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16. ABSTRACT

This test was conducted to investigate the crash-worthiness of a popular saddle style mount used on many concrete barriers in California. A 46-m (150-ft) section of Caltrans Type 60 concrete median barrier (previously approved) had two aluminum signs with a 101.6-mm (4-in) outside diameter steel support post mounted onto it for the purpose of investigating the affect the signpost has on a ¾-ton pick-up truck impacting the barrier. The parameters and conditions used for this test are in compliance with NCHRP Report 350, Test 3-31. This particular method of mounting the signpost to the barrier was selected for testing because it is commonly used throughout California’s highway system.

The test involved a 1993 Chevy Cheyenne pick-up truck impacting the combination barrier and sign support at an angle of 25.5º and a velocity of 99.1 km/h (61.6 mph). The barrier redirected the vehicle, but the impact with the barrier created a high risk to its occupants and possibly dangerous debris. The recommendations given in this report are only pertinent to NCHRP Report 350 TL-3 criteria.

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF RESEARCH AND INNOVATION
OFFICE OF SAFETY INNOVATION AND COOPERATIVE RESEARCH

Supervised by.. Pete Zaniewski, P.E.

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Metric System (SI) to English of Measurement

SI CONVERSION FACTORS

To Convert From	To	Multiply By
	ACCELERATION	
m/s^2	ft/s^2	3.281
	AREA	
m^2	ft^2	10.76
	ENERGY	
Kilojoules (KJ)	kip-ft	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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Don Tateishi, Headquarters Photography; Tillat Satter, Bridge Engineer; Stan Johnson, Signs and Overhead Structures; Robert Meline, Stephanie Davis, and Larry Baumeister, test support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Problem

All concrete barriers must be tested using the criteria listed in the National Cooperative Highway Research Program (NCHRP) Report 350[1] before being installed on California roadways. Over the years, various types of signs, fences, and associated mounting hardware have been placed on top of concrete barriers. Recent research (see below) has indicated that such items should not be placed within the "zone of intrusion" which lies above and behind the barrier. Caltrans designers have already placed many types of hardware within this zone, and continue to do so because there are no guidelines to assist them in selecting the appropriate type and placement of the specific hardware used by Caltrans. As a result, many of the configurations being specified have not been crash tested to ensure they meet NCHRP Report 350 Criteria. The concern is that these types of hardware will become a snagging hazard or a danger to opposing traffic.

1.2. Objective

The purpose of this test was to check the crashworthiness of a signpost with a saddle mount that is commonly attached to a concrete median barrier. This combination is often used on California's highways to mount high occupancy vehicle (HOV) signs. To determine if this type of mounted hardware meets current crashworthiness guidelines (see Test Level 3 in NCHRP Report 350) a 2000-kg (4409-lb_m) pickup truck would impact a barrier and signpost system at a speed of 100 km/h (62.1 mph) and an angle of 25º. If the combination of the signpost and mount successfully passed the full-scale crash test, consideration would be given to the 820C test. If both the 2000P and the 820C tests passed, the barrier mounted sign support system would be submitted to the Federal Highway Administration (FHWA) for acceptance. If the sign system failed, the data gathered from the test would be used to make design change recommendations.

1.3. Background

Recently completed research utilized past crash test results to define a "zone of intrusion" on and around commonly used traffic barriers[2]. This zone of intrusion is the open space above and behind a barrier into which impacting vehicles will likely penetrate. Hardware and other obstacles placed within this zone are then likely to be struck by an errant vehicle. Caltrans has recently become aware that some of the hardware currently being placed on various barriers throughout the State are within this zone of intrusion and therefore needs to be investigated for crashworthiness. The list of hardware that can be found on the roads but have not been crash-tested to current crash test guidelines includes: HOV signs, glare screens, fences, speed limit signs, warning signs, etc. Many of these items have not been tested to current crash testing standards. Furthermore, the vehicle fleet on the highway today contains many vehicles for which some of these hardware devices were not designed. There are insufficient crash test data to verify that these items will comply with NCHRP Report 350 criteria.

1.4. Literature Search

A literature search using the Transportation Research Information Service (TRIS) and National Technical Information Service (NTIS) databases was conducted at the beginning of the project to find research reports or publications related to the objectives of the project. Also, a number of Traffic Safety Engineers and Safety Devices Coordinators from each of the Caltrans districts were contacted for any additional concrete barrier mounted hardware that should be considered for testing.

1.5. Scope

A barrier mounted aluminum sign supported by a 101.6-mm (4-in) outside diameter (O.D.) support post was mounted to an existing Type 60 concrete barrier installed at the Caltrans Dynamic Testing Facility in West Sacramento. Previous crash tests with 2000-kg (4409-lb_m) pick-up trucks were evaluated to find the critical impact point. This point was selected based on the snagging potential between the vehicle and the post[3,4]. This test followed the guidelines of NCHRP Report 350, Test Designation 3-11 for longitudinal barriers. The test criteria for Test 3-11 involve a 2000-kg (4409-lb_m) pick-up truck impacting the barrier at an angle of 25° with a speed of 100 km/h (62.1 mph).

2. TECHNICAL DISCUSSION

2.1. Test Conditions – Crash Tests

2.1.1. Test Facilities

The crash test was conducted at the Caltrans Dynamic Testing Facility in West Sacramento, California. The test area is a large, flat, asphalt concrete surface. There were no obstructions nearby except for a prototype bridge rail 100 m (328 ft) downstream from the tested barrier.

2.1.2. Test Barrier

A private contractor, M. Bumgarner, Inc., constructed a 46-m (150-ft) section of Type 60 concrete barrier at the Caltrans Dynamic Testing Facility in 2005. The barrier design conformed to Caltrans 1999 Standard Plans A76A and A76B, shown in the Section 7.5. A photo of the completed test barrier (without the saddle-mounted post) is shown in Figure 2-1.

Figure 2-1 Type 60 Concrete Barrier Prior to Test

2.1.3. Construction

The design of the signpost was based on the Type F configuration found in the "Placement of Roadside Sign (Barrier Mount)" plan, shown in the Section 7.5. This configuration requires that a 2748-mm by 88.9-mm (108-in by 3.5-in) nominal steel pipe (i.e. with an outside diameter of 101.6-mm (4.0-in)) be welded to a 10-mm (0.375-in) thick saddle. This assembly was then mounted to the barrier with two 25-mm (1.0-in) bolts. The general shape of the signs was designed using the Caltrans standard plan for HOV sign R84-1 (CA) (Figure 7-8). The sign configuration used two 914-mm (36.0-in) by 1524-mm (60.0-in) panels placed back to back, negating the need for braces. A local contractor, National Concrete Cutting, was hired to use a coring drill to core two 32-mm (1.25-in) horizontal holes into the type 60 barrier. The impact point was then marked two meters upstream from the center of the signpost assembly.

Figure 2-2 Signpost Mounted on Type 60 Median Barrier

2.1.4. Test Vehicle

The test vehicle complied with NCHRP Report 350 criteria. With the exception of a large dent in the passenger side of the front bumper, the vehicle was in good condition, free of major body damage and was not missing any structural parts. It was decided that since the impact would be on the driver side, the dent would have no effect on the results of the test. A note was made of its size and location. The vehicle had standard equipment (see Table 7-1). The vehicle's inertial mass was 1952.6 kg (4305 lb_m)*.

* The Test inertial mass was 2.4 kg (5.3 lb_m) under the recommended minimum in Report 350 (see Table 2-1), but the impact severity at nominal speed and angle was 134.8 kJ (99.4 kip-ft) which is still within tolerance (see Table 2-4).

Table 2-1 Test Vehicle Information

Test No.	Vehicle	Ballast kg (lb_m)	Test Inertial kg (lb_m)	Max. Test Inertial kg (lb_m)	Min. Test Inertial kg (lb_m)
SS641	1993 Chevy Cheyenne	70.4 (155.2)	1952.6 (4304.7)	2045 (4508)	1955 (4310)

The vehicle was self-powered. The engine was modified to include a speed-control device, which limited acceleration once the impact speed had been reached. Additional modifications included a remote braking system, a modification to the front right wheel for the guidance system, and the addition of various sensors and electronics. A detailed description of the test vehicle equipment and guidance system is contained in Appendices 7.1 and 7.2.

2.1.5. Data Acquisition System

The crash test was recorded with high-speed digital video cameras, one digital movie video camera, and one digital SLR camera. The test vehicle and the barrier were photographed before and after impact with a digital movie camera and a digital SLR camera. A film report of this project was assembled using edited portions of the film coverage.

Two sets of orthogonal accelerometers were mounted in the vehicle at the center of gravity. One set of rate gyro transducers was placed 191 mm (7.5 in) behind the center of gravity (along the X-axis) to measure the roll, pitch, and yaw rates. The data collected by these devices were to be used to calculate the occupant impact velocities, ridedown accelerations, and maximum vehicle rotation. **Due to an unexpected problem the data recorders did not record any useable data.**

Two separate digital transient data recorders (TDRs) manufactured by GMH Engineering (Model II) were used to record electronic data during the test. The digital data would have been analyzed with TRAP (Test Risk Assessment Program) and a personal computer. (A custom DADiSP worksheet created by the Roadside Safety Research Group might also have been used).

2.2. Test Results – Crash Tests

A description of the impact, vehicle damage, and barrier damage is given in this section. A film report with edited footage from the test has been compiled and is available for viewing. Contact the Office of Safety Innovation and Cooperative Research part of the Division of Research and Innovation to request a copy of the film report.

2.2.1. Test SS641

2.2.1.2. Impact Description – Test SS641

The impact angle was set at 25° by placement of a guide rail. Film analysis indicated that the impact angle was 25.5°. The impact speed of 99.1 km/h (61.6 mph) was obtained by averaging the two speed traps located just upstream from the impact point along with the speed calculated by analyzing the film. The front left corner of the vehicle impacted the barrier at 2.0 m (6.6 ft) upstream from the centerline of the signpost assembly. As the corner of the vehicle deformed, the hood rode over the top of the barrier. At 0.032 seconds after first contact with the barrier the vehicle had traveled one meter and the hood had penetrated past the barrier face by 150 mm (6 in). At 0.060 seconds the hood had penetrated the barrier face by 460 mm (18 in) and was about to hit the signpost. At 0.084 seconds after impact the hood had snagged on the signpost and the front wheels were off the ground. The hood deformed and was pulled toward the driver, exposing the engine compartment. The driver side doorframe started to deform outward. At 0.130 seconds, the signpost had pushed the hood into the windshield. The front grill had broken away and roughly a third of the engine compartment had been exposed. At this point the radiator ruptured causing the coolant to explode outward.

The vehicle was parallel and had full contact with the barrier at 0.254 seconds after impact. Also, the front grill had completely broken away from the vehicle and was thrown along the top of the barrier. The brake flash bulb located on the top of the vehicle triggered at 0.284[*]seconds after impact and occurred while the vehicle was fully airborne. The vehicle lost contact with the barrier at 0.414 seconds. At 0.634 seconds all four of the vehicle's tires were in contact with the ground. The grill of the vehicle crossed to other side of the barrier at 1.184 seconds. The final resting place of the grill was in the opposing traffic side of the barrier. The vehicle came to rest at 3.064 seconds after the impact.

[*] The purpose of the brake flash is to indicate when the brakes are applied after an impact. However, since there were other failures in the electronics during the test, and since the operator for the brakes (John Jewell) stated that the brakes were not applied until well after the vehicle had lost contact with the barrier, it is very possible that the brake flash triggered prematurely.

2.2.1.3. Vehicle Damage – Test SS641

The driver's side front quarter of the vehicle sustained significant damage in the initial impact with the barrier. The amount of damage increased as the hood impacted the signpost. The front left wheel was pushed backward 340 mm (13.4 in) from its initial location. The hood penetrated the windshield by 250 mm (9.8 in) measured from the bottom center of the windshield to the resting place of the hood. The vehicle's battery had been thrown out of the engine compartment but was still held in place by the negative terminal cable. The top of the driver side door had buckled outward from the vehicle's frame. The jagged slice down the side of the vehicle caused by the signpost bolts is due to the sustained contact with the barrier. Inspection of the occupant compartment revealed that the dashboard was pushed back 202 mm (8.0 in) toward the driver. The driver side had a peak loss of 98 mm (4.0 in) measured between the bottom of the dashboard and the floorboard.

2.2.1.4. Barrier Damage – Test SS641

There was only cosmetic damage to the barrier. The signpost saddle was pushed 19 mm (0.75 in) downstream and the two bolts were also bent slightly downstream. The sign pole had a dynamic deflection of 10.6° and a static deflection of 3.4° leaning downstream of impact.

Figure 2-3 Downstream View of the Barrier and Vehicle SS641

Figure 2-4 Side View of the Barrier and Vehicle SS641

Figure 2-5 View of Vehicle SS641 at Impact Location

Figure 2-6 Test Vehicle Prior to Test Internal

Figure 2-7 Vehicle Impacting Signpost and Barrier

Figure 2-8 Vehicle After Test (1)

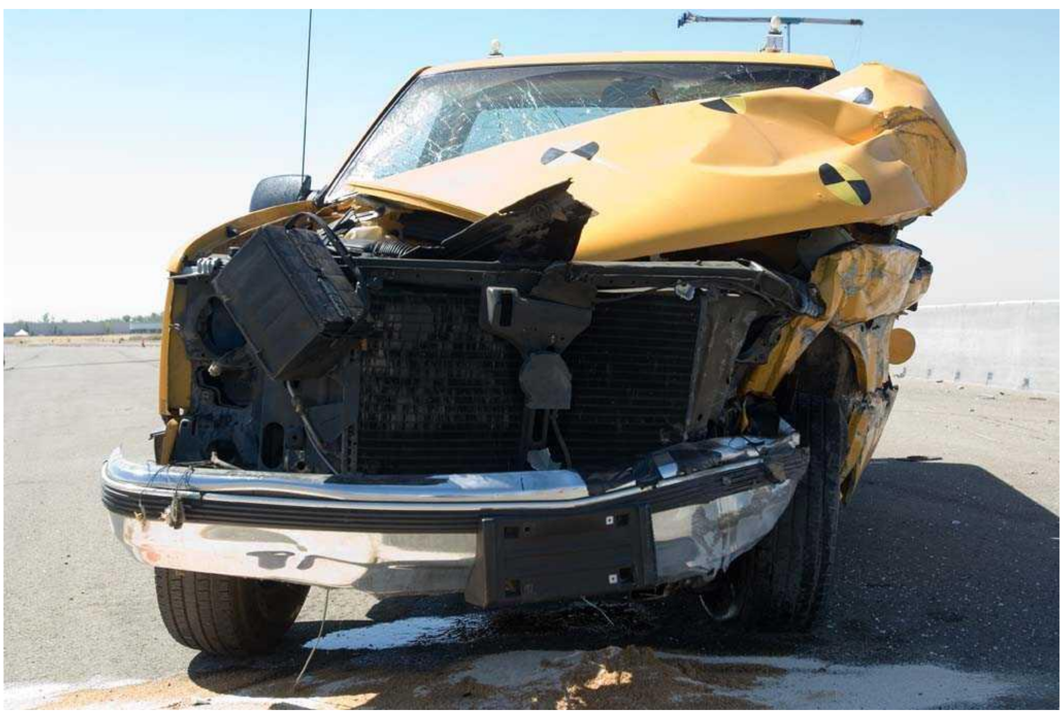


Figure 2-9 Vehicle After Test (2)

Figure 2-10 Vehicle After Test (3)

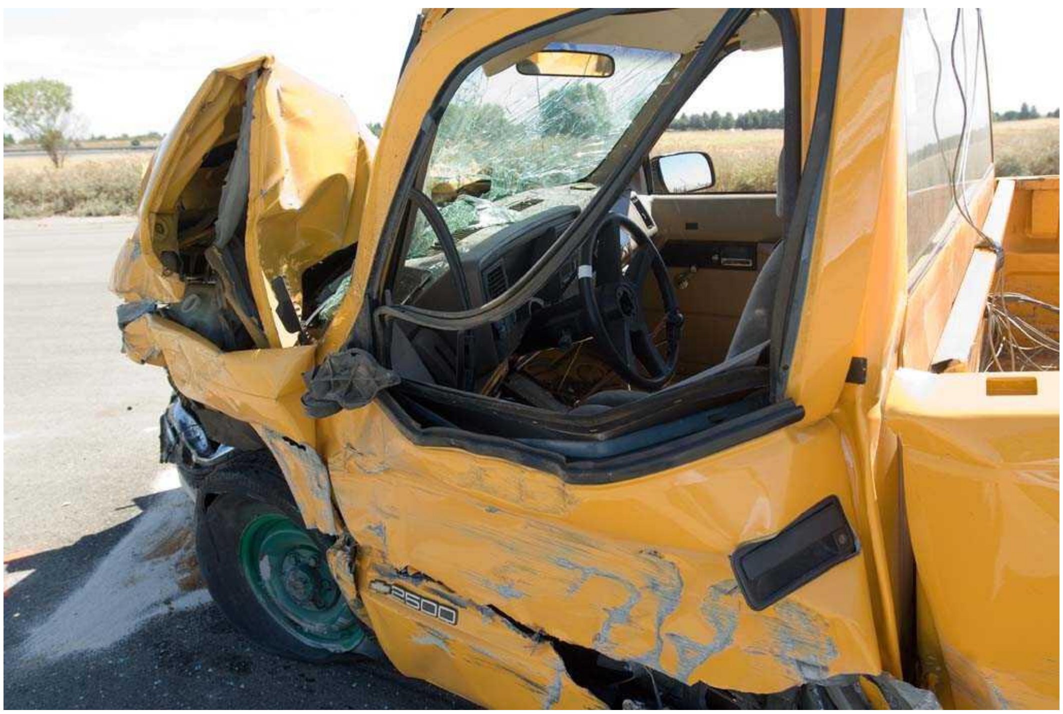


Figure 2-11 Vehicle After Test (4)

Figure 2-12 Vehicle After Test Internal (1)

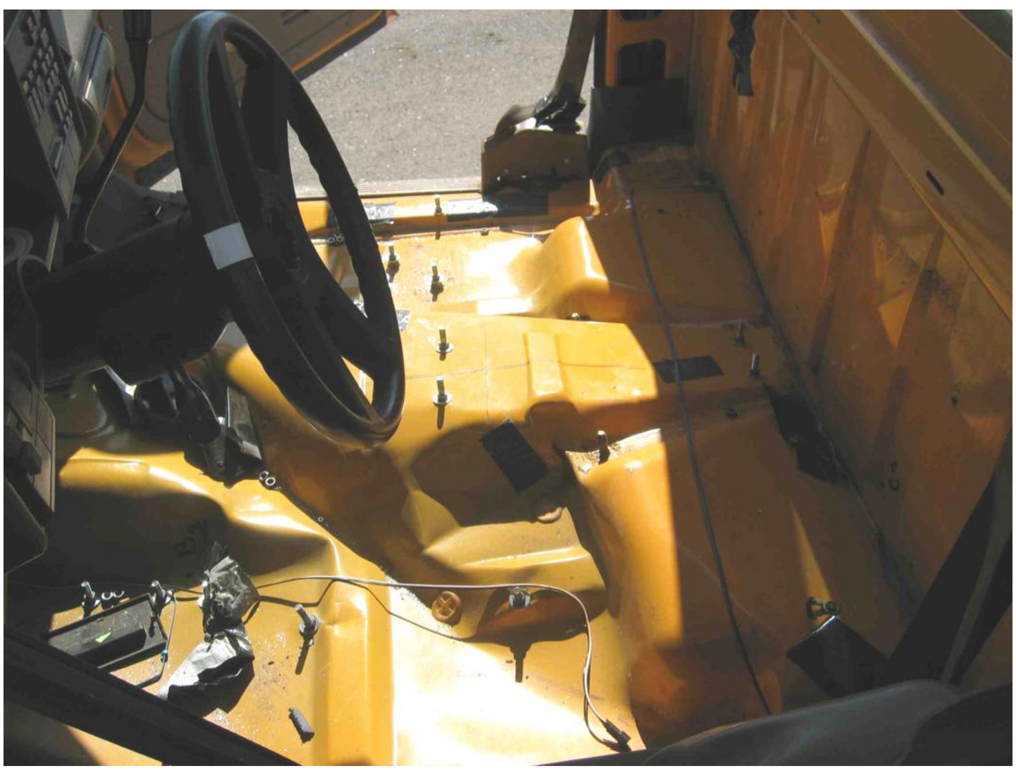


Figure 2-13 Vehicle After Test Internal (2)

Figure 2-14 Impact Area Prior to Test

Figure 2-15 Signpost Saddle Prior to Test

Figure 2-16 Impact Area After Test

Figure 2-17 Signpost Saddle After Test

2.2.1.5. Data Summary Sheet

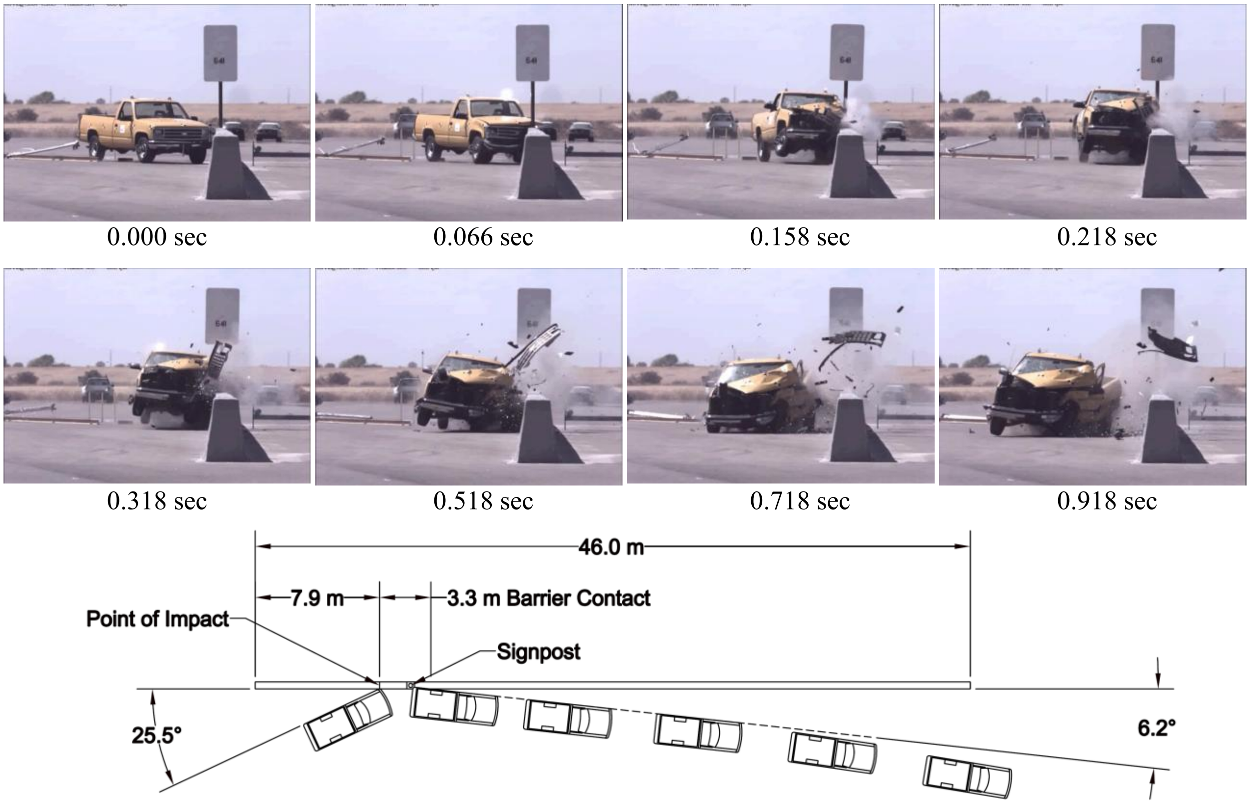


Figure 2-18 Test SS641 – Impact Sequence and Diagram

General Information

Testing Agency	California DOT
Test Number	SS641
Test Date	August 30, 2007

Test Article

Type	Type 60 concrete barrier w/barrier mounted metal post 101.6 mm (4.0 in) O.D.
Installation Length	46 m (150 ft)
Height	910 mm (36 in)

Test Vehicle

Type	¾-Ton Pick-up Truck
Designation	2000P
Model	1993 Chevy Cheyenne
Mass Curb	1882.2 kg (4149.5 lb_m)
Test Inertial	1952.6 kg (4304.7 lb_m)

Impact Conditions

Impact Velocity	99.1 km/h (61.6 mph)
Impact Angle	25.5°

Exit Conditions

Exit Velocity	~62.3 km/h (38.7 mph)
Exit Angle	6.2°

Test Data

Occupant Impact Velocity	
Long	n/a*
Lat	n/a*
Ridedown Acceleration	
Long	n/a*
Lat	n/a*
Vehicle Exterior:	
VDS[5,6]	FL-6, LD-4, LFQ-7
CDC[7]:	11FFAW5
Vehicle Interior:	
O.C.D.I.[1]:	LF3111121

Post-Impact Vehicular Behavior

(*Data Analysis/Video Analysis*)

Maximum Roll Angle	n/a* / -7.2°
Maximum Pitch Angle	n/a* / 5.9°
Maximum Yaw Angle	n/a* / 31.7°

Barrier Damage

There were minor scrapes to the barrier. The signpost assembly was pushed 19 mm (0.75 in) downstream and leaned 3.4° downstream from its initial location.

* Data acquisition system triggered early, no data available

2.3. Discussion of Test Results – Crash Test

2.3.1. General – Evaluation Methods

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

The structural adequacy, occupant risk, and vehicle trajectory associated with the barrier were evaluated in comparison with Tables 3.1 and 5.1 of NCHRP Report 350.

2.3.2. Structural Adequacy

The structural adequacy was acceptable. The test vehicle was contained and redirected, while the barrier was not penetrated or overridden. An assessment summary of the structural adequacy is shown in Table 2-2.

2.3.3. Occupant Risk

The occupant risk for this test is unacceptable. The hood penetrated the windshield by 250 mm (10 in) and would have showered the occupants with glass. The front grill broke off and would have been a hazard to opposing traffic. The battery was almost thrown from the vehicle and was only restrained by the negative terminal wire. There was excessive deformation on the driver side of the occupant compartment. Table 2-2 has a summary of the occupant risk. (Due to problems with the data acquisition system, there was no usable information to find the occupant impact velocities or ridedown accelerations.)

2.3.4. Vehicle Trajectory

The trajectory of the vehicle was acceptable. The exit angle from the barrier was 6.2°, which is less then 60% of the impact angle. Also, the vehicle would not have traveled into adjacent traffic. See Table 2-2 for more information.

Table 2-2 Test SS641 Assessment Summary

Test No.	SS641
Date	08/30/2007
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 redirected smoothly	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.	The front grill presented a hazard to oncoming traffic. The hood penetrated the windshield and there was significant deformation to the driver side of the compartment.	Fail Fail
F. The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.	The vehicle remained upright.	Pass
H. Occupant impact velocities (see Appendix A, Section A5.3 in NCHRP Report 350 for calculation procedure) should satisfy the following: Occupant Impact Velocity Limits (m/s) Component / Preferred / Maximum Longitudinal and Lateral / 9 / 12	Data bricks fired too early to collect appropriate data.	N/A
I. Occupant ridedown accelerations (see Appendix A, Section A5.3 in NCHRP Report 350 for calculation procedure) should satisfy the following: Occupant Ridedown Acceleration Limits (g) Component / Preferred / Maximum Longitudinal and Lateral / 15 / 20	Data bricks fired too early to collect appropriate data.	N/A
Vehicle Trajectory		
K. After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.	The vehicle did not intrude into adjacent traffic lanes.	Pass
M. The exit angle from the test article preferably should be less than 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device.	The exit angle was 6.2°, which is only 25% of the impact angle.	Pass

Table 2-3 Vehicle Trajectories and Speeds

Test Number	Impact Angle	60% of Impact Angle	Exit Angle	Impact Speed (V_i), km/h (mph)	Exit Speed (V_e), km/h (mph)	Speed Change (V_i-V_e), km/h (mph)	Impact Severity, kJ (kip-ft)
SS641	25.5°	15°	6.2°	99.1 (61.6)	62.3* (38.7)*	36.8* (22.9)*	137.1 (101.1)
* Calculated Velocity based on high-speed video							

Table 2-4 Tolerances for Impact Angle, Velocity, and Severity

	Nominal	Negative Tolerance	Positive Tolerance
Impact Angle	25°	23.5°	26.5°
Impact Velocity km/h (mph)	100 (62.1)	96 (59.7)	104 (64.6)
Impact Severity kJ (kip-ft)	138.1 (101.9)	127.3 (93.9)	149.4 (110.2)

3. CONCLUSION

Based on the testing of a metal sign post mounted on top of a Type 60 concrete barrier the following conclusions can be drawn:

1. The impact of a ¾-ton pick-up truck into the 101.6-mm (4-in) O.D. steel signpost mounted to a Type 60 barrier caused significant occupant compartment deformation on the impacted side of the vehicle, which could cause excessive injuries to the driver and passengers. The majority of the vehicle deformation consisted of 1) hood snagging on the post and 2) sheet metal tearing on the transverse mounting bolts.
2. There was an excessive amount of debris that could become a hazard to on-coming traffic.
3. The barrier successfully redirected the vehicle as designed and had cosmetic damage only.
4. The signpost assembly successfully remained on the concrete barrier and would require minor maintenance.
5. Based on the conclusions listed above, the saddle-mounted sign support is not crash-worthy according to NCHRP Report 350 criteria.

4. RECOMMENDATION

Based on the data gathered from this test, there is an excessive amount of debris and occupant risk with a ¾-ton truck impacting a signpost mounted onto a concrete median barrier. It is recommended that the practice of placing signposts onto median barriers be stopped, except where the potential for hood snagging is non-existent (such as the Type 60G barrier). If signposts must be mounted onto median barriers it is recommended that the barriers be modified in the following ways:

4.1. Type 60 Concrete Median Barrier

4.1.1. Increasing the Height of the Barrier:

The height of the Type 60 barrier can be increased from the standard 36 inch (910 mm) height to 46 inches (1170 mm) using a 4:1 slope. The 4:1 slope is the same that is used to transition between the Type 742 Concrete Bridge Barriers and thrie beam guardrail in Caltrans 2006 Standard Plan B11-57. The addition of 10 inches (254 mm) to the height of the barrier will prevent the hood of a standard pick-up truck from hitting the signpost during an impact. The signpost can be mounted to the barrier with the use of a mounting plate, see Figure 4-1.

The 46-inch (1170-mm) height is based on the 2009 "Manual for Assessing Safety Hardware" (MASH) criteria that will be replacing the NCHRP Report 350 criteria. The "MASH" pickup has a height of 42 inches (1070 mm) from the ground up to the start of the front edge of the hood while the "Report 350" pickup has a height of 38 inches (970 mm) measured from the same points. The other difference between the two pickups is that the shape of the "Report 350" pickup's hood is more of a square shape, while the shape of the "MASH" pickup's hood is like an isosceles trapezoid with the narrow end at the front of the vehicle. At the time this report was written, the Roadside Safety Research Group did not have any videos of crash tests of the "MASH" pickup impacting the Type 60 barrier. Therefore, it is hard to say how far the hood will override the barrier during an impact. Though the "MASH" pickup is higher it may not override as much as the "Report 350" pickup because of the shape of the hood. It was decided the height of the "MASH" pickup would be used in this recommendation as the most severe case because there was not any information on how far it would override in an impact.

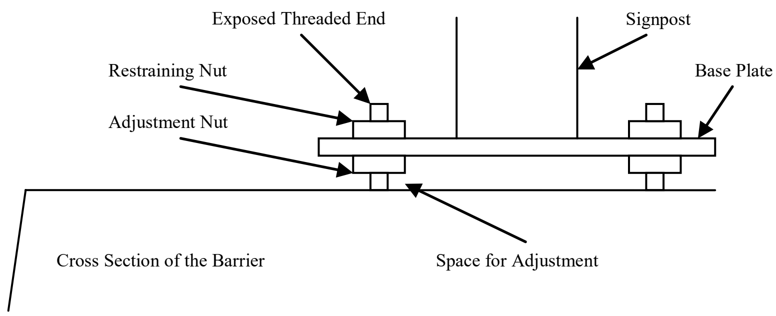


Figure 4-1 Example of the Mounting Plate with Adjustment Bolts

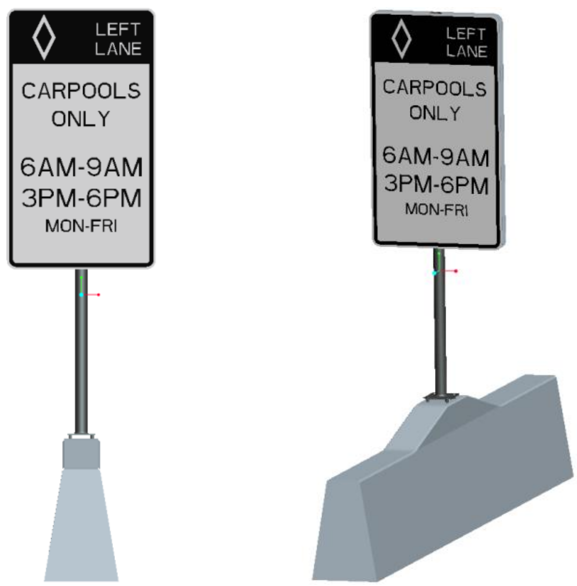


Figure 4-2 Example of Raised Type 60 Barrier

4.1.2. Increasing the Width of the Barrier:

The width of the Type 60 barrier can be increased so that the top and bottom of the barrier has a width of 34 inches (864 mm). The width of the barrier can be increased with a 20:1 slope on each side of the barrier. The 20:1 slope is the same that is used in the Caltrans 2006 Standard Plan A76C for transitions between the Type 60 and the Type 60E Concrete Barriers. The 34-inch (864 mm) width provides a 15 inch (381 mm) set back between the top corner of the barrier and the edge of the signpost. The 15 inches should help to minimize the potential for hood-snagging, but would not eliminate it completely. Also, a mounting plate will need to be used to mount the signpost to the barrier. Depending on the need for adjustment nuts under the mounting plate, the set back may need to be between the edge of the bolts to the face of the barrier if the height of the treaded end extends past one inch (25.4 mm) from the top of the barrier. This will also increase the width of the barrier. Another option could be to create a recess in the barrier that the mounting plate can fit into that will keep the mounting bolts from impacting the vehicle's hood.

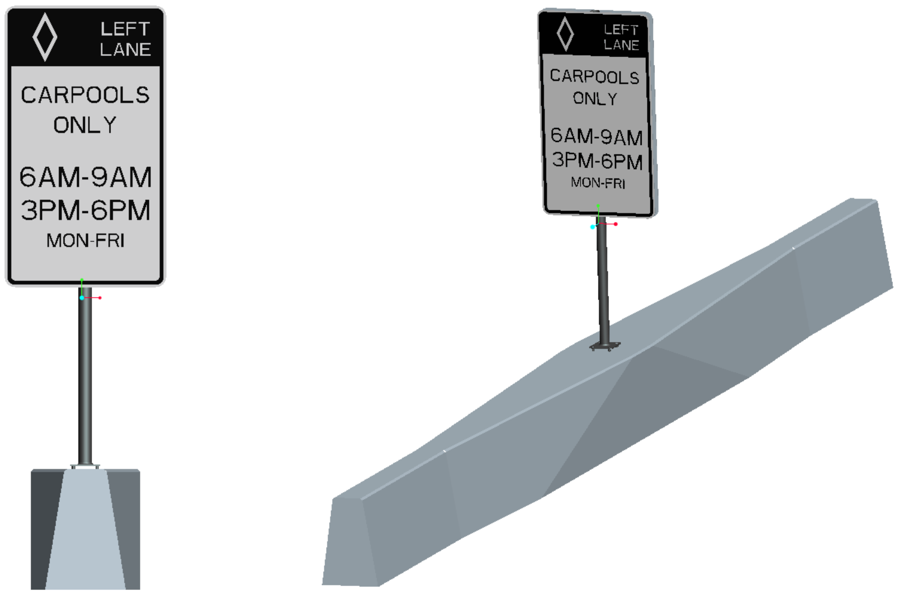


Figure 4-3 Example of the Widened Type 60 Barrier

4.1.3. Mounting the Sign Directly to the Barrier

As a future project for retrofitting existing locations where signposts are mounted onto median barriers, the signpost could be removed and the sign mounted directly to the barrier. This could be accomplished by cutting a groove at an angle in the top of the barrier. A new sign will have to be developed that can be placed inside the groove. Along with the groove, brackets on the front and back face of the sign can be used to hold the sign in place. Tie down cables can be used to help restrain the sign and keep vibrations to a minimum. The cables can also act as tethers in the event of an impact. See Figure 4-4 for an example of this concept. Further research will need to be conducted to find what angles will provide the best visibility for the motorist, how these angles will affect the reflective surface of the sign at night, and the crashworthiness of the concept.

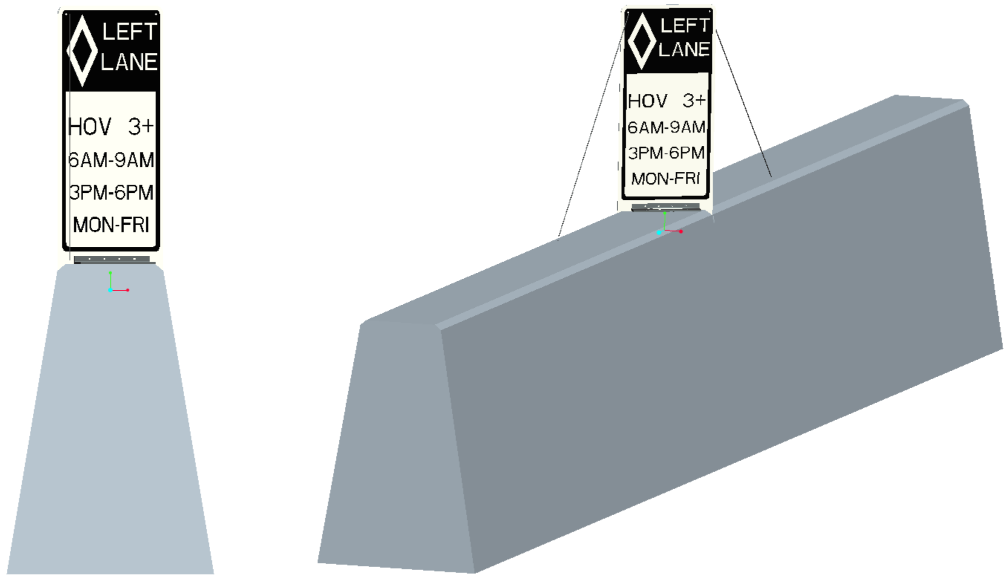


Figure 4-4 Example of a Sign Mounted Directly to the Barrier

4.2. Type 60S Concrete Median Barrier

The Type 60S concrete median barrier is designed to allow for sight distance around a curve and its use is limited. Therefore, it is recommended that no signposts be mounted onto the Type 60S barrier.

4.3. Type 50 Concrete Median Barrier

It is recommended that signposts are not mounted onto the Type 50 concrete median barrier due to the top of the barrier having a width of only 6 inches (152.4 mm). If signposts must be mounted onto the median then the Type 50 should be replaced with a Type 60 barrier with one of the above recommended modifications.

5. IMPLEMENTATION

The Offices of Structures Design and Traffic Operations will be responsible to collaborate and develop policies for mounting sign and signpost structures on median barriers based on the information provided in this report.

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. Keller, E.A., et al., "Guidelines for Attachments to Bridge Rails and Median Barriers", Midwest State's Regional Pooled Fund Program, Report No. SPR-3(017), February 2003.
3. White, Michael, et al., "Crash Testing of Various Textured Barriers", California Department of Transportation, Report No. FHWA/CA/TL-2002/03, September 2002.
4. Jewell, John, et al., "Vehicle Crash Tests of a Slip-Formed, Single-Slope, Concrete Median Barrier with Integral Concrete Glare Screen", California Department of Transportation, Report No. FHWA/CA/ESC-98/02, December 1997.
5. "Vehicle Damage Scale for Traffic Accident Investigators", Traffic Accident Data Project, National Safety Council, 1968.
6. "Vehicle Damage Scale for Traffic Crash Investigators", Crash Records Bureau, Texas Department of Public Safety, 2006.
7. "Collision Deformation Classification" – SAE J224 Mar80, SAE Recommended Practices, 1980.

7. APPENDICES

7.1. Test Vehicle Equipment

The test vehicle was modified as follows for the crash test:

- The gas tank on the test vehicle was disconnected from the fuel supply line and drained. A 12-L safety gas tank was installed in the truck bed and connected to the fuel supply line. Gaseous CO_2 was added to purge the gasoline vapors from the stock fuel tank.

  One 12-volt, deep cycle, gel cell motorcycle storage battery was mounted in the vehicle. The battery operated the solenoid-valve braking/accelerator system, rate gyros and the electronic control box. Another pair of 12-volt, deep cycle, gel cell batteries powered the transient data recorder and rate gyros.
- A 4800-kPa (700-psi) 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 that 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 via a radio control at a console trailer. When the brakes were applied by the remote control from the console trailer, the ignition was automatically rendered inoperable by removing power to the coil. The braking system would also automatically engage in the event of a lost signal between the transmitter and the receiver.
- The vehicle was self-propelled and an accelerator switch was located on the passenger side above the rear tire 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.

  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 all tests by conducting a series of trials runs through a speed trap comprised of two tape-switches set at a specified distance apart and a digital timer.

- A micro-switch 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 vehicle passed over it. The switch would open the ignition circuit and shut off the vehicle's engine prior to impact.

Table 7-1 gives specific information regarding vehicle dimensions and weights for Test SS641.

Table 7-1 Test SS641 – Vehicle Specifications

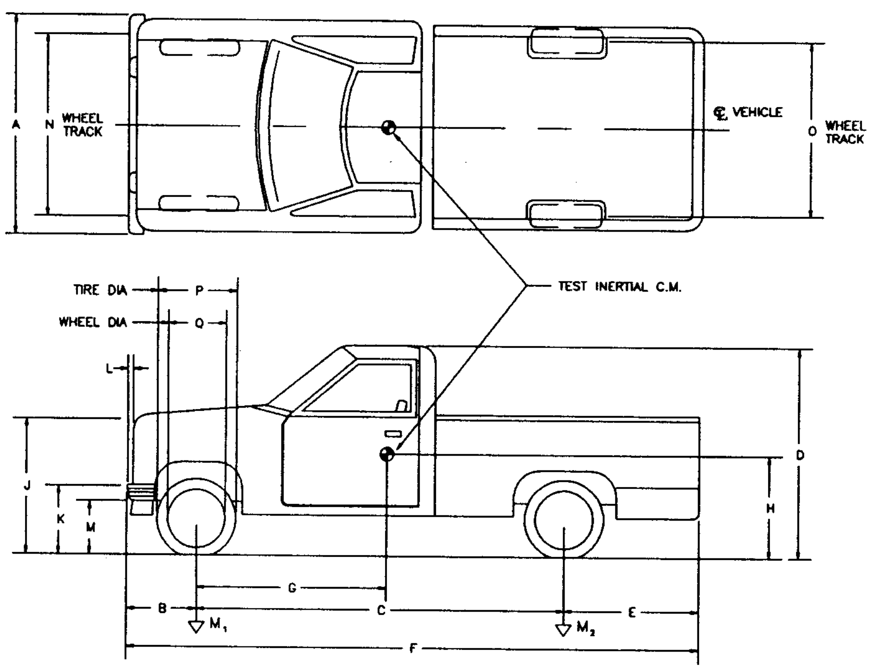
DATE: 08/01/2007 TEST NO: SS641 VIN: 1GCFC24H5PE206599 MAKE: Chevrolet

MODEL: Cheyenne YEAR: 1993 ODOMETER: 186943 mi TIRE SIZE: TL245175R16

TIRE INFLATION PRESSURE (psig): LF 65 RF 65 LR 65 RR 65

MASS DISTRIBUTION (kg): LF 538.45 RF 544.65 LR 397.80 RR 401.30

DESCRIBE ANY DAMAGE TO VECHILE PRIOR TO TEST: Large dent on the RF side of the front bumper. (1-ft X 8-in)



ENGINE TYPE: V8

ENGINE CID: 5.0L

TRANSMISSION TYPE:

● AUTO

MANUAL

OPTIONAL EQUIPMENT:

None

DUMMY DATA:

TYPE: N/A

MASS: N/A

SEAT POSITION: N/A

GEOMETRY (mm)

A 1900mm	D 1750mm	G 1467mm	K 613mm	N 1590mm	Q 440mm
B 880mm	E 1330mm	H	L 110mm	O 1620mm	
C 3340mm	F 5590mm	J 1050mm	M 513mm	P 750mm	

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M1	1083.1 kg	1094.8 kg	1094.8 kg
M2	799.1 kg	857.8 kg	857.8 kg
MT	1882.2 kg	1952.6 kg	1952.6 kg

7.2. Test Vehicle Guidance System

A rail guidance system directed the vehicle into the barrier. The guidance rail, anchored at 3.8-m (12.5-ft) intervals along its length, was used to guide a mechanical arm that is attached to the front passenger side wheel of the vehicle (Figure 7-1). A 10-mm (0.375-in) nylon rope was used to trigger the release mechanism on the guidance arm, thereby releasing the vehicle from the guidance system before impact.

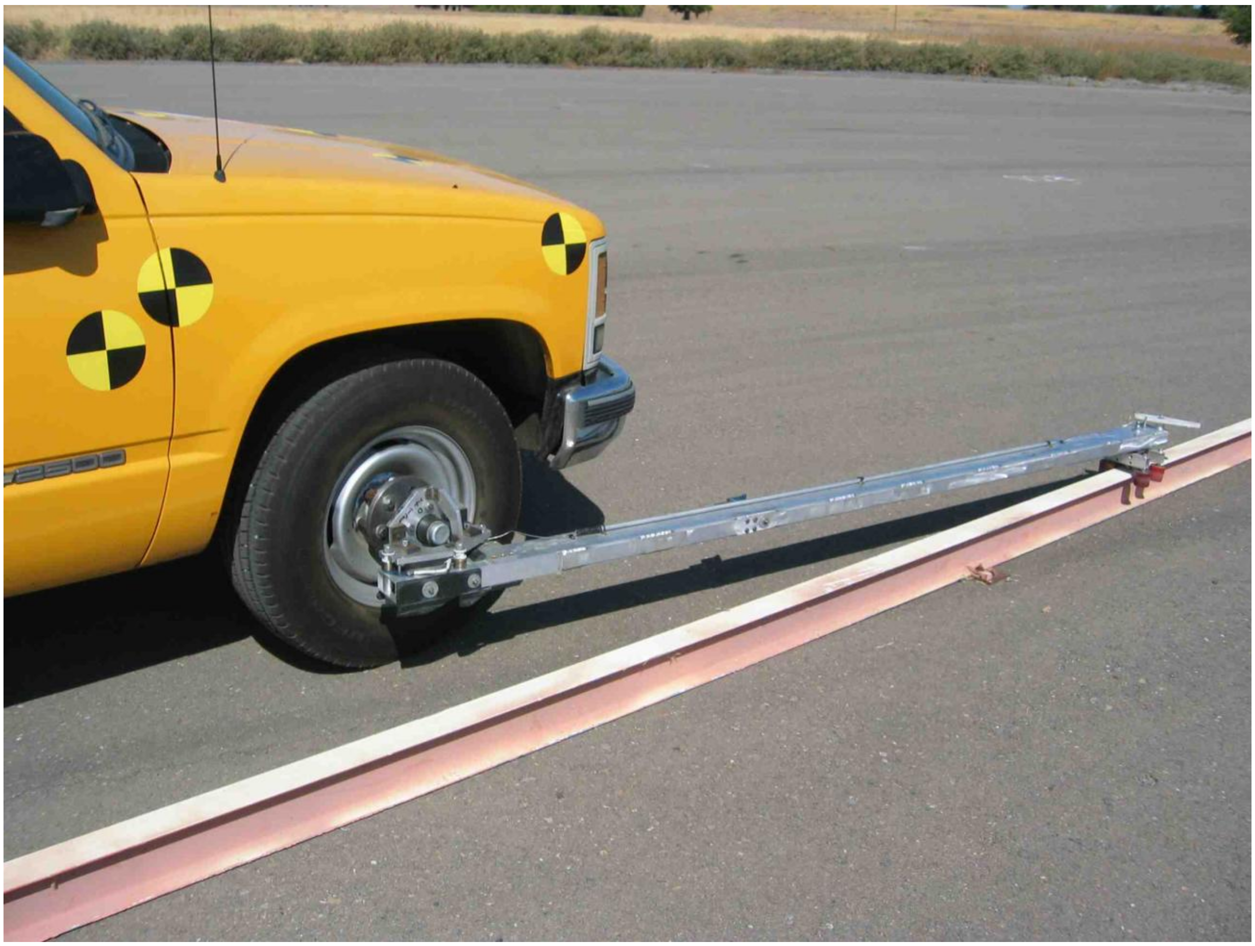


Figure 7-1 Test Vehicle Guidance System

7.3. Photo - Instrumentation

Several high-speed movie cameras recorded the impact during the crash test. The types of cameras and their locations are shown in Table 7-2 and Figure 7-2. All of these cameras were mounted on tripods except the three that were mounted on a 10.7-m (35-ft) high tower directly over the impact location.

A manually operated video camera and digital SLR camera were used to pan through the movement of the vehicle during the test. A tape-switch inline with the vehicle's tire path near the impact area remotely triggered the high-speed digital cameras. Both the vehicle and the barrier were photographed before and after impact with a digital video camera and a digital SLR camera. A video report of this project has been assembled using selected portions of the crash testing coverage.

Table 7-2 Typical Camera Type and Locations

Typical Coordinates					
Camera Label	Camera Type	Figure 7-2 Labels	Test SS641		
			X*	Y*	Z*
Upstream	Weinberger SpeedCam Visario 1500	A	-28.7 m	0	1.2 m
Downstream	Weinberger SpeedCam Visario 1500	B	79.8 m	0	1.2 m
Across	Weinberger SpeedCam Visario 1500	C	3.5 m	-20.6 m	1.2 m
Behind	Weinberger SpeedCam Visario 1500	D	25.5 m	9.7 m	1.8 m
Tower Upstream	Weinberger SpeedCam Visario 1500	E	-610 m	0	9.1 m
Tower Center	Weinberger SpeedCam Visario 1500	F	0	0	9.1 m
Tower Downstream	Weinberger SpeedCam Visario 1500	G	610 m	0	9.1 m
Pan Digital Camera	Canon XL-1	H	16.1 m	-22.2 m	4.5 m
Digital SLR Camera	Nikon D2X	I	17.2 m	-22.2 m	4.5 m
Note: *X, Y, and Z distances are relative to the impact point.					

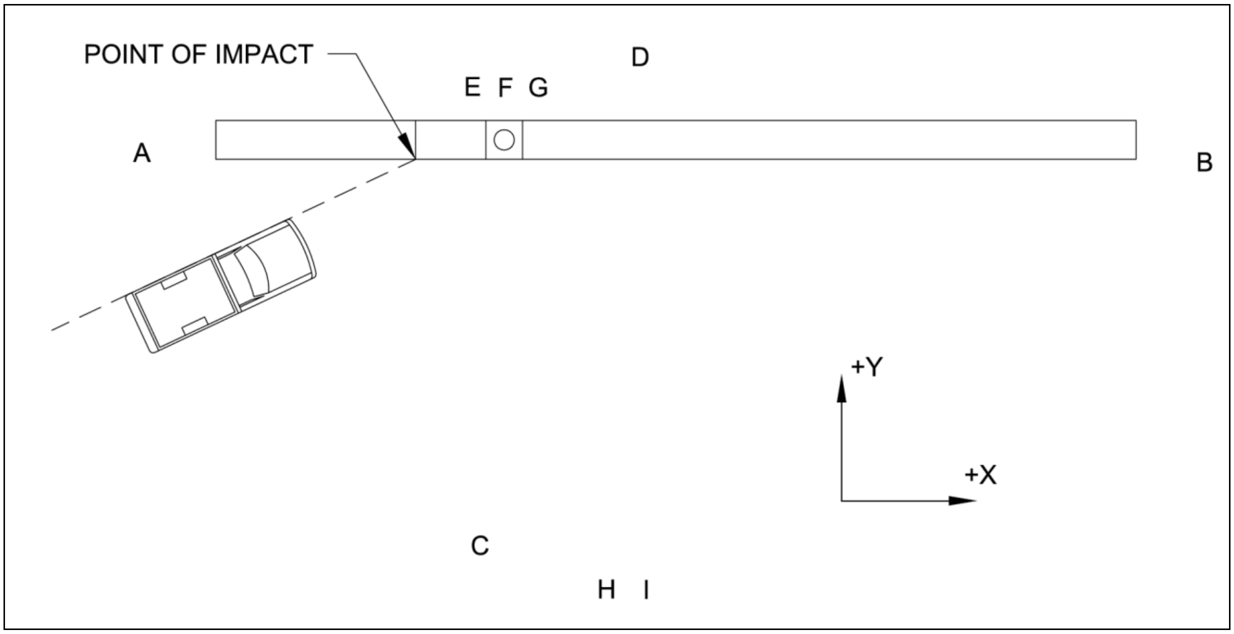


Figure 7-2 Camera Locations (Not to Scale)

The following are the pretest procedures that were required to enable film data reproduction to be performed using film motion analyzer or video analysis software:

1) Quad targets were attached to the top and sides of the test vehicle. The targets were located on the vehicle at intervals of 0.5-m and 1.0-m (1.64-ft and 3.28-ft). The targets established scale factors and horizontal and vertical alignment.

2) Flashbulbs, mounted on the test vehicle, were electronically triggered to establish a) initial vehicle-to-article contact, and b) the time of the application of the vehicle brakes. The flashbulbs begin to glow immediately upon activation, but have a delay of several milliseconds before lighting up to full intensity.

3) High-speed digital video cameras were all time-coded through the use of a portable computer and were triggered as the test vehicle passed over a tape switch located on the vehicle path upstream of impact.

7.4. Electronic Instrumentation and Data

Transducer data were recorded on two separate GMH Engineering Data Brick Model II digital transient data recorders (TDRs) that were mounted in the vehicle. The transducers mounted on the vehicle include two sets of accelerometers at the center of gravity (CG) and one set of rate gyros 191 mm (7.5 in) behind the CG (along the X-axis). The TDR data would have been reduced using a desktop personal computer running TRAP (A custom DADiSP spreadsheet created by the Roadside Safety Research Group might also have been used).

Accelerometer and gyro specifications are shown in Table 7-3. The vehicle accelerometer sign convention used throughout this report is the same that is described in NCHRP Report 350 and is shown on Figure 7-3.

A rigid stand with three retro reflective 90º polarizing tape strips was placed on the ground near the test article and alongside the path of the test vehicle, Figure 7-4. The strips were spaced at carefully measured intervals of 1.0-m (3.28-ft). The test vehicle had an onboard optical sensor that produced sequential impulses or "event blips" that were recorded concurrently with the accelerometer signals on the TDR, serving as "event markers". The impact velocity of the vehicle could be determined from these sensor impulses and timing cycles and the known distance between the tape strips. A pressure sensitive 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 flashbulb mounted on the top of the vehicle was activated. Two other pressure sensitive tape switches, connected to a speed trap, were placed 4.0 m (13.1 ft) apart just upstream of the test article specifically to establish the impact speed of the test vehicle. The layout for all of the pressure sensitive tape switches is shown in Figure 7-4.

Due to unforeseen problems there was no usable data recovered from the data bricks. Therefore, there was no way to develop data curves needed to calculate the occupant impact velocity and accelerations defined in NCHRP Report 350.

Table 7-3 Accelerometer and Gyro Specifications

TYPE	LOCATION	RANGE	ORIENTATION	TEST NUMBER
Endevco	Vehicle's CG	100 G	Longitudinal (primary)	SS641
Endevco	Vehicle's CG	100 G	Lateral (primary)	SS641
Endevco	Vehicle's CG	100 G	Vertical (primary)	SS641
Endevco	Vehicle's CG	100 G	Longitudinal (secondary)	SS641
Endevco	Vehicle's CG	100 G	Lateral (secondary)	SS641
Endevco	Vehicle's CG	100 G	Vertical (secondary)	SS641
BEI Systron Donner Inertial	191 mm (7.5-in) behind the CG (along the X-axis)	500 deg/s	Roll	SS641
BEI Systron Donner Inertial	191 mm (7.5-in) behind the CG (along the X-axis)	500 deg/s	Pitch	SS641
BEI Systron Donner Inertial	191 mm (7.5-in) behind the CG (along the X-axis)	500 deg/s	Yaw	SS641

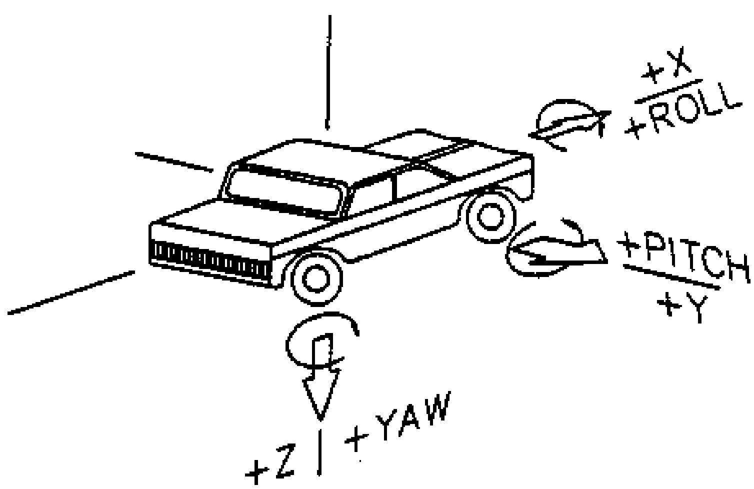


Figure 7-3 Vehicle Accelerometer Sign Convention

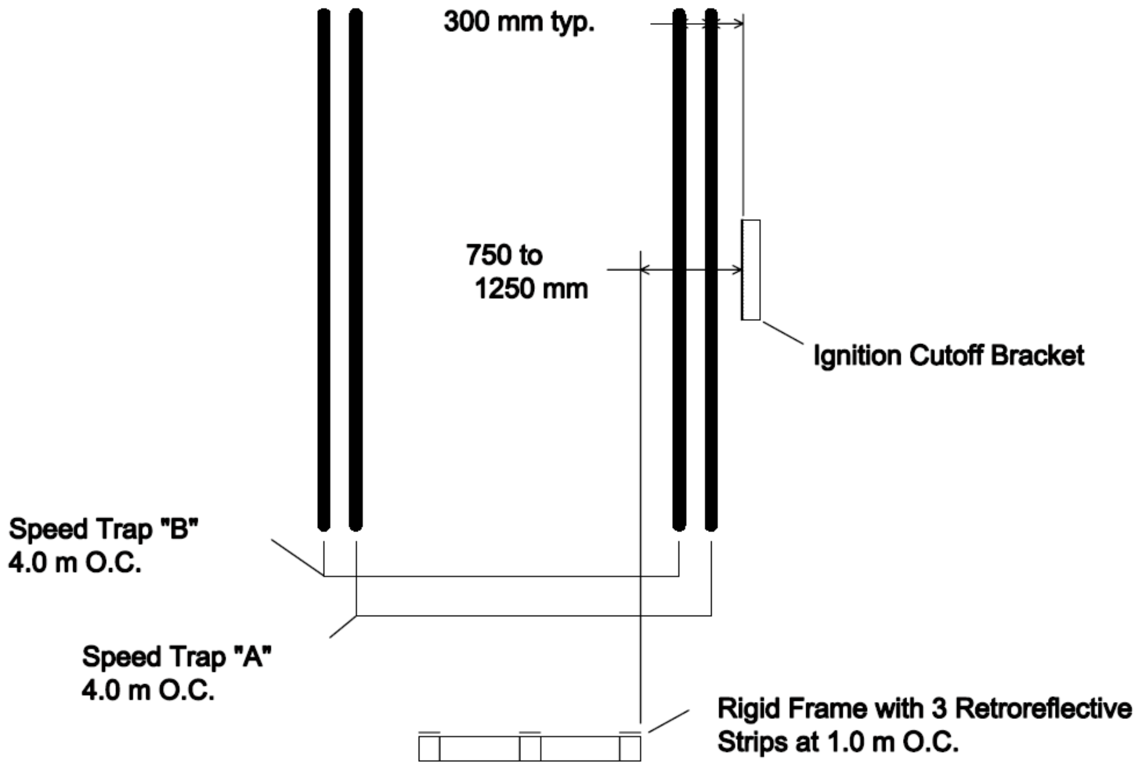


Figure 7-4 Event Switch Layout

7.5. Detailed Drawings

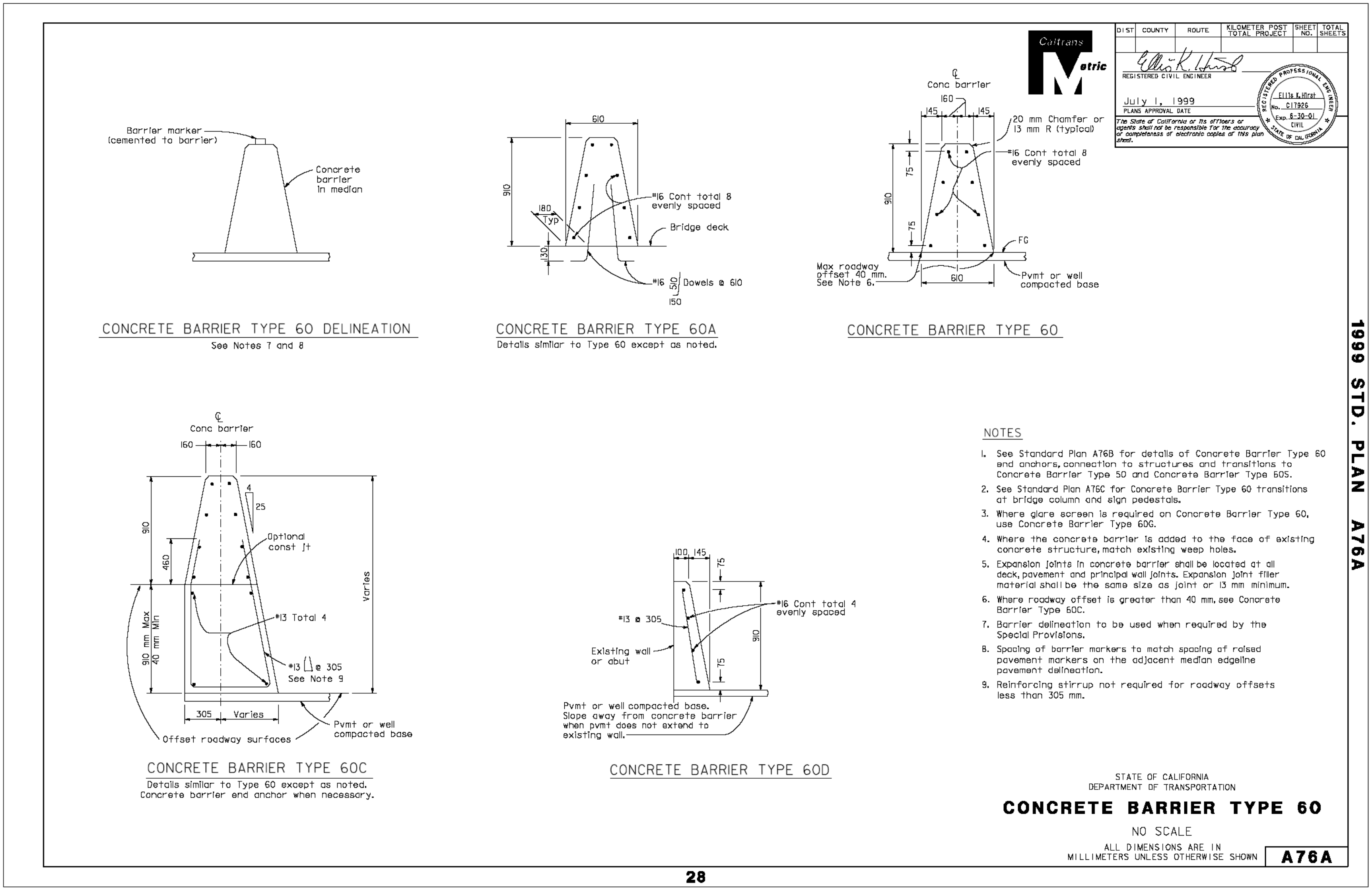


Figure 7-5 Standard Plan for Type 60 Barrier

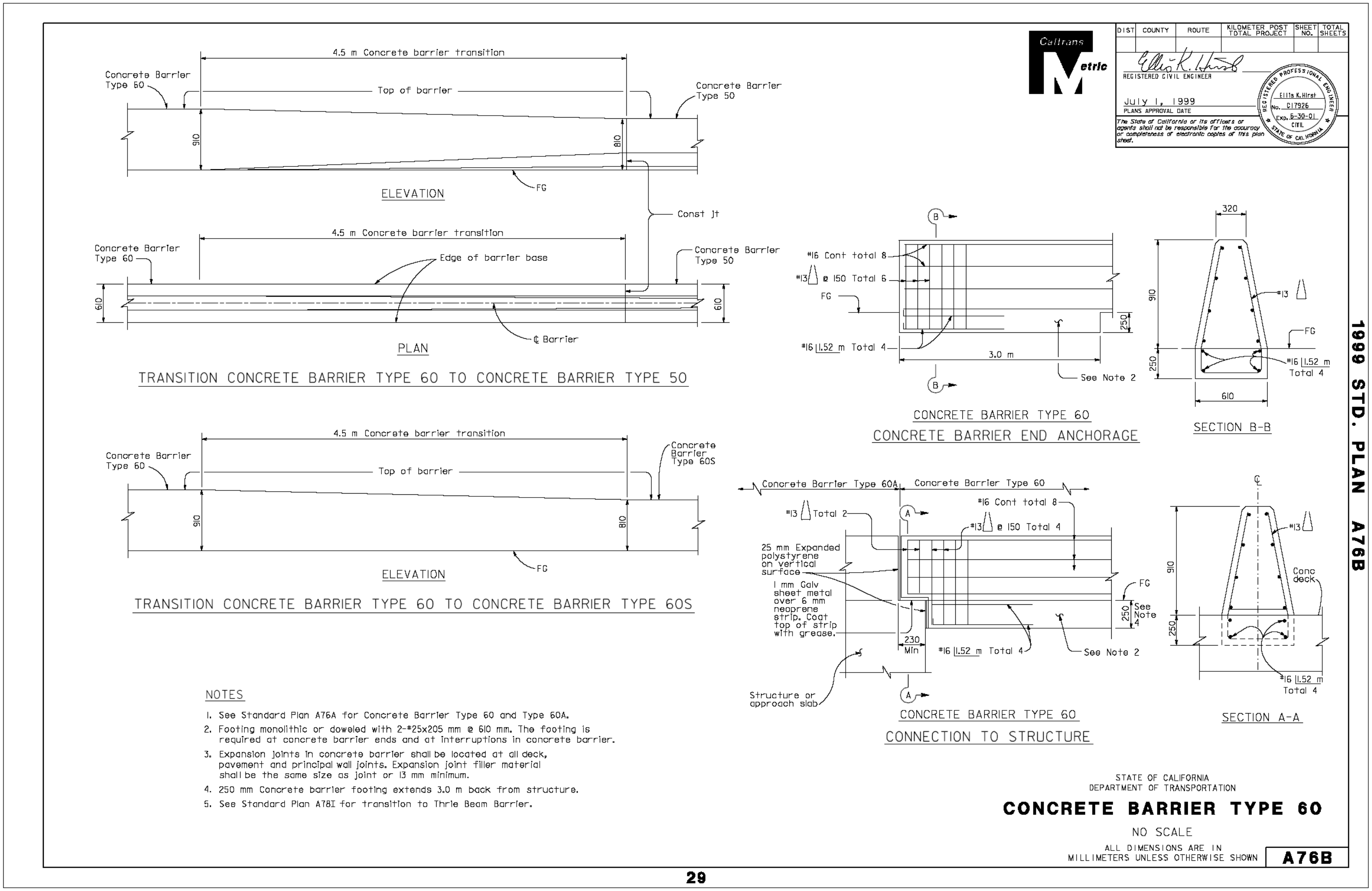


Figure 7-6 Standard Plan for Type 60 Barrier (End Anchorage)

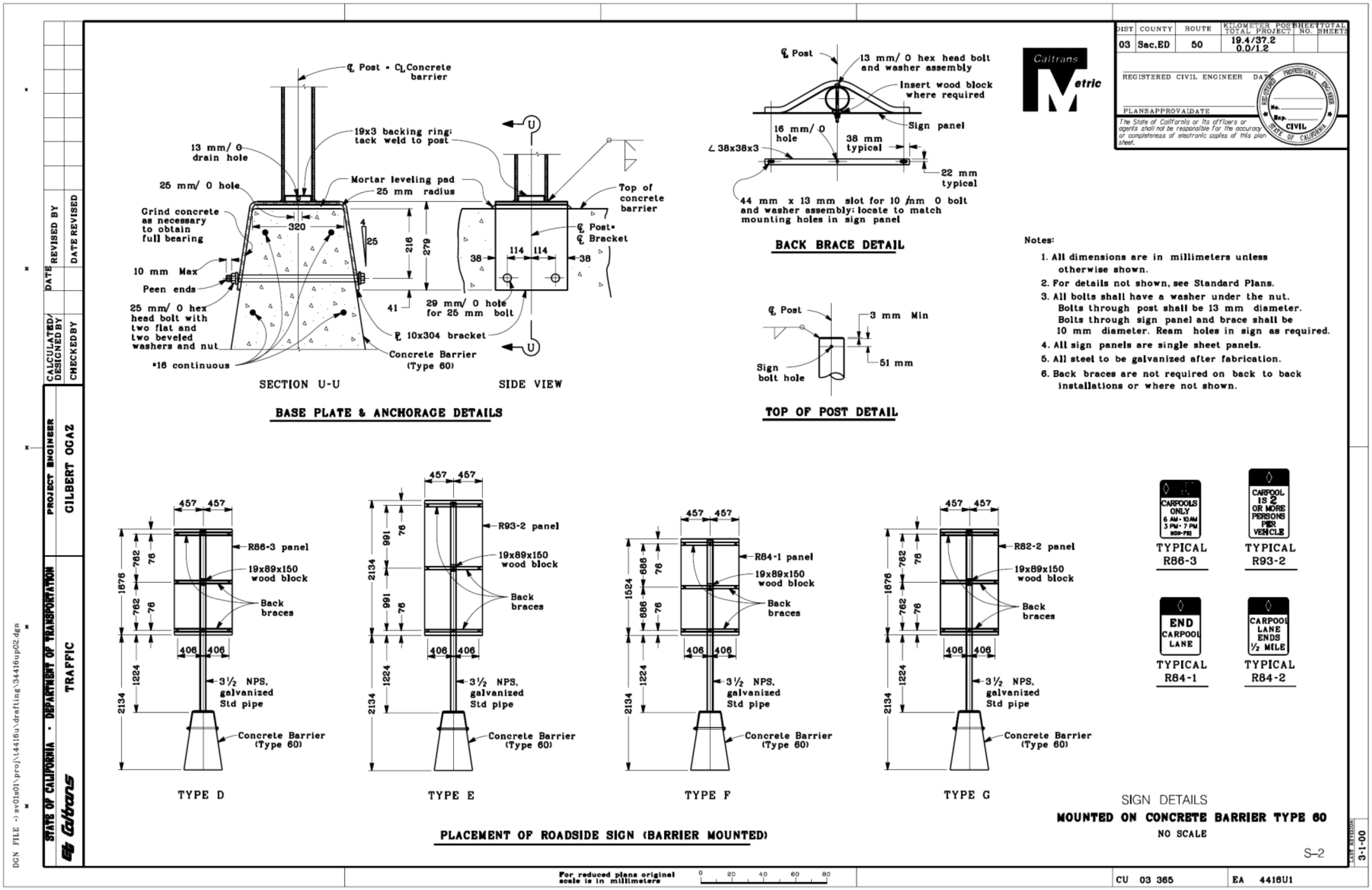
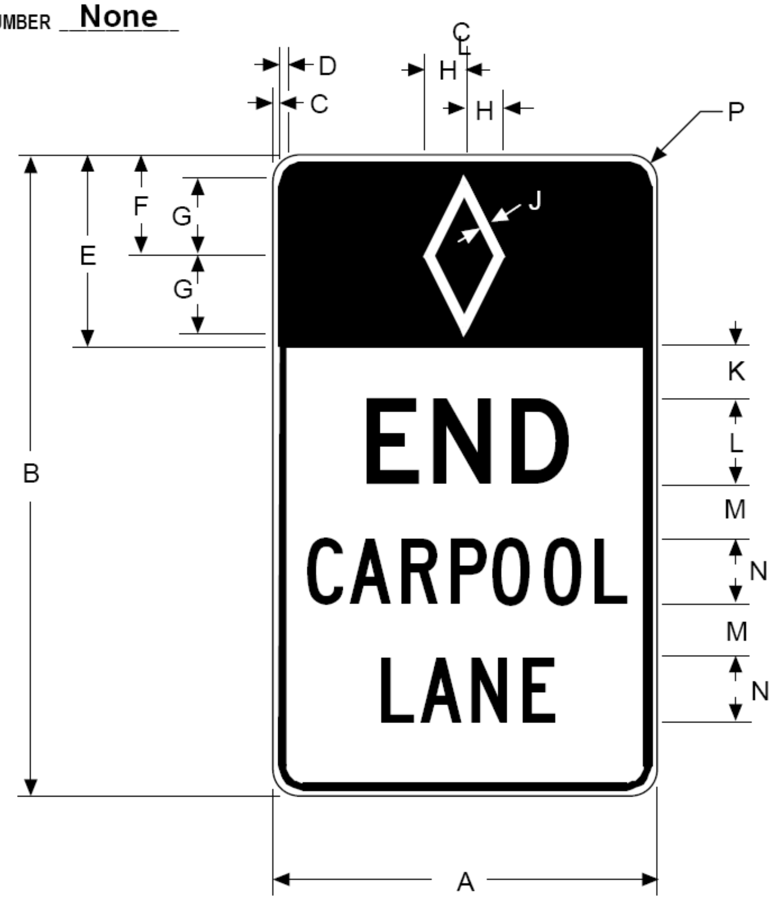


Figure 7-7 Placement of Roadside Sign (Barrier Mount)

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

MUTCD NUMBER None

CODE R84-1



SIGN SIZE (Inches)	DIMENSIONS (Inches)													
	A	B	C	D	E	F	G	H	J	K	L	M	N	P
30 x 54	30	54	1/2	3/4	18	9-1/4	7-1/2	3-3/4	1-1/8	5	6D	4	5C	1-7/8
36 x 60	36	60	5/8	7/8	18	9-5/16	7-1/2	3-3/4	1-1/8	5	8D	5	6C	2-1/4
48 x 72	48	72	3/4	1-1/4	18	9-3/8	7-1/2	3-3/4	1-1/8	7	10D	6	8C	3

SIGN SIZE (mm)	DIMENSIONS (Millimeters)													
	A	B	C	D	E	F	G	H	J	K	L	M	N	P
762 x 1372	762	1372	13	19	450	235	191	95	29	127	150D	102	125C	48
914 x 1524	914	1524	16	22	450	237	191	95	29	127	200D	127	150C	57
1219 x 1829	1219	1829	19	31	450	238	191	95	29	178	250D	152	200C	76

COLORS
BORDER, LEGEND & DIAMOND BACKGROUND - BLACK (NON-REFLECTIVE)
DIAMOND & BACKGROUND - WHITE (REFLECTIVE)

- THE POLICY FOR INTENDED USAGE OF THIS SIGN IS SHOWN ON REVERSE SIDE -

Gerry Meis

CHIEF, OFFICE OF SIGNS AND DELINEATION

8/1/02

DATE

REVISION

REVISION

Figure 7-8 HOV Sign R84-1 (CA)