U.S. Department of Transportation

Federal Highway Administration

Guardrail Testing Program III

Final Report

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NOTICE

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6220 Culebra Road
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15. Supplementary Notes
Federal Highway Administration Contract Manager (COTR): C. F. McDevitt (HSR-20)

16. Abstract
This report summarizes seven full-scale crash tests that were conducted on three different longitudinal barriers. The following table summarizes the test conditions.

Test No.	Vehicle Mass (kg)	Vehicle Type	Impact Velocity (Km/h)	Impact Angle (degrees)	Barrier Installation	NCHRP Report 350 Criteria
1	2,000	Pickup	40	25	Variable height stone masonry guardwall	Pass - No TL
2	820	Sedan	40	20	Variable height stone masonry guardwall	Pass - No TL
3	2,000	Pickup	70	25	Variable height stone masonry guardwall	Fail - TL2
4	2,000	Pickup	50	25	Variable height stone masonry guardwall	Pass - TL1
5	820	Sedan	50	20	Variable height stone masonry guardwall	Pass - TL1
6	2,000	Pickup	100	24.9	W-beam transition to Texas Type 101 Bridge Rail	Pass - TL3
7	2,000	Pickup	100	25	Thrie beam on wood post transition to NJ-shape parapet	Fail - TL3

17. Key Words
Highway safety, longitudinal barriers, crash tests

18. Distribution Statement
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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	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	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	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		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	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		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	psi

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

(Revised August 1992)

Table of Contents

1.0 INTRODUCTION

This project is part of the Coordinated Federal Lands Highways Technology Improvement Program (CTIP). It is intended to serve the immediate needs of those who design and construct federal lands highways, including Indian reservation roads, national park roads and parkways, and forest highways.

A wide assortment of guardrails, bridge rails, and transitions are being used on roads under the jurisdiction of the National Park Service and other federal agencies. These guardrails, bridge rails, and transitions are intended to blend in with the roadside in order to preserve the visual integrity of the parks and parkways; however, many of them have never been crash tested.[1 2] A testing program is necessary in order to ensure that the guardrails, bridge rails, and transitions being used are safe for the traveling public.

The objective of this program was to design, test, and develop aesthetic guardrails, bridge rails, and transitions for park roads and parkways and other roads under federal jurisdiction.

[1]Hancock, K.L., Hansen, A.G., and Mayer, J.B., "Aesthetic Bridge Rails, Transitions, and Terminals for Park Roads and Parkways," Federal Highway Administration Report No. FHWA-RD-90-052, June 1990.

[2]Stout, D., Hinch, J., and Sawyer, D., "Guardrail Testing Program," Draft Final Report on Contract No. DTFH71-87-C-00002, June 1990.

2.0 APPROACH

A series of full-scale crash tests was conducted in accordance with NCHRP Report 350[3] on three different longitudinal barriers. The test matrix table summarizes the results of these tests. The test reports for the different tests are included in the following appendices:

Appendix A - Crash Test Evaluation of a Variable Height Stone Masonry Guardwall

Appendix B - Crash Test Evaluation of a W-beam Transition to a Texas Type 101 Bridge Rail

Appendix C - Crash Test Evaluation of a Thrie Beam on Wood Post Transition to a New Jersey Shaped Parapet.

3.0 CONCLUSIONS

The variable height stone masonry guardwall and the W-beam transition to a Texas type 101 bridge rail meet the requirements of NCHRP Report 350 test level 1 and test level 3, respectively. The 820-kg car test (3-20) was not conducted on the type 101 transition. The masonry guardwall failed the Report 350 test level 2 test (2-21). The thrie beam on wood post transition to a New Jersey shaped parapet does not meet the requirements of NCHRP Report 350.

[3]Ross, H.E., Jr., Sicking, D.L., Zimmer, R.A., and Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," NCHRP Report 350, Washington, D.C., 1993.

Test Matrix

Test No.	Vehicle Mass (kg)	Vehicle Type	Impact Velocity (km/h)	Impact Angle (degrees)	Barrier Installation	NCHRP 350 Criteria
1	2,000	Pickup	40	25	Variable height stone masonry guardwall	Pass (a)
2	820	Sedan	40	20	Variable height stone masonry guardwall	Pass (a)
3	2,000	Pickup	70	25	Variable height stone masonry guardwall	Fail (b)
4	2,000	Pickup	50	25	Variable height stone masonry guardwall	Pass (c)
5	820	Sedan	50	20	Variable height stone masonry guardwall	Pass (c)
6	2,000	Pickup	100	24.9	W-beam transition to Texas type 101 bridge rail	Pass (d)
7	2,000	Pickup	100	25	Thrie beam on wood post transition to NJ shaped parapet	Fail (d)

(a) There is no Test Level in Report 350 that specifies a 40 km/h speed.

(b) Report 350 Test Level 2

(c) Report 350 Test Level 1

(d) Report 350 Test Level 3

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Test Report
May 1994 - April 1996

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15. Supplementary Notes
Federal Highway Administration Contract Manager (COTR): C. F. McDevitt (HSR-20)

16. Abstract
This report summarizes five full-scale crash tests that were conducted on a variable height stone masonry guardwall. The following table summarizes the test conditions.

Test No.	Vehicle Mass (kg)	Vehicle Type	Impact Velocity (km/h)	Impact Angle (degrees)	NCHRP Report 350 Criteria
1	2,000	Pickup	40	25	**Pass**
2	820	Sedan	40	20	**Pass**
3	2,000	Pickup	70	25	**Fail**
4	2,000	Pickup	50	25	**Pass**
5	820	Sedan	50	20	**Pass**

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gal	gallons	3.785	liters	l
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NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
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T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
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fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
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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
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g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
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°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
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lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
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1.0 INTRODUCTION

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The objective of this program is to design, test, and develop aesthetic guardrails, bridge rails, and transitions for park roads and parkways and other roads under federal jurisdiction. Figures and tables follow the text. The test matrix is shown in Table 1.

The following sections of this report will describe the:

- Test installations
- Test vehicles
- Tests
- Barrier damage
- Vehicle damage
- Recommendations and conclusions of the project.

This report describes full-scale crash test evaluation of a variable height stone masonry guardwall according to procedures of NCHRP Report 350.[3] The test numbers are 1-11 and 2-11 from NCHRP Report 350.

2.0 TEST FACILITY

These tests were performed on the east inactive runway at Brooks Air Force Base, San Antonio, TX.

3.0 TEST INSTALLATION CONSTRUCTION

Modified variable height stone masonry guardwalls are used by the National Park Service in national parks in the Western United States. These guardwalls are commonly used on national park roads that have

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[1]Hancock, K.L., Hansen, A.G., and Mayer, J.B., "Aesthetic Bridge Rails, Transitions, and Terminals for Park Roads and Parkways," Federal Highway Administration Report No. FHWA-RD-90-052, June 1990.

[2]Stout, D., Hinch, J., and Sawyer, D., "Guardrail Testing Program," Draft Final Report on Contract No. DTFH71-87-C-00002, June 1990.

[3]Ross, H.E., Jr., Sicking, D.L., Zimmer, R.A., and Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," NCHRP Report 350, Washington, D.C., 1993.

lower posted speed limits and/or limits on sizes of vehicles that use the roads. These longitudinal barriers are 0.46 m wide and are composed of two sections of different heights. One section is 0.46 m tall by 3.66 m long, and the other section is 0.61 m tall by 1.68 m long. The sections are staggered, such that there is a 0.61-m-tall section and then a 0.46-m-tall section and then another 0.61-m-tall section. This alternating height pattern continues for the length of the installation. The guardwall consists of a reinforced concrete footing and a reinforced concrete core. Rock that is indigenous to the park is placed on the sides and top of the concrete core. The majority of the rock is 0.30 m to 0.46 m in diameter, with smaller rocks and masonry mortar used to complete the assembly of the guardwall.

Details of the modified variable height stone masonry guardwall are shown in Figure 1. A section of the guardwall measuring 30.48 m in length was constructed in accordance with specifications contained in "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-92."[4] Construction of the stone guardwall was carried out under the supervision of National Park Service personnel and consisted of the steps listed below. All of the rock used in the construction of the rock wall was furnished by the Government from Glacier National Park. Dovetails were used to assist in bonding the masonry grout to the concrete core. The dovetails were 0.13 m long by 1.5 mm thick. Graphs of the concrete strength and masonry strength are shown in Figures 2 and 3, respectively. The results of the sieve analysis for the masonry mortar sand are shown in Figure 4. There were no unusual problems encountered during the construction of this test installation.

The rock wall was constructed as follows:

- The concrete for the footing was placed.
- The rock walls were constructed up to a height of 0.30 m.
- The concrete for the core was placed.
- The rest of the rock sides and cap were placed.

4.0 TEST VEHICLE AND DUMMY

The vehicles used in these tests are listed in Table 2. An uninstrumented dummy was seated in the driver's seat of the test vehicles. The shoulder-and-lap seatbelt was in place around the dummy.

4.1 Test Vehicle Guidance

The test vehicle was guided to the impact point by use of a 6.4-mm-diameter steel cable, 101 m long, that was pretensioned alongside of the run-up strip where it would not interfere with post-impact vehicle trajectory. A guide tube that slides along the cable was attached to the front wheel to provide guidance to the car. Just prior to impact, the guide bracket was sheared off.

Braking of the test vehicle was accomplished by use of an air cylinder attached to

[4]"Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-92," Federal Highway Administration, Washington, D.C., 1992.

the brake pedal of the vehicle. Activation of the cylinder was achieved by remote activation of a gas-charged accumulator controlled by a solenoid valve.

Vehicle test speed control was achieved by means of an automatic controller attached to the engine distributor of the tow vehicle. After the vehicle accelerated to the predetermined test speed, the controller pulsed the ignition and maintained the vehicle at a constant velocity. The test vehicle was towed to the impact area using the reverse-tow method.

4.2 Vehicle Data Acquisition

The vehicle accelerometers were mounted near the vehicle center of gravity. These accelerometers were oriented to obtain data in directions parallel to the longitudinal, lateral, and vertical axes of the vehicle. A rate gyro was mounted near the accelerometers to measure the rate of yaw angular change the vehicle experiences during impact. The transducer data were recorded by a Pacific Instruments Model 5600 Data Acquisition System (DAS). The DAS contains up to 32 channels of signal conditioners, amplifiers, and appropriate SAEJ211 filters and digitizers with onboard memory for each channel. It conditions, amplifies, digitizes, and records transducer signals at programmable sample rates to 100 kHz per channel. Digitized data were recorded in solid state nonvolatile memory with a capacity of 65,000 data points per channel. Four channels were used on this test to measure X, Y, Z accelerations and the rate gyro. Camera coverage for this test consisted of an onboard camera, an overhead camera, and four other high-speed cameras.

4.3 Data Processing

Transducer data were downloaded to a personal computer after the test. The data were processed through an Institute-developed computer program, which provides output in either tabular or graphical form. Typical output of the program, which is developed from accelerometer and load cell data, includes vehicle accelerations, velocities, and displacements instantaneous with time. The 50-ms average accelerations are calculated, and times over which they occur are displayed. The vehicle heading angle was computed from data taken by the rate gyro.

5.0 SOIL CONDITIONS FOR THE MODIFIED VARIABLE HEIGHT STONE GUARDWALL

The footing for the stone guardwall was cast-in-place. The in-situ soil was a sandy loam. A 0.1-m-thick reinforced concrete approach slab was cast against the impact side of the guardwall. The soil was in a saturated, surface dry condition with a minimal moisture content for each of the tests.

6.0 TEST RW-1

The barrier installation and test vehicle before the test are shown in Figure 5. Actual impact conditions were 40.2 km/h and a 25-degree impact angle. Ambient temperature at test time was 35 degrees C. As shown in Figure 6, the 2,039-kg pickup impacted the barrier at the beginning of the 0.64-m-tall section. The vehicle was smoothly redirected and rolled to a stop. Figure 7 shows the redirection sequence of the vehicle during impact. Maximum 50-ms average accelerations of -3.75 g's longitudinal and 4.10 g's lateral were measured from onboard transducer data. Test conditions and results are summarized in Figure 8. Figure 9 contains plots of the transducer data. Barrier and vehicle damage are shown in Figure 10.

6.1 Barrier Damage

Damage to the barrier consisted of minor scuffing of the rock wall.

6.2 Vehicle Damage

The test vehicle sustained damage to the left front tire.

6.3 Assessment of Test Results

A comparison of the test data shown in Table 3 with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 1-11.

6.4 Conclusions

A comparison of the test data with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 1-11. In conclusion, the variable height stone masonry guardwall meets all the requirements for a longitudinal barrier.

7.0 TEST RW-2

The barrier installation and test vehicle before the test are shown in Figure 11. Actual impact conditions were 40.2 km/h and a 20-degree impact angle. Ambient temperature at test time was 35 degrees C. As shown in Figure 12, the 915-kg car impacted the barrier at the beginning of the 0.46-m-tall section. Figure 13 shows the redirection sequence of the vehicle during impact. Maximum 50-ms average accelerations of -7.05 g's longitudinal and 4.33 g's lateral were measured from onboard transducer data. Test conditions and results are summarized in Figure 14. Figure 15 contains plots of the transducer data. Barrier and vehicle damage are shown in Figure 16.

7.1 Barrier Damage

Damage to the barrier consisted of scuffing of the rock wall.

7.2 Vehicle Damage

The test vehicle sustained damage to the left side of the front bumper, which was deformed rearward.

7.3 Assessment of Test Results

A comparison of the test data shown in Table 4 with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 1-11.

7.4 Conclusions

A comparison of the test data with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 1-11. In conclusion, the variable height stone guardwall meets the requirements for a longitudinal barrier.

8.0 TEST RW-3

The barrier installation and test vehicle before the test are shown in Figure 17. Actual impact conditions were 70 km/h and a 25-degree impact angle. Ambient temperature at test time was 35 degrees C. As shown in Figure 18, the 2,039-kg pickup impacted the barrier at the beginning of the 0.46-m-tall section. The vehicle vaulted over the wall and rolled to a stop. Figure 19 shows the redirection sequence of the vehicle during impact. Maximum 50-ms average accelerations of -5.38 g's longitudinal and 4.33 g's lateral were measured from onboard transducer data. Test conditions and results are summarized in Figure 20. Figure 21 contains plots of the transducer data. Barrier and vehicle damage are shown in Figure 22.

8.1 Barrier Damage

Damage to the barrier consisted of minor scuffing of the rock wall.

8.2 Vehicle Damage

The test vehicle sustained damage to all four tires, the drive shaft, and the frame.

8.3 Assessment of Test Results

A comparison of the test data shown in Table 5 with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates noncompliance with the requirements of test 2-11.

8.4 Conclusions

A comparison of the test data with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates noncompliance with the requirements of test 2-11.

9.0 TEST RW-4

The barrier installation and test vehicle before the test are shown in Figure 23. Actual impact conditions were 60.2 km/h and a 25-degree impact angle. Ambient temperature at test time was 35 degrees C. As shown in Figure 24, the 2,039-kg pickup impacted the barrier at the beginning of the 0.46-m-tall section. The vehicle vaulted over the wall and rolled to a stop. Figure 25 shows the redirection sequence of the vehicle during impact. Maximum 50-ms average accelerations of -3.27 g's longitudinal and 3.49 g's lateral were measured from onboard transducer data. Test conditions and results are summarized in Figure 26. Figure 27 contains plots of the transducer data. Barrier and vehicle damage are shown in Figure 28.

9.1 Barrier Damage

Damage to the barrier consisted of minor scuffing of the rock wall.

9.2 Vehicle Damage

The test vehicle sustained damage to the left front fender, door, and headlight/grill area. The left side of the front bumper was deformed rearward.

9.3 Assessment of Test Results

A comparison of the test data shown in Table 6 with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 1-11.

9.4 Conclusions

A comparison of the test data with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 1-11. In conclusion, the variable height stone guardwall meets the requirements for a longitudinal barrier.

10.0 TEST RW-5

The barrier installation and test vehicle before the test are shown in Figure 29. Actual impact conditions were 60.2 km/h and a 25-degree impact angle. Ambient temperature at test time was 35 degrees C. As shown in Figure 30, the 915-kg car impacted the barrier at the beginning of the 0.64-m-tall section. The vehicle vaulted over the wall and rolled to a stop. Figure 31 shows the redirection sequence of the vehicle during impact. Maximum 50-ms average accelerations of -6.42 g's longitudinal and 4.56 g's lateral were measured from onboard transducer data. Test conditions and results are summarized in Figure 32. Figure 33 contains plots of the transducer data. Barrier and vehicle damage are shown in Figure 34.

10.1 Barrier Damage

Damage to the barrier consisted of minor scuffing of the rock wall.

10.2 Vehicle Damage

The test vehicle sustained damage to the left front fender, door, and headlight/grill area. The left side of the front bumper was deformed rearward.

10.3 Assessment of Test Results

A comparison of the test data shown in Table 7 with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 1-11.

10.4 Conclusions

A comparison of the test data with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 1-11. In conclusion, the variable height stone guardwall meets all of the requirements for a longitudinal barrier.

Table 1. Test Matrix

Test No.	Vehicle Mass (kg)	Vehicle Type	Impact Velocity (km/h)	Impact Angle (degrees)	NCHRP Report 350 Criteria
RW-1	2,000	Pickup	40	25	**PASS**
RW-2	820	Sedan	40	20	**PASS**
RW-3	2,000	Pickup	70	25	**FAIL**
RW-4	2,000	Pickup	50	25	**PASS**
RW-5	820	Sedan	50	20	**PASS**

Table 2. Test Vehicle Summary

Test Number	Vehicle			Mass (kg)			
	Make	Model	Year	Curb	Test Inertial	Dummy	Gross Static
RW-1	Ford	F250 Pickup	1989	2,050	1,965	75	2,039
RW-2	Ford	Festiva Sedan	1989	845	840	75	915
RW-3	Chevrolet	C2500 Pickup	1989	2,050	1,965	75	2,039
RW-4	Ford	F250 Pickup	1989	2,050	1,965	75	2,039
RW-5	Ford	Festiva Sedan	1989	845	840	75	915

Table 3. Test Assessment Summary - Test RW-1

Designation	Factor	Description			Test Results	Assessment
A	Structural Adequacy	Test article shall 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.			Vehicle contained and smoothly redirected.	PASS
D	Occupant Risk	Detached elements, fragments, or other debris from the test article shall 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 shall not be permitted.			Test article and its elements did not penetrate the occupant compartment.	PASS
F	Occupant Risk	The vehicle shall remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.			Vehicle remained upright during and after the collision.	PASS
H	Occupant Risk	Occupant impact velocities shall satisfy the following: Occupant Impact Velocity Limits (m/s)			Impact Velocity (m/s)	
	(Not Required)	**Component**	**Preferred**	**Maximum**		
		Longitudinal	9	12	0.58	PASS
		Lateral	9	12	1.15	PASS
I	Occupant Risk	Occupant ridedown accelerations shall satisfy the following: Occupant Ridedown Acceleration Limits (g's)			Ridedown Acceleration (g's)	
	(Not Required)	**Component**	**Preferred**	**Maximum**		
		Longitudinal	15	20	0.02	PASS
		Lateral	15	20	1.25	PASS
K	Vehicle Trajectory	After collision, it is preferable that the vehicle trajectory not intrude into adjacent traffic lanes.			Vehicle did not intrude into adjacent traffic lanes.	PASS
L	Vehicle Trajectory	The occupant impact velocity in the longitudinal direction and the occupant ridedown acceleration in the longitudinal direction shall satisfy the following:				
		Longitudinal Criteria		**Maximum**	**Test Result**	
		Occupant Impact Velocity (m/s)		12	0.58	PASS
		Occupant Ridedown Acceleration (g's)		20	0.02	PASS
M	Vehicle Trajectory	The exit angle from the test article preferably shall be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.			0	PASS

Table 4. Test Assessment Summary - Test RW-2

Designation	Factor	Description			Test Results	Assessment
A	Structural Adequacy	Test article shall 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.			Vehicle contained and smoothly redirected.	PASS
D	Occupant Risk	Detached elements, fragments, or other debris from the test article shall 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 shall not be permitted.			Test article and its elements did not penetrate the occupant compartment.	PASS
F	Occupant Risk	The vehicle shall remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.			Vehicle remained upright during and after the collision.	PASS
H	Occupant Risk	Occupant impact velocities shall satisfy the following: Occupant Impact Velocity Limits (m/s)			Impact Velocity (m/s)	
		Component	**Preferred**	**Maximum**		
		Longitudinal	9	12	1.75	PASS
		Lateral	9	12	0.83	PASS
I	Occupant Risk	Occupant ridedown accelerations shall satisfy the following: Occupant Ridedown Acceleration Limits (g's)			Ridedown Acceleration (g's)	
		Component	**Preferred**	**Maximum**		
		Longitudinal	15	20	-0.37	PASS
		Lateral	15	20	-	PASS
K	Vehicle Trajectory	After collision, it is preferable that the vehicle trajectory not intrude into adjacent traffic lanes.			Vehicle did not intrude into adjacent traffic lanes.	PASS
L	Vehicle Trajectory	The occupant impact velocity in the longitudinal direction and the occupant ridedown acceleration in the longitudinal direction shall satisfy the following:				
		Longitudinal Criteria		**Maximum**	**Test Result**	
	(Not Required)	Occupant Impact Velocity (m/s)		12	1.75	PASS
		Occupant Ridedown Acceleration (g's)		20	-0.37	PASS
M	Vehicle Trajectory	The exit angle from the test article preferably shall be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.			Vehicle exit angle less than 60 percent of impact angle.	PASS

Table 5. Test Assessment Summary - Test RW-3

Designation	Factor	Description			Test Results	Assessment
A	Structural Adequacy	Test article shall 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.			Vehicle vaulted over the barrier.	**FAIL**
D	Occupant Risk	Detached elements, fragments, or other debris from the test article shall 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 shall not be permitted.			Test article and its elements did not penetrate the occupant compartment.	**PASS**
F	Occupant Risk	The vehicle shall remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.			Vehicle remained upright during and after the collision.	**PASS**
H	Occupant Risk	Occupant impact velocities shall satisfy the following: Occupant Impact Velocity Limits (m/s)			Impact Velocity (m/s)	
	(Not Required)	**Component**	**Preferred**	**Maximum**		
		Longitudinal	9	12	1.75	**PASS**
		Lateral	9	12	0.78	**PASS**
I	Occupant Risk	Occupant ridedown accelerations shall satisfy the following: Occupant Ridedown Acceleration Limits (g's)			Ridedown Acceleration (g's)	
	(Not Required)	**Component**	**Preferred**	**Maximum**		
		Longitudinal	15	20	-5.06	**PASS**
		Lateral	15	20	6.84	**PASS**
K	Vehicle Trajectory	After collision, it is preferable that the vehicle trajectory not intrude into adjacent traffic lanes.			Vehicle did not intrude into adjacent traffic lanes.	**PASS**
L	Vehicle Trajectory	The occupant impact velocity in the longitudinal direction and the occupant ridedown acceleration in the longitudinal direction shall satisfy the following:				
		Longitudinal Criteria		**Maximum**	**Test Result**	
		Occupant Impact Velocity (m/s)		12	1.75	**PASS**
		Occupant Ridedown Acceleration (g's)		20	-5.06	**PASS**
M	Vehicle Trajectory	The exit angle from the test article preferably shall be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.			Vehicle vaulted over the barrier.	**FAIL**

Table 6. Test Assessment Summary - Test RW-4

Designation	Factor	Description			Test Results	Assessment
A	Structural Adequacy	Test article shall 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.			Vehicle contained and smoothly redirected.	PASS
D	Occupant Risk	Detached elements, fragments, or other debris from the test article shall 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 shall not be permitted.			Test article and its elements did not penetrate the occupant compartment.	PASS
F	Occupant Risk	The vehicle shall remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.			Vehicle remained upright during and after the collision.	PASS
H	Occupant Risk	Occupant impact velocities shall satisfy the following: Occupant Impact Velocity Limits (m/s)			Impact Velocity (m/s)	
	(Not Required)	**Component**	**Preferred**	**Maximum**		
		Longitudinal	9	12	1.44	PASS
		Lateral	9	12	1.18	PASS
I	Occupant Risk	Occupant ridedown accelerations shall satisfy the following: Occupant Ridedown Acceleration Limits (g's)			Ridedown Acceleration (g's)	
	(Not Required)	**Component**	**Preferred**	**Maximum**		
		Longitudinal	15	20	-1.87	PASS
		Lateral	15	20	-	PASS
K	Vehicle Trajectory	After collision, it is preferable that the vehicle trajectory not intrude into adjacent traffic lanes.			Vehicle did not intrude into adjacent traffic lanes.	PASS
L	Vehicle Trajectory	The occupant impact velocity in the longitudinal direction and the occupant ridedown acceleration in the longitudinal direction shall satisfy the following:				
		Longitudinal Criteria		**Maximum**	**Test Result**	
		Occupant Impact Velocity (m/s)		12	1.44	PASS
		Occupant Ridedown Acceleration (g's)		20	-1.87	PASS
M	Vehicle Trajectory	The exit angle from the test article preferably shall be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.			Vehicle exit angle less than 60 percent of impact angle.	PASS

Table 7. Test Assessment Summary - Test RW-5

Designation	Factor	Description			Test Results	Assessment
A	Structural Adequacy	Test article shall 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.			Vehicle contained and smoothly redirected.	**PASS**
D	Occupant Risk	Detached elements, fragments, or other debris from the test article shall 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 shall not be permitted.			Test article and its elements did not penetrate the occupant compartment.	**PASS**
F	Occupant Risk	The vehicle shall remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.			Vehicle remained upright during and after the collision.	**PASS**
H	Occupant Risk	Occupant impact velocities shall satisfy the following: Occupant Impact Velocity Limits (m/s)			Impact Velocity (m/s)	
		Component	**Preferred**	**Maximum**		
		Longitudinal	9	12	1.02	**PASS**
		Lateral	9	12	1.43	**PASS**
I	Occupant Risk	Occupant ridedown accelerations shall satisfy the following: Occupant Ridedown Acceleration Limits (g's)			Ridedown Acceleration (g's)	
		Component	**Preferred**	**Maximum**		
		Longitudinal	15	20	0.81	**PASS**
		Lateral	15	20	1.98	**PASS**
K	Vehicle Trajectory	After collision, it is preferable that the vehicle trajectory not intrude into adjacent traffic lanes.			Vehicle did not intrude into adjacent traffic lanes.	**PASS**
L	Vehicle Trajectory	The occupant impact velocity in the longitudinal direction and the occupant ridedown acceleration in the longitudinal direction shall satisfy the following:				
		Longitudinal Criteria		**Maximum**	**Test Result**	
	(Not Required)	Occupant Impact Velocity (m/s)		12	3.63	**PASS**
		Occupant Ridedown Acceleration (g's)		20	-6.42	**PASS**
M	Vehicle Trajectory	The exit angle from the test article preferably shall be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.			Vehicle exit angle less than 60 percent of impact angle.	**PASS**

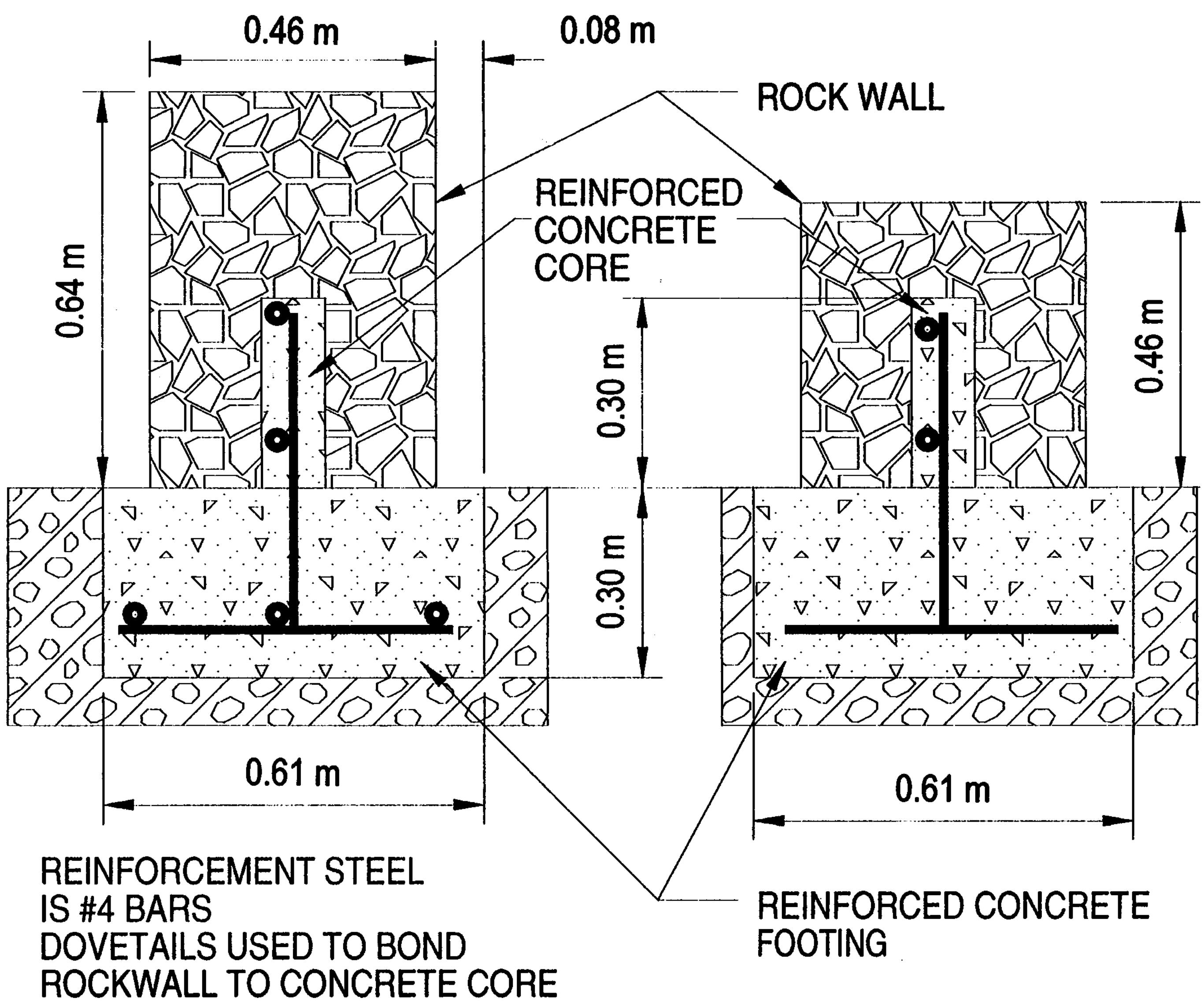


Figure 1. Variable Height Guardwall Construction Details

Figure 1. (Continued) Variable Height Guardwall Construction Details

Figure 1. (Continued) Variable Height Guardwall Construction Details

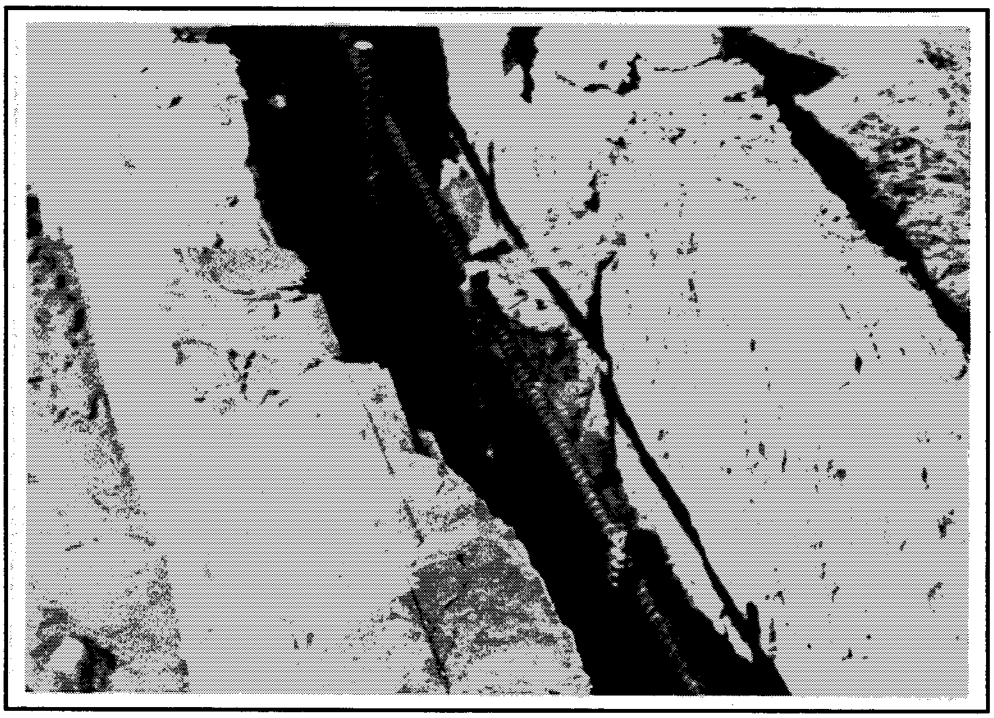


Figure 1. (Continued) Variable Height Guardwall Construction Details

Figure 1. (Continued) Variable Height Guardwall Construction Details

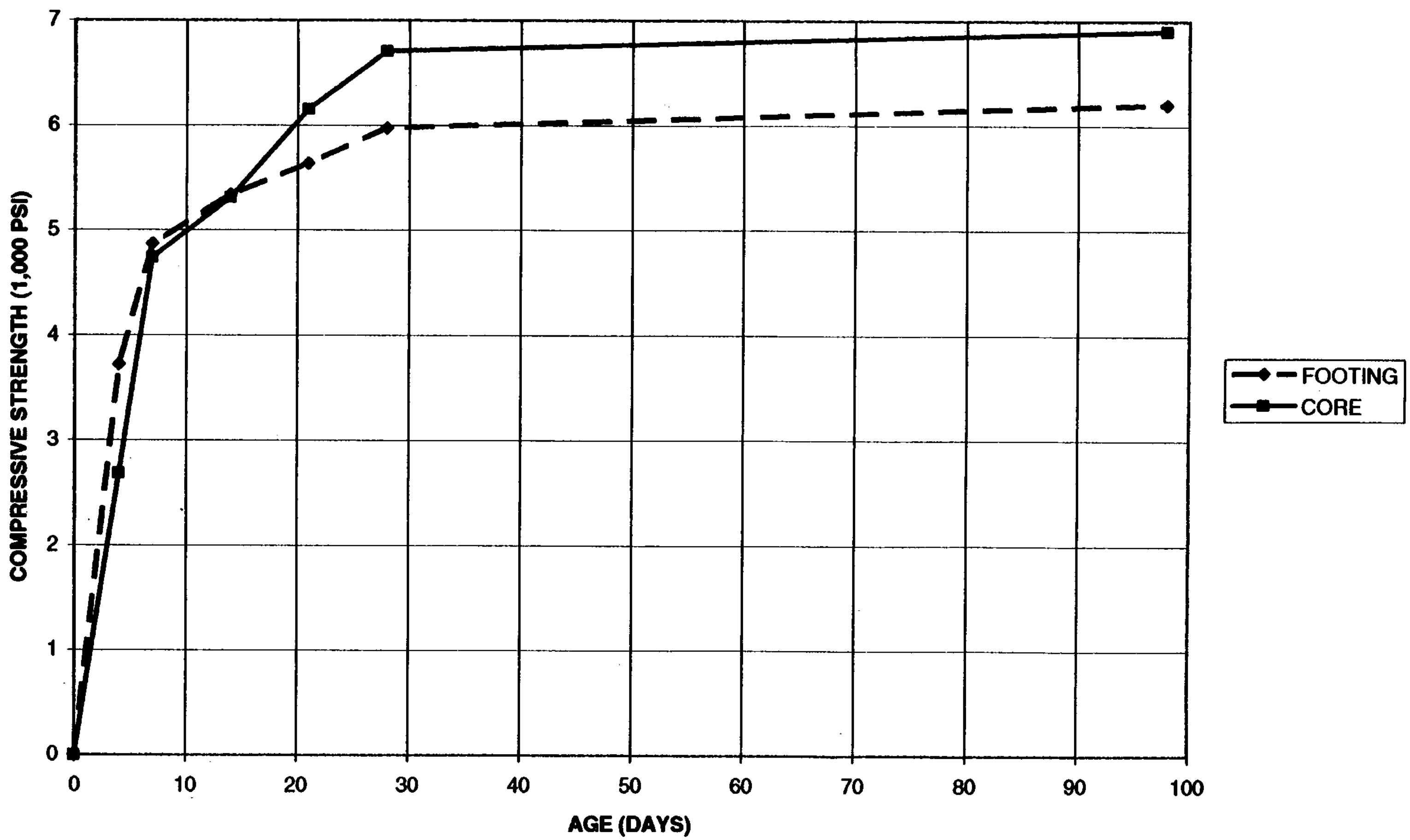


Figure 2. Rock Wall Concrete Compressive Strength

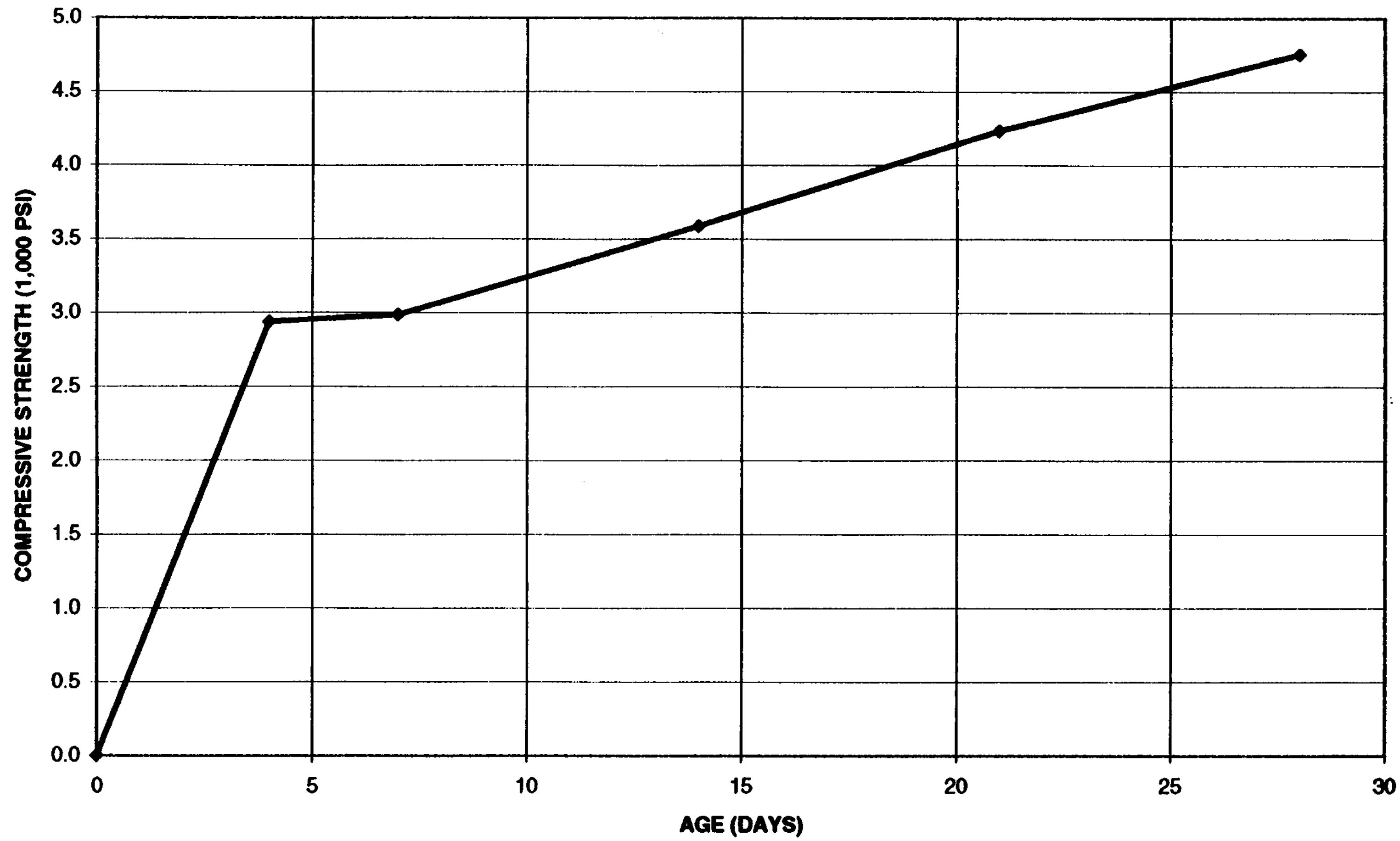


Figure 3. Rock Wall Mortar Compressive Strength

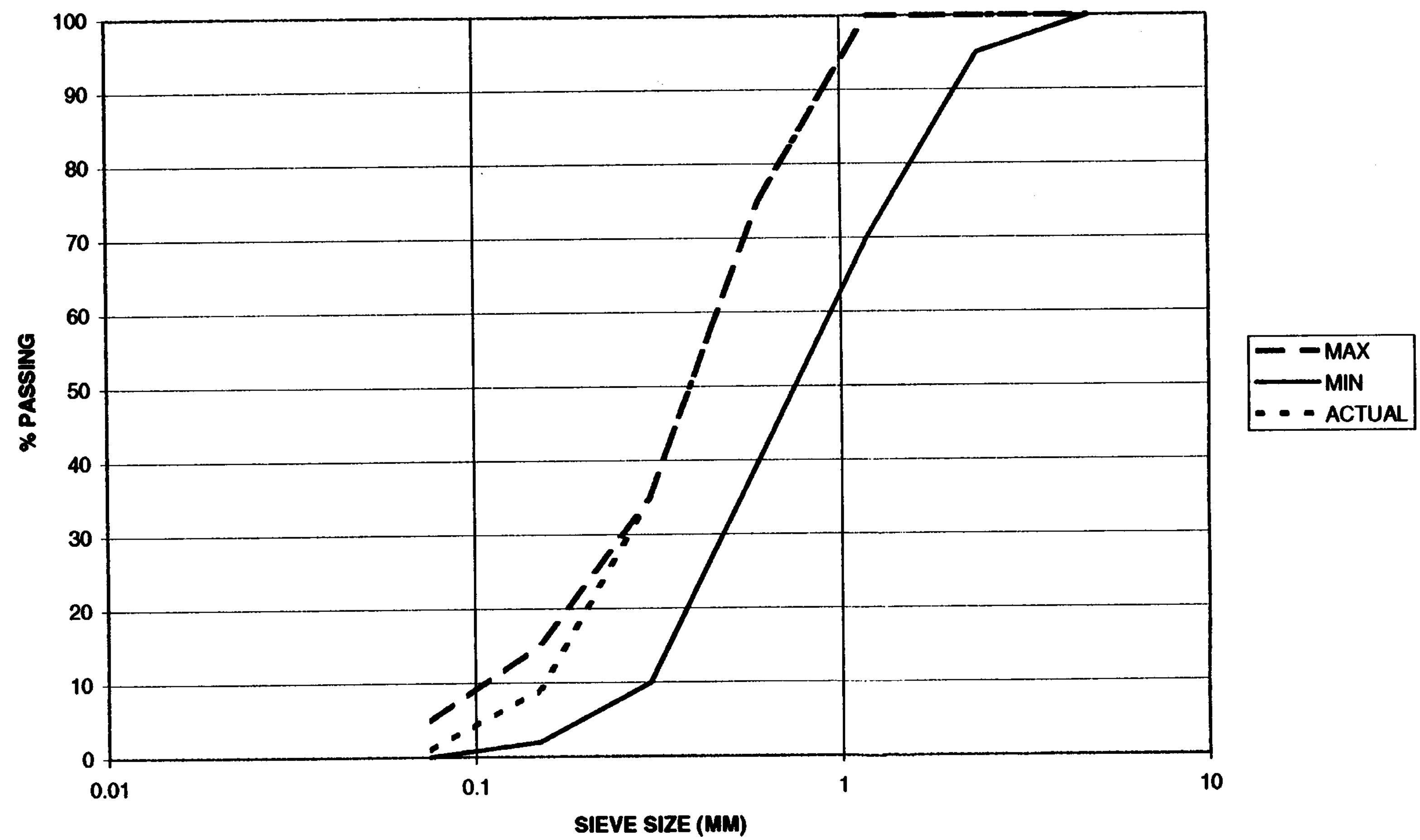


Figure 4. Rock Wall Mortar Sand Sieve Analysis

Figure 5. Before Test Photographs - Test RW-1

Figure 5. (Continued) Before Test Photographs - Test RW-1

Figure 5. (Continued) Before Test Photographs - Test RW-1

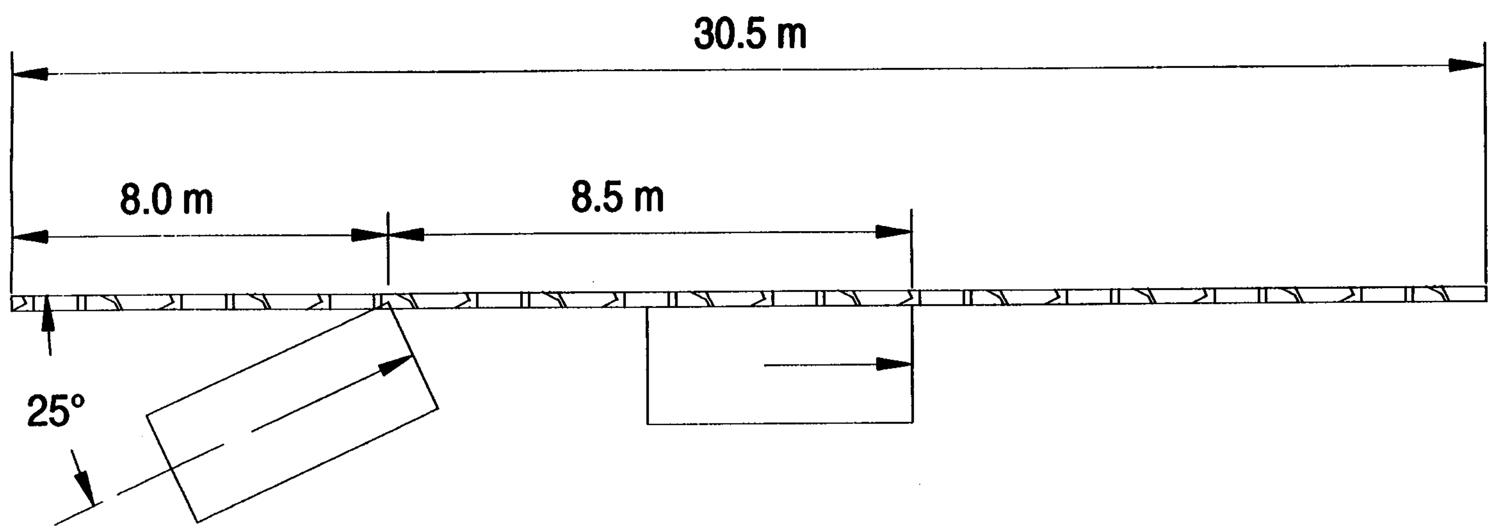


Figure 6. Test Layout - Test RW-1

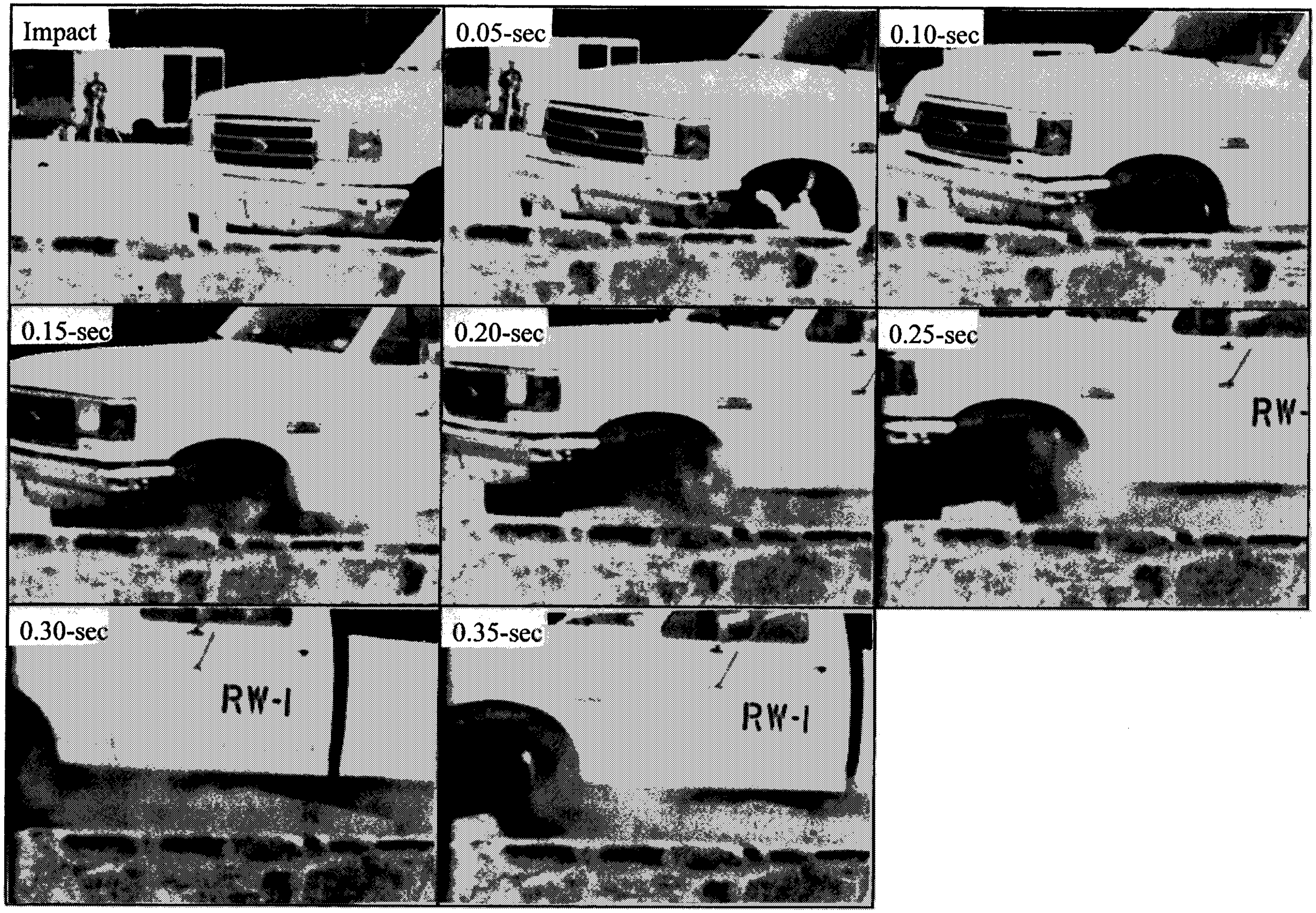


Figure 7. Sequential Photographs - Test RW-1

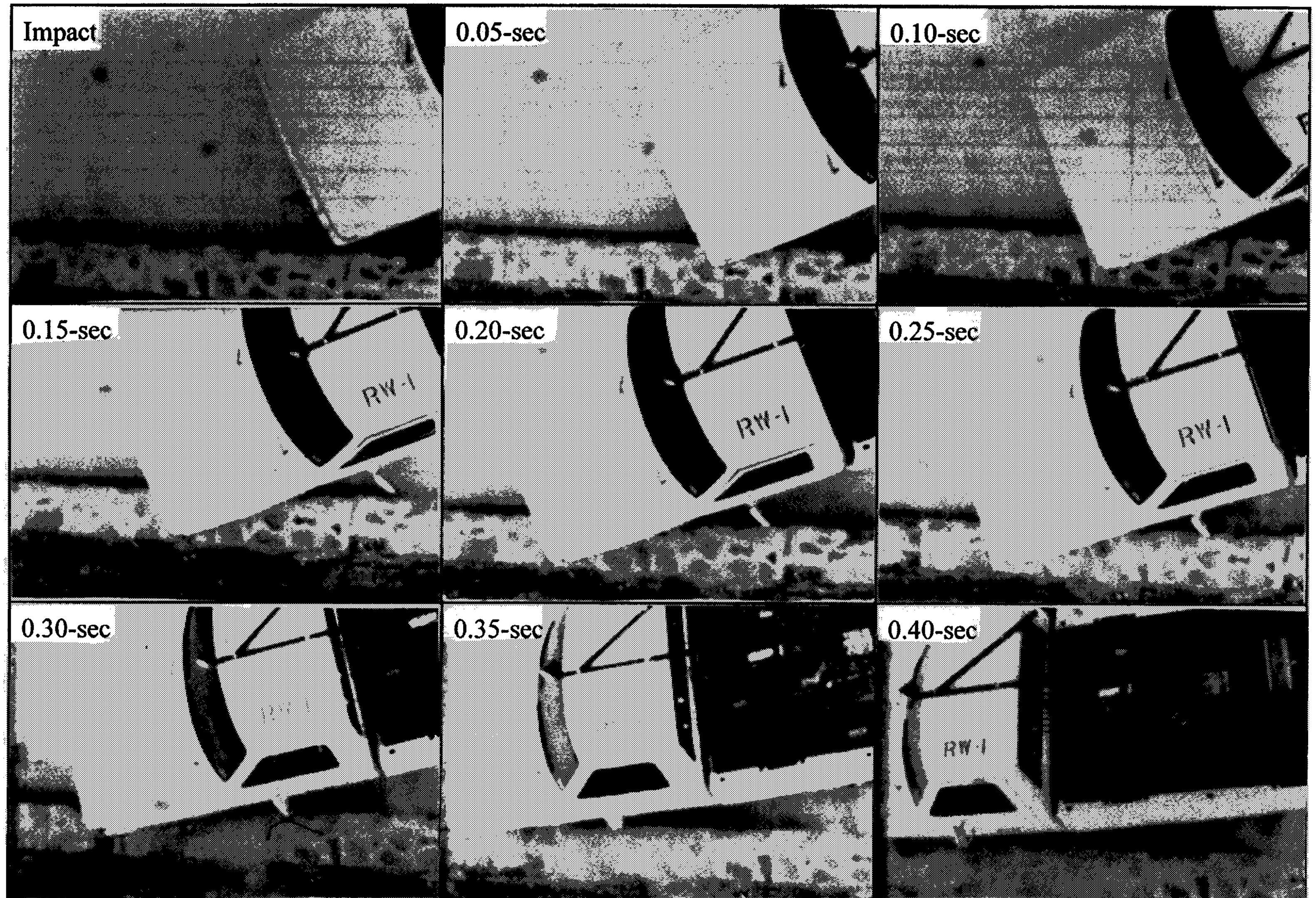
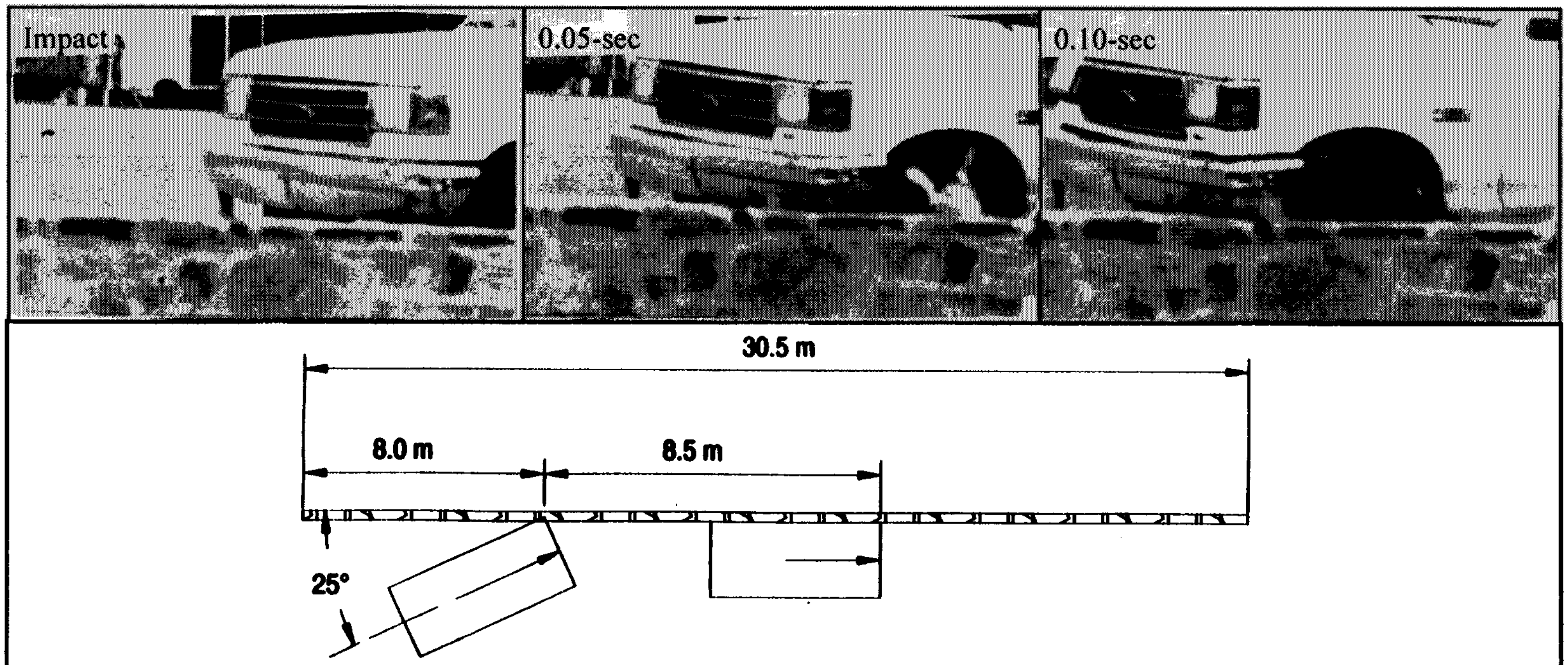


