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16. Abstract

Large sign panels have long used extruded aluminum panels as a signage substrate. See Texas Department of Transportation (TxDOT) Sign Mounting Detail (SMD) (2-1) through SMD (2-4). The aluminum panels are extruded with wind beams integral to the sign panel and have typically been mounted on hot rolled W-shape supports with 4-bolt uni-directional slip bases. The supports incorporate fuse plates just below the sign panel that serve as hinge points when errant vehicles impact the supports.

In addition, TxDOT uses 2.5-in (64 mm) diameter schedule 80 pipe with triangular slip bases to support a range of small signs (see TxDOT SMD [1-1] through SMD [1-5]). One of TxDOT's districts proposed mating the extruded aluminum panels with the schedule 80 pipe supports. Such a system would provide a cost-effective solution for dual support sign installations with sign panels up to 60 ft^2 (5.6 m^2). Since the pipe support does not have a hinge point, the impact performance of this type installation was unknown, and full-scale testing was deemed necessary.

This report summarizes the results of an investigation of the performance of extruded aluminum sign panels up to 2.5-in (64 mm) mounted on dual schedule 80 pipe supports with triangular slip bases. Static testing of the pipe clamp/extruded aluminum panel connection was performed prior to full-scale crash testing to determine the strength of the connection and controlling failure mode. This information was used to select an appropriate number of connectors for sign panels up to 60 ft^2 (5.6 m^2), which is the maximum area permitted on two 2.5-in (64 mm) diameter schedule 80 pipe supports per TxDOT standards.

Extruded aluminum sign panels up to 60 ft^2 (5.6 m^2) mounted on dual 2.5-in (64 mm) diameter schedule 80 pipe supports with triangular slip bases meet *National Cooperative Highway Research Program* (*NCHRP) Report 350* requirements and are considered suitable for implementation. Four universal pipe clamps, two on each support, should be used in field installations.

17. Key Words
Sign Support, Triangular Slip Base, Pipe Clamp, Static Testing, Crash Testing, Roadside Safety

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DISCLAIMER

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CHAPTER 1. INTRODUCTION

BACKGROUND

Through their research program, the Texas Department of Transportation (TxDOT) continues to be proactive in their ongoing commitment to providing safer roadsides for the traveling public. TxDOT-sponsored research has resulted in the development of many satisfactory sign support designs with demonstrated impact performance. The department uses the results of in-service performance evaluations and feedback from field crews to continually assess the performance of these systems and identify areas in which design improvements can be realized in terms of cost, maintenance, and/or impact behavior.

Large sign panels have long used extruded aluminum panels as a signage substrate. See TxDOT Sign Mounting Detail (SMD) (2-1) through SMD (2-4). The aluminum panels are extruded with wind beams integral to the sign panel and have typically been mounted on hot rolled W-shape supports with 4-bolt uni-directional slip bases. The supports incorporate fuse plates just below the sign panel that serve as hinge points when errant vehicles impact the supports.

In addition, TxDOT uses 2.5-in (64 mm) diameter schedule 80 pipe with triangular slip bases to support a range of small signs (see TxDOT SMD [1-1] through SMD [1-5]). One of TxDOT's districts proposed mating the extruded aluminum panels with the schedule 80 pipe supports. Such a system would provide a cost-effective solution for dual support sign installations with sign panels up to 60 ft^2 (5.6 m^2). Since the pipe support does not have a hinge point, the impact performance of this type installation was unknown, and full-scale testing was deemed necessary.

OBJECTIVES/SCOPE OF RESEARCH

This report summarizes the results of an investigation of the performance of extruded aluminum sign panels up to 60 ft^2 (5.6 m^2) mounted on dual schedule 80 pipe supports with triangular slip bases. Static testing of the pipe clamp/extruded aluminum panel connection was performed prior to full-scale crash testing to determine the strength of the connection and controlling failure mode. This information was used to select an appropriate number of connectors for sign panels up to 60 ft^2 (5.6 m^2), which is the maximum area permitted on two 2.5-in (64 mm) diameter schedule 80 pipe supports per TxDOT standards.

National Cooperative Highway Research Program (*NCHRP) Report 350* recommends two tests for test level 3 evaluation of breakaway support structures (*1*). These tests involve an 1800-lb (820-kg) passenger car impacting the sign support at an impact angle of 0 degrees and impact speeds of 21.7 mi/h (35 km/h) and 62.1 mi/h (100 km/h). Both tests were conducted on the dual pipe support sign installation with triangular slip bases.

Chapter 2 features the research approach and testing methodologies followed for this project. Chapter 3 presents the results of full-scale crash tests performed to determine the impact performance of the dual slip-base sign supports with extruded aluminum panel. Chapter 4 presents a summary of findings and conclusions. Chapter 5 highlights implementation recommendations.

CHAPTER 2. STUDY APPROACH

STATIC LOAD TESTING

Several static load tests were performed to evaluate the clamp connection between the 2.5-in (64 mm) diameter schedule 80 pipe support and aluminum extruded sign panel. This testing served to quantify the strength and controlling failure mode of the connection. This information was used to determine the required number of mounting attachment points to accommodate design wind loads.

A 12-in (305 mm) long section of 2.5-in (64 mm) diameter schedule 80 pipe was attached to a short section of extruded aluminum panel with the standard universal pipe clamp used by TxDOT in small sign supports. Figure 1 shows details of the extruded aluminum panel and clamp. The extruded aluminum panel was clamped to a rigid backup structure using 3/8-in (9.5 mm) thick steel strap and 5/8-in (15.8 mm) diameter bolts. The edges of the steel strap were rounded to prevent high localized stresses. Stranded cable was passed through the pipe and attached to a hydraulic ram (see Figure 2). The specimens were loaded in tension until failure. The test clamp points were adjusted during the test program to minimize localized effects and more closely simulate potential wind load conditions. Figures 3 through 5 depict the different test conditions evaluated.

The aluminum extruded panel ruptured in test S1. The steel straps, which clamped the extruded panel to the backup structure, were placed in close proximity to the load application point. The sharp corners of the steel strap initiated tearing of the aluminum. Maximum applied load was 2700 lb (12.0 kN).

The steel straps were moved to the outside wind beam for the second static test. Load at failure of the connection was 700 lb (3.1 kN). No S3 x 5.7 stiffener was used in this test. This permitted large localized deformation in the extruded aluminum panel, which limited the failure load.

It was noted that vertical stiffeners are often used to tie the extruded aluminum panels together and make them behave more integrally to resist wind loads. Test S3 was a repeat of test S2 with an S3 x 5.7 vertical stiffener attached to the sign panel 5.75 in (146 mm) from the pipe support. Ultimate load at failure was 3000 lb (13.3 kN).

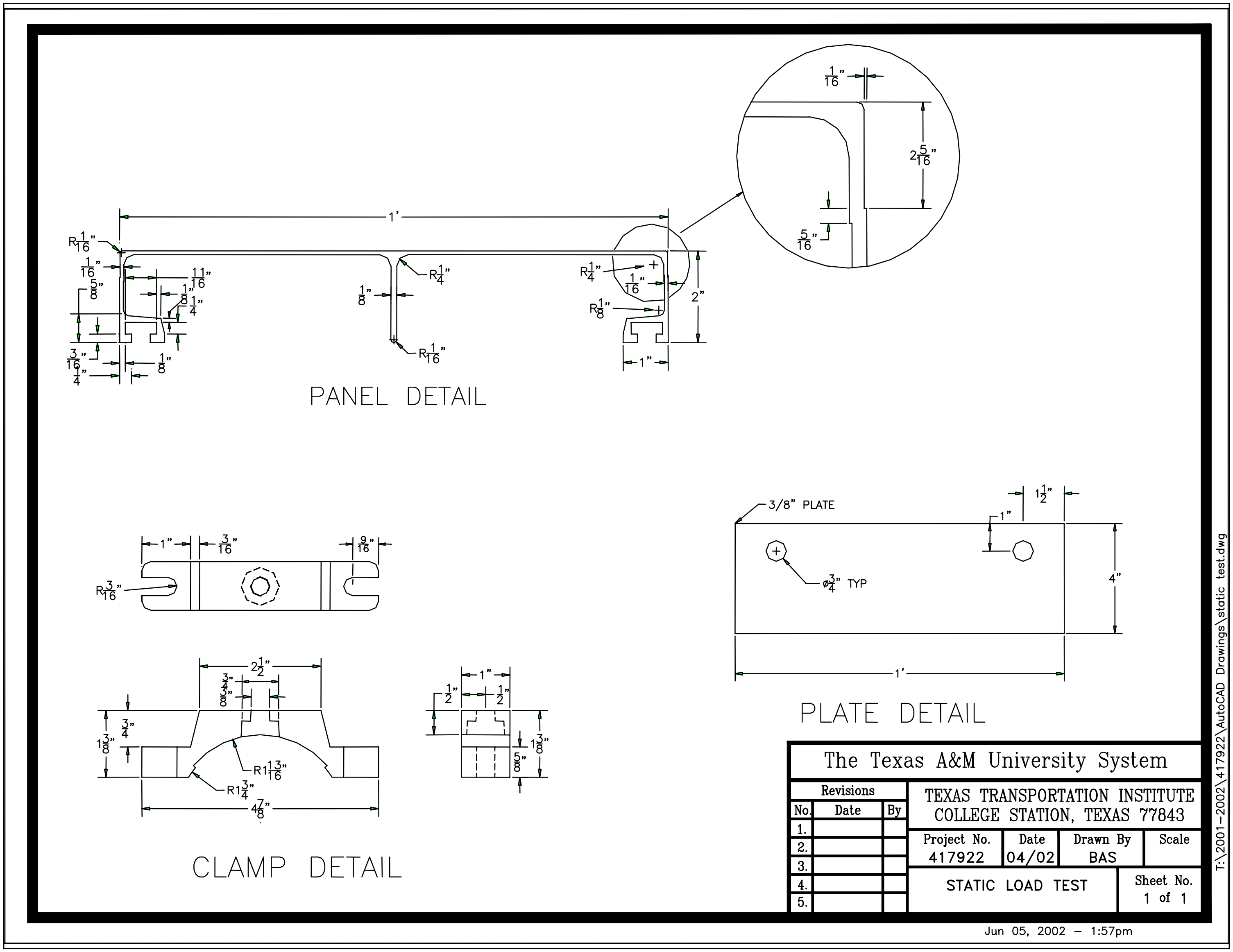


Figure 1. Details of the Extruded Aluminum Sign Panel and Standard Universal Pipe Clamp.

