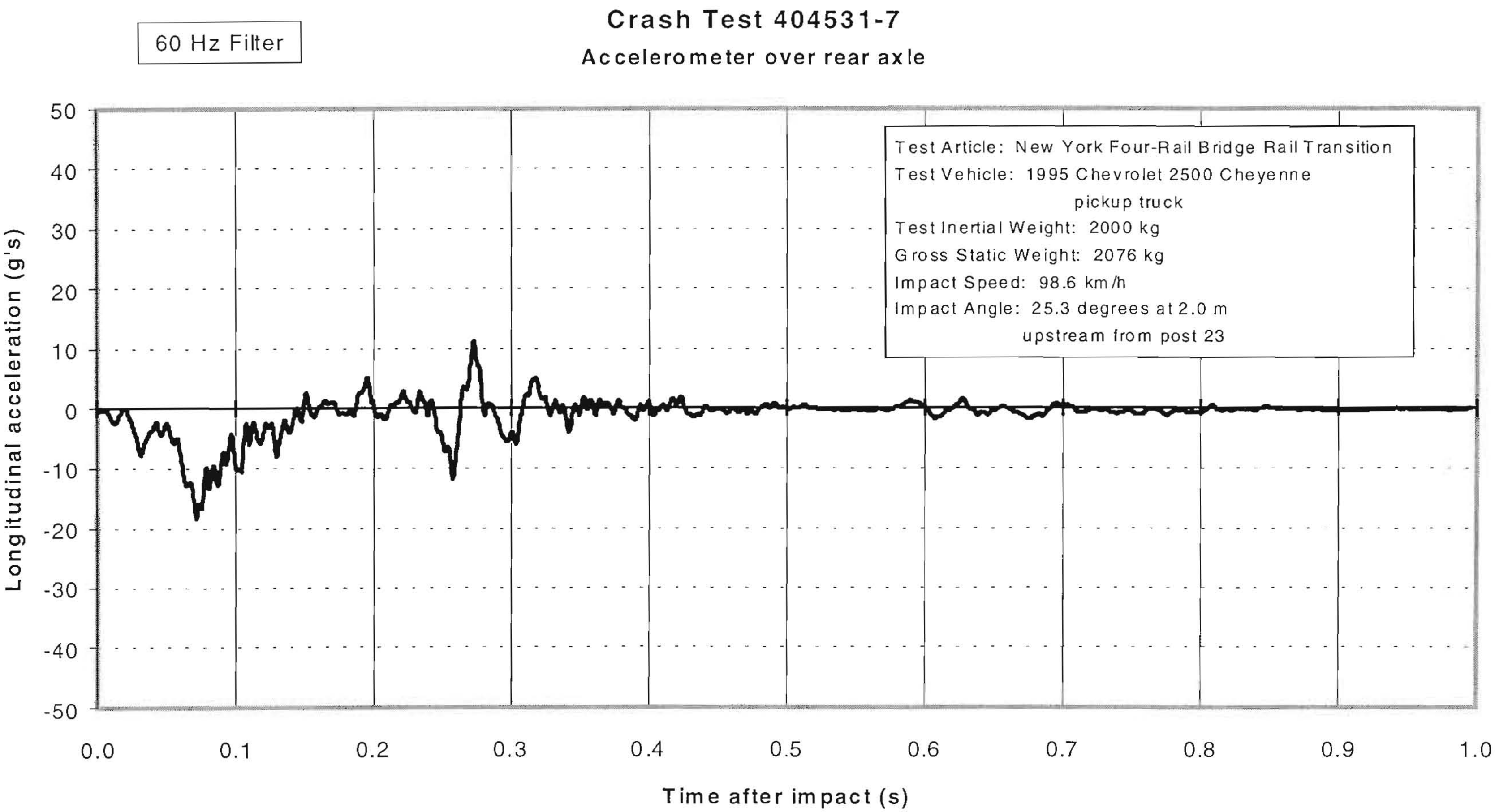


Figure 136. Vehicle longitudinal accelerometer trace for test 404531-7
(accelerometer located over rear axle).