Figure 7. (Continued) Sequential Photographs - Test RW-1



4. General Information		7. Test Vehicle (Continued)			
Test Agency	Southwest Research Institute	Mass (kg) Dummy(s)	75	y-direction	
Test Number	RW-1	Mass (kg) Gross Static	2,039	11. Test Article Deflection (m)	
Test Date	5/11/94	8. Impact Conditions		Dynamic	0.0
5. Test Article		Speed (km/h)	40.2	Permanent	0.0
Type	Longitudinal	Angle (deg)	25	12. Vehicle Damage	
Installation Length (m)	30.5	9. Exit Conditions		Exterior	
Barrier	Variable Height Stone Masonry Guardwall	Speed (km/h)	0	VDS	11LFQ1
6. Soil Type and Condition	Standard Soil, Dry Compacted	Angle (deg)	0	CDC	11FFEN5
7. Test Vehicle		10. Occupant Risk Values		Interior	
Type	Production Model	Impact Velocity (m/s)		OCDI	LF0112000
Designation	2000 P	x-direction	0.58	13. Post-Impact Vehicular Behavior	
Model	1989 Ford F250	y-direction	1.15	Maximum Roll Angle (deg)	15 Estimated
Mass (kg) Curb	2,050	Ridedown Acceleration (g's)		Maximum Pitch Angle (deg)	5 Estimated
Mass (kg) Test Inertial	1,964	x-direction	0.02	Maximum Yaw Angle (deg)	0 Estimated

Figure 8. Summary of Test Conditions and Results - Test RW-1

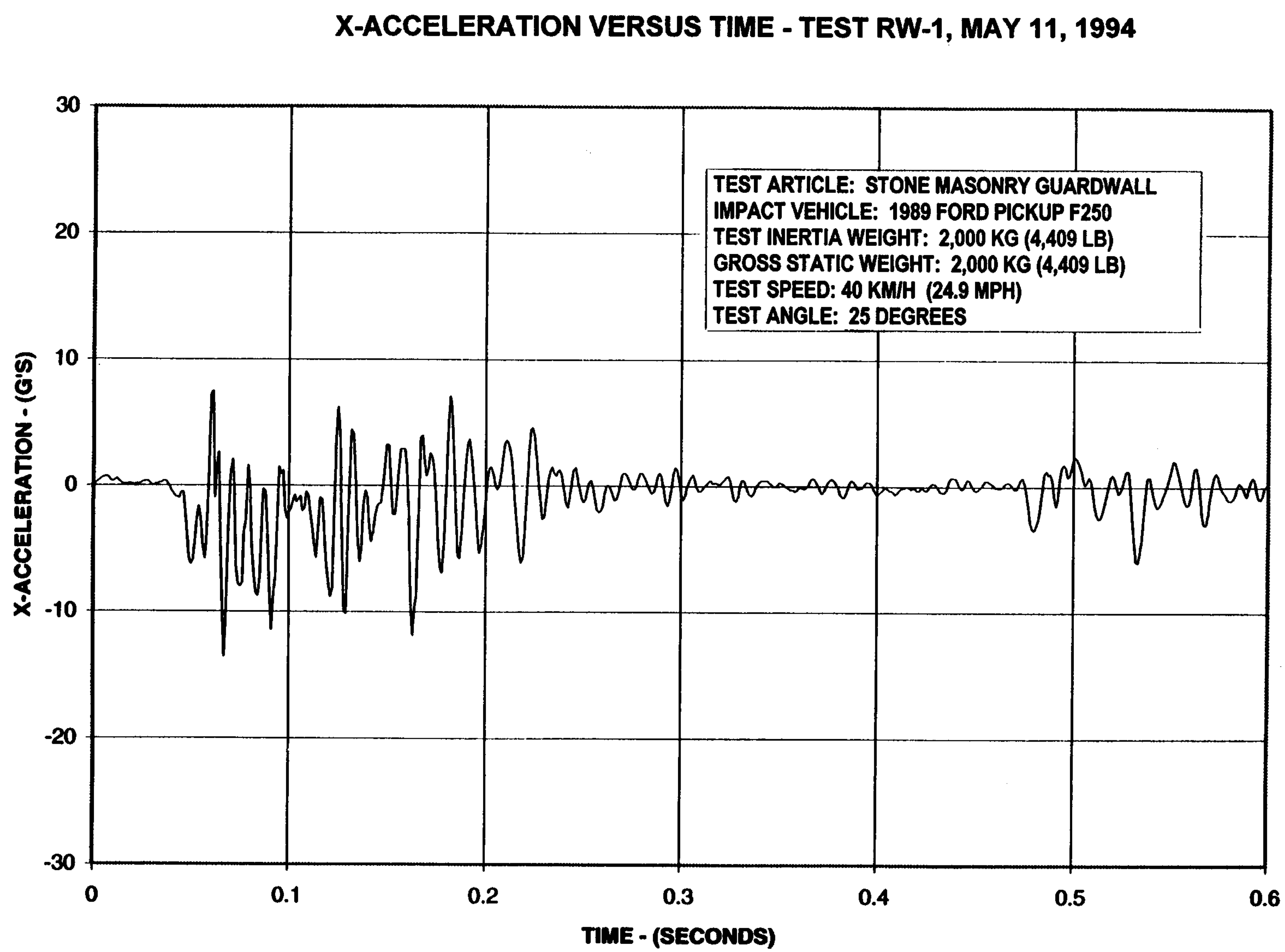


Figure 9. Vehicle Acceleration Plot - Test RW-1

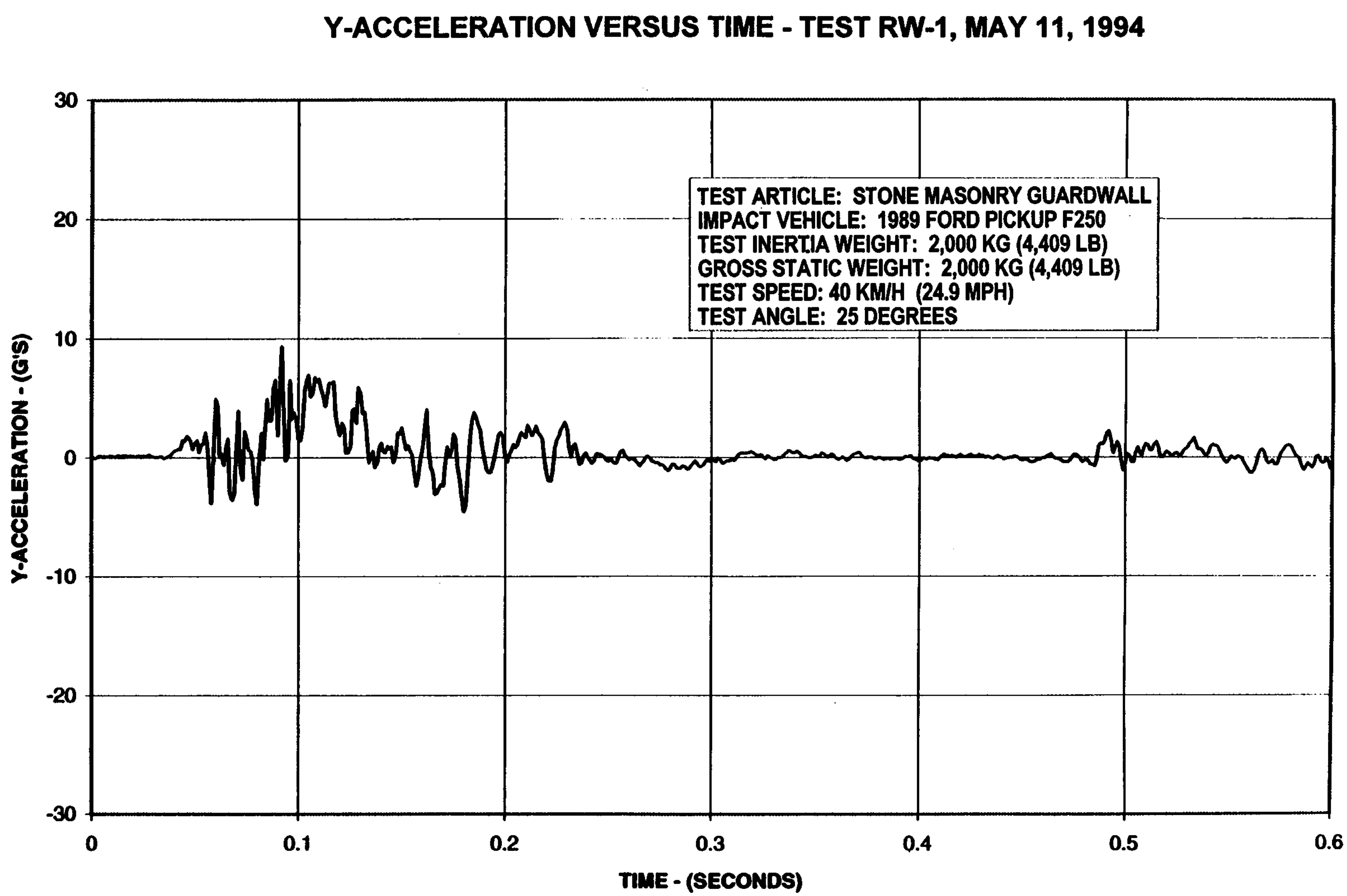


Figure 9. (Continued) Vehicle Acceleration Plot - Test RW-1

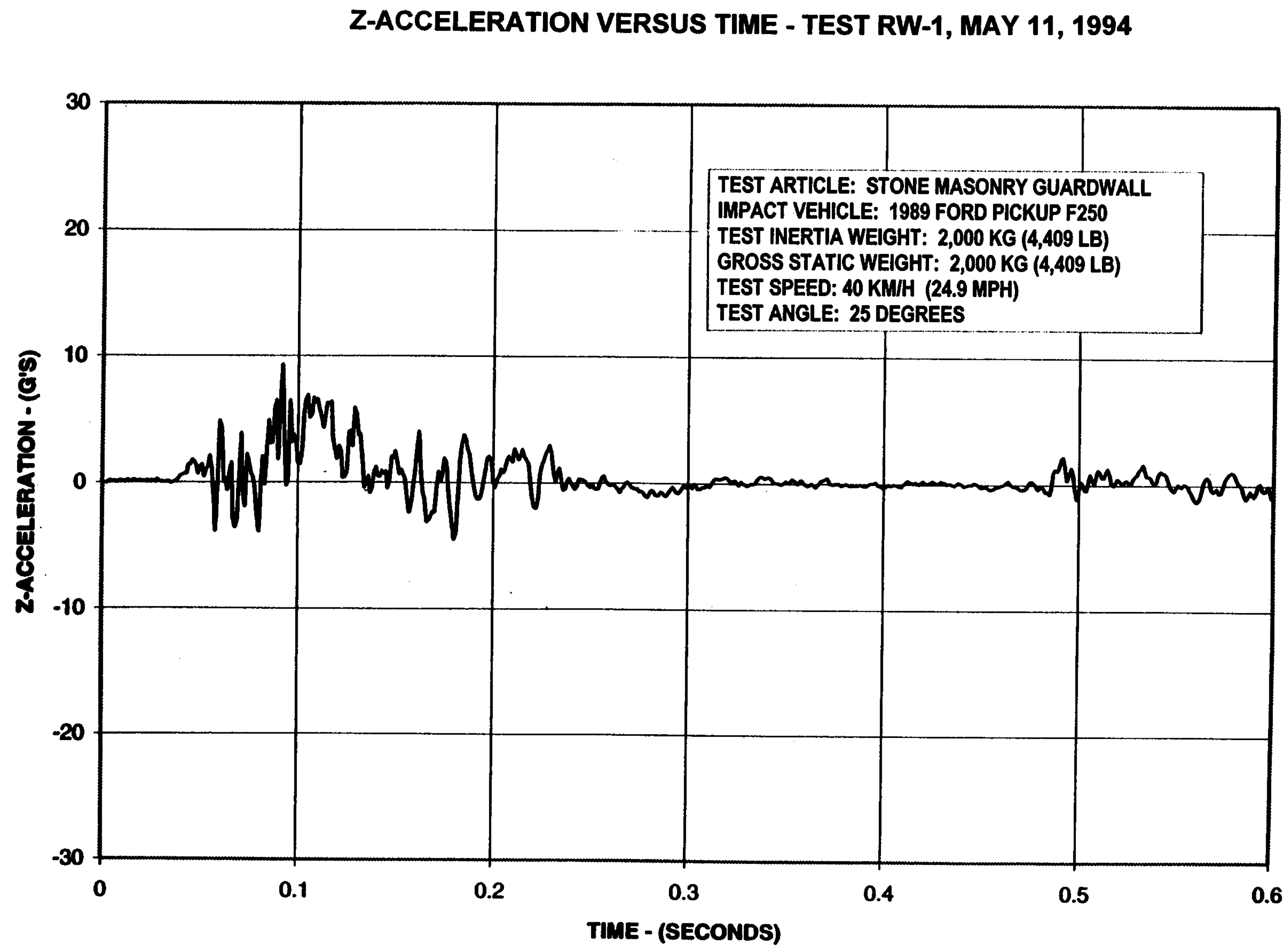


Figure 9. (Continued) Vehicle Acceleration Plot - Test RW-1

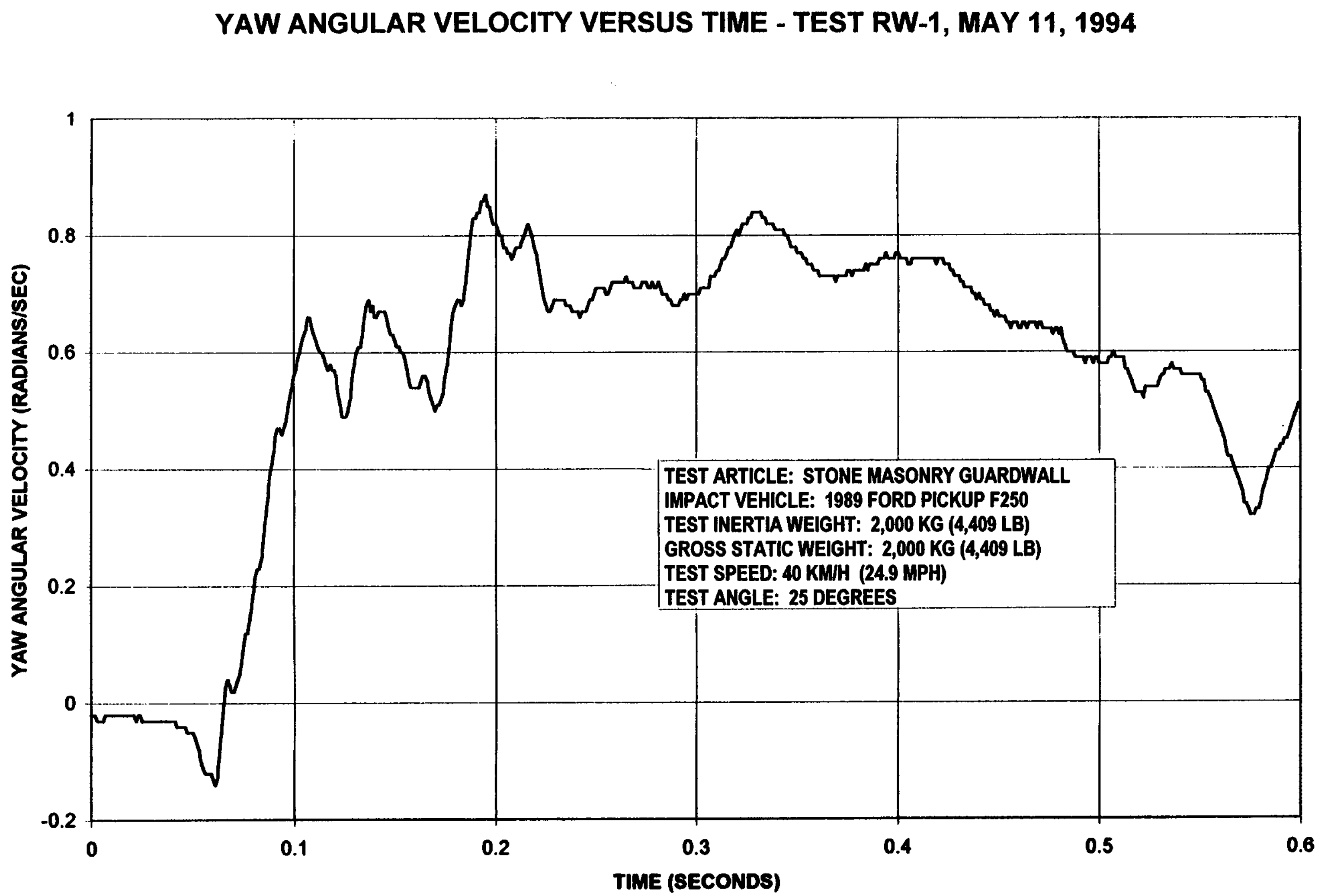


Figure 9. (Continued) Vehicle Acceleration Plot - Test RW-1

TEST ID ------- RW-1
TEST DATE ----- 05-11-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 11.18 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.000	.1	.0	.4	25.0	11.2	.0	.0	.0	.0	.0
.010	.4	.1	.3	25.0	11.2	.0	.0	.1	.0	.0
.020	.1	.1	.3	25.0	11.3	.0	.1	.2	.1	.0
.030	.0	.1	.5	25.0	11.3	.0	.1	.3	.1	.0
.040	-.4	.5	.2	25.1	11.3	.1	.1	.4	.2	.0
.050	-6.2	1.2	4.1	25.1	11.1	.2	.1	.5	.2	.0
.060	7.2	4.9	-5.4	25.1	10.8	.2	-.1	.6	.3	.0
.070	1.0	.8	-10.5	25.2	10.5	.2	-.3	.7	.3	.0
.080	-.3	-3.9	-7.9	25.1	10.2	.3	-.4	.8	.4	.0
.090	-7.7	1.9	3.7	24.9	9.8	.5	-.6	.9	.4	.0
.100	-2.2	1.5	-3.2	24.7	9.4	.8	-.8	1.0	.4	.0
.110	-.8	6.6	-4.5	24.3	9.3	1.2	-.9	1.1	.5	.0
.120	-7.6	1.8	.1	24.0	8.9	1.7	-1.0	1.2	.5	.0
.130	-4.4	5.4	3.3	23.7	8.6	1.9	-1.0	1.3	.5	.0
.140	-.9	1.2	-8.2	23.3	8.5	2.0	-1.2	1.3	.5	-.1
.150	3.2	2.5	-2.8	22.9	8.4	2.0	-1.3	1.4	.5	-.1
.160	1.6	.8	-2.1	22.6	8.5	2.0	-1.3	1.5	.6	-.1
.170	.8	-2.4	1.8	22.3	8.2	1.9	-1.3	1.6	.6	-.1
.180	-.3	-4.5	2.6	21.9	8.0	1.8	-1.1	1.7	.6	-.1
.190	1.8	-.1	-3.3	21.5	8.1	1.8	-1.0	1.8	.6	-.1
.200	-1.4	.2	1.5	21.0	8.0	1.8	-.9	1.8	.6	-.1
.210	3.3	1.7	1.2	20.6	8.1	1.8	-.7	1.9	.6	-.1
.220	-3.8	-1.1	2.7	20.1	8.0	1.9	-.6	2.0	.6	-.1
.230	-2.5	2.3	3.5	19.7	8.1	1.9	-.5	2.1	.6	-.1
.240	-.3	.0	1.2	19.3	8.2	1.9	-.5	2.2	.7	-.2
.250	-1.3	-.3	1.6	19.0	8.2	1.9	-.4	2.3	.7	-.2
.260	-1.5	-.2	.2	18.5	8.1	1.8	-.3	2.3	.7	-.2
.270	.9	.0	.5	18.1	8.1	1.7	-.2	2.4	.7	-.2
.280	1.0	-.9	-.8	17.7	8.1	1.6	-.2	2.5	.7	-.2
.290	.7	-.7	.3	17.3	8.2	1.5	-.2	2.6	.7	-.2
.300	-.6	-.2	1.7	16.9	8.2	1.4	-.2	2.7	.7	-.2
.310	-.4	-.2	1.7	16.5	8.2	1.3	-.1	2.7	.7	-.2
.320	.2	.4	.4	16.1	8.2	1.2	.0	2.8	.7	-.2
.330	-.1	-.2	.6	15.6	8.2	1.2	.0	2.9	.7	-.2
.340	.3	.4	.8	15.1	8.2	1.1	.2	3.0	.8	-.2
.350	.3	.2	1.0	14.7	8.2	1.1	.3	3.1	.8	-.2

Figure 9. (Continued) Vehicle Acceleration Plot - Test RW-1

TEST ID ------- RW-1
TEST DATE ----- 05-11-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 11.18 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.360	-.1	-.1	1.5	14.2	8.2	1.0	.5	3.2	.8	-.2
.370	.0	.4	2.1	13.8	8.3	1.0	.6	3.2	.8	-.2
.380	-.1	.0	1.8	13.4	8.3	.9	.8	3.3	.8	-.1
.390	-.2	-.2	1.7	13.0	8.3	.9	.9	3.4	.8	-.1
.400	-.7	-.3	1.2	12.5	8.3	.8	1.0	3.5	.8	-.1
.410	-.5	.0	.5	12.1	8.2	.7	1.1	3.6	.8	-.1
.420	-.3	.2	-.2	11.7	8.2	.7	1.1	3.7	.8	-.1
.430	.1	.2	-.7	11.2	8.2	.6	1.1	3.7	.8	-.1
.440	.6	.0	-.8	10.8	8.2	.6	1.1	3.8	.9	-.1
.450	-.3	-.2	-.3	10.4	8.2	.5	1.0	3.9	.9	-.1
.460	-.1	.0	-.6	10.1	8.3	.4	1.0	4.0	.9	-.1
.470	-.2	-.3	.0	9.7	8.3	.4	1.0	4.1	.9	-.1
.480	-3.5	-.3	-.4	9.3	8.2	.3	1.0	4.1	.9	.0
.490	-.8	1.4	-4.0	9.0	8.1	.3	.9	4.2	.9	.0
.500	2.2	-.4	1.5	8.7	8.2	.3	.9	4.3	.9	.0
.510	-.4	1.2	1.1	8.3	8.3	.3	.9	4.4	.9	.0
.520	1.0	.5	.6	8.0	8.2	.3	1.1	4.5	.9	.0
.530	-2.0	.8	.9	7.7	8.2	.3	1.3	4.5	.9	.0
.540	.0	.3	-1.0	7.4	7.9	.3	1.3	4.6	.9	.0
.550	1.4	-.2	-1.2	7.0	7.9	.3	1.2	4.7	1.0	.0
.560	-.8	-1.3	-.1	6.7	7.9	.3	1.2	4.8	1.0	.0
.570	-1.0	-.4	-.2	6.5	7.8	.2	1.2	4.9	1.0	.1
.580	-1.0	.9	-.9	6.3	7.8	.2	1.2	4.9	1.0	.1
.590	-.1	-.9	.1	6.1	7.8	.1	1.1	5.0	1.0	.1

HIGHEST 50.0-MS AVG. ACCEL.

	G'S	TIME (SEC) START	END
LONG.	-3.75	.073	.123
LAT.	4.10	.084	.134

Figure 9. (Continued) Vehicle Acceleration Plot - Test RW-1

TEST ID ------- RW-1
TEST DATE ----- 05-11-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 11.18 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	(----- VEHICLE	------)		(----------- OCCUPANT			-----------)
TIME	ACCEL. (G'S)		ANG.VEL	VEL. (M/S)		DISP. (M)	
(S)	LONG.	LAT.	(RAD/S)	LONG.	LAT.	LONG.	LAT.
.000	.05	.02	.43	.00	.00	.00	.00
.010	.48	.13	.32	-.02	.00	.00	.01
.020	.15	.13	.32	-.02	.01	.01	.03
.030	.21	.09	.49	-.03	.02	.01	.04
.040	-.31	.54	.15	-.03	.02	.01	.06
.050	-3.34	1.26	4.08	.04	.06	.01	.07
.060	.01	.65	-5.39	.17	.09	.02	.09
.070	-5.45	-.12	-10.54	.17	.08	.02	.10
.080	-5.04	.27	-7.86	.18	.06	.03	.11
.090	-4.86	4.11	3.74	.20	.10	.03	.12
.100	-.92	3.83	-3.23	.24	.16	.04	.13
.110	-2.46	5.77	-4.52	.25	.27	.04	.14
.120	-3.31	3.03	.11	.38	.39	.05	.15
.130	-1.11	3.16	3.32	.48	.44	.05	.15
.140	-3.07	.44	-8.17	.46	.43	.06	.16
.150	-.06	1.08	-2.80	.52	.42	.06	.16
.160	-2.65	.15	-2.08	.53	.40	.07	.16
.170	.97	-1.19	1.81	.64	.35	.08	.16
.180	-.50	-.45	2.60	.60	.28	.08	.17
.190	-.65	.72	-3.30	.50	.26	.09	.17
.200	-1.52	.91	1.47	.53	.22	.10	.17
.210	1.53	1.92	1.22	.52	.21	.10	.17
.220	-1.09	.25	2.68	.55	.21	.11	.17
.230	.11	1.60	3.52	.56	.20	.12	.17
.240	.11	-.11	1.19	.54	.18	.12	.17
.250	-.01	-.14	1.64	.52	.13	.13	.17
.260	-.98	-.05	.22	.54	.09	.13	.17
.270	.05	-.30	.49	.55	.04	.14	.17
.280	.27	-.81	-.79	.53	-.02	.15	.17
.290	-.27	-.70	.26	.53	-.08	.16	.17
.300	.22	-.30	1.72	.51	-.14	.16	.17
.310	.14	-.11	1.72	.49	-.19	.17	.17
.320	.38	.30	.36	.44	-.24	.18	.17
.330	-.32	-.02	.57	.42	-.29	.18	.17
.340	.06	.37	.84	.43	-.33	.19	.17
.350	.08	.14	1.05	.44	-.36	.20	.17

Figure 9. (Continued) Vehicle Acceleration Plot - Test RW-1

TEST ID ------- RW-1
TEST DATE ----- 05-11-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 11.18 M/S

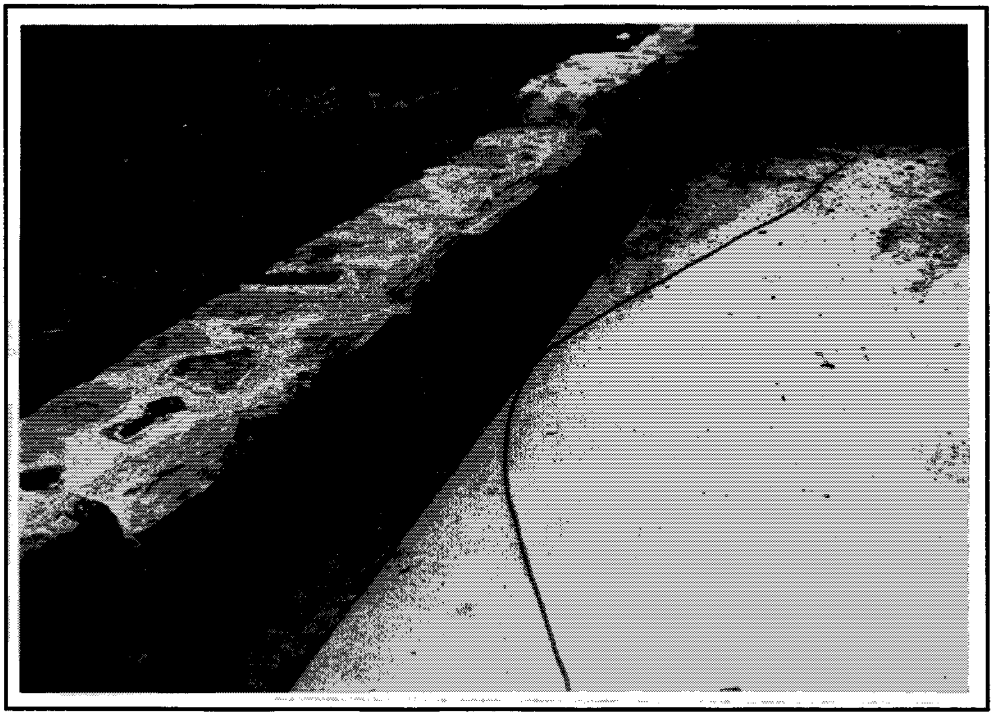
OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

TIME (S)	VEHICLE ACCEL. (G'S) LONG.	VEHICLE ACCEL. (G'S) LAT.	VEHICLE ANG.VEL (RAD/S)	OCCUPANT VEL. (M/S) LONG.	OCCUPANT VEL. (M/S) LAT.	OCCUPANT DISP. (M) LONG.	OCCUPANT DISP. (M) LAT.
.360	-.20	.01	1.47	.45	-.40	.20	.17
.370	.10	.14	2.09	.44	-.44	.21	.17
.380	-.11	-.06	1.82	.43	-.48	.22	.17
.390	.10	-.07	1.72	.42	-.53	.22	.17
.400	-.19	-.13	1.16	.41	-.58	.23	.17
.410	-.30	.02	.53	.41	-.63	.24	.16
.420	-.20	.13	-.20	.41	-.67	.24	.16
.430	-.14	.11	-.72	.42	-.70	.25	.16
.440	.28	-.01	-.76	.43	-.74	.26	.16
.450	.10	-.13	-.34	.44	-.77	.26	.16
.460	.13	-.05	-.62	.44	-.82	.27	.16
.470	.23	-.18	.01	.43	-.86	.28	.15
.480	-1.90	-.21	-.45	.45	-.89	.29	.15
.490	.43	1.04	-4.00	.49	-.92	.29	.15
.500	1.55	.08	1.53	.46	-.93	.30	.15
.510	-.83	.75	1.09	.42	-.96	.31	.15
.520	-.17	.37	.59	.48	-.96	.32	.14
.530	-2.22	.83	.88	.46	-.98	.32	.14
.540	-.97	.66	-1.04	.52	-.99	.33	.14
.550	.68	-.01	-1.24	.54	-1.01	.34	.13
.560	-.17	-.55	-.10	.57	-1.04	.35	.13
.570	-.90	-.11	-.16	.64	-1.06	.36	.13
.580	-.54	.48	-.89	.66	-1.07	.36	.12
.590	-.03	-.51	.11	.61	-1.11	.37	.12

OCCUP. RISK FACTORS	TIME (S)	VELOCITY (M/S)
>LONG. VEL. AFTER 0.6 M DISP. --	.600	.58
>LAT. VEL. AFTER 0.3 M DISP. --	.600	1.15

MAX. ACCEL. AFTER OCCUPANT IMPACT	TIME(S)	ACC.(GS)
>LONG. ACCELERATION --	.600	.02
>LAT. ACCELERATION --	.600	1.25

Figure 9. (Continued) Vehicle Acceleration Plot - Test RW-1



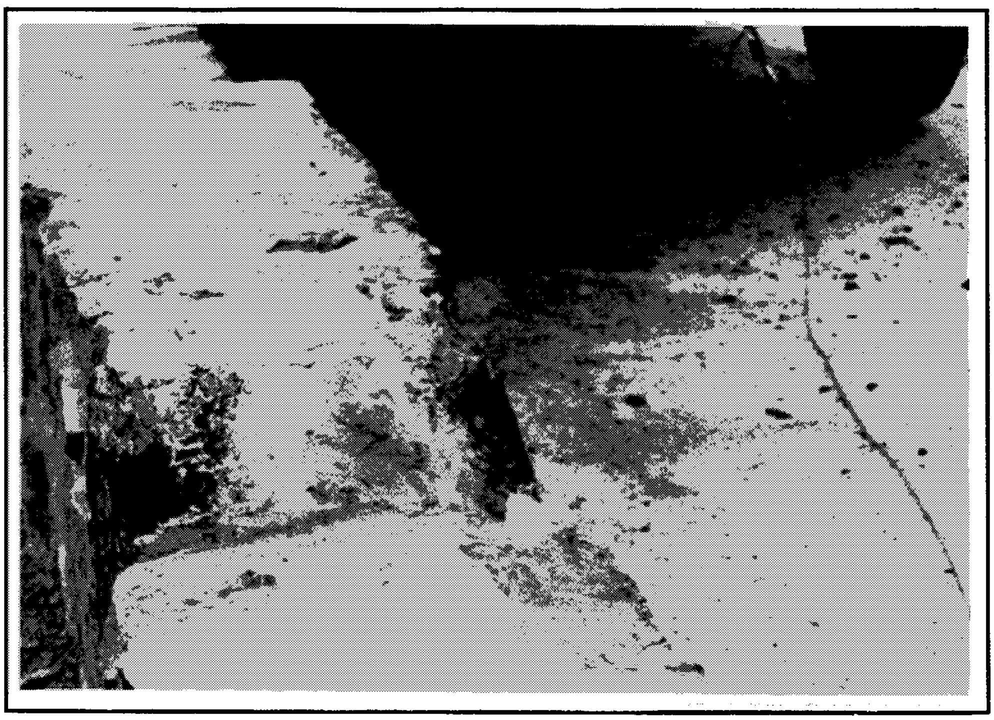


Figure 10. After Test Photographs - Test RW-1

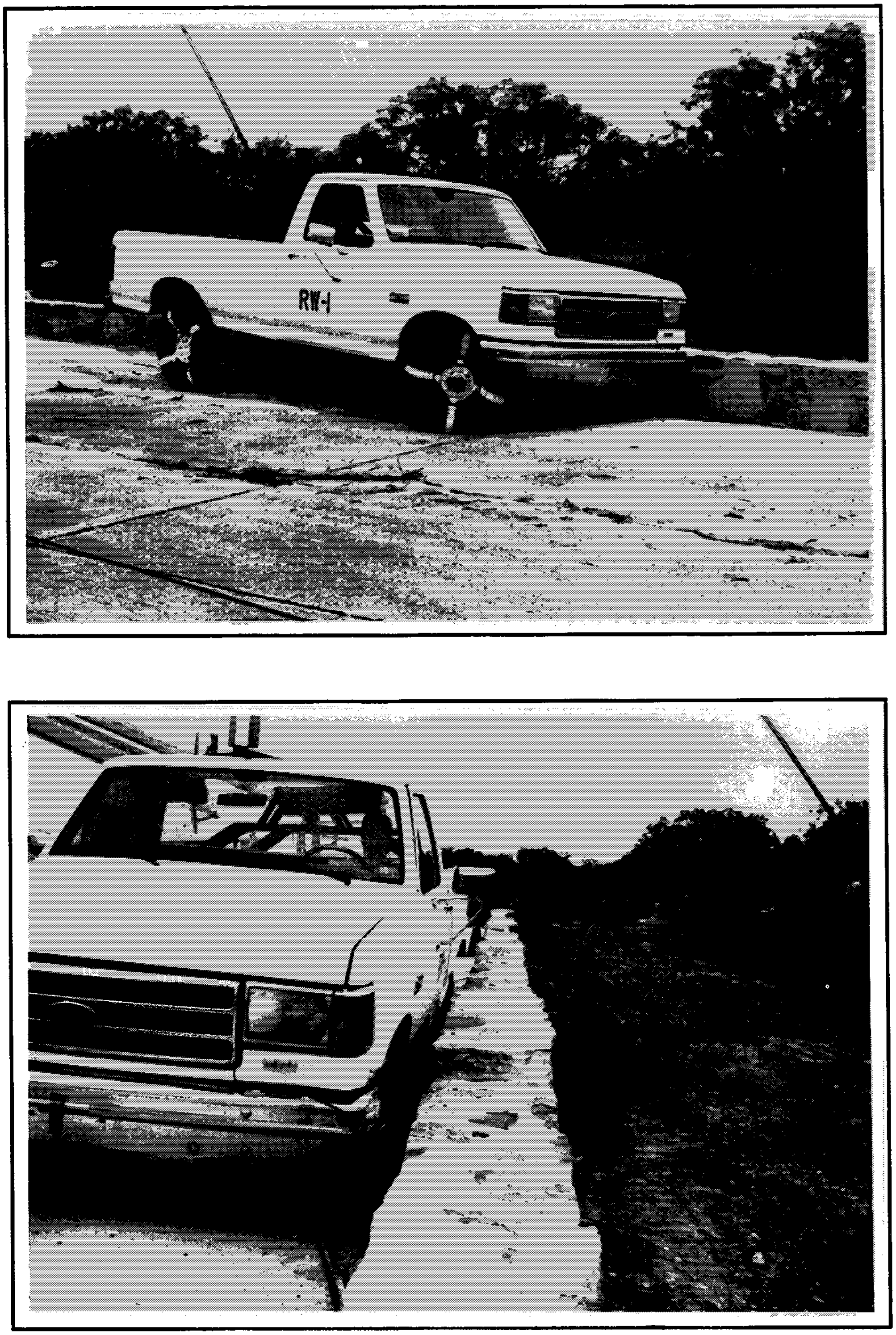


Figure 10. (Continued) After Test Photographs - Test RW-1

Figure 10. (Continued) After Test Photographs - Test RW-1

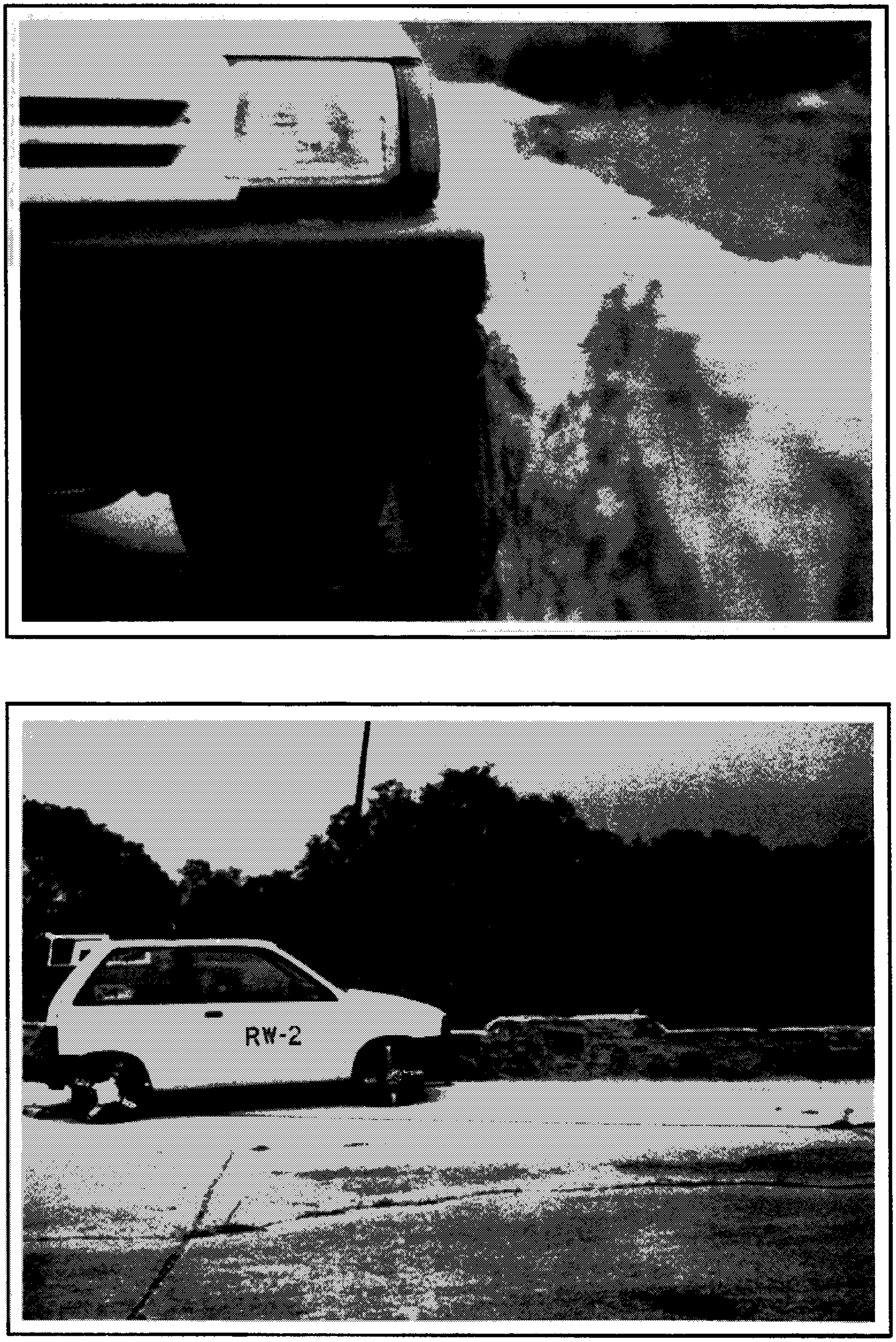


Figure 11. Before Test Photographs - Test RW-2

Figure 11. (Continued) Before Test Photographs - Test RW-2

Figure 11. (Continued) Before Test Photographs - Test RW-2

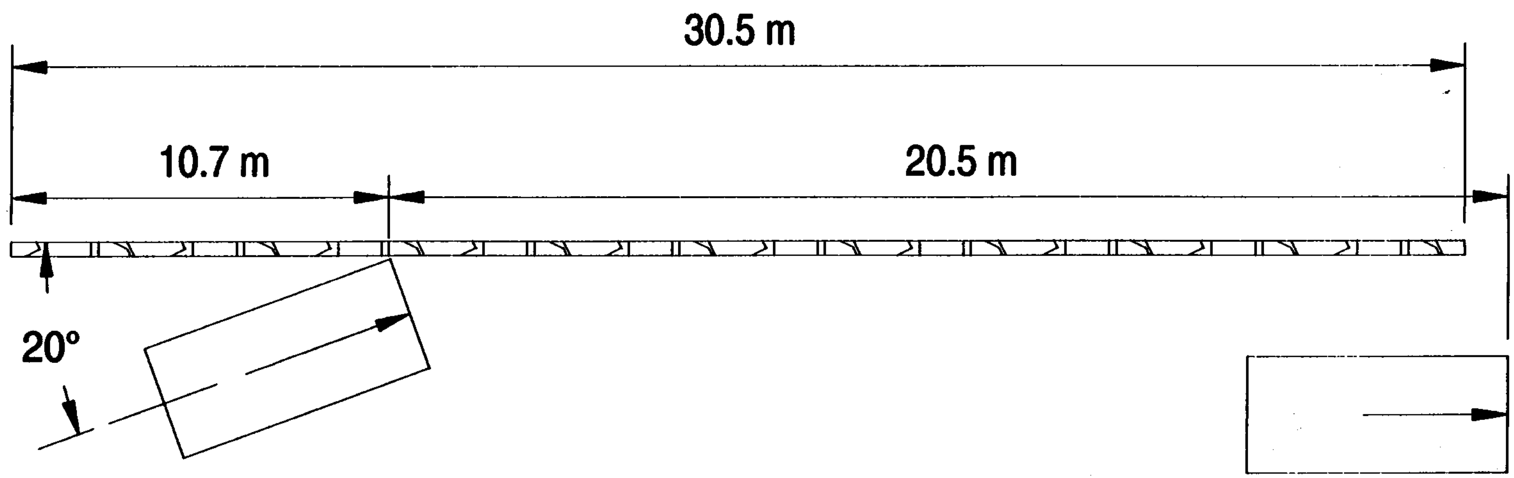


Figure 12. Test Layout - Test RW-2

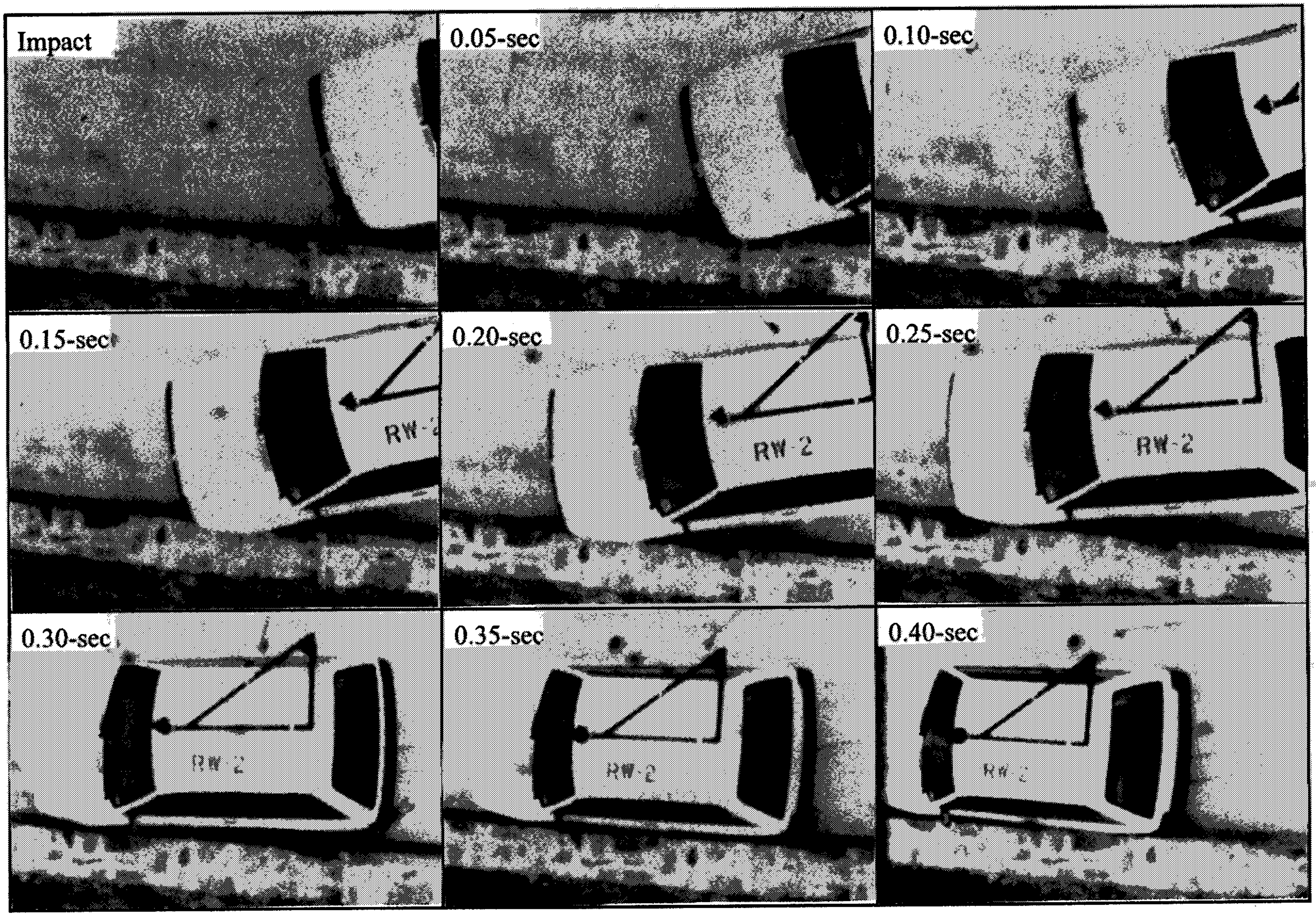


Figure 13. Sequential Photographs - Test RW-2

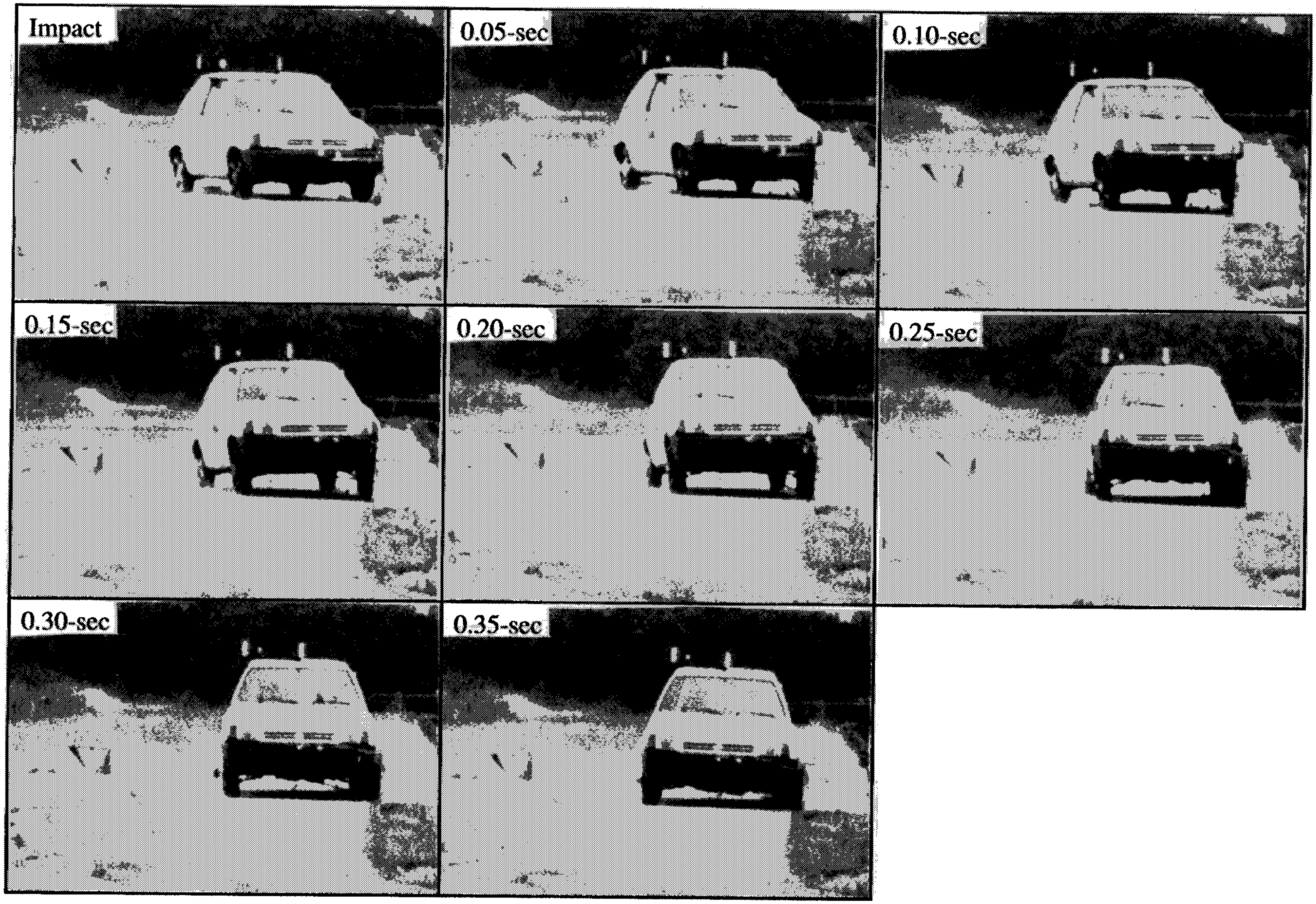
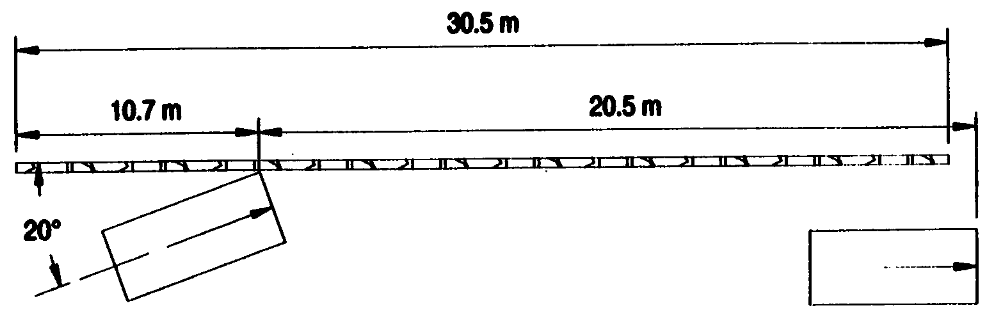


Figure 13. (Continued) Sequential Photographs - Test RW-2



4. General Information		**7. Test Vehicle (Continued)**			
Test Agency	Southwest Research Institute	Mass (kg) Dummy(s)	75	y-direction	
Test Number	RW-2	Mass (kg) Gross Static	915	**11. Test Article Deflection (m)**	
Test Date	5/13/94	**8. Impact Conditions**		Dynamic	0.0
5. Test Article		Speed (km/h)	40.2	Permanent	0.0
Type	Longitudinal	Angle (deg)	20	**12. Vehicle Damage**	
Installation Length (m)	30.5	**9. Exit Conditions**		Exterior	
Barrier	Variable Height Stone Masonry Guardwall	Speed (km/h)	0	VDS	11LFQ1
6. Soil Type and Condition	Standard Soil, Dry Compacted	Angle (deg)	0	CDC	11FFEN1
7. Test Vehicle		**10. Occupant Risk Values**		Interior	
Type	Production Model	Impact Velocity (m/s)		OCDI	LF0112000
Designation	820 C	x-direction	1.75	**13. Post-Impact Vehicular Behavior**	
Model	1989 Ford Festiva	y-direction	0.83	Maximum Roll Angle (deg)	15 Estimated
Mass (kg) Curb	845	Ridedown Acceleration (g's)		Maximum Pitch Angle (deg)	5 Estimated
Mass (kg) Test Inertial	840	x-direction	0.37	Maximum Yaw Angle (deg)	0 Estimated

Figure 14.. Summary of Test Conditions and Results - Test RW-2

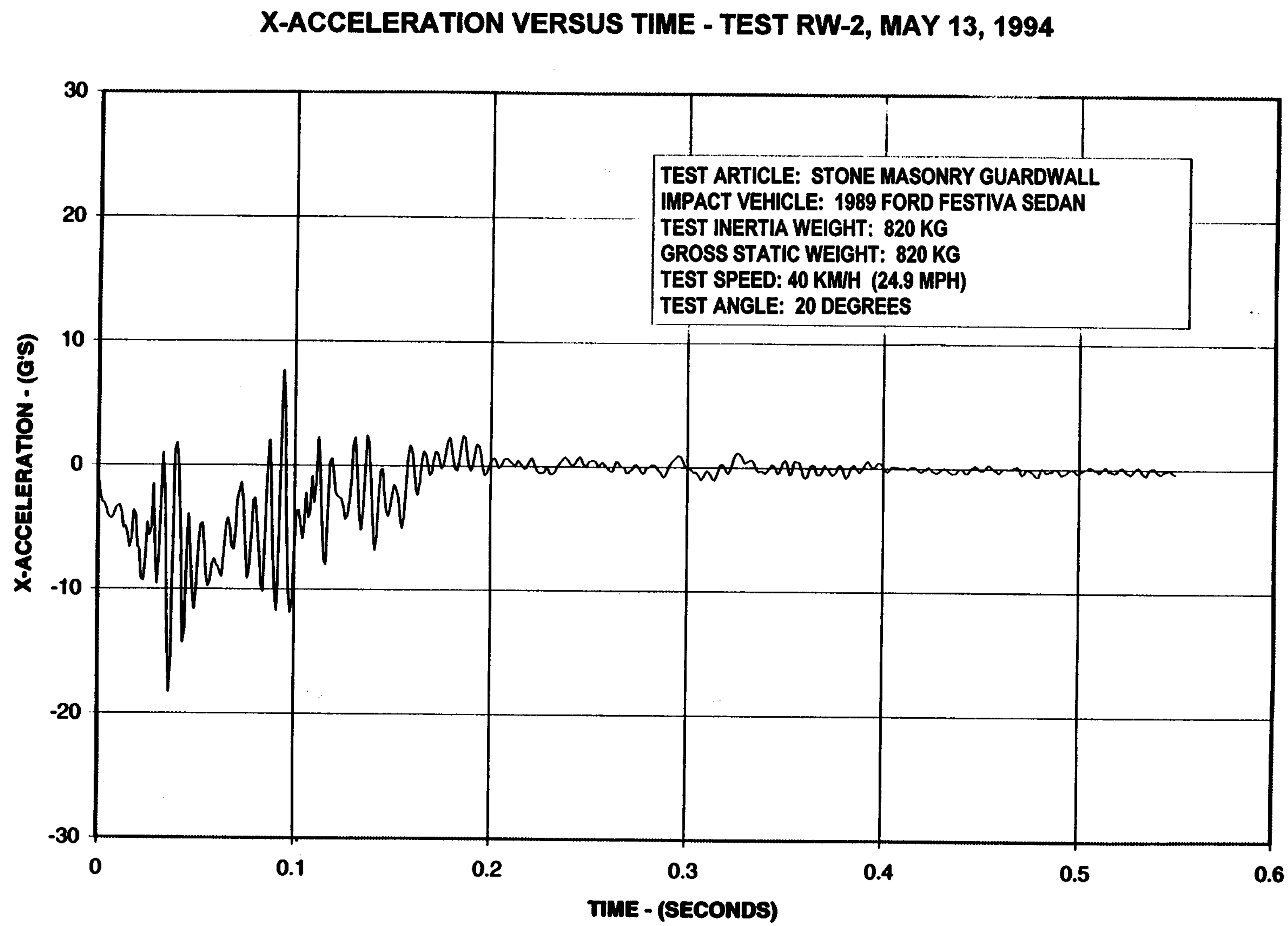


Figure 15. Vehicle Acceleration Plot - Test RW-2

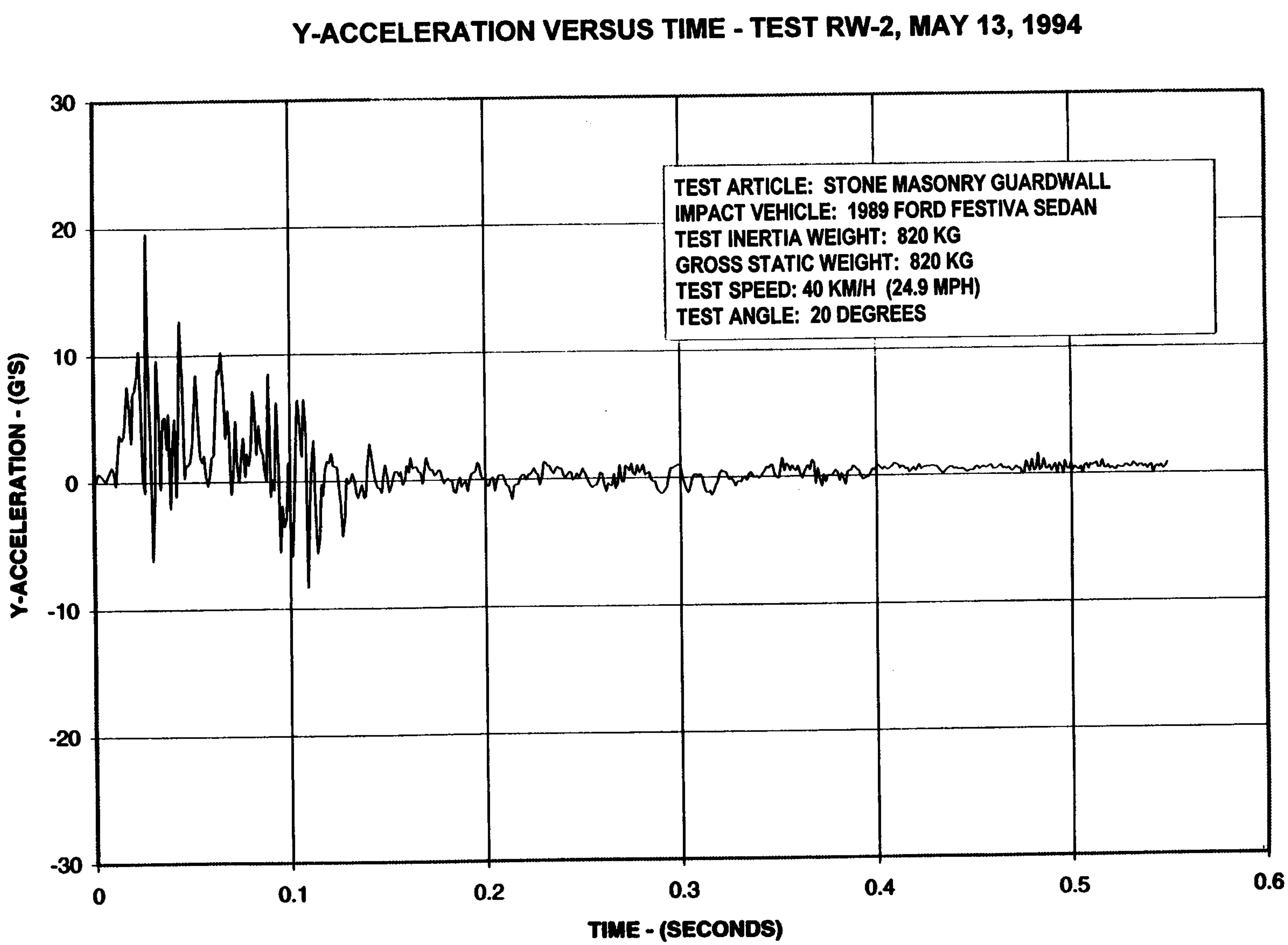


Figure 15. (Continued) Vehicle Acceleration Plot - Test RW-2

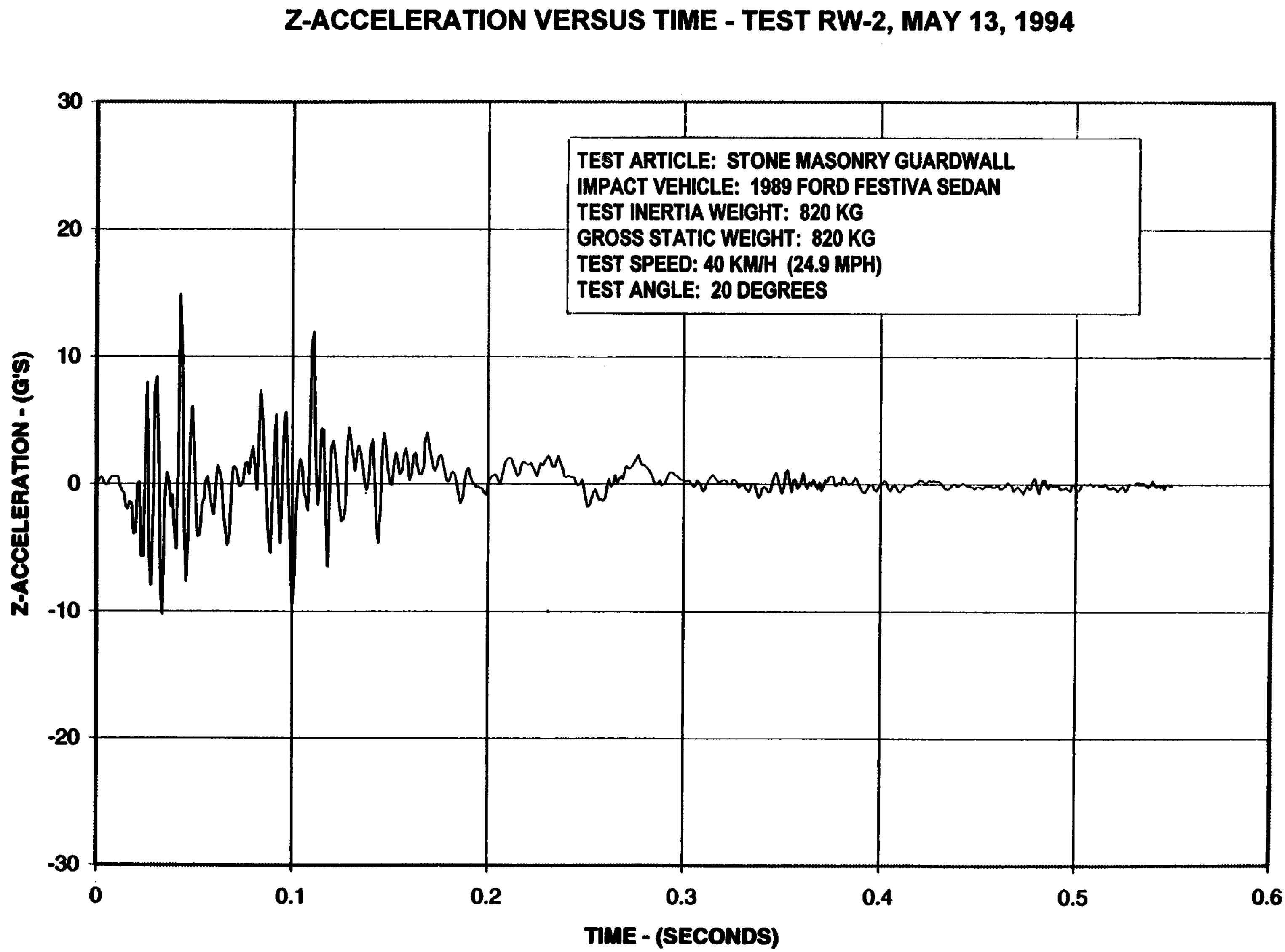


Figure 15. (Continued) Vehicle Acceleration Plot - Test RW-2

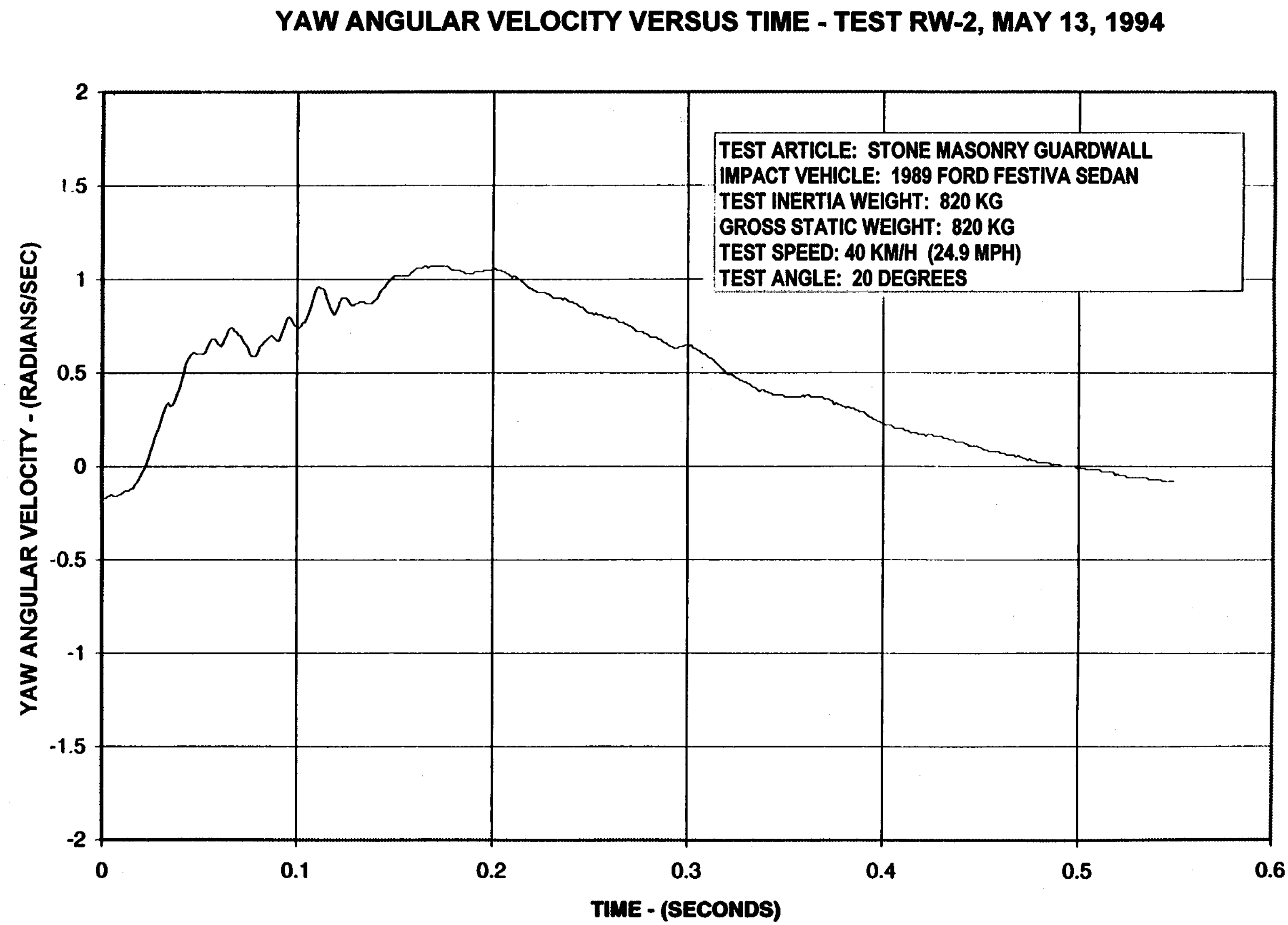


Figure 15. (Continued) Vehicle Acceleration Plot - Test RW-2

TEST ID ------- RW-2
TEST DATE ----- 05-13-94
VEHICLE CLASS - 820C
IMPACT SPEED -- 11.18 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.000	-.5	.3	.3	20.0	11.2	.0	.0	.0	.0	.0
.010	-3.3	.9	.6	20.1	10.8	.1	.0	.1	.0	.0
.020	-6.7	7.0	-3.8	20.2	10.4	.4	-.1	.2	.1	.0
.030	-9.6	-6.2	7.6	20.1	9.7	1.0	-.2	.3	.1	.0
.040	1.8	2.9	-3.6	19.9	9.1	1.3	-.3	.4	.1	.0
.050	-9.9	3.1	2.9	19.6	8.3	1.6	-.1	.5	.1	.0
.060	-8.0	2.0	-2.4	19.2	7.6	1.8	-.3	.6	.1	.0
.070	-5.1	-1.0	1.4	18.8	7.0	2.3	-.4	.6	.2	.0
.080	-2.6	2.7	3.0	18.5	6.5	2.4	-.3	.7	.2	.0
.090	-10.0	-1.2	-1.3	18.1	6.1	2.7	-.2	.8	.1	.0
.100	-6.8	-2.5	-9.5	17.6	5.6	2.6	-.2	.8	.1	.0
.110	-3.0	-1.9	11.1	17.2	5.2	2.6	-.2	.9	.1	.0
.120	-.7	1.5	2.9	16.7	5.0	2.5	.0	1.0	.1	.0
.130	1.5	-.2	3.5	16.2	4.8	2.5	.0	1.0	.1	.0
.140	-4.3	1.4	2.8	15.7	4.8	2.4	.2	1.1	.1	.0
.150	-2.3	.3	.1	15.1	4.5	2.4	.3	1.1	.1	.0
.160	1.2	1.2	.3	14.5	4.3	2.4	.4	1.2	.1	.0
.170	-.5	1.8	3.0	13.9	4.3	2.4	.6	1.2	.1	.0
.180	1.8	.0	.2	13.3	4.4	2.4	.7	1.3	.0	.0
.190	-.4	-.1	1.3	12.7	4.5	2.4	.8	1.3	.0	.0
.200	.3	.2	.0	12.1	4.6	2.3	.7	1.4	.0	.0
.210	.3	.1	2.0	11.5	4.6	2.3	.8	1.4	.0	.0
.220	.5	.3	1.6	11.0	4.6	2.2	1.0	1.5	.0	.0
.230	-.6	1.4	2.1	10.4	4.7	2.2	1.1	1.5	.0	.0
.240	.3	.2	.5	9.9	4.7	2.2	1.3	1.6	.0	.1
.250	.4	.8	-1.1	9.4	4.7	2.2	1.3	1.6	.0	.1
.260	-.2	.4	-1.0	9.0	4.8	2.2	1.2	1.7	-.1	.1
.270	-.5	-.3	1.1	8.5	4.8	2.1	1.2	1.7	-.1	.1
.280	-.1	.7	1.6	8.1	4.8	2.1	1.4	1.8	-.1	.1
.290	-.2	-1.2	.0	7.7	4.8	2.1	1.4	1.8	-.1	.1
.300	-.1	1.0	.3	7.3	4.8	2.1	1.5	1.9	-.1	.1
.310	-.3	.3	-.6	7.0	4.8	2.0	1.5	1.9	-.1	.1
.320	-.4	.3	.3	6.7	4.8	1.9	1.5	2.0	-.1	.2
.330	.4	-.3	.0	6.4	4.8	1.9	1.5	2.0	-.2	.2
.340	-.5	-.1	-.3	6.2	4.8	1.9	1.5	2.1	-.2	.2
.350	.6	-.1	-.7	5.9	4.8	1.9	1.5	2.1	-.2	.2

Figure 15. (Continued) Vehicle Acceleration Plot - Test RW-2

TEST ID ------- RW-2
TEST DATE ----- 05-13-94
VEHICLE CLASS - 820C
IMPACT SPEED -- 11.18 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.360	-.8	.9	.4	5.7	4.9	1.9	1.5	2.2	-.2	.2
.370	.2	.6	-.5	5.5	4.8	2.0	1.5	2.2	-.2	.2
.380	-.5	.3	.0	5.3	4.8	2.0	1.5	2.3	-.2	.3
.390	.1	.5	-.3	5.1	4.8	2.0	1.6	2.3	-.2	.3
.400	.1	.7	-.1	5.0	4.8	2.0	1.5	2.4	-.3	.3
.410	.1	.9	-.6	4.9	4.8	2.0	1.5	2.4	-.3	.3
.420	-.3	.3	.4	4.8	4.8	2.1	1.5	2.5	-.3	.3
.430	.0	.7	.3	4.7	4.8	2.1	1.5	2.5	-.3	.3
.440	.0	.5	-.1	4.6	4.8	2.2	1.5	2.6	-.3	.3
.450	-.2	.3	-.2	4.5	4.8	2.2	1.5	2.6	-.3	.4
.460	-.2	.4	.0	4.5	4.8	2.2	1.5	2.7	-.4	.4
.470	-.3	.3	-.1	4.4	4.8	2.3	1.5	2.7	-.4	.4
.480	-.3	1.2	-.2	4.4	4.8	2.3	1.5	2.8	-.4	.4
.490	-.3	.2	-.1	4.4	4.7	2.4	1.5	2.8	-.4	.4
.500	-.3	.9	-.3	4.4	4.7	2.4	1.4	2.9	-.4	.4
.510	-.3	.8	.0	4.4	4.7	2.5	1.4	2.9	-.5	.4
.520	.0	.3	-.3	4.4	4.7	2.6	1.4	3.0	-.5	.5
.530	.2	.5	.0	4.5	4.7	2.6	1.4	3.0	-.5	.5
.540	-.3	.6	.0	4.5	4.7	2.7	1.4	3.0	-.5	.5

HIGHEST 50.0-MS AVG. ACCEL.

	G'S	TIME (SEC) START	END
LONG.	-7.05	.020	.070
LAT.	4.33	.016	.067

Figure 15. (Continued) Vehicle Acceleration Plot - Test RW-2

TEST ID ------- RW-2
TEST DATE ----- 05-13-94
VEHICLE CLASS - 820C
IMPACT SPEED -- 11.18 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	(----- VEHICLE	------)		(----------- OCCUPANT	-----------		)
TIME	ACCEL. (G'S)		ANG.VEL	VEL. (M/S)		DISP. (M)	
(S)	LONG.	LAT.	(RAD/S)	LONG.	LAT.	LONG.	LAT.
.000	-.53	.32	.33	.00	.00	.00	.00
.010	-4.15	1.41	.64	.09	.03	.00	.01
.020	-6.53	6.21	-3.85	.20	.19	.01	.02
.030	-4.80	3.50	7.63	.30	.48	.01	.03
.040	-8.31	4.36	-3.59	.43	.62	.01	.04
.050	-7.23	3.30	2.88	.61	.76	.02	.05
.060	-8.25	3.72	-2.39	.81	.83	.03	.05
.070	-4.28	3.27	1.42	.99	.98	.03	.06
.080	-6.64	3.23	2.99	1.15	.96	.04	.06
.090	-2.30	1.46	-1.29	1.27	1.06	.06	.06
.100	-6.12	-.74	-9.53	1.39	1.03	.07	.06
.110	-2.34	-.19	11.13	1.43	1.09	.08	.06
.120	-2.78	.55	2.94	1.53	.98	.09	.06
.130	-2.19	-1.00	3.46	1.58	.94	.11	.06
.140	-1.82	.22	2.78	1.59	.90	.12	.06
.150	-2.85	.04	.12	1.63	.92	.14	.06
.160	-1.15	.74	.27	1.67	.89	.15	.06
.170	.40	.77	2.99	1.67	.87	.17	.05
.180	.77	.00	.22	1.64	.84	.18	.05
.190	1.12	-.11	1.27	1.61	.77	.20	.05
.200	.03	.22	-.04	1.58	.74	.21	.04
.210	.31	-.36	2.00	1.57	.67	.23	.04
.220	.07	.17	1.58	1.58	.59	.24	.03
.230	-.34	.64	2.10	1.58	.54	.26	.03
.240	.44	.50	.54	1.58	.51	.27	.02
.250	.36	.10	-1.08	1.58	.45	.29	.02
.260	.04	-.37	-1.03	1.57	.40	.30	.01
.270	-.12	.23	1.11	1.58	.34	.32	.01
.280	-.12	.54	1.58	1.59	.30	.33	.00
.290	-.07	-.61	.01	1.61	.25	.35	-.01
.300	.12	.20	.33	1.59	.22	.36	-.01
.310	-.71	-.29	-.56	1.62	.16	.37	-.02
.320	.05	-.25	.33	1.65	.08	.39	-.03
.330	.63	-.26	-.04	1.65	.03	.40	-.04
.340	-.17	.24	-.30	1.66	-.01	.42	-.04
.350	.00	.63	-.72	1.66	-.02	.44	-.05

Figure 15. (Continued) Vehicle Acceleration Plot - Test RW-2

TEST ID ------- RW-2
TEST DATE ----- 05-13-94
VEHICLE CLASS - 820C
IMPACT SPEED -- 11.18 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	(----- VEHICLE	------)		(----------- OCCUPANT			-----------)
TIME (S)	ACCEL. (G'S) LONG.	LAT.	ANG.VEL (RAD/S)	VEL. (M/S) LONG.	LAT.	DISP. (M) LONG.	LAT.
.360	-.05	.50	.43	1.66	-.02	.45	-.06
.370	-.29	.19	-.46	1.66	-.03	.47	-.07
.380	-.21	.03	-.04	1.68	-.06	.48	-.08
.390	.06	.27	-.30	1.69	-.08	.50	-.09
.400	.08	.46	-.09	1.70	-.11	.51	-.10
.410	.02	.69	-.61	1.71	-.12	.53	-.10
.420	-.09	.51	.38	1.72	-.12	.54	-.11
.430	-.20	.56	.27	1.72	-.11	.56	-.12
.440	-.24	.47	-.09	1.74	-.12	.57	-.13
.450	.05	.41	-.19	1.75+	-.12	.59+	-.14
.460	-.11	.59	-.04	1.76	-.12	.61	-.15
.470	-.12	.42	-.14	1.77	-.12	.62	-.16
.480	-.32	.54	-.19	1.79	-.12	.64	-.17
.490	-.24	.58	-.09	1.79	-.10	.66	-.18
.500	-.15	.48	-.35	1.81	-.09	.67	-.19
.510	-.04	.58	.01	1.82	-.09	.69	-.20
.520	-.13	.51	-.25	1.83	-.07	.70	-.21
.530	-.22	.59	.01	1.84	-.06	.72	-.22
.540	-.13+	.52	.01	1.84	-.05	.74	-.24

OCCUP. RISK FACTORS	TIME (S)	VELOCITY (M/S)
>LONG. VEL. AFTER 0.6 M DISP. --	.456	1.75
>LAT. VEL. AFTER 0.3 M DISP. --	.550	.83

MAX. ACCEL. AFTER OCCUPANT IMPACT	TIME(S)	ACC.(GS)
>LONG. ACCELERATION --	.550	-.37

Figure 15. (Continued) Vehicle Acceleration Plot - Test RW-2

Figure 16. After Test Photographs - Test RW-2

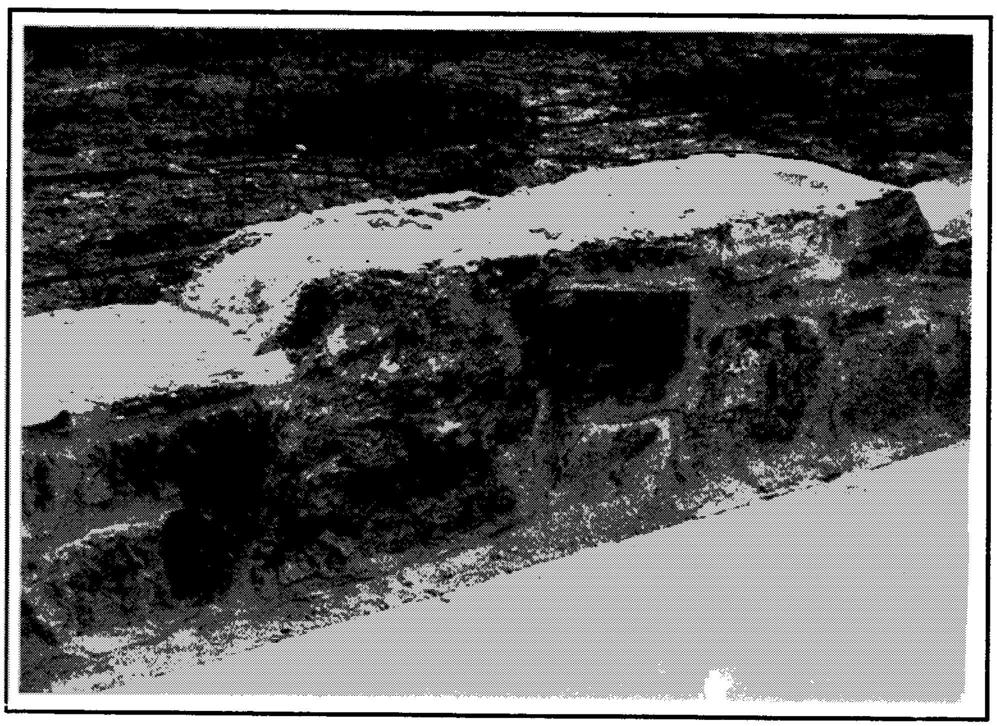


Figure 16. (Continued) After Test Photographs - Test RW-2

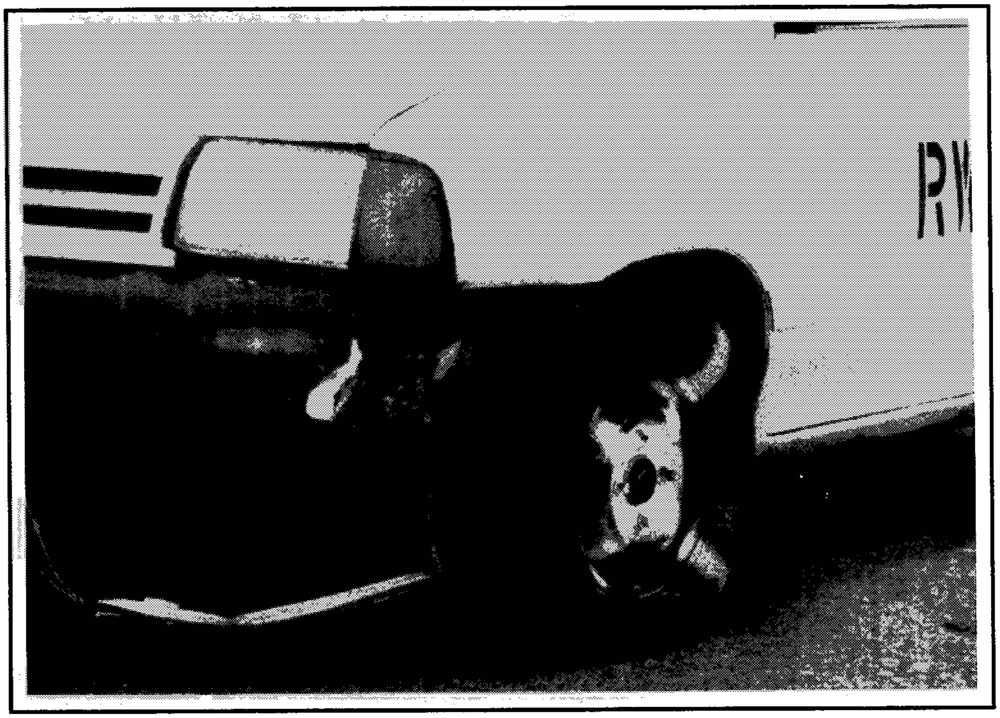


Figure 16. (Continued) After Test Photographs - Test RW-2

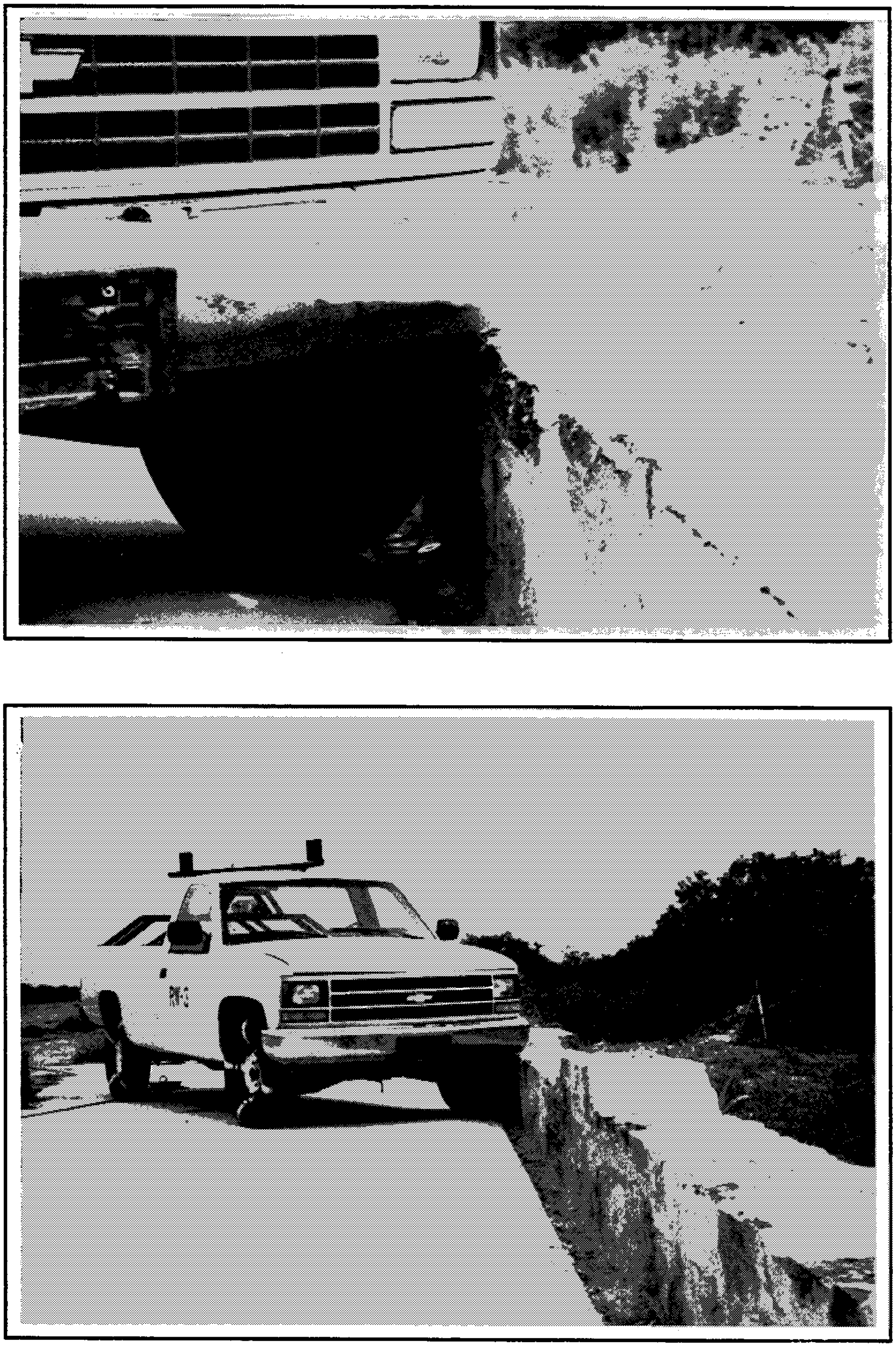


Figure 17. Before Test Photographs - Test RW-3

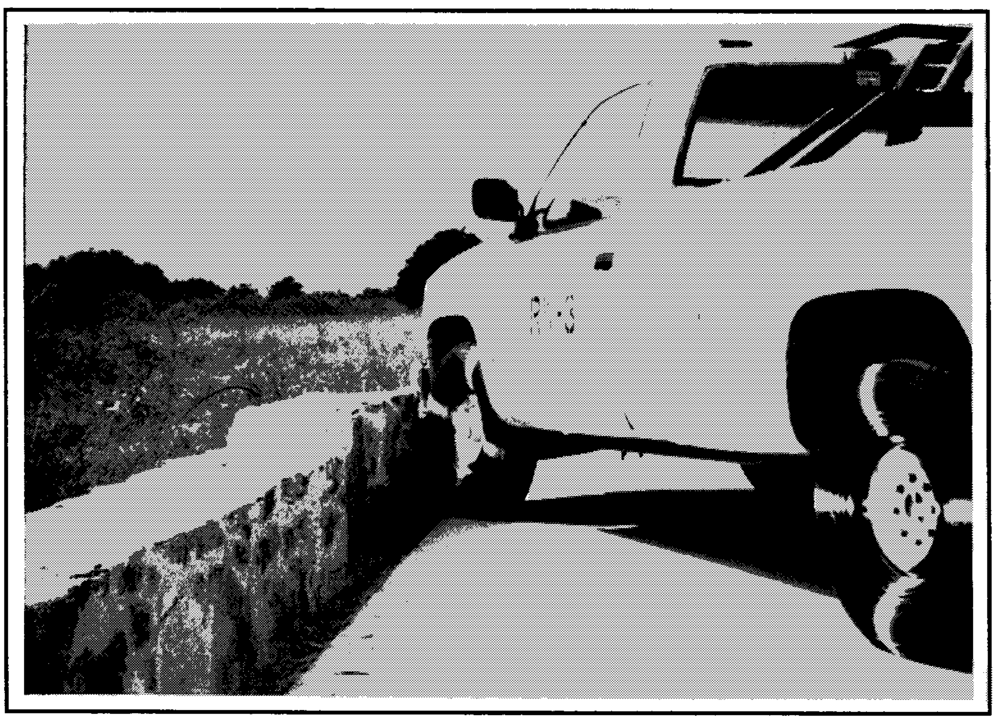


Figure 17. (Continued) Before Test Photographs - Test RW-3

Figure 17. (Continued) Before Test Photographs - Test RW-3

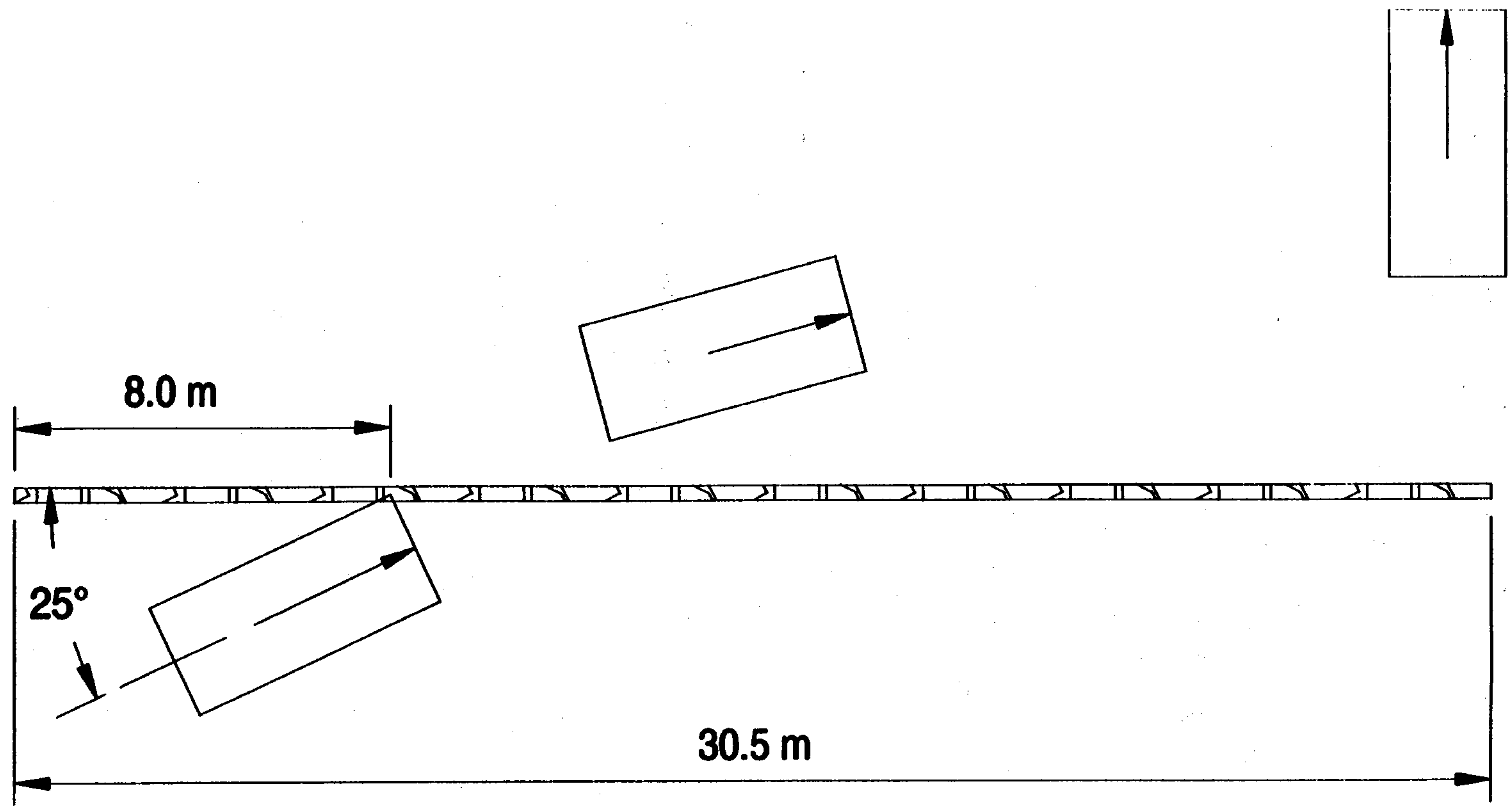


Figure 18. Test Layout - Test RW-3

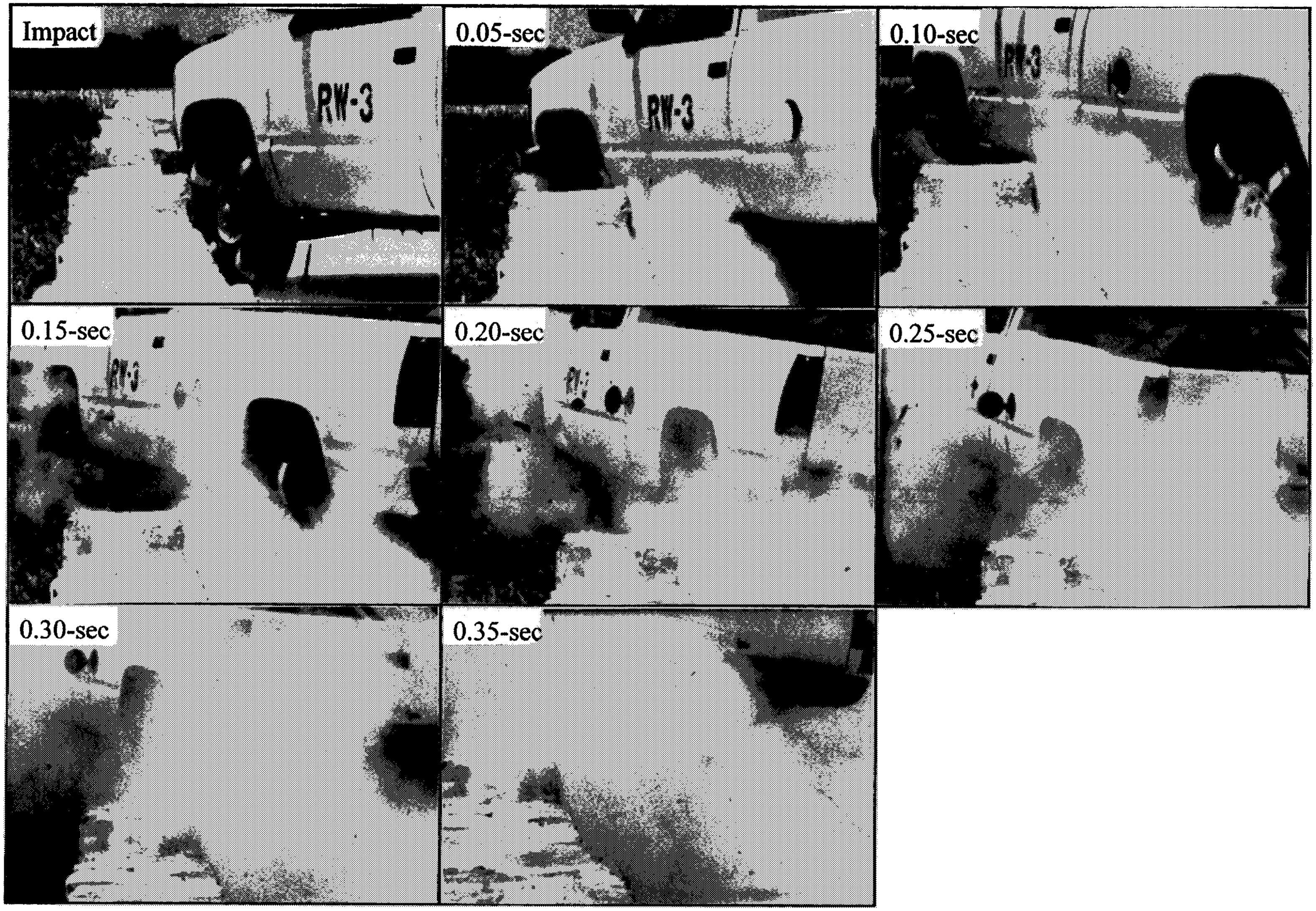


Figure 19. Sequential Photographs - Test RW-3

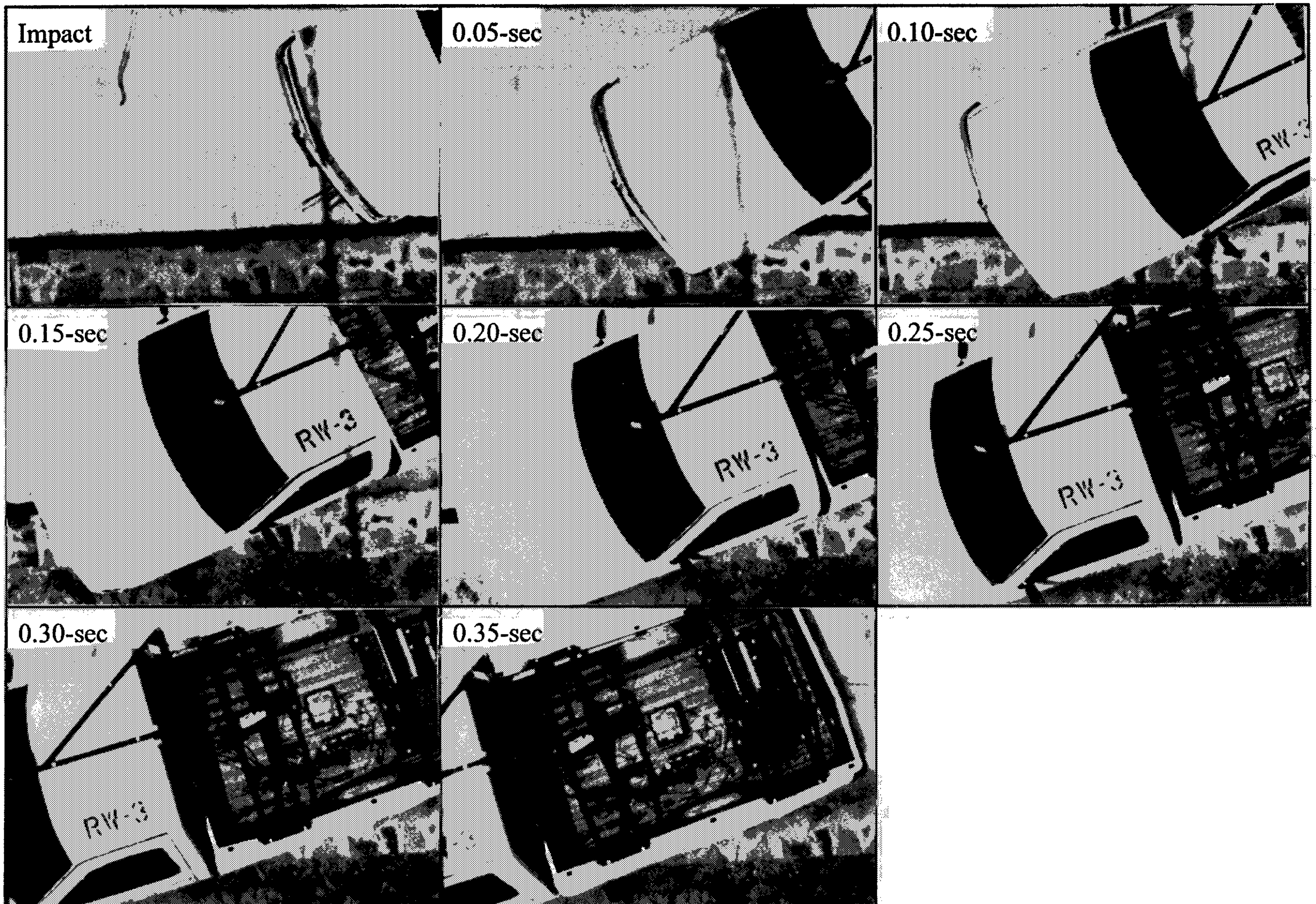
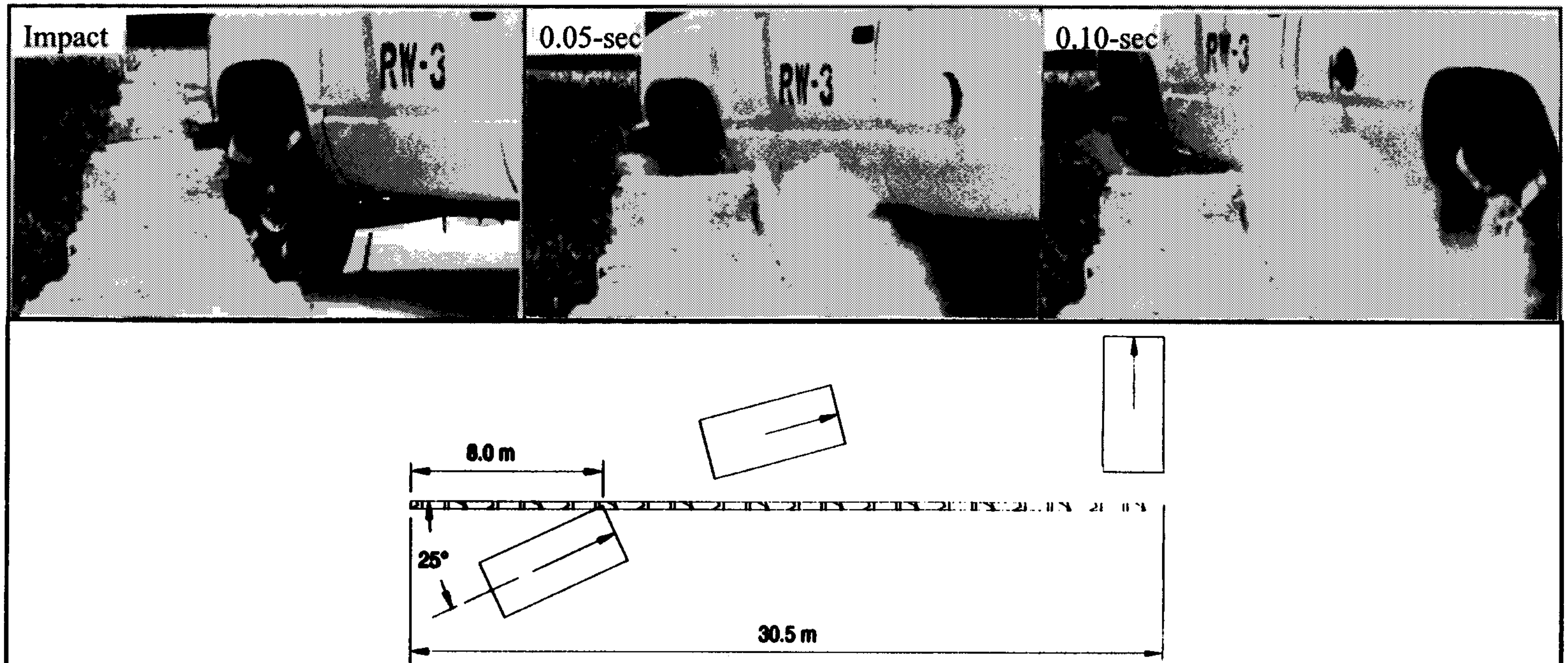


Figure 19. (Continued) Sequential Photographs - Test RW-3



4. General Information		7. Test Vehicle (Continued)			
Test Agency	Southwest Research Institute	Mass (kg) Dummy(s)	75	y-direction	6.84
Test Number	RW-3	Mass (kg) Gross Static	2,039	11. Test Article Deflection (m)	
Test Date	6/13/94	8. Impact Conditions		Dynamic	0.0
5. Test Article		Speed (km/h)	70.0	Permanent	0.0
Type	Longitudinal	Angle (deg)	25	12. Vehicle Damage	
Installation Length (m)	30.5	9. Exit Conditions		Exterior	
Barrier	Variable Height Stone Masonry Guardwall	Speed (km/h)	0	VDS	11LFQ1
6. Soil Type and Condition	Standard Soil, Dry Compacted	Angle (deg)	0	CDC	11FFEN1
7. Test Vehicle		10. Occupant Risk Values		Interior	
Type	Production Model	Impact Velocity (m/s)		OCDI	LF0112000
Designation	2000 P	x-direction	1.75	13. Post-Impact Vehicular Behavior	
Model	1989 Chevrolet C 2500	y-direction	0.78	Maximum Roll Angle (deg)	15 Estimated
Mass (kg) Curb	2,050	Ridedown Acceleration (g's)		Maximum Pitch Angle (deg)	5 Estimated
Mass (kg) Test Inertial	1,964	x-direction	-5.06	Maximum Yaw Angle (deg)	0 Estimated

Figure 20. Summary of Test Conditions and Results - Test RW-3

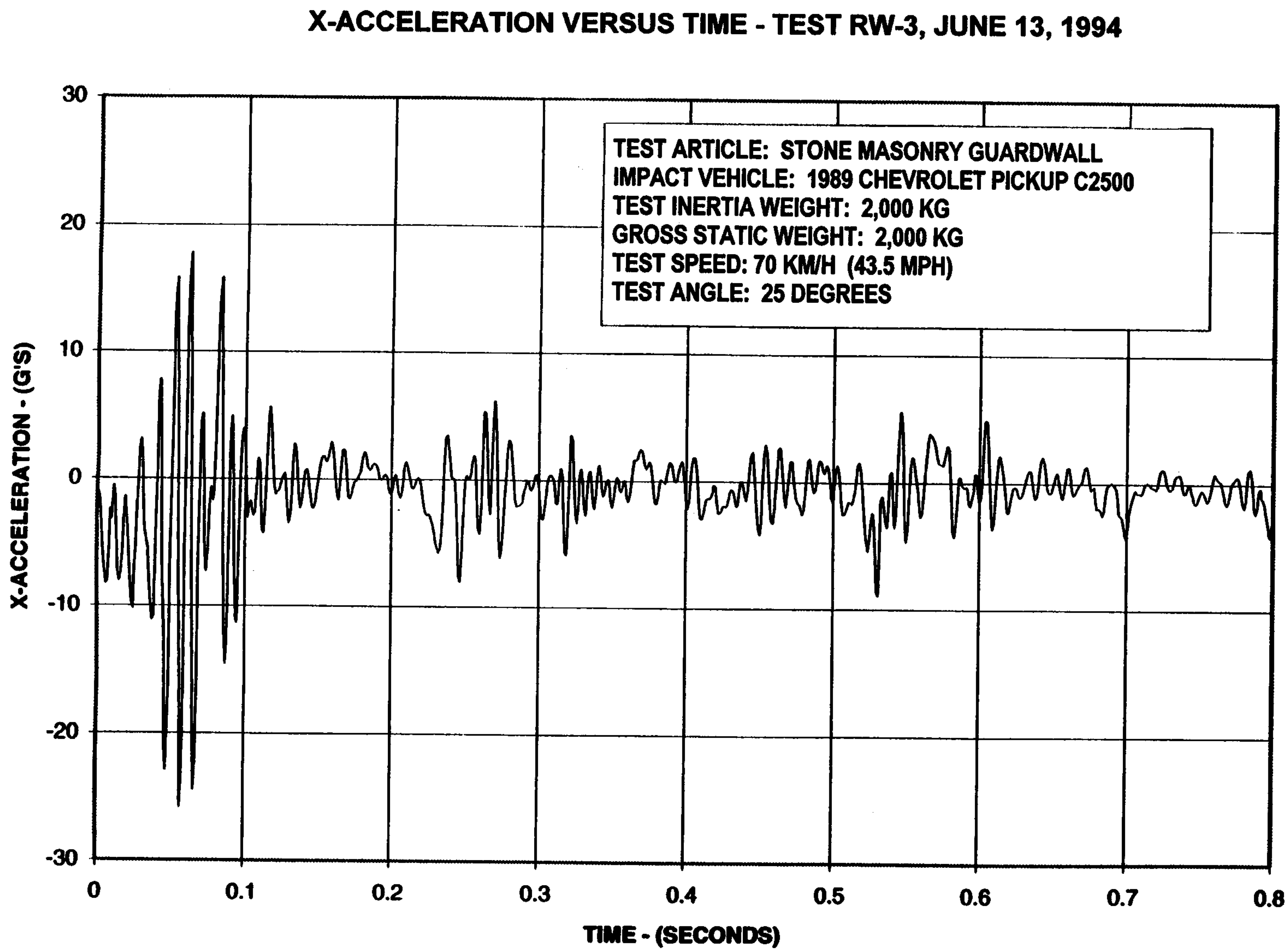


Figure 21. Vehicle Acceleration Plot - Test RW-3

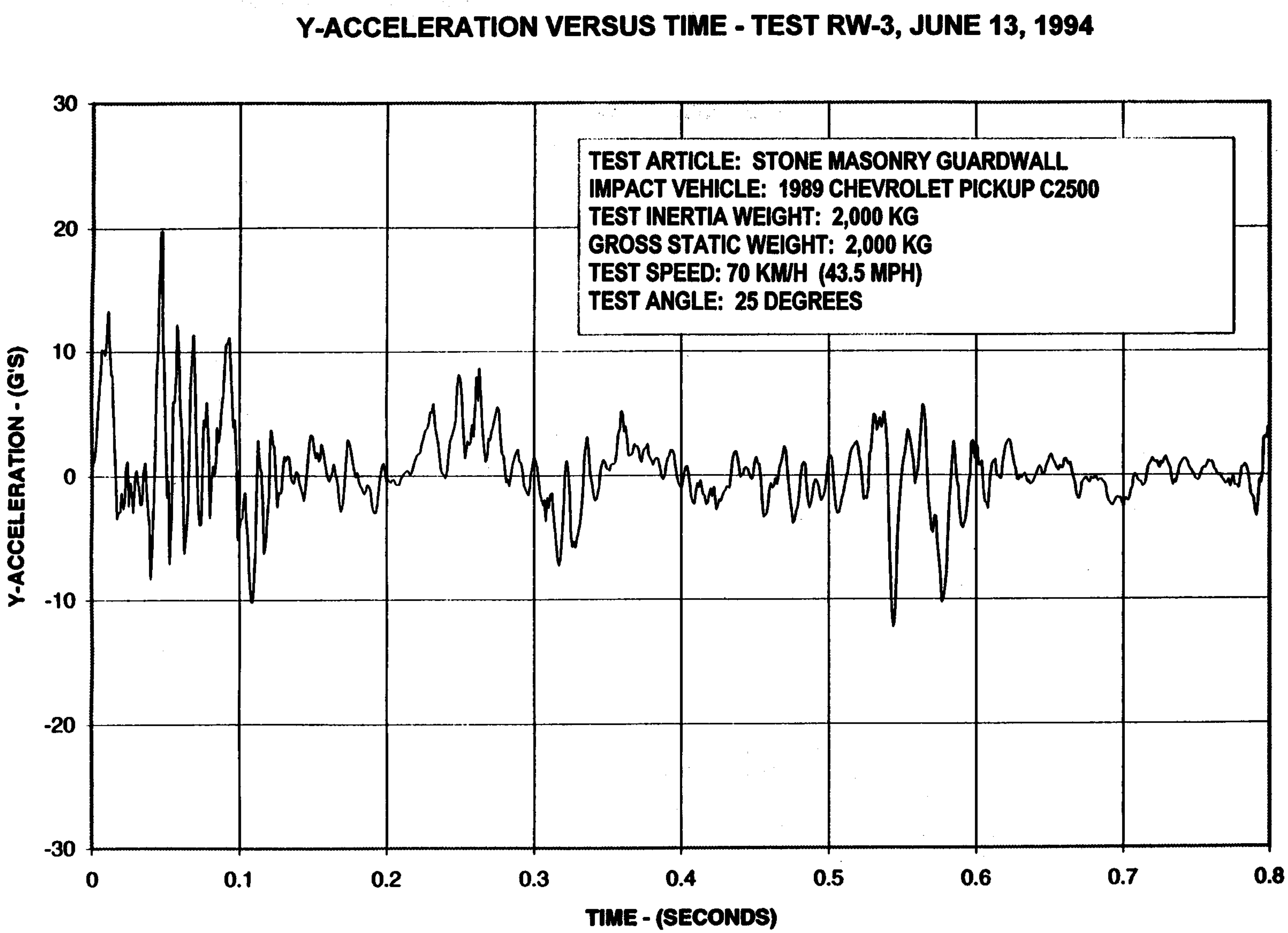


Figure 21. (Continued) Vehicle Acceleration Plot - Test RW-3

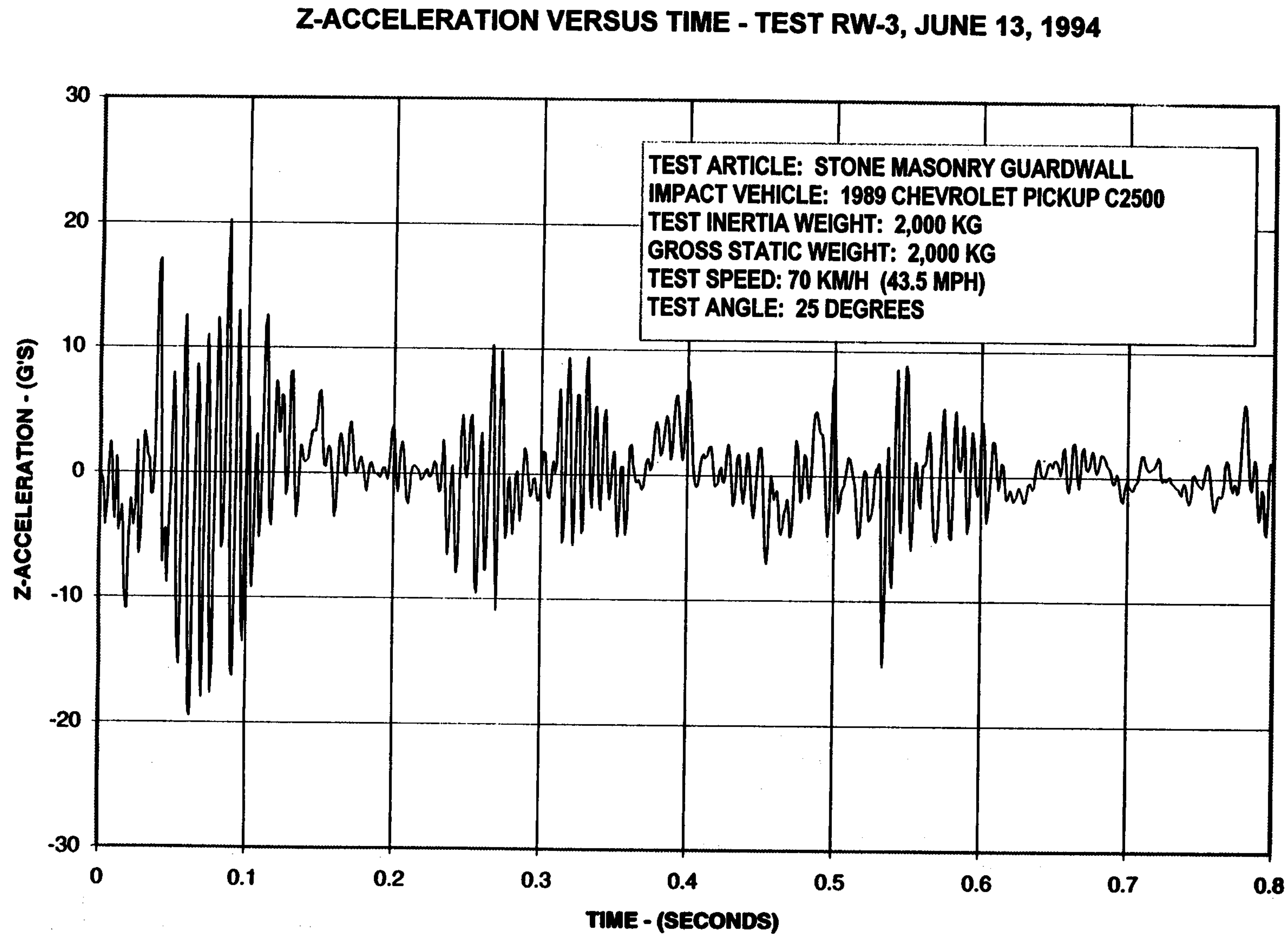


Figure 21. (Continued) Vehicle Acceleration Plot - Test RW-3

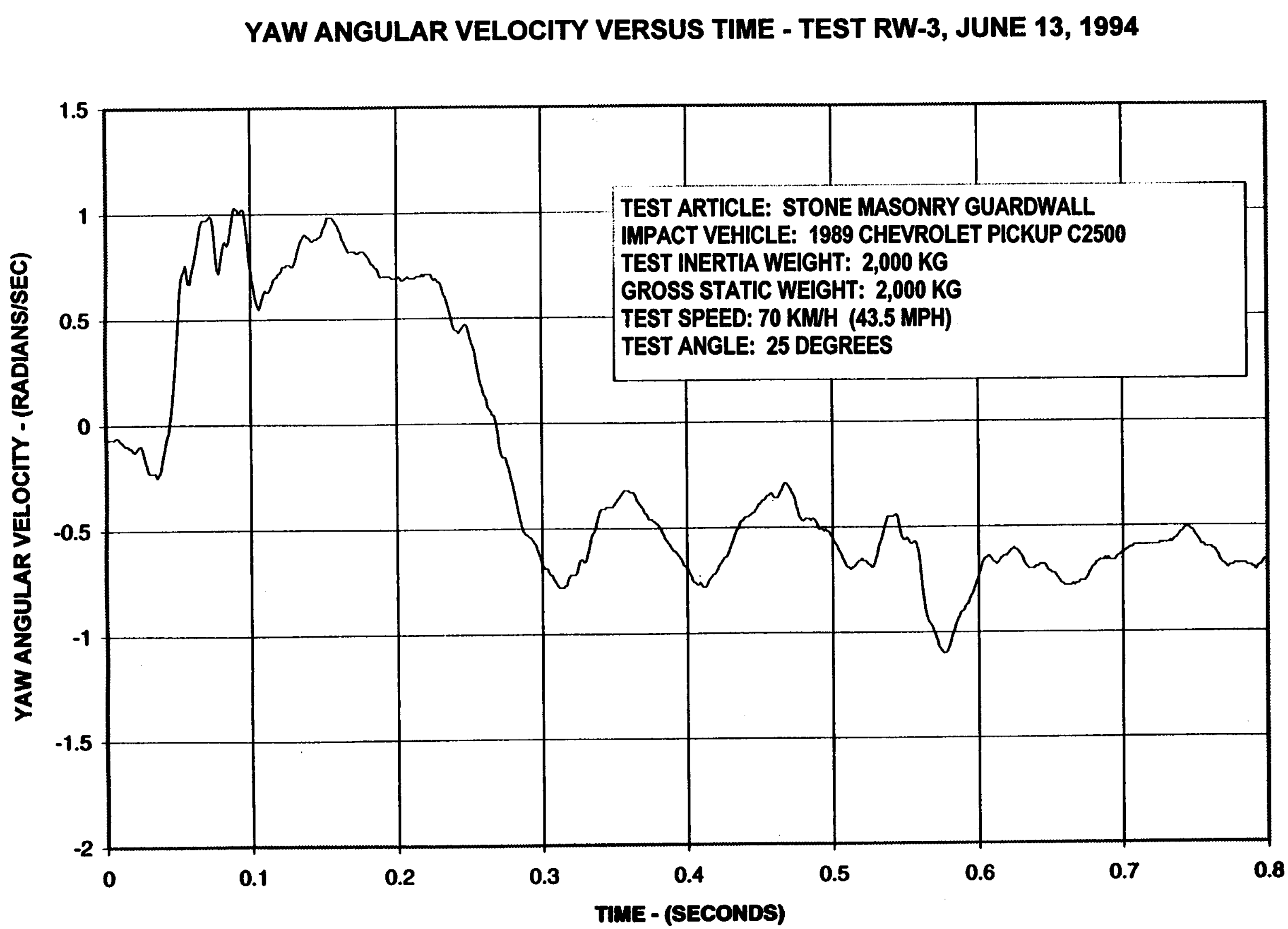


Figure 21. (Continued) Vehicle Acceleration Plot - Test RW-3

TEST ID ------- RW-3
TEST DATE ----- 06-13-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 19.44 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.000	-.8	.8	-.3	25.0	19.4	.0	.0	.0	.0	.0
.010	-3.2	10.7	-3.8	25.0	19.0	.6	-.1	.2	.1	.0
.020	-3.0	-1.4	-5.8	25.1	18.6	1.0	-.6	.3	.2	.0
.030	1.6	.5	3.3	25.2	18.2	.9	-.8	.5	.2	.0
.040	.0	-8.3	17.1	25.3	17.5	.8	-.5	.7	.3	.0
.050	.7	3.4	7.9	25.3	16.8	1.5	-.5	.8	.4	.0
.060	6.8	5.2	-9.9	24.9	16.5	1.7	-.7	1.0	.4	.0
.070	4.2	7.4	-18.0	24.3	16.1	1.8	-1.4	1.2	.5	.0
.080	2.9	-3.4	12.4	23.8	16.0	1.7	-1.7	1.3	.5	-.1
.090	2.9	9.1	-15.9	23.3	16.1	1.9	-1.4	1.5	.6	-.1
.100	2.2	-4.2	3.4	22.8	15.9	2.2	-1.7	1.6	.6	-.1
.110	1.0	-8.5	-3.2	22.4	15.8	1.6	-1.9	1.8	.7	-.1
.120	-.6	-1.8	7.3	22.0	15.9	1.3	-1.5	1.9	.7	-.1
.130	-3.5	.6	8.0	21.6	15.8	1.2	-1.2	2.1	.7	-.1
.140	-.5	.2	.9	21.1	15.8	1.1	-1.0	2.2	.8	-.1
.150	-.2	3.1	6.6	20.6	15.7	1.0	-.7	2.4	.8	-.2
.160	2.6	-.2	-3.5	20.1	15.9	1.0	-.6	2.5	.9	-.2
.170	-.6	-2.6	3.4	19.6	15.9	.8	-.5	2.7	.9	-.2
.180	1.4	.3	-.1	19.1	15.9	.7	-.4	2.8	1.0	-.2
.190	1.0	-2.4	-.2	18.7	16.0	.5	-.4	3.0	1.0	-.2
.200	-1.2	-.6	3.8	18.3	16.0	.3	-.3	3.2	1.1	-.2
.210	1.3	-.3	-2.5	17.9	16.0	.1	-.3	3.3	1.1	-.2
.220	-.4	1.3	-.5	17.5	16.0	.0	-.3	3.5	1.2	-.2
.230	-5.0	5.2	-.6	17.1	15.7	.2	-.3	3.6	1.2	-.2
.240	1.1	-.2	.6	16.8	15.6	.4	-.5	3.8	1.3	-.2
.250	-.2	7.8	-.4	16.5	15.3	.7	-.6	3.9	1.3	-.2
.260	-4.3	5.7	3.3	16.3	15.3	1.0	-.7	4.1	1.3	-.2
.270	6.2	2.8	-10.9	16.3	15.4	1.4	-.8	4.2	1.4	-.2
.280	3.2	.3	-2.6	16.4	15.3	1.8	-.8	4.4	1.4	-.2
.290	-1.0	1.1	1.7	16.7	15.2	1.9	-1.0	4.5	1.4	-.2
.300	-.6	1.5	-.9	17.0	15.2	2.0	-1.1	4.7	1.4	-.2
.310	.1	-2.6	.1	17.4	15.1	2.0	-1.1	4.8	1.5	-.2
.320	-3.1	-2.3	5.6	17.8	14.9	1.7	-.8	5.0	1.5	-.3
.330	-.4	-4.5	1.6	18.2	14.9	1.5	-.9	5.1	1.5	-.3
.340	.4	-1.5	-2.0	18.5	14.7	1.5	-.5	5.3	1.6	-.3
.350	-2.1	.5	1.9	18.8	14.7	1.6	-.5	5.4	1.6	-.3

Figure 21. (Continued) Vehicle Acceleration Plot - Test RW-3

TEST ID ------- RW-3
TEST DATE ----- 06-13-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 19.44 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.360	-1.3	4.8	-.6	19.0	14.6	1.8	-.7	5.5	1.6	-.3
.370	2.3	2.4	-1.0	19.2	14.7	2.1	-.7	5.7	1.6	-.3
.380	-1.8	1.2	3.7	19.4	14.8	2.4	-.5	5.8	1.7	-.3
.390	1.3	.9	1.9	19.7	14.8	2.5	-.2	6.0	1.7	-.3
.400	-1.4	-1.0	7.0	20.1	14.8	2.7	.1	6.1	1.7	-.3
.410	-3.0	-1.3	1.5	20.5	14.7	2.7	.3	6.3	1.8	-.3
.420	-.4	-1.1	-.8	21.0	14.6	2.7	.5	6.4	1.8	-.3
.430	-.9	-1.2	-.3	21.3	14.4	2.6	.5	6.6	1.8	-.3
.440	-1.3	-.2	.8	21.6	14.3	2.7	.4	6.7	1.8	-.3
.450	-4.2	1.0	2.2	21.9	14.2	2.8	.4	6.9	1.9	-.3
.460	-2.2	-1.1	-1.4	22.1	14.1	2.7	.2	7.0	1.9	-.3
.470	.4	2.3	-4.9	22.3	14.1	2.8	-.1	7.1	1.9	-.3
.480	-2.2	-1.7	1.7	22.5	14.0	2.7	-.2	7.3	1.9	-.3
.490	1.2	-.7	3.7	22.8	14.0	2.7	.0	7.4	2.0	-.3
.500	-1.6	1.4	7.8	23.1	14.1	2.7	.1	7.6	2.0	-.3
.510	-1.8	-1.5	1.5	23.4	14.0	2.6	.1	7.7	2.0	-.3
.520	-.5	2.2	-.3	23.8	13.9	2.8	.0	7.8	2.1	-.3
.530	-8.6	3.3	.4	24.2	13.5	2.9	-.1	8.0	2.1	-.3
.540	.9	2.3	-8.9	24.5	13.2	3.4	-.6	8.1	2.1	-.3
.550	-4.7	.2	8.0	24.8	13.2	2.9	-.4	8.2	2.2	-.3
.560	-2.8	-.1	-.5	25.1	13.1	3.1	-.5	8.4	2.2	-.3
.570	2.6	-4.5	-5.3	25.6	13.3	3.4	-.5	8.5	2.2	-.3
.580	.6	-8.0	-5.0	26.2	13.4	2.9	-.6	8.6	2.2	-.3
.590	-.4	-4.1	-1.6	26.8	13.3	2.9	-.4	8.8	2.3	-.3
.600	-1.5	2.0	2.8	27.3	13.2	2.9	-.4	8.9	2.3	-.3
.610	-3.2	.1	1.3	27.6	13.2	3.0	-.4	9.0	2.3	-.3
.620	-2.3	2.3	-1.0	28.0	13.2	3.1	-.4	9.2	2.4	-.3
.630	-.7	.0	-2.0	28.4	13.1	3.3	-.6	9.3	2.4	-.3
.640	-.2	-.2	.8	28.8	13.1	3.4	-.6	9.4	2.4	-.3
.650	-.3	1.5	1.3	29.2	13.1	3.5	-.5	9.6	2.5	-.3
.660	1.2	1.3	-1.2	29.6	13.0	3.7	-.5	9.7	2.5	-.3
.670	.2	-2.0	2.4	30.0	13.0	3.8	-.4	9.8	2.5	-.3
.680	-2.0	-.4	.6	30.5	13.0	3.8	-.2	10.0	2.6	-.3
.690	.1	-2.1	-.5	30.8	12.8	3.9	-.1	10.1	2.6	-.4
.700	-4.4	-2.6	-.3	31.2	12.6	3.7	-.2	10.2	2.6	-.4
.710	-.8	-.4	1.8	31.6	12.4	3.7	-.2	10.3	2.7	-.4

Figure 21. (Continued) Vehicle Acceleration Plot - Test RW-3

TEST ID ------- RW-3
TEST DATE ----- 06-13-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 19.44 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.720	-.5	1.3	1.3	31.9	12.4	3.8	-.1	10.5	2.7	-.4
.730	-.5	1.0	-.3	32.2	12.4	3.9	-.1	10.6	2.7	-.4
.740	-.8	1.0	-.7	32.6	12.4	4.0	-.2	10.7	2.8	-.4
.750	-.7	-.4	-.6	32.9	12.3	4.1	-.3	10.8	2.8	-.4
.760	.8	1.0	-2.7	33.2	12.2	4.2	-.3	11.0	2.8	-.4
.770	-.9	-.8	.2	33.6	12.1	4.3	-.4	11.1	2.9	-.4
.780	-1.9	-.3	5.9	33.9	12.1	4.3	-.3	11.2	2.9	-.4
.790	-.5	-2.9	-3.4	34.3	12.0	4.4	-.2	11.3	2.9	-.4

HIGHEST 50.0-MS AVG. ACCEL.

	G'S	TIME (SEC) START	END
LONG.	-5.38	.000	.050
LAT.	4.33	.044	.094

Figure 21. (Continued) Vehicle Acceleration Plot - Test RW-3

TEST ID ------- RW-3
TEST DATE ----- 06-13-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 19.44 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

TIME	(----- VEHICLE	------)		(----------- OCCUPANT			-----------)
	ACCEL. (G'S)		ANG.VEL	VEL. (M/S)		DISP. (M)	
(S)	LONG.	LAT.	(RAD/S)	LONG.	LAT.	LONG.	LAT.
.000	-.77	.79	-.29	.00	.00	.00	.00
.010	-5.01	9.24	-3.78	.14	.19	.01	.02
.020	-6.15	-1.29	-5.79	.30	.32	.01	.05
.030	-2.46	-1.26	3.28	.47	.31	.02	.07
.040	-4.24	-.74	17.11	.61	.28	.03	.09
.050	-3.44	5.95	7.93	.51	.41	.04	.11
.060	-4.54	3.26	-9.94	.49	.41	.05	.12
.070	-8.04	2.87	-18.03	.48	.36	.05	.14
.080	4.18	1.91	12.36	.60	.32	.06	.15
.090	-6.00	7.42	-15.91	.46	.28	.07	.17
.100	-1.13	-.87	3.36	.65	.37	.08	.18
.110	-1.50	-4.69	-3.21	.74	.15	.09	.19
.120	1.22	-.83	7.35	.67	-.01	.10	.20
.130	-.37	-.11	8.01	.67	-.08	.11	.21
.140	-.49	-.69	.86	.62	-.17	.12	.22
.150	-.20	1.73	6.57	.61	-.26	.14	.24
.160	.93	.76	-3.55	.55	-.32	.15	.25
.170	.11	-.27	3.42	.59	-.42	.16	.26
.180	.89	.08	-.11	.60	-.48	.17	.27
.190	.62	-1.85	-.21	.61	-.58	.18	.28
.200	-.33	-.06	3.78	.61	-.69	.19	.29
.210	-.11	-.21	-2.48	.62	-.77*	.21	.30*
.220	-1.18	1.26	-.47	.60	-.84	.22	.31
.230	-4.20	4.12	-.60	.70	-.82	.23	.32
.240	.58	1.33	.65	.85	-.78	.25	.33
.250	-2.52	4.70	-.39	.95	-.71	.26	.34
.260	.71	4.98	3.28	1.09	-.61	.27	.34
.270	-.33	3.22	-10.93	1.16	-.46	.29	.35
.280	-.08	1.39	-2.64	1.30	-.31	.30	.36
.290	-1.18	.69	1.67	1.45	-.22	.32	.37
.300	-1.21	-.23	-.86	1.54	-.15	.33	.37
.310	-.36	-2.72	.10	1.63	-.10	.35	.38
.320	-.98	-3.33	5.63	1.68	-.16	.36	.39
.330	-1.14	-3.35	1.56	1.65	-.18	.38	.40
.340	-.58	-.17	-2.01	1.57	-.16	.39	.41
.350	-.64	.81	1.88	1.57	-.13	.41	.43

Figure 21. (Continued) Vehicle Acceleration Plot - Test RW-3

TEST ID ------- RW-3
TEST DATE ----- 06-13-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 19.44 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	(----- VEHICLE	------)		(----------- OCCUPANT			-----------)
TIME	ACCEL. (G'S)		ANG.VEL	VEL. (M/S)		DISP. (M)	
(S)	LONG.	LAT.	(RAD/S)	LONG.	LAT.	LONG.	LAT.
.360	-.42	3.17	-.63	1.51	.01	.45	.41
.370	1.70	1.91	-1.04	1.51	.15	.47	.42
.380	-.34	1.53	3.68	1.52	.27	.48	.43
.390	.50	.87	1.93	1.56	.38	.50	.44
.400	.10	.06	6.96	1.58	.50	.51	.45
.410	-1.13	-1.21	1.51	1.63	.58	.52	.46
.420	-1.51	-1.84	-.81	1.67	.60	.54	.48
.430	-1.49	-1.13	-.29	1.70	.58	.55	.49
.440	-.21	.80	.78	1.69	.60	.57	.50
.450	-.54	.26	2.22	1.69	.63	.58	.51
.460	-.20	-1.77	-1.41	1.71+	.62	.60+	.52
.470	-.09	.24	-4.93	1.69	.64	.61	.53
.480	-.78	-1.41	1.72	1.77	.68	.63	.54
.490	.53	-1.38	3.68	1.78	.71	.64	.56
.500	.19	-.35	7.80	1.78	.76	.66	.57
.510	-1.78	-1.25	1.49	1.85	.83	.67	.58
.520	-1.54+	1.14	-.26	1.86	.92	.69	.60
.530	-4.13	2.25	.36	1.98	.99	.70	.61
.540	-1.38	-1.75	-8.92	2.02	1.11	.72	.63
.550	.60	-1.41	8.03	2.05	1.01	.74	.64
.560	-.17	2.19	-.47	2.10	1.15	.75	.65
.570	2.56	-2.11*	-5.27	2.16	1.38	.77	.67
.580	-.34	-5.27	-5.04	2.13	1.31	.78	.69
.590	-.58	-2.00	-1.64	2.13	1.32	.80	.71
.600	.75	1.22	2.79	2.11	1.32	.81	.73
.610	.07	-.61	1.25	2.07	1.35	.83	.75
.620	-.77	1.50	-1.04	2.07	1.43	.84	.77
.630	-.23	.03	-2.04	2.10	1.53	.86	.79
.640	.41	-.09	.75	2.12	1.60	.88	.81
.650	-.10	.86	1.30	2.12	1.70	.89	.83
.660	-.19	.79	-1.23	2.15	1.82	.90	.85
.670	.31	-.85	2.42	2.16	1.89	.92	.87
.680	-1.44	-.35	.55	2.14	1.92	.93	.89
.690	-.58	-1.62	-.47	2.17	1.95	.95	.91
.700	-2.69	-1.95	-.29	2.22	1.95	.96	.93
.710	-.50	-.58	1.80	2.26	1.96	.98	.95

Figure 21. (Continued) Vehicle Acceleration Plot - Test RW-3

TEST ID ------- RW-3
TEST DATE ----- 06-13-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 19.44 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	VEHICLE			OCCUPANT			
TIME (S)	ACCEL. (G'S) LONG.	LAT.	ANG.VEL (RAD/S)	VEL. (M/S) LONG.	LAT.	DISP. (M) LONG.	LAT.
.720	.13	.71	1.28	2.27	2.01	.99	.97
.730	.13	.54	-.29	2.26	2.09	1.01	.99
.740	-.25	.62	-.73	2.24	2.14	1.02	1.01
.750	-1.10	.04	-.60	2.28	2.21	1.04	1.03
.760	-.05	.65	-2.66	2.32	2.29	1.05	1.05
.770	-.54	-.45	.23	2.35	2.38	1.07	1.07
.780	-.21	-.14	5.95	2.37	2.43	1.08	1.09
.790	-1.27	-1.50	-3.42	2.40	2.49	1.10	1.11

OCCUP. RISK FACTORS	TIME (S)	VELOCITY (M/S)
>LONG. VEL. AFTER 0.6 M DISP. --	.472	1.75
>LAT. VEL. AFTER 0.3 M DISP. --	.211	.78

MAX. ACCEL. AFTER OCCUPANT IMPACT	TIME(S)	ACC.(GS)
>LONG. ACCELERATION --	.527	-5.06
>LAT. ACCELERATION --	.576	6.84

Figure 21. (Continued) Vehicle Acceleration Plot - Test RW-3

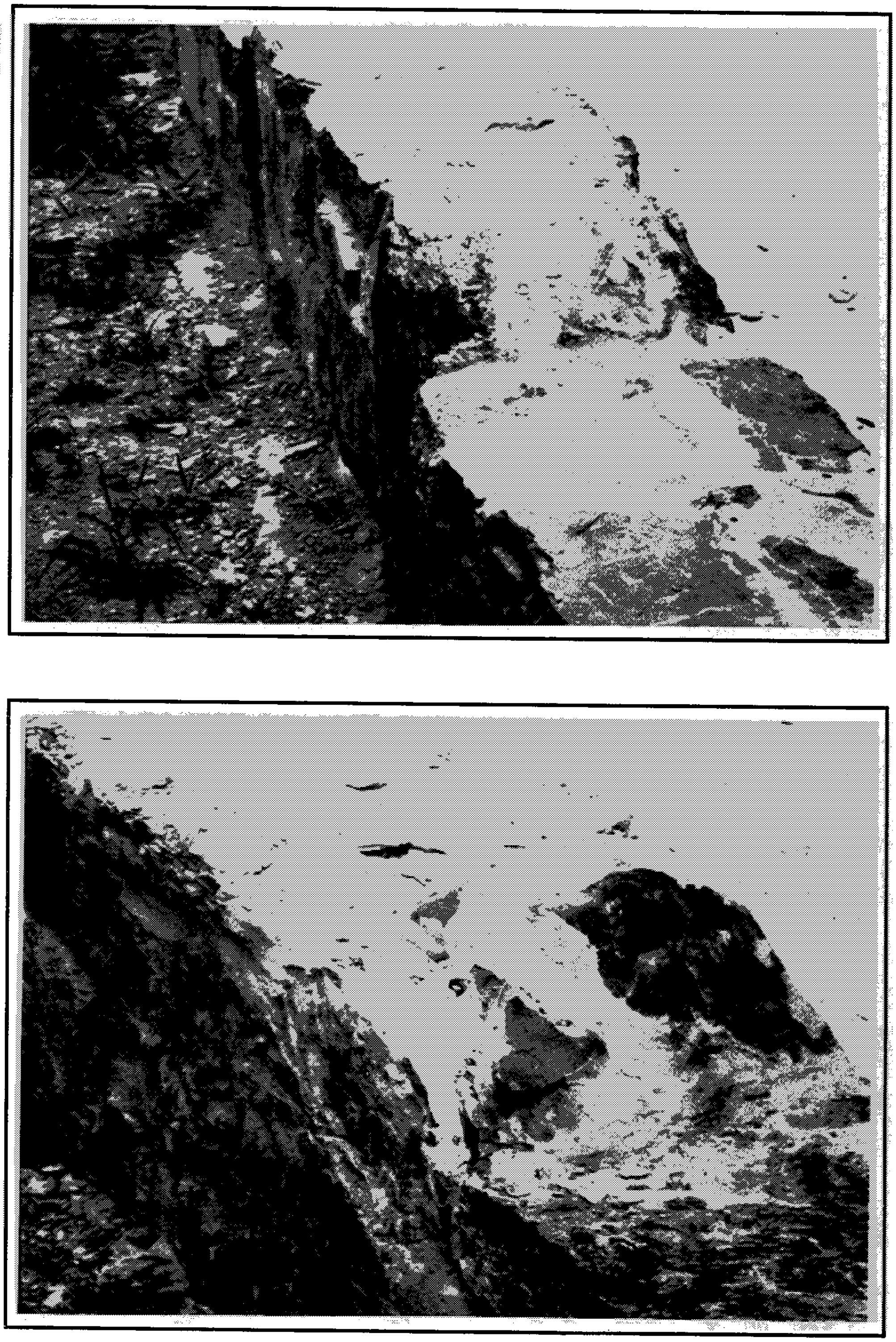


Figure 22. After Test Photographs - Test RW-3

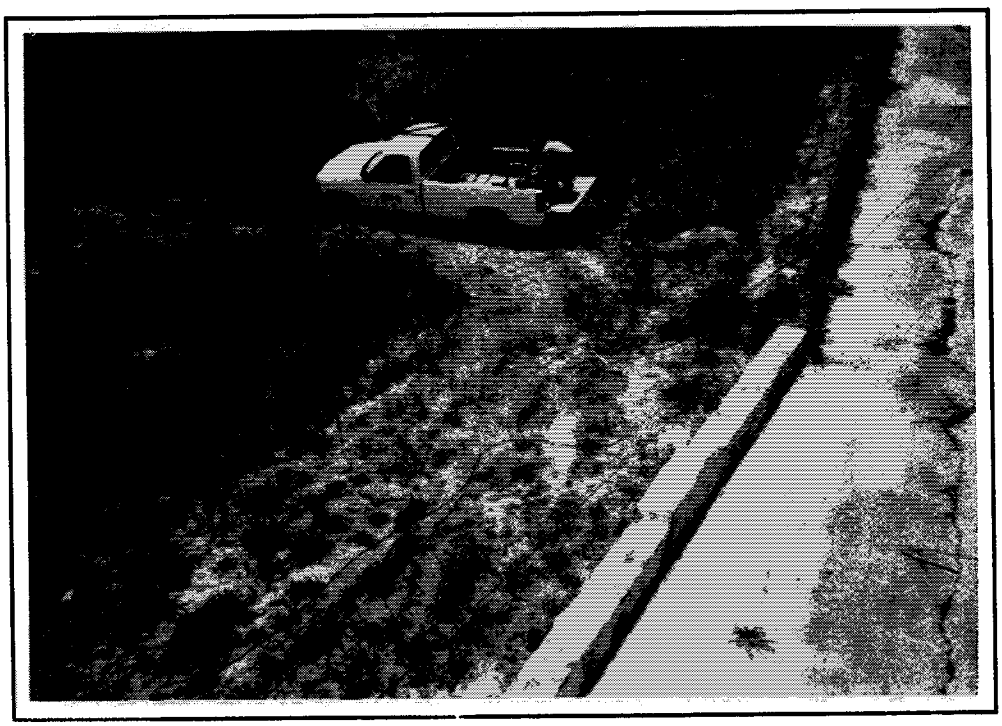


Figure 22. (Continued) After Test Photographs - Test RW-3

Figure 22. (Continued) After Test Photographs - Test RW-3

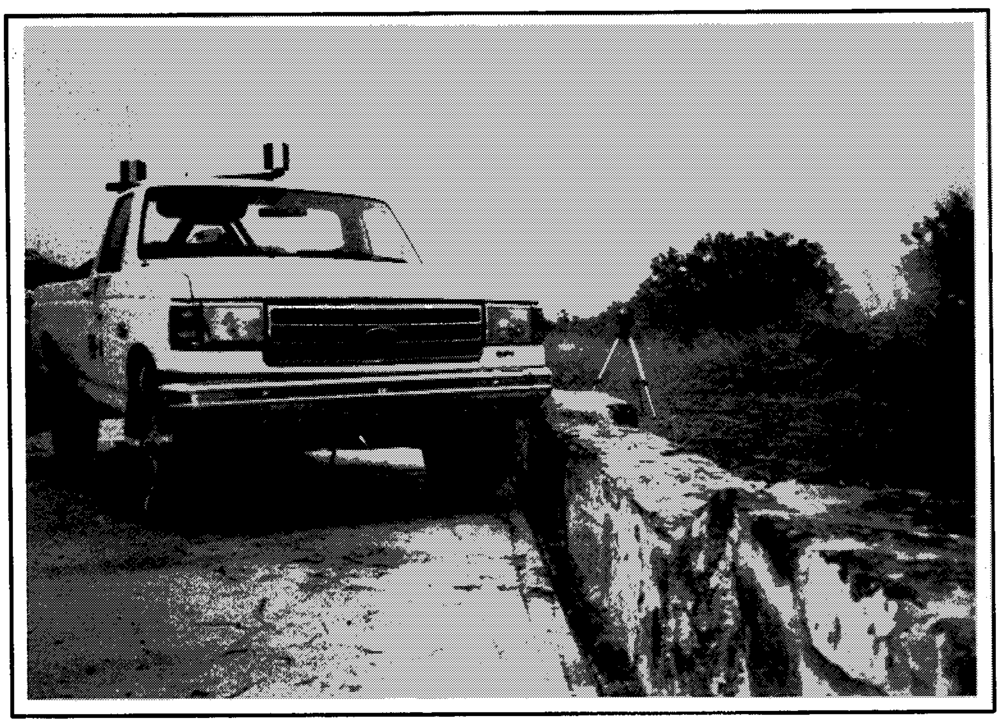


Figure 23. Before Test Photographs - Test RW-4

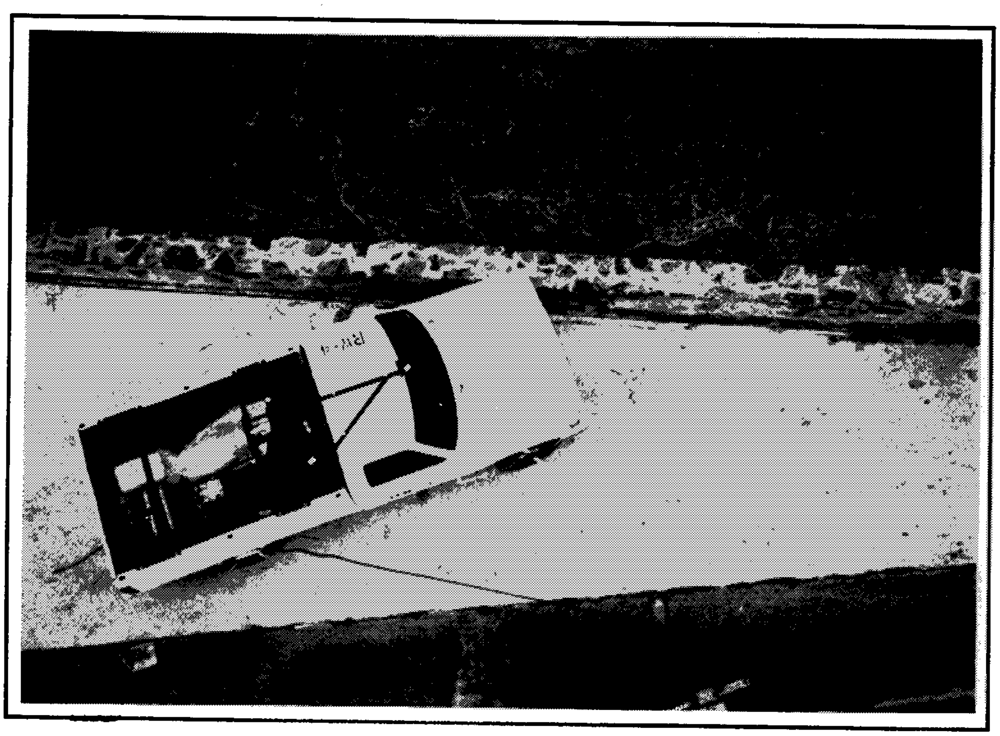


Figure 23. (Continued) Before Test Photographs - Test RW-4

Figure 23. (Continued) Before Test Photographs - Test RW-4

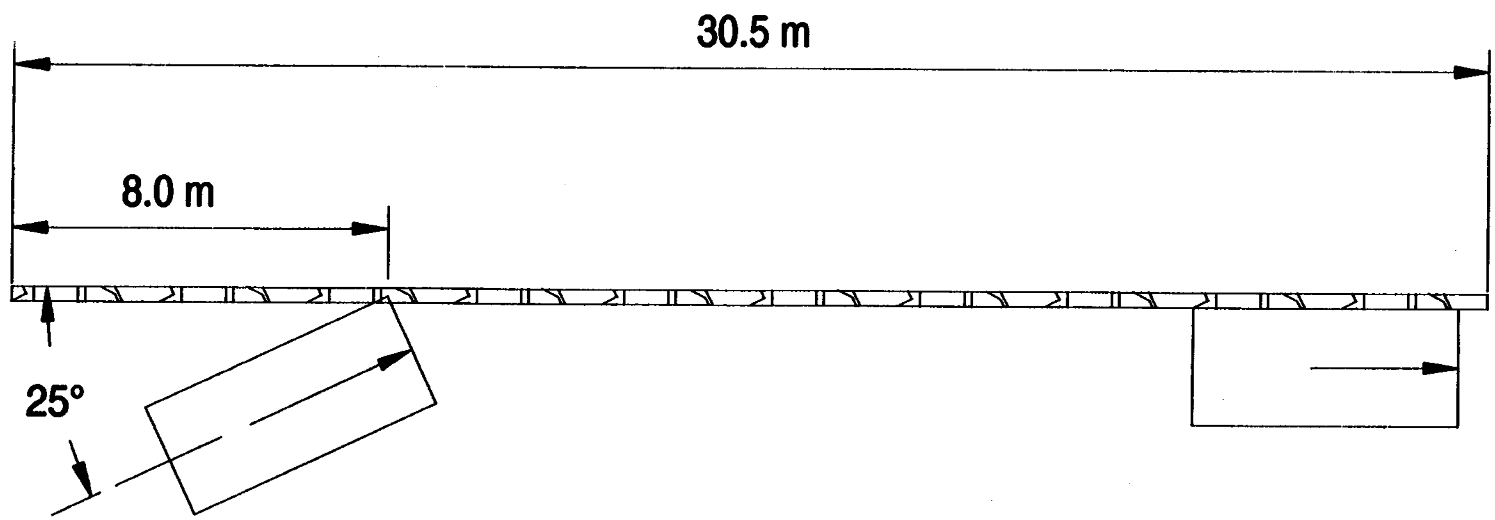


Figure 24. Test Layout - Test RW-4

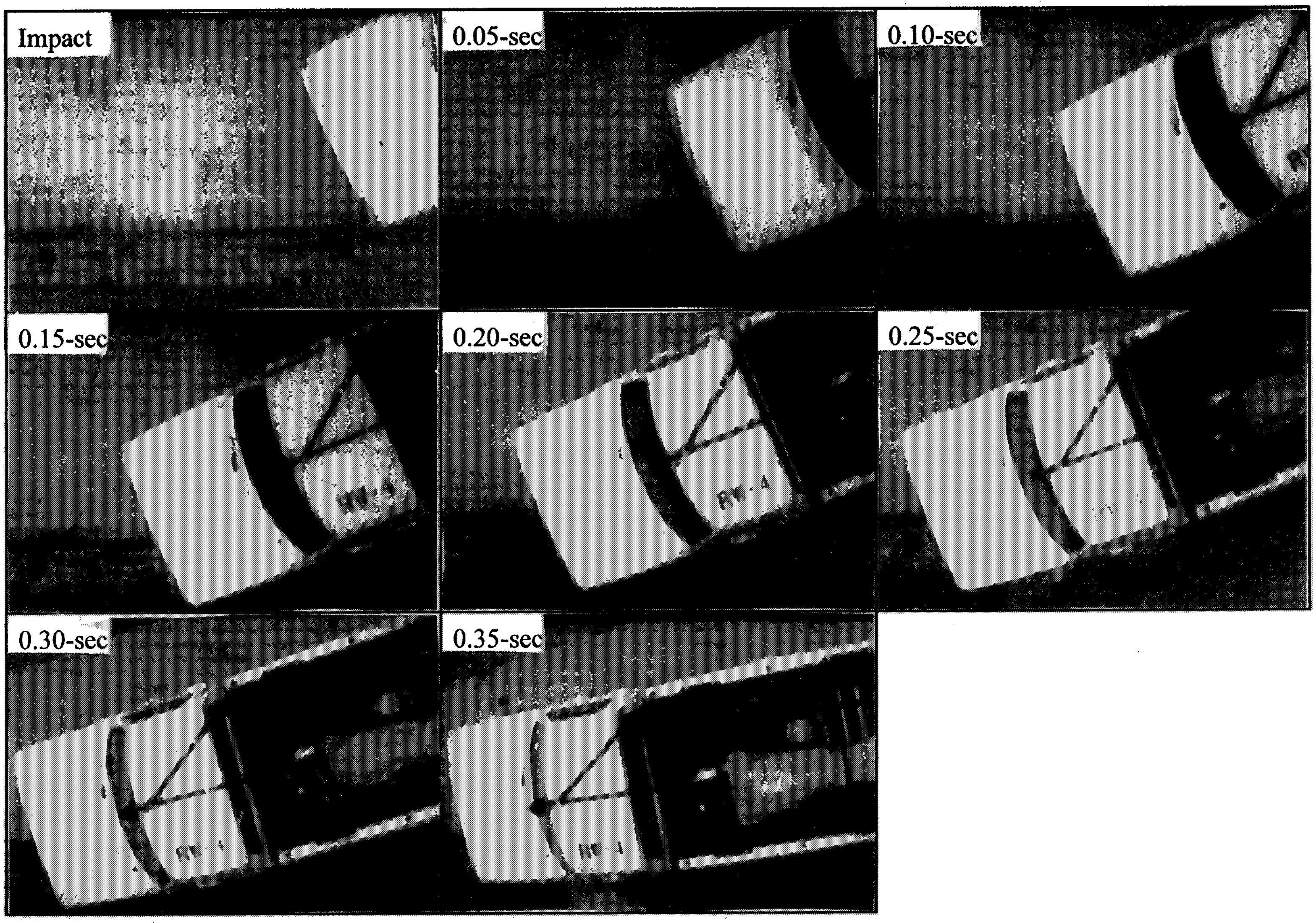


Figure 25. Sequential Photographs - Test RW-4

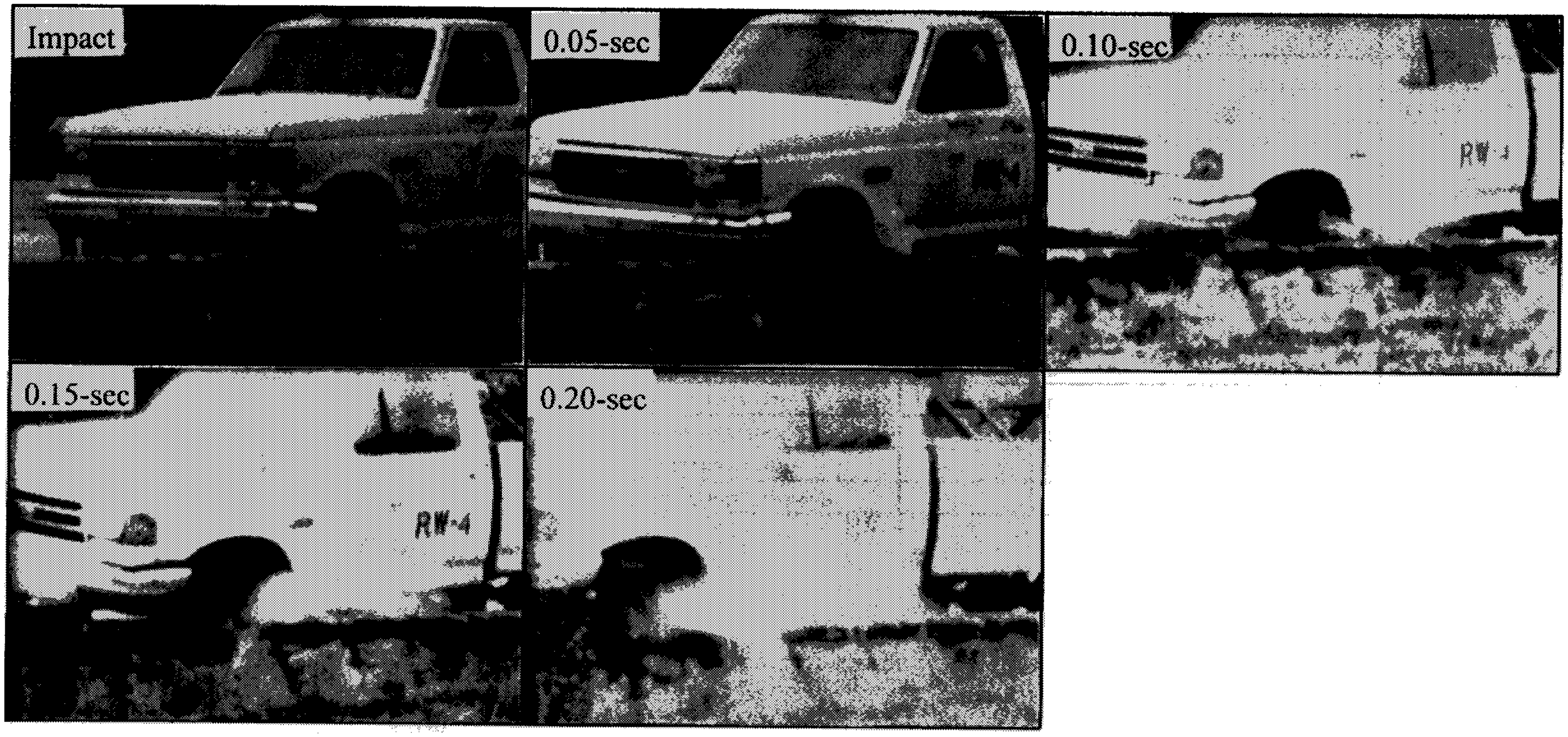
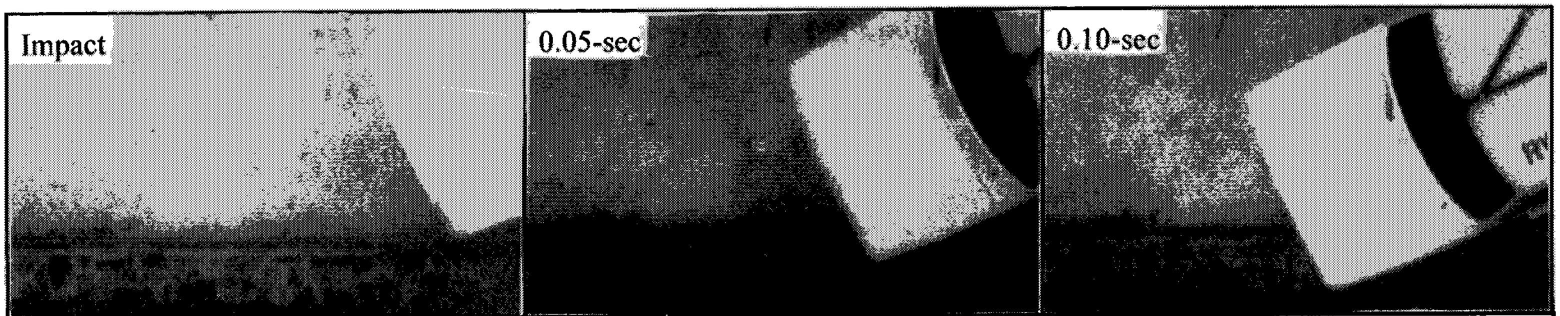
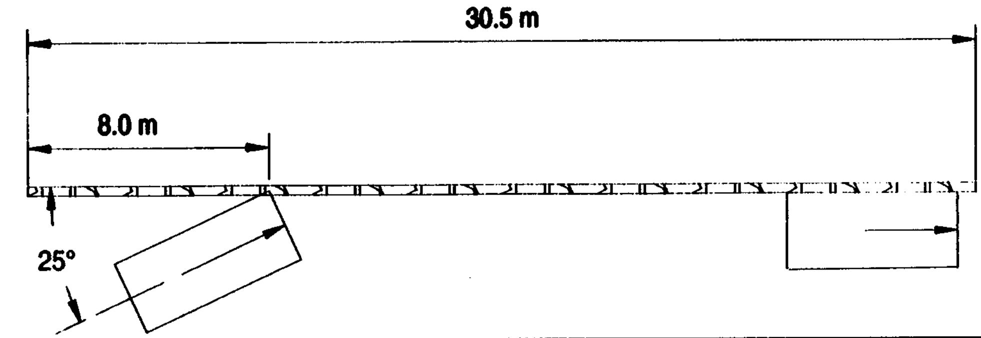


Figure 25. (Continued) Sequential Photographs - Test RW-4





4. General Information		**7. Test Vehicle (Continued)**			
Test Agency	Southwest Research Institute	Mass (kg) Dummy(s)	75	y-direction	
Test Number	RW-4	Mass (kg) Gross Static	2,039	**11. Test Article Deflection (m)**	
Test Date	8/9/94	**8. Impact Conditions**		Dynamic	0.3
5. Test Article		Speed (km/h)	50	Permanent	0.2
Type	Longitudinal	Angle (deg)	25	**12. Vehicle Damage**	
Installation Length (m)	30.5	**9. Exit Conditions**		Exterior	
Barrier	Variable Height Stone Masonry Guardwall	Speed (km/h)	0	VDS	11LFQ1
6. Soil Type and Condition	Standard Soil, Dry Compacted	Angle (deg)	0	CDC	11FFEN1
7. Test Vehicle		**10. Occupant Risk Values**		Interior	
Type	Production Model	Impact Velocity (m/s)		OCDI	LF0112000
Designation	2000 P	x-direction	1.44	**13. Post-Impact Vehicular Behavior**	
Model	1989 Ford F250	y-direction	1.18	Maximum Roll Angle (deg)	15 Estimated
Mass (kg) Curb	2,050	Ridedown Acceleration (g's)		Maximum Pitch Angle (deg)	5 Estimated
Mass (kg) Test Inertial	1,965	x-direction	-1.87	Maximum Yaw Angle (deg)	0 Estimated

Figure 26. Summary of Test Conditions and Results - Test RW-4

X-ACCELERATION VERSUS TIME - TEST RW-4, AUG. 9, 1994

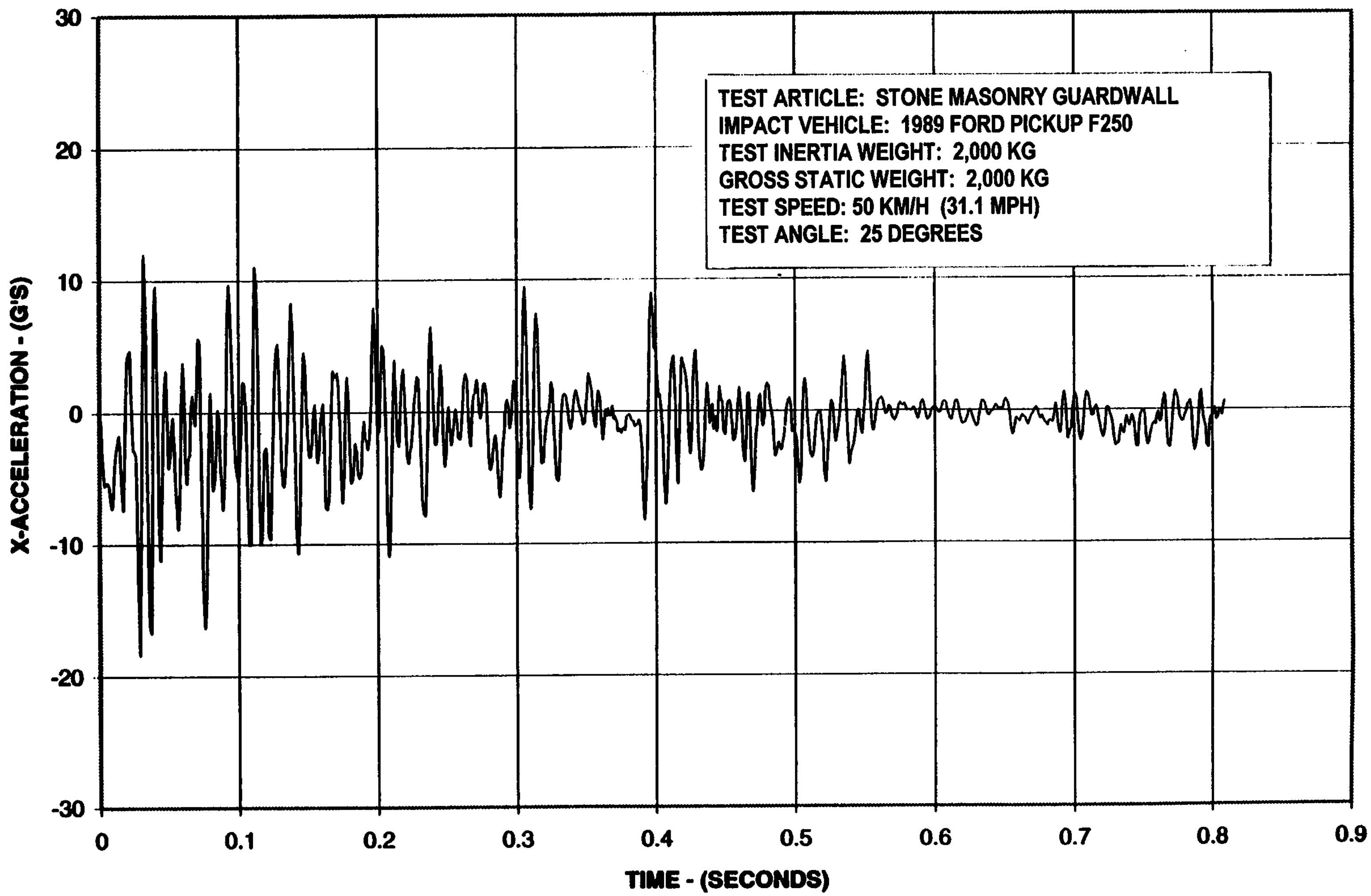


Figure 27. Vehicle Acceleration Plot - Test RW-4

Y-ACCELERATION VERSUS TIME - TEST RW-4, AUG. 9, 1994

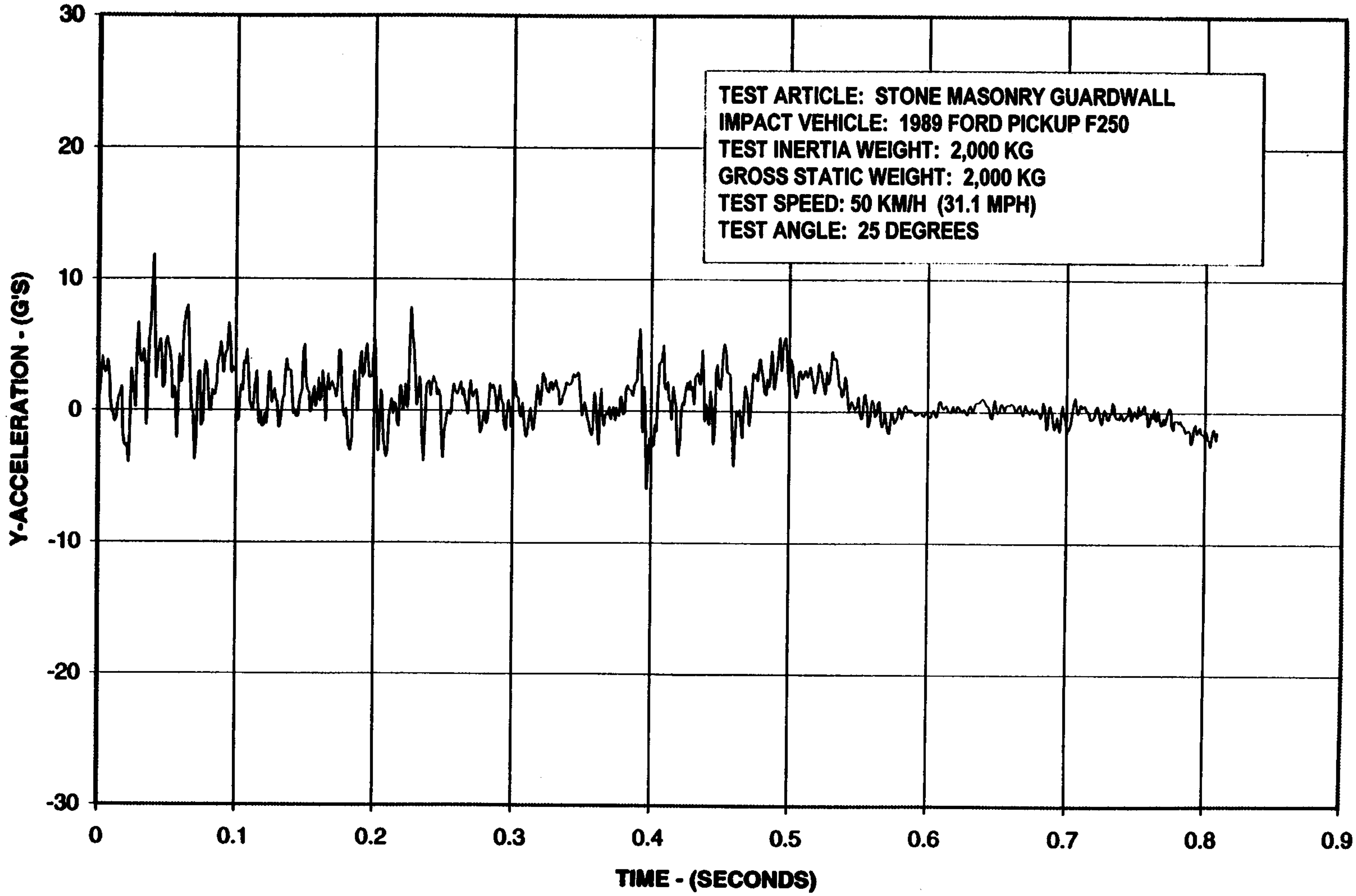


Figure 27. (Continued) Vehicle Acceleration Plot - Test RW-4

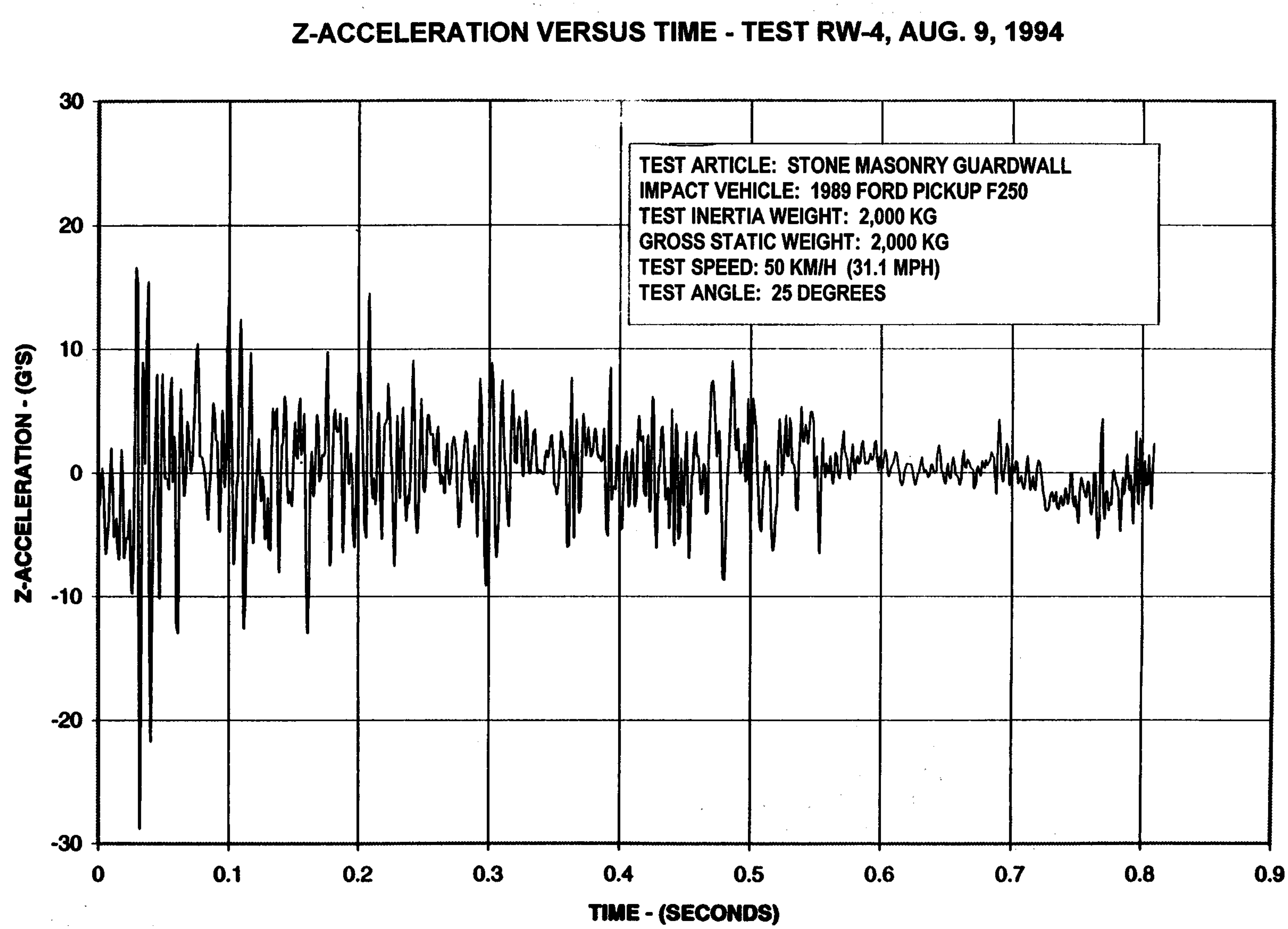


Figure 27. (Continued) Vehicle Acceleration Plot - Test RW-4

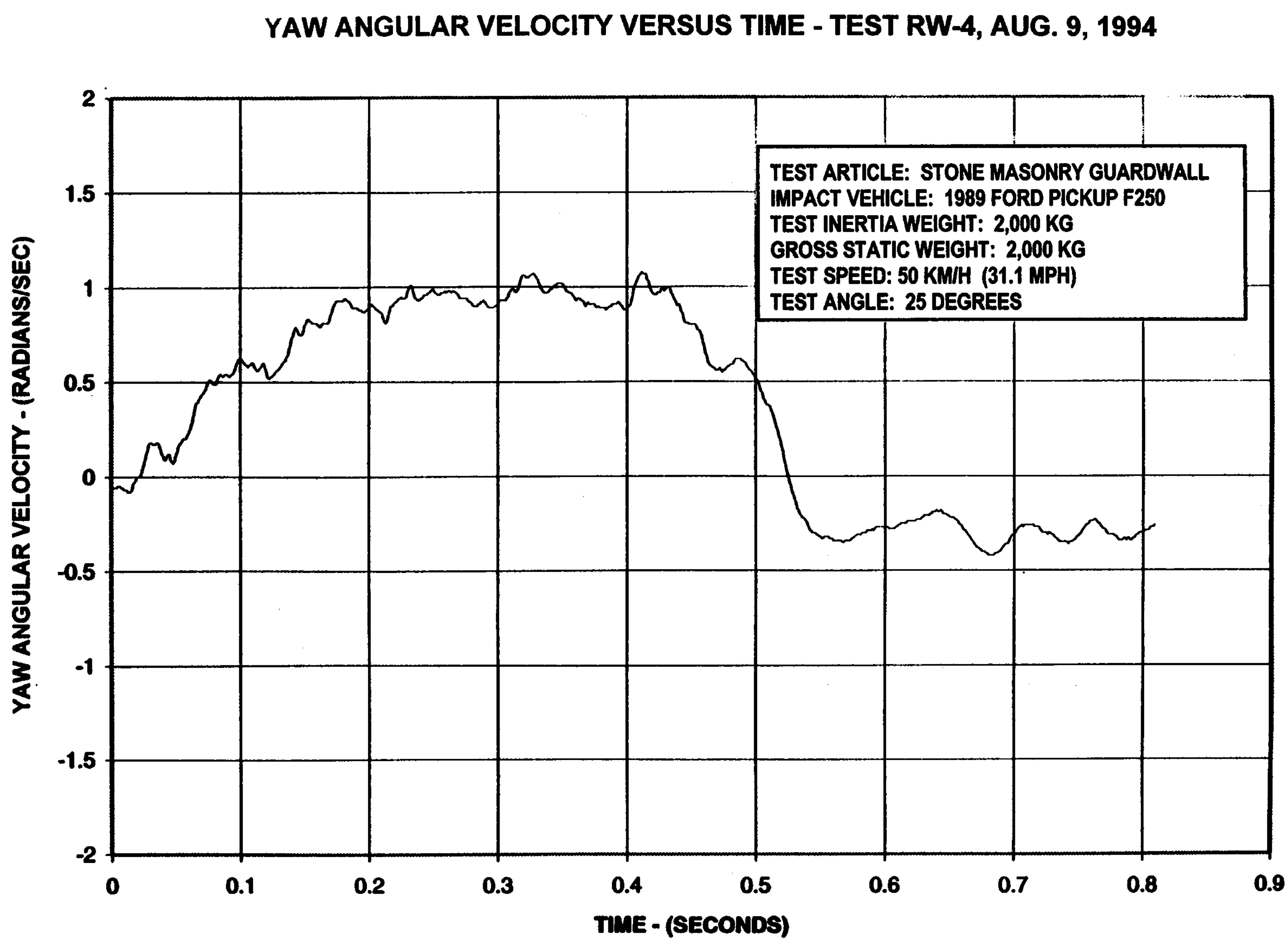


Figure 27. (Continued) Vehicle Acceleration Plot - Test RW-4

TEST ID ------- RW-4
TEST DATE ----- 08-09-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 16.72 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.000	-.3	.6	-1.4	25.0	16.7	.0	.0	.0	.0	.0
.010	-5.8	-.1	2.0	25.0	16.3	.3	-.2	.2	.1	.0
.020	4.1	-2.8	-6.9	25.1	16.0	.2	-.5	.3	.1	.0
.030	-8.3	4.7	15.2	25.0	15.5	.3	-.7	.4	.2	.0
.040	9.6	11.9	-21.8	24.9	15.4	.8	-.9	.6	.3	.0
.050	-4.2	5.6	4.2	24.9	15.2	1.2	-1.1	.7	.3	.0
.060	3.8	2.1	-12.1	24.8	14.9	1.4	-1.0	.9	.4	.0
.070	2.0	-3.7	1.6	24.6	14.8	1.7	-1.0	1.0	.4	-.1
.080	1.5	1.9	1.1	24.3	14.3	1.8	-.6	1.2	.5	-.1
.090	-5.8	4.7	2.7	24.0	14.0	1.9	-.5	1.3	.5	-.1
.100	-5.3	2.9	14.3	23.7	14.1	2.3	-.3	1.4	.5	-.1
.110	-3.4	.9	8.7	23.3	13.8	2.4	.0	1.6	.6	-.1
.120	-2.7	-1.2	-3.5	23.0	13.8	2.3	-.1	1.7	.6	-.1
.130	-.8	.8	-2.0	22.7	13.6	2.4	-.3	1.8	.6	-.1
.140	1.4	3.1	-1.4	22.3	13.6	2.4	-.3	2.0	.7	-.1
.150	-1.8	5.1	2.1	21.9	13.4	2.4	-.3	2.1	.7	-.1
.160	.1	2.5	-9.8	21.4	13.3	2.5	.0	2.2	.7	-.1
.170	2.7	2.3	-.7	21.0	13.1	2.5	-.2	2.4	.7	-.1
.180	-2.4	.2	1.0	20.4	13.1	2.6	-.1	2.5	.8	-.1
.190	-.6	3.9	4.5	19.9	12.7	2.5	.1	2.6	.8	-.1
.200	-1.2	4.8	8.1	19.4	12.8	2.7	.1	2.8	.8	-.1
.210	-4.3	-2.8	-.6	18.9	12.7	2.6	.5	2.9	.8	-.1
.220	-1.1	1.9	4.0	18.4	12.7	2.5	.4	3.0	.8	-.1
.230	.1	3.0	4.7	17.9	12.7	2.7	.6	3.1	.9	-.1
.240	.2	2.3	-.4	17.3	12.6	2.6	.6	3.3	.9	-.1
.250	-.4	-3.6	-1.4	16.8	12.5	2.6	.7	3.4	.9	-.1
.260	-1.4	1.3	3.0	16.2	12.4	2.5	.9	3.5	.9	-.1
.270	1.4	2.3	-1.0	15.7	12.5	2.5	1.0	3.7	.9	.0
.280	-3.6	.0	1.1	15.1	12.6	2.4	1.0	3.8	.9	.0
.290	-2.7	.9	-1.0	14.6	12.2	2.4	1.1	3.9	.9	.0
.300	-1.4	.6	2.8	14.1	12.3	2.3	.9	4.0	.9	.0
.310	-7.4	-1.9	7.5	13.5	12.3	2.2	1.1	4.2	.9	.0
.320	-2.5	.5	.8	13.0	12.3	2.1	1.3	4.3	.9	.0
.330	-5.3	1.9	.8	12.4	12.3	2.1	1.5	4.4	1.0	.0
.340	-.6	2.1	.1	11.8	12.2	2.2	1.6	4.5	1.0	.0
.350	.1	-.3	-.9	11.2	12.3	2.2	1.8	4.7	1.0	.1

Figure 27. (Continued) Vehicle Acceleration Plot - Test RW-4

TEST ID ------- RW-4
TEST DATE ----- 08-09-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 16.72 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME (S)	---ACCEL. (G'S)--- LONG.	LAT.	VERT.	HEAD. ANG(D)	--VELOCITY (MPS)-- LONG.	LAT.	VERT.	-----DISP. (M)---- X	Y	Z
.360	1.1	1.1	-6.0	10.7	12.4	2.1	1.8	4.8	1.0	.1
.370	-.6	.3	-2.7	10.1	12.4	2.0	1.8	4.9	1.0	.1
.380	-.4	-.2	2.2	9.6	12.3	1.9	2.0	5.0	1.0	.1
.390	-2.8	2.4	-4.6	9.1	12.2	1.9	2.1	5.2	1.0	.1
.400	4.6	-2.1	-2.3	8.6	12.3	1.8	2.2	5.3	1.0	.2
.410	.6	1.9	2.0	8.0	12.2	1.8	2.1	5.4	1.0	.2
.420	3.5	-3.4	-1.9	7.4	12.3	1.7	2.2	5.5	1.0	.2
.430	1.7	1.9	.6	6.9	12.4	1.7	2.2	5.7	1.0	.2
.440	.4	.6	5.2	6.3	12.3	1.8	2.2	5.8	1.0	.2
.450	-1.8	1.7	1.2	5.8	12.3	1.7	2.1	5.9	1.0	.3
.460	1.8	-4.2	1.4	5.4	12.3	1.9	2.1	6.0	1.0	.3
.470	-6.2	.9	7.2	5.1	12.2	1.8	2.1	6.1	.9	.3
.480	2.1	3.0	-8.7	4.7	12.1	1.9	2.2	6.3	.9	.3
.490	-3.0	2.7	3.6	4.4	12.0	2.1	2.4	6.4	.9	.3
.500	-1.7	2.0	-4.2	4.1	11.9	2.4	2.5	6.5	.9	.4
.510	-2.3	2.6	-.5	3.8	11.8	2.6	2.5	6.6	.9	.4
.520	-2.4	2.3	-2.5	3.7	11.6	2.8	2.3	6.8	.9	.4
.530	-1.9	3.6	4.4	3.7	11.4	3.1	2.5	6.9	.9	.4
.540	-3.2	2.7	2.5	3.8	11.4	3.4	2.7	7.0	.8	.5
.550	1.0	1.2	1.0	3.9	11.3	3.5	3.0	7.1	.8	.5
.560	.8	.9	-.1	4.1	11.4	3.6	2.9	7.2	.8	.5
.570	-.6	-.7	2.4	4.3	11.4	3.6	3.0	7.3	.8	.6
.580	-.1	.2	-.1	4.5	11.4	3.6	3.1	7.4	.7	.6
.590	.5	.0	.7	4.7	11.4	3.6	3.2	7.6	.7	.6
.600	.3	-.2	1.0	4.8	11.4	3.6	3.3	7.7	.7	.7
.610	-.4	.4	1.2	5.0	11.4	3.7	3.4	7.8	.6	.7
.620	-1.0	.1	.8	5.1	11.3	3.7	3.4	7.9	.6	.7
.630	-1.3	.5	.7	5.3	11.3	3.8	3.4	8.0	.6	.8
.640	-.3	1.0	.1	5.4	11.3	3.8	3.5	8.1	.6	.8
.650	.6	-.1	.1	5.5	11.3	3.9	3.5	8.3	.5	.8
.660	-.8	.7	-1.0	5.6	11.2	4.0	3.5	8.4	.5	.9
.670	-.3	.6	.2	5.8	11.1	4.0	3.6	8.5	.5	.9
.680	-1.0	-.2	1.0	6.0	11.1	4.1	3.6	8.6	.4	.9
.690	-1.8	-.5	4.3	6.3	11.0	4.1	3.7	8.7	.4	1.0
.700	.9	-1.2	.9	6.5	10.9	4.1	3.8	8.8	.4	1.0
.710	1.3	.6	-.9	6.6	10.9	4.1	3.7	8.9	.4	1.0

Figure 27. (Continued) Vehicle Acceleration Plot - Test RW-4

TEST ID ------- RW-4
TEST DATE ----- 08-09-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 16.72 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.720	-1.8	-.3	1.0	6.8	10.9	4.1	3.7	9.1	.3	1.1
.730	-2.8	-.6	-1.6	7.0	10.8	4.2	3.6	9.2	.3	1.1
.740	-1.3	-.2	-2.5	7.2	10.6	4.2	3.3	9.3	.3	1.2
.750	.0	-.2	-3.0	7.4	10.4	4.2	3.2	9.4	.3	1.2
.760	-.3	-.7	-2.5	7.5	10.3	4.2	3.0	9.5	.2	1.2
.770	-2.2	-.4	-1.7	7.7	10.2	4.2	2.9	9.6	.2	1.2
.780	-.5	-.6	-.9	7.8	10.2	4.2	2.7	9.7	.2	1.3
.790	-.8	-2.3	-1.4	8.0	10.1	4.1	2.6	9.8	.1	1.3
.800	-.6	-1.8	-2.4	8.2	10.0	4.0	2.6	9.9	.1	1.3

HIGHEST 50.0-MS AVG. ACCEL.

		TIME (SEC)	
	G'S	START	END
LONG.	-3.27	.034	.084
LAT.	3.49	.024	.074

Figure 27. (Continued) Vehicle Acceleration Plot - Test RW-4

TEST ID ------- RW-4
TEST DATE ----- 08-09-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 16.72 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	(----- VEHICLE	------)		(----------- OCCUPANT		----------)	
TIME	ACCEL. (G'S)		ANG.VEL	VEL. (M/S)		DISP. (M)	
(S)	LONG.	LAT.	(RAD/S)	LONG.	LAT.	LONG.	LAT.
.000	-.26	.60	-1.38	.00	.00	.00	.00
.010	-4.54	1.15	2.02	.15	.08	.01	.02
.020	-.79	-.61	-6.88	.20	.07	.01	.04
.030	-3.27	3.32	15.21	.23	.08	.02	.06
.040	-4.71	5.42	-21.75	.31	.21	.02	.08
.050	-1.64	3.61	4.21	.36	.34	.03	.10
.060	-3.48	3.60	-12.10	.41	.38	.04	.11
.070	-.50	1.23	1.57	.34	.44	.04	.12
.080	-6.07	1.37	1.15	.45	.42	.05	.14
.090	.56	3.96	2.69	.53	.44	.06	.15
.100	-1.17	2.52	14.25	.44	.50	.06	.16
.110	-.62	2.23	8.74	.55	.51	.07	.17
.120	-6.38	.25	-3.54	.58	.47	.08	.18
.130	-.59	.59	-1.98	.62	.45	.09	.19
.140	-1.04	1.68	-1.38	.53	.42	.09	.19
.150	-.19	1.81	2.09	.56	.38	.10	.20
.160	-2.92	1.35	-9.80	.60	.34	.11	.21
.170	-.32	1.84	-.67	.62	.32	.12	.21
.180	-2.49	.06	1.00	.60	.28	.13	.21
.190	-2.71	2.84	4.49	.72	.20	.14	.22
.200	3.16	2.12	8.12	.67	.23	.14	.22
.210	-3.01	-.74	-.62	.74	.15	.15	.22
.220	-.91	.56	3.95	.68	.07	.16	.22
.230	-2.17	3.23	4.65	.65	.07	.17	.22
.240	.88	.90	-.41	.71	.00	.18	.22
.250	-1.03	-.32	-1.35	.70	-.05	.19	.22
.260	.20	1.36	3.01	.72	-.13	.20	.22
.270	.22	1.19	-.98	.70	-.18	.21	.22
.280	-1.26	-.08	1.10	.69	-.24	.22	.22
.290	-2.41	.81	-.98	.78	-.30	.23	.21
.300	-.17	.60	2.82	.77	-.37	.24	.21
.310	1.66	-.67	7.49	.70	-.45	.25	.21
.320	-.64	1.34	.84	.65	-.55	.26	.20
.330	-1.32	1.66	.82	.67	-.58	.27	.20
.340	.40	1.95	.11	.70	-.61	.28	.19
.350	.71	1.07	-.93	.66	-.64	.29	.19

Figure 27. (Continued) Vehicle Acceleration Plot - Test RW-4

TEST ID ------- RW-4
TEST DATE ----- 08-09-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 16.72 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	(----- VEHICLE	------)		(----------- OCCUPANT			-----------)
TIME	ACCEL. (G'S)		ANG.VEL	VEL. (M/S)		DISP. (M)	
(S)	LONG.	LAT.	(RAD/S)	LONG.	LAT.	LONG.	LAT.
.360	-.26	-.40	-6.02	.65	-.72	.30	.18
.370	-.59	-.24	-2.73	.65	-.81	.31	.17
.380	-.85	.79	2.15	.68	-.88	.32	.17
.390	-2.97	2.31	-4.58	.68	-.91	.33	.16
.400	3.79	-1.90	-2.34	.66	-.98	.33	.15
.410	-1.09	2.30	1.96	.59	-1.05	.34	.15
.420	.28	-.19	-1.92	.58	-1.12	.35	.14
.430	-.76	2.09	.58	.51	-1.18	.36	.13
.440	-.14	.94	5.15	.58	-1.19	.37	.12
.450	.16	2.53	1.18	.62	-1.23	.38	.11
.460	-1.17	.06	1.39	.68	-1.21	.38	.10
.470	-1.57	.66	7.23	.77	-1.26	.39	.09
.480	.28	2.63	-8.68	.76	-1.24	.40	.08
.490	-2.02	3.51	3.58	.77	-1.22	.41	.07
.500	-1.89	3.46	-4.19	.83	-1.14	.42	.06
.510	-1.04	2.72	-.54	.94	-1.08	.43	.05
.520	-2.01	2.57	-2.52	1.08	-1.00	.44	.03
.530	.13	3.12	4.44	1.29	-.90	.45	.02
.540	-1.18	1.46	2.48	1.36	-.78	.46	.01
.550	.79	.46	1.02	1.44	-.72	.48	.00
.560	.05	.18	-.05	1.43	-.69	.49	-.01
.570	-.14	-.71	2.38	1.43	-.66	.50	-.02
.580	.21	-.12	-.07	1.42	-.66	.52	-.04
.590	-.05	.00	.66	1.42	-.63	.53	-.05
.600	-.12	-.16	1.05	1.43	-.62	.54	-.06
.610	.07	.28	1.18	1.43	-.59	.55	-.07
.620	-.33	.20	.76	1.43	-.57	.57	-.08
.630	-.35	.26	.68	1.44	-.55	.58	-.09
.640	.09	.65	.11	1.43+	-.51	.59+	-.10
.650	.20	.27	.06	1.45	-.48	.61	-.12
.660	-.90	.42	-1.01	1.50	-.45	.62	-.13
.670	-.42	.22	.22	1.58	-.40	.63	-.14
.680	-.82	.01	1.05	1.62	-.36	.65	-.15
.690	-.19	-.61	4.31	1.64	-.33	.66	-.16
.700	-.70	-.51	.95	1.63	-.33	.68	-.17
.710	-.07	.42	-.88	1.62	-.32	.69	-.18

Figure 27. (Continued) Vehicle Acceleration Plot - Test RW-4

TEST ID ------- RW-4
TEST DATE ----- 08-09-94
VEHICLE CLASS - 2000P
IMPACT SPEED -- 16.72 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	VEHICLE			OCCUPANT			
TIME	ACCEL. (G'S)		ANG.VEL	VEL. (M/S)		DISP. (M)	
(S)	LONG.	LAT.	(RAD/S)	LONG.	LAT.	LONG.	LAT.
.720	-.70	-.18	1.00	1.64	-.30	.71	-.19
.730	-1.59+	-.05	-1.64	1.69	-.27	.72	-.20
.740	-1.17	-.27	-2.55	1.77	-.24	.74	-.21
.750	-1.49	.01	-3.02	1.80	-.22	.75	-.22
.760	-.70	-.16	-2.50	1.81	-.21	.77	-.24
.770	-.48	-.34	-1.71	1.86	-.20	.79	-.25
.780	-.16	-.75	-.91	1.90	-.18	.80	-.26
.790	-.97	-1.48	-1.43	1.94	-.19	.82	-.27
.800	-.98	-1.73	-2.39	1.95	-.21	.84	-.28

OCCUP. RISK FACTORS	TIME (S)	VELOCITY (M/S)
>LONG. VEL. AFTER 0.6 M DISP. --	.645	1.44
>LAT. VEL. AFTER 0.3 M DISP. --	.810	1.18

MAX. ACCEL. AFTER OCCUPANT IMPACT	TIME(S)	ACC.(GS)
>LONG. ACCELERATION --	.733	-1.87

Figure 27. (Continued) Vehicle Acceleration Plot - Test RW-4

Figure 28. After Test Photographs - Test RW-4

Figure 28. (Continued) After Test Photographs - Test RW-4

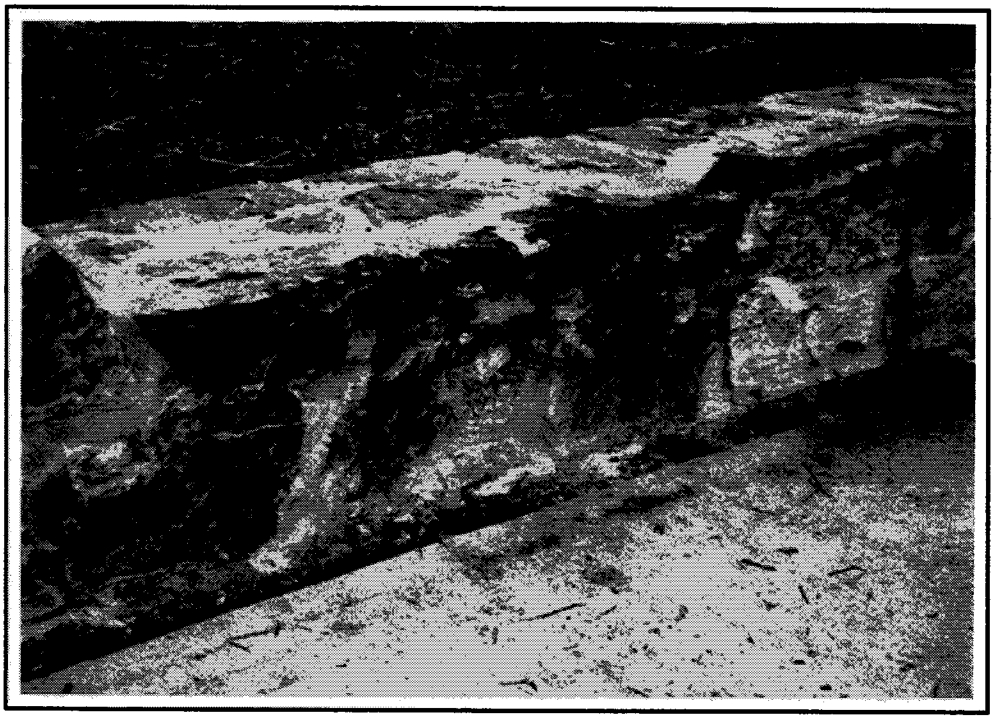


Figure 28. (Continued) After Test Photographs - Test RW-4

Figure 29. Before Test Photographs - Test RW-5

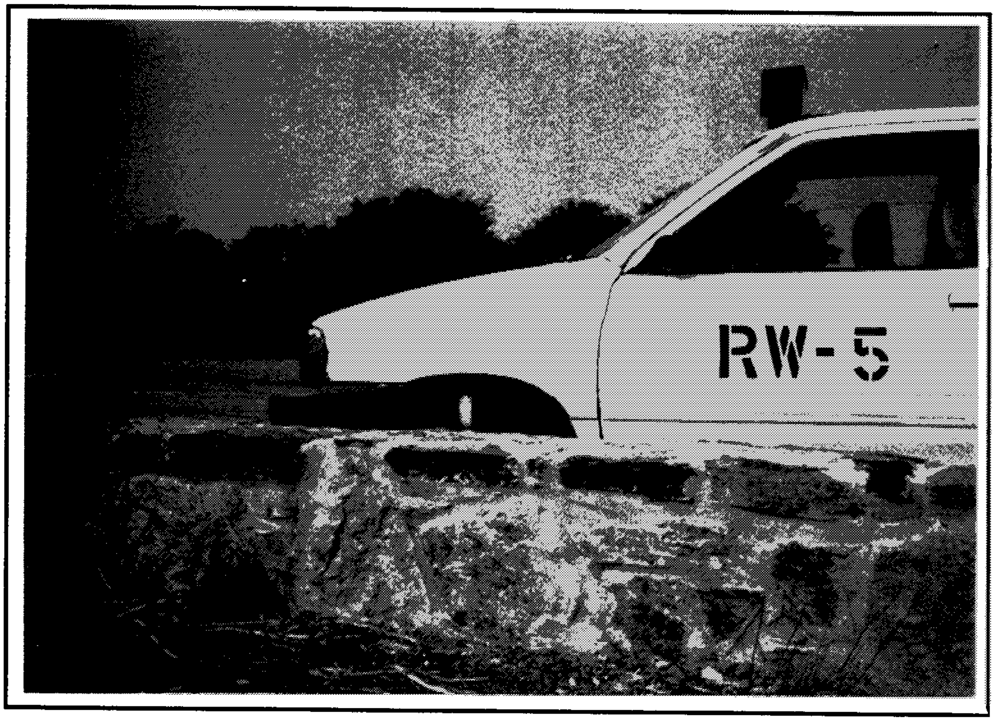


Figure 29. (Continued) Before Test Photographs - Test RW-5

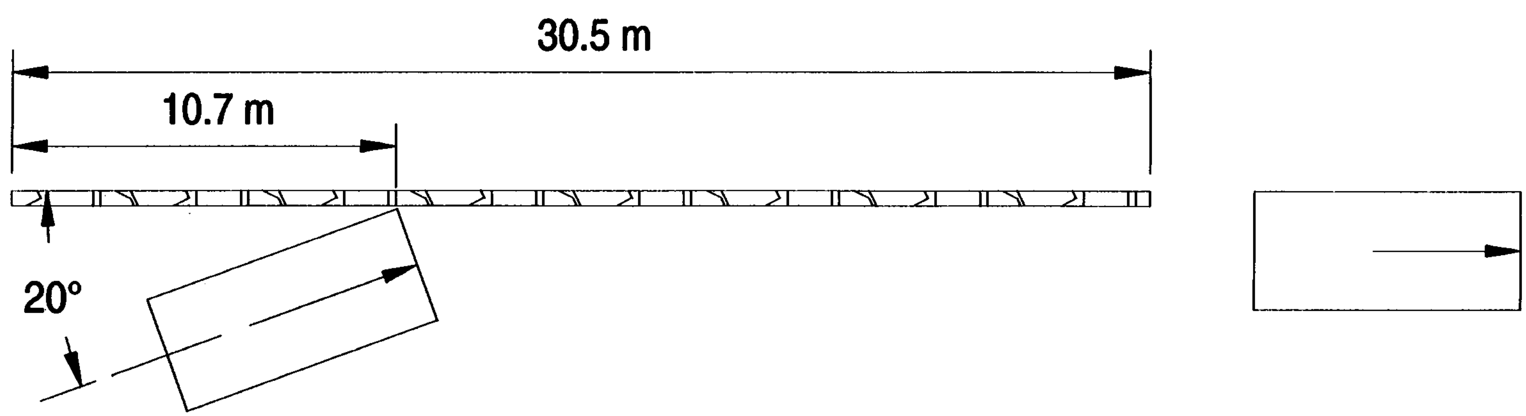


Figure 30. Test Layout - Test RW-5

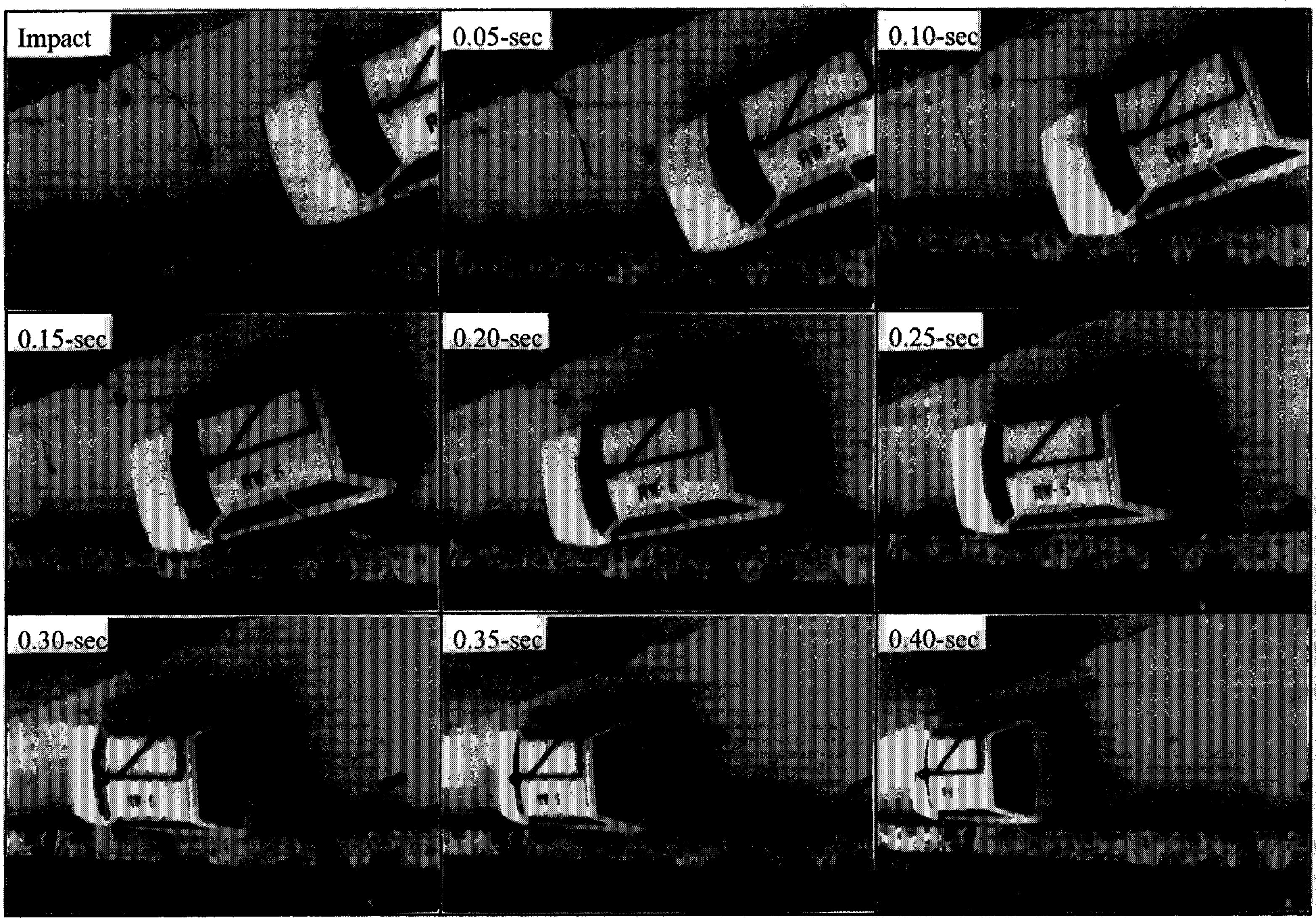


Figure 31. Sequential Photographs - Test RW-5

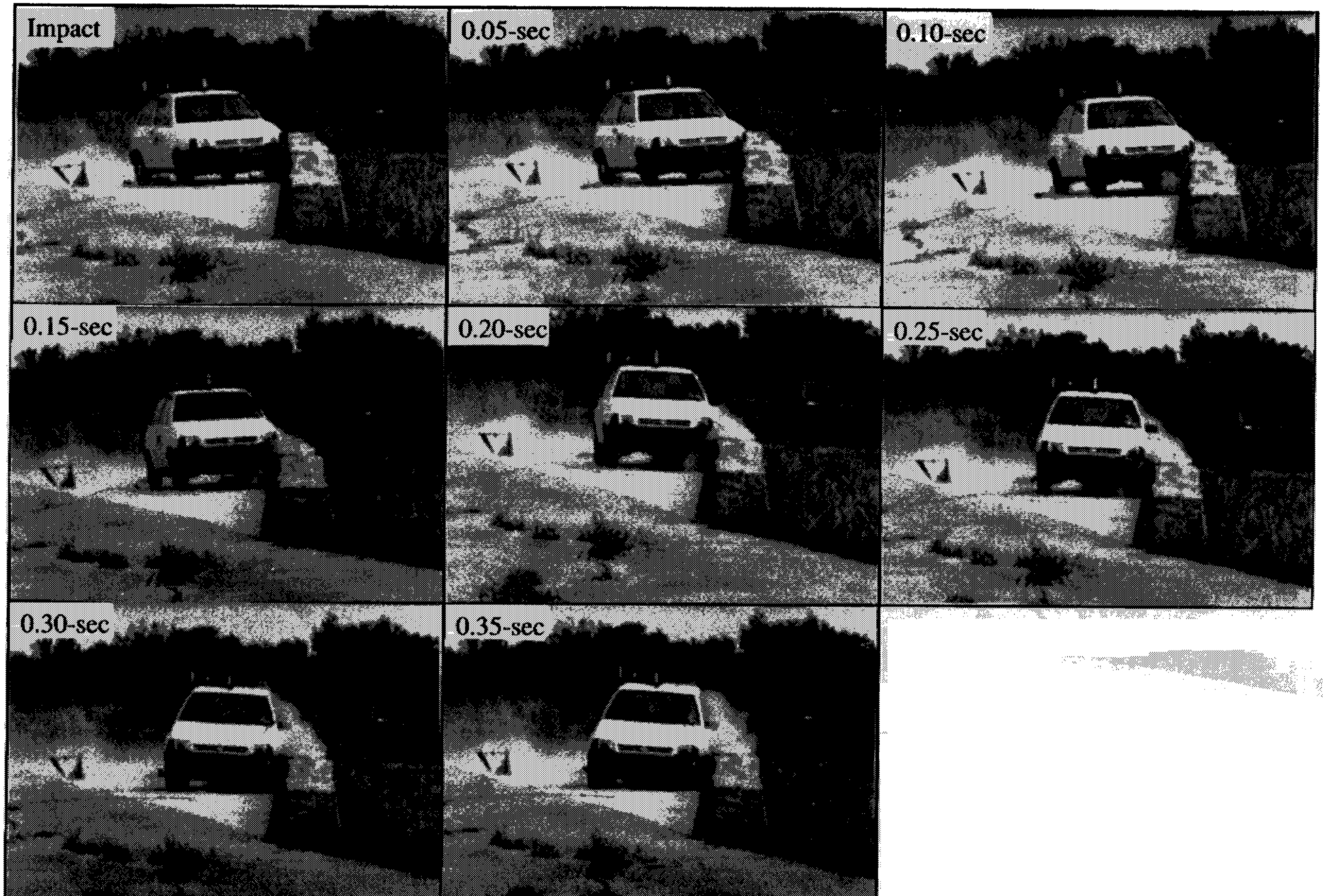
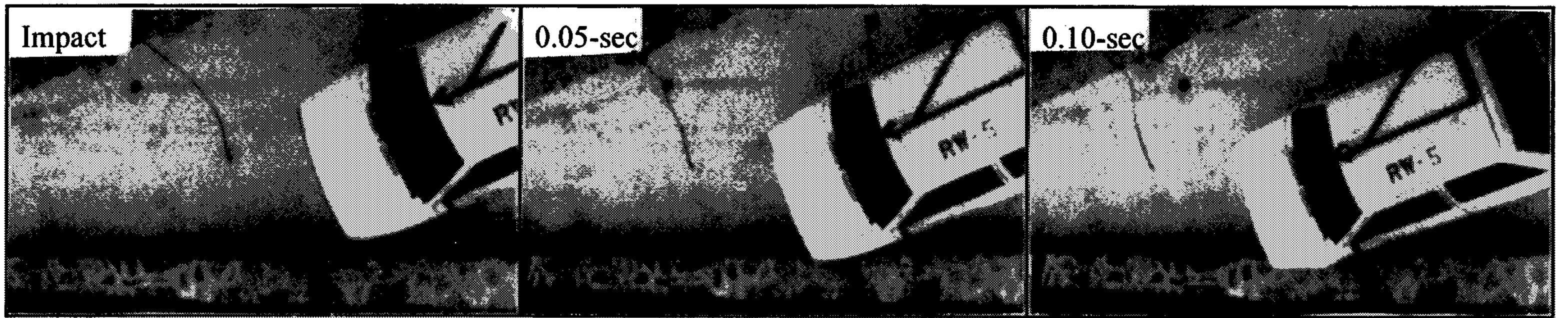
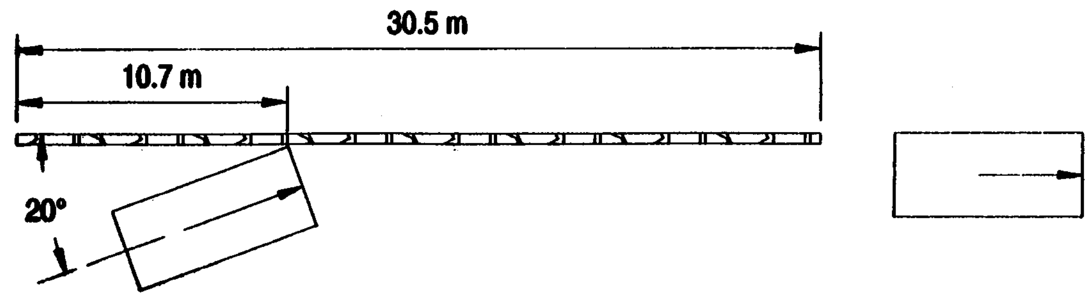


Figure 31. (Continued) Sequential Photographs - Test RW-5





4. General Information		**7. Test Vehicle (Continued)**			
Test Agency	Southwest Research Institute	Mass (kg) Dummy(s)	75	y-direction	1.98
Test Number	RW-5	Mass (kg) Gross Static	915	**11. Test Article Deflection (m)**	
Test Date	8/12/94	**8. Impact Conditions**		Dynamic	0.0
5. Test Article		Speed (km/h)	50	Permanent	0.0
Type	Longitudinal Barrier	Angle (deg)	20	**12. Vehicle Damage**	
Installation Length (m)	30.5	**9. Exit Conditions**		Exterior	
Barrier	Variable Height Stone Masonry Guardwall	Speed (km/h)	0	VDS	11LFQ1
6. Soil Type and Condition	Standard Soil, Dry Compacted	Angle (deg)	0	CDC	11FFEN1
7. Test Vehicle		**10. Occupant Risk Values**		Interior	
Type	Production Model	Impact Velocity (m/s)		OCDI	LF0112000
Designation	820 C	x-direction	1.02	**13. Post-Impact Vehicular Behavior**	
Model	1989 Ford Festiva	y-direction	1.43	Maximum Roll Angle (deg)	15 Estimated
Mass (kg) Curb	845	Ridedown Acceleration (g's)		Maximum Pitch Angle (deg)	5 Estimated
Mass (kg) Test Inertial	840	x-direction	0.81	Maximum Yaw Angle (deg)	0 Estimated

Figure 32. Summary of Test Conditions and Results - Test RW-5

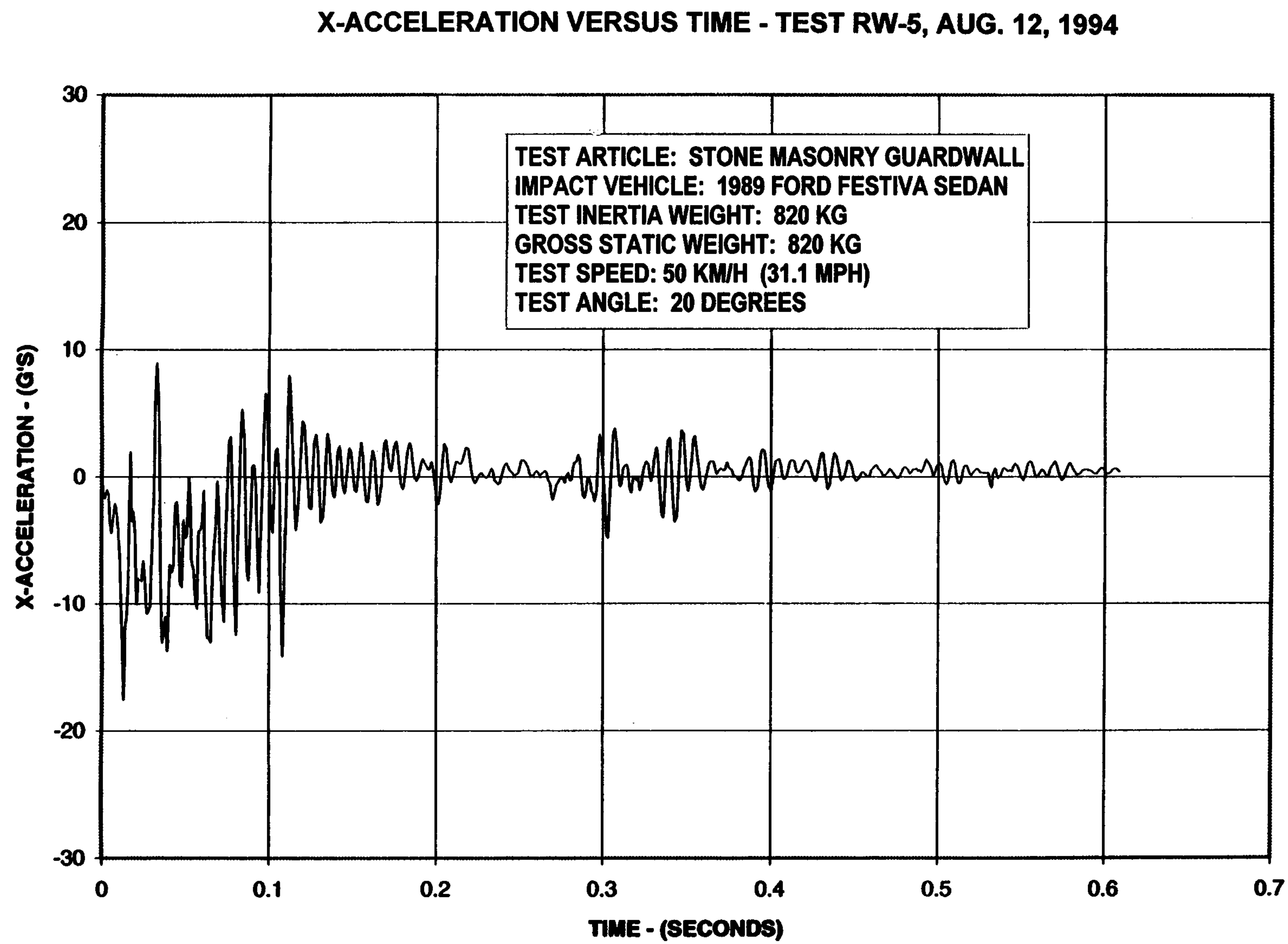


Figure 33. Vehicle Acceleration Plot - Test RW-5

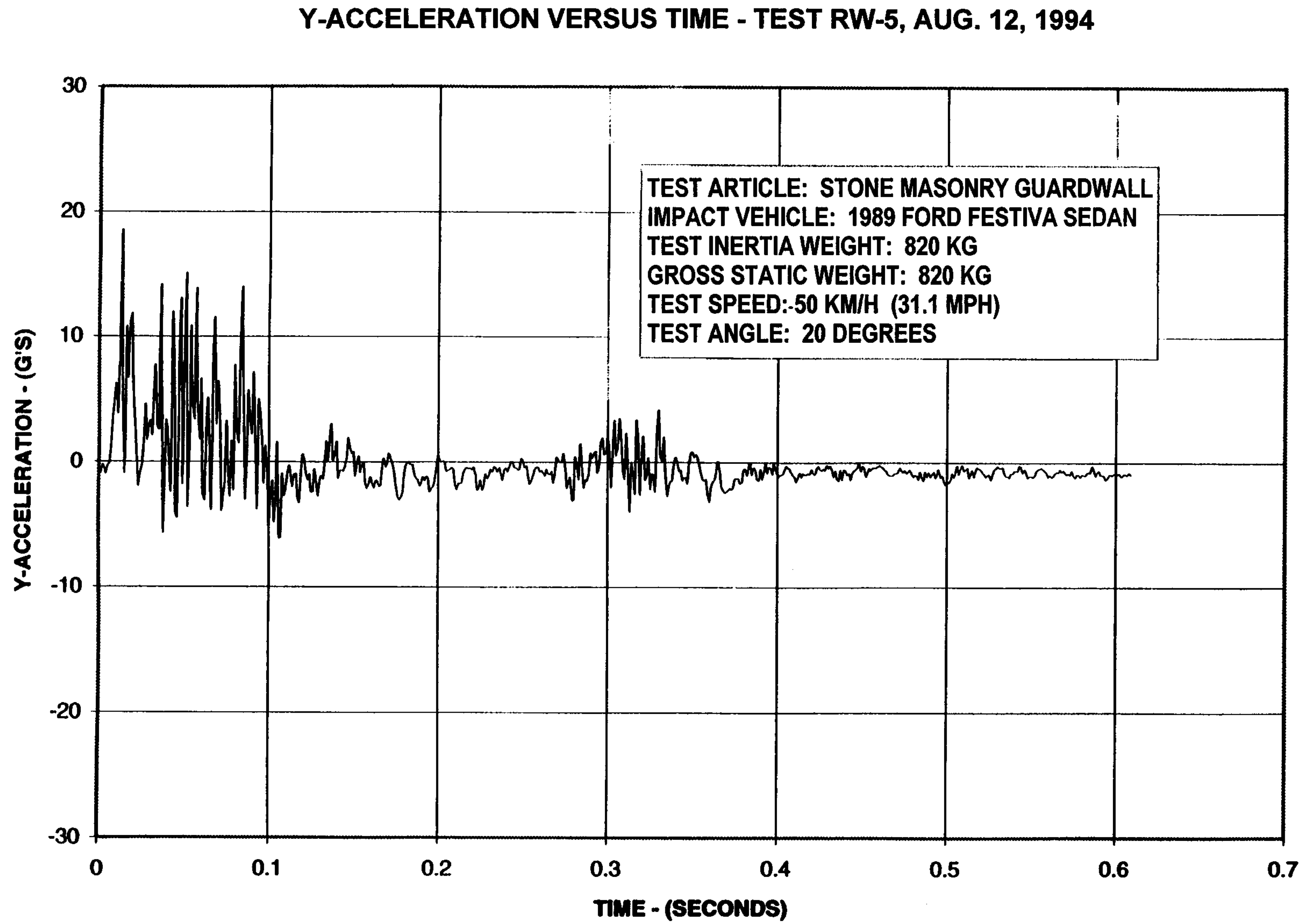


Figure 33. (Continued) Vehicle Acceleration Plot - Test RW-5

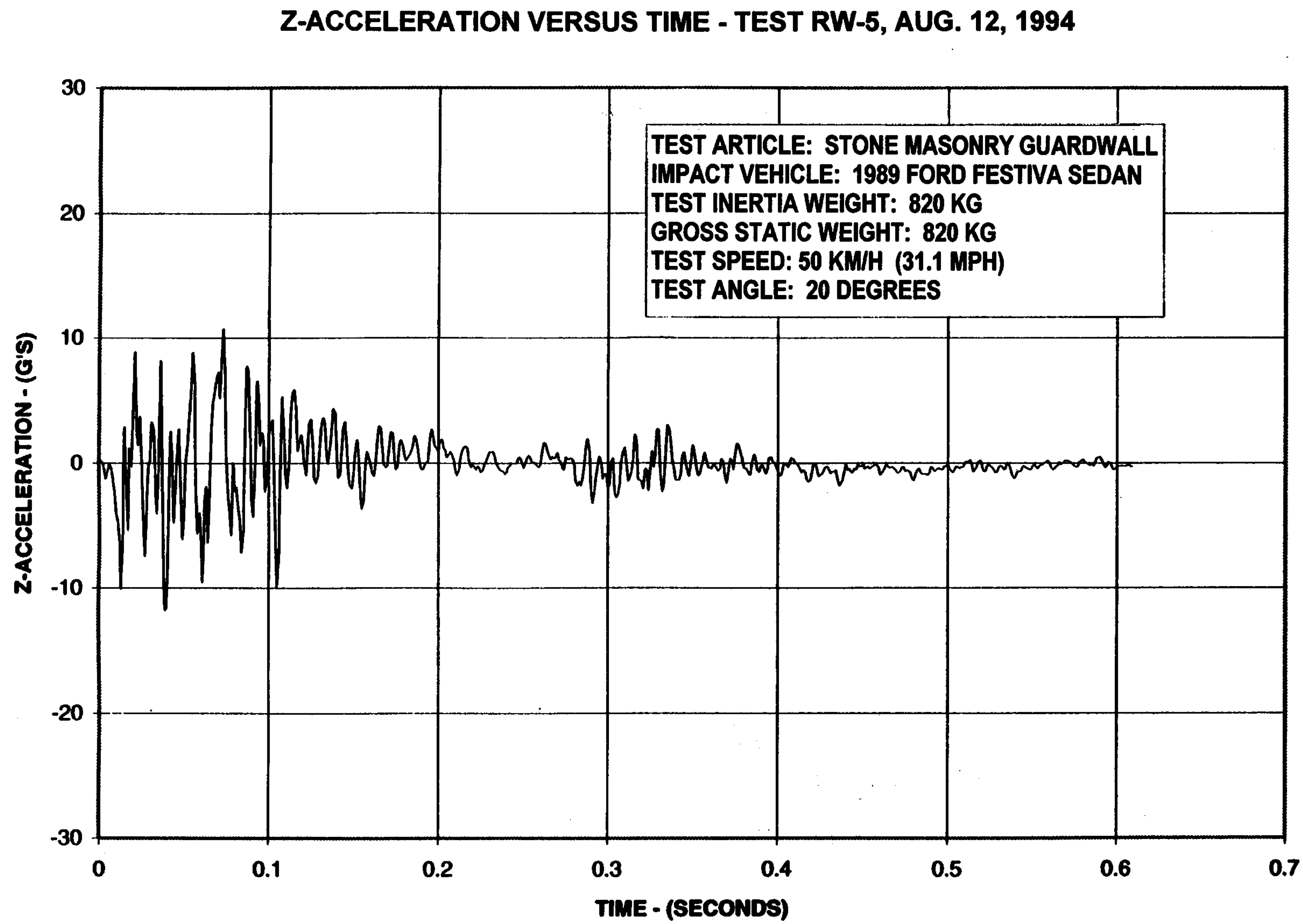


Figure 33. (Continued) Vehicle Acceleration Plot - Test RW-5

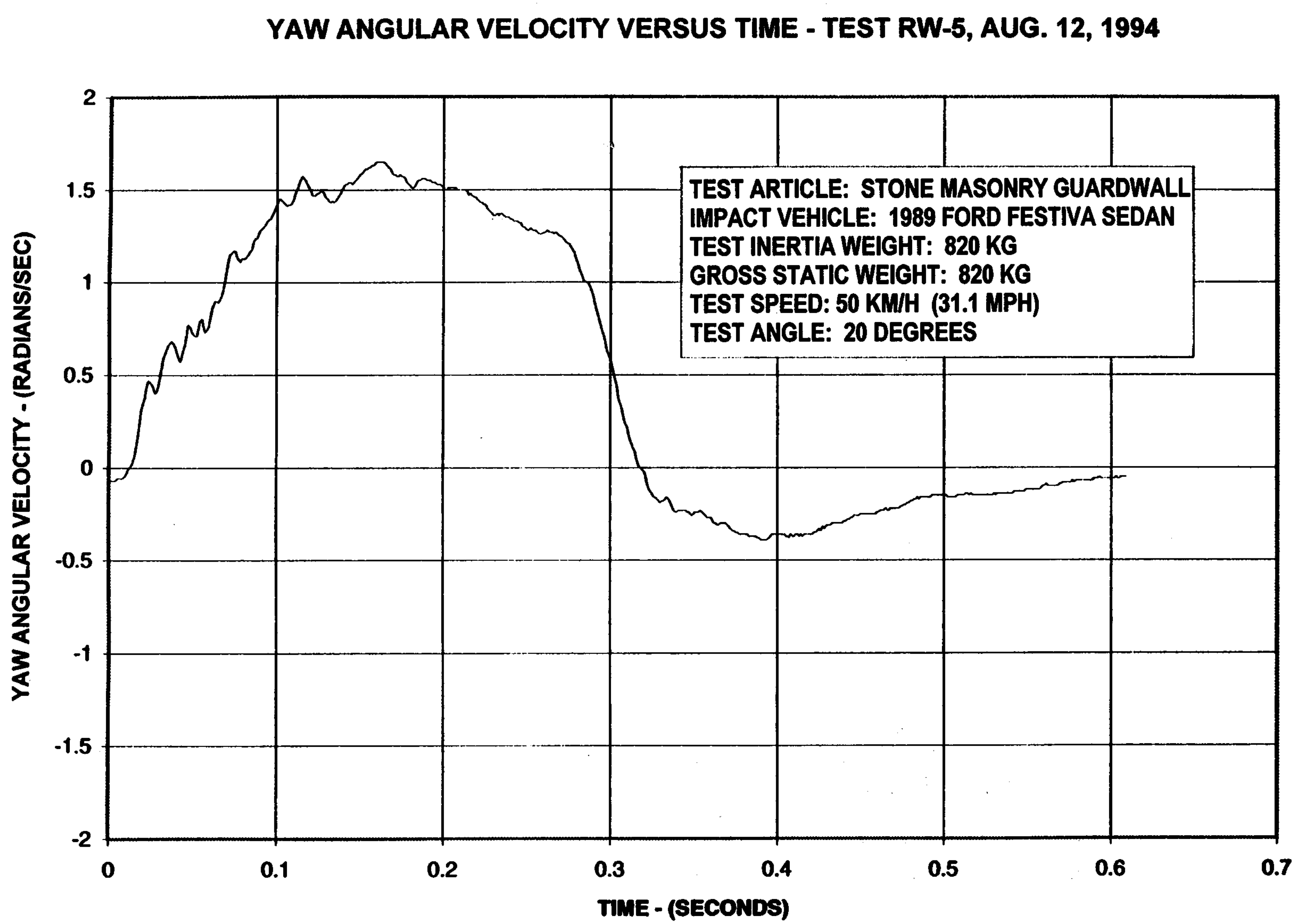


Figure 33. (Continued) Vehicle Acceleration Plot - Test RW-5

TEST ID ------- RW-5
TEST DATE ----- 08-12-94
VEHICLE CLASS - 820C
IMPACT SPEED -- 16.72 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.000	-.1	-1.0	.3	25.0	16.7	.0	.0	.0	.0	.0
.010	-4.1	6.3	-4.0	25.0	16.5	.1	-.1	.2	.1	.0
.020	-4.6	5.6	4.3	25.0	15.7	.9	-.4	.3	.1	.0
.030	-6.2	3.3	.2	24.7	14.9	.9	-.4	.4	.2	.0
.040	-10.2	2.5	-11.7	24.4	14.4	1.2	-.5	.6	.2	.0
.050	-4.8	8.0	-4.2	24.0	13.9	1.4	-.7	.7	.3	.0
.060	-3.7	6.6	-6.3	23.6	13.4	1.9	-.6	.8	.3	.0
.070	-2.9	6.4	7.3	23.0	12.7	2.1	-.6	1.0	.4	.0
.080	-12.5	7.7	-2.3	22.4	12.3	2.0	-.4	1.1	.4	.0
.090	.9	2.2	-3.2	21.7	12.1	2.2	-.5	1.2	.4	.0
.100	.7	-5.3	2.2	20.9	12.1	2.2	-.4	1.3	.4	.0
.110	-3.9	-2.1	-1.1	20.1	11.7	1.7	-.5	1.5	.5	.0
.120	4.4	.6	1.3	19.2	11.9	1.4	-.3	1.6	.5	-.1
.130	-1.4	-1.6	1.0	18.4	12.0	1.0	-.2	1.7	.5	-.1
.140	-.2	1.6	.9	17.6	12.0	.9	.0	1.8	.5	-.1
.150	.3	.8	-1.0	16.7	12.1	.7	.0	1.9	.6	-.1
.160	-.8	-1.2	.0	15.7	12.1	.5	.0	2.0	.6	-.1
.170	2.9	-.1	-.3	14.8	12.1	.1	.0	2.2	.6	-.1
.180	-1.0	-1.0	.6	13.9	12.2	-.2	.1	2.3	.7	-.1
.190	.5	-1.7	-.6	13.0	12.3	-.4	.2	2.4	.7	-.1
.200	-1.4	.5	.9	12.1	12.3	-.8	.3	2.5	.7	.0
.210	.1	-1.8	-.6	11.3	12.3	-1.0	.4	2.6	.8	.0
.220	1.4	-.6	-.2	10.4	12.5	-1.3	.4	2.8	.8	.0
.230	-.1	-1.0	.9	9.6	12.4	-1.6	.4	2.9	.8	.0
.240	.6	-.5	-.8	8.9	12.4	-1.9	.4	3.0	.9	.0
.250	.8	.1	-.4	8.1	12.4	-2.1	.4	3.1	.9	.0
.260	.5	-.8	-.2	7.4	12.5	-2.3	.4	3.2	.9	.0
.270	-1.9	.4	.8	6.6	12.4	-2.5	.5	3.4	1.0	.0
.280	-.3	-3.1	-.1	6.0	12.4	-2.8	.5	3.5	1.0	.0
.290	-1.0	.7	-2.2	5.4	12.4	-3.0	.4	3.6	1.1	.0
.300	.6	2.0	-2.0	5.0	12.3	-3.0	.3	3.7	1.1	.0
.310	-.8	-1.4	1.2	4.7	12.3	-3.0	.2	3.8	1.1	.0
.320	-.3	.4	-1.5	4.7	12.3	-3.0	.2	4.0	1.2	.0
.330	.3	4.2	2.6	4.8	12.3	-3.0	.2	4.1	1.2	.0
.340	3.0	.4	-1.4	4.9	12.4	-3.0	.2	4.2	1.3	.0
.350	-.4	.8	1.4	5.0	12.4	-3.0	.2	4.3	1.3	.0

Figure 33. (Continued) Vehicle Acceleration Plot - Test RW-5

TEST ID ------- RW-5
TEST DATE ----- 08-12-94
VEHICLE CLASS - 820C
IMPACT SPEED -- 16.72 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.360	-1.1	-3.2	-.3	5.2	12.5	-3.1	.2	4.4	1.3	.0
.370	.6	-2.4	-1.6	5.3	12.5	-3.2	.1	4.6	1.4	.0
.380	-.1	-.6	-.4	5.5	12.6	-3.3	.2	4.7	1.4	.0
.390	-.8	-.6	-.3	5.7	12.7	-3.4	.1	4.8	1.5	.0
.400	-1.1	-.9	-.6	6.0	12.7	-3.4	.1	4.9	1.5	.0
.410	.3	-1.2	.1	6.2	12.8	-3.4	.1	5.0	1.6	.0
.420	1.1	-.6	-.8	6.4	12.9	-3.5	.0	5.2	1.6	.0
.430	1.9	-.5	-.6	6.6	12.9	-3.5	-.1	5.3	1.7	.0
.440	1.0	-.7	-.2	6.7	13.0	-3.5	-.2	5.4	1.7	.0
.450	-.2	-.3	-.2	6.9	13.1	-3.6	-.2	5.5	1.8	.0
.460	.5	-.2	-1.0	7.0	13.1	-3.6	-.2	5.7	1.8	.0
.470	.4	-.9	-.8	7.2	13.1	-3.6	-.3	5.8	1.9	.0
.480	.8	-1.2	-1.4	7.3	13.2	-3.7	-.3	5.9	1.9	.0
.490	.3	-1.1	-.3	7.4	13.2	-3.8	-.4	6.0	2.0	.0
.500	.9	-1.5	-.2	7.5	13.3	-3.8	-.5	6.2	2.0	.0
.510	1.0	-.7	.0	7.6	13.4	-3.9	-.5	6.3	2.1	.0
.520	.2	-.6	-.2	7.6	13.4	-4.0	-.5	6.4	2.1	.0
.530	.3	-.3	-.3	7.7	13.4	-4.0	-.6	6.6	2.2	.0
.540	.6	-.7	-1.1	7.8	13.4	-4.1	-.6	6.7	2.3	.0
.550	-.1	-1.1	-.3	7.9	13.5	-4.1	-.7	6.8	2.3	.0
.560	.2	-1.2	.0	7.9	13.5	-4.2	-.7	6.9	2.4	.0
.570	1.2	-.8	.2	8.0	13.6	-4.3	-.7	7.1	2.4	-.1
.580	.8	-.9	.3	8.0	13.6	-4.4	-.7	7.2	2.5	-.1
.590	.5	-.7	.5	8.1	13.7	-4.4	-.7	7.3	2.6	-.1
.600	.4	-.9	-.3	8.1	13.7	-4.5	-.7	7.5	2.6	-.1

HIGHEST 50.0-MS AVG. ACCEL.

	G'S	TIME (SEC) START	END
LONG.	-6.42	.010	.060
LAT.	4.56	.008	.058

Figure 33. (Continued) Vehicle Acceleration Plot - Test RW-5

TEST ID ------- RW-5
TEST DATE ----- 08-12-94
VEHICLE CLASS - 820C
IMPACT SPEED -- 16.72 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	(----- VEHICLE	------)		(----------- OCCUPANT			-----------)
TIME (S)	ACCEL. (G'S) LONG.	LAT.	ANG.VEL (RAD/S)	VEL. (M/S) LONG.	LAT.	DISP. (M) LONG.	LAT.
.000	-.09	-.96	.28	.00	.00	.00	.00
.010	-7.31	4.75	-4.01	.06	.05	.01	.02
.020	-6.14	4.45	4.35	.16	.43	.01	.04
.030	-3.38	3.22	.15	.37	.49	.02	.06
.040	-8.66	3.34	-11.66	.46	.59	.02	.08
.050	-4.81	4.56	-4.15	.60	.66	.03	.10
.060	-7.76	3.49	-6.34	.72	.81	.04	.11
.070	-6.30	2.12	7.30	.83	.91	.05	.12
.080	-1.35	3.33	-2.31	.94	.84	.06	.14
.090	-3.66	2.10	-3.22	.95	.92	.07	.15
.100	.76	-1.49	2.24	.90	.89	.09	.16
.110	-1.57	-2.19	-1.06	1.00	.68	.10	.17
.120	-.04	-1.24	1.33	.93	.53	.11	.18
.130	.11	-1.16	.98	.89	.34	.13	.19
.140	.53	.30	.94	.87	.25	.14	.20
.150	.52	.23	-.99	.81	.15	.15	.21
.160	.05	-1.48	-.04	.78	.01	.17	.22
.170	.77	-.49	-.25	.77	-.19	.18	.23
.180	1.16	-1.40	.58	.75	-.40	.20	.24
.190	.67	-1.41	-.56	.70	-.54	.21	.25
.200	.01	-.73	.88	.68	-.73	.23	.26
.210	.88	-1.24	-.65	.66	-.88	.24	.27
.220	.91	-.98	-.15	.63	-1.07	.26	.28
.230	.16	-1.11	.90	.64	-1.27	.27	.29
.240	.22	-.59	-.77	.64	-1.41*	.29	.30*
.250	.69	-.63	-.45	.63	-1.56	.31	.31
.260	.29	-.80	-.15	.61	-1.70	.32	.32
.270	-.57	-.39	.81	.61	-1.85	.34	.32
.280	.29	-1.15	-.12	.66	-2.03	.36	.33
.290	-.58	-.51	-2.21	.71	-2.22	.37	.34
.300	-.71	1.01	-2.01	.82	-2.40	.39	.35
.310	1.24	.16	1.22	.94	-2.54	.41	.35
.320	-.29	-.18	-1.50	1.02	-2.66	.43	.36
.330	.59	.09	2.59	1.08	-2.72	.44	.37
.340	-.79	-.99	-1.38	1.08	-2.73	.46	.37
.350	1.43	-.18	1.41	1.08	-2.74	.48	.38

Figure 33. (Continued) Vehicle Acceleration Plot - Test RW-5

TEST ID ------- RW-5
TEST DATE ----- 08-12-94
VEHICLE CLASS - 820C
IMPACT SPEED -- 16.72 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

TIME (S)	VEHICLE ACCEL. (G'S) LONG.	VEHICLE ACCEL. (G'S) LAT.	VEHICLE ANG.VEL (RAD/S)	OCCUPANT VEL. (M/S) LONG.	OCCUPANT VEL. (M/S) LAT.	OCCUPANT DISP. (M) LONG.	OCCUPANT DISP. (M) LAT.
.360	.52	-1.61	-.35	1.07	-2.75	.50	.39
.370	.66	-1.86*	-1.62	1.07	-2.79	.51	.40
.380	.21	-.97	-.45	1.07	-2.83	.53	.41
.390	.51	-.82	-.28	1.07	-2.83	.55	.42
.400	.60	-.70	-.65	1.05	-2.80	.56	.43
.410	.66	-.92	.08	1.05	-2.80	.58	.44
.420	.73	-.77	-.77	1.02+	-2.79	.60+	.45
.430	.38	-.61	-.55	.99	-2.76	.62	.46
.440	.54	-1.02	-.15	.96	-2.75	.63	.47
.450	.38	-.57	-.15	.94	-2.74	.65	.48
.460	.44	-.47	-.97	.93	-2.73	.66	.49
.470	.29	-.85	-.77	.91	-2.72	.68	.50
.480	.35	-.94	-1.40	.89	-2.71	.70	.52
.490	.73+	-1.01	-.35	.87	-2.72	.71	.53
.500	.43	-1.29	-.15	.84	-2.74	.73	.54
.510	.24	-.66	-.04	.83	-2.75	.75	.56
.520	.52	-.79	-.24	.82	-2.75	.76	.57
.530	.13	-.69	-.35	.81	-2.77	.78	.58
.540	.37	-.77	-1.07	.81	-2.77	.80	.60
.550	.52	-.88	-.26	.78	-2.78	.81	.61
.560	.42	-.84	-.04	.76	-2.78	.83	.63
.570	.44	-.81	.17	.74	-2.79	.84	.64
.580	.47	-.99	.26	.73	-2.81	.86	.66
.590	.42	-.90	.49	.71	-2.82	.88	.67
.600	.45	-1.01	-.34	.70	-2.85	.89	.69

OCCUP. RISK FACTORS	TIME (S)	VELOCITY (M/S)
>LONG. VEL. AFTER 0.6 M DISP. --	.421	1.02
>LAT. VEL. AFTER 0.3 M DISP. --	.241	1.43

MAX. ACCEL. AFTER OCCUPANT IMPACT	TIME(S)	ACC.(GS)
>LONG. ACCELERATION --	.497	.81
>LAT. ACCELERATION --	.372	1.98

Figure 33. (Continued) Vehicle Acceleration Plot - Test RW-5

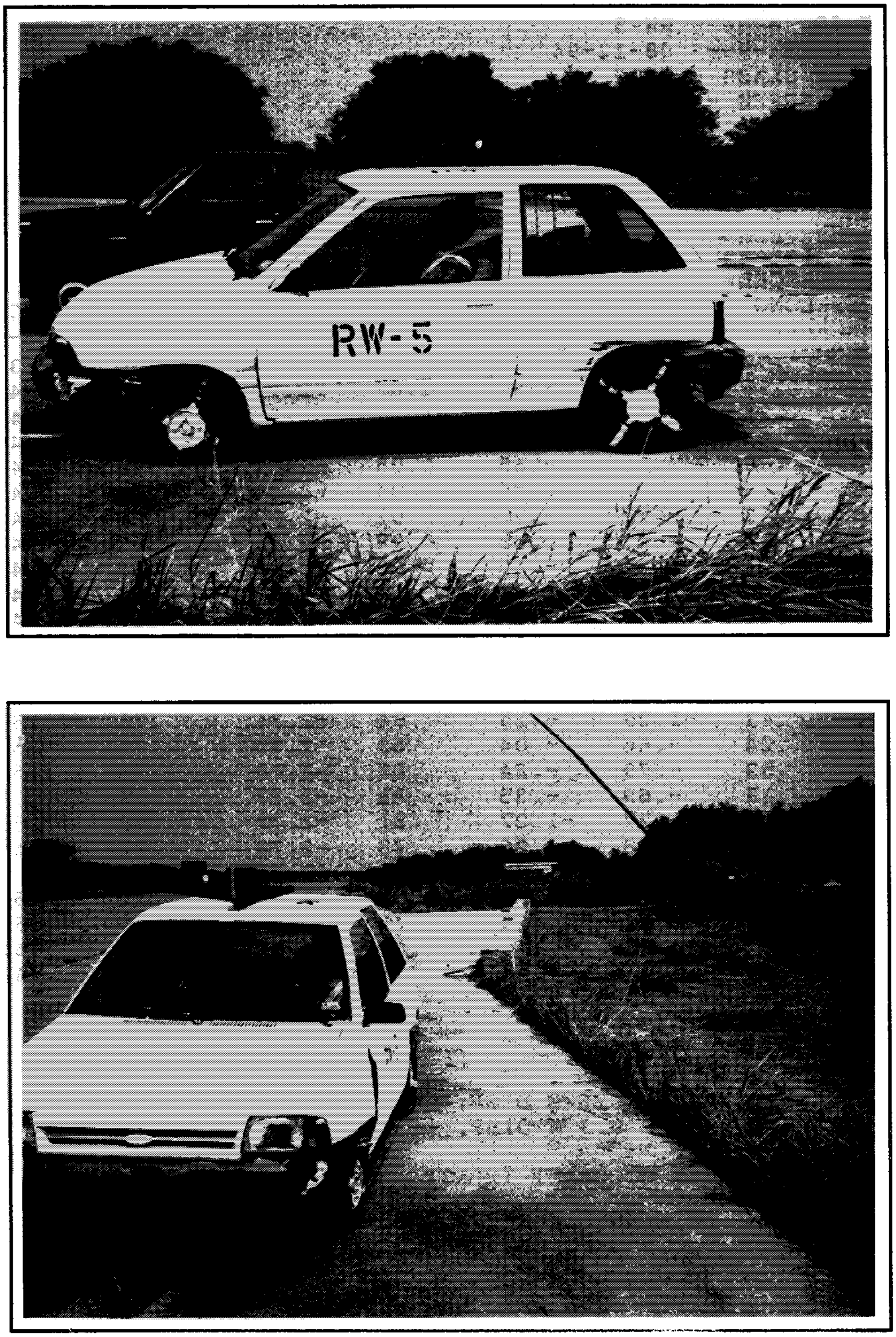


Figure 34. After Test Photographs - Test RW-5

Figure 34. (Continued) After Test Photographs - Test RW-5

Figure 34. (Continued) After Test Photographs - Test RW-5

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA-FLP-96-012	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Crash Test Evaluation of a W-Beam Transition to a Texas Type 101 Bridge Rail		5. Report Date April 1996
		6. Performing Organization Code
7. Author(s) Strybos, J.W., Mayer, J.B., Bronstad, M.E.		8. Performing Organization Report No. 06-6038
9. Performing Organization Name and Address Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas 78228-0510		10. Work Unit No.(TRAIS)
		11. Contract or Grant No. DTFH71-93-C-00023
12. Sponsoring Agency Name and Address Federal Highway Administration, Eastern Federal Lands Highway Division, 21400 Ridge Top Circle, Sterling, Virginia 20166		13. Type of Report and Period Covered Test Report May 1994 - April 1996
		14. Sponsoring Agency Code

15. Supplementary Notes

Federal Highway Administration Contract Manager (COTR): C. F. McDevitt (HSR-20)

16. Abstract

This report summarizes one full-scale crash test that was conducted on a W-Beam Transition to a Texas Type 101 Bridge Rail. The following table summarizes the test conditions according to Test 3-21 from NCHRP Report 350.

Vehicle		Impact Velocity	Impact Angle	Barrier Installation	NCHRP Report 350 Criteria
Mass (kg)	Type	(Km/h)	(degrees)		
2,000	Pickup	100	24.9	W-Beam Transition to Texas Type 101 Bridge Rail	Pass

17. Key Words Highway safety, longitudinal barriers, crash tests	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 33	22. Price

Form DOT F 1700.7 (8-72)

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.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	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	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		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	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		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	psi

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

(Revised August 1992)

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1.0 INTRODUCTION

This project is part of the Coordinated Federal Lands Highways Technology Improvement Program (CTIP). It is intended to serve the immediate needs of those who design and construct Federal lands highways, including Indian reservation roads, national park roads and parkways, and forest highways.

A wide assortment of guardrails, bridge rails, and transitions are being used on roads under the jurisdiction of the National Park Service and other federal agencies. These guardrails, bridge rails, and transitions are intended to blend in with the roadside in order to preserve the visual integrity of the parks and parkways; however, many of them have never been crash tested.[1 2] A testing program is necessary in order to ensure that the guardrails, bridge rails, and transitions being used are safe for the traveling public.

The objective of this program is to design, test, and develop aesthetic guardrails, bridge rails, and transitions for park roads and parkways and other roads under federal jurisdiction. Figures and tables follow the text. The following sections of this report will describe the:

- Test installations
- Test vehicles
- Tests
- Barrier damage
- Vehicle damage
- Recommendations and conclusions of the project.

This report describes full-scale crash test evaluation of a transition design according to procedures of NCHRP Report 350.[3] The test number is 3-21 from Report 350.

2.0 TEST FACILITY

This test was performed on the east inactive runway at Brooks Air Force Base, San Antonio, TX.

3.0 TEST INSTALLATION CONSTRUCTION

The National Park Service uses a variety of bridge railings and longitudinal barriers with the transitions from the longitudinal

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[1]Hancock, K.L., Hansen, A.G., and Mayer, J.B., "Aesthetic Bridge Rails, Transitions, and Terminals for Park Roads and Parkways," Federal Highway Administration Report No. FHWA-RD-90-052, June 1990.

[2]Stout, D., Hinch, J., and Sawyer, D., "Guardrail Testing Program," Draft Final Report on Contract No. DTFH71-87-C-00002, June 1990.

[3]Ross, H.E., Jr., Sicking, D.L., Zimmer, R.A., and Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," NCHRP Report 350, Washington, D.C., 1993.

barrier to the bridge railing. This installation involves the transition from a W-beam on wood post (G4-2W system in "Roadside Design Guide"[4]) to a Texas type 101 bridge rail. The transition design was adopted from the Texas Department of Transportation. The transition from a W-beam to a Texas type 101 bridge rail, shown in Figure 1, was constructed in accordance with specifications contained in "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-92."[5] Construction of this transition system consisted of the steps listed below. Graphs of the concrete strength are shown in Figure 2. This installation consisted of a 3.8-m length of doubled W-beam backed by steel tubing attached to steel posts. A 15.2-m length of W-beam mounted on wood posts was upstream and downstream of the doubled W-beam section, mounted at reduced post spacing. The guardrail installation included a 1.91-m straight breakaway cable terminal (BCT) at the upstream end. There were no unusual problems encountered during the construction of the test installation.

The transition system was constructed as follows:

- The site was excavated and base material was backfilled.
- The concrete headwall was excavated, and the concrete and reinforcement steel placed.
- The steel posts were mounted on the headwall using cast in place anchor bolts. The steel tubing was attached to the steel posts.
- The holes for the guardrail posts were drilled, the posts placed in the holes, and the holes were backfilled. The backfilled base material was compacted in place using a handheld pneumatic tamper.
- The W-beam and associated hardware were installed to complete the test installation.

4.0 TEST VEHICLE AND DUMMY

The vehicle used in this test was a 1989 Ford F250 pickup. Gross test weight, including the dummy and instrumentation, was 2,039 kg. The barrier installation and test vehicle before the test are shown in Figure 3. An uninstrumented dummy was seated in the driver's seat of the test vehicle. The shoulder-and-lap seatbelt was in place around the dummy.

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[4]"Roadside Design Guide," American Association of State Highway and Transportation Officials, Washington, D.C., 1989.

[5]"Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-92," Federal Highway Administration, Washington, D.C., 1992.

4.1 Test Vehicle Guidance

The test vehicle was guided to the impact point by use of a 6.4-mm-diameter steel cable, 101 m long, that was pretensioned alongside of the run-up strip where it would not interfere with post-impact vehicle trajectory. A guide tube that slides along the cable was attached to the front wheel to provide guidance to the car. Just prior to impact, the guide bracket was sheared off.

Braking of the test vehicle was accomplished by use of an air cylinder attached to the brake pedal of the vehicle. Activation of the cylinder was achieved by remote activation of a gas-charged accumulator controlled by a solenoid valve.

Vehicle test speed control was achieved by means of an automatic controller attached to the engine distributor of the tow vehicle. After the vehicle accelerated to the predetermined test speed, the controller pulsed the ignition and maintained the vehicle at a constant velocity. The test vehicle was towed to the impact area using the reverse-tow method.

4.2 Vehicle Data Acquisition

The vehicle accelerometers were mounted near the vehicle center of gravity. These accelerometers were oriented to obtain data in directions parallel to the longitudinal, lateral, and vertical axes of the vehicle. A rate gyro was mounted near the accelerometers to measure the rate of yaw angular change the vehicle experiences during impact. The transducer data were recorded by a Pacific Instruments Model 5600 Data Acquisition System (DAS). The DAS contains up to 32 channels of signal conditioners, amplifiers, and appropriate SAEJ211 filters and digitizers, with onboard memory for each channel. It conditions, amplifies, digitizes, and records transducer signals at programmable sample rates to 100 kHz per channel. Digitized data were recorded in solid state nonvolatile memory with a capacity of 65,000 data points per channel. Four channels were used on this test to measure X, Y, Z accelerations and the rate gyro. Camera coverage for this test consisted of an onboard camera, an overhead camera, and four other high-speed cameras.

4.3 Data Processing

Transducer data were downloaded to a personal computer after the test. The data were processed through an Institute-developed computer program, which provides output in either tabular or graphical form. Typical output of the program, which is developed from accelerometer and load cell data, includes vehicle accelerations, velocities, and displacements instantaneous with time. The 50-ms average accelerations are calculated, and times over which they occur are displayed. The vehicle heading angle was computed from data taken by the rate gyro.

5.0 SOIL CONDITIONS

The 1.8-m-long wood posts were embedded in a standard soil for a depth of 1.1 m. This soil is a crushed, graded, limestone-base material that is used as highway base material by the City of San Antonio and the Texas Department of Transportation. A 0.6-m-diameter by 1.5-m-deep hole was drilled by a truck-mounted auger for each post. Each hole was then partially filled with the base material in 150-mm lifts and compacted using a handheld air-operated compactor. The posts were placed in the holes, and the base material was placed around the posts and compacted in 150-mm lifts using the compactor. At the time of the test, the posts had been in place for 2 weeks. The base material around the posts was in a saturated, surface dry condition with a minimal moisture content. The last rainfall at the test site was more than 1 week prior to the test date. The sieve analysis for this soil is shown in Figure 4.

6.0 TEST DESCRIPTION

Actual impact conditions were 100.1 km/h and a 25-degree impact angle. Ambient temperature at test time was 35 degrees C. As shown in Figure 5, the vehicle impacted the barrier 1 m upstream of the bridge rail. The vehicle was smoothly redirected and rolled to a stop 50 m past the end of the installation. Figure 6 shows the redirection sequence of the vehicle during impact. Maximum 50-ms average accelerations of -5.78 g's longitudinal and -4.62 g's lateral were measured from onboard transducer data. Test conditions and results are summarized in Figure 7. Figure 8 contains plots of the transducer data. Barrier and vehicle damage are shown in Figure 9.

7.0 BARRIER DAMAGE

Damage to the barrier consisted of the concrete spalling at the first bridge rail post. One blockout split, and two sections of W-beam were damaged.

8.0 VEHICLE DAMAGE

The test vehicle sustained damage to the left front fender, door, and headlight/grill area. The left side of the front bumper was deformed rearward. The vehicle frame was bent.

9.0 ASSESSMENT OF TEST RESULTS

A comparison of the test data with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 3-21.

10.0 CONCLUSIONS

A comparison of the test data with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates compliance with the requirements of test 3-21. In conclusion, the W-beam transition to a Texas type 101 bridge rail meets the requirements for a longitudinal barrier transition.

Test Assessment Summary Table - Test 3-21

Designation	Factor	Description			Test Results	Assessment
A	Structural Adequacy	Test article shall 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.			Vehicle contained and smoothly redirected.	**PASS**
D	Occupant Risk	Detached elements, fragments or other debris from the test article shall 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 shall not be permitted.			Test article and its elements did not penetrate the occupant compartment.	**PASS**
F	Occupant Risk	The vehicle shall remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.			Vehicle remained upright during and after the collision.	**PASS**
H	Occupant Risk	Occupant impact velocities shall satisfy the following: Occupant Impact Velocity Limits (m/s)			Impact Velocity (m/s)	
		Component	**Preferred**	**Maximum**		
		Longitudinal	9	12	3.63	**PASS**
		Lateral	9	12	0.41	**PASS**
I	Occupant Risk	Occupant ridedown accelerations shall satisfy the following: Occupant Ridedown Acceleration Limits (g's)			Ridedown Acceleration (g's)	
		Component	**Preferred**	**Maximum**		
		Longitudinal	15	20	-5.78	**PASS**
		Lateral	15	20	4.62	**PASS**

Test Assessment Summary Table - Test 3-21 (Continued)

Designation	Factor	Description		Test Results	Assessment
K	Vehicle Trajectory	After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.		Vehicle did not intrude into adjacent traffic lanes.	**PASS**
L	Vehicle Trajectory	The occupant impact velocity in the longitudinal direction and the occupant ridedown acceleration in the longitudinal direction shall satisfy the following:			
		Longitudinal Criteria	**Maximum**	**Test Result**	
		Occupant Impact Velocity (m/s)	12	3.63	**PASS**
		Occupant Ridedown Acceleration (g's)	20	-5.78	**PASS**
M	Vehicle Trajectory	The exit angle from the test article preferably shall be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.		.Vehicle exit angle less than 60 percent of impact angle.	**PASS**

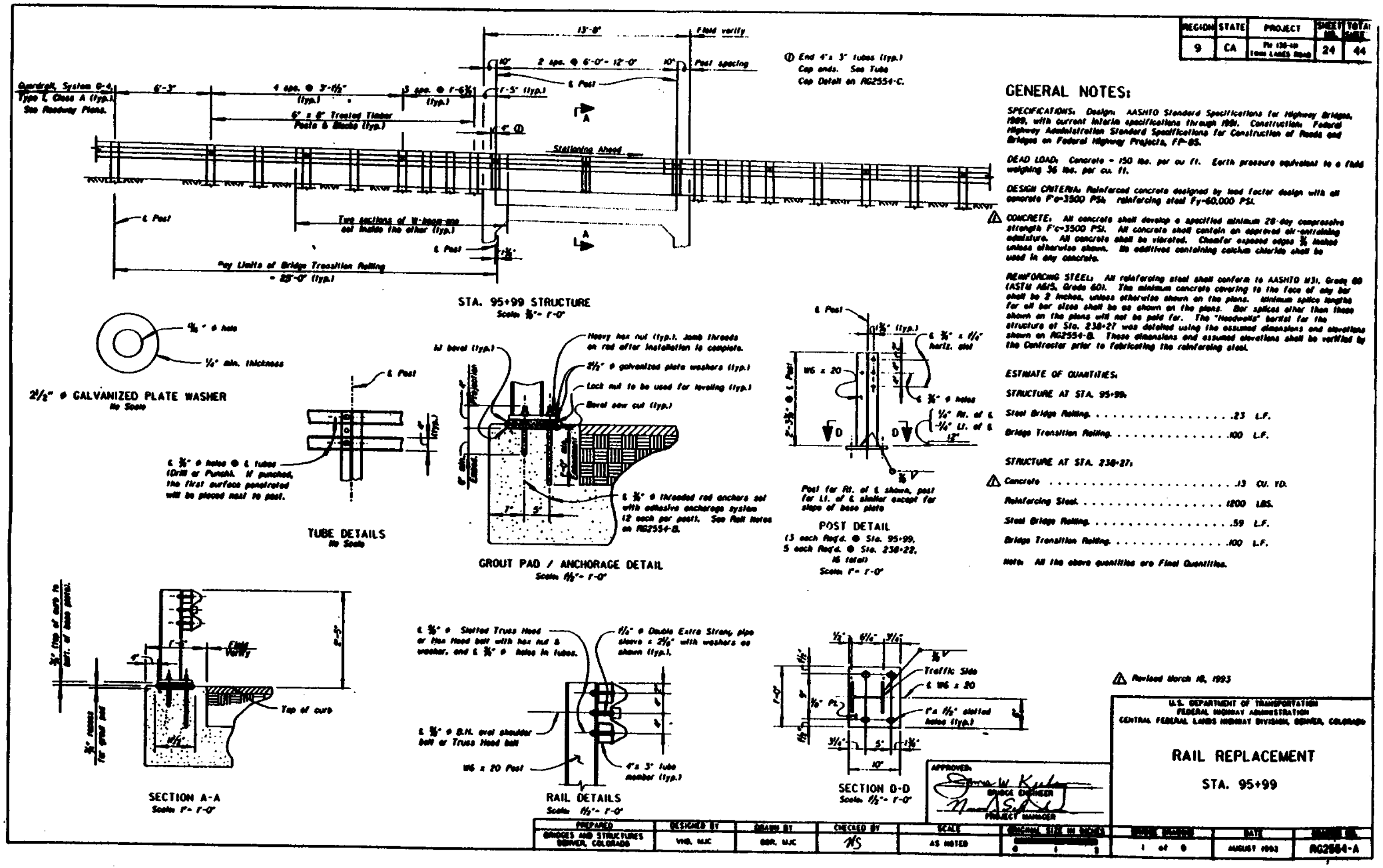


Figure 1. Test Installation Construction Details

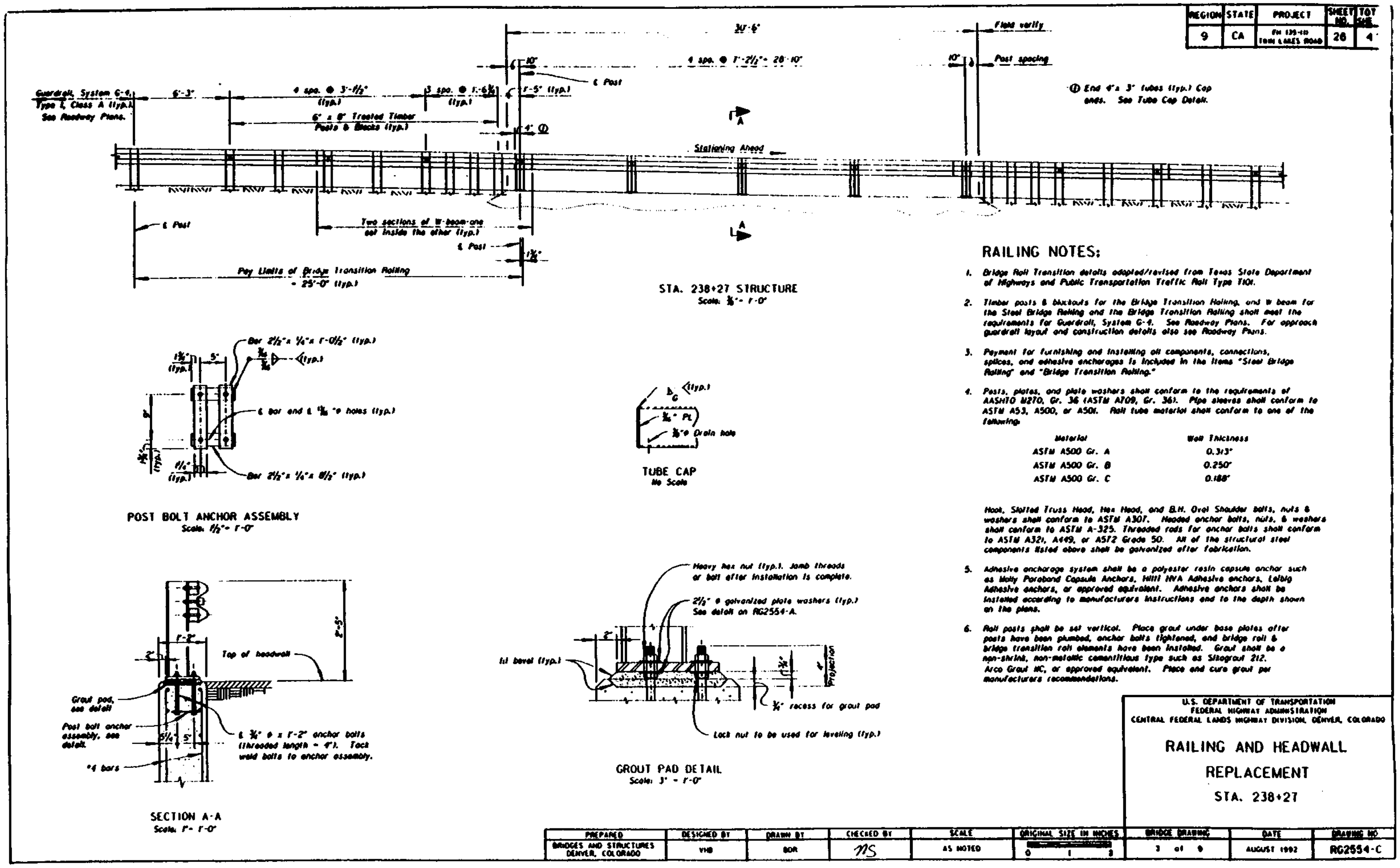


Figure 1. (Continued) Test Installation Construction Details

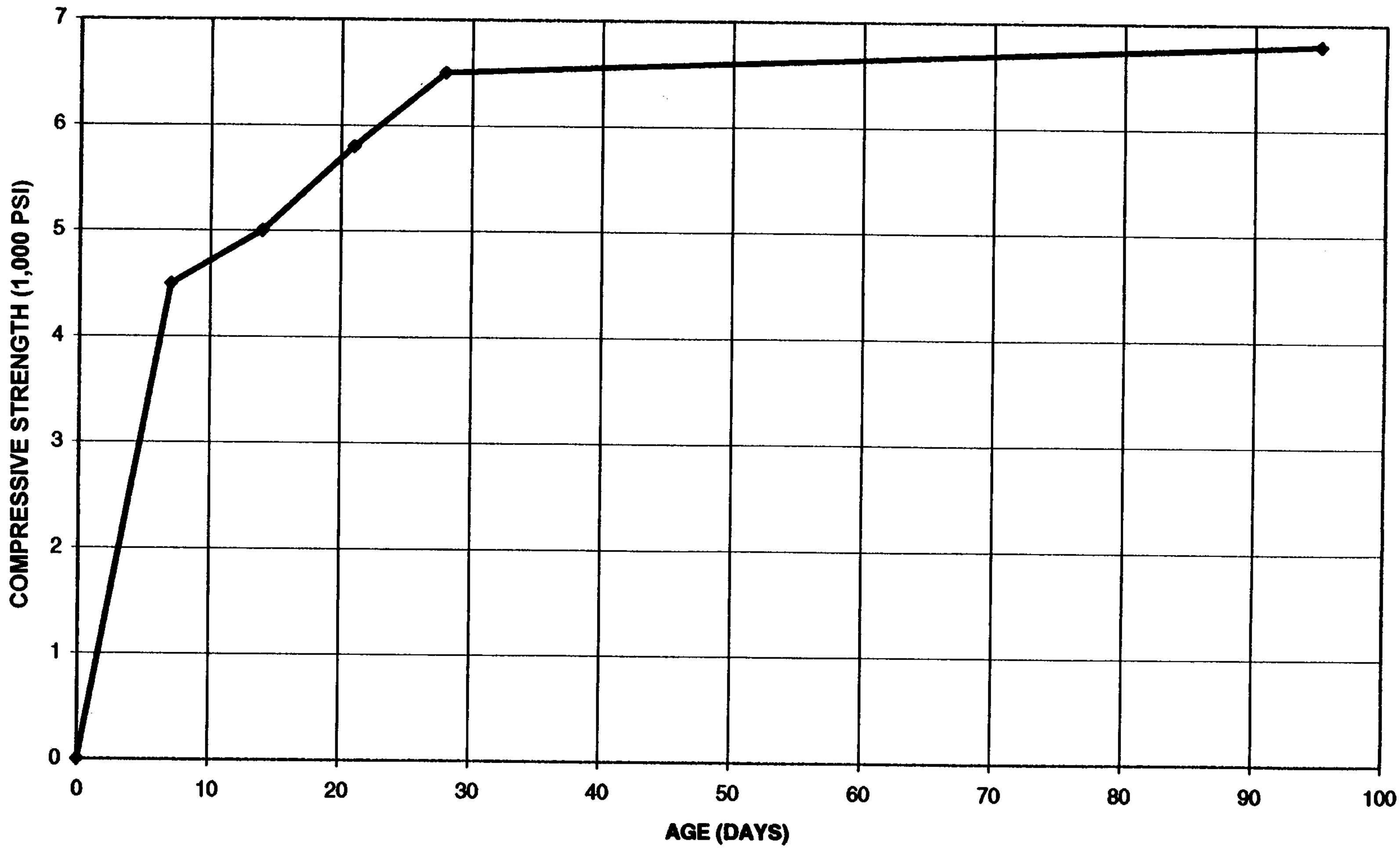


Figure 2. Concrete Headwall Compressive Strength

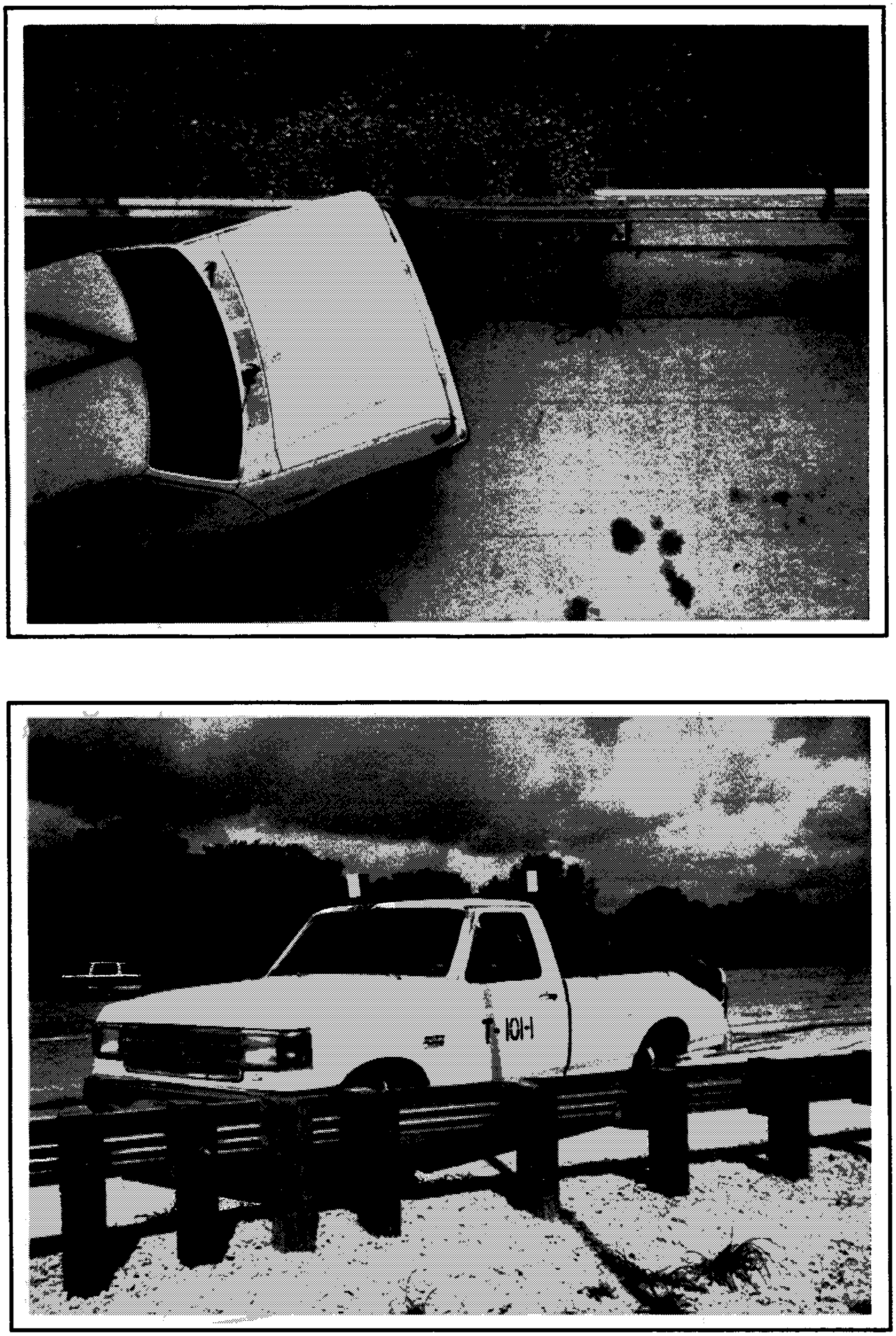


Figure 3. Before Test Photographs

Figure 3. (Continued) Before Test Photographs

Figure 3. (Continued) Before Test Photographs

Figure 3. (Continued) Before Test Photographs

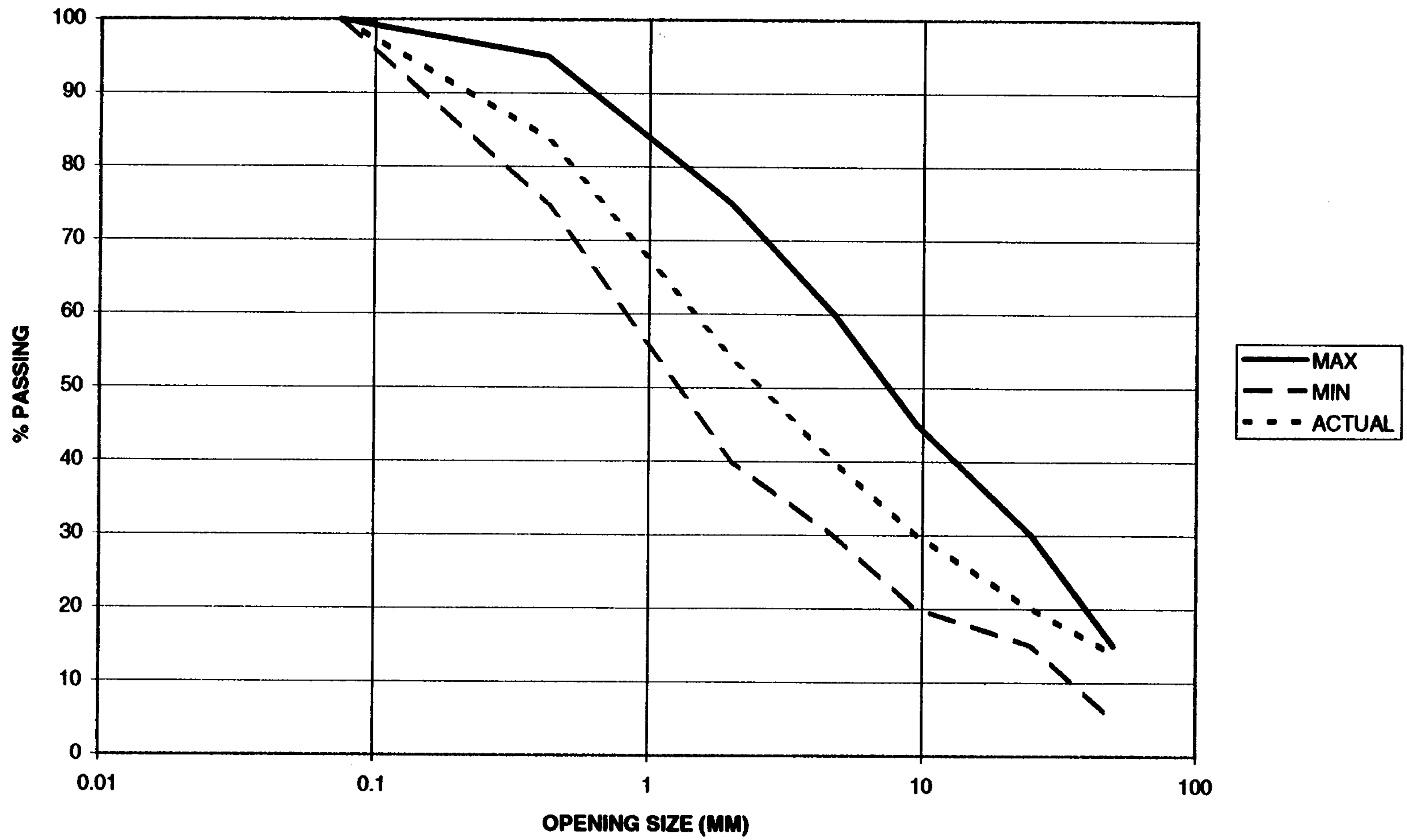


Figure 4. Strong Soil Sieve Analysis

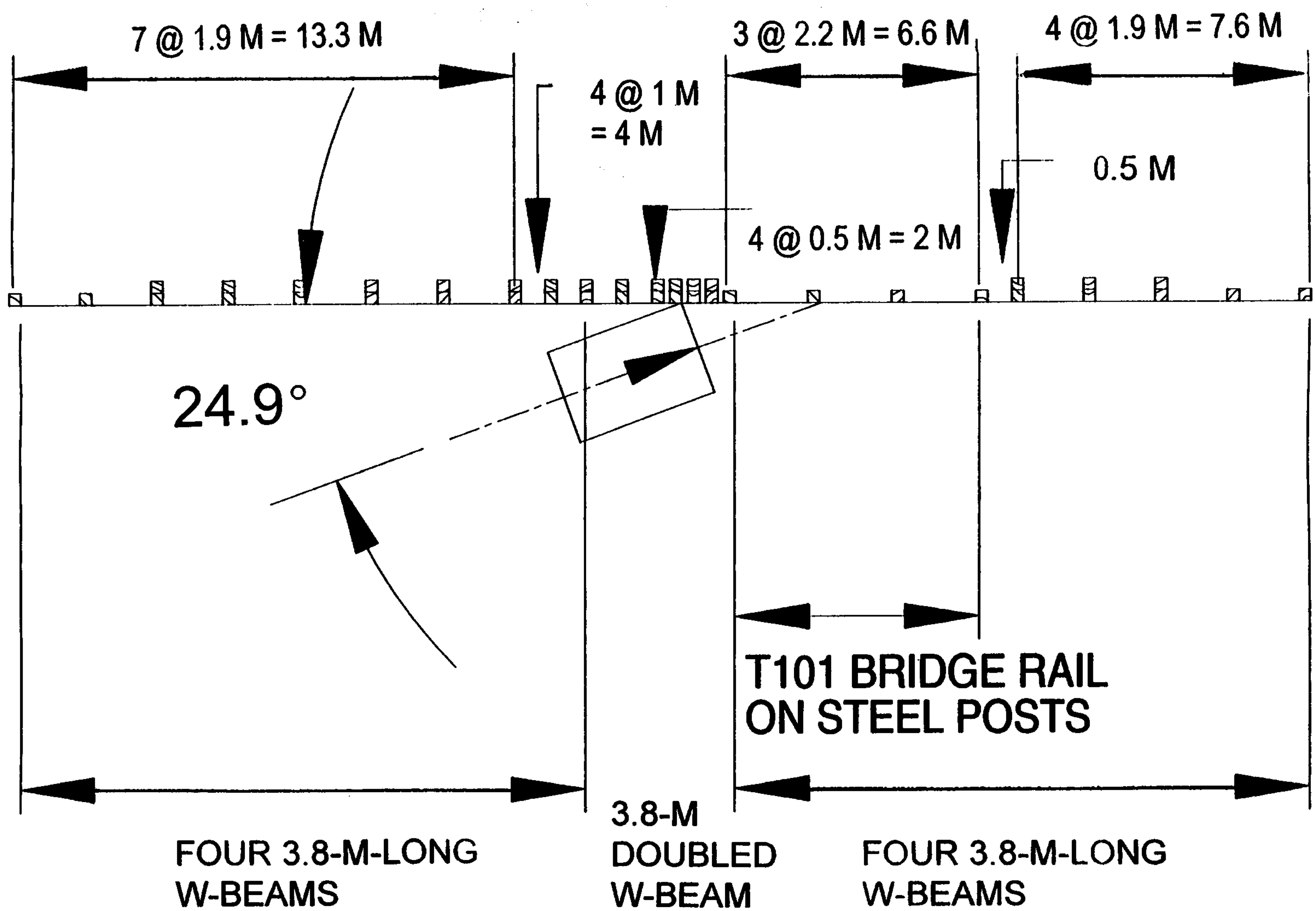


Figure 5. Test Layout

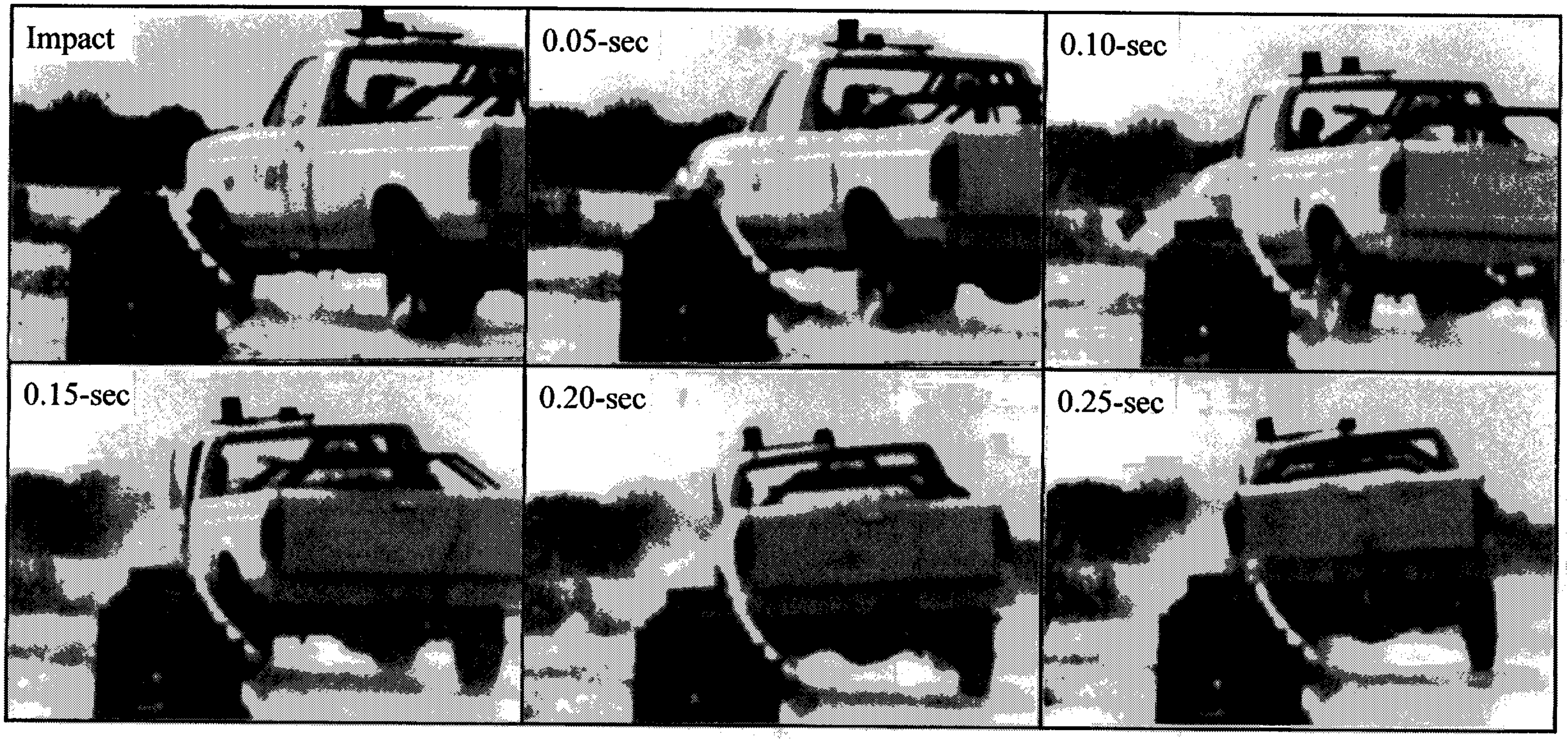


Figure 6. Sequential Photographs

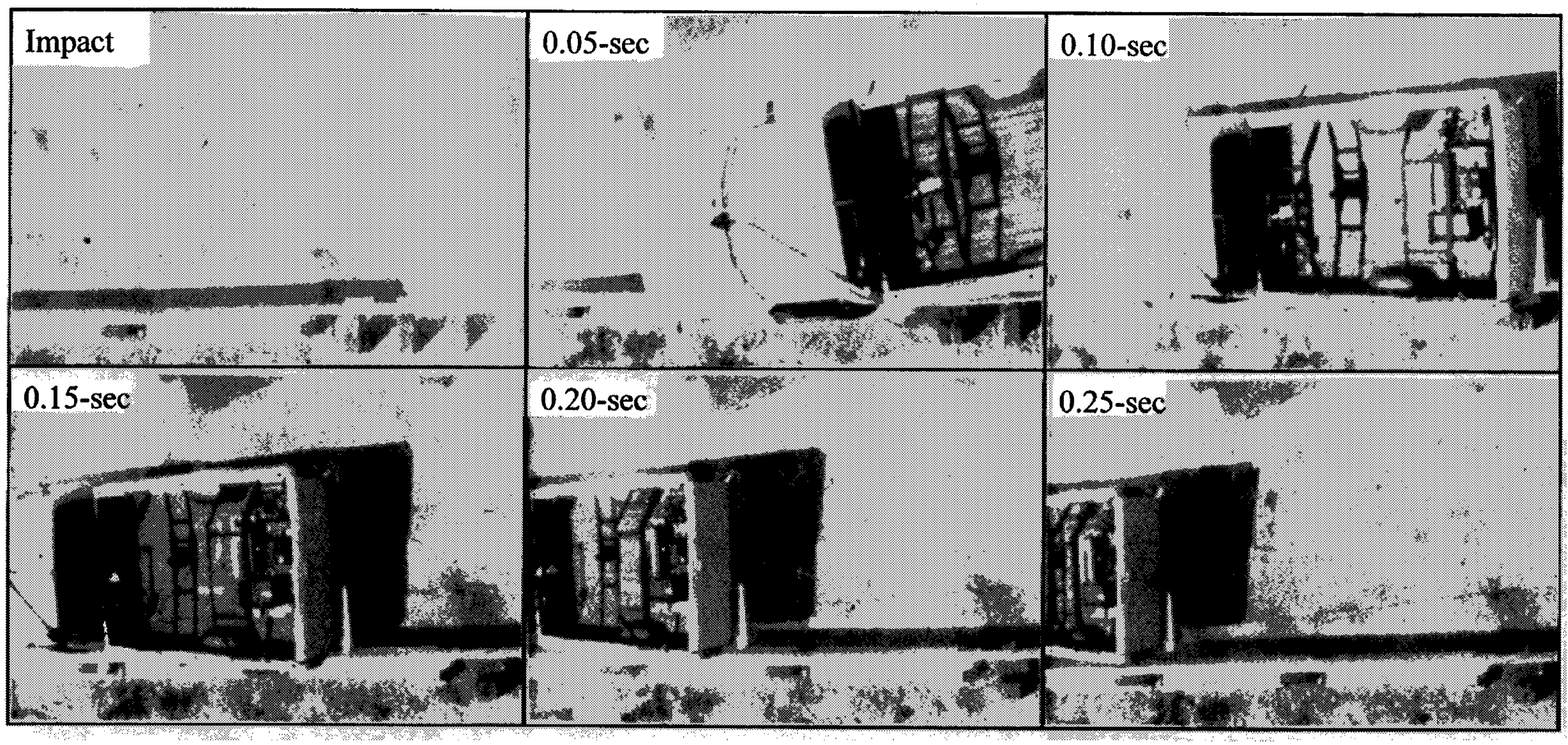


Figure 6. (Continued) Sequential Photographs

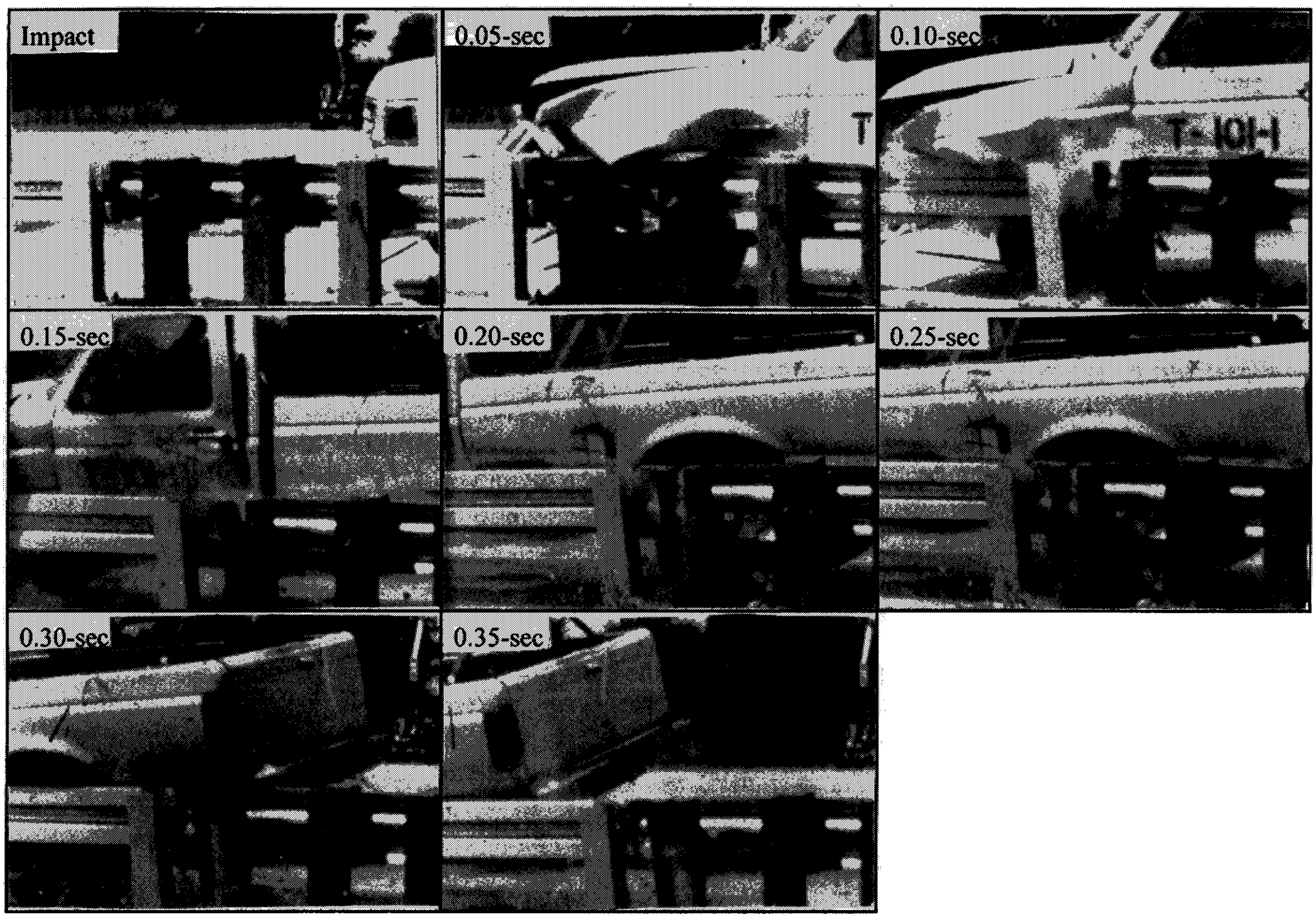
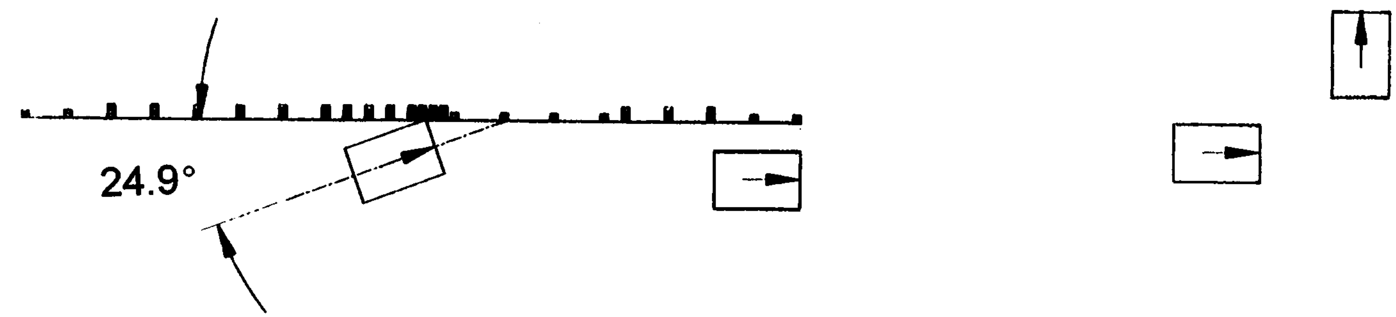


Figure 6. (Continued) Sequential Photographs



4. General Information		**7. Test Vehicle (Continued)**			
Test Agency	Southwest Research Institute	Mass (kg) Dummy(s)	75	y-direction	4.62
Test Number	T101	Mass (kg) Gross Static	2,039	**11. Test Article Deflection (m)**	
Test Date	8/9/95	**8. Impact Conditions**		Dynamic	0.2
5. Test Article		Speed (km/h)	100.1	Permanent	0.1
Type	Transition	Angle (deg)	24.9	**12. Vehicle Damage**	
Installation Length (m)	19.1	**9. Exit Conditions**		Exterior	
Barrier	G4-2W	Speed (km/h)	72	VDS	11LFQ4
6. Soil Type and Condition	Standard Soil, Dry Compacted	Angle (deg)	10	CDC	11FFEN9
7. Test Vehicle		**10. Occupant Risk Values**		Interior	
Type	Production Model	Impact Velocity (m/s)		OCDI	LF0112000
Designation	2000 P	x-direction	3.63	**13. Post-Impact Vehicular Behavior**	
Model	1989 Ford F250	y-direction	0.41	Maximum Roll Angle (deg)	15 Estimated
Mass (kg) Curb	2,050	Ridedown Acceleration (g's)		Maximum Pitch Angle (deg)	5 Estimated
Mass (kg) Test Inertial	1,964	x-direction	-5.78	Maximum Yaw Angle (deg)	0 Estimated

Figure 7. Summary of Test Conditions and Results

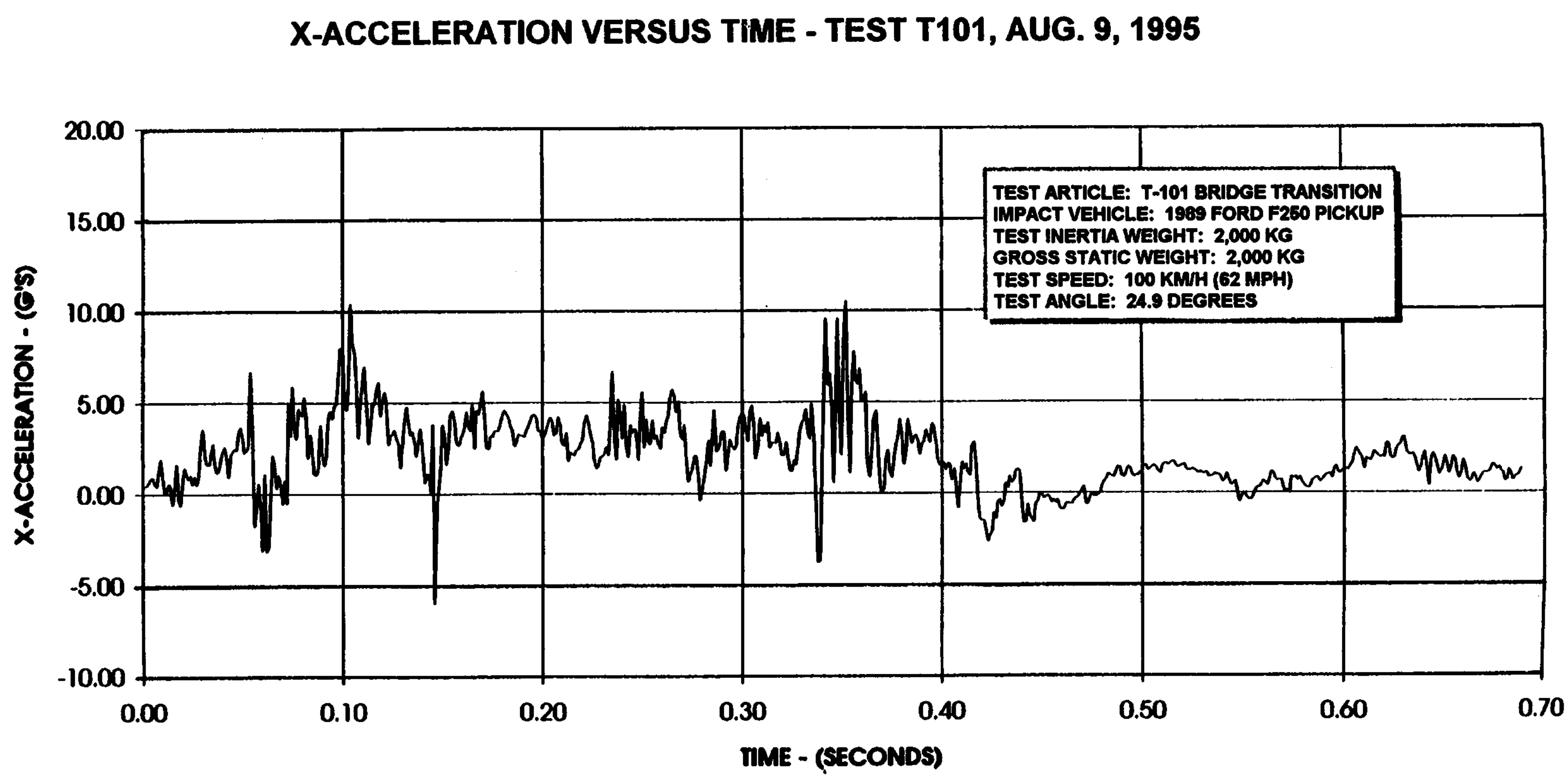


Figure 8. Vehicle Acceleration Plot

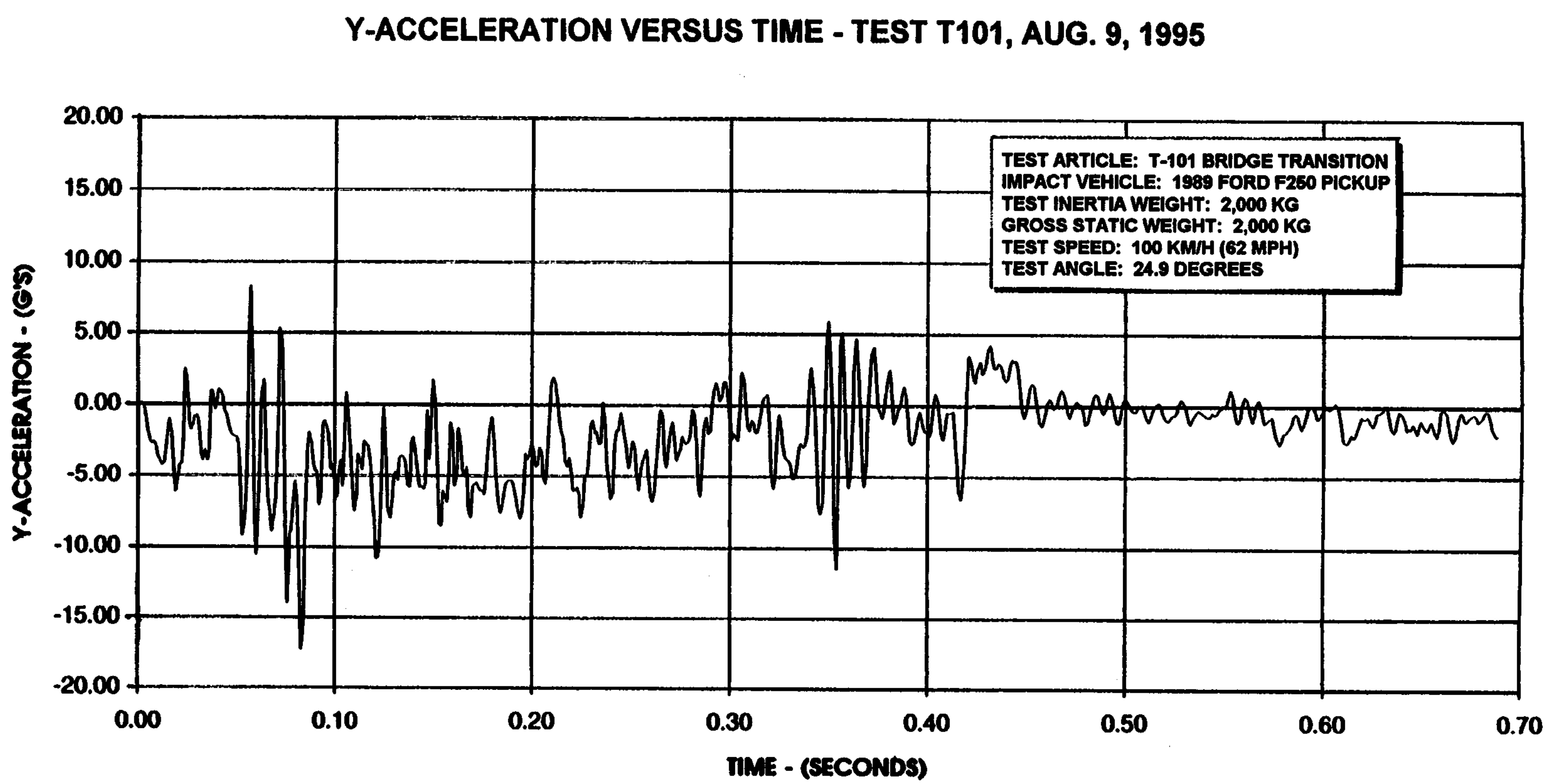


Figure 8. (Continued) Vehicle Acceleration Plot

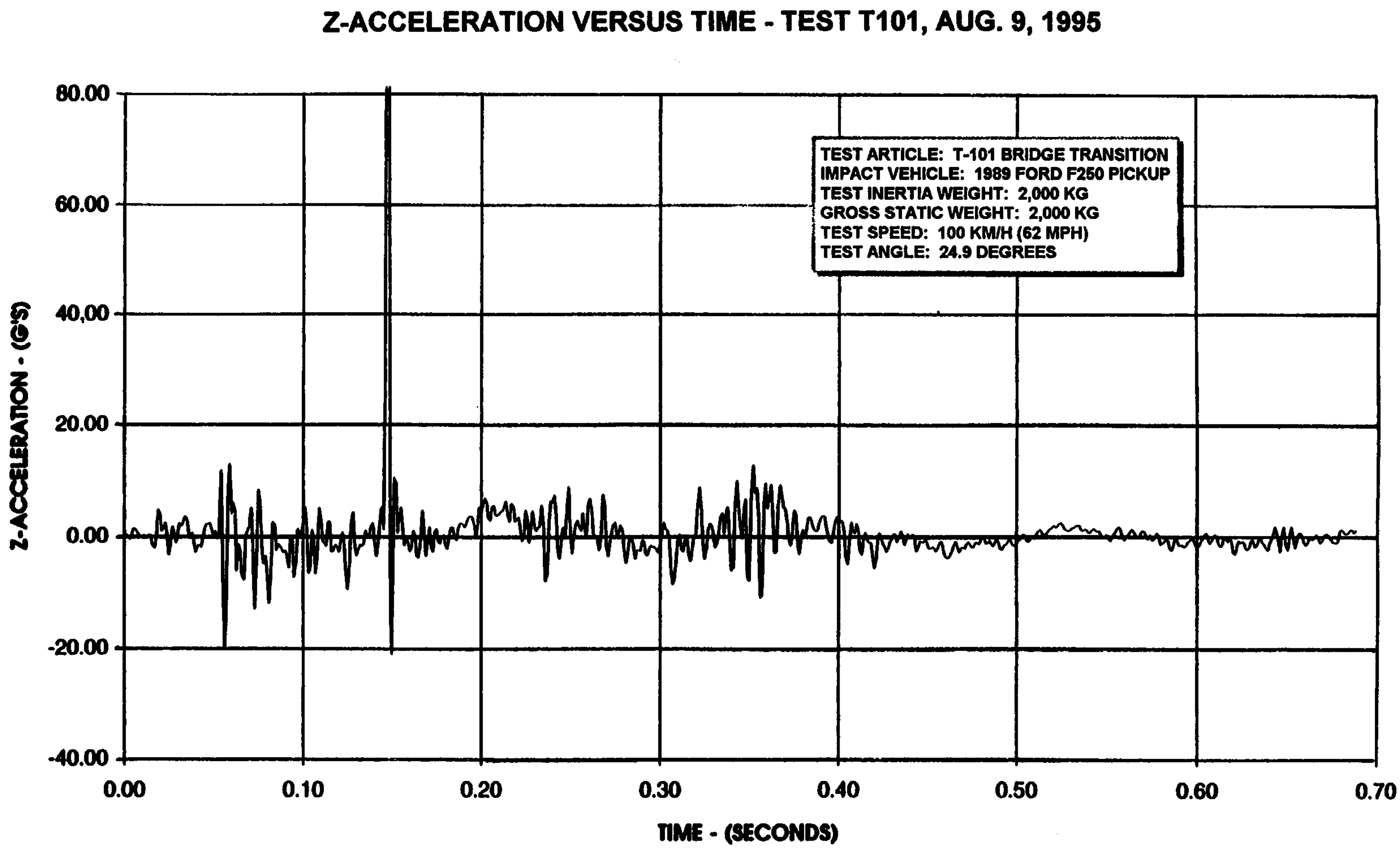


Figure 8. (Continued) Vehicle Acceleration Plot

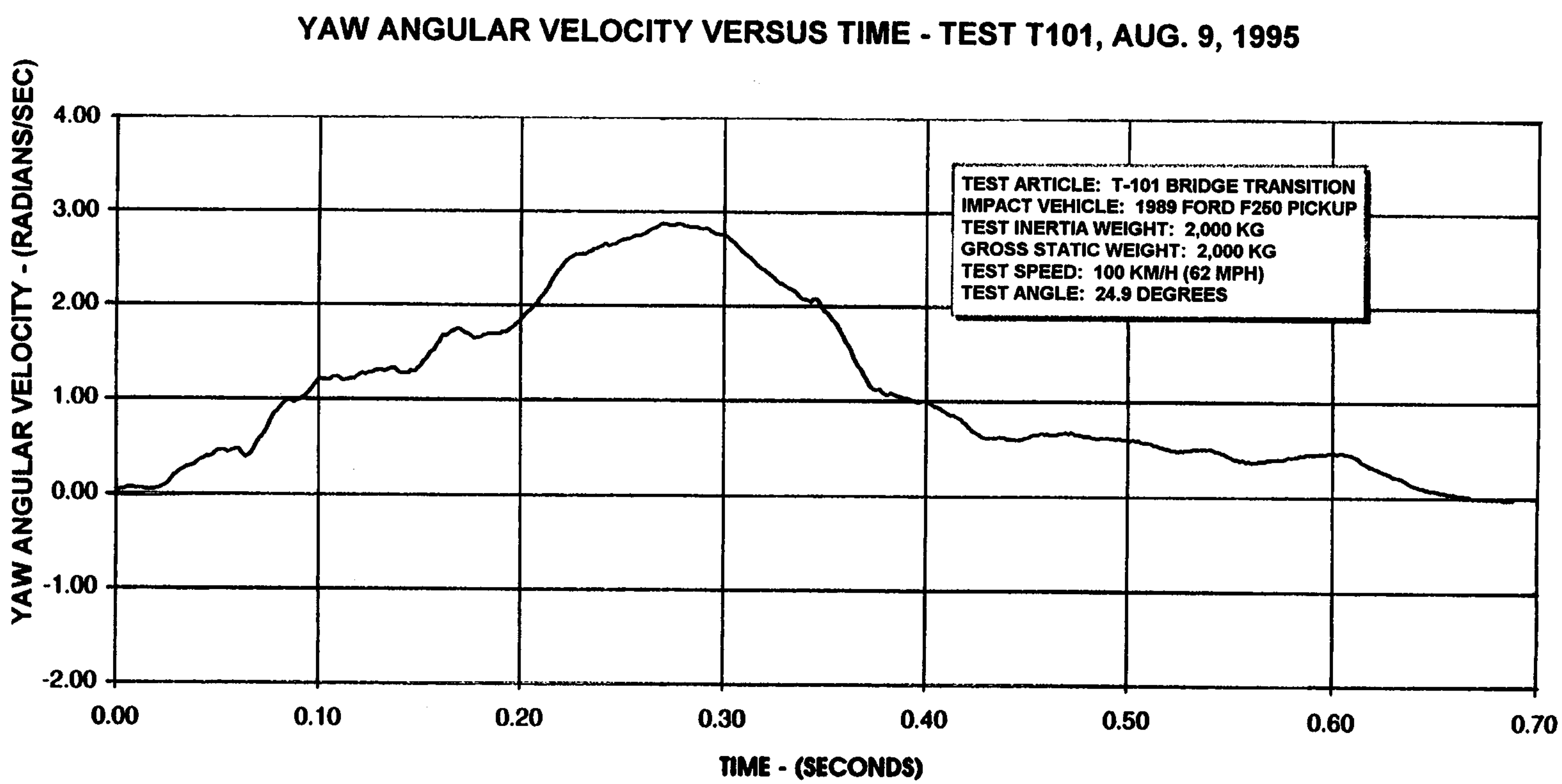


Figure 8. (Continued) Vehicle Acceleration Plot

TEST ID ------- T101
TEST DATE ----- 08-09-95
VEHICLE CLASS - 2000P
IMPACT SPEED -- 27.76 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.000	-.3	.4	.0	20.0	27.8	.0	.0	.0	.0	.0
.010	-3.7	1.0	-.2	20.0	27.6	.1	.0	.3	.1	.0
.020	-5.2	.8	3.8	19.9	27.2	.1	.0	.5	.2	.0
.030	-.8	3.5	.8	19.9	27.1	.2	.1	.8	.3	.0
.040	.1	2.3	-2.9	19.7	26.9	.3	.2	1.0	.4	.0
.050	-2.3	3.0	.0	19.5	26.8	.4	.2	1.3	.5	.0
.060	-10.6	-3.1	3.8	19.3	26.5	.5	.2	1.5	.5	.0
.070	-6.7	-.6	1.7	19.0	26.0	.3	.1	1.8	.6	.0
.080	-5.4	4.3	-6.4	18.6	25.6	.5	-.1	2.0	.7	.0
.090	-4.7	2.2	-2.7	18.1	24.8	.5	-.4	2.3	.8	.0
.100	-5.3	8.0	2.2	17.4	24.5	.7	-.6	2.5	.8	.0
.110	-7.5	6.0	3.2	16.8	24.1	1.0	-.7	2.7	.9	.0
.120	-8.2	5.1	-2.9	16.1	23.6	1.2	-.7	3.0	1.0	.0
.130	-5.1	2.9	-3.5	15.3	23.0	1.3	-.9	3.2	1.0	.0
.140	-2.3	2.3	-.8	14.6	22.6	1.3	-1.0	3.4	1.1	.0
.150	1.7	3.8	-21.3	13.8	22.2	1.0	1.5	3.6	1.1	.0
.160	-2.1	3.3	-2.7	13.0	21.8	1.0	1.7	3.9	1.1	.0
.170	-5.8	5.7	-1.3	12.0	21.3	1.1	1.6	4.1	1.2	.0
.180	-.9	4.3	-1.5	11.1	20.9	1.1	1.5	4.3	1.2	.0
.190	-5.4	3.2	2.0	10.1	20.4	1.1	1.6	4.5	1.2	.0
.200	-2.7	3.0	4.6	9.1	19.8	1.1	1.9	4.7	1.3	.0
.210	1.4	2.8	3.9	8.0	19.5	1.1	2.3	4.9	1.3	.1
.220	-4.8	3.0	2.9	6.7	19.4	.9	2.7	5.1	1.3	.1
.230	-1.3	2.0	1.5	5.3	18.9	.7	2.9	5.3	1.3	.1
.240	-6.7	3.0	6.0	3.8	18.6	.5	3.0	5.5	1.3	.2
.250	-3.8	5.6	2.0	2.3	18.3	.4	3.2	5.6	1.3	.2
.260	-6.4	3.7	5.9	.7	17.9	.2	3.3	5.8	1.3	.2
.270	-2.0	3.0	-1.7	-.9	17.6	.1	3.6	6.0	1.3	.2
.280	-2.2	.3	-2.3	-2.5	17.3	-.2	3.6	6.2	1.3	.3
.290	-1.9	3.4	-.8	-4.1	17.1	-.5	3.4	6.3	1.3	.3
.300	-1.1	4.4	-1.5	-5.7	17.1	-.7	3.1	6.5	1.3	.4
.310	-1.8	3.2	-.8	-7.2	17.0	-.8	2.9	6.7	1.3	.4
.320	-1.4	2.1	.5	-8.7	16.9	-.9	2.8	6.9	1.3	.4
.330	-3.9	3.9	.2	-10.0	16.6	-1.1	3.0	7.0	1.3	.4
.340	.7	.6	-6.2	-11.2	16.2	-1.3	3.1	7.2	1.2	.5
.350	5.8	2.1	-8.1	-12.4	16.0	-1.1	3.2	7.3	1.2	.5

Figure 8. (Continued) Vehicle Acceleration Plot

TEST ID ------- T101
TEST DATE ----- 08-09-95
VEHICLE CLASS - 2000P
IMPACT SPEED -- 27.76 M/S

VEHICLE KINETICS SUMMARY
NOTE: VALUES ARE INSTANTANEOUS AT TIME

TIME	---ACCEL. (G'S)---			HEAD.	--VELOCITY (MPS)--			-----DISP. (M)----		
(S)	LONG.	LAT.	VERT.	ANG(D)	LONG.	LAT.	VERT.	X	Y	Z
.360	-5.8	5.0	4.9	-13.4	15.9	-.7	3.5	7.5	1.2	.5
.370	-.4	.0	4.8	-14.2	15.7	-.7	3.9	7.7	1.2	.6
.380	1.7	3.0	1.1	-14.8	15.8	-.6	4.0	7.8	1.1	.6
.390	-.9	2.8	3.2	-15.4	15.9	-.5	4.2	8.0	1.1	.7
.400	-1.8	1.5	2.2	-16.0	15.7	-.4	4.3	8.1	1.1	.7
.410	-.6	1.7	2.2	-16.5	15.6	-.5	4.4	8.3	1.0	.7
.420	1.4	-1.5	-5.7	-17.0	15.3	-.5	4.2	8.4	1.0	.8
.430	3.1	-.8	-.6	-17.4	15.5	-.7	4.1	8.6	.9	.8
.440	1.7	-.6	-.2	-17.7	15.8	-.8	4.0	8.7	.9	.9
.450	-.6	-.1	-1.2	-18.1	16.0	-1.0	3.9	8.9	.9	.9
.460	-.5	-.9	-3.6	-18.4	16.0	-1.1	3.7	9.0	.8	.9
.470	.3	.2	-2.0	-18.8	16.0	-1.3	3.5	9.2	.8	1.0
.480	-1.4	.4	-1.0	-19.2	16.0	-1.4	3.3	9.3	.7	1.0
.490	-.3	.9	-1.1	-19.5	15.9	-1.4	3.2	9.5	.7	1.0
.500	.4	1.2	-1.4	-19.9	15.9	-1.4	3.1	9.7	.7	1.1
.510	-.6	1.5	-.3	-20.2	15.9	-1.3	3.0	9.8	.6	1.1
.520	-1.0	1.5	1.6	-20.5	15.8	-1.2	3.1	10.0	.6	1.1
.530	.0	1.0	1.0	-20.8	15.8	-1.2	3.2	10.1	.5	1.2
.540	-.7	.6	.7	-21.0	15.7	-1.2	3.4	10.3	.5	1.2
.550	.1	.0	.1	-21.3	15.7	-1.2	3.4	10.4	.4	1.2
.560	.6	.6	-.8	-21.5	15.7	-1.3	3.4	10.6	.4	1.3
.570	-1.2	.3	1.0	-21.7	15.6	-1.3	3.5	10.7	.3	1.3
.580	-1.9	.4	-1.4	-21.9	15.5	-1.3	3.5	10.9	.3	1.3
.590	-1.3	.9	-1.6	-22.2	15.3	-1.3	3.3	11.0	.3	1.4
.600	-.3	1.2	-2.0	-22.5	15.3	-1.2	3.2	11.2	.2	1.4
.610	-2.4	1.3	.3	-22.7	15.2	-1.1	3.1	11.3	.2	1.4
.620	-.9	1.9	-3.1	-22.9	15.0	-1.0	3.1	11.4	.1	1.5
.630	-.3	3.0	-.6	-23.1	15.0	-.8	2.9	11.6	.1	1.5
.640	-.7	2.2	-1.3	-23.2	14.9	-.7	2.8	11.7	.0	1.5
.650	-1.3	2.0	-2.5	-23.2	14.8	-.5	2.7	11.9	.0	1.6
.660	-.3	1.3	-1.6	-23.3	14.6	-.4	2.7	12.0	-.1	1.6
.670	-.6	1.1	.1	-23.3	14.5	-.3	2.6	12.1	-.2	1.6
.680	-.8	.6	1.3	-23.3	14.4	-.2	2.6	12.3	-.2	1.6
.690	-1.5	1.0	1.4	-23.2	14.3	-.1	2.7	12.4	-.3	1.7

HIGHEST 50.0-MS AVG. ACCEL.

	G'S	TIME (SEC) START	END
LONG.	-5.78	.074	.124
LAT.	4.62	.073	.123

Figure 8. (Continued) Vehicle Acceleration Plot

TEST ID ------- T101
TEST DATE ----- 08-09-95
VEHICLE CLASS - 2000P
IMPACT SPEED -- 27.76 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	(----- VEHICLE	------)		(----------- OCCUPANT			----------)
TIME	ACCEL. (G'S)		ANG.VEL	VEL. (M/S)		DISP. (M)	
(S)	LONG.	LAT.	(RAD/S)	LONG.	LAT.	LONG.	LAT.
.000	-.30	.40	.03	.00	.00	.00	.00
.010	-3.25	.64	-.21	.04	.02	.01	.03
.020	-2.68	.58	3.80	.15	.02	.01	.06
.030	-1.93	1.78	.79	.11	.02	.02	.08
.040	-.30	1.86	-2.93	.11	.02	.02	.11
.050	-4.04	3.35	.03	.08	.02	.03	.14
.060	-1.64	-.85	3.80	.16	-.02	.04	.16
.070	-3.70	1.63	1.69	.27	-.10	.04	.19
.080	-10.61	3.86	-6.42	.24	-.16	.05	.21
.090	-4.00	2.52	-2.68	.41	-.24	.06	.23
.100	-4.09	6.50	2.21	.41	-.30	.07	.25
.110	-3.71	5.30	3.18	.50	-.30	.08	.27
.120	-5.83	4.68	-2.93	.62	-.34	.10	.28
.130	-5.01	3.31	-3.51	.78	-.44*	.11	.29*
.140	-4.49	2.00	-.75	.90	-.54	.12	.30
.150	-3.71	1.56	-21.25	.98	-.73	.14	.31
.160	-4.22	3.60	-2.71	.95	-.88	.16	.32
.170	-5.92	3.89	-1.34	1.01	-1.03	.18	.32
.180	-4.58	3.89	-1.49	1.17	-1.16	.19	.32
.190	-6.34	3.33	1.95	1.28	-1.31	.22	.32
.200	-4.03	3.76	4.58	1.34	-1.46	.24	.32
.210	-1.41	3.05	3.89	1.29	-1.66	.26	.31
.220	-4.86	3.05	2.92	1.12	-1.94	.28	.30
.230	-3.63	2.44	1.51	1.16	-2.22	.30	.29
.240	-3.11	3.67	5.98	1.13	-2.48	.32	.28
.250	-3.41	3.43	1.98	1.12	-2.75	.34	.26
.260	-4.32	3.65	5.90	1.14	-3.04	.37	.24
.270	-2.61	3.19	-1.69	1.10	-3.29	.39	.21
.280	-2.71	1.50	-2.25	1.10	-3.62	.41	.18
.290	-.96	2.84	-.84	1.10	-3.91	.43	.15
.300	-.59	3.65	-1.51	1.02	-4.18	.44	.12
.310	-.58	3.25	-.78	1.05	-4.39	.46	.09
.320	-1.85	2.37	.48	1.07	-4.59	.48	.06
.330	-3.65	3.13	.22	1.17	-4.79	.49	.02
.340	-1.57	2.94	-6.21	1.26	-4.99	.51	-.01
.350	-3.32	5.15*	-8.08	1.29	-5.06	.53	-.05

Figure 8. (Continued) Vehicle Acceleration Plot

TEST ID ------- T101
TEST DATE ----- 08-09-95
VEHICLE CLASS - 2000P
IMPACT SPEED -- 27.76 M/S

OCCUPANT RISK SUMMARY
NOTE: INSTANTANEOUS 10-MS AVERAGE ACCELERATIONS

	(----- VEHICLE	------)		(----------- OCCUPANT			-----------)
TIME (S)	ACCEL. (G'S) LONG.	LAT.	ANG.VEL (RAD/S)	VEL. (M/S) LONG.	LAT.	DISP. (M) LONG.	LAT.
.360	.17	4.90	4.87	1.42	-5.06	.54	-.09
.370	-.07	1.93	4.83	1.60	-5.10	.56	-.13
.380	.14	2.73	1.08	1.60	-5.15	.58	-.16
.390	-.92	2.96	3.23	1.56+	-5.19	.59+	-.20
.400	-.95	1.97	2.16	1.58	-5.22	.61	-.24
.410	-1.33	1.00	2.18	1.63	-5.28	.63	-.28
.420	-1.03	-.66	-5.74	1.74	-5.33	.65	-.32
.430	2.98+	-.34	-.59	1.70	-5.44	.66	-.36
.440	2.55	-.18	-.24	1.59	-5.49	.68	-.40
.450	.85	-.48	-1.18	1.50	-5.58	.70	-.43
.460	-.40	-.63	-3.62	1.45	-5.67	.71	-.47
.470	.14	-.22	-2.05	1.40	-5.76	.73	-.51
.480	-.25	.36	-1.05	1.40	-5.84	.75	-.55
.490	.16	1.16	-1.08	1.38	-5.88	.76	-.59
.500	-.33	1.18	-1.36	1.37	-5.91	.77	-.63
.510	-.47	1.45	-.28	1.36	-5.93	.79	-.66
.520	-.54	1.44	1.56	1.37	-5.94	.80	-.70
.530	-.43	1.08	1.04	1.37	-5.95	.82	-.74
.540	-.60	.80	.66	1.36	-5.98	.83	-.78
.550	.07	-.09	.14	1.39	-6.01	.85	-.82
.560	-.41	.50	-.80	1.40	-6.05	.86	-.86
.570	-.65	.52	.97	1.38	-6.07	.88	-.90
.580	-1.88	.55	-1.43	1.39	-6.10	.89	-.94
.590	-.67	.86	-1.64	1.39	-6.13	.90	-.99
.600	-.38	1.37	-2.05	1.37	-6.15	.92	-1.03
.610	-1.43	1.93	.31	1.37	-6.14	.93	-1.07
.620	-1.23	2.13	-3.06	1.47	-6.11	.94	-1.11
.630	-.65	2.39	-.63	1.52	-6.06	.96	-1.16
.640	-1.14	1.59	-1.26	1.59	-6.01	.98	-1.20
.650	-1.39	1.51	-2.47	1.65	-5.97	1.00	-1.24
.660	-1.22	1.06	-1.60	1.71	-5.93	1.01	-1.28
.670	-1.03	1.04	.10	1.76	-5.90	1.03	-1.32
.680	-.73	1.02	1.28	1.79	-5.86	1.06	-1.37
.690	-1.36	1.04	1.39	1.83	-5.83	1.08	-1.41

Figure 8. (Continued) Vehicle Acceleration Plot

TEST ID ------- T101
TEST DATE ----- 08-09-95
VEHICLE CLASS - 2000P
IMPACT SPEED -- 27.76 M/S

OCCUP. RISK FACTORS	TIME (S)	VELOCITY (M/S)
>LONG. VEL. AFTER 0.6 M DISP. --	.393	1.58
>LAT. VEL. AFTER 0.3 M DISP. --	.138	.52

MAX. ACCEL. AFTER OCCUPANT IMPACT	TIME(S)	ACC.(GS)
>LONG. ACCELERATION --	.431	3.02
>LAT. ACCELERATION --	.356	-6.24

Figure 8. (Continued) Vehicle Acceleration Plot

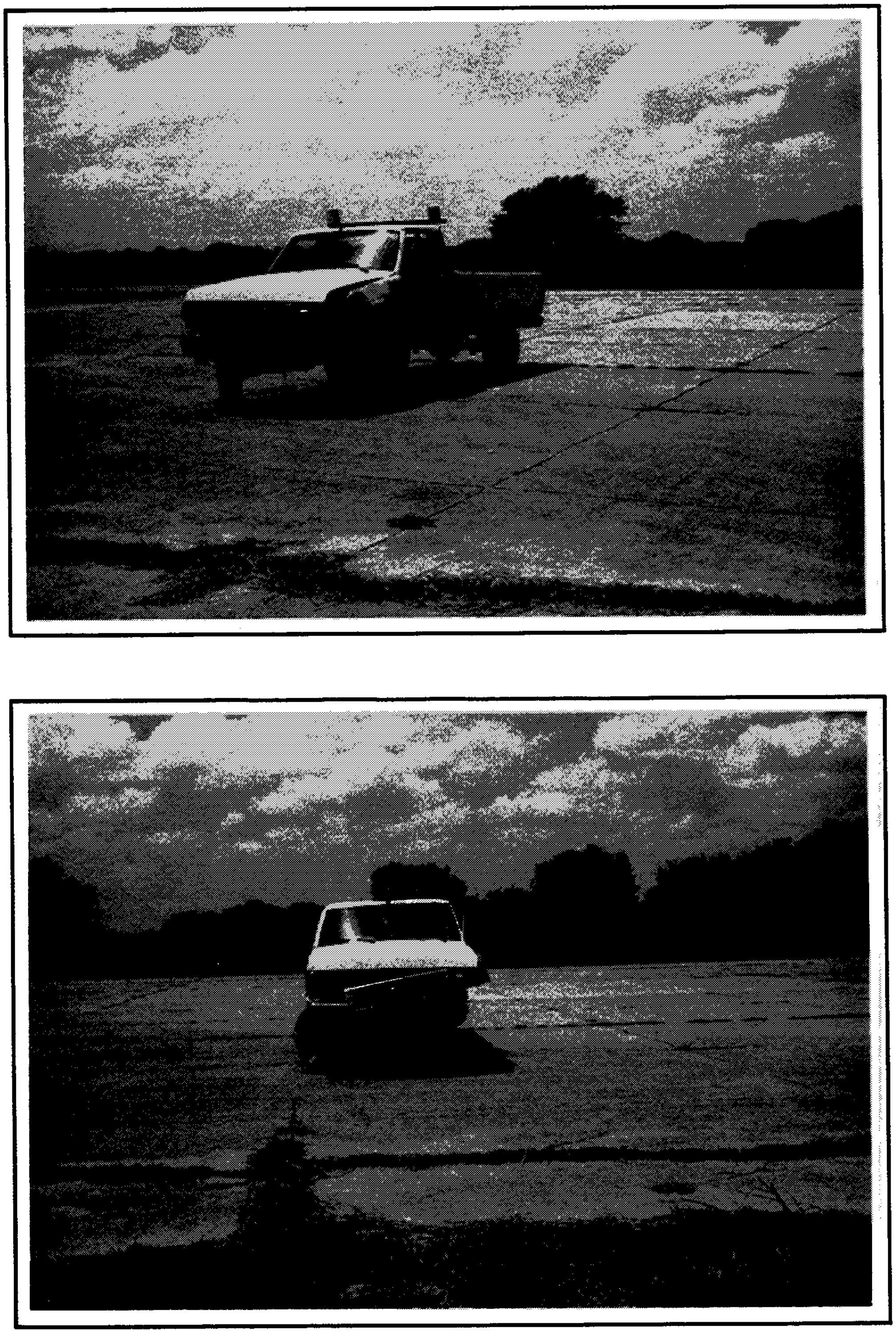


Figure 9. After Test Photographs

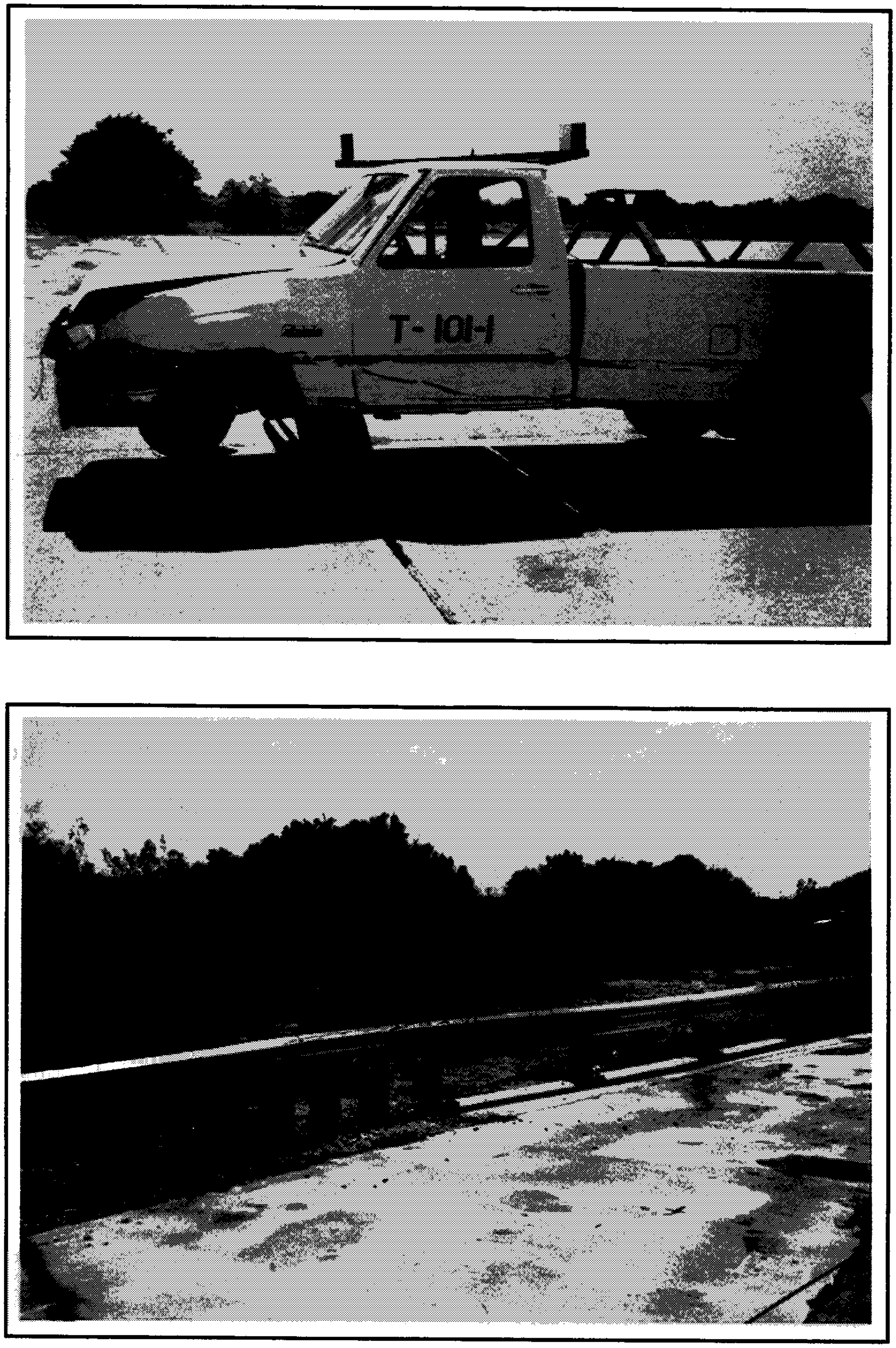


Figure 9. (Continued) After Test Photographs

Figure 9. (Continued) After Test Photographs

Figure 9. (Continued) After Test Photographs

Figure 9. (Continued) After Test Photographs

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA-FLP-96-012	2. Government Accession No.	3. Recipient's Catalog No.
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12. Sponsoring Agency Name and Address Federal Highway Administration Eastern Federal Lands Highway Division 21400 Ridge Top Circle Sterling, Virginia 20166		13. Type of Report and Period Covered Test Report May 1994 - April 1996
		14. Sponsoring Agency Code

15. Supplementary Notes

Federal Highway Administration Contract Manager (COTR): C. F. McDevitt (HSR-20)

16. Abstract

This report summarizes one full-scale crash test that was conducted on a Thrie Beam on Wood Post Transition to a New Jersey Shaped Parapet. The following table summarizes the test conditions according to test 3-21 from NCHRP Report 350.

Vehicle Mass (kg)	Vehicle Type	Impact Velocity (km/h)	Impact Angle (degrees)	NCHRP Report 350 Criteria
2,000	Pickup	100	25	Fail

17. Key Words Highway safety, longitudinal barriers, crash tests	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 32	22. Price

Form DOT F 1700.7 (8-72)

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	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	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	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
		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	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		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	psi

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

(Revised August 1992)

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List of Figures

1.0 INTRODUCTION

This project is part of the Coordinated Federal Lands Highways Technology Improvement Program (CTIP). It is intended to serve the immediate needs of those who design and construct federal lands highways, including Indian reservation roads, national park roads and parkways, and forest highways.

A wide assortment of guardrails, bridge rails, and transitions are being used on roads under the jurisdiction of the National Park Service and other federal agencies. These guardrails, bridge rails, and transitions are intended to blend in with the roadside in order to preserve the visual integrity of the parks and parkways; however, many of them have never been crash tested.[1 2] A testing program is necessary in order to ensure that the guardrails, bridge rails, and transitions being used are safe for the traveling public.

The objective of this program is to design, test, and develop aesthetic guardrails, bridge rails, and transitions for park roads and parkways and other roads under federal jurisdiction. Figures and tables follow the text. The following sections of this report will describe the:

- Test installations
- Test vehicles
- Tests
- Barrier damage
- Vehicle damage
- Recommendations and conclusions of the project.

This report describes full-scale crash test evaluation of a transition design according to procedures of NCHRP Report 350.[3]

2.0 TEST FACILITY

This test was performed on the Southwest Research Institute test track, located on the Institute campus in San Antonio, TX.

3.0 TEST INSTALLATION CONSTRUCTION

The National Park Service uses a variety of bridge railings and longitudinal barriers with the transitions from the longitudinal barrier to the bridge railing. This instal-

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[1]Hancock, K.L., Hansen, A.G., and Mayer, J.B., "Aesthetic Bridge Rails, Transitions, and Terminals for Park Roads and Parkways," Federal Highway Administration Report No. FHWA-RD-90-052, June 1990.

[2]Stout, D., Hinch, J., and Sawyer, D., "Guardrail Testing Program," Draft Final Report on Contract No. DTFH71-87-C-00002, June 1990.

[3]Ross, H.E., Jr., Sicking, D.L., Zimmer, R.A., and Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," NCHRP Report 350, Washington, D.C., 1993.

lation involves the transition from a thrie beam on wood post (G9 system in "Roadside Design Guide"[4]) to a New Jersey shaped parapet bridge rail. The transition design was adopted from the Missouri Highway and Transportation Department, Bridge Anchor Section, Drawing 606.22 K, dated January 1992. The installation that was tested was based on drawings for the Fish Creek Bridge in San Juan National Forest, CO.

The thrie beam on wood post transition to a New Jersey shaped parapet shown in Figure 1 was constructed in accordance with specifications contained in "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-92."[5] Construction of this transition system consisted of the steps listed below. Graphs of the concrete strength are shown in Figure 2. This installation consisted of 4.6 m of parapet and 15.2 m of guardrail. The parapet was tapered from the safety shape to a rectangle at the upstream end. The guardrail installation included a 1.9-m straight breakaway cable terminal (BCT) at the upstream end, 7.6 m of G4-2W guardrail system, 1.9 m for a W-beam to thrie beam transition, and 3.8 m of nested thrie beam guardrail system with reduced post spacing. There were no unusual problems encountered during the construction of the test installation.

The transition system was constructed as follows:

- The site was excavated and base material was backfilled.

- Two 0.60-m diameter by 1.80-m-long drilled shafts were excavated and completed by placing reinforcing steel and concrete in the shaft. The drilled shafts served to anchor the New Jersey parapet so that the parapet would behave similar to a full installation on a bridge deck.

- The New Jersey parapet reinforcing steel was tied and the concrete placed.

- The holes for the 6 x 8 timber guardrail posts were drilled, the posts placed in the holes, and the holes were backfilled. The backfilled base material was compacted in place using a handheld pneumatic tamper.

- The thrie beam and associated hardware was installed to complete the test installation.

4.0 TEST VEHICLE AND DUMMY

The vehicle used in this test was a 1989 GMC C2500 pickup. Gross test weight,

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[4] "Roadside Design Guide," American Association of State Highway and Transportation Officials, Washington, D.C., 1989.

[5] "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-92," Federal Highway Administration, Washington, D.C., 1992.

including the dummy and instrumentation, was 2,039 kg. The barrier installation and test vehicle before the test are shown in Figure 3. An uninstrumented dummy was seated in the driver's seat of the test vehicle. The shoulder-and-lap seatbelt was in place around the dummy.

4.1 Test Vehicle Guidance

The test vehicle was guided to the impact point by use of a 6.4-mm-diameter steel cable, 101 m long, that was pretensioned alongside of the run-up strip where it would not interfere with post-impact vehicle trajectory. A guide tube that slides along the cable was attached to the front wheel to provide guidance to the car. Just prior to impact, the guide bracket was sheared off.

Braking of the test vehicle was accomplished by use of an air cylinder attached to the brake pedal of the vehicle. Activation of the cylinder was achieved by remote activation of a gas-charged accumulator controlled by a solenoid valve.

Vehicle test speed control was achieved by means of an automatic controller attached to the engine distributor of the tow vehicle. After the vehicle accelerated to the predetermined test speed, the controller pulsed the ignition and maintained the vehicle at a constant velocity. The test vehicle was towed to the impact area using the reverse-tow method.

4.2 Vehicle Data Acquisition

The vehicle accelerometers were mounted near the vehicle center of gravity. These accelerometers were oriented to obtain data in directions parallel to the longitudinal, lateral, and vertical axes of the vehicle. A rate gyro was mounted near the accelerometers to measure the rate of yaw angular change the vehicle experiences during impact. The transducer data were recorded by a Pacific Instruments Model 5600 Data Acquisition System (DAS). The DAS contains up to 32 channels of signal conditioners, amplifiers, and appropriate SAEJ211 filters and digitizers with onboard memory for each channel. It conditions, amplifies, digitizes, and records transducer signals at programmable sample rates to 100 kHz per channel. Digitized data were recorded in solid state nonvolatile memory with a capacity of 65,000 data points per channel. Four channels were used on this test to measure X, Y, Z accelerations and the rate gyro. Camera coverage for this test consisted of an onboard camera, an overhead camera, and four other high-speed cameras.

4.3 Data Processing

Transducer data were downloaded to a personal computer after the test. The data were processed through an Institute-developed computer program, which provides output in either tabular or graphical form. Typical output of the program, which is developed from accelerometer and load cell data, includes vehicle accelerations, velocities, and displacements instantaneous with time. The 50-ms average accelerations are calculated, and times over which they occur are displayed. The vehicle heading angle was computed from data taken by the rate gyro.

5.0 SOIL CONDITIONS

The 1.8-m-long wood posts were embedded in a standard soil for a depth of 1.1 m. This soil is a crushed, graded, limestone base material that is used as highway base material by the City of San Antonio and the Texas Department of Transportation. A 0.6-m-diameter by 1.5-m-deep hole was drilled by a truck-mounted auger for each post. Each hole was then partially filled with the base material in 150-mm lifts and compacted using a handheld air-operated compactor. The posts were placed in the holes, and the base material was placed around the posts and compacted in 150-mm lifts using the compactor. At the time of the test, the posts had been in place for 2 weeks. The base material around the posts was in a saturated, surface dry condition with a minimal moisture content. The last rainfall at the test site was more than 1 week prior to the test date. The sieve analysis for this soil is shown in Figure 4.

6.0 TEST DESCRIPTION

Actual impact conditions were 100.1 km/h and a 25-degree impact angle. Ambient temperature at test time was 35 degrees C. As shown in Figure 5, the vehicle impacted the barrier 1 m upstream of the New Jersey parapet. The vehicle was redirected and rolled on its side. Figure 6 shows the redirection sequence of the vehicle during impact. Maximum 50-ms average accelerations of -12.08 g's longitudinal and 11.22 g's lateral were measured from onboard transducer data. Test conditions and results are summarized in Figure 7. Figure 8 contains plots of the transducer data. Barrier and vehicle damage are shown in Figure 9.

7.0 BARRIER DAMAGE

Damage to the barrier consisted of minor spalling of the concrete and slight damage to the thrie beam.

8.0 VEHICLE DAMAGE

The test vehicle sustained damage to the left front fender, door, and headlight/grill area. The front bumper was deformed rearward. The vehicle frame was bent when the vehicle rolled.

9.0 ASSESSMENT OF TEST RESULTS

A comparison of the test data with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates noncompliance with the requirements of test 3-21 because of vehicle rollover.

10.0 CONCLUSIONS

A comparison of the test data with the evaluation criteria set forth in NCHRP Report 350, Table 1, Safety Evaluation Guidelines, indicates noncompliance with the requirements of test 3-21. In conclusion, this transition design should be modified to prevent vehicle rollover.

Test Assessment Summary Table - Test 3-21

Designation	Factor	Description			Test Results	Assessment
A	Structural Adequacy	Test article shall 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.			Vehicle redirected and rolled on its side.	**FAIL**
D	Occupant Risk	Detached elements, fragments or other debris from the test article shall 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 shall not be permitted.			Test article and its elements did not penetrate the occupant compartment.	**PASS**
F	Occupant Risk	The vehicle shall remain upright during and after collision, although moderate roll, pitching, and yawing are acceptable.			Vehicle remained upright during and after the collision.	**PASS**
H	Occupant Risk	Occupant impact velocities shall satisfy the following: Occupant Impact Velocity Limits (m/s)			Impact Velocity (m/s)	
		Component	**Preferred**	**Maximum**		
		Longitudinal	9	12	2.29	**PASS**
		Lateral	9	12	3.11	**PASS**
I	Occupant Risk	Occupant ridedown accelerations shall satisfy the following: Occupant Ridedown Acceleration Limits (g's)			Ridedown Acceleration (g's)	
		Component	**Preferred**	**Maximum**		
		Longitudinal	15	20	-12.08	**PASS**
		Lateral	15	20	11.22	**PASS**

Test Assessment Summary Table (Continued) - Test 3-21

Designation	Factor	Description		Test Results	Assessment
K	Vehicle Trajectory	After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.		Vehicle did not intrude into adjacent traffic lanes.	**PASS**
L	Vehicle Trajectory	The occupant impact velocity in the longitudinal direction and the occupant ridedown acceleration in the longitudinal direction shall satisfy the following:			
		Longitudinal Criteria	**Maximum**	**Test Result**	
		Occupant Impact Velocity (m/s)	12	-12.08	**FAIL**
		Occupant Ridedown Acceleration (g's)	20	2.29	**PASS**
M	Vehicle Trajectory	The exit angle from the test article preferably shall be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.		10°	**PASS**

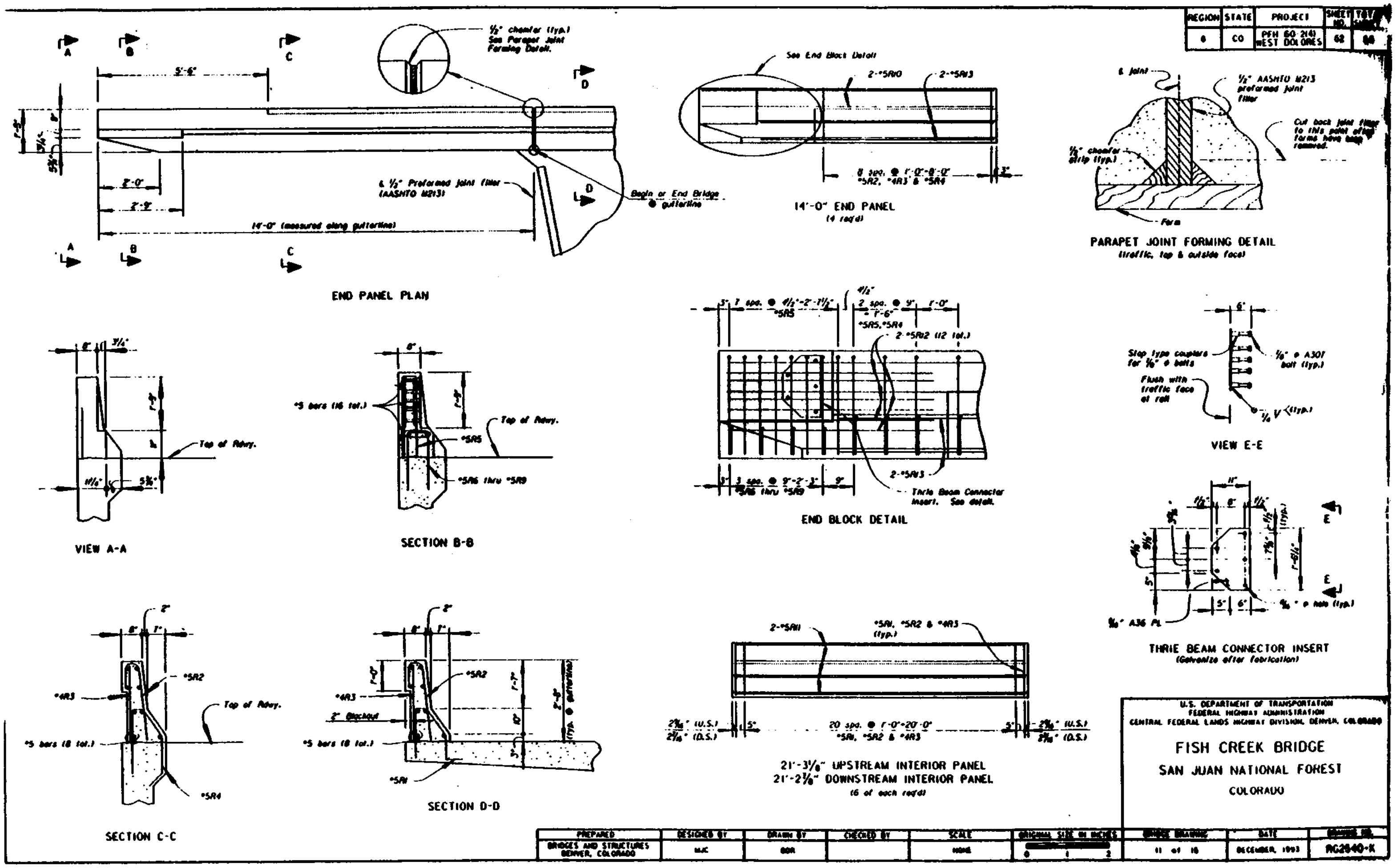

Figure 1. Test Installation Construction Details

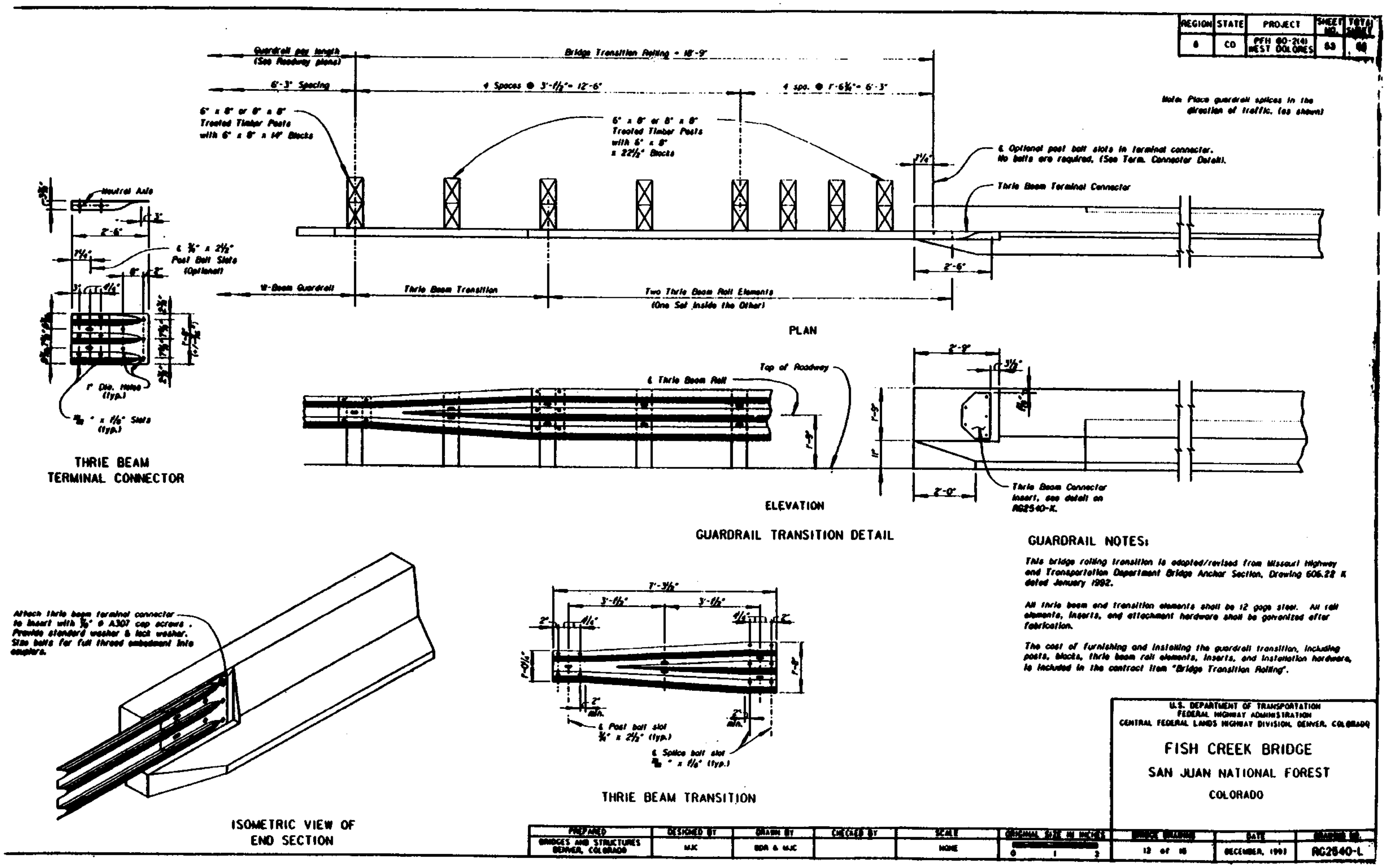

Figure 1. (Continued) Test Installation Construction Details

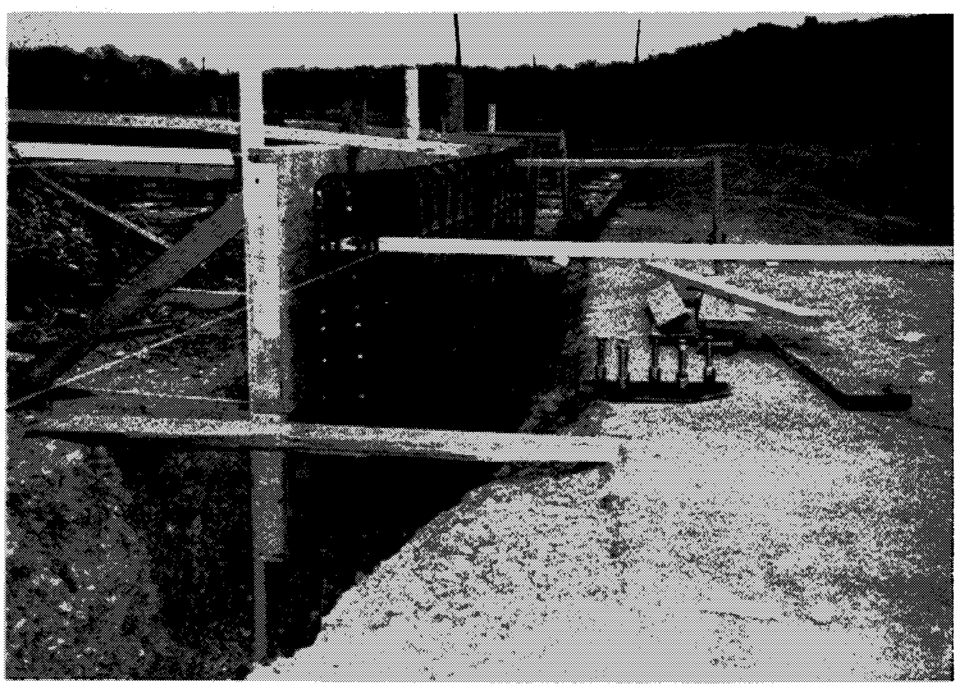

Figure 1. (Continued) Test Installation Construction Details

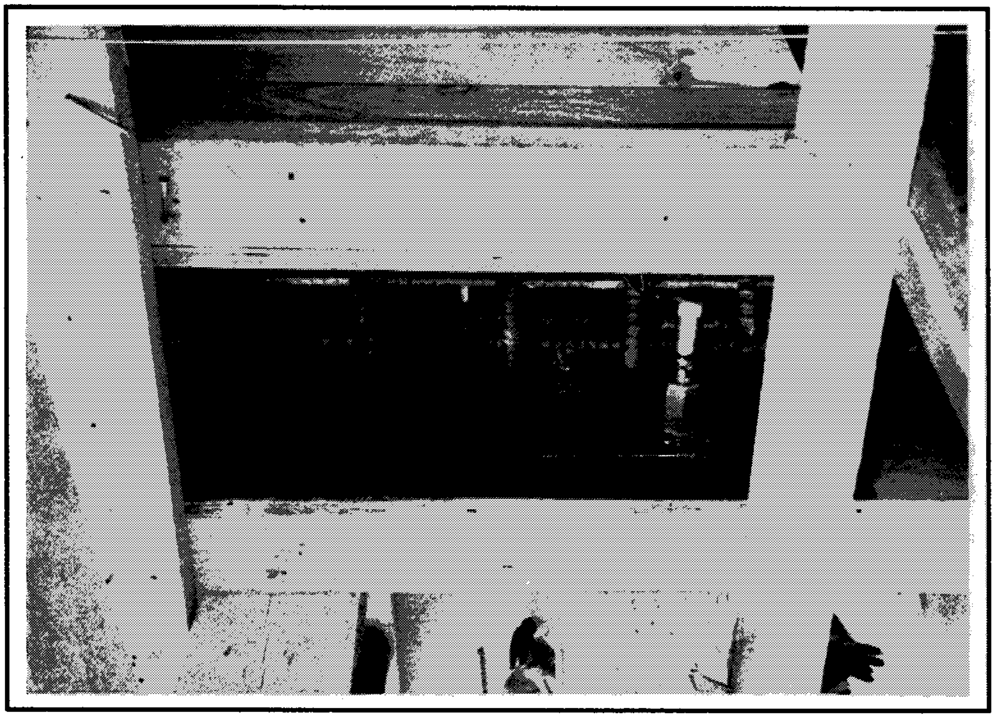

Figure 1. (Continued) Test Installation Construction Details

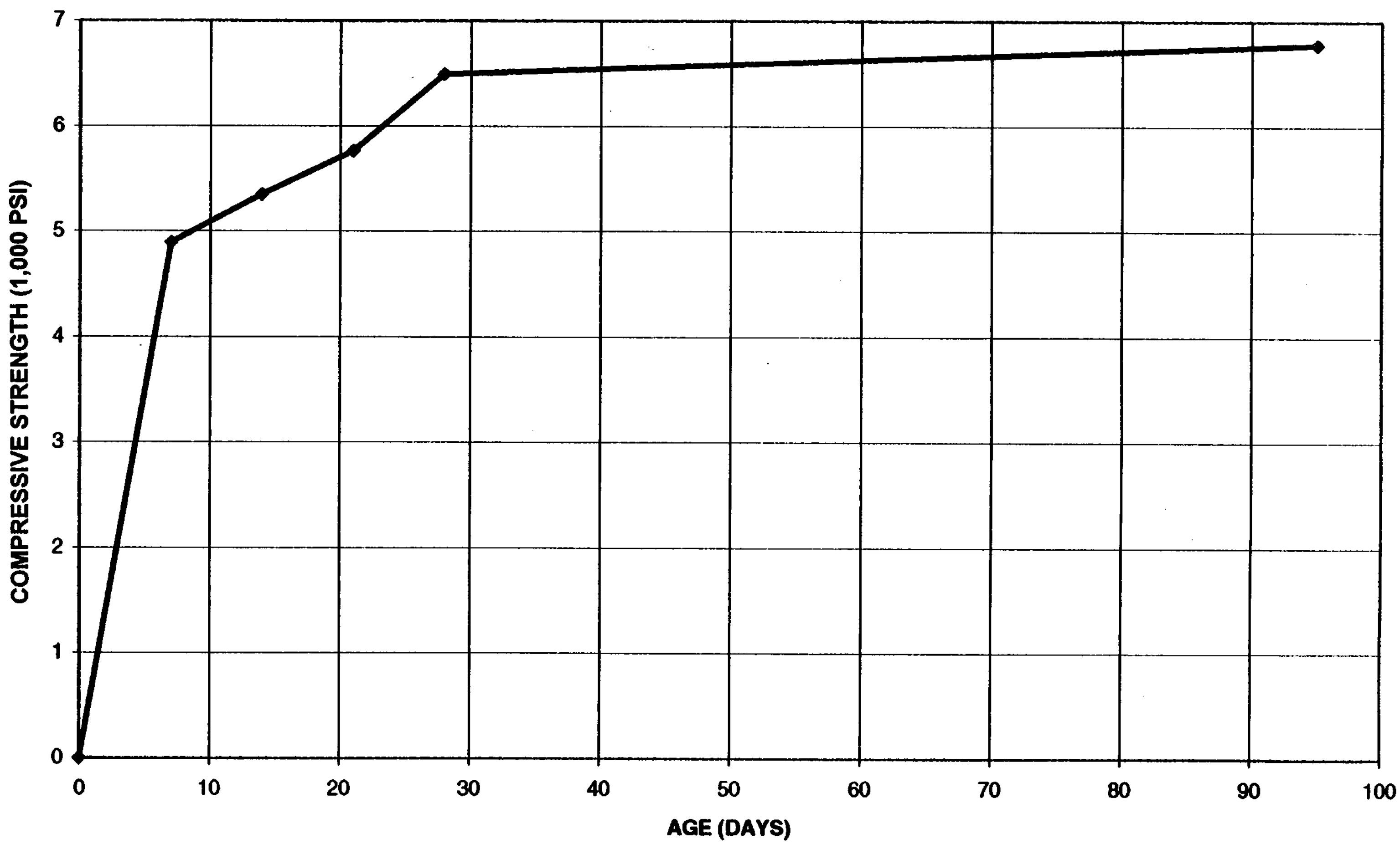

Figure 2. Concrete Parapet Compressive Strength

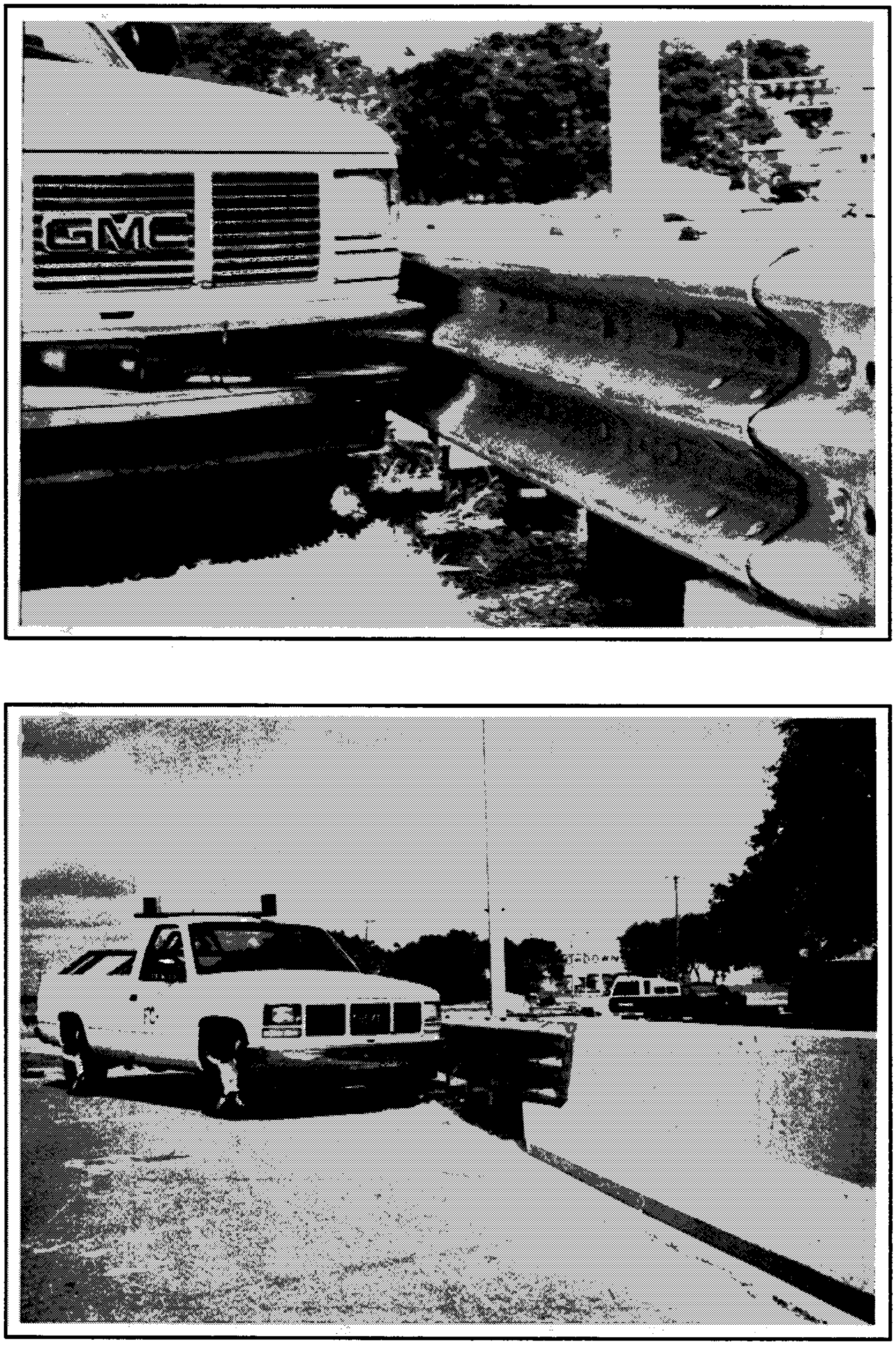

Figure 3. Before Test Photographs

Figure 3. (Continued) Before Test Photographs

Figure 3. (Continued) Before Test Photographs

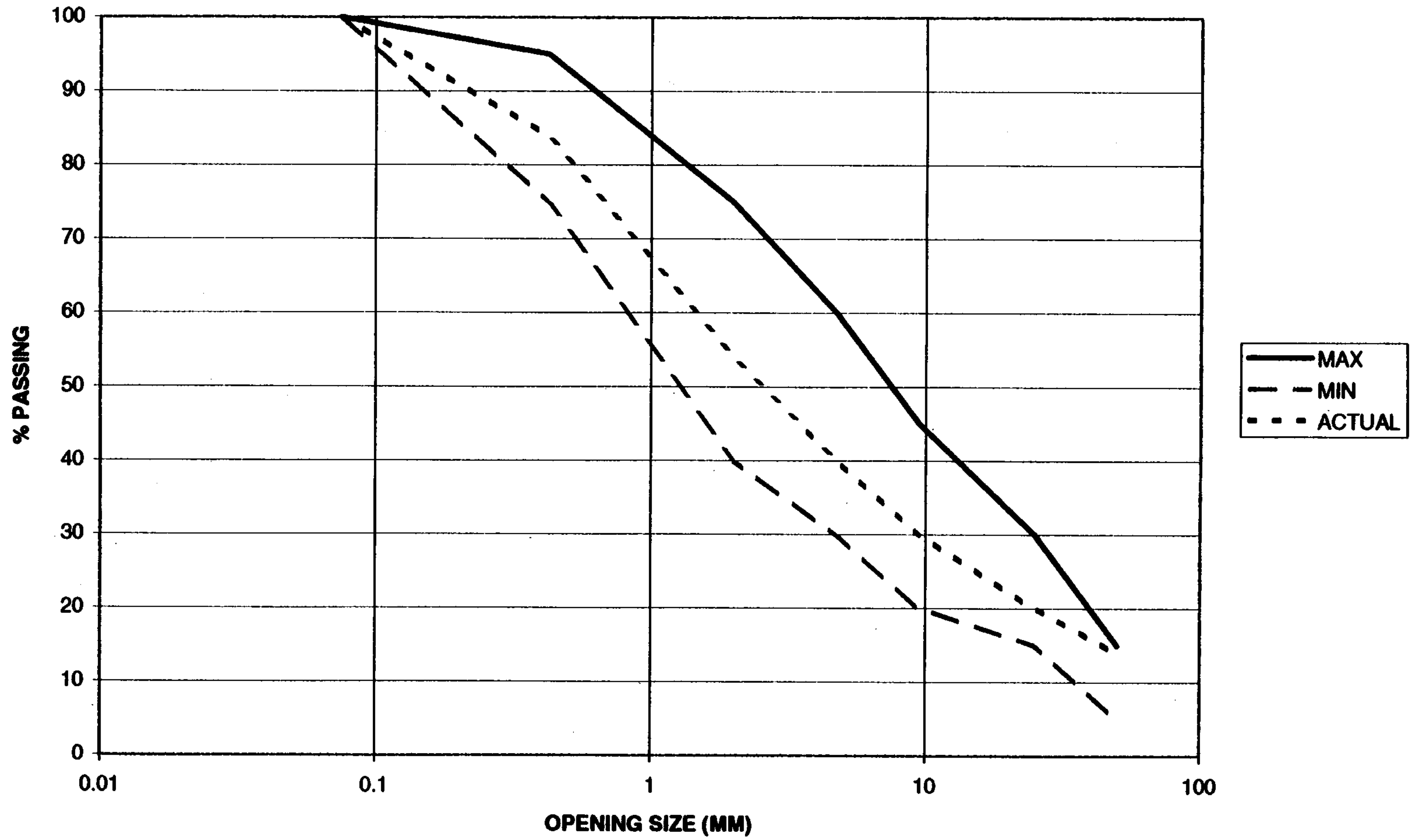

Figure 4. Strong Soil Sieve Analysis

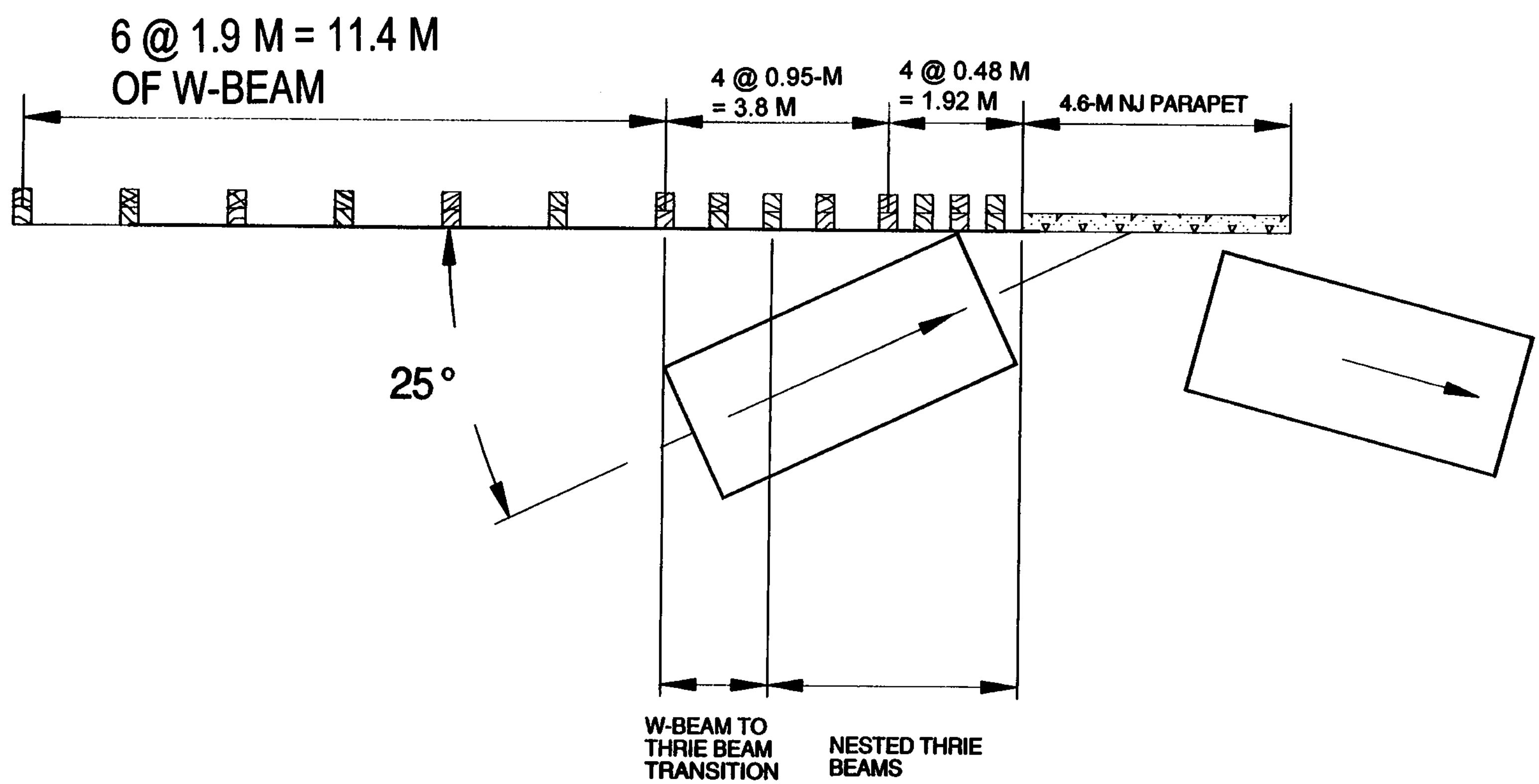

Figure 5. Test Layout

Figure 9. (Continued) After Test Photographs

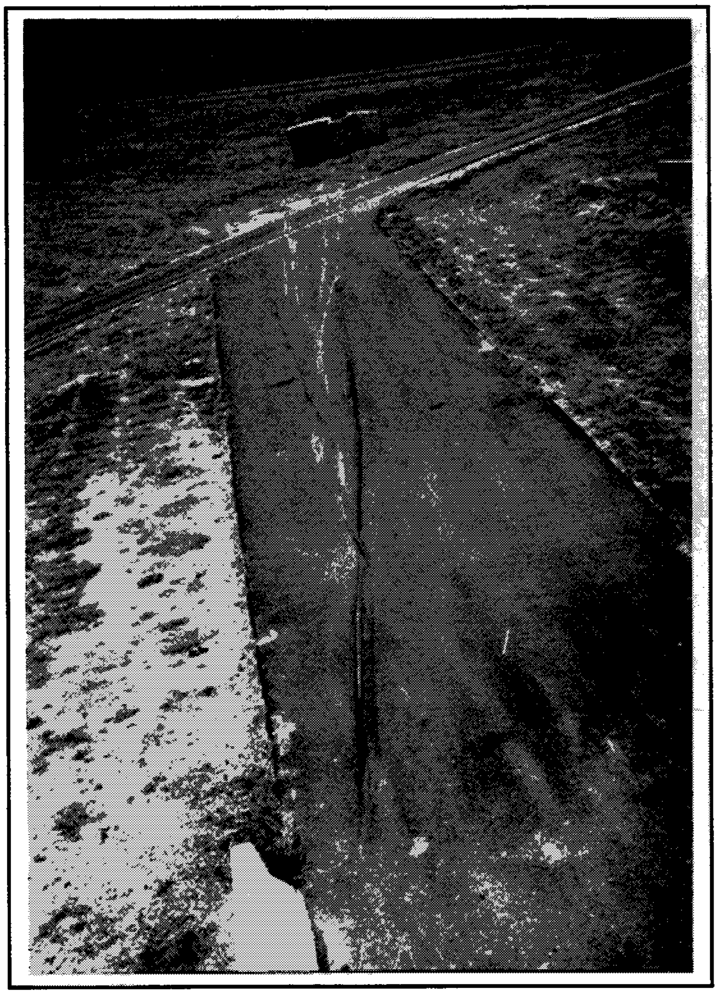

Figure 9. (Continued) After Test Photographs