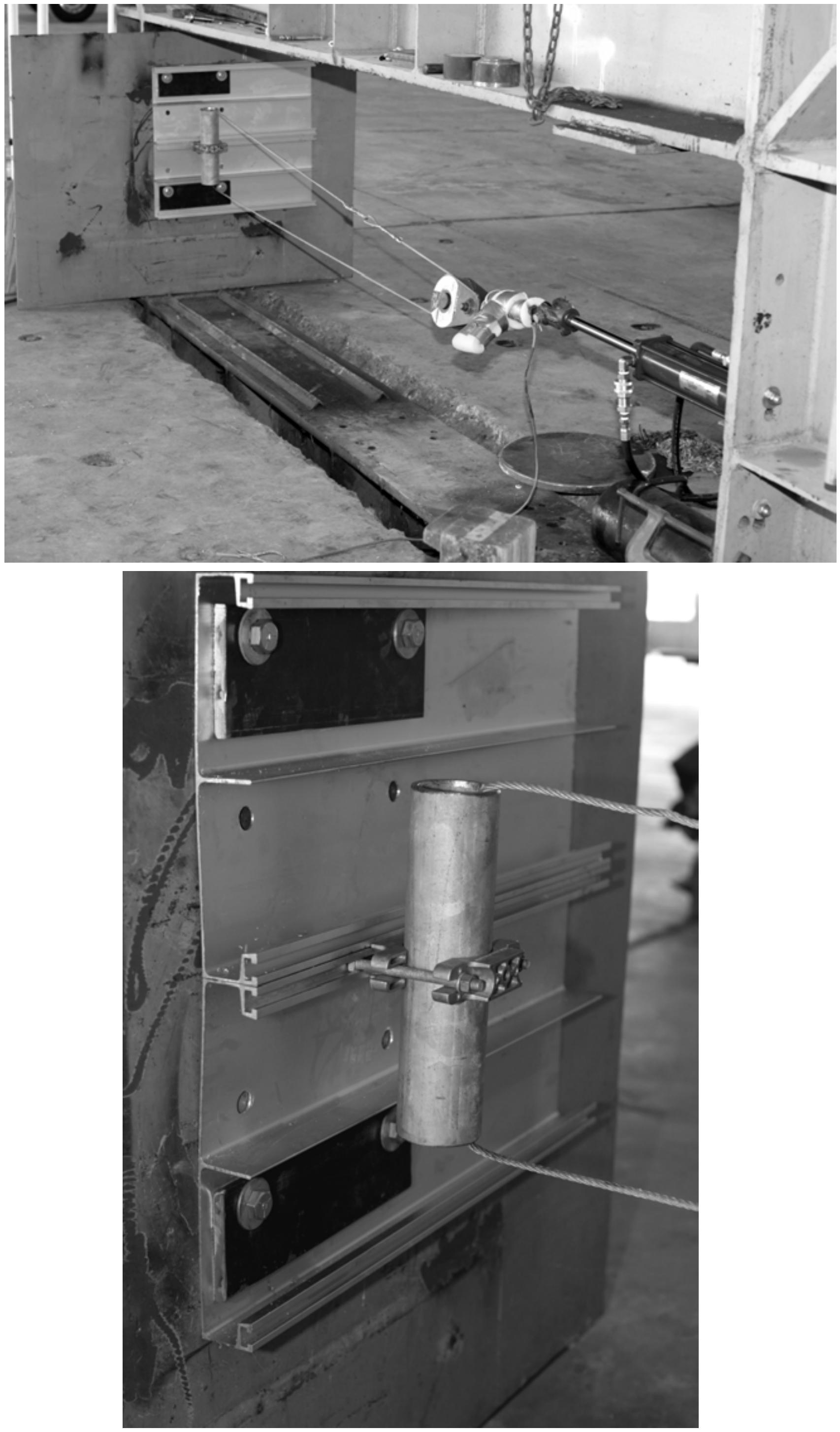


Figure 2. Typical Set-up for Static Load Testing.

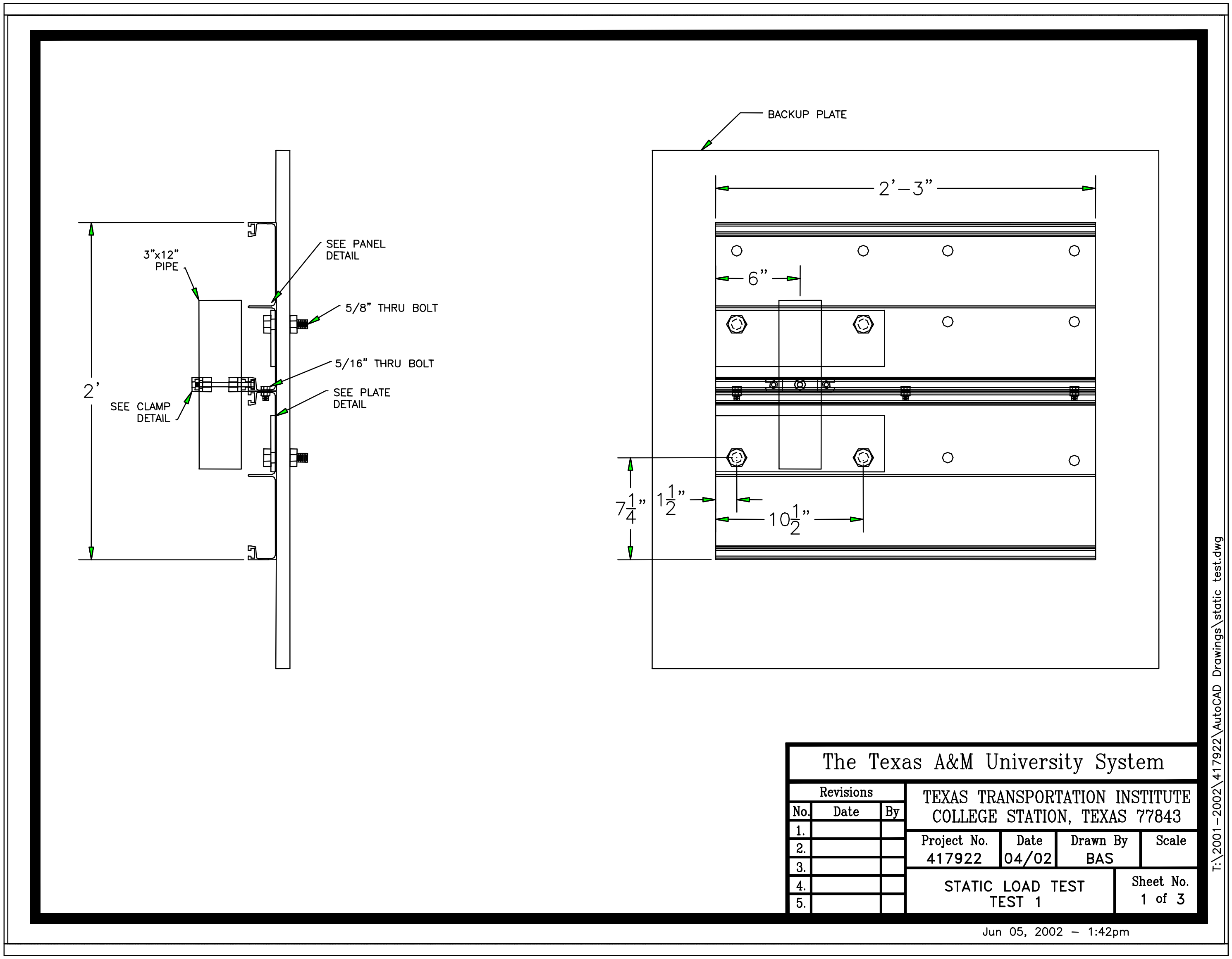


Figure 3. Set-up Details for Static Test 417922-S1.

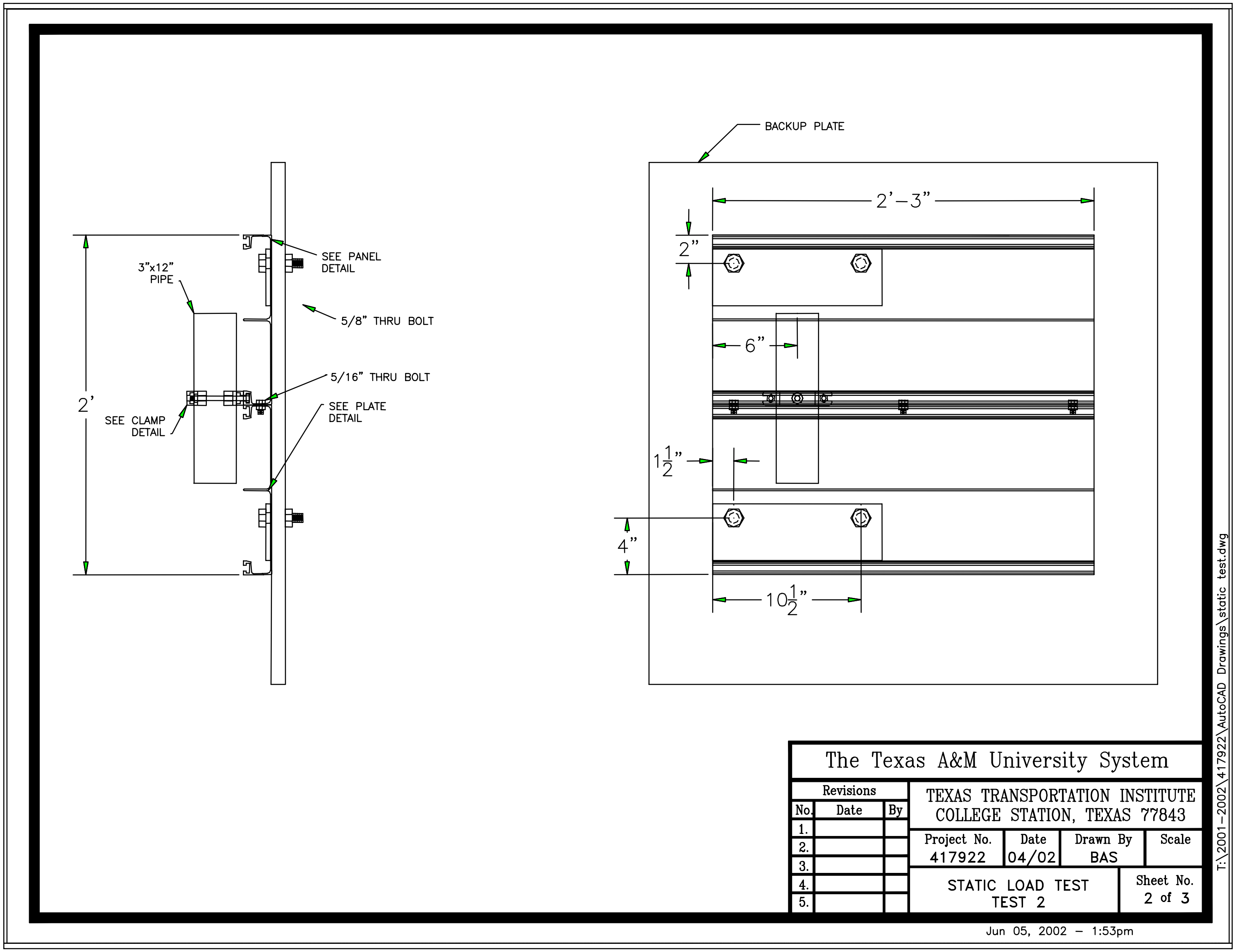


Figure 4. Set-up Details for Static Test 417922-S2.

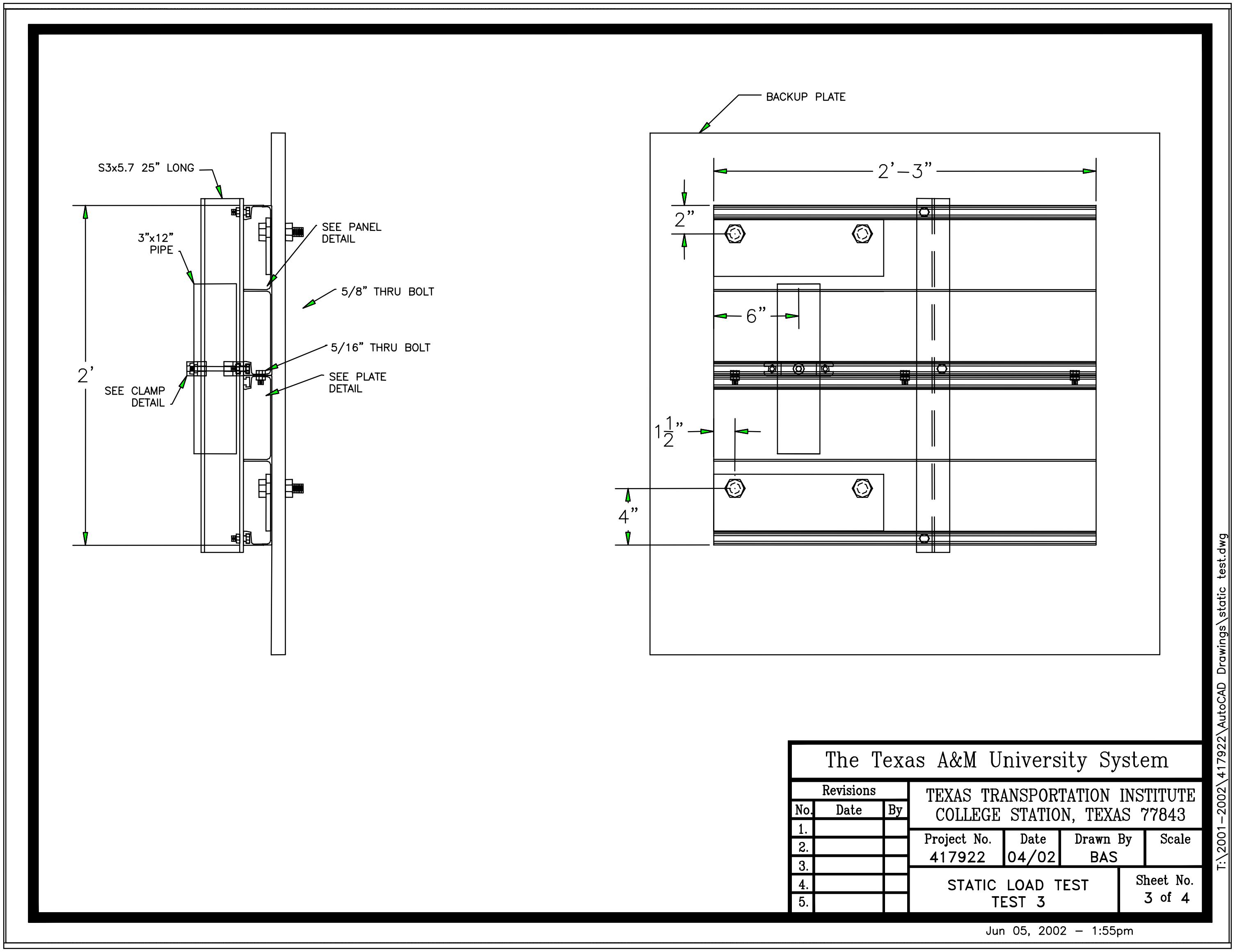


Figure 5. Set-up Details for Static Test 417922-S3.

The 1994 *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* has a procedure for predicting wind pressures for given wind velocities. A design wind speed of 70 mph (112.7 km/ph) wind will produce a wind pressure of approximately 25 psf (1.2 kPa). If the sign area is limited to 60 ft^2 (5.6 m^2) and the minimum number of supports is two, the maximum load applied to each support is 750 lb (3.3 kN). In test S2, the connection failure load for an unstiffened sign panel was 700 lb (3.1 kN). Therefore, two connections per support will provide adequate resistance to accommodate the design wind loads as verified by the worst case static load test.

FULL-SCALE CRASH TESTING

The researchers selected a 10 ft (3.0 m) wide by 6 ft (1.8 m) tall sign panel for full-scale crash testing. TxDOT standards specify a maximum sign panel size of 60 ft^2 (5.6 m^2) for two 2.5-in (64 mm) diameter schedule 80 pipe supports. To achieve acceptable performance in a full-scale crash test, the lower pipe-to-sign panel connection must release in some fashion. The selected aspect ratio creates a shorter, wider sign panel that can have up to three S3 × 5.7 vertical stiffeners, which creates a more torsionally rigid sign panel. In addition, the prying distance from the upper connection point to the lower connection point is most critical in shorter sign panels.

TEST ARTICLE

An extruded aluminum sign panel measuring 10 ft (3.0 m) wide by 6 ft (1.8 m) tall with three S3 × 5.7 vertical stiffeners was mounted on two 2.5-in (64 mm) diameter schedule 80 pipe supports. A modular cast triangular slip base, supplied by Northwest Pipe, was placed on the end of each schedule 80 pipe support and fastened to matching triangular baseplates mounted in a standard TxDOT concrete footing. Center-to-center distance between the pipe supports is 6 ft (1.8 m). The bottom edge of the sign panel was mounted 7.0 ft (2.1 m) above ground level and the S3 × 5.7 stiffeners were attached 6.0 in (152 mm) outside of each pipe support and at the center of the sign panel. Figure 6 shows the vertical stiffeners were attached to the extruded aluminum sign panel using standard post clamps.

The bolt torques used in the installation are:

- Slip base = 80 ft-lb (108.5 N-m)
- Locking ring = 60 ft-lb (81.3 N-m)
- Pipe clamp = 20 ft-lbs (27.1 N-m)

The total weight of the assembled dual sign support system is 460.4 lb (208.8 kg). The weights of components and total system are:

- Sign panel = 140 lb (63.5 kg)
- Wind brace – 36.6 lb (16.6 kg) × 3 = 109.8 lb (49.8 kg)
- Casting and ring – 11 lb (5.0 kg) × 2 = 22 lb (10.0 kg)
- 2.5 in schedule 80 pipe – 94.3 lb (42.8 kg) × 2 = 188.6 lb (85.5 kg)

Figure 6 features other dimensional information. Figures 7 and 8 show photographs of the installations.

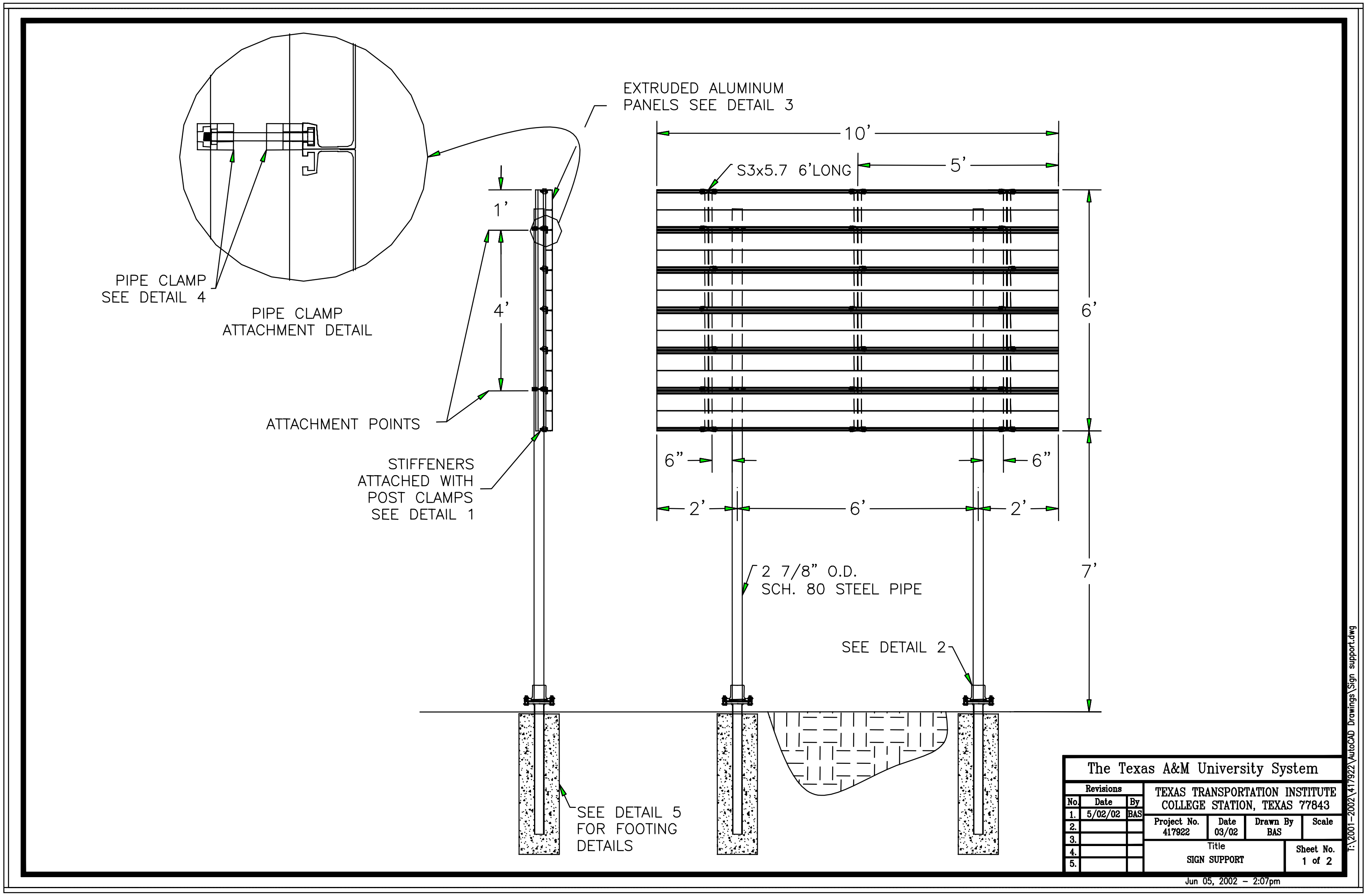


Figure 6. Details of the Sign Support Installation before Crash Testing.

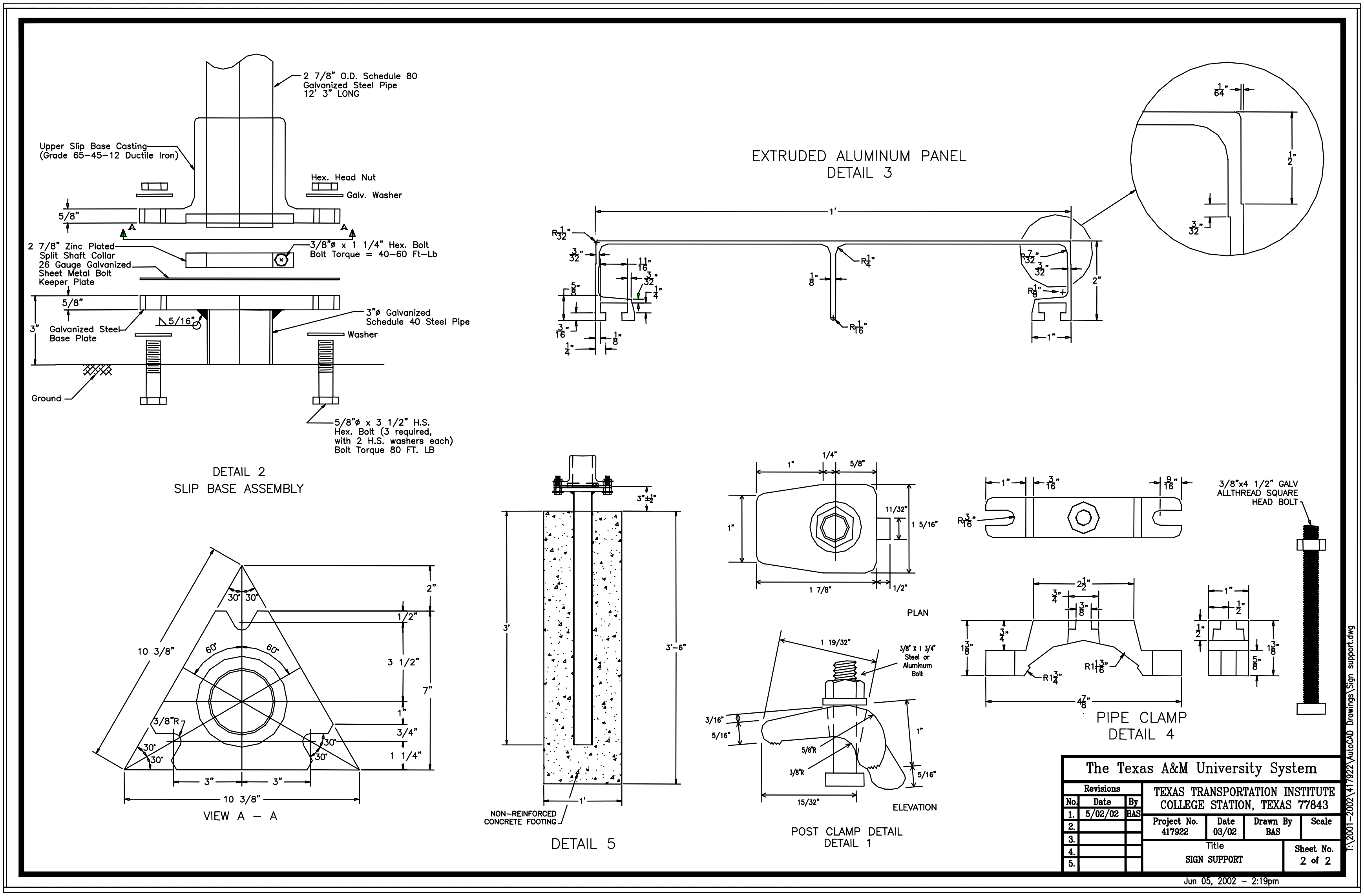


Figure 6. Details of the Sign Support Installation before Crash Testing (Continued).

Figure 7. Test Article/Installation before Test 417922-1.

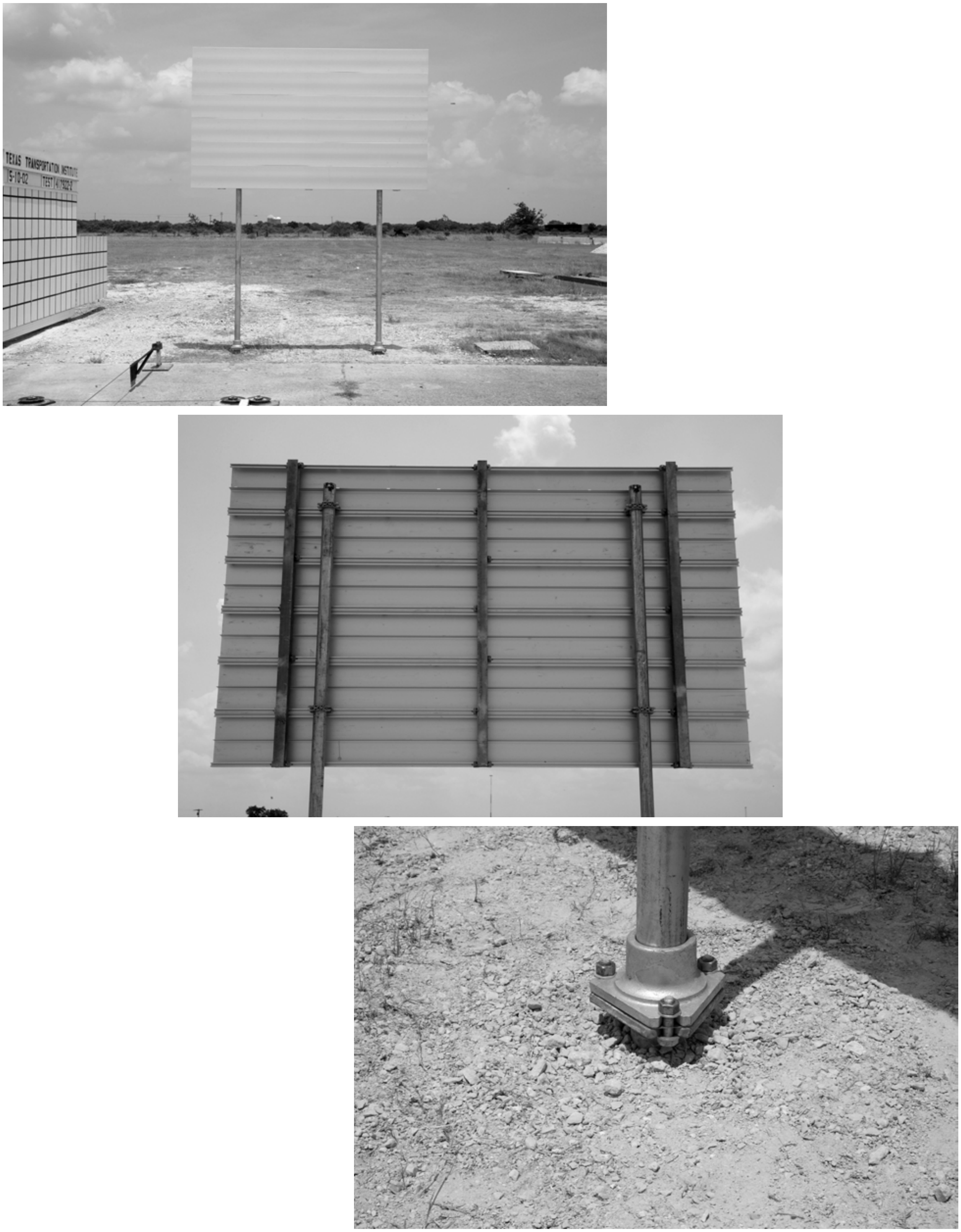


Figure 8. Test Article/Installation before Test 417922-2.

CRASH TEST CONDITIONS

NCHRP Report 350 recommends two tests for test level 3 evaluation of breakaway support structures:

> ***NCHRP Report 350* Test Designation 3-60**: This test involves an 1806 lb (820 kg) passenger vehicle (820C) impacting the support structure at a nominal speed of 21.7 mi/h (35 km/h) and an angle ranging from 0–20 degrees. The purpose of this test is to evaluate the breakaway, fracture, or yielding mechanism of the support and occupant risk.
>
> ***NCHRP Report 350* Test Designation 3-61**: This test involves an 1806 lb (820 kg) passenger car (820C) impacting the support structure at a nominal speed of 62.1 mi/h (100 km/h) and an angle ranging from 0–20 degrees. The test is intended to evaluate vehicle and test article trajectory and occupant risk.

Both of these tests were run on the dual support sign installation, and the results are reported herein. Test No. 417922-1 corresponds to *NCHRP Report 350* test designation 3-60, and test no. 417922-2 corresponds to *NCHRP Report 350* test 3-61.

The crash test and data analysis procedures followed for these tests were in accordance with guidelines presented in *NCHRP Report 350*. Appendix A presents brief descriptions of these procedures.

EVALUATION CRITERIA

The crash tests performed on the dual support sign installation were evaluated in accordance with *NCHRP Report 350*. As stated in *NCHRP Report 350*, "Safety performance of a highway appurtenance cannot be measured directly but can be judged on the basis of three factors: structural adequacy, occupant risk, and vehicle trajectory after collision." Accordingly, researchers used the safety evaluation criteria from Table 5.1 of *NCHRP Report 350* to evaluate the crash test reported herein.

In addition, the results were evaluated in accordance with the 1994 American Association of State Highway and Transportation Officials (AASHTO) *"Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals,"* which states:

> *"Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800 pound [817 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mi/h to 60 mi/h [32 km/h to 97 km/h] does not exceed 16 ft/s [4.87 m/s], but preferably does not exceed 10 ft/s [3.05 m/s] or less….*
>
> *To avoid vehicle undercarriage snagging, any substantial remains of a breakaway support, when it is broken away, should not project more than four inches (0.102 m) above a 60-inch (1.524 m) chord aligned radially to the centerline of the highway and connecting any point, within the length of the chord, on the ground surface on one side of the support to a point on the ground surface on the other side (2)."*

CHAPTER 3. CRASH TEST RESULTS

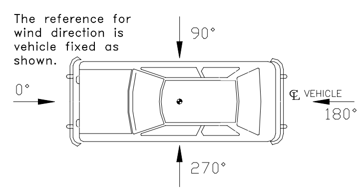
TEST NO. 417922-1 (*NCHRP Report 350* TEST NO. 3-60)

Test Vehicle

The crash test used a 1998 Geo Metro, shown in Figures 9 and 10. Test inertia mass of the vehicle was 1806 lb (820 kg) and its gross static mass was 1969 lb (894 kg). The height to the lower edge of the vehicle bumper was 15.7 in (400 mm), and the height to the upper edge of the bumper was 20.7 in (525 mm). Additional dimensions and information on the vehicle are given in Appendix B, Figure 23. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

Researchers performed the test on the morning of May 10, 2002. No rainfall was recorded during the 10 days prior to the test. Moisture content of the *NCHRP Report 350* soil in which the device was installed was 6 percent. Weather conditions at the time of testing were as follows: Wind speed: 6 mi/h (10 km/h); Wind direction: 170 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 79°F (26°C); Relative humidity: 79 percent.



Test Description

The left front quarter point of the vehicle impacted the left pipe support traveling at a speed of 21.7 mi/h (34.9 km/h) and an impact angle of 0 degree. Shortly after impact, the left sign support began to move, and at 0.013 s, the upper base began to slip from the lower base. The upper base separated from the lower base at 0.024 s, and the vehicle lost contact with the support at 0.077 s (vehicle speed was 20.8 mi/h (33.4 km/h)). At 0.240 s, the lower post clamp on the left support separated and at 0.396 s, the upper clamp separated. The support subsequently released from the sign panel at 0.402 s with the vehicle traveling at a speed of 18.5 mi/h (29.8 km/h). The rotating support contacted the top edge of the roof/windshield frame at 0.768 s. Brakes on the vehicle were applied 2.3 s after impact. The vehicle subsequently came to rest 100.1 ft (30.5 m) directly downstream of impact with the left support resting against the hood and roof/windshield frame. Appendix C, Figure 25 shows sequential photographs of the test period.

Figure 9. Vehicle/Installation Geometrics for Test 417922-1.

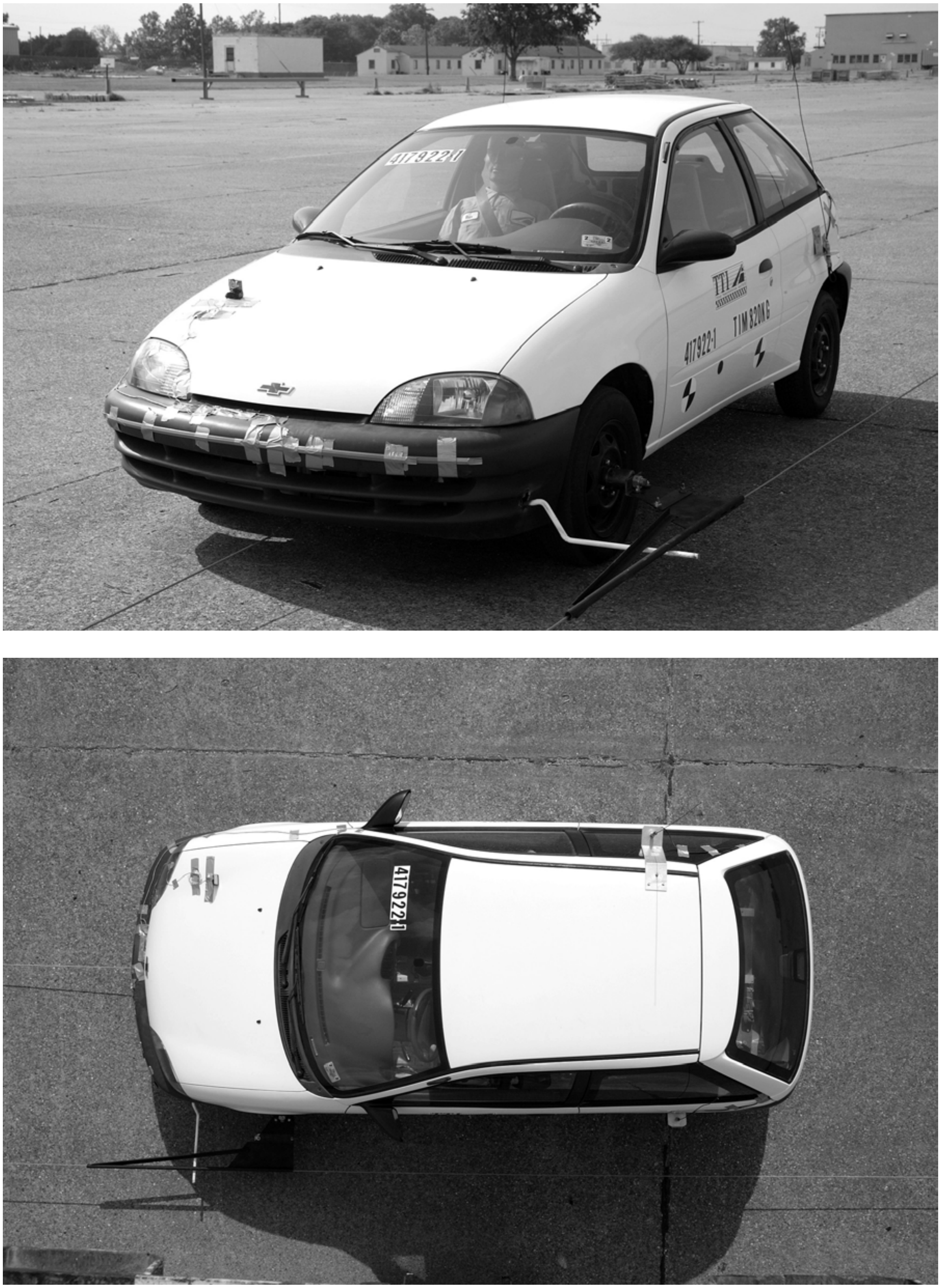


Figure 10. Vehicle before Test 417922-1.

Damage to Test Installation

Figures 11 and 12 show damage to the sign support. The right support remained attached to the base, and the sign panel was considered reusable. The left support and upper slip base separated from the base and the sign panel. The lower pipe clamp on the impacted pipe support released from the extruded aluminum sign panel when the inside clamp bolt pulled out of the aluminum channel. The lower outside clamp bolt remained with the sign panel. As the vehicle passed under the installation, the upper pipe clamp released from the aluminum panel. One of the slip base bolts remained in the base, one came to rest 11.2 ft (3.4 m) to the right of impact, and a third came to rest 61.3 ft (18.7 m) downstream of impact. The support then rode along with the vehicle and came to rest on the hood, windshield, and roof edge of the vehicle 100.1 ft (30.5 m) downstream of impact. The support was only slightly deformed and was considered to be reusable.

Vehicle Damage

The vehicle sustained minor scrapes to the front bumper and hood during initial contact with the sign support. As the vehicle traveled through the test site, the support fell against the roof and windshield of the vehicle. As shown in Figure 13, the windshield was shattered; however, visibility was not obstructed. The exterior of the roof was deformed downward a maximum of 2.8 in (72 mm). Maximum occupant compartment deformation in that area was 2 in (52 mm). Photographs of the interior of the vehicle are shown in Figure 14. Exterior vehicle crush and occupant compartment deformation are presented in Appendix B, Tables 3 and 4.

Occupant Risk Factors

Data from the accelerometer located at the vehicle center of gravity were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity was 3.0 ft/s (0.9 m/s) at 0.732 s, the highest 0.010-s occupant ridedown acceleration was 0.6 g's from 1.014 to 1.024 s, and the maximum 0.050-s average acceleration was –0.9 g's between 0.163 and 0.213 s. In the lateral direction, the occupant impact velocity was 0.7 ft/s (0.2 m/s) at 0.732 s, the highest 0.010-s occupant ridedown acceleration was 0.3 g's from 1.124 to 1.134 s, and the maximum 0.050-s average was 0.4 g's between 0.205 and 0.255 s. These data and other pertinent information from the test are summarized in Figure 15. Vehicle angular displacements and accelerations versus time traces are presented in Appendix D, Figures 27 and 29 through 34, respectively.

Figure 11. After Impact Trajectory for Test 417922-1.

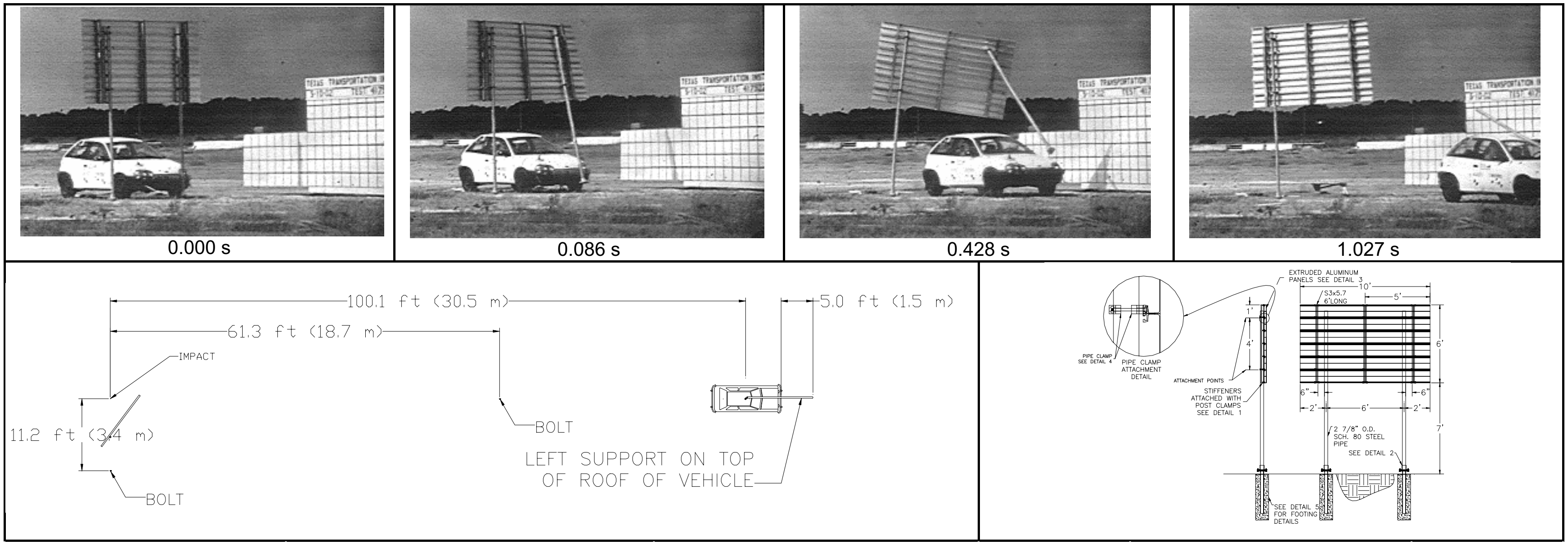
Figure 12. Installation after Test 417922-1.

Figure 13. Vehicle after Test 417922-1.

Before Test

After Test

Figure 14. Interior of Vehicle for Test 417922-1.



General Information
- Test Agency .... Texas Transportation Institute
- Test No. 417922-1
- Date 05/10/02

Test Article
- Type .... Sign Support
- Name .... Dual Support, Triangular Slip Base Sign
- Installation Length (ft) .... N/A
- Material or Key Elements .... Schedule 80 Pipe Supports, Aluminum Sign Panel And Triangular Slip Base

Soil Type and Condition .... Standard Soil, Dry

Test Vehicle
- Type .... Production
- Designation 820C
- Model .... 1998 Geo Metro
- Mass (lbs)
  - Curb .... 1786 (811 kg)
  - Test Inertial .... 1806 (820 kg)
  - Dummy.............................. 163 (74 kg)
  - Gross Static .... 1969 (894 kg)

Impact Conditions
- Speed (mi/h)................................ 21.7 (34.9 km/h)
- Angle (deg).................................. 0.0

Exit Conditions
- Speed (mi/h)................................ 18.5 (29.7 km/h)
- Angle (deg).................................. 0.0

Occupant Risk Values
- Impact Velocity (ft/s)
  - x-direction................................ 2.9 (0.9 m/s)
  - y-direction................................ 0.7 (0.2 m/s)
- THIV (mi/h) .... 11.1 (3.4 m/s)
- Ridedown Accelerations (g's)
  - x-direction................................ 0.6
  - y-direction................................ 0.3
- PHD (g's)...................................... 0.6
- ASI 0.10
- Max. 0.050-s Average (g's)
  - x-direction................................ -0.9
  - y-direction................................ 0.4
  - z-direction................................ -0.8

Test Article Debris Scatter (ft)
- Longitudinal.......................... 100.1 (30.5 m)
- Lateral .... 11.3 (3.4 m)
- Working Width .... N/A

Vehicle Damage
- Exterior
  - VDS.................................. 12FC1
  - CDC 12TPCN1
- Maximum Exterior
  - Vehicle Crush (in) .... None
- Interior
  - OCDI FS0100000
- Max. Occ. Compart.
  - Deformation (in) .... 2 (52 mm)

Post-Impact Behavior
- (during 1.0 s after impact)
- Max. Yaw Angle (deg)........... -0.6
- Max. Pitch Angle (deg).......... -3.1
- Max. Roll Angle (deg) .... -1.6

Figure 15. Summary of Results for Test 417922-1, *NCHRP Report 350* Test 3-60.

Assessment of Test Results

An assessment of the test based on the applicable *NCHRP Report 350* safety evaluation criteria is provided below.

- **Structural Adequacy**

  B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.

  Results: The slip base sign support readily yielded to the vehicle as designed by slipping away at the base of the support (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.

  Results: One leg of the dual support separated at the base and at the attachment to the sign panel. The sign panel remained near the impact point and the support traveled along with the vehicle. The support fell against the roof and windshield of the vehicle, shattering the windshield, but neither the support nor the damage to the windshield restricted visibility. Maximum occupant compartment deformation was 2.0 in (52 mm) (pass).

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

  Results: The vehicle remained upright during and after the collision period (pass).

  H. Occupant impact velocities should satisfy the following:

  Longitudinal and Lateral Occupant Impact Velocity – m/s

Preferred	*Maximum*
3	*5*

  Results: Longitudinal occupant impact velocity was 3.0 ft/s (0.9 m/s) and lateral occupant impact velocity was 0.7 ft/s (0.2 m/s) (pass).

  I. Occupant ridedown accelerations should satisfy the following:

  Longitudinal and Lateral Occupant Ridedown Accelerations – g's

Preferred	*Maximum*
15	*20*

  Results: Longitudinal ridedown acceleration was 0.6 g's, and lateral ridedown acceleration was 0.3 g's (pass).

♦ **Vehicle Trajectory**

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

Results: The vehicle did not intrude into adjacent traffic lanes (pass).

N. Vehicle trajectory behind the test article is acceptable.

Results: The vehicle came to rest behind the sign support installation (pass).

In addition, the 1994 AASHTO Specification states:

"Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800 pound (816.5 kg) vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph (32 km/h to 97 km/h) does not exceed 16 fps (4.87 m/s), but preferably does not exceed 10 fps (3.05 m/s)…"

Results: Maximum change in velocity was 4.7 ft/s (1.4 m/s) (pass).

"To avoid vehicle undercarriage snagging, any substantial remains of a breakaway support, when it is broken away, should not project more than four inches (102 mm) above a 60-inch (1524 mm) chord aligned radially to the centerline of the highway and connecting any point, within the length of the chord, on the ground surface on one side of the support to a point on the ground surface on the other side."

Results: The height to the top of the lower portion of the base remaining in the ground was 3.3 in (85 mm) (pass).

The following supplemental evaluation factors and terminology, as presented in the FHWA memo entitled "Action: Identifying Acceptable Highway Safety Features," were used for visual assessment of test results:

♦ **Passenger Compartment Intrusion**

1. Windshield Intrusion
   a. No windshield contact
   b. Windshield contact, no damage
   c. <u>Windshield contact, no intrusion</u>
   d. Device embedded in windshield, no significant intrusion
   e. Complete intrusion into passenger compartment
   f. Partial intrusion into passenger compartment
2. Body Panel Intrusion — <u>yes</u> or no

- **Loss of Vehicle Control**
  1. Physical loss of control
  2. Loss of windshield visibility
  3. Perceived threat to other vehicles
  4. Debris on pavement

- **Physical Threat to Workers or Other Vehicles**
  1. Harmful debris that could injure workers or others in the area
  2. Harmful debris that could injure occupants in other vehicles

     If yes,
     Mass: 94.3 lb (42.8 kg)
     Speed: high or low
     Trajectory: rode along with vehicle

- **Vehicle and Device Condition**
  1. Vehicle Damage
     a. None
     b. Minor scrapes, scratches, or dents
     c. Significant cosmetic dents
     d. Major dents to grill and body panels
     e. Major structural damage
  2. Windshield Damage
     a. None
     b. Minor chip or crack
     c. Broken, no interference with visibility
     d. Broken or shattered, visibility restricted but remained intact
     e. Shattered, remained intact but partially dislodged
     f. Large portion removed
     g. Completely removed
  3. Device Damage
     a. None
     b. Superficial
     c. Substantial, but can be straightened
     d. Substantial, replacement parts needed for repair
     e. Cannot be repaired

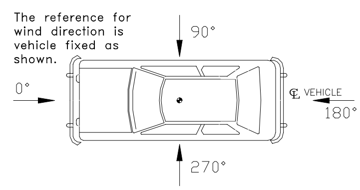
TEST NO. 417922-2 (*NCHRP Report 350* TEST NO. 3-61)

Test Vehicle

A 1997 Geo Metro, shown in Figures 16 and 17, was used for the crash test. Test inertia mass of the vehicle was 1806 lb (820 kg), and its gross static mass was 1943 lb (896 kg). The height to the lower edge of the vehicle bumper was 15.7 in (400 mm), and the height to the upper edge of the bumper was 20.7 in (525 mm). Additional dimensions and information on the vehicle are given in Appendix B, Figure 24. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed on the afternoon of May 10, 2002. No rainfall was recorded during the 10 days prior to the test. Moisture content of the *NCHRP Report 350* soil in which the device was installed was 6 percent. Weather conditions at the time of testing were as follows: Wind speed: 5 mi/h (8 km/h); Wind direction: 190 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 86°F (30°C); Relative humidity: 85 percent.



Test Description

The left front quarter point of the vehicle impacted the left support traveling at a speed of 61.4 mi/h (98.8 km/h) and an impact angle of 0 degree. Immediately after impact, the support began to move, and at 0.017 s, the upper slip base separated from the lower base. The support began to pull out of the top bracket at 0.051 s, and the lower bracket fractured at 0.061s. By 0.075 s, the support had completely pulled out of the top bracket. At 0.082 s, the vehicle lost contact with the support, and the vehicle was traveling at a speed of 59.3 mi/h (95.4 km/h). As the vehicle continued traveling forward, the support went up and over the vehicle and was parallel with the ground at 0.204 s. Brakes on the vehicle were applied at 1.5 s after impact, and the vehicle subsequently came to rest 455.3 ft (138.8 m) downstream of impact and 82.6 ft (16.0 m) to the left of centerline. Appendix C, Figure 26 shows sequential photographs of the test period.

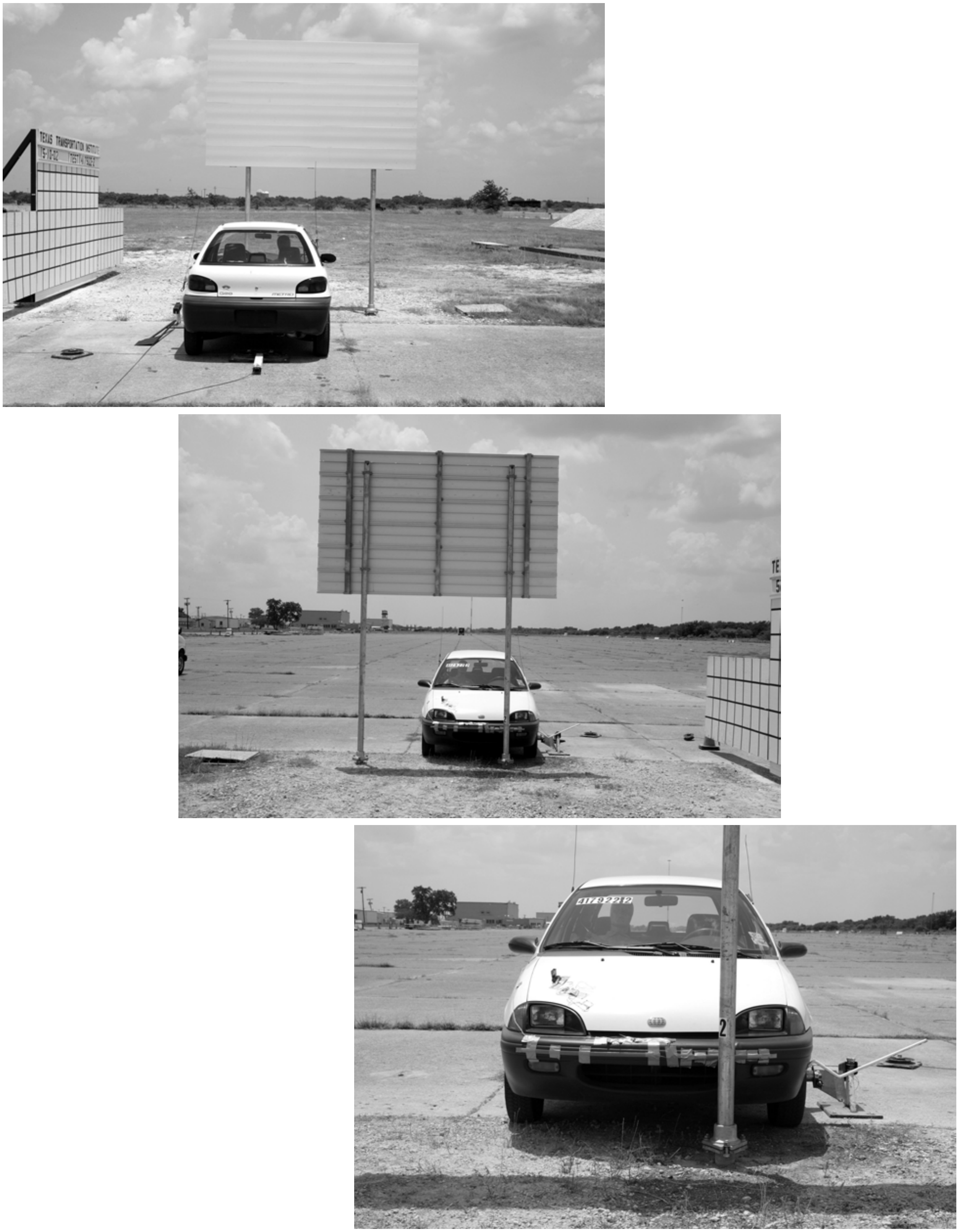


Figure 16. Vehicle/Installation Geometrics for Test 417922-2.

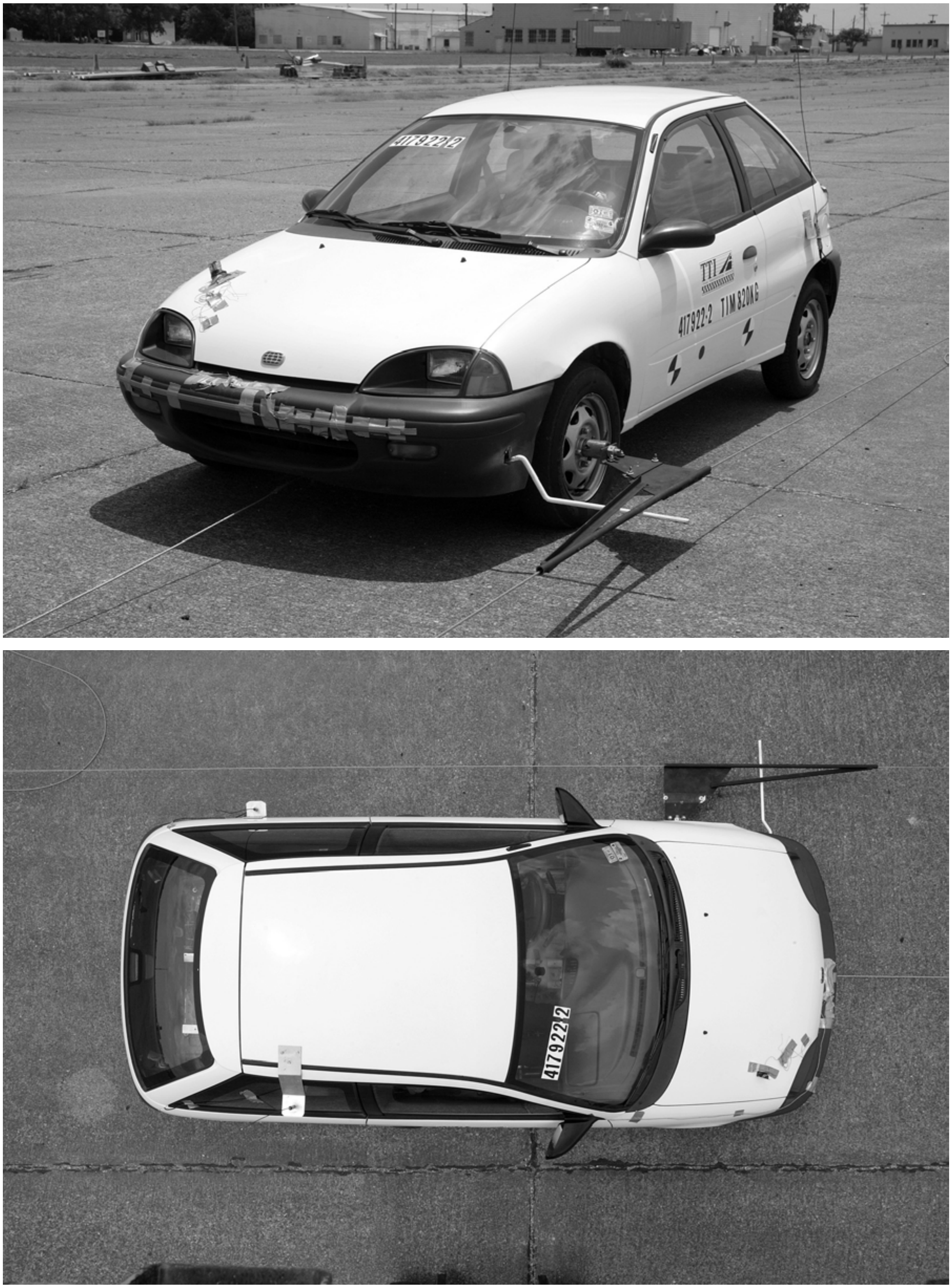


Figure 17. Vehicle before Test 417922-2.

Damage to Test Installation

Damage to the sign installation is shown in Figures 18 and 19. The right support remained attached to the base, but separated from the sign panel. The sign panel came to rest against this support. The left support and upper slip base separated from the lower base and the sign panel and traveled over the vehicle to come to rest 97.4 ft (29.7 m) downstream and 2.5 ft (0.8 m) to the left of impact. One of the slip base bolts came to rest 5.7 in (145 mm) to the left of the base, the second came to rest 2.6 ft (0.8 m) downstream and 20.0 ft (6.1 m) to the right of the base, and the third came to rest 225.1 ft (68.6 m) downstream and 2.6 ft (0.8 m) to the left of the base. The left support was deformed slightly and the lower casting used to attach the support to the sign panel fractured. The right support could be reused, but the sign panel would likely need to be replaced.

Vehicle Damage

The vehicle sustained minor dents and scrapes to the front bumper and hood during initial contact with the sign support, as shown in Figure 20. Also damaged were the left front quarter panel, radiator, and fan. Maximum exterior crush to the vehicle was 4.7 in (120 mm) in the frontal plane at the left quarter point at bumper height. There was no deformation of the occupant compartment. Figure 21 shows photographs of the interior of the vehicle. Exterior vehicle crush and occupant compartment deformation are presented in Appendix B, tables 5 and 6.

Occupant Risk Factors

Data from the accelerometer located at the vehicle center of gravity were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity was 2.6 ft/s (0.8 m/s) at 0.580 s, the highest 0.010-s occupant ridedown acceleration was –0.7 g's from 1.712 to 1.722 s, and the maximum 0.050-s average acceleration was –1.9 g's between 0.003 and 0.053 s. In the lateral direction, the occupant impact velocity was 3.3 ft/s (1.0 m/s) at 0.580 s, the highest 0.010-s occupant ridedown acceleration was 0.4 g's from 1.246 to 1.256 s, and the maximum 0.050-s average was –0.4 g's between 0.038 and 0.088 s. Figure 22 summarizes these data and other pertinent information from the test. Vehicle angular displacements and accelerations versus time traces are presented in Appendix D, Figures 28 and 35 through 40, respectively.

Figure 18. After Impact Trajectory for Test 417922-2.

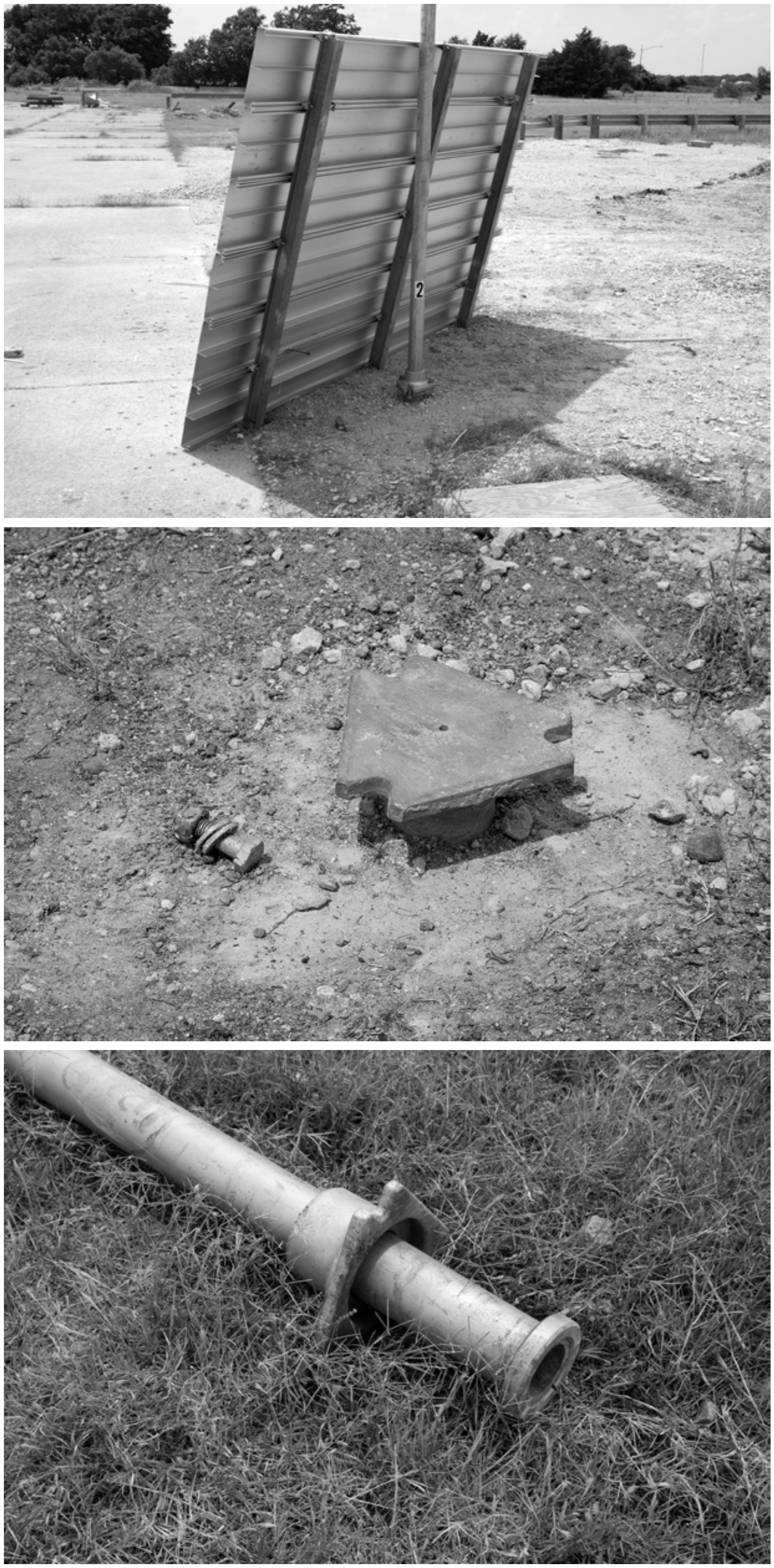


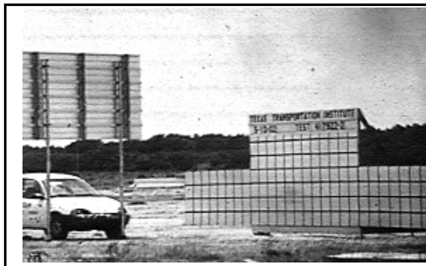
Figure 19. Installation after Test 417922-2.

Figure 20. Vehicle after Test 417922-2.

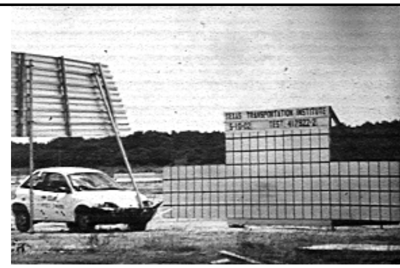
Before Test

After Test

Figure 21. Interior of Vehicle for Test 417922-2.



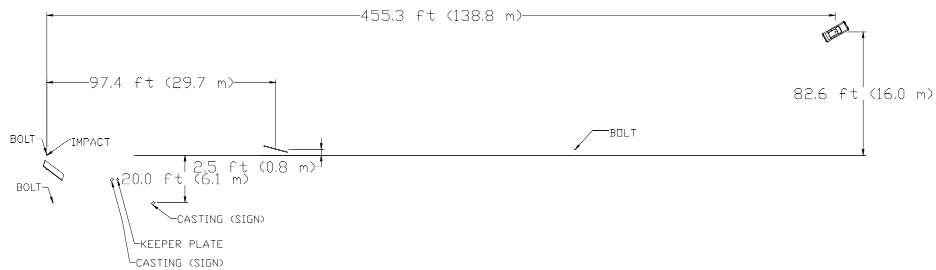
0.000 s

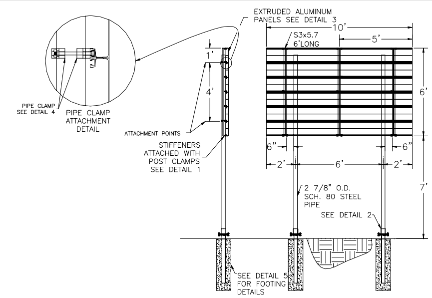


0.063 s

0.231 s

0.399 s





General Information	
Test Agency	Texas Transportation Institute
Test No.	417922-2
Date	05/10/02
Test Article	
Type	Sign Support
Name	Dual Support, Triangular Slip Base Sign
Installation Length (ft)	N/A
Material or Key Elements	Schedule 80 Supports, Aluminum Sign Panel And Triangular Slip Base
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	820C
Model	1997 Geo Metro
Mass (lbs)	
Curb	1755 (797 kg)
Test Inertial	1806 (820 kg)
Dummy	167 (76 kg)
Gross Static	1973 (896 kg)

Impact Conditions	
Speed (mi/h)	61.4 (98.8 km/h)
Angle (deg)	0.0
Exit Conditions	
Speed (mi/h)	58.4 (94.1 km/h)
Angle (deg)	0.0
Occupant Risk Values	
Impact Velocity (ft/s)	
x-direction	2.6 (0.8 m/s)
y-direction	3.3 (1.0 m/s)
THIV (mi/h)	15.4 (4.7 m/s)
Ridedown Accelerations (g's)	
x-direction	-0.7
y-direction	0.4
PHD (g's)	0.7
ASI	0.16
Max. 0.050-s Average (g's)	
x-direction	-1.9
y-direction	-0.4
z-direction	-0.8

Test Article Debris Scatter (ft)	
Longitudinal	225.1 (68.6 m)
Lateral	22.5 (6.9 m)
Working Width	N/A
Vehicle Damage	
Exterior	
VDS	12FC2
CDC	12FLMN2
Maximum Exterior Vehicle Crush (in)	4.7 (120 mm)
Interior	
OCDI	LF0000000
Max. Occ. Compart. Deformation (in)	None
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	-5.9
Max. Pitch Angle (deg)	1.5
Max. Roll Angle (deg)	2.8

Figure 22. Summary of Results for Test 417922-2, *NCHRP Report 350* Test 3-61.

Assessment of Test Results

An assessment of the test based on the applicable *NCHRP Report 350* safety evaluation criteria is provided below.

- **Structural Adequacy**

  B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.

  Results: The slip base sign support readily yielded to the vehicle as designed by slipping away at the base of the support (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.

  Results: One leg of the dual support separated at the base and at the attachment to the sign panel. The sign panel remained near the impact point, and the support traveled over the vehicle. No occupant compartment deformation occurred (pass).

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

  Results: The vehicle remained upright during and after the collision period (pass).

  H. Occupant impact velocities should satisfy the following:

  Longitudinal and Lateral Occupant Impact Velocity – m/s

Preferred	*Maximum*
3	*5*

  Results: Longitudinