VEHICLE CRASH TESTS OF THE AESTHETIC, SEE-THROUGH CONCRETE BRIDGE RAIL WITH SIDEWALK, TYPE 80SW

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
ENGINEERING SERVICE CENTER,
OFFICE OF MATERIALS ENGINEERING AND TESTING SERVICES

Supervised by...Phil Stolarski, P.E.
Principal Investigator .... Rich Peter, P.E.
Report Prepared by..Robert Meline, P.E. and John Jewell, P.E.
Research Performed by ....Roadside Safety Technology Unit

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16. ABSTRACT

An aesthetic, see-through concrete bridge rail with sidewalk, Type 80SW, was built and tested in accordance with NCHRP Report 350. The Type 80SW is an 810 mm-tall, reinforced concrete barrier on a 200 mm-high sidewalk. The rail has 280 mm-high by 1620 mm-long gaps, 230 mm above the sidewalk surface. The rail is fitted with a single metal tube spanning the gap and a 250 mm-high handrail attached to the top of the concrete barrier. The barrier tested was 22.8 m-long and was constructed at the Caltrans Dynamic Test Facility in West Sacramento, California.

A total of four crash tests were conducted under Report 350 test Level 4, two with 820 kg cars, one with a 2000 kg pickup truck and one with an 8000 kg single unit van truck. The first test of the 820 kg car showed a potential snagging problem on one of the vertical members. The potential problem with the first car led to a reduction in the vertical gap from 310 mm to 280 mm and a retest with a different car. The second test did not show snagging problems, with all results within the guidelines. The hood of the 2000 kg pickup snagged on a vertical handrail support tube during impact causing minor occupant compartment deformation.

Since this bridge rail is intended for pedestrian use and alone does not provide for pedestrian protection, it should only be used in low speed applications of 70 km/h or less. In addition, the handrail has been found to be a snagging hazard at the higher speed. For these two reasons, the Type 80SW is recommended for approval on California highways requiring TL-2 bridge rails.

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To Convert From	To	Multiply By
	ACCELERATION	
m/s^2	ft/s^2	3.281
	AREA	
m^2	ft^2	10.76
	ENERGY	
Joule (J)	$ft.lb_f$	0.7376
	FORCE	
Newton (N)	lb_f	0.2248
	LENGTH	
m	ft	3.281
m	in	39.37
cm	in	0.3937
mm	in	0.03937
	MASS	
kg	lb_m	2.205
	PRESSURE OR STRESS	
kPa	psi	0.1450
	VELOCITY	
km/h	mph	0.6214
m/s	ft/s	3.281
km/h	ft/s	0.9113

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The bridge rail was constructed by R.J. Frank Construction, Redding CA, under the supervision of Brian Baker.

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1. INTRODUCTION

1.1. *Problem*

Most new or retrofit bridge rails on California highways since the 1970's have been the standard Caltrans solid concrete parapet, 810 mm high, with a New Jersey safety-shape profile. When districts requested a self-cleaning "see-through" bridge rail about 14 years ago, Caltrans developed a steel post and beam design, the Type 18. This design has been used infrequently because it is relatively expensive. It requires a minimum 300 mm thick deck overhang. Though it is attached to the side of the deck, it occupies 600 mm of deck width. It is also more likely to need repairs after an impact and to exhibit corrosion problems than a reinforced concrete bridge rail. Another design which was developed was the Type 115 bridge rail. This system had problems with the wheels of impacting vehicles snagging on the posts. Additionally, neither the Type 115 nor the Type 18 met the AASHTO PL-2 requirement that the rail be able to contain an 8000 kg, medium-duty cargo truck.

It was clear an alternative bridge rail was desired by Caltrans' district offices. This alternative would need to be more attractive and have better see-through characteristics than existing approved designs and meet the design criteria discussed in Section 2.1.2.1 Design.

1.2. *Objective*

To crash test an 810 mm-tall, reinforced concrete bridge railing with sidewalk, lower metal rail and hand rail (designated throughout this report as the Type 80SW) to test level 4 in NCHRP Report 350[1]. These crash testing procedures include impacts of an 820 kg sedan at 100 km/h, a 2000 kg pickup at 100 km/h and an 8000 kg truck at 80 km/h.

1.3. *Background*

Several bridge barrier railings have been tested by Caltrans and other agencies in recent years. None of these designs nor the ten railings in the AASHTO "Roadside Design Guide"[2] meet Caltrans' current requirements for an aesthetic, see-through railing. Of the ten railings listed in the AASHTO Guide, four are concrete barriers which are not see-through. Three out of the ten are mounted on reinforced concrete posts, or on concrete curbs and parapets. None of the designs have been tested to retain the 8000 kg truck. One of these (the Oklahoma TR-1 bridge rail) is a see-through, self-cleaning design, but the aesthetics of the rail are arguable. The size of the posts and rail are too large to provide good see-through qualities. The other three designs are based on thrie beam and w-section guardrail which do not provide the see-through, low maintenance or aesthetic properties that Caltrans wants in a bridge rail.

A few years ago California crash tested the Type 115 bridge rail[3]. It consists of two structural steel rails on structural steel posts which are mounted on the side of the bridge deck. Even though the design could structurally withstand impacts from pickup trucks at 100 km/h, there were some problems with front wheel snagging on the posts during the tests. The railing was consequently downgraded to a PL-1 level as defined in the AASHTO "Guide Specifications for Bridge Railings"[4] and is only recommended for use on narrow, low-volume, low-speed roads.

The Type 80SW was designed using the AASHTO "Guide Specifications for Bridge Railings"[4] requirements. The AASHTO Guide Specifications stipulate that a bridge rail to be used for high-speed applications must conform to PL-2 level testing. However, according to the FHWA, the PL-2 test level has since been replaced by the similar NCHRP Report 350[1] test level 4, so the railing was tested according to test level 4 criteria. Table 1.1 summarizes the testing requirements for PL-1, PL-2 and Test Level 4, including test vehicle masses and vehicle impact angles. Notice that the pickup truck weight is different in AASHTO than in NCHRP Report 350. Nevertheless, the higher impact angle required in Report 350 provides a higher impact severity because the kinetic energy due to the lateral component of the impact velocity is 33% higher. Test level 4 requires testing with an 8,000 kg, two-axle, single-unit truck in addition to the 820 kg sedan and the 2000 kg pickup.

Levels	Small Automobile	Pick-up truck	Single-Unit Truck
PL-1 (AASHTO)	816 kg (1800 lb_m) 80 km/h (50 mph) @ 20°	2449 kg (5400 lb_m) 72 km/h (45 mph) @ 20°	
PL-2 (AASHTO)	816 kg (1800 lb_m) 97 km/h (60 mph) @ 20°	2449 kg (5400 lb_m) 97 km/h (60 mph) @ 20°	8165 kg (18,000 lb_m) 80 km/h (50 mph) @ 15°
Test Level 4 (NCHRP 350)	820 kg 100 km/h @ 20°	2000 kg 100 km/h @ 25°	8000 kg 80 km/h @ 15°

Table 1.1 - Comparison of Different Test Levels

1.4. Literature Search

A literature search using the TRIS, NTIS, and the Compendex Plus databases was conducted at the beginning of the project to find research reports or publications related to the objectives of this project. There were two references found and both were for the Texas Type T411[5, 6]. The Texas T411 is a concrete beam and post bridge rail 813 mm high by 305 mm thick and contains openings 203 mm wide by 457 mm high. This rail had not been tested to Report 350[1] or to the PL-2 requirements discussed above. The post arrangement also made it difficult to see through the rail except at near perpendicular angles. In addition, the post configuration seemed to provide an excessively high effective coefficient of friction[6]. The Texas T411 did not meet Caltrans' requirements.

1.5. Scope

A total of four tests were performed and evaluated in accordance with NCHRP Report 350[1]. The testing matrix established for this project is shown in Table 1.2. Although test 541 was properly conducted, concerns with the test findings led to the conclusion that a reduction in the concrete bridge rail gap was preferred (see Section 2.2.1.5 for more detail). The concerns prompted a retest designated as Test 548.

Test #	Barrier type	Mass (kg)	Speed (km/h)	Angle (deg)
541	Type 80SW	820	100	20
542	Type 80SW	2000	100	25
543	Type 80SW	8000	80	15
548*	Type 80SW	820	100	20
*This is a retest of Test 541				

Table 1.2 - Target Impact Conditions

2. TECHNICAL DISCUSSION

2.1. Test Conditions - Crash Tests

2.1.1. Test Facilities

Each of the crash tests was conducted at the Caltrans Dynamic Test Facility in West Sacramento, California. The test area is a large, flat, asphalt concrete surface. There were no obstructions nearby except for a 2 m-high earth berm 40 m downstream from the bridge rail. A temporary bridge deck was constructed for the purpose of this project.

2.1.2. Test Barriers

2.1.2.1.Design

The Type 80SW was designed to meet specific design criteria. The bridge rail had to be crash-worthy according to the latest federal guidelines as well as functional, aesthetically pleasing and allow a partial view otherwise obscured by a "solid" concrete rail design.

The general shape of the barrier was determined for three main reasons. The first reason was to provide a partial view through the rail. A viewing space 310 mm high by 1620 mm long was chosen to meet structural and safety requirements. The space height was later reduced to 280 mm due to evidence of potential wheel snagging from the first 820 kg test. The second reason for the general shape was based on the satisfactory results of previous testing concerning wheel snagging potential on posts [3] and involved setting the posts back 100 mm from the barrier beam face. The final main reason was to provide an aesthetically pleasing rail. These criteria where kept in mind during the design process and a conscious effort was made to provide a clean and simple-appearing rail while meeting the other design criteria. The general shape of the bridge rail is the same with or without the sidewalk. However, to provide the necessary pedestrian safety, a metal handrail and lower rail were added to the "with sidewalk" design. A "without sidewalk" design is also being constructed for testing but will be discussed in a future report. The functionality of a concrete rail was another desired feature.

The low maintenance of concrete is advantageous in regard to long-term costs and roadside worker exposure. In general, concrete barriers see less damage and require fewer repairs. There is also a decreased corrosion problem in marine environments and fewer specially-fabricated, galvanized parts in a concrete barrier compared with a steel barrier. However the "with sidewalk" version of this rail does include some galvanized, non-structural parts for pedestrian safety. After the purpose of the barrier was resolved, the design criteria were applied.

The design criteria were based on highway safety design standards and material specifications. Section 13 from NCHRP Project 12-33 "Development of a Comprehensive Bridge Specification and Commentary" [7] and the 1989 AASHTO "Guide Specifications for Bridge Railings" [4] were used as guidelines for the design standard. These guidelines were followed for Performance Level Two (PL-2) crash test requirements. Material specifications for the steel reinforcement and concrete were provided by the July, 1995 Caltrans "Standard

Specifications"[8]. Once the design criteria were evaluated and the necessary changes were incorporated, a specific configuration was determined.

The design configuration for the Type 80SW includes viewing spaces 310 mm high by 1620 mm long, chosen to meet structural and safety requirements. A structural cross-section is shown in Figure 2-1. The space height was later reduced to 280 mm due to evidence of potential wheel snagging from Test 541. The reinforcing steel is covered with a minimum of 25 mm of concrete and all longitudinal reinforcing is terminated in 90 degree hooks. The 810 mm-high design was used in the tests as the shortest configuration to be placed in service. This provided a more conservative test configuration for the evaluation. Additional as-built drawings for the Type 80SW can be found in Appendix 7.5. Caltrans, Office of Structures Design should be contacted to obtain the most current and complete plans for future construction projects.

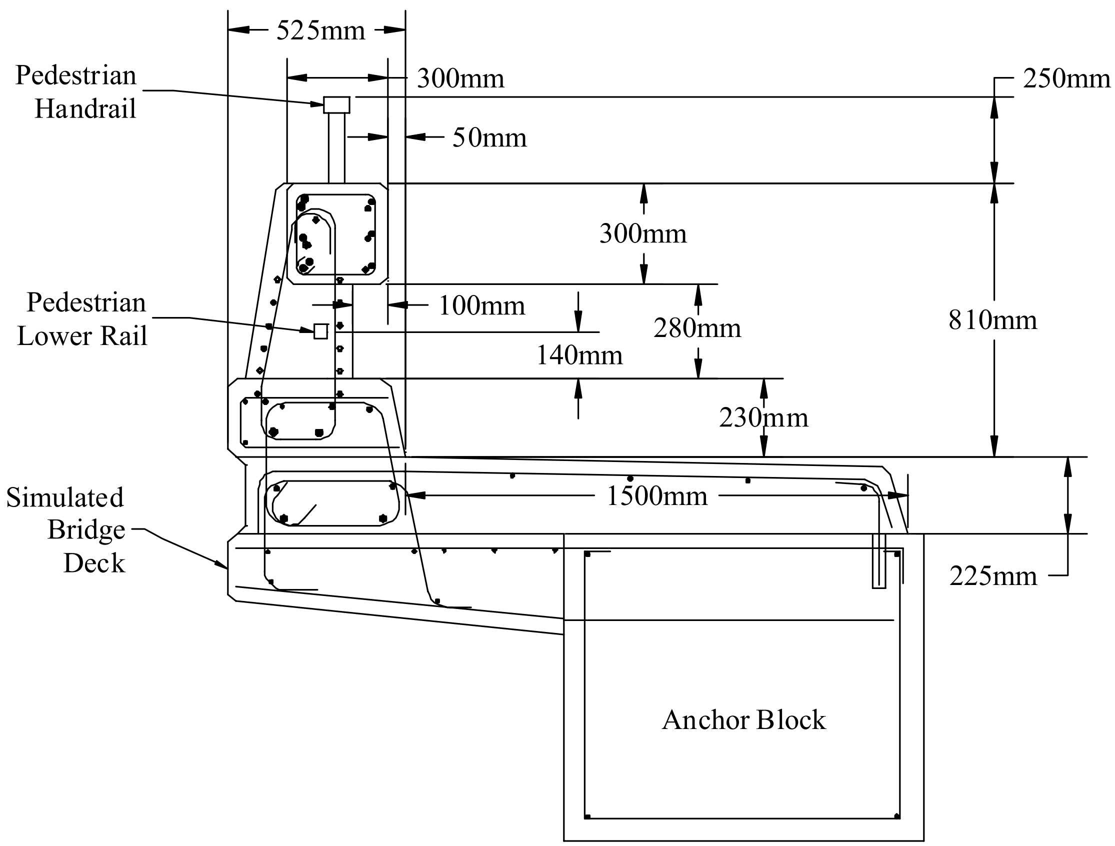


Figure 2-1 - Type 80SW

2.1.3. Construction

The Type 80SW was constructed at the north end of the Caltrans Dynamic Test Facility in West Sacramento, California. The north end of the facility was chosen in order to accommodate the trajectory and acceleration distance needed for the 8000 kg test vehicle. Over 600 m of test track was made available for test, with 550 m used to get the self-powered vehicle up to speed. A simulated bridge deck was attached to an existing anchor block for the bridge rail installation.

The bridge rail was constructed in several stages. An existing anchor block with a simulated bridge deck was utilized for the new bridge rail. The existing simulated bridge deck was demolished with the reinforcing steel retained for use in the new deck (Figure 2-2). Additional reinforcing steel was added to the steel retained including bars which looped up out of the deck approximately 200 mm above the deck surface. The forms for the new simulated deck were completed and concrete was poured level to the deck surface (Figure 2-3). To construct the sidewalk, reinforcing steel was placed over part of the anchor block and deck. Short curved bars were doweled into the anchor block at the front edge of the sidewalk to provide a positive connection. At the same time reinforcing steel for the barrier base and posts were tied into place as shown in Figure 2-4. The forms were completed and concrete poured to include the sidewalk and the base of the barrier, 200 mm above the back edge of the sidewalk (Figure 2-5).

Next, the reinforcing steel was installed for the beam section of the barrier (Figure 2-6 through Figure 2-9). The orientation of reinforcement loops and end loops for some of the bars were changed from the original plans to aid installation due to the high concentration of reinforcement. After all of the post and beam reinforcing was tied in place and the forms set, the last concrete pour was completed. The final items installed were the galvanized lower pedestrian rail and the pedestrian hand rail. The handrail was attached to the top of the beam with threaded rods on a 25 mm-high grout pad. Wood forms were used throughout and all concrete was vibrated. Figure 2-10 through Figure 2-13 show the completed barrier.

Figure 2-2 - Concrete Anchor Block with Simulated Bridge Deck Reinforcing Steel

Figure 2-3 - Simulated Bridge Deck Construction

Figure 2-4 - Reinforcing Steel for the Sidewalk and Lower Portion of the Bridge Rail

Figure 2-5 - Concrete Pour for Sidewalk and Curb Section of Bridge Rail

Figure 2-6 - Reinforcing Steel for Posts and Beam Section of Bridge Rail

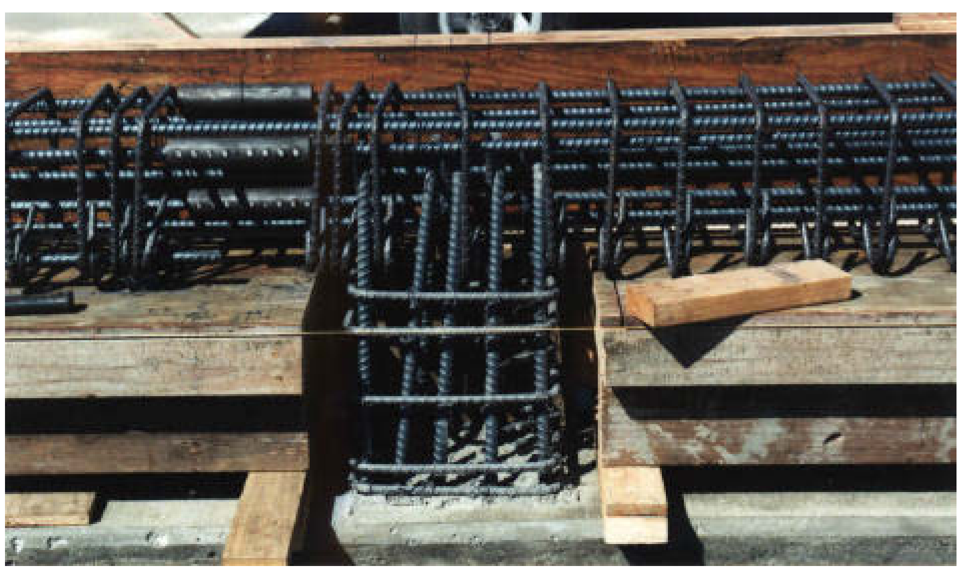


Figure 2-7 - Close up of Post and Beam Reinforcing Steel, Couplers and Wood Forms

Figure 2-8 - Expansion Joint Post and Beam Configuration

Figure 2-9 - Reinforcing Steel Placement for the Post and Beam Sections

Figure 2-10 - Pedestrians Walking on Completed Sidewalk

Figure 2-11 - View of Completed Barrier and Sidewalk

Figure 2-12 - Completed Expansion Joint

Figure 2-13 - Backside of Competed Bridge Rail

2.1.4. Test Vehicles

The test vehicles complied with NCHRP Report 350[1]. For all tests, the vehicles were in good condition, free of major body damage and were not missing any structural parts. All of the vehicles had standard equipment and front-mounted engines. The vehicle inertial masses were within acceptable limits (Table 2.1).

Table 2.1 - Test Vehicle Masses

Test No.	Vehicle	Ballast (kg)	Test Inertial (kg)
541	1992 Geo Metro	0	823
542	1993 Chevrolet 2500	5	1954
543	1992 GMC Top Kick	2918	8020
548*	1994 Geo Metro	0	824

*Test 548 is a retest of Test 541 which had a potential snagging problem with the passenger side front wheel.

The Chevrolet truck and the GMC TopKick were self-powered; a speed control device limited acceleration once the impact speed had been reached. The two Geos were connected by a steel cable to another vehicle and towed to impact speed. Remote braking was possible at any time during the test for all vehicles through a tetherline. For Test 542 an elastic cord was attached to the vehicle's steering wheel to prevent oscillation in the steering system. A short distance before the point of impact, each vehicle was released from the guidance rail and the ignition was turned off (for the Geos, the tow cable was released). A detailed description of the test vehicle equipment and guidance system is contained in Appendix 7.1 and 7.2.

2.1.5. Data Acquisition System

The impact phase of each crash test was recorded with seven high-speed 16 mm movie cameras, one norma1-speed 16 mm movie camera, one Beta format video camera, one 35 mm still camera with an autowinder and one 35 mm sequence camera. Due to technical difficulties not all of the cameras functioned properly for each test, as will be discussed later. The test vehicles and the barrier were photographed before and after impact with a normal-speed 16 mm movie camera, a Beta format video camera and a color 35 mm camera. A film report of this project was assembled using edited portions of the film coverage.

Three sets of orthogonal accelerometers were mounted in all vehicles (except the 8000 kg truck), two at the center of gravity and one at 600 mm behind the center of gravity. Rate gyro transducers were also placed at the center of gravity of each vehicle (except the 8000 kg truck) to measure the roll, pitch and yaw. The data were used in calculating the occupant impact velocities and ridedown accelerations, and maximum vehicle rotation.

An anthropomorphic dummy was used in Test 541 and Test 548 to obtain motion data. The dummy, a Hybrid III built to conform to Federal Motor Vehicle Safety Standards by the Sierra Engineering Company, simulated a 50th percentile American male weighing 75 kg. The dummy was placed in the passenger's seat and was restrained with a lap and shoulder belt.

A digital transient data recorder (TDR), Pacific Instruments model 5600 was used to record electronic data during the tests. The digital data were analyzed with custom DADiSP workbooks using a Fieldworks Model FW 7666P portable computer.

2.2. Test Results - Crash Tests

A film report with edited footage from tests 541, 542, 543, and 548 has been compiled and is available for viewing.

2.2.1.1.Impact Description - Test 541

The measured speed of the 823 kg vehicle on impact with sidewalk curb was 102.0 km/h with an angle of 20°. Impact with the sidewalk curb and bridge rail occurred 0.38 m and 4.9 m, respectively, from the upstream end of the 23-m long bridge rail. Contact with the bridge rail continued for approximately 4.3 m, as determined by scuff marks on the rail. At the point of last contact with the bridge rail, all four vehicle wheels were on or above the sidewalk. As the vehicle continued its exit trajectory, the driver's front then rear wheel went off the sidewalk approximately 5 m and 10 m, respectively, after the point of last contact with the bridge rail face. The exit angle and speed of the car were 10° and 75 km/h, respectively. The brakes were applied approximately 25 m after impact with the bridge rail. The stopping point for the vehicle was about 40 m from the point of last contact with the barrier as shown in Figure 2-22. The vehicle remained upright throughout and after the collision.

Due to a global camera error none of the seven 16 mm, high speed cameras or the one 35 mm sequence camera functioned during the test. The test was documented with the manually operated 16 mm normal speed film camera, 35 mm film still camera with an autowinder and betacam video camera. From the on-board data acquisition system, available photo and film documentation and physical evidence, enough information was available to be confident in the results presented for this test.

The first point of contact for the constructed test article was the sidewalk. The right front passenger wheel was damaged and the tire deflated as a result of the impact with the sidewalk curb. During the examination of the impact area after the test there was evidence that the front passenger wheel had contacted and rotated around the post 6 m from the upstream end of the barrier (Figure 2-25 and Figure 2-26). The tire also contacted the pedestrian steel tube within the gap. The next post at 8 m had black tire marks along its face, but the wheel did not enter into the gap (Figure 2-23). It was the contact and rotation around post 6 and the contact with the steel tube that led to the decision to reduce the gap and re-run the 820 kg test. The retest was performed as Test 548 and is discussed starting in Section 2.2.1.11.

Figure 2-14 - Downstream View of the Bridge Rail with Vehicle 541

Figure 2-15 - Side View Of Vehicle 541

Figure 2-16 - Front View Of The Bridge Rail at the Impact Location

Figure 2-17 - Side View Of Vehicle 541 at the Impact Location

Figure 2-18 - Vehicle 541 Impact Sequence Photos

Figure 2-19 - Post Impact Passenger Floorboard Damage, Vehicle 541

Figure 2-20 - Post Impact Side View of Vehicle 541

Figure 2-21 - Close up of Passenger Side Front Damage, Vehicle 541

Figure 2-22 - Post Impact Front View, Vehicle 541

Figure 2-23 - Post Impact Bridge Rail Scuff Marks Test 541

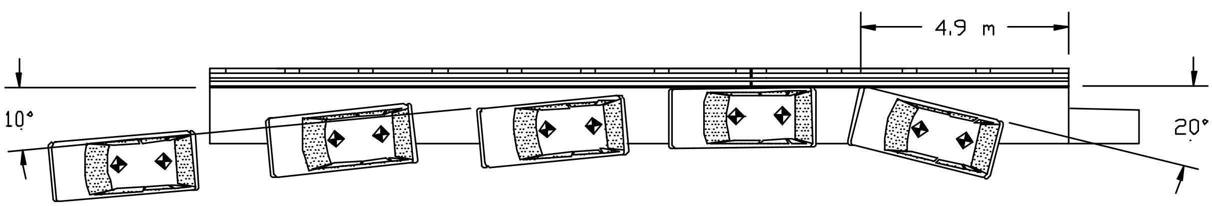
Figure 2-24 - Post Impact Bridge Rail Scuff Marks Test 541

Figure 2-25 - Close up of Post Impact Bridge Rail Scuff Marks

Figure 2-26 - Wheel Rotation Marks Around Bridge Rail Post

Figure 2-27 - Test 541 Data Summary Sheet

Frontal impact photo series unavailable,
refer to Figure 2-18 for alternate photo series.



Test Barrier
- Type: Type 80SW
- Length: 22.8 m

Test Date: December 10, 1997

Test Vehicle:
- Model: 1992 Geo Metro
- Inertial Mass: 823 kg
- Impact / Exit Velocity: 102 km/h / 75 km/h
- Impact / Exit Angle: 20° / 10°

Test Dummy:
- Type: Hybrid III
- Weight / Restraint: 74.8 kg / lap and shoulder
- Position: Front Right

Test Data:
- Occ. Impact Velocity (Long / Lat): 5.98 m/s / 6.34 m/s
- Ridedown Acceleration (Long / Lat): -5.5 *g* / -9.9 *g*
- Max. 50 ms Avg. Accel. (Long / Lat): -8.58 *g* / -10.15 *g*
- Exterior: VDS[(9)]/CDC[(10)] FR-5, RD-4 / 02RFEW3
- Interior: OCDI[(1)] RF0000000

Barrier Damage: Superficial scuffing

2.2.1.2.Vehicle Damage - Test 541

The right front section of the vehicle sustained crushing of the bumper and minor unibody frame deformation, damage to the suspension and a flat tire. Initial right front wheel damage occurred on impact with the sidewalk 0.38 m from the beginning of the bridge rail installation. The sidewalk contact caused deformation of the wheel and tire deflation. Other tires experienced minor deformation on impact with the sidewalk but remained inflated. After contacting the bridge rail the right front wheel was pushed back, forcing the wheel well area to deform (Figure 2-21).

As the vehicle turned parallel to the bridge rail, the sheet metal on both the right doors came into contact with the bridge rail face and caused minor scraping. The right rear tire rubbed along the bridge rail, but was not damaged beyond moderate scuffing. The vehicle continued along the sidewalk with the left wheels dropping off the curb 19 m from the beginning of the bridge rail. The shock absorber and right drive shaft of the right front wheel were bent but remained attached. The interior of the vehicle experienced minor deformation, less than 130 mm in the front passenger right foot floorboard area with negligible deformation elsewhere. The right front passenger door was jammed but the other three doors and hatchback functioned properly. The windshield was cracked on the passenger side. The hood and headlights where not damaged.

Occupant impact velocities and occupant ridedown accelerations were below the preferred maximums summarized in Table 2.2 - Test 541 Assessment Summary, page 45. The lateral and longitudinal occupant impact velocities were 6.34 m/s and 5.98 m/s, respectively. The lateral and longitudinal occupant ridedown accelerations were -9.90 g and -5.50 *g*, respectively.

2.2.1.3.Barrier Damage - Test 541

Barrier damage was cosmetic only, consisting of scrapes and tire marks. Both of the right side tires left marks on the sidewalk curb then on the curb and beam section of the bridge rail. Small amounts of concrete spalled from the face of the barrier where the vehicle's sheet metal and wheels made contact.

2.2.1.4.Dummy Response - 541

The dummy was lap and shoulder belted into the passenger's seat. Due to the lack of film coverage, the dummy response at impact is unavailable. However, an examination of the dummy revealed no apparent contact between the dummy and the barrier face. The dummy remained upright and secure during the remainder of the test. The final resting position of dummy was upright in the passenger's seat.

2.2.1.5.Impact Description - Test 542

The measured speed of the 1954 kg vehicle on impact with sidewalk curb was 110.2 km/h with an angle of 25.0°. The impact speed was substantially above the intended 100 km/h and was due to an onboard speed control device malfunction. Impact with the sidewalk curb then bridge rail occurred 2.5 m and 5.9 m, respectively, from the upstream end of the 23 m-long bridge rail. The right front tire was damaged by the curb section of the bridge rail and deflated quickly. Following the impact with the sidewalk curb the vehicle started to roll left and pitch up slightly. The maximum roll of -7.1° occurred just before impact with the rail, then shifted to a maximum positive roll of 5.6° after impact with the rail.

The vehicle bumper first contacted the beam section of the bridge rail 0.11 s after the right front tire contacted the sidewalk. At this point the right rear wheel was in contact with the sidewalk curb and moving upward, causing the vehicle to pitch down. The vehicle was redirected parallel with the rail at about 0.23 s after contact with the beam section. It continued to pitch down after the vehicle left contact with the rail due in part to the deflated front tires and the left front wheel dropping off the sidewalk. A maximum pitch of 15.5° occurred after the vehicle passed the downstream end of the bridge rail.

During the impact with the rail, the vehicle hood overlapped the top of the beam section of the rail and caught on the vertical handrail support tubes. The right front corner of the hood was held back as the vehicle continued along the rail. As a result the hood was pulled toward the barrier and backward, impacting the passenger side "A" pillar and windshield, causing minor occupant compartment deformation.

The vehicle stayed in contact with the rail for approximately 6.5 m. The exit angle and speed were 7° and 77 km/h respectively. The vehicle remained upright throughout and after the collision. Brakes were applied 0.75 s after initial contact with the rail and the stopping point for the vehicle was approximately 34 m from the point of last contact with the barrier. Figure 2-34 shows the vehicle in its final resting position.

Figure 2-28 - Vehicle and Bridge Rail before Test 542

Figure 2-29 - Vehicle and Bridge Rail before Test 542

Figure 2-30 - Impact Side of Vehicle before Test 542

Figure 2-31 - Bridge Rail before Test 542-View from Upstream

Figure 2-32 - Bridge Rail before Test 542-Close-up View

Figure 2-33 - Bridge Rail before Test 542-Close-up View

Figure 2-34 - Final Position Of Test Vehicle 542

Figure 2-35 - Impacting Corner Of Tested Vehicle 542

Figure 2-36 - Close-up of Impacting Corner Of Tested Vehicle 542

Figure 2-37 - Interior View of Test Vehicle 542

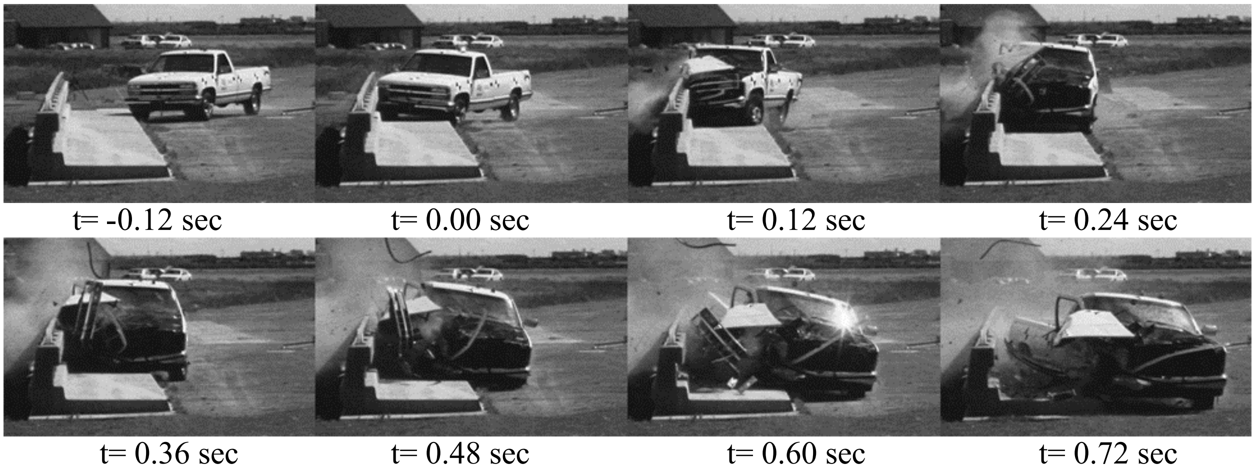
Figure 2-38 - Floorboard of Vehicle 542

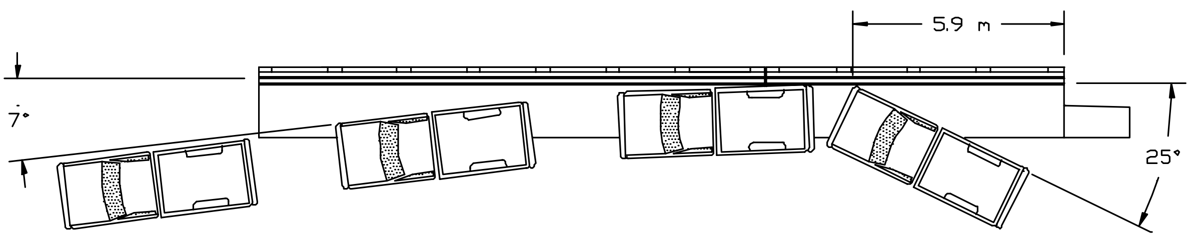
Figure 2-39 - Bridge Rail after Test 542-View from Upstream

Figure 2-40 - View Perpendicular to Point of Impact

Figure 2-41 - Impact Area and Expansion Joint

Figure 2-42 - Test 542 Data Summary Sheet





Test Barrier
- Type: Type 80SW
- Length: 22.8 m

Test Date: April 1, 1998

Test Vehicle:
- Model: 1993 Chevrolet 2500
- Inertial Mass: 1954 kg
- Impact / Exit Velocity: 110.2 km/h / 77 km/h
- Impact / Exit Angle: 25.0° / 7°

Test Dummy:
- Type: NA
- Weight / Restraint: NA
- Position: NA

Test Data:
- Occ. Impact Velocity (Long / Lat): 9.37 m/s / 8.16 m/s
- Ridedown Acceleration (Long / Lat): -7.45 *g* / -12.75 *g*
- Max. 50 ms Avg. Accel. (Long / Lat): -9.26 *g* / -14.41 *g*
- Exterior: VDS[9]/CDC[10] FR-5, RD-6 / 02RFEW9
- Interior: OCD[1] RF2012110

Barrier Damage: The barrier sustained minor spalls from the point of impact to roughly 4 m downstream. Other barrier damage was cosmetic only, consisting of scrapes and tire marks.

2.2.1.6. Vehicle Damage - Test 542

The sidewalk curb and the bridge rail face were the two initial impact locations causing vehicle damage. The sidewalk curb damaged the wheels and quickly deflated all the tires on impact except the left rear. The first point of contact with the bridge rail occurred on the beam section, causing the majority of damage to the right front quarter panel area. Additional damage occurred when the hood caught on the handrail, breaking the left hinge.

The extra speed of the vehicle, 10.2 km/h over target, undoubtedly contributed to higher deformation of the impacting right corner of the vehicle than would have otherwise occurred. Figure 2-36 shows the right front wheel pushed back into the wheel well, caused by impact with the rail curb and beam face. All of the wheels stayed connected to the vehicle throughout the test. The front right shock absorber, stabilizer bar and upper and lower control arms were bent but still attached. The rear and left front suspension components were intact and appeared undamaged. There was minor deformation of the right front frame.

As contact continued along the rail, the vehicle hood slid along the top of the beam section, extending approximately 0.38 m past the beam face toward the backside of the barrier. As the hood slid along the top of the beam, it caught on the handrail support tubes. The left hinge mechanism attached to the hood failed and the hood buckled over the right hinge. As mentioned in section “Impact Description - Test 542” above, the hood was then pushed into the passenger side “A” pillar and windshield. The “A” pillar was pushed back about 170 mm and the windshield was torn vertically 150 mm, 100 mm from the “A” pillar.

Additional damage included other notable items specifically attributed to the right front wheel being forced to the rear of the wheel well. The dashboard was pushed upward just left of the centerline of the cab with the right side displaced down from the center (Figure 2-37). A crease in the passenger floor board extending from the front center to the right rear of the cab was 130 mm at its highest point (Figure 2-37). There was also minor sheet metal deformation in the roof near the rear of the door sill. The vehicle battery was demolished but the engine components were intact. The rear glass was undamaged and the driver’s door and the tail gate still functioned properly.

The occupant compartment deformation was judged not to be serious because of the nature and location of the deformation. Creasing in the floor of the compartment would not have affected the driver significantly. The passenger seat would have tilted backward and perhaps to the right, but neither headroom nor overall passenger compartment volume appeared to be seriously reduced. Moreover, as mentioned previously, the deformation would have been less if the vehicle had impacted the bridge rail at the target speed. At 110.2 km/h, the test vehicle had 21% greater kinetic energy than if it had impacted the rail at the intended 100 km/h.

The longitudinal occupant impact velocity and longitudinal occupant ridedown acceleration were below the allowed maximums of 12 m/s and 20 *g*, respectively. The longitudinal occupant impact velocity was 9.37 m/s and the longitudinal occupant ridedown acceleration was -7.45 *g*.

2.2.1.7.Barrier Damage - Test 542

The barrier sustained minor spalls from the point of impact to roughly 4 m downstream. Other barrier damage was cosmetic only, consisting of scrapes and tire marks. Both of the right side tires left marks along the face of the barrier for the 6.5 m of contact. Small amounts of concrete spalled from the face of the barrier where the vehicle's sheet metal and wheel made contact with the beam face and beam lower edge. The pedestrian handrail remained intact. The barrier remained fully functional after the impact with only minor, mainly cosmetic, repairs needed for complete restoration.

2.2.1.8.Impact Description - Test 543

The measured speed of the 8020 kg single-unit, van-bodied truck on impact with the sidewalk curb was 80.8 km/h with an angle of 15.0°. Impact with the sidewalk curb and bridge rail occurred 1.1 m and 7.38 m, respectively, from the upstream end of the 23 m-long bridge rail. Following the impact with the sidewalk, the right front tire stayed in contact with the upper surface of the sidewalk. The vehicle was not instrumented with accelerometers or rate gyros. The vehicle impacted the bridge rail 0.04 s after contact with the sidewalk curb, 1.0 m in front of the expansion joint.

It appeared that the right front lug nuts scraped along the beam face, causing most of the concrete spalling seen in Figure 2-55. The right wheel well hit the handrail 0.028 s after initial contact with the bridge rail. Beginning 0.177 s after contact with the bridge rail, both the left front and left rear tires rose approximately 1 m off the ground and remained off the ground for 0.480 s and 0.757 s, respectively. The vehicle continued to make contact with the barrier for approximately 4.5 m. A peak roll of the vehicle box section to the right and then left was 17.5° at 0.521 s and 14.5° at 1.099 s, respectively, from the impact with the rail. These peaks were taken before the vehicle exited the end of the test article installation. Higher values may have occurred later after the brakes were applied. The vehicle continued to a point of rest on an earth berm about 43 m from the point of impact. The vehicle remained upright throughout and after the collision.

The 2918 kg of ballast, comprised of two separate pallets of sand bags strapped down to the cargo floor. The pallets were constrained by 150 mm angle iron and the sand bags were held down by 100 mm trucking straps as shown in Figure 2-47. The sand was allowed to shift slightly but is unlikely to have affected the test. None of the sand bags broke loose during the test (Figure 2-49).

Figure 2-43 - 543 Test Vehicle

Figure 2-44 - Vehicle 543 Relative To Bridge Rail

Figure 2-45 - Rear View of 543 Test Vehicle

Figure 2-46 - Impact Side of 543 Test Vehicle

Figure 2-47 - 150 mm Angle Irons Used To Constrain Two Pallets of Sand

Figure 2-48 - Before Test View of Bridge Rail from Upstream

Figure 2-49 - Impact Side View of Vehicle 543 after Impact

Figure 2-50 - Vehicle 543 after Impact

Figure 2-51 - Close-up of Impact side of Vehicle 543

Figure 2-52 - Left Side Of Cab After Test 543

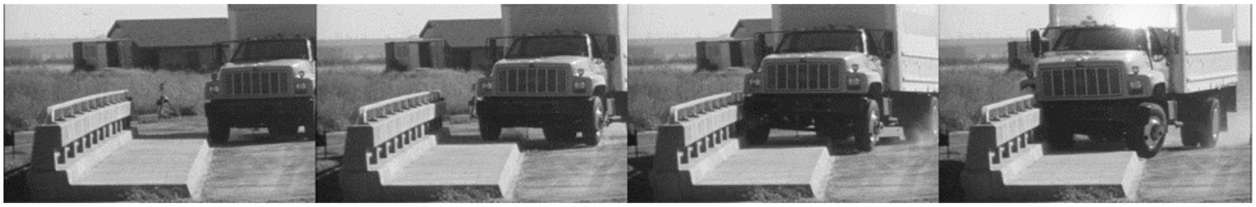
Figure 2-53 - Bridge Rail and Vehicle After Test 543

Figure 2-54 - Impact Area for Test 543

Figure 2-55 - Close-up of Impact Area for Test 543

Figure 2-56 - Backside of Expansion Joint Area after Test 543

Figure 2-57 - Test 543 Data Summary Sheet



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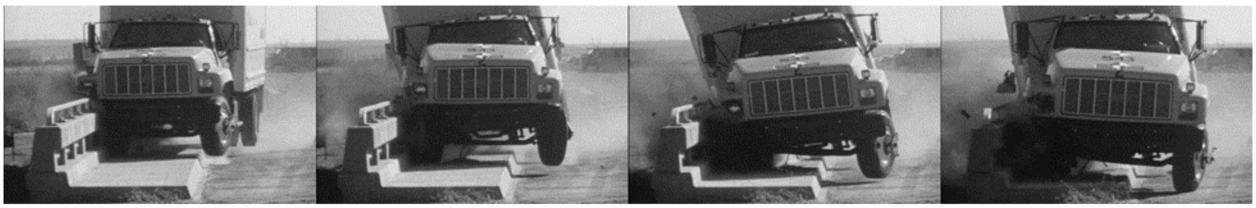

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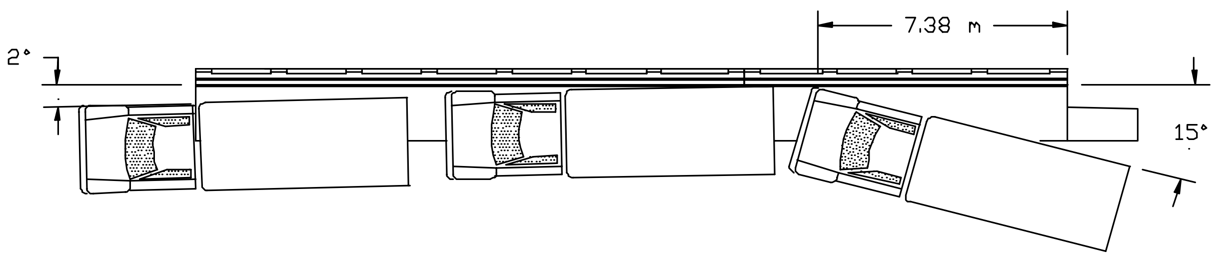


Test Barrier
- Type: Type 80SW
- Length: 22.8 m

Test Date: October 28, 1997

Test Vehicle:
- Model: 1992 GMC TopKick
- Inertial Mass / Ballast: 8020 kg / 2918 kg
- Impact / Exit Velocity: 80.8 km/h / 72 km/h
- Impact / Exit Angle: 15.0 / 2°

Test Dummy:
- Type: NA
- Weight / Restraint: NA
- Position: NA

Test Data:
- Occ. Impact Velocity (Long / Lat): not measured
- Ridedown Acceleration (Long / Lat): not measured
- Max. 50 ms Avg. Accel (Long / Lat: not measured
- Interior: OCDI[1] RF0000000

Barrier Damage: The barrier was scraped along the face and edges over a 3 m length. There was also spalling on the underside of the beam and at the expansion joint with no structural damage.

2.2.1.9.Vehicle Damage - Test 543

The sidewalk curb and the bridge rail face were the two initial impact locations. The impact with the sidewalk curb did not damage the tires or wheels of the 8000 kg truck. On contact with the bridge rail the impacting tire was pushed back and to the left. This severed the U-bolts connecting the shock absorbers and leaf springs to the front axle and sheared the pitman arm to the power steering. The right front wheel lug nuts were worn due to scraping along the rail. None of the tires deflated during the test.

Also damaged were the battery box, fuel tank and right front quarter panel. The battery box sustained substantial crushing. The fuel tank was deflected about 0.5m and dented in about 0.15 m, but was not penetrated. Damage to the right front quarter panel occurred on contact with rail face and handrail. There was no visible damage to the cargo box or frame beyond minor scuffing. Both doors, the hood and rear rolling door functioned properly with no visible occupant compartment deformation.

2.2.1.10.Barrier Damage - Test 543

The barrier was scraped along the face and edges over a 3 m length. There was also spalling on the underside of the beam caused by the downward force of the rotating right front wheel lug nuts. The tire marks along the barrier were only a little longer than the scraping along the face. A concrete spall at the expansion joint was 80 mm to 100 mm deep and extended to the back face of the rail, shown in Figure 2-55 and Figure 2-56. The spall exposed the end of a piece of rebar but no structural damage was evident. The bridge rail withstood the impact from vehicle 543 well with only spall repairs necessary before subsequent tests.

2.2.1.11.Impact Description - Test 548

The measured speed of the vehicle on impact with sidewalk curb was 80.5 km/h with an angle of 19.5°. The impact speed was substantially below the intended 100 km/h and was a result of an improper speed obtained by the tow vehicle. Impact with the sidewalk curb and bridge rail occurred 0.4 m and 5.3 m, respectively, from the upstream end of the 23 m-long bridge rail. Following the impact with the sidewalk curb, the vehicle started to roll left and pitch up.

As the vehicle continued toward the bridge rail, first the right front then right rear tires left contact with the top of the sidewalk. Figure 2-69 provides a frontal view of the vehicle during impact. The right front of the vehicle continued to rise until it contacted the bridge rail . On contact with the bridge rail both right wheels were off the ground, the left front wheel was on the sidewalk and the left rear wheel was on the pavement. After contact with the bridge rail the vehicle was redirected parallel to the barrier. The vehicle was in contact with the barrier face 0.27 seconds and for a distance of approximately 4 m.

The exit speed and angle were approximately 62 km/h and 4°, respectively. The maximum roll of -14.3° occurred during the initial contact with the bridge rail and a maximum pitch of 5° was obtained as the vehicle's side came into contact with the beam section. The vehicle remained upright throughout and after the collision. Brakes were not applied and the stopping point for the vehicle was approximately 37 m from the point of last contact with the barrier. Figure 2-64 and Figure 2-67 show the vehicle in its resting position.

Test 548 was a supplement to Test 541 due to the potential snagging of the right front wheel as mentioned previously. The only change to the bridge rail from Test 541 to 548 was that the gap was reduced 30 mm. The gap was reduced by raising the bridge rail curb height. The guidance rail used had not been moved from Test 541 to provide the same angle and impact location for Test 548. Attention was directed to the wheel and its snag potential on post 6 during Test 548.

The right front wheel of test vehicle 548 did not show the snagging potential that was seen in Test 541. Tire marks are seen on post 6, Figure 2-68, but they do not enter the gap area to the extent they did on Test 541. It is unknown how much the lower than anticipated impact velocity affected the wheel penetration for Test 548. However, both impacts were similar, other than the speeds, and the initial concerns of wheel snagging were largely eliminated based on the results of the second test. Moreover, by reducing the bridge rail gap by 30 mm, the gap was smaller than the vehicle wheel diameter, so there should be much less chance for significant wheel snagging. There were no problems encountered for either test other than tire marks in the gap area in Test 541. For both tests the vehicle was smoothly redirected at an acceptable angle, meeting all of the criteria listed for test level 4 in NCHRP Report 350[1].

Figure 2-58 - Right Side of Vehicle 548

Figure 2-59 - Left Side of Vehicle 548

Figure 2-60 - Rear and Impact side of Vehicle 548

Figure 2-61 - Downstream View of The Bridge Rail

Figure 2-62 - Perpendicular View of the Bridge Rail

Figure 2-63 - Upstream View of the Bridge Rail

Figure 2-64 - Final Resting Position of Vehicle 548

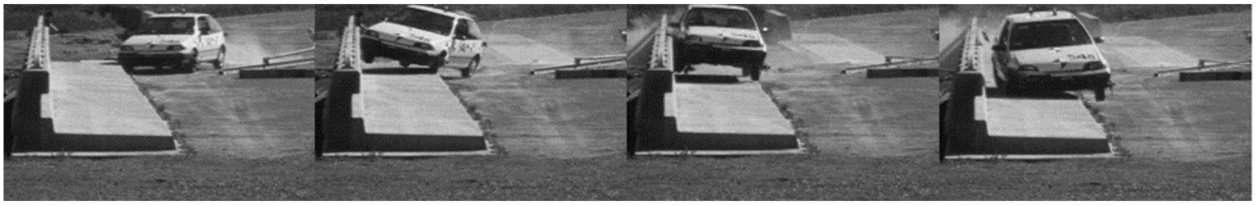
Figure 2-65 - Right Side of Vehicle 548 after Impact

Figure 2-66 - The Front Right Tire of Vehicle 548 after Impact

Figure 2-67 - Downstream View of Bridge Rail and Vehicle after Test 548

Figure 2-68 - Close-up View of Bridge Rail at Impact Point for Test 548

Figure 2-69 - Test 548 Data Summary Sheet



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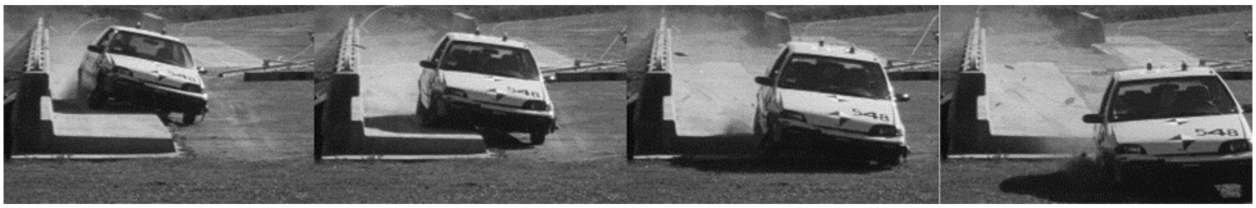

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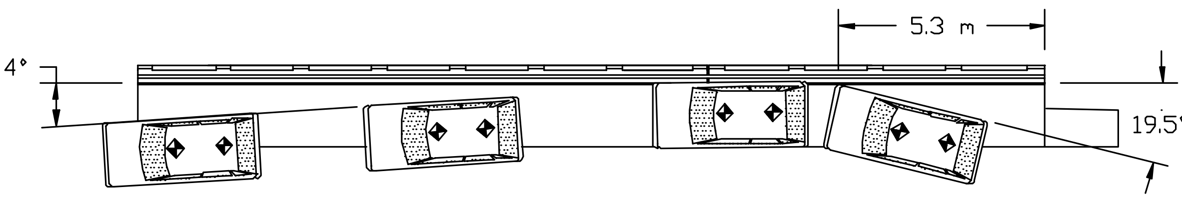


Test Barrier
- Type: Type 80SW
- Length: 22.8 m

Test Date: March 4, 1998

Test Vehicle:
- Model: 1994 Geo Metro
- Inertial Mass: 824
- Impact / Exit Velocity: 80.5 km/h / 62 km/h
- Impact / Exit Angle: 19.5° / 4°

Test Dummy:
- Type: NA
- Weight / Restraint: NA
- Position: NA

Test Data:
- Occ. Impact Velocity (Long / Lat): 4.54 m/s / 4.22 m/s
- Ridedown Acceleration (Long / Lat): -3.22g / -8.15g
- Max. 50 ms Avg. Accel. (Long / Lat): -5.50 *g* / -7.28 *g*
- Exterior: VDS[9]/CDC[10] FR-3, RD-4 / 02RFEW3
- Interior: OCDI[1] RF0001000

Barrier Damage: Damage consisted of only moderate scraping and tire scuffing over a length of four meters

2.2.1.12. Vehicle Damage - Test 548

The right front section of the vehicle sustained crushing of the bumper and right front quarter panel, damage to the suspension and a flat tire. Initial right front wheel damage occurred on impact with the sidewalk 0.4 m from the beginning of the bridge rail. The sidewalk contact caused deformation of the wheel and tire deflation. Wheel damage is shown in Figure 2-66. Other wheels were slightly deformed upon impact with the sidewalk, but the tires remained inflated. The vehicle first contacted the bridge rail on the curb section below the beam approximately 5.1 m from the beginning of the rail. After contacting the bridge rail, the right front wheel was pushed back, forcing the wheel well area to deform (Figure 2-65). The strut and axle for the right front wheel were bent, but remained attached.

As the vehicle turned parallel to the bridge rail, the sheet metal on the right rear quarter panel came into contact with the bridge rail face and caused minor scraping. The passenger door was not scraped during the test. The right rear tire rubbed along the bridge rail, but was not damaged beyond moderate scuffing. All four wheels were on or above the sidewalk as the vehicle left contact with the beam face. The vehicle continued along the sidewalk with the left wheels dropping off the sidewalk curb about 17 m from the beginning of the bridge rail. The interior of the vehicle experienced negligible deformation in the front passenger floorboard and elsewhere in the occupant compartment. Both vehicle doors and hatchback functioned properly and there was no windshield or other glass damage to the vehicle. Headlights and hood remained undamaged.

Occupant impact velocities and occupant ridedown accelerations were below the preferred maximums summarized in Table 2.5 - Test 548 Assessment Summary, page 48. The lateral and longitudinal occupant impact velocities were 4.22 and 4.54 m/s, respectively. The lateral and longitudinal occupant ridedown accelerations were -8.15 and -3.22 *g*, respectively.

2.2.1.13. Barrier Damage - Test 548

Since this was a repeat of Test 541, the impact location for Test 548 was set at the same location as Test 541. In order to see clearly the impact marks on the test article, previously damaged or marked areas of the rail had been painted. The impact damage due to Test 548 consisted of only minor scraping and tire scuffing. The total length of impact with the bridge rail was only slightly more than 4 m.

2.3. Discussion of Test Results - Crash Tests

2.3.1. General - Evaluation Methods (Tests 541-543,548)

NCHRP Report 350[1] stipulates that crash test performance be assessed according to three evaluation factors: 1) Structural Adequacy, 2) Occupant Risk, and 3) Vehicle Trajectory.

The structural adequacy, occupant risk and vehicle trajectories associated with both barriers were evaluated in comparison with Tables 3.1 and 5.1 of NCHRP Report 350.

2.3.2. Structural Adequacy

The structural adequacy of the Type 80SW bridge rail is acceptable. There was negligible movement of the rail during any of the tests. During the time of contact between the test vehicles and the barriers there were minor amounts of scraping and spalling.

A detailed assessment summary of structural adequacy is shown in Table 2.2 through Table 2.5.

2.3.3. Occupant Risk

The occupant risk for the Type 80SW is also acceptable. In none of the tests did spalling concrete exhibit any tendency to penetrate the occupant compartment of the vehicles. All of the calculated occupant ridedown accelerations and occupant impact velocities were within the "preferred" range. Please refer to Table 2.2 through Table 2.5 for a detailed assessment summary of occupant risk.

2.3.4. Vehicle Trajectory

The post-impact vehicle trajectory is also acceptable for the Type 80SW. The detailed assessment summary of vehicle trajectories may be seen in Table 2.6.

Table 2.2 - Test 541 Assessment Summary

Test No.	541
Date	May 6,1997
Test agency	California Dept. of Transportation

<table>
<tr><th>Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td>Structural Adequacy
A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the article is acceptable</td><td>The vehicle was contained and smoothly redirected</td><td>pass</td></tr>
<tr><td>Occupant Risk
D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td><td>The impact resulted only in a small amount of barrier spalling. Debris generated was insignificant. There was no significant deformation of the occupant compartment.</td><td>pass</td></tr>
<tr><td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable</td><td>The maximum roll, pitch and yaw were -12.3°, -5.2°, and -32.0°, respectively. These are all acceptable.</td><td>pass</td></tr>
<tr><td>H. Occupant impact velocities (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:
<table>
<tr><th colspan="3">Occupant Impact Velocity Limits (m/s)</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and lateral</td><td>9</td><td>12</td></tr>
</table></td><td>Long. Occ. Impact Vel. = 5.98 m/s
Lat. Occ. Impact Vel. = 6.34 m/s</td><td>pass</td></tr>
<tr><td>I. Occupant Ridedown Accelerations (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:
<table>
<tr><th colspan="3">Occupant Ridedown Acceleration Limits (g)</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and lateral</td><td>15</td><td>20</td></tr>
</table></td><td>Longitudinal Acceleration. = -5.50 g
Lateral Acceleration. = -9.90 g</td><td>pass</td></tr>
<tr><td>Vehicle Trajectory
K. After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes</td><td>The vehicle maintained a relatively straight course after exiting the barrier</td><td>pass</td></tr>
<tr><td>M. The exit angle from the test article preferably should be less that 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device.”</td><td>The exit angle was 10°, or 50% of the impact angle.</td><td>pass</td></tr>
</table>

Table 2.3 - Test 542 Assessment Summary

Test No.	542
Date	June 11, 1997
Test agency	California Dept. of Transportation

Evaluation Criteria	Test Results	Assessment
Structural Adequacy		
A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the article is acceptable.	The vehicle was contained and smoothly redirected	pass
Occupant Risk		
D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.	Only moderate amounts of spalling were created during impact. There was no significant debris from the vehicle.	pass
	The vehicle hood snagged on the handrail, damaging but not penetrating the windshield.	marginal
	There was moderate occupant compartment deformation.	pass
F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.	The maximum roll, pitch and yaw were -7.08, -15.47, and -25.75°, respectively. These are all acceptable.	pass
Vehicle Trajectory		
K. After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	The vehicle maintained a relatively straight course after exiting the barrier.	pass
L. The occupant impact velocity in the longitudinal direction should not exceed 12 m/sec and the occupant ridedown acceleration in the longitudinal direction should not exceed 20 *g*.	Long. Occ. Impact Vel. = 9.37 m/s Long. Occ. Ridedown = -7.45 *g*	pass
M. The exit angle from the test article preferably should be less that 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device."	Exit angle = 7°, 28% of the impact angle.	pass

Table 2.4 - Test 543 Assessment Summary

Test No.	543
Date	September 3, 1997
Test agency	California Dept. of Transportation

Evaluation Criteria	Test Results	Assessment
Structural Adequacy		
A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the article is acceptable	The vehicle was contained and smoothly redirected	pass
Occupant Risk		
D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.	There was not any significant debris from the test article and negligible deformation of the occupant compartment.	pass
G. It is preferable, although not essential, that the vehicle remain upright during and after collision.	The vehicle remained upright	pass
Vehicle Trajectory		
K. After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes	The vehicle maintained a relatively straight course after exiting the barrier	pass
M. The exit angle from the test article preferably should be less that 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device."	Exit angle =4°, 27% of the impact angle.	pass

Table 2.5 - Test 548 Assessment Summary

Test No.	548
Date	March 4, 1998
Test agency	California Dept. of Transportation

<table>
<tr><th colspan="4">Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td colspan="4">Structural Adequacy
A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the article is acceptable</td><td>The vehicle was contained and smoothly redirected</td><td>pass</td></tr>
<tr><td colspan="4">Occupant Risk
D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td><td>There was no significant debris from the test article nor substantial deformation of the occupant compartment.</td><td>pass</td></tr>
<tr><td colspan="4">F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable</td><td>The maximum roll, pitch and yaw were -14.27, 4.97, and -22.5°, respectively. All are acceptable.</td><td>pass</td></tr>
<tr><td colspan="4">H. Occupant impact velocities (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:</td><td></td><td></td></tr>
<tr><td></td><td colspan="3">Occupant Impact Velocity Limits (m/s)</td><td></td><td></td></tr>
<tr><td></td><td>Component</td><td>Preferred</td><td>Maximum</td><td></td><td></td></tr>
<tr><td></td><td>Longitudinal and lateral</td><td>9</td><td>12</td><td>Long. Occ. Impact Vel. = 4.54 m/s Lat. Occ. Impact Vel. = 4.22 m/s</td><td>pass</td></tr>
<tr><td colspan="4">I. Occupant Ridedown Accelerations (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:</td><td></td><td></td></tr>
<tr><td></td><td colspan="3">Occupant Ridedown Acceleration Limits (g)</td><td></td><td></td></tr>
<tr><td></td><td>Component</td><td>Preferred</td><td>Maximum</td><td></td><td></td></tr>
<tr><td></td><td>Longitudinal and lateral</td><td>15</td><td>20</td><td>Longitudinal Acceleration. = -3.22 g
Lateral Acceleration. = -8.15 g</td><td>pass</td></tr>
<tr><td colspan="4">Vehicle Trajectory
K. After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes</td><td>The vehicle maintained a relatively straight course after exiting the barrier</td><td>pass</td></tr>
<tr><td colspan="4">M. The exit angle from the test article preferably should be less that 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device."</td><td>Exit angle = 4°, 20% of the impact angle.</td><td>pass</td></tr>
</table>

Table 2.6 - Vehicle Trajectories and Speeds

Test Number	Impact Angle (deg)	60% of Impact Angle (deg)	Exit Angle (deg)	Impact Speed, V_i (km/h)	Exit Speed, V_e (km/h)	Speed Change $V_i - V_e$ (km/h)
541	20	12	10	102.0	75	27
542	25.0	15	7	110.2	77	33
543	15.0	9	2	80.8	72	7
548*	19.5	12	4	80.5	62	18

*Test 548 is a retest of Test 541.

3. CONCLUSION

Based on the testing of the Type 80SW discussed in this report, the following conclusions can be drawn:

1. The Type 80SW can smoothly and successfully contain an 820 kg sedan impacting at 20° and 100 km/h.

2. The Type 80SW can successfully contain and redirect a 2000 kg pickup truck impacting at 25° and 100 km/h. There was moderate occupant compartment deformation, mainly in the cab floorboard area. In addition, the vehicle hood snagged on the vertical handrail support tube, causing moderate occupant compartment deformation. However, this deformation was judged to be insufficient to cause serious injury to vehicle occupants.

3. The Type 80SW can successfully contain and redirect an 8000 kg, single unit, van-bodied truck impacting at 15° and 80 km/h.

4. Damage to the Type 80SW in accidents similar to the tests conducted for this project will result in small to moderate amounts of scraping and spalling of the rail. Therefore, the majority of impacts into the rail will not require urgent repairs. By structurally performing well at NCHRP Report 350 Test Level 4, the bridge rail meets the Performance Level 2 requirements of the 1989 AASHTO "Guide Specifications for Bridge Railings."

5. The Type 80SW meets the criteria set in the National Cooperative Highway Research Program's Report 350 "Recommended Procedures for the Safety Performance Evaluation of Highway Features" under Test Level 2 for longitudinal barriers.

4. RECOMMENDATION

The Type 80SW is recommended for use as new or retrofit bridge railing on low-speed (70 km/h or less) highways as Test Level 2.

Vehicle behavior observed during the test series demonstrated the inability of the sidewalk to provide any pedestrian protection at the tested speeds and angles. This vehicle behavior evidence and requirements given in Section 13.4 from NCHRP Project 12-33 "Bridge Design Specification" (7) and Article G2.7 of the 1989 AASHTO "Guide Specification for Bridge Railings" (4) clearly specify that a pedestrian sidewalk needs to be separated from traffic for high-speed applications (45 mi/h or greater).

In addition, the 2000 kg truck hood overlapped the top of the barrier and snagged on a vertical handrail support tube. The snagging caused minor occupant compartment deformation. The need for pedestrian sidewalk protection and the problem of the hood snagging make it appropriate to recommend the Type 80SW for low-speed (70 km/h or less) highways. At the lower speeds of Test Level 2, there would be substantially reduced front fender crush resulting in significantly reduced potential for hood snagging.

5. IMPLEMENTATION

The Office of Structures Design will be responsible for the preparation of standard plans and specifications for the Type 80SW, with technical support from the Office of Materials Engineering and Testing Services and the Traffic Operations Program. Similarly, the Office of Structures Design, with assistance from the Office of Materials Engineering and Testing Services and the Traffic Operations Program, will be responsible for the in-service evaluation.

6. REFERENCES

1. “Recommended Procedures for the Safety Performance Evaluation of Highway Features”, Transportation Research Board, National Cooperative Highway Research Program Report 350, 1993.

2. “Roadside Design Guide”, American Association of State Highway and Transportation Officials, 1988.

3. Jewell, John, et al., "Vehicle Crash Tests of Type 115 Barrier Rail Systems for Use on Secondary Highways", Transportation Research Record 1419, Transportation Research Board, Oct. 1993.

4. “Guide Specifications For Bridge Railings”, American Association of State Highway and Transportation Officials, 1989.

5. Hirsch, T.J. et. al., “Aesthetically Pleasing Concrete Beam and Posts Bridge Rail - Texas Type T411”, Texas Transportation Institute, Report No. TTI-2-5-88/89-1185-1, March 1989.

6. Hirsch, T.J. et. al., “Aesthetically Pleasing Concrete Beam-and-Post Bridge Rail”, Transportation Research Record 1258, Transportation Research Board, 1990.

7. “Development of a Comprehensive Bridge Specification and Commentary” - Section 13, National Cooperative Highway Research Program Project 12-33, 1993.

8. “Standard Specifications”, California Department of Transportation, Sacramento, CA., 1995.

9 “Vehicle Damage Scale for Traffic Accident Investigators”, Traffic Accident Data Project, National Safety Council, 1968.

10. “Collision Deformation Classification” - SAE J224 Mar80, SAE Recommended Practices, 1980.

7. APPENDICES

7.1. Test Vehicle Equipment

The test vehicles were modified as follows for the crash tests:

- The gas tanks on the test vehicles were disconnected from the fuel supply line and drained. A 12 L safety gas tank was installed in the truck bed or non-impact cab step and connected to the fuel supply line. The stock fuel tanks had dry ice or gaseous CO_2 added in order to purge the gas vapors.

  (For Test 541 and 548, a 12 L safety tank was not installed because the vehicle was towed to impact instead of self-powered.)

- One pair of 12-volt wet cell motorcycle storage batteries were mounted in the vehicle. The batteries operated the solenoid-valve braking/accelerator system, rate gyros and the electronic control box. A second 12-volt deep cycle gel cell battery powered the transient data recorder.

- A 4800 kPa CO_2 system, actuated by a solenoid valve, controlled remote braking after impact and emergency braking if necessary. Part of this system was a pneumatic ram which was attached to the brake pedal. The operating pressure for the ram was adjusted through a pressure regulator during a series of trial runs prior to the actual test. Adjustments were made to assure the shortest stopping distance without locking up the wheels. When activated, the brakes could be applied in less than 100 milliseconds.

- The remote brakes were controlled at a console trailer. A cable ran from the console trailer to an electronic instrumentation trailer. From there, the remote brake signal was carried on one channel of a multi-channel tether line which was connected to the test vehicle. Any loss of continuity in these cables would have activated the brakes and cut off the ignition automatically. Also, when the brakes were applied by remote control from the console trailer, the ignition for self powered vehicle was automatically cut by removing power to the coil.

- For Test 541 and 548, the vehicle speed was regulated by the speed of a tow vehicle. The tow vehicle pulled a tow cable through a series of sheaves arranged to produce a 2:1 mechanical advantage. Vehicle speed control was attained though a calibrated speedometer in the tow vehicle.

- For tests 542 and 543, an accelerator switch was located on the rear fender of the vehicle. The switch opened an electric solenoid which, in turn, released compressed CO_2 from a reservoir into a pneumatic ram that had been attached to the accelerator pedal. The CO_2 pressure for the accelerator ram was regulated to the same pressure of the remote braking system with a valve to adjust CO_2 flow rate.

- For tests 542 and 543, a speed control device, connected in-line with the primary winding of the coil, was used to regulate the speed of the test vehicle based on the signal from a speed sensor output from the vehicle transmission. This device was calibrated prior to the test by conducting a series of trial runs through a speed trap comprised of two tape switches set a specified distance apart and a digital timer.

- For tests 542 and 543, a microswitch was mounted below the front bumper and connected to the ignition system. A trip plate on the ground near the impact point triggered the switch when the car passed over it. The switch would open the ignition circuit and shut off the vehicle's engine prior to impact.

Table 7.1 - Test 541 Vehicle Dimensions

DATE: 12/5/97 **TEST NO:** 541 **VIN NO:** 2CIMR646XN6721298 **MAKE:** GEO

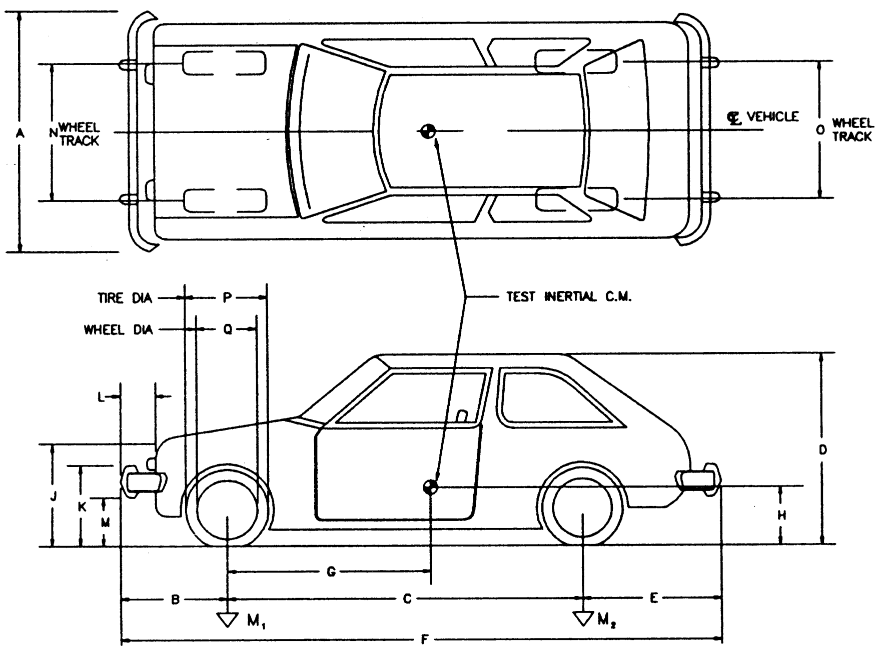
MODEL: METRO **YEAR:** 1992 **ODOMETER:** 66386 (MI) **TIRE SIZE:** 155R1276T

TIRE INFLATION PRESSURE: 36 (PSI)

MASS DISTRIBUTION (kg) **LF** 258.5 **RF** 237.2 **LR** 168.7 **RR** 158.3

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST: SCRATCH ON HOOD, APPROXIMATELY 30 MM LONG ON RIGHT FRONT SIDE OF

HOOD



ENGINE TYPE: IN-LINE 3 CYL.

ENGINE CID: 1.0 LITER

TRANSMISSION TYPE :

X **AUTO**

____ **MANUAL**

OPTIONAL EQUIPMENT:

AIR CONDITIONING

DUMMY DATA:

TYPE: HYBRID II 50th %

MASS: 75 KG

SEAT POSITION: RIGHT FRONT

GEOMETRY (cm)

A	157	D	140	G	112	K	47	N	136	Q	34
B	79	E	70	H	25	L	9	O	135		
C	237	F	390	J	70	M	20	P	56		

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M1		496	534
M2		327	372
MT		823	898

Table 7.2 - Test 542 Vehicle Dimensions

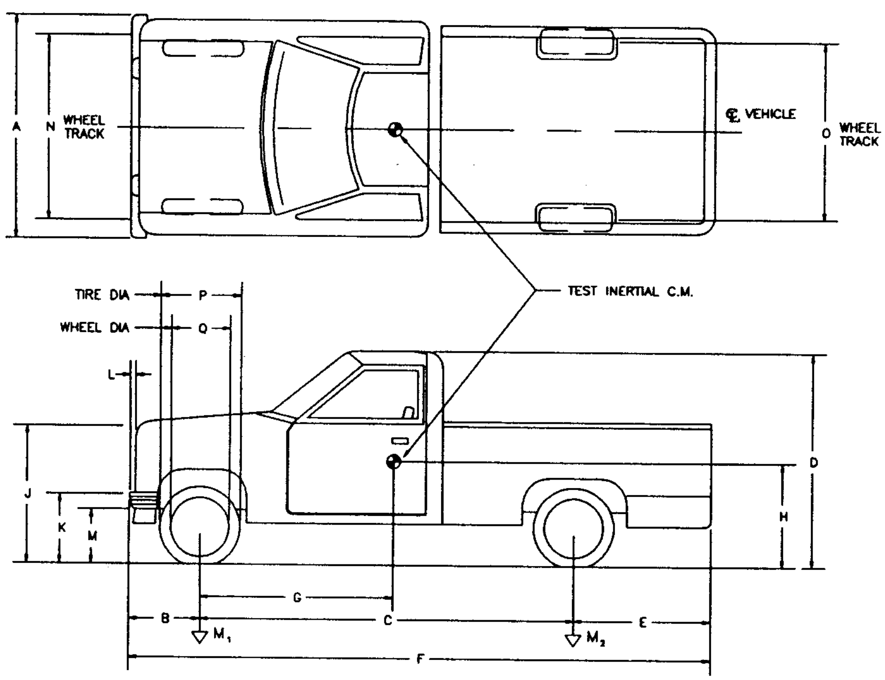
DATE: 3/16/98 **TEST NO:** 542 **VIN NO:** 1GCFC24K5PE177505 **MAKE:** CHEVROLET

MODEL: 2500 **YEAR:** 1993 **ODOMETER:** 118457 (MI) **TIRE SIZE:** LT 245 175R16

TIRE INFLATION PRESSURE: 44 (PSI)

MASS DISTRIBUTION (kg) **LF** 542.2 **RF** 555.4 **LR** 430.8 **RR** 425.8

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST: NONE



ENGINE TYPE: V8

ENGINE CID: 5.8L

TRANSMISSION TYPE :

X **AUTO**

___ **MANUAL**

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: NA

MASS: NA

SEAT POSITION: NA

GEOMETRY (cm)

A 192.3	D 169.3	G 150.5	K 74.0	N 166.0	Q 43.2
B 76.8	E 131.2	H 55.9	L 6.3	O 166.0	
C 340.5	F 544.7	J 120.0	M 50.8	P 79.8	

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M1	1079	1097.6	1097.6
M2	800	856.6	856.6
MT	1879	1954.2	1954.2

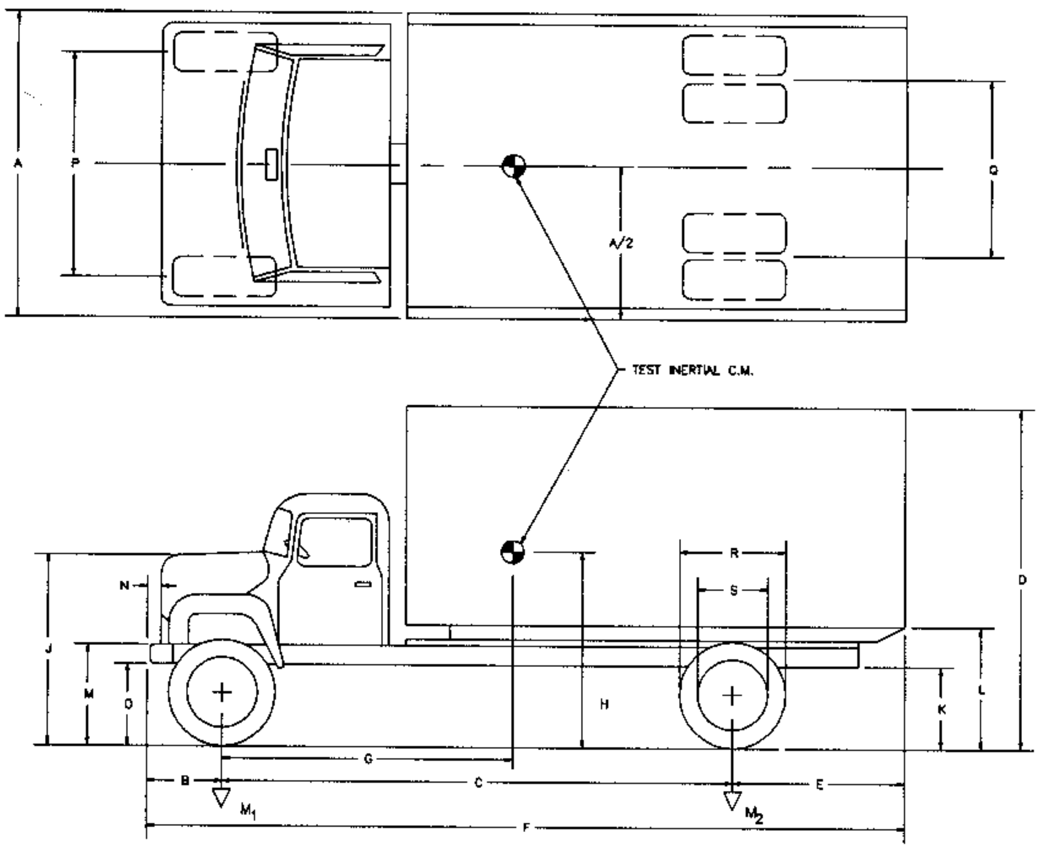
Table 7.3 - Test 543 Vehicle Dimensions

DATE: 9/30/97 **TEST NO:** 543 **VIN NO:** 1GDJ7H1P4NJ516563 **MAKE:** GMC

MODEL: TOP KICK **YEAR:** 1992 **ODOMETER:** 109902 (MI) **TIRE SIZE:** 11R22.5

MASS DISTRIBUTION (kg) **LF**____ **RF**____ **LR**____ **RR**____

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST: Right rear backup light missing



GEOMETRY (cm)

A 243	**D** 345	**G** 363	**K** 73.5	**N** 10	**Q** 183
B 85	**E** 242	**H**	**L** 111	**O** 57	**R** 103
C 530	**F** 858	**J** 174	**M** 96	**P** 202	**S** 59

MASS - (kg)	**CURB**	**TEST INERTIAL**	**GROSS STATIC**
M1	2136	2558	2558
M2	2966	5461	5461
MT	5102	8020	8020

Table 7.4 - Test 548 Vehicle Dimensions

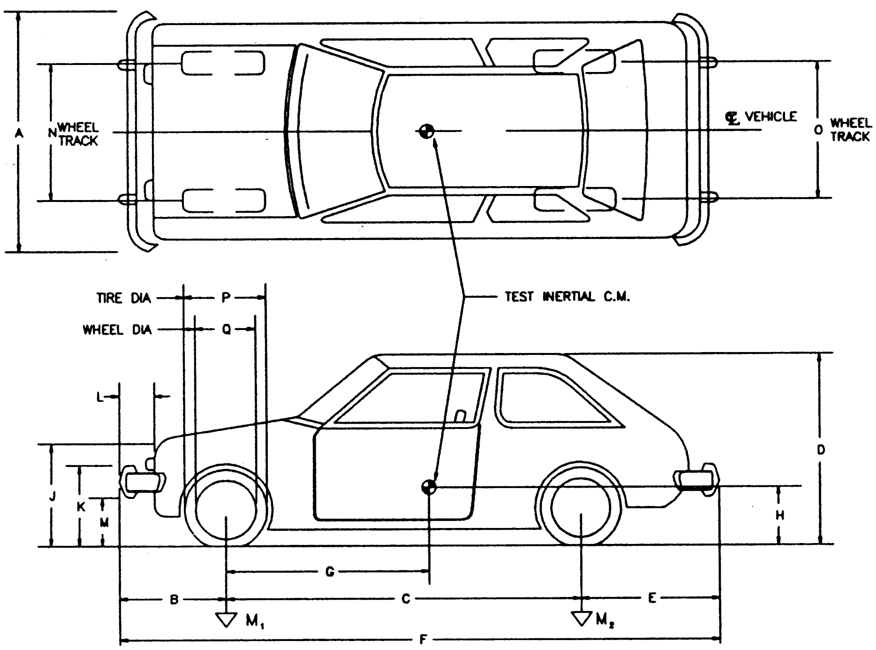
DATE: 2/26/98 **TEST NO:** 541 **VIN NO:** 2C1MR2465R6757107 **MAKE:** GEO

MODEL: METRO **YEAR:** 1994 **ODOMETER:** 60992 (MI) **TIRE SIZE:** 155 S R12

TIRE INFLATION PRESSURE: 32 (PSI)

MASS DISTRIBUTION (kg) **LF** 255 **RF** 238 **LR** 166 **RR** 165

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST: NONE



ENGINE TYPE: IN-LINE 3 CYL.

ENGINE CID: 1.0 LITER

TRANSMISSION TYPE :

X **AUTO**

MANUAL

OPTIONAL EQUIPMENT:

AIR CONDITIONING

DUMMY DATA:

TYPE: HYBRID II 50th %

MASS: 75 KG

SEAT POSITION: RIGHT FRONT

GEOMETRY (cm)

A 140	**D** 124	**G** 91	**K** 47	**N** 138	**Q** 34
B 76	**E** 68	**H**	**L** 8	**O** 134	
C 226	**F** 365	**J** 69	**M** 20	**P** 55	

MASS - (kg)	**CURB**	**TEST INERTIAL**	**GROSS STATIC**
M1	487	493	531
M2	263	331	368
MT	750	824	899

7.2. Test Vehicle Guidance System

A rail guidance system directed the vehicle into the barrier. The guidance rail, anchored at 3.8 m intervals along its length, was used to guide a mechanical arm which was attached to the front left wheel of each of the vehicles. A rope was used to trigger the release mechanism on the guidance arm, thereby releasing the vehicle from the guidance system before impact.

7.3. Photo - Instrumentation

Several high-speed movie cameras recorded the impact during the crash tests. The types of cameras and their locations are shown Figure 7-1 and Table 7.5.

All of these cameras were mounted on tripods except the three that were mounted on a 10.7-m high tower directly over the impact point on the test barrier.

A video camera and a 16 mm film camera were turned on by hand and used for panning during the test. All other cameras were remotely triggered by switches on a console trailer near the impact area. The test vehicle and test barrier were photographed before and after impact with a normal-speed movie camera, a beta video camera and a color still camera. A film report of this project has been assembled using edited portions of the crash testing coverage.

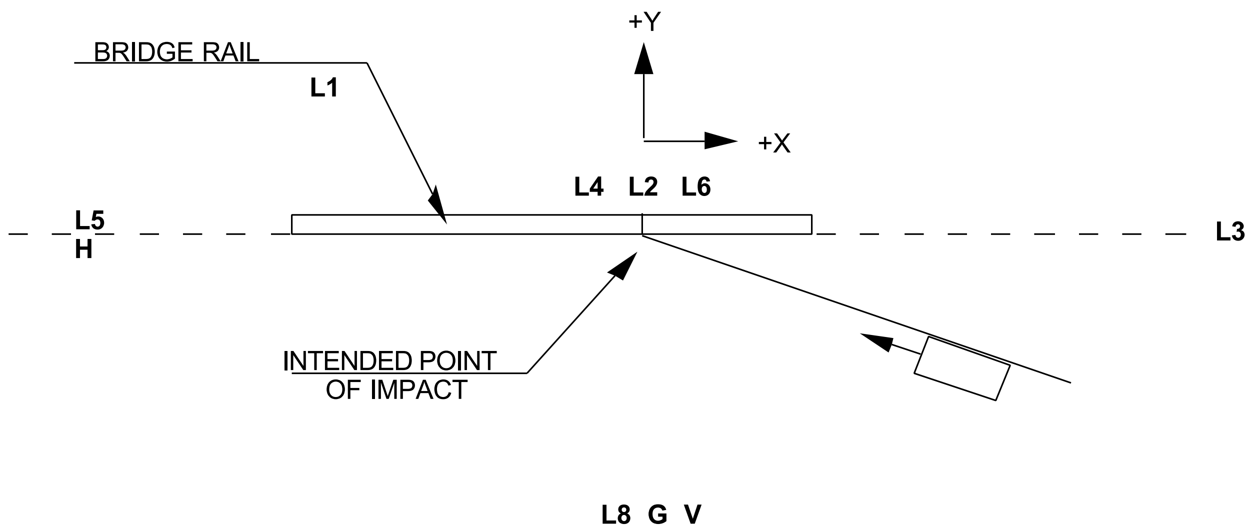


Figure 7-1 - Camera Locations

Typical Coordinates, m						
Camera Label	Film Size (mm)	Camera Type	Rate: (fr./sec.)	Test 541		
				X*	Y*	Z*
L1	16	LOCAM 1	400	-33.8	10.1	1.5
L2	16	LOCAM 2	400	0.0	0.0	12.0
L3	16	LOCAM 3	400	30.4	1.1	1.5
L4	16	LOCAM 4	400	-0.6	0.0	12.0
L5	16	LOCAM 5	400	-49.6	-2.7	3.5
L6	16	LOCAM 6	400	+0.6	0.0	12.0
L8	16	LOCAM 8	400	-4.5	-19.3	1.5
G	16	GISMO	64	-3.2	-24.3	1.5
V	1.27	SONY BETACAM	30	-6	-19.1	1.5
H	35	HULCHER	40	-49.7	-1.8	3.5
Note: Camera location measurements were approximated and are typical for all crash tests involved in this report. *X, Y and Z distances are relative to the impact point.						

Table 7.5 - Typical Camera Type and Locations

The following are the pretest procedures that were required to enable film data reduction to be performed using a film motion analyzer:

1) Butterfly targets were attached to the top and sides of each test vehicle. The targets were located on the vehicle at intervals of 0.305, 0.610 and 1.219 meters (1, 2 and 4 feet.). The targets established scale factors and horizontal and vertical alignment. The test barrier was targeted with stenciled numbers every 1 or 2 meters..

2) Flashbulbs, mounted on the test vehicle, were electronically triggered to establish 1) initial vehicle-to-barrier contact, and 2) the time of the application of the vehicle brakes. The

impact flashbulbs begin to glow immediately upon activation, but have a delay of several milliseconds before lighting up to full intensity.

3) Five tape switches, placed at 4 m intervals, were attached to the ground near the barrier and were perpendicular to the path of the test vehicle. Flash bulbs were activated sequentially when the tires of the test vehicle rolled over the tape switches. The flashbulb stand was placed in view of most of the cameras. The flashing bulbs were used to correlate the cameras with the impact events and to calculate the impact speed independent of the electronic speed trap. The tape switch layout is shown in Figure 7-2.

4) High-speed cameras had timing light generators which exposed red timing pips on the film at a rate of 100 per second. The pips were used to determine camera frame rates.

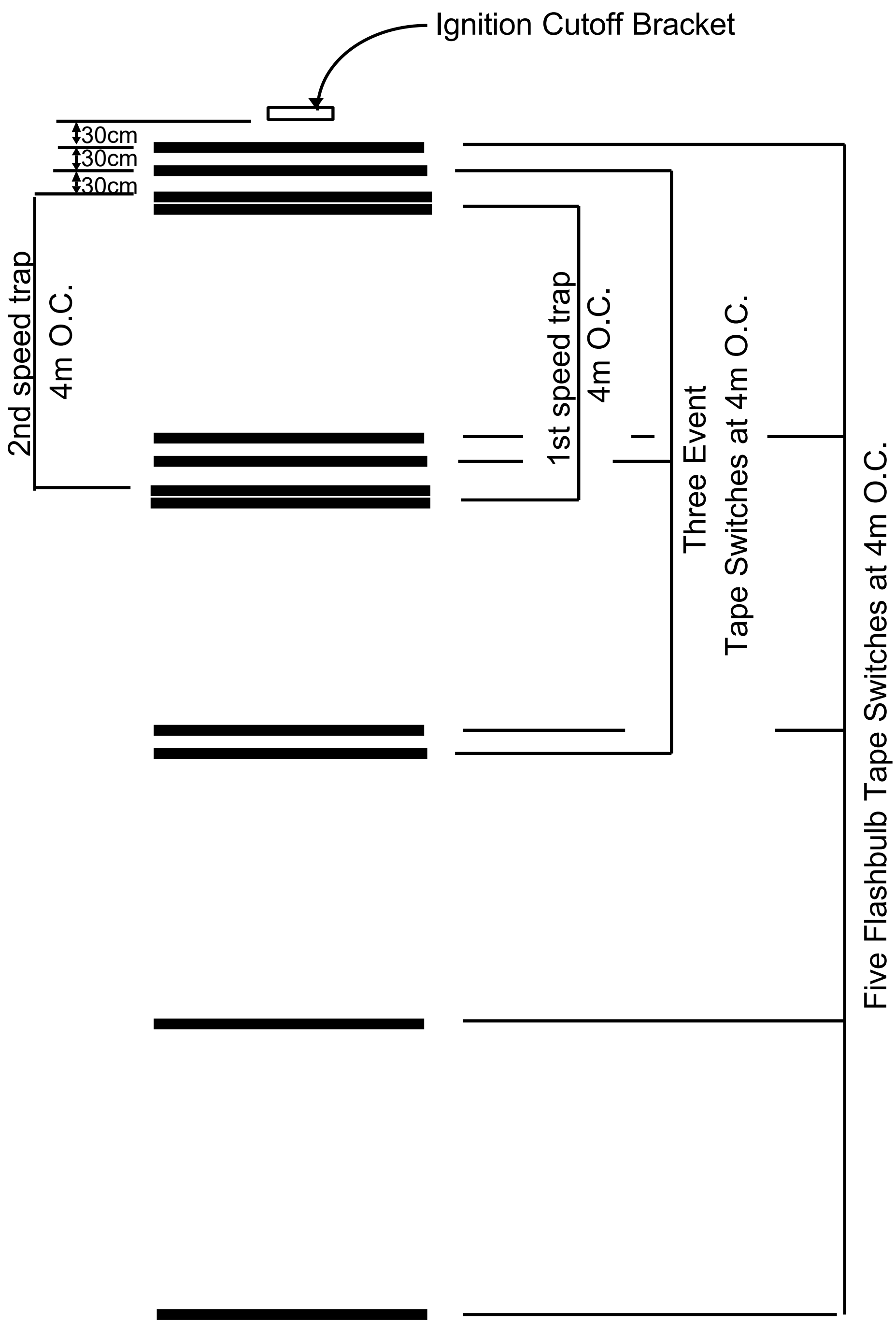


Figure 7-2 - Tape Switch Layout

7.4. *Electronic Instrumentation and Data*

Transducer data were recorded on a Pacific Instruments digital transient data recorder (TDR) model 5600 which was mounted in the vehicle. The transducers mounted on the vehicle include two sets of accelerometers at the center of gravity, one set of accelerometers 600 mm behind the center of gravity, and one set of rate gyros at the center of gravity. The TDR data were reduced using a laptop computer.

Three pressure-activated tape switches were placed on the ground in front of the test barrier (see Figure 7-2). They were spaced at carefully measured intervals of 4 m. When the test vehicle tires passed over them, the switches produced sequential impulses or "event blips" which were recorded concurrently with the accelerometer signals on the TDR, serving as "event markers". A tape switch on the front bumper of the vehicle closed at the instant of impact and triggered two events: 1) an “event marker” was added to the recorded data, and 2) a flash bulb mounted on the top of the vehicle was activated. A time cycle was recorded continuously on the TDR with a frequency of 500 cycles per second. The impact velocity of the vehicle could be determined from the tape switch impulses and timing cycles. Two other tape switches, connected to a speed trap, were placed 4 m apart just upstream of the test barrier specifically to establish the impact speed of the test vehicle. The tape switch layout for all tape switches is shown in Figure 7-2.

The data curves are shown in Figure 7-4 through Figure 7-8 and include the accelerometer and rate gyro records from the test vehicles. They also show the longitudinal velocity and displacement versus time. These plots were needed to calculate the occupant impact velocity defined in NCHRP Report 350. All data were analyzed using software written by DADiSP and modified by Caltrans.

NOTE: There are no data plots for Test 543 because NCHRP Report 350 did not require accelerometer data.

Table 7.6 - Accelerometer Specifications

TYPE	LOCATION	RANGE	ORIENTATION	TEST NUMBER
STATHAM	VEHICLE C.G.	100 G	LONGITUDINAL	ALL
STATHAM	VEHICLE C.G.	100 G	LATERAL	ALL
STATHAM	VEHICLE C.G.	50 G	VERTICAL	ALL
HUMPHREY	VEHICLE C.G.	180 DEG/SEC	ROLL	ALL
HUMPHREY	VEHICLE C.G.	90 DEG/SEC	PITCH	ALL
HUMPHREY	VEHICLE C.G.	180 DEG/SEC	YAW	ALL
ENDEVCO	VEHICLE C.G.	200 G	LONGITUDINAL	ALL
ENDEVCO	VEHICLE C.G.	200 G	LATERAL	ALL
ENDEVCO	VEHICLE C.G.	200 G	VERTICAL	ALL

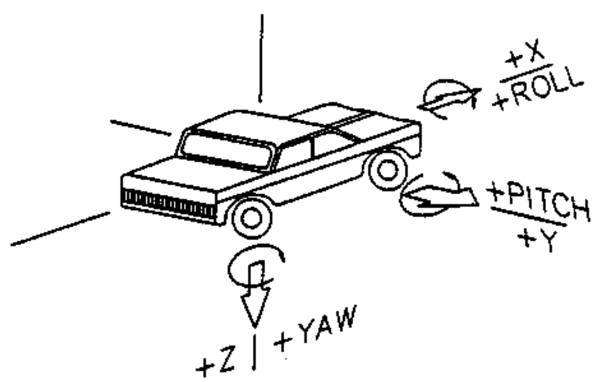


Figure 7-3 - Vehicle Accelerometer Sign Convention

Figure 7-4 - Test 541 Vehicle Accelerations -vs- Time

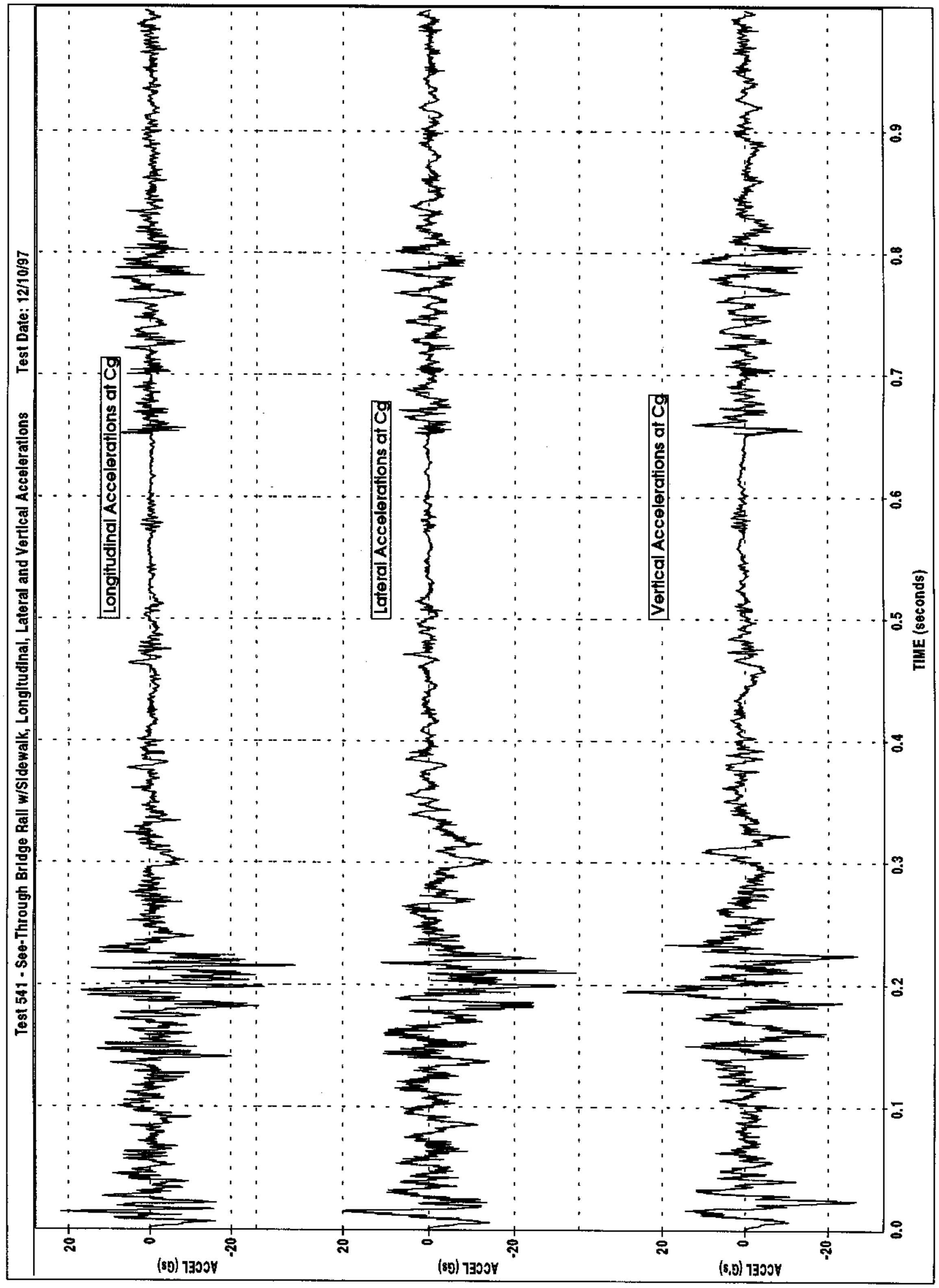


Figure 7-5 - Test 541 Vehicle Longitudinal Acceleration, Velocity and Distance -vs- Time

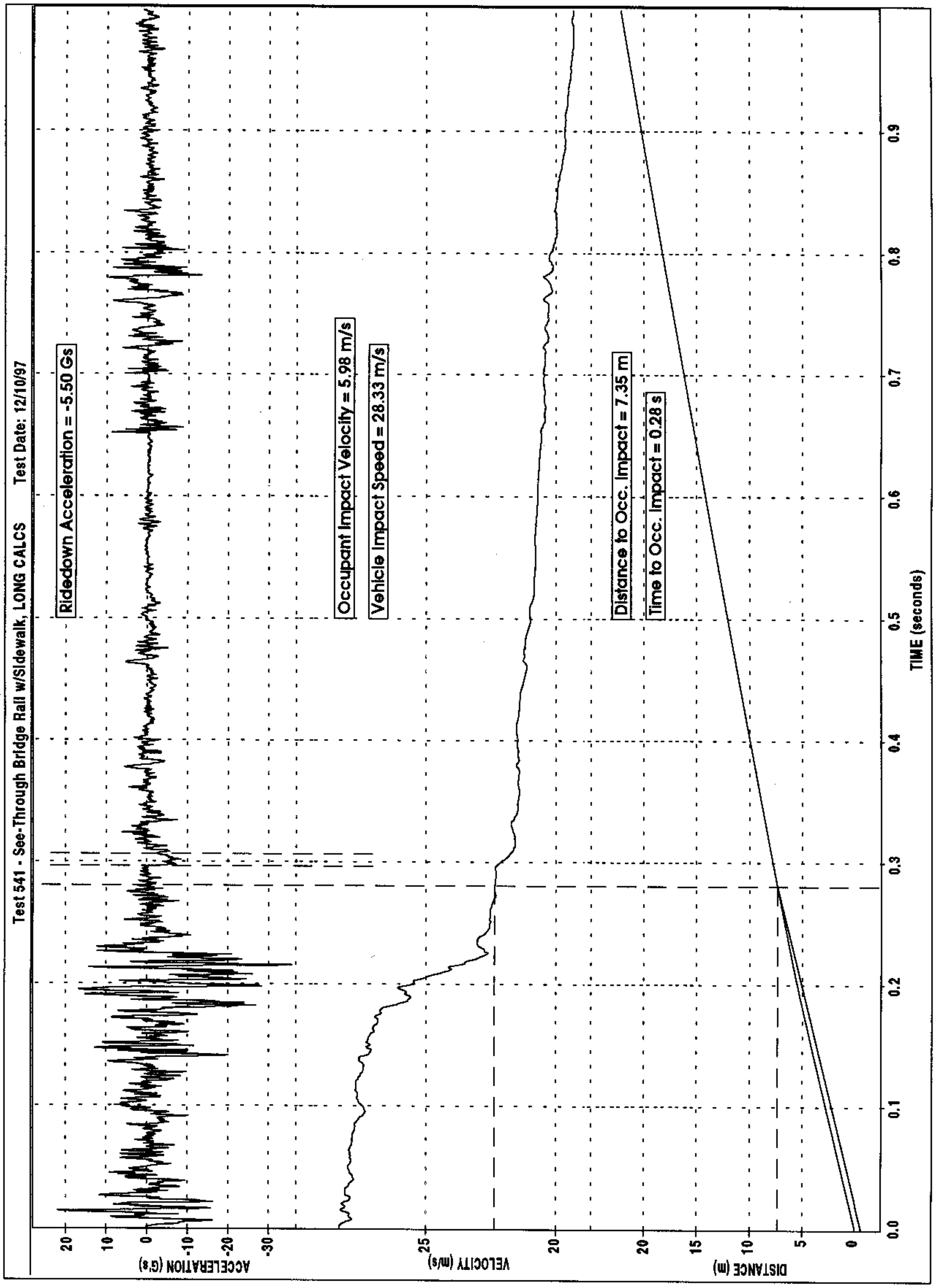


Figure 7-6 - Test 541 Vehicle Lateral Acceleration, Velocity and Distance -vs- Time

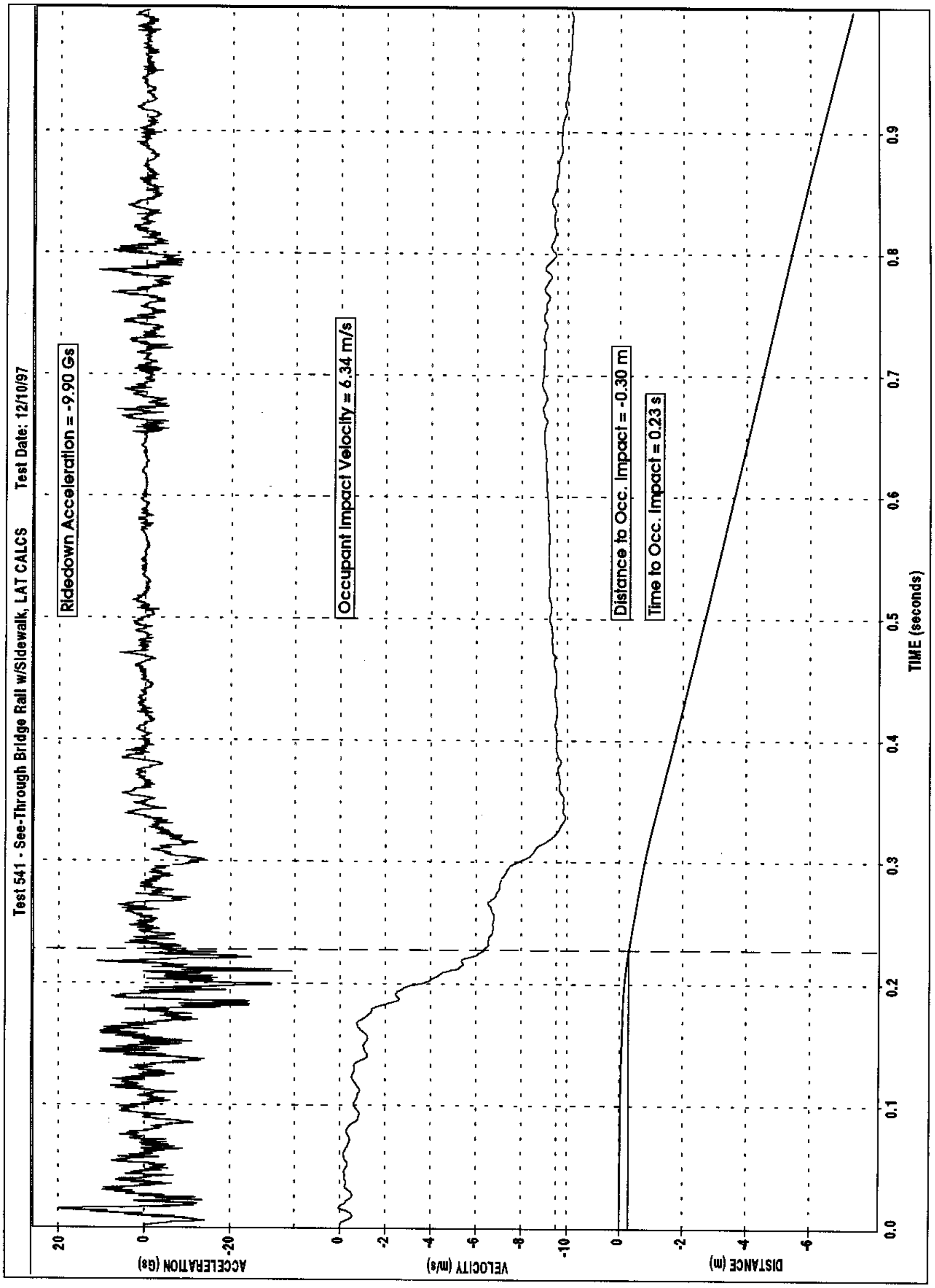


Figure 7-7 - Test 541 Vehicle Roll, Pitch and Yaw -vs- Time

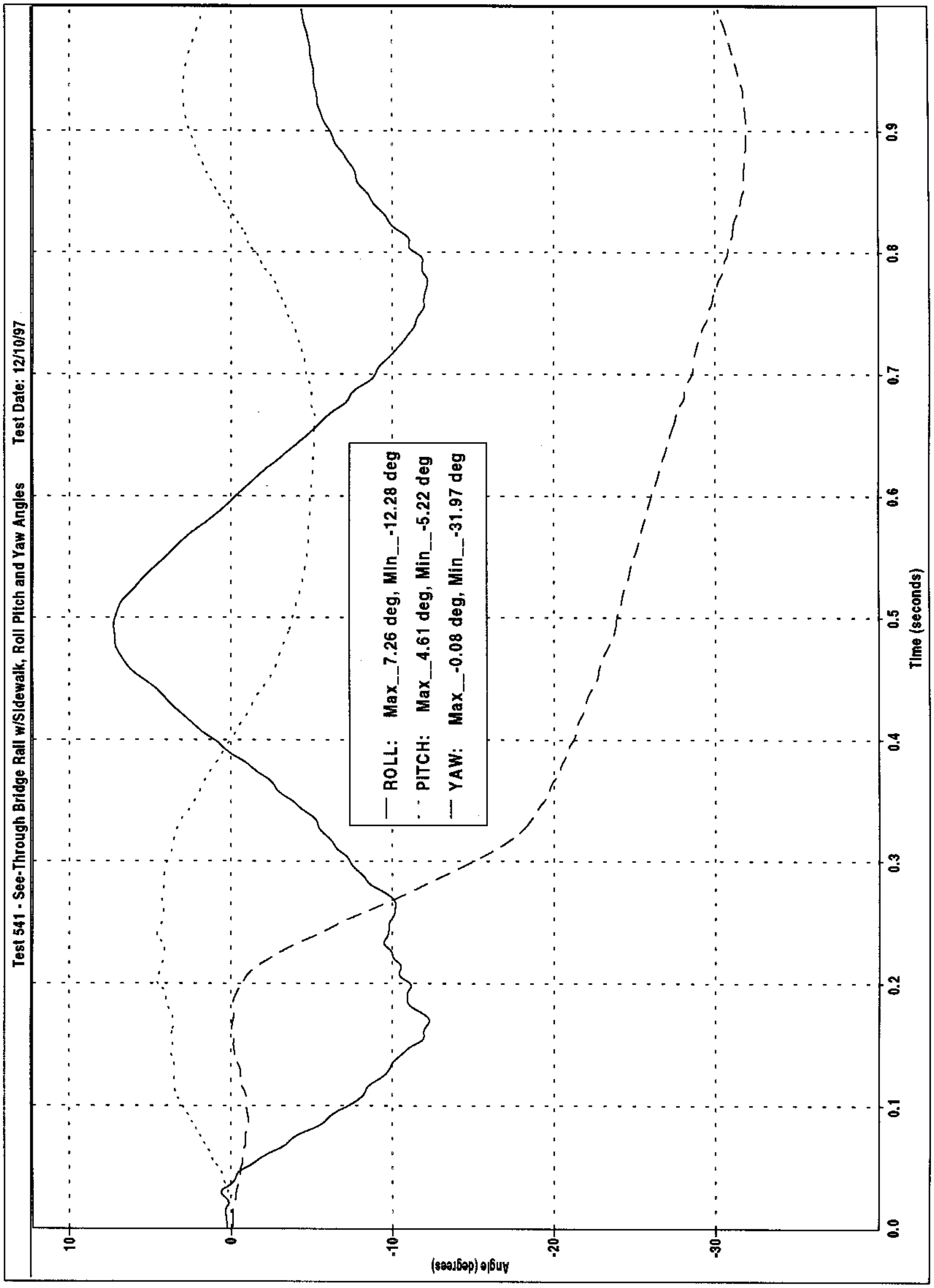


Figure 7-8 - Test 542 Vehicle Accelerations -vs- Time

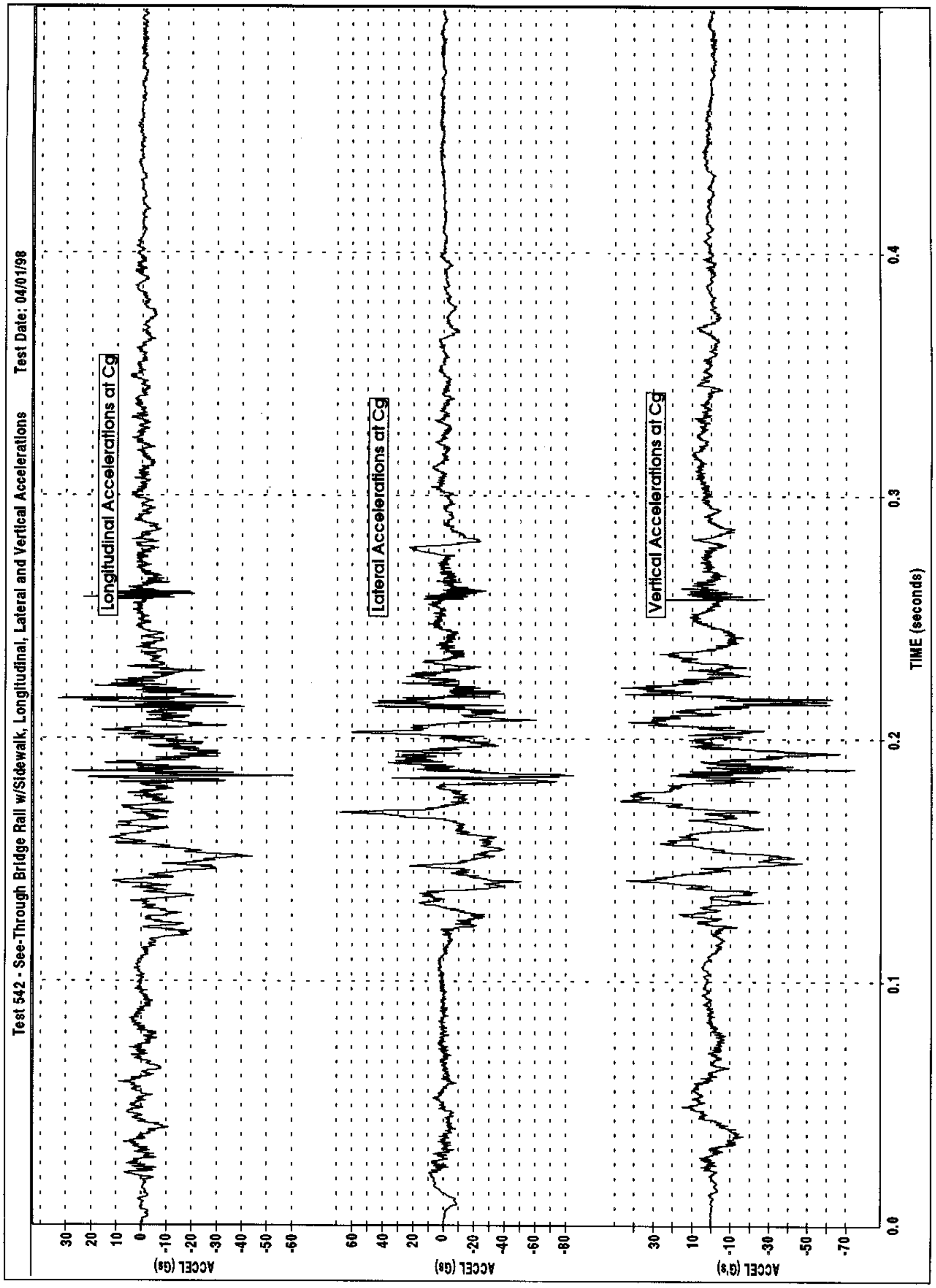


Figure 7-9 - Test 542 Vehicle Longitudinal Acceleration,
Velocity and Distance -vs- Time

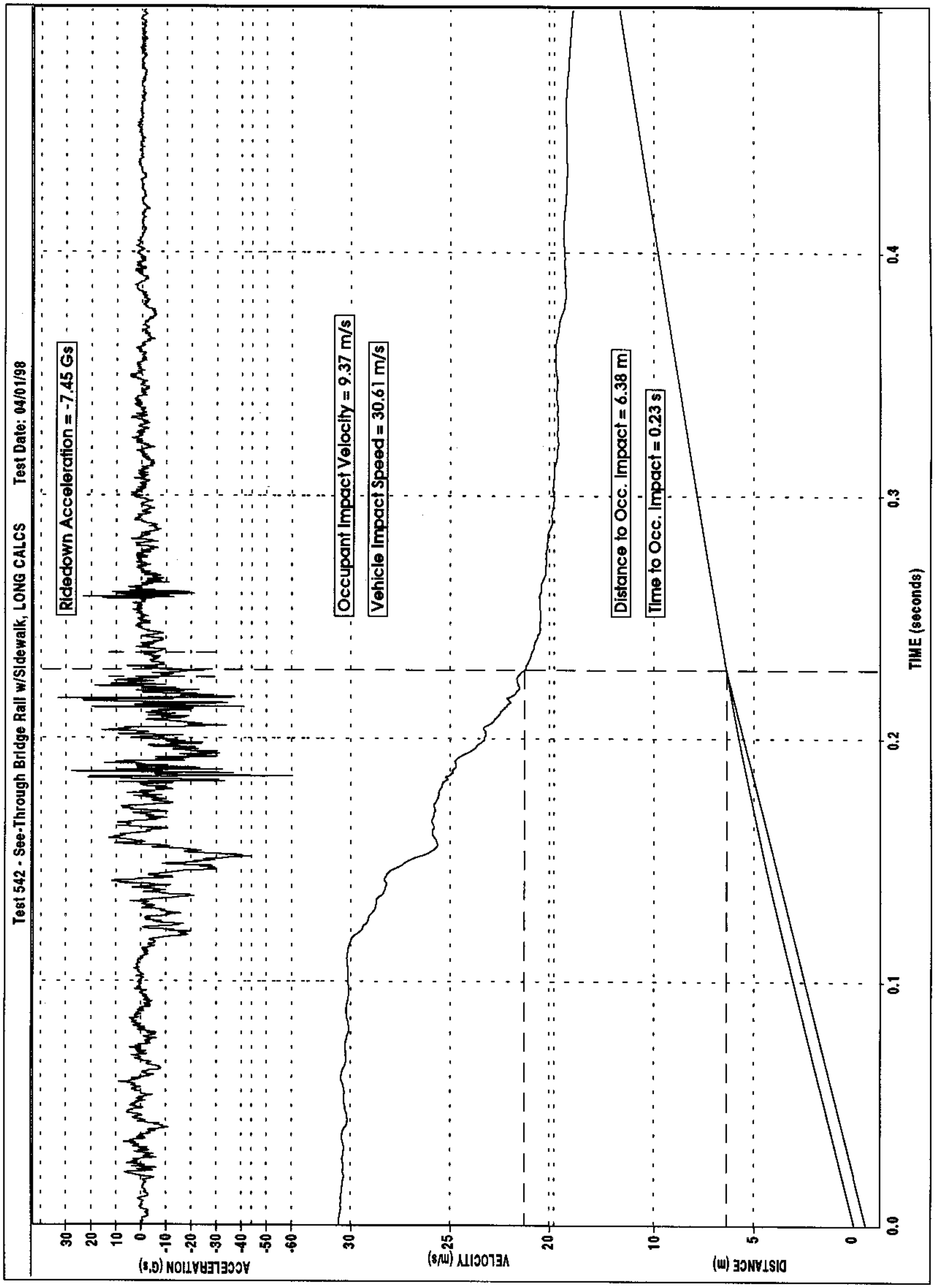


Figure 7-10 - Test 542 Vehicle Lateral Acceleration, Velocity and Distance -vs- Time

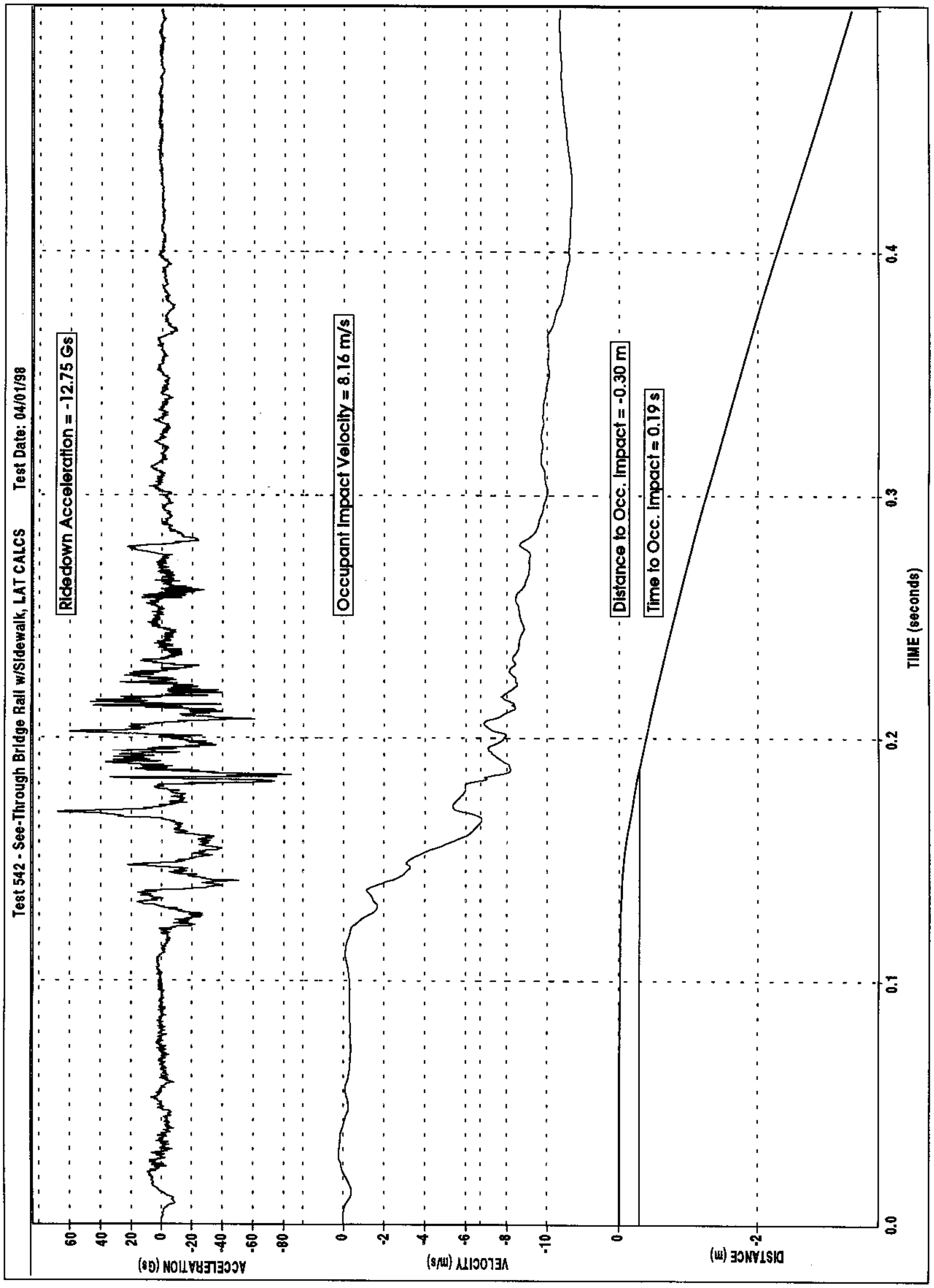


Figure 7-11 - Test 542 Vehicle Roll, Pitch and Yaw -vs- Time

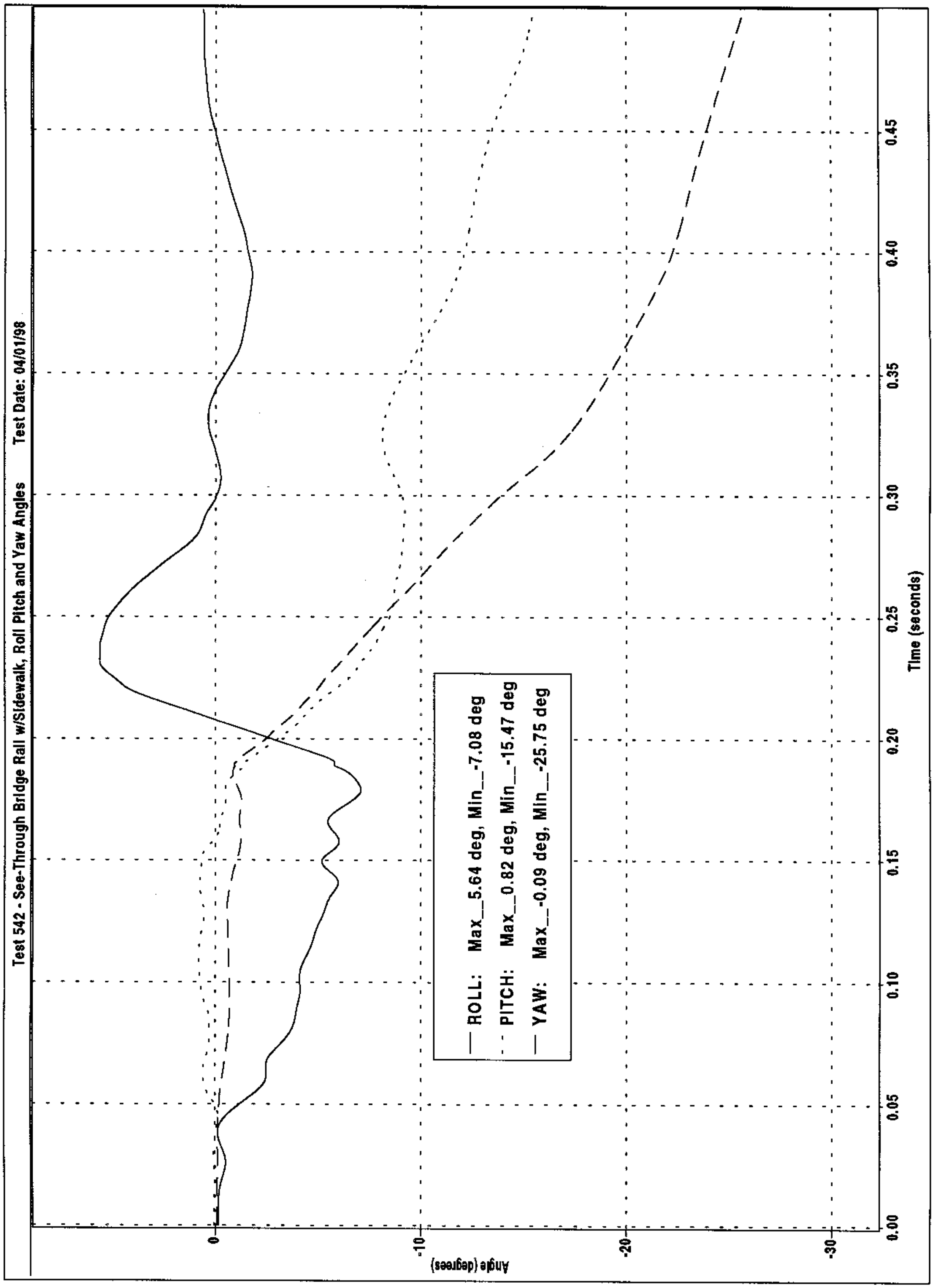


Figure 7-12 - Test 548 Vehicle Accelerations -vs- Time

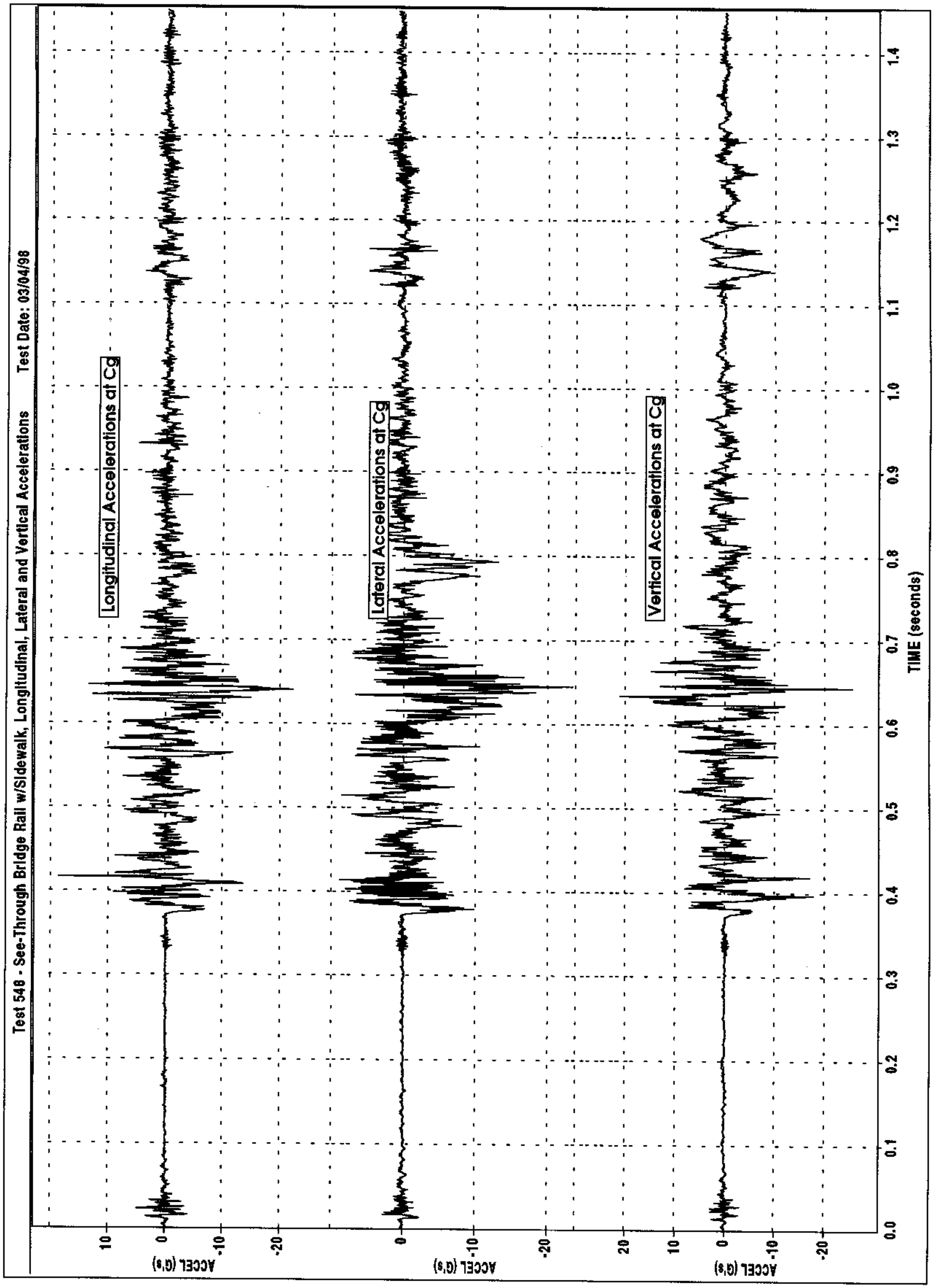


Figure 7-13 - Test 548 Vehicle Longitudinal Acceleration, Velocity and Distance -vs- Time

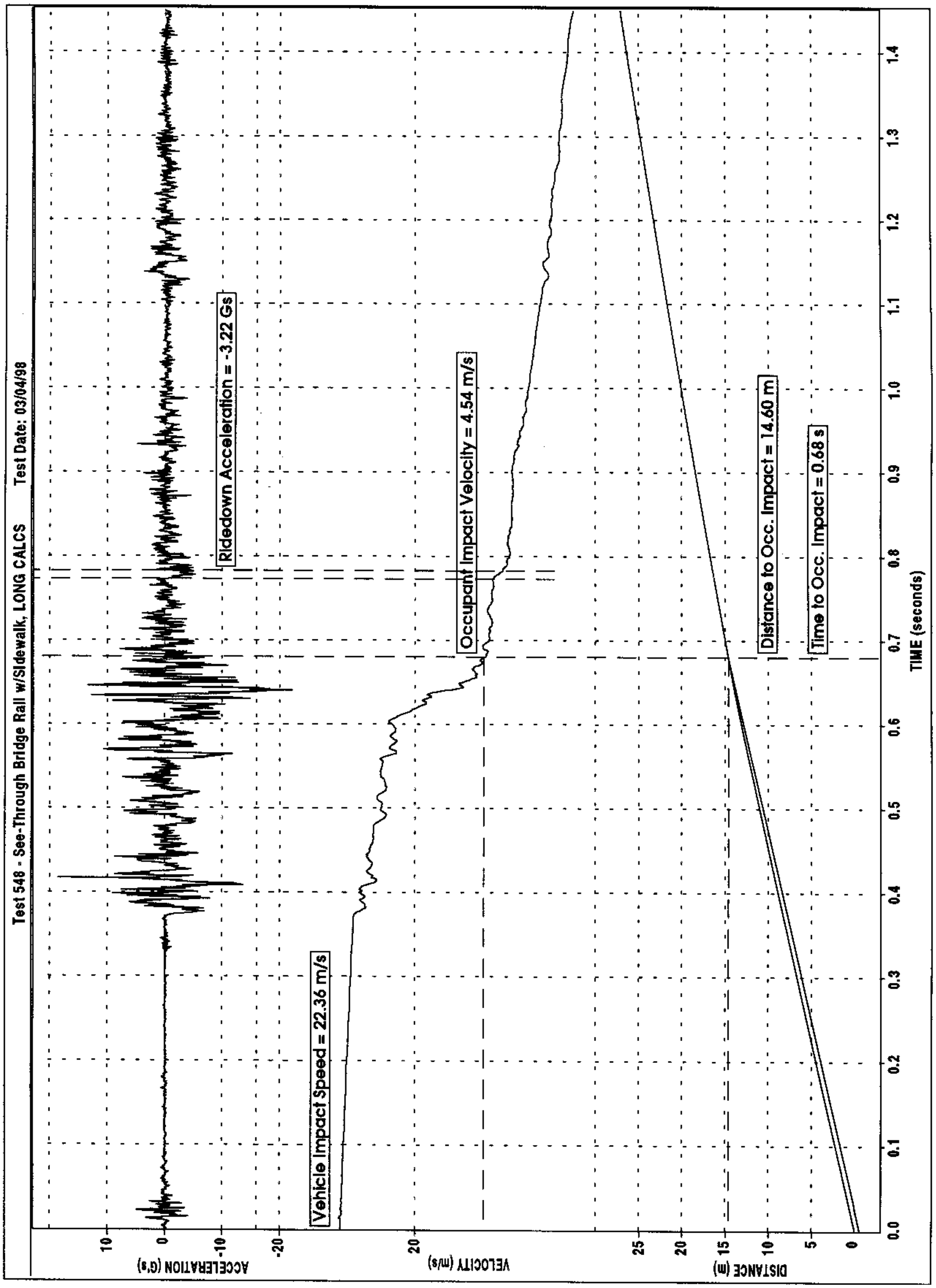


Figure 7-14 - Test 548 Vehicle Lateral Acceleration, Velocity and Distance -vs- Time

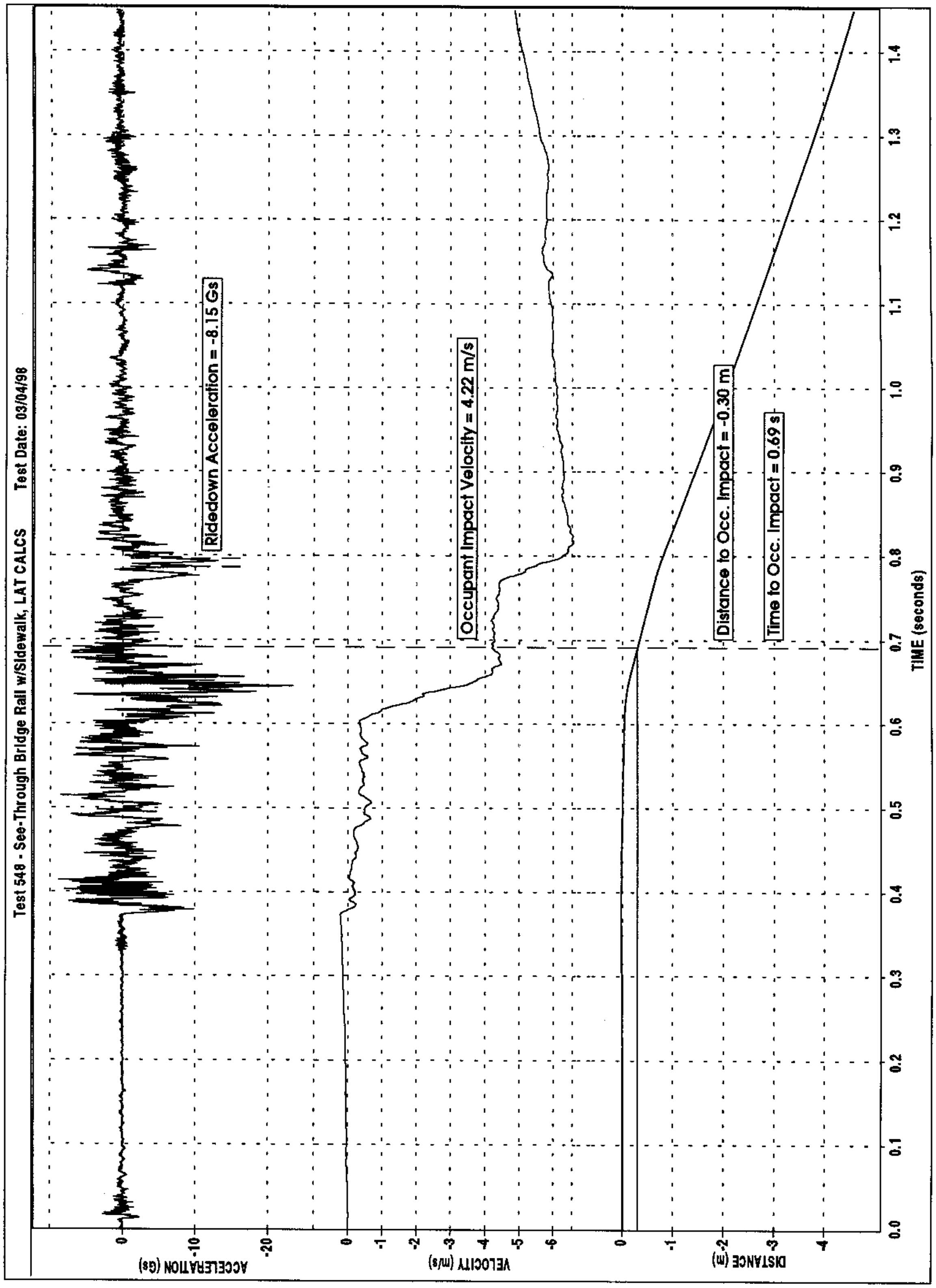
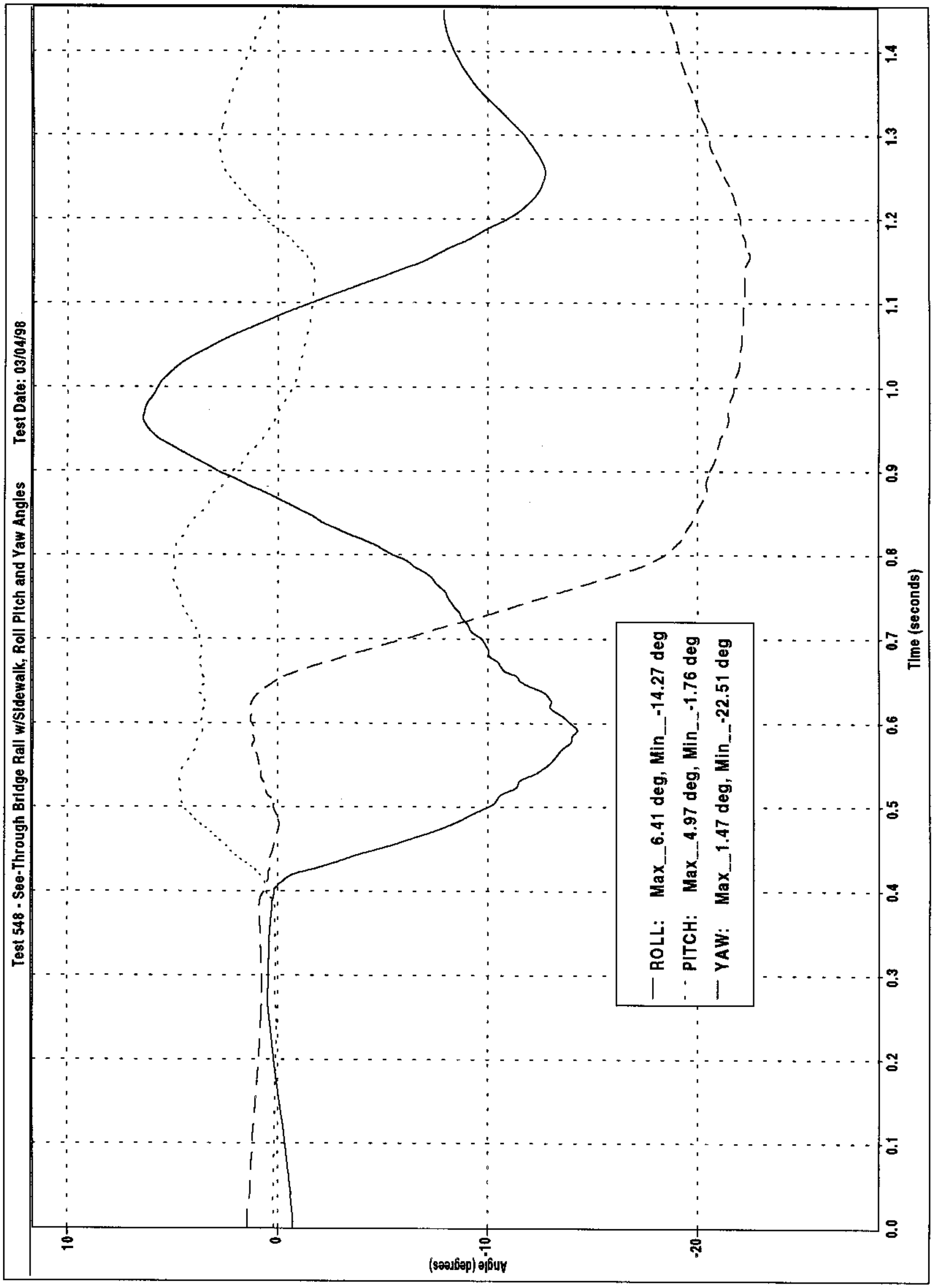


Figure 7-15 - Test 548 Vehicle Roll, Pitch and Yaw -vs- Time

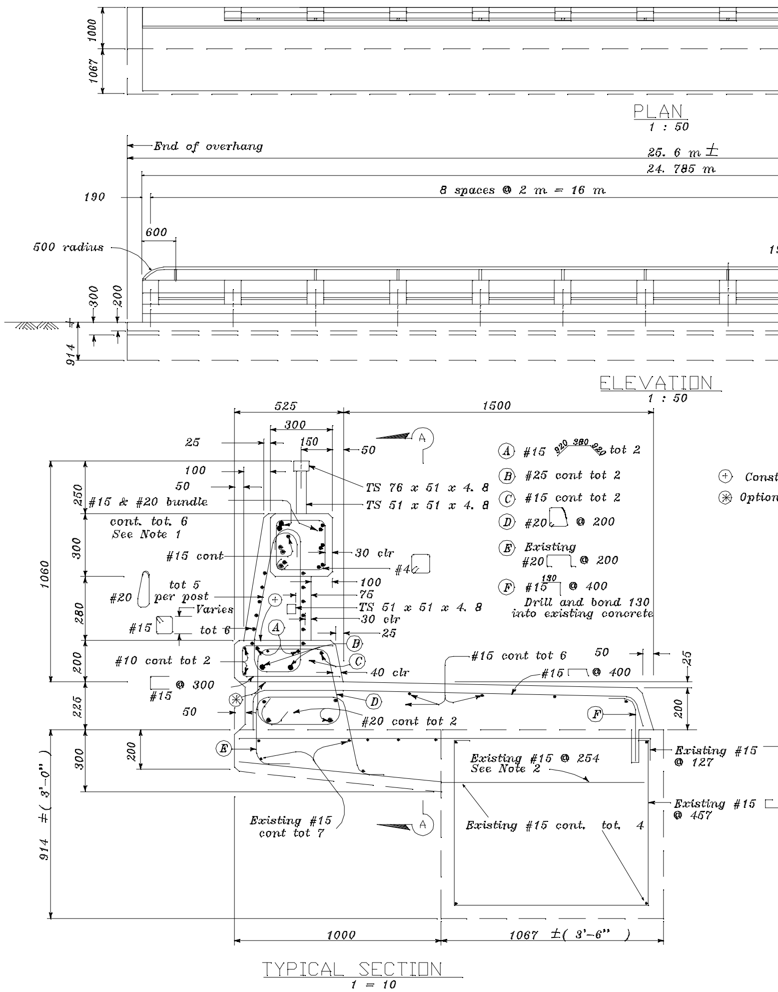


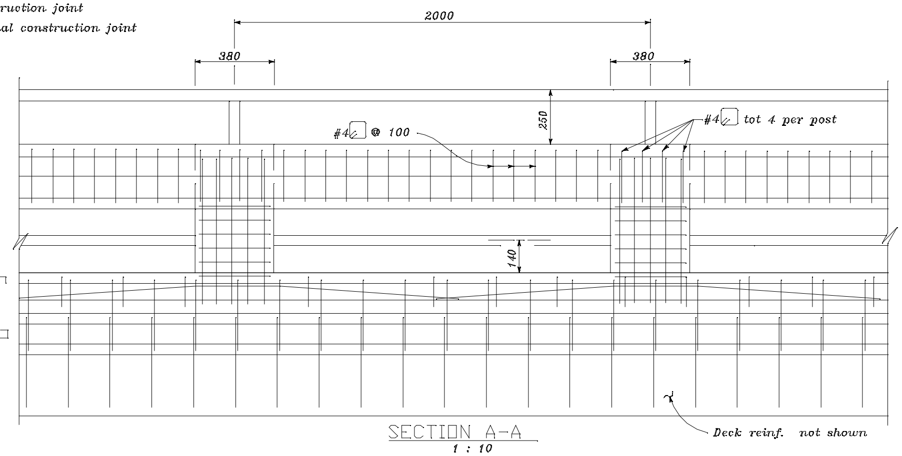
7.5. Detailed Drawing

The following three pages are "as-built" construction drawings. They do not contain some rebar modifications changed to aid constructability. Please contact Caltrans, Structures Design for the most current and complete plans.

California Department of Transportation
Engineering Service Center
Structures Design
1801 30th Street
Sacramento, CA 95816

Telephone: 916-227-8115





Caltrans Metric

DIST.	COUNTY	ROUTE	KILOMETER POST TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

REGISTERED ENGINEER - CIVIL

REGISTERED PROFESSIONAL ENGINEER R.C. ANDERSON No. 17180 Exp. 6-30-97 CIVIL STATE OF CALIFORNIA

PLANS APPROVAL DATE

The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.

— — Denotes existing structure

NOTES:

1. *Splicing of longitudinal rail reinf. shall be by butt welding, mechanical butt splicing or mechanical lap splicing only. No lap splicing allowed on the longitudinal rail reinf.*
2. *Terminate all longitudinal rail, curb and deck reinf. in standard 90 hooks.*

ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SHOWN

DESIGN	BY D. SOON	CHECKED R. BISHOP
DETAILS	BY R. YEE	CHECKED D. SOON
QUANTITIES	BY	CHECKED

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

DIVISION OF STRUCTURES
STRUCTURE DESIGN

BRIDGE NO. — SEE THROUGH CONCRETE BARRIER TEST

KILOMETER POST — SEE THROUGH CONCRETE BARRIER WITH SIDEWALK-DETAILS #1

DS OSD 2147A (CADD 4/89)

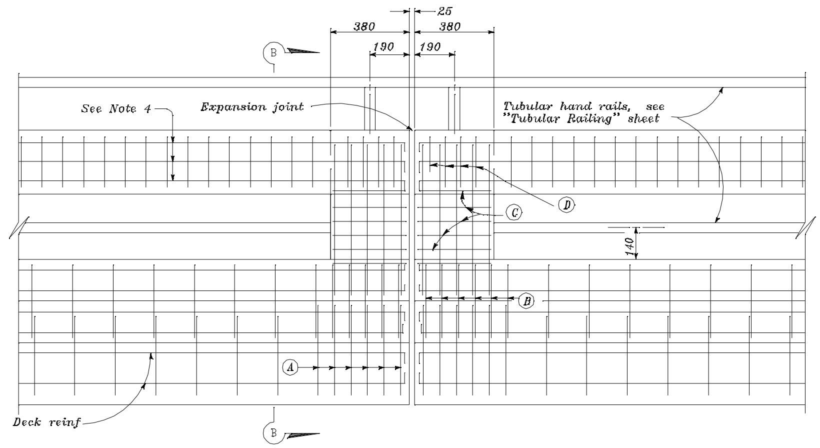
ORIGINAL SCALE IN MILLIMETERS FOR REDUCED PLANS 0 10 20 30 40 50 60 70 80 90 100

CU 0
EA 0

DISREGARD PRINTS BEARING EARLIER REVISION DATES — REVISION DATES (PRELIMINARY STAGE ONLY) — SHEET 5 OF 8

Drawing modifications done 8-3-99 for report publication. 80swmod5.dwg

BARRIER5.DGN



EXPANSION JOINT DETAIL

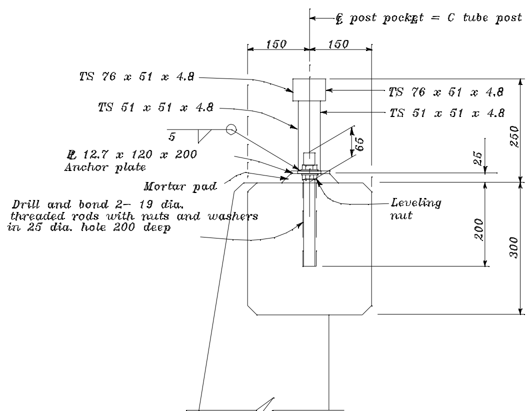
1 : 10

A Existing (Salvaged)
#20 tot 6 @ 75
each side of expansion joint

B #20 tot 6 @ 75
each side of expansion joint

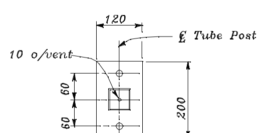
C #15 Varies tot 6

D #15 tot 4 per post

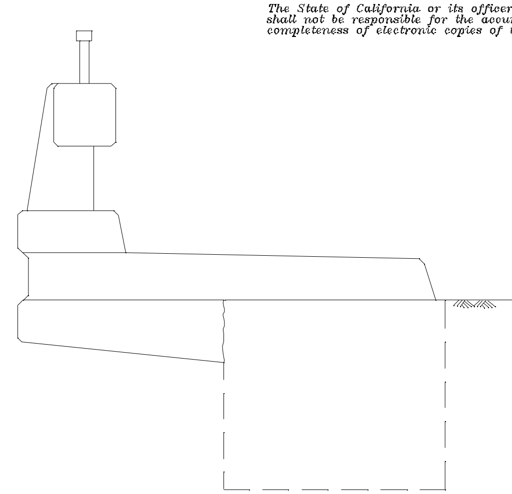


HAND RAIL ANCHORAGE DETAIL

1 : 5



ANCHOR PLATE



SECTION B-B

1 : 10

Note: For details and notes not shown see other sheets.

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Metric

DIST.	COUNTY	ROUTE	KILOMETER POST TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

REGISTERED ENGINEER - CIVIL

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SHOWN

	BY	CHECKED
DESIGN	D. SOON	R. BISHOP
DETAILS	R. YEE	D. SOON
QUANTITIES		

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

DIVISION OF STRUCTURES
STRUCTURE DESIGN

BRIDGE NO.
SEE THROUGH CONCRETE BARRIER TEST

KILOMETER POST
SEE THROUGH CONCRETE BARRIER WITH SIDEWALK-DETAILS #2

DS OSD 2147A (CADD 4/89)

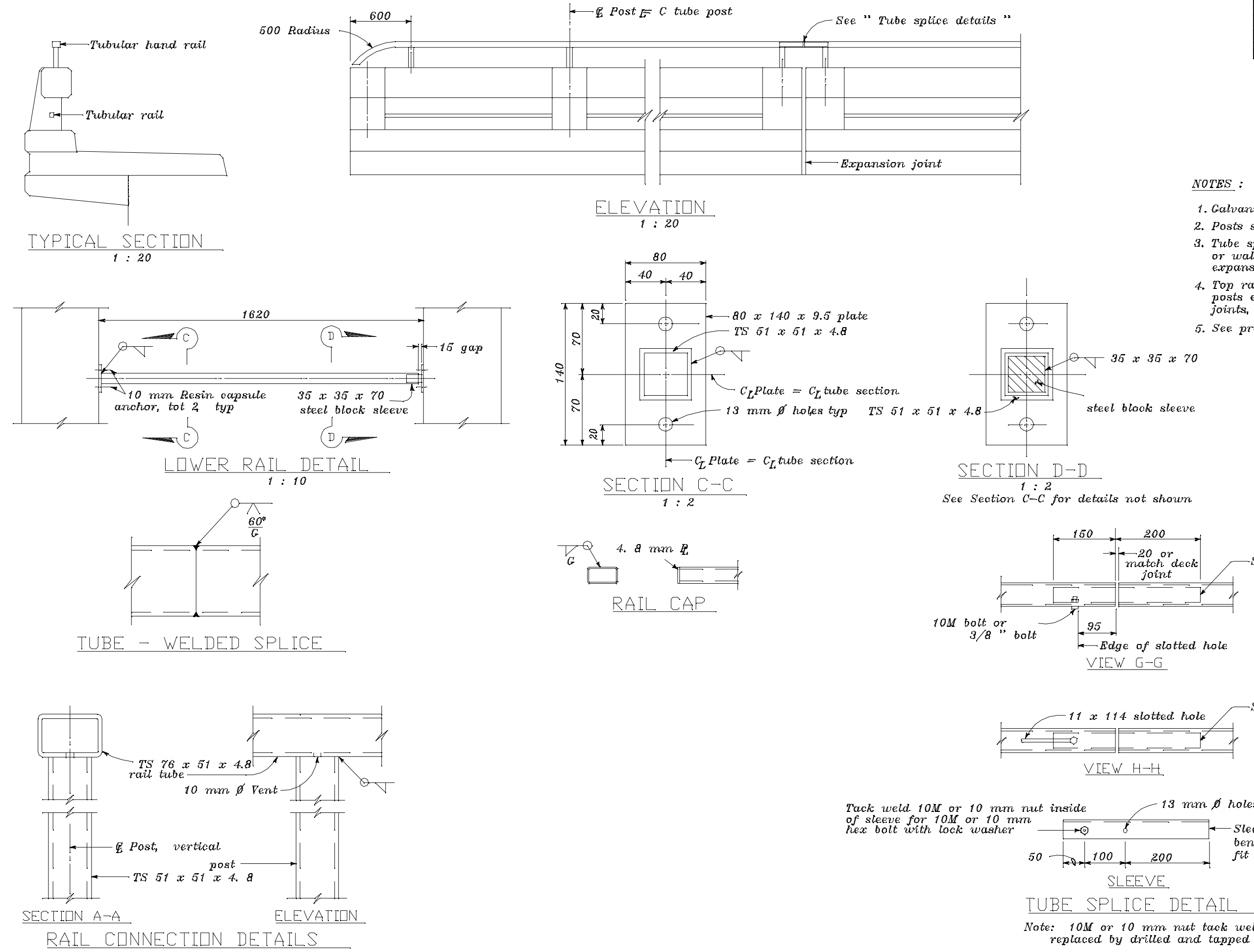
ORIGINAL SCALE IN MILLIMETERS FOR REDUCED PLANS
0 10 20 30 40 50 60 70 80 90 100

CU 0
EA 0

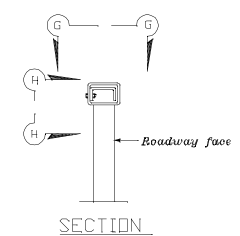
DISREGARD PRINTS BEARING EARLIER REVISION DATES
REVISION DATES (PRELIMINARY STAGE ONLY)
SHEET 6 OF 8

Drawing modifications done 8-3-99 for report publication. 80swmod6.dwg

BARRIER6.DGN;1



Note: 10M or 10 mm nut tack welded to sleeve may be replaced by drilled and tapped hole in sleeve.



DIST.	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

REGISTERED ENGINEER - CIVIL

REGISTERED PROFESSIONAL ENGINEER R.C. ANDERSON No. 17180 Exp. 6-30-97 CIVIL STATE OF CALIFORNIA

PLANS APPROVAL DATE

The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.

NOTES :

1. *Galvanize rail assembly after fabrication.*
2. *Posts shall be normal to railing.*
3. *Tube splices shall be located in the tubes spanning deck or wall joints. Increase joint width in tubes to match expansion joint width and increase sleeve length accordingly.*
4. *Top rail tube shall be continuous over not less than two posts except a short length is permitted near deck or wall joints, electroliers, or other rail discontinuities.*
5. *See project plans for limits of Tubular Hand Railing.*

DESIGN	BY D. SOON	CHECKED R. BISHOP	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION	DIVISION OF STRUCTURES STRUCTURE DESIGN	BRIDGE NO. — SEE THROUGH CONCRETE BARRIER TEST
DETAILS	BY R. YEE	CHECKED D. SOON			POST MILE — TUBULAR RAILING
QUANTITIES	BY	CHECKED			

DS OSD 2147A (CADD 4/89)

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

CU 0
EA 0

DISREGARD PRINTS BEARING EARLIER REVISION DATES → 4/12/98/30/440/18/36

REVISION DATES (PRELIMINARY STAGE ONLY) SHEET 7 OF 8

Drawing modifications done 8-3-99 for report publication. 80swmod6.dwg BARRIER7.DGN:V1=1

U.S. Department
of Transportation

**Federal Highway
Administration**

400 Seventh St., S.W.
Washington, D.C. 20590

May 18, 1999

Refer to: HMHS

Mr. Rich Peter, Chief
Roadside Safety Technology Section
Office of Materials Engineering and
Testing Services - MS #5
5900 Folsom Boulevard
Sacramento, California 95819-0128

Dear Mr. Peter:

In your April 6 letter to Mr. Henry Rentz, you requested formal Federal Highway Administration acceptance of the California Type 80 Bridge Rail at NCHW Report 350 test level 4 (TL-4). To support your request, you also sent a copy of your March 1999 report entitled "Vehicle Crash Tests of the Type 80 Bridge Rail" and a video tape of the three tests you conducted. Copies of these materials were also sent to Mr. Charles MeDevitt for his concurrent review and comments.

The Type 80 Bridge Rail is an aesthetic concrete post and beam design incorporating a 230-nun high curb, a 280-mm clear opening, and a 300-mm deep top beam. The posts are offset 100 mm from the face of the upper beam. Encbsure 1 is a schematic drawing of the final design. Staff members have reviewed the results of the tests you conducted on the Type 80 Bridge Rail and concur with your assessment that appropriate NCIW Report 3 5 0 evaluation criteria were met. The summary results of each test are shown in Enclosure 2. This design may be considered acceptable for use on the National Highway System as a TL-4 bridge railing.

As you recall, you previously sent information to Mr. Rentz on a similar design called the Type 80SW Bridge Railing. This design was identical to the Type 80, but it was tested behind a 200-mm high curb and a 1 500-mm wide sidewalk. Additionally, it had a horizontal TS 5 1 x 5 1 x 4.8 steel tube at the midpoint of the clear opening, and a TS 76 x 51 x 4.8 steel tube mounted on the top beam to raise the total height to 1060 mm. This design is shown in Enclosure 3. The Type 80SW Bridge Railing was actually tested at TL-4, but there was significant passenger compartment intrusion when this design was impacted by the 2000-kg pickup truck at 1 00 k/hr and at an angle of 25 degrees. Summary results for 0 three tests are shown in Enclosure 4. My December 2, 1998 letter to you indicated that we would accept the Type SOSW Bridge Rail as a TL-2 design without additional testing, thus permitting its use on the NHS at locations where impact speeds are not expected to exceed 70 k/hr.

There is a significant interest in acceptable, aesthetic bridge railing designs nationwide. 1 am assuming that any agency interested in using the Type 80 or the Type 80SW designs will be able to obtain copies of detailed plans and specifications directly from your Department.

Sincerely yours,

Dwight A. Horne
Director, Office of I-Eghway Safety
Infrastructure

4 Enclosures