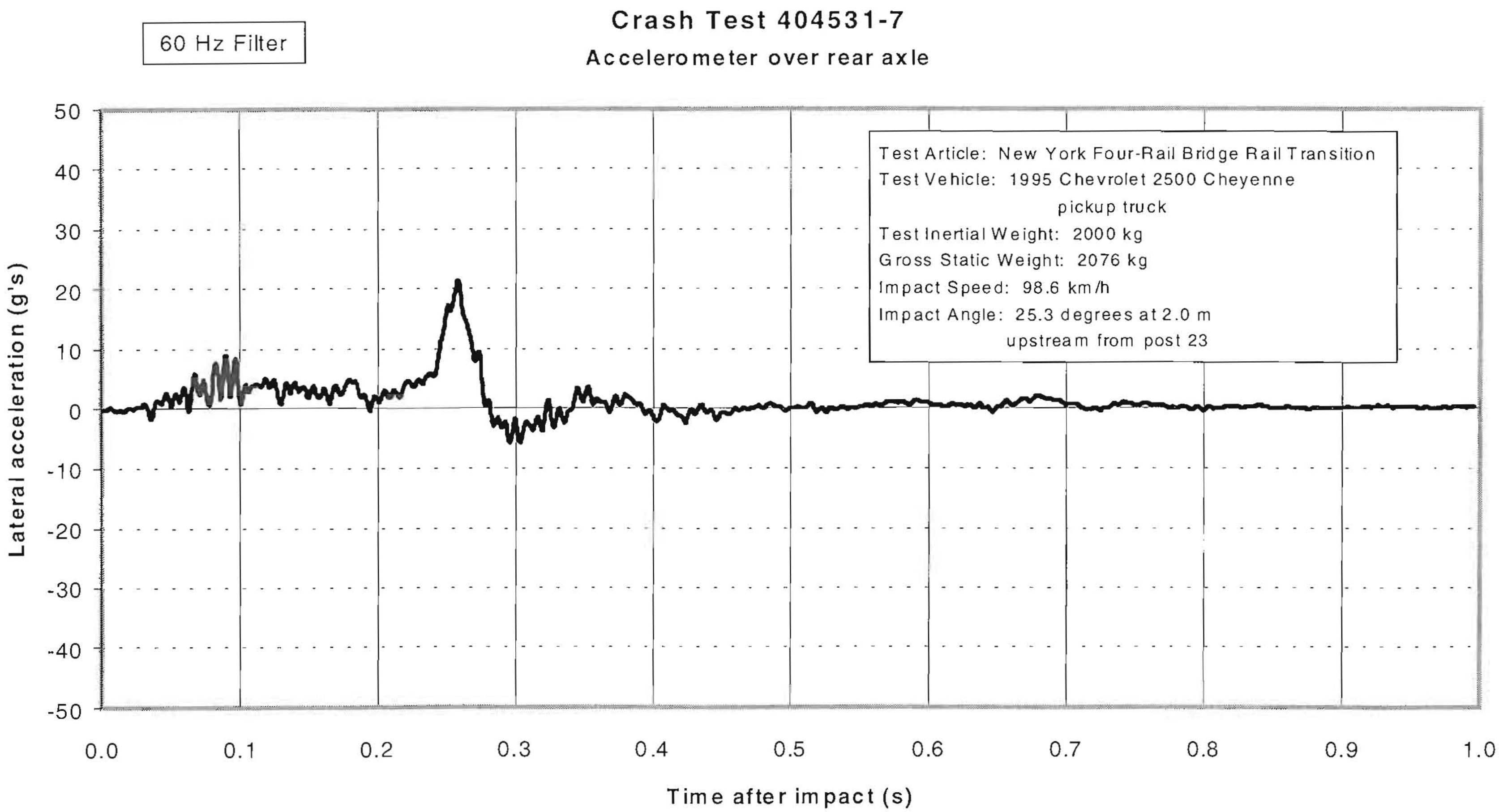


Figure 137. Vehicle lateral accelerometer trace for test 404531-7
(accelerometer located over rear axle).

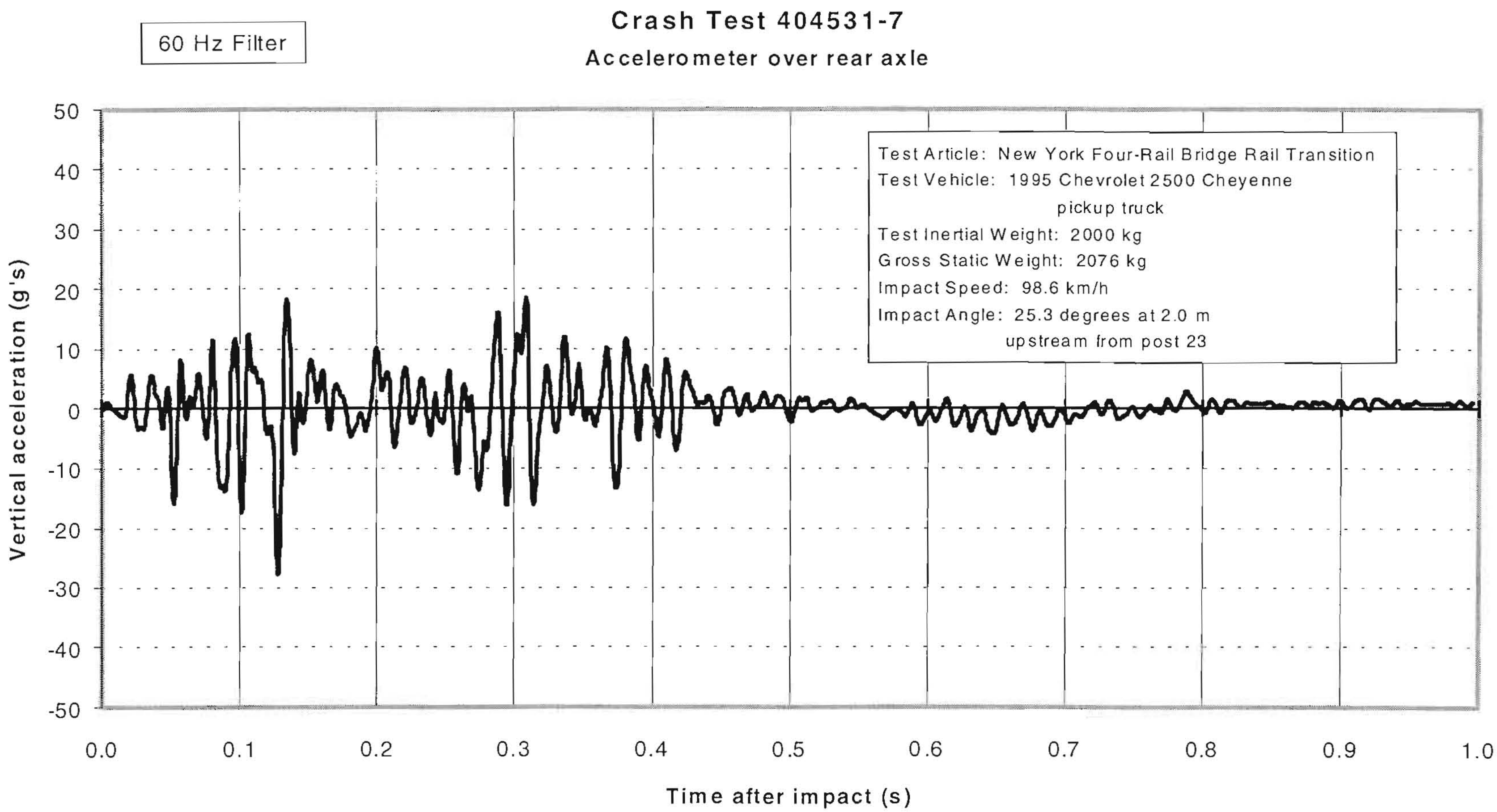


Figure 138. Vehicle vertical accelerometer trace for test 404531-7 (accelerometer located over rear axle).

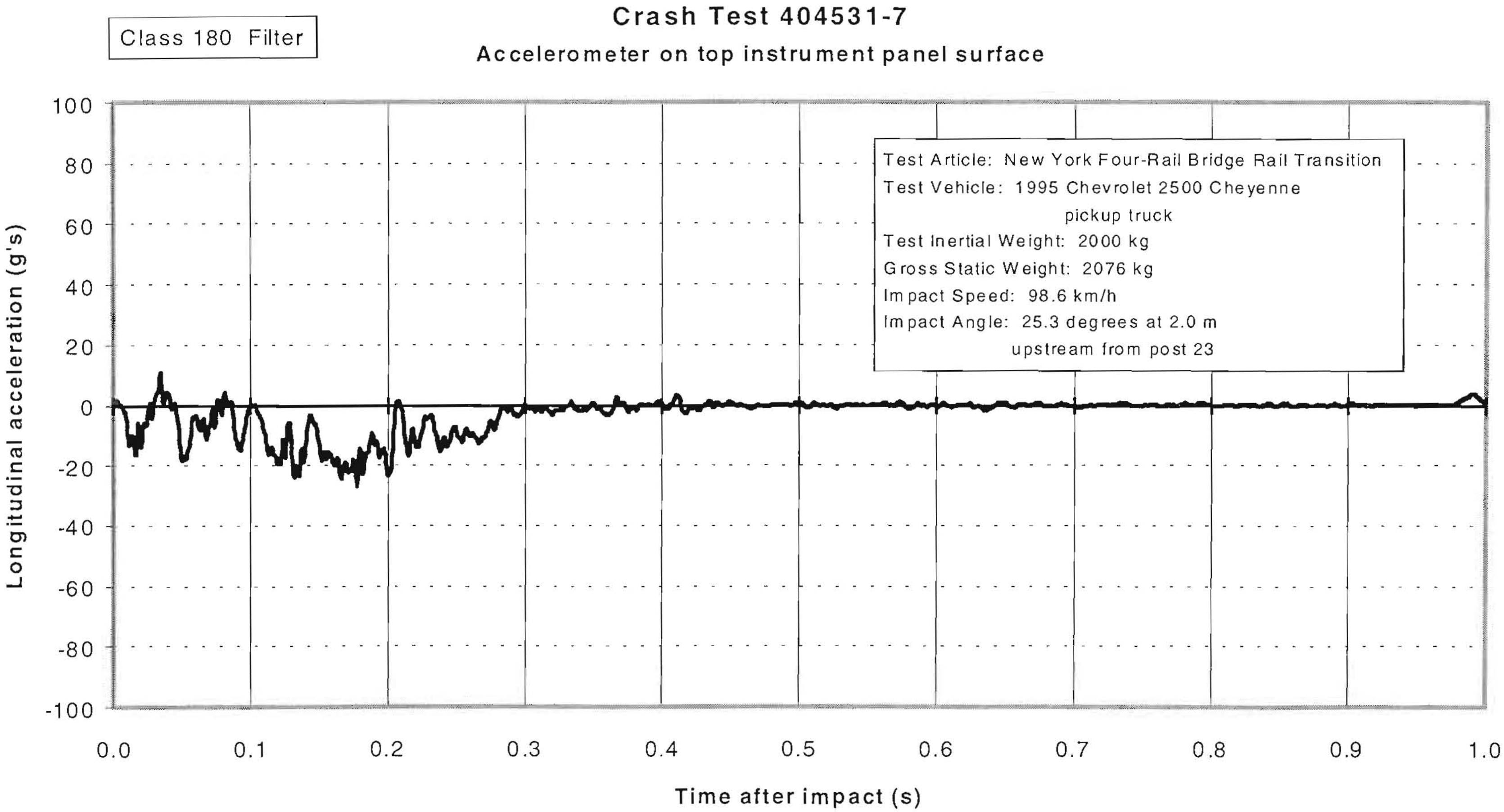


Figure 139. Vehicle longitudinal accelerometer trace for test 404531-7 (accelerometer located on top surface of instrument panel).

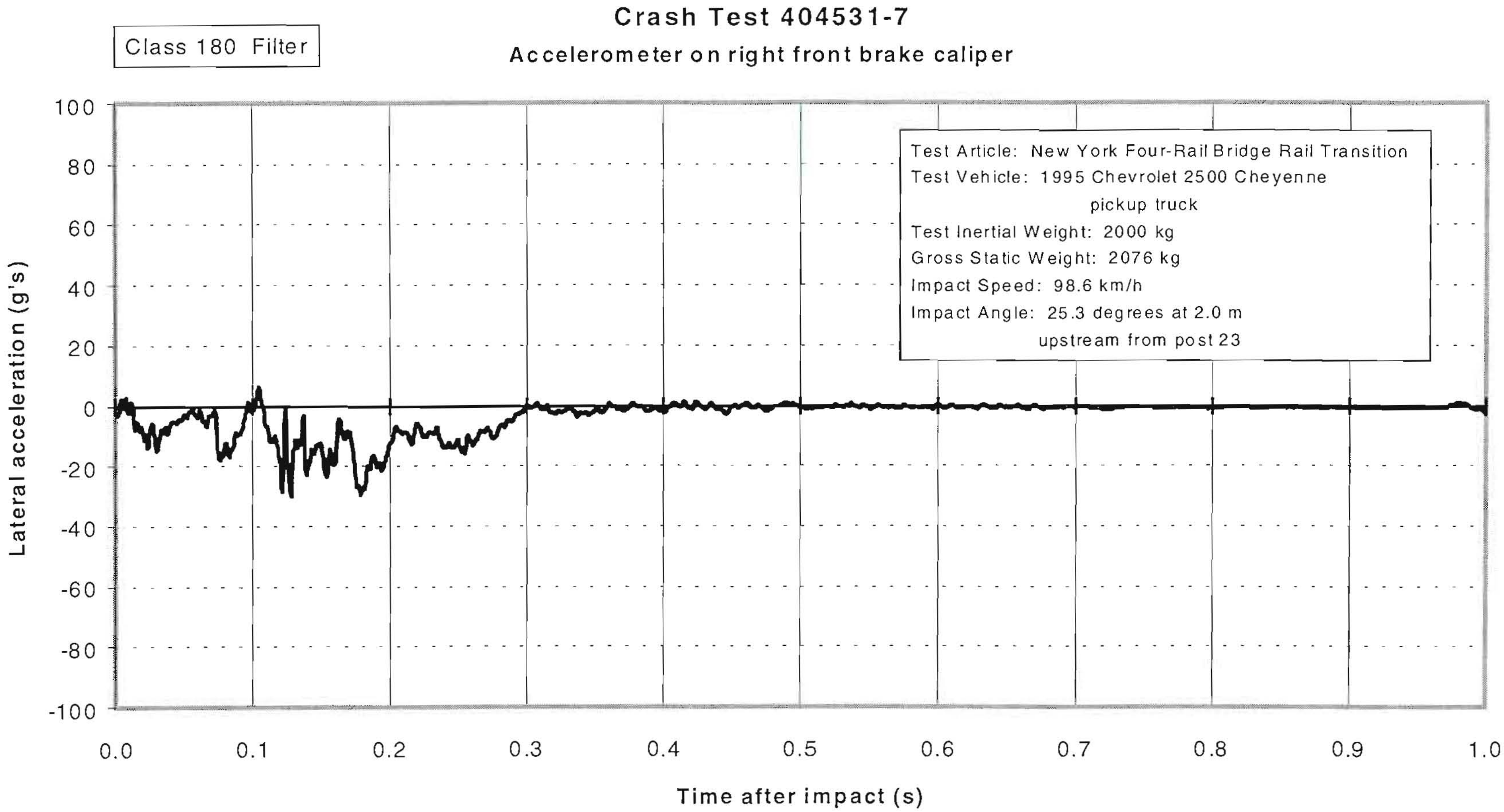


Figure 140. Vehicle lateral accelerometer trace for test 404531-7
(accelerometer located on right front brake caliper).

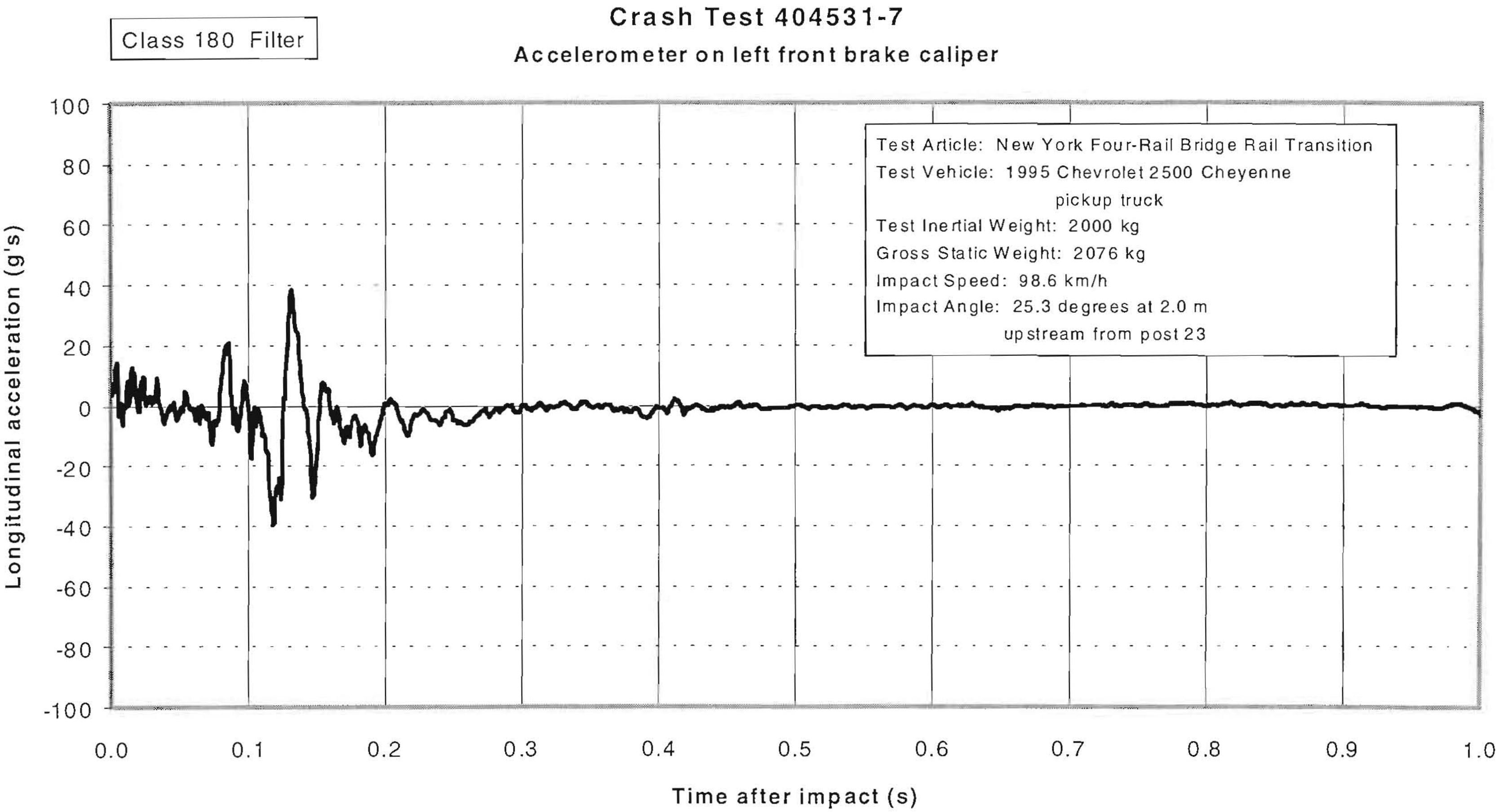


Figure 141. Vehicle longitudinal accelerometer trace for test 404531-7 (accelerometer located on left front brake caliper).

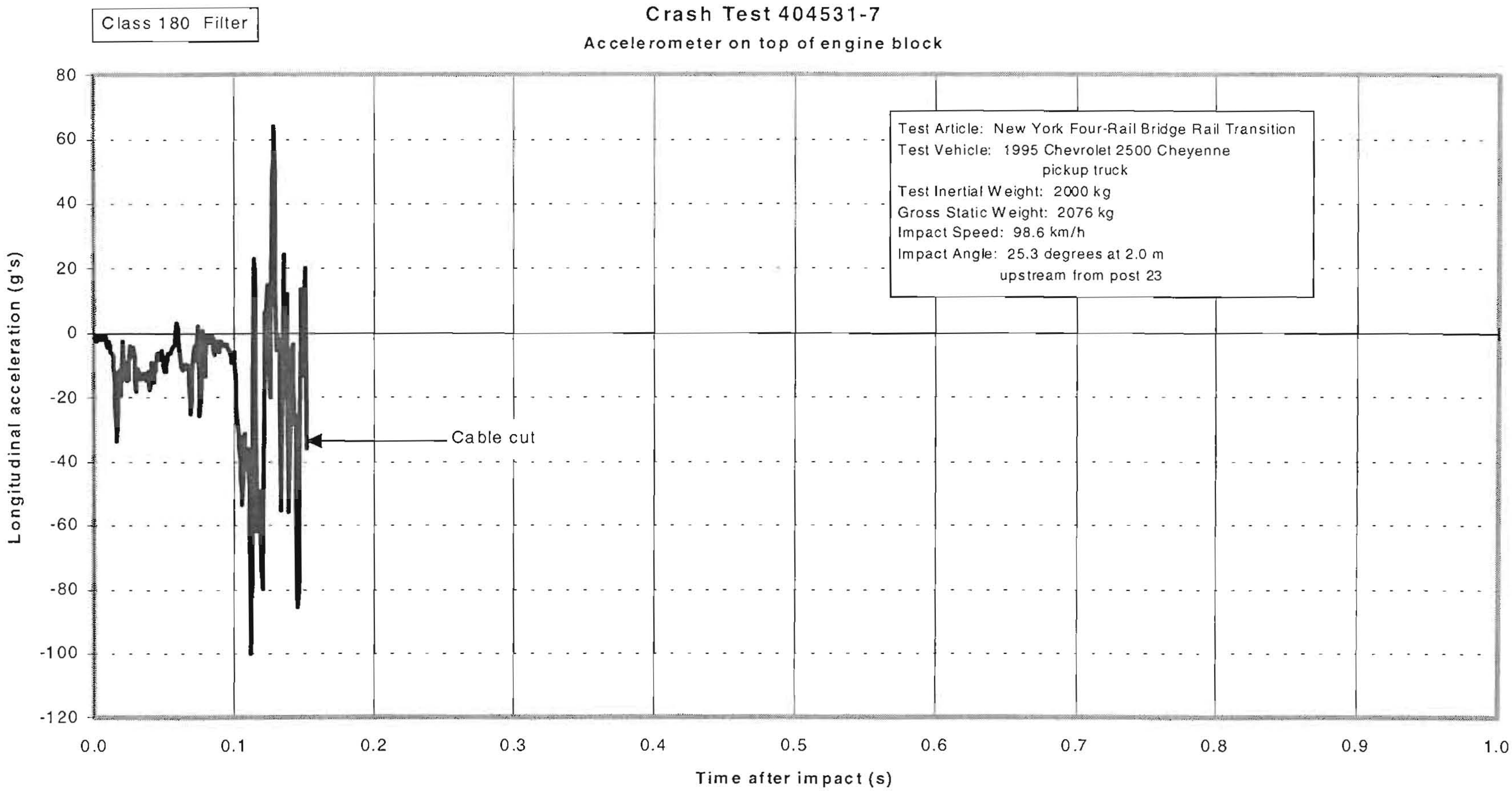


Figure 142. Vehicle longitudinal accelerometer trace for test 404531-7 (accelerometer located on top of engine block).

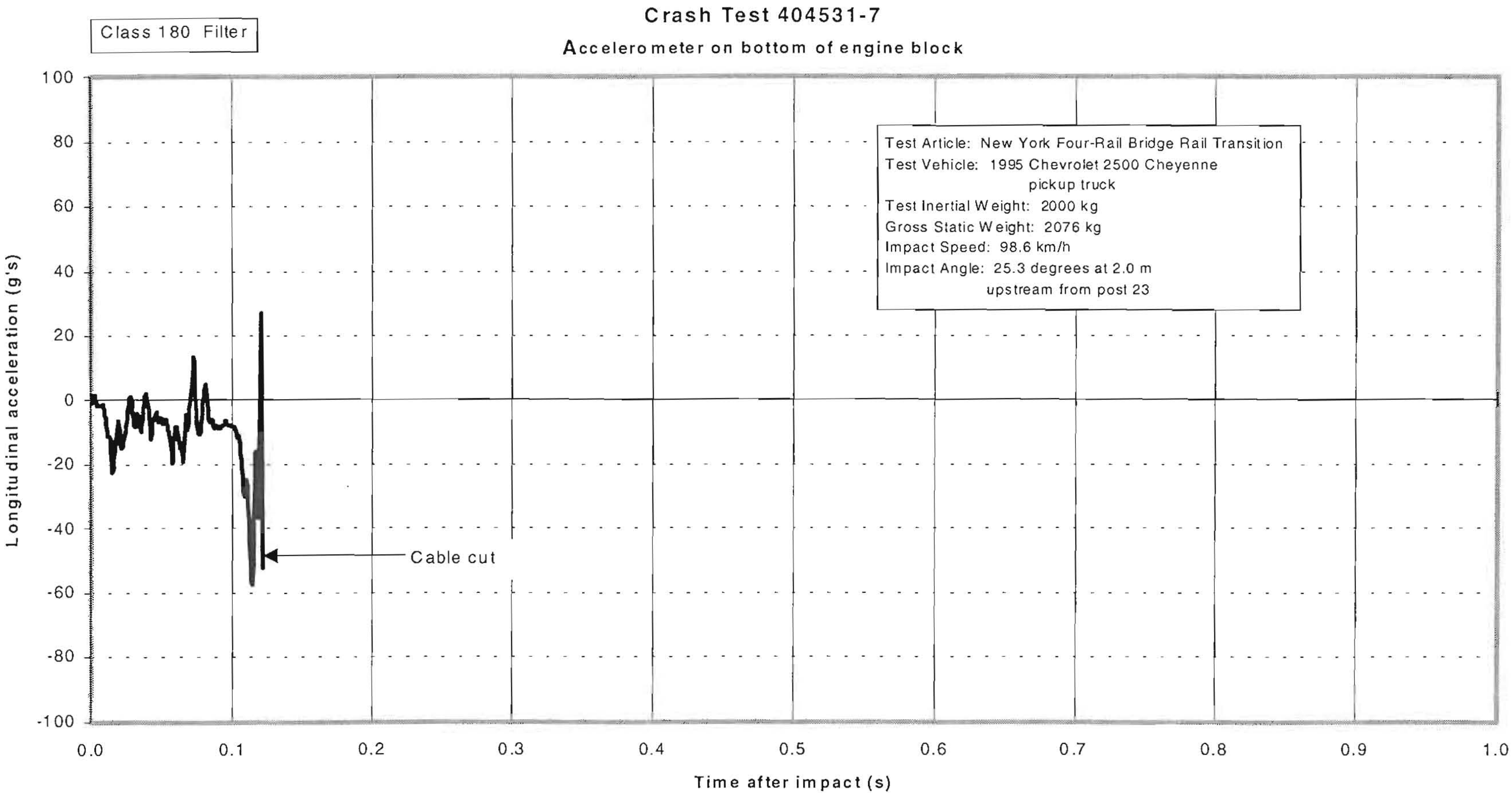


Figure 143. Vehicle longitudinal accelerometer trace for test 404531-7 (accelerometer located on bottom of engine block).

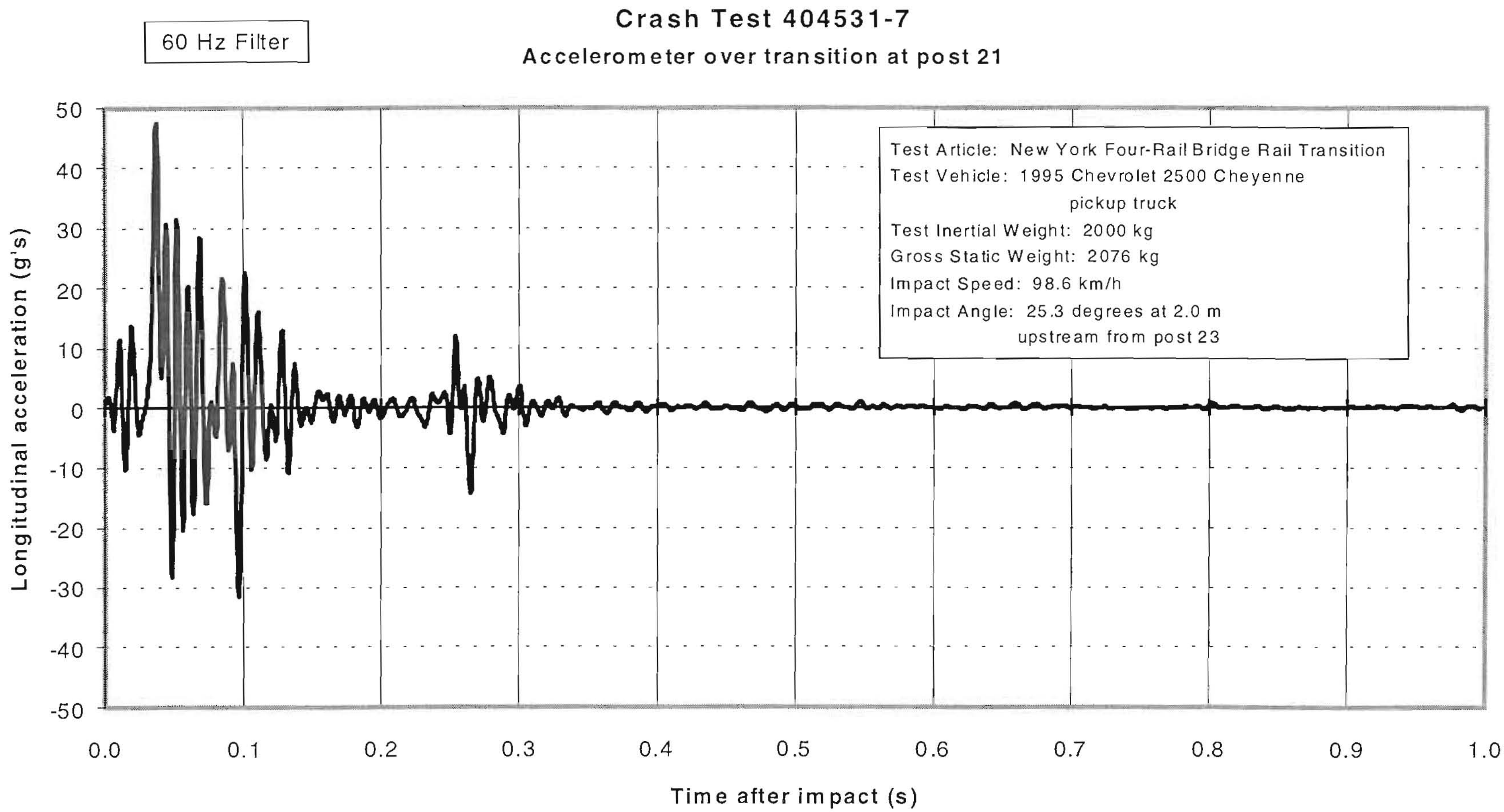


Figure 144. Transition longitudinal accelerometer trace for test 404531-7
(accelerometer located over transition at post 21).

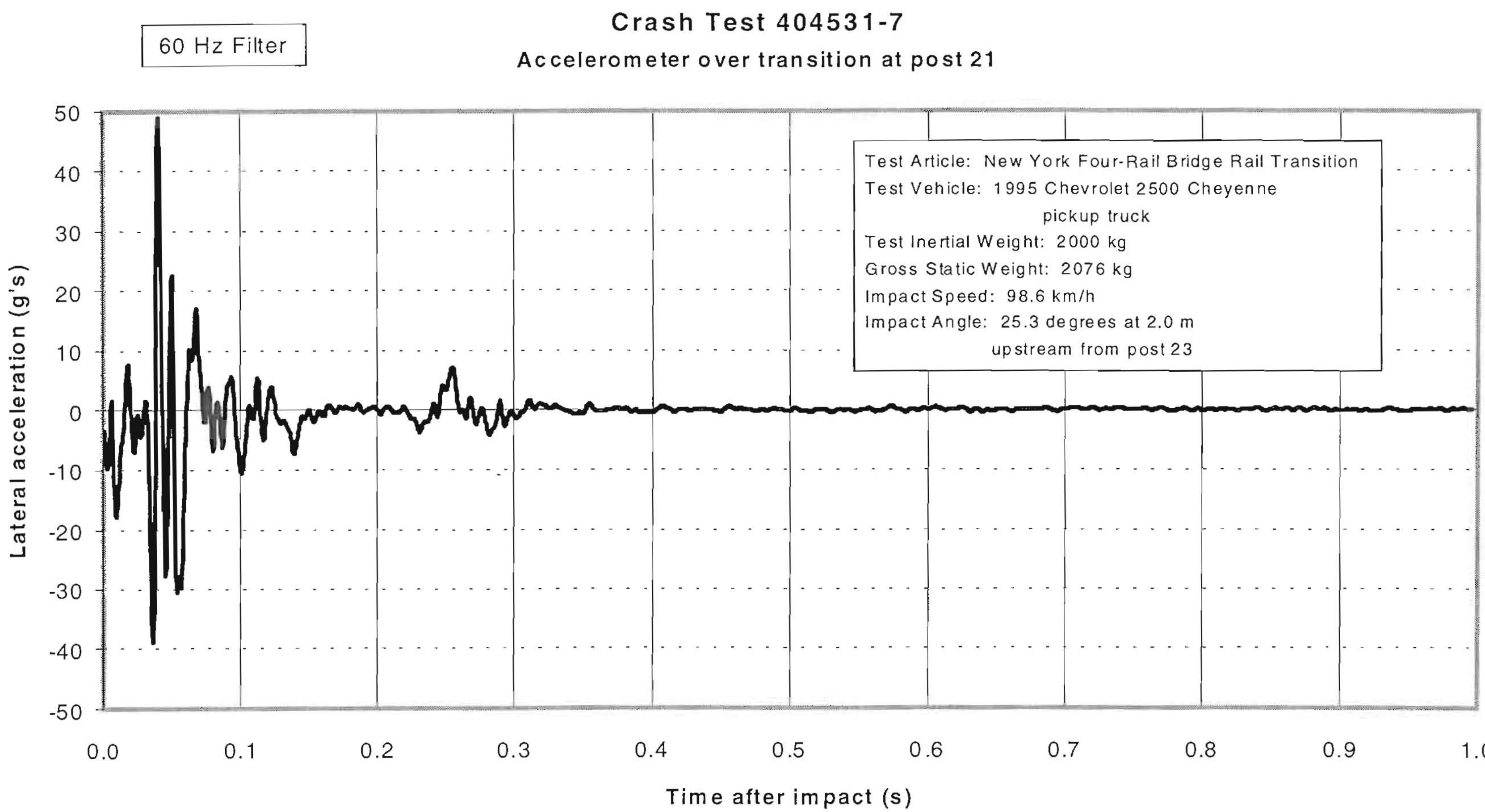


Figure 145. Transition lateral accelerometer trace for test 404531-7 (accelerometer located over transition at post 21).

APPENDIX E. COMMENTS FROM NEW YORK DOT

U.S. Department
of Transportation

Federal Highway Administration

Memorandum

Subject: Tests 4-10 & 4-11
Draft Reports

Date: February 3, 1999

From: Harold J. Brown
Division Administrator
Albany, New York

Reply to
Attn. of: HBR-NY

To: Director, Office of Safety and Traffic
Operations Research and Development
Federal Highway Administration (HSR-20)
Turner-Fairbanks Highway Research Center, Room T301
McLean, Virginia

Attn: Mr. Charlie McDevitt

Thank you for the opportunity to comment on the Texas Transportation Institute's draft reports. We provided the reports to the New York State Department of Transportation for their comments. Attached are the States comments.

We share the State's concerns for the conclusions and recommendations stated in Test 4-11's draft report. We believe additional information is important to evaluate the reduction of the overall occupant compartment space. The occupant's compartment overall volume was reduced by approximately 3%. The space under the instrument panel actually increases by 5%.

It is our understanding that the Office of Highway Safety Infrastructure has developed a draft discussion paper providing guidance on occupant compartment deformations. This paper suggests a test will be considered unacceptable if an intrusion is significantly greater than 150mm **and** at a location where serious injuries are deemed likely to result. This paper indicates an importance to the location of the deformation. The 38.8% represent a reduction in one dimension in a location where it is highly unlikely an individual's body part large enough to be trapped or crushed would ever be located.

John Formosa
Division Bridge Engineer

Attachment

MEMORANDUM
DEPARTMENT OF TRANSPORTATION

TO: J. P. Formosa, Federal Highway Administration, HBR-NY

FROM: A. P. Yannotti, Structures Division, 5-600, MC 0600

SUBJECT: **BRIDGE RAIL CRASH TEST DRAFT REPORTS**

DATE: January 4, 1999

Thank you for forwarding the draft reports and video tapes for test reports 4-10 and 4-11. There are no comments on test report 4-10. There are several comments on the conclusions and recommendations for test report 4-11 as follows:

- TTI determined that the two-rail curbless bridge rail failed the test because of Evaluation Criteria D, Occupant Risk. NYSDOT disputes this conclusion.

- Evaluation Criteria D states, "Deformations or intrusions into the occupant compartment that could cause serious injuries should not be permitted". NYSDOT believes that this criteria is vague and its evaluation is highly subjective. It should be noted that the deformation of the floor pan of the test vehicle was in the center of the passenger compartment. The test vehicle did not have a front bench seat, so there would be no passenger present in the area of the deformation. If a test vehicle with a front bench seat was used, it is likely that the test results may have been quite different because of the different rigidity imposed to the passenger compartment by a bench seat. In addition, it is highly questionable whether the maximum measured deformation of 199 mm to the floor pan would result in a serious injury.

- The statement that a 38.8 percent reduction of space occurred in the occupant compartment can be misleading. This was a reduction of a dimension not the volume of the compartment. This reduction only occurred in the area between the bottom of the instrument panel and the raised center section of the floor pan over the drive train. Because there was no bench seat in this vehicle, no passenger would be present in this area.

- The draft report stated concern that the separation of the floor panel could cause serious injury to the occupant's feet. This separation is not quantified in the report. Judging from the photographs, it appears that it is only *possible* for an occupant's foot to penetrate the opening, not *probable*. The evaluation criteria of NCHRP 350 does not directly lead to an assessment of failure. This criteria is subject to interpretation and we do not agree with TTI's interpretation of the result. It should be noted that in a previous TTI test report, 7069-21, the crash dummy's head penetrated 406 mm through the side window of the test vehicle and was not cited by TTI as a cause for failing the test. This seems inconsistent.

As you are aware, we have discontinued the use of two-rail curbless bridge railing, by the issuance of EB 98-059 on November 16, 1998. The primary reason for this decision was the unacceptable damage caused to the bridge deck by the crash test, not by our judgment that the two-rail curbless system had failed the crash test.

It is our opinion that the presence of a curb with the two-rail system or the additional lower rail of the four-rail curbless system will result in superior performance. This should be verified by the future scheduled crash tests.

We would appreciate your forwarding our comments on the draft reports to TTI. If there are any questions, I may be contacted at (518) 485-1148. Thank you for giving us the opportunity to comment.

APY:ds
8.18

cc J. M. O'Connell, Structures Division, 5-600, MC 0600
R. C. Holt, Structures Division, 5-600, MC 0600

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION ONE
NEW YORK DIVISION
LEO W. O'BRIEN FEDERAL BUILDING, NINTH FLOOR
ALBANY, NEW YORK 12207

June 21, 1999

IN REPLY REFER TO:

HU-NY

Dr. Mort S. Oskard
Federal Highway Administration (HSR-20)
Turner-Fairbanks Highway Research Center, Room T301
6300 Georgetown Pike
McLean, Virginia 22101-2296

Dear Dr. Oskard:

Thank you for the opportunity to comment on the Texas Transportation Institute's Crash reports. We provided the reports to the New York State Department of Transportation for their comments. Enclosed are the States mainly editorial comments.

We are concerned that test report 4-11, which documents a crash test of New York's four-rail curbless bridge rail, incorrectly leads to the conclusion that the vehicle came to rest within the adjacent travel lanes due to the bridge rails performance. The crash test video shows a secondary impact by the right front of the truck with the temporary barriers associated with the test equipment. Prior to the impact, the truck is moving forward and sliding laterally with respect to the truck's orientation and only upon impact with the temporary barrier is the truck prevented from leaving the adjacent traffic lanes. We believe the report could better represent the evaluation of the vehicle trajectory criteria and the secondary impact with test equipment.

We are also concerned, that test report 4-12, which documents a crash test of New York's four-rail curbless bridge rail, incorrectly leads to the conclusion that the front axle separated from the vehicle due to the bridge rails performance. The crash test video shows a secondary impact by the left front wheel of the single unit truck with an adjacent traffic barrier installation that is unrelated to New York's crash testing program. We believe that it is this severe impact with the adjacent barrier that causes the resultant snagging of the left front wheel and the front axle's separation from the vehicle. We also believe, the report could better represent the evaluation of the occupant risk criteria and the effect of secondary impact with test equipment.

Sincerely

Christopher Allen
Structural Engineer

Enclosures

cc: Art Yannotti, Structures Design & Construction Division, NYSDOT **MC 0600**

REFERENCES

1. H. E. Ross, Jr., D. L. Sicking, R. A. Zimmer and J. D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C., 1993.

2. Jarvis D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*, National Cooperative Highway Research Program Report 230, Transportation Research Board, National Research Council, Washington, D.C., March 1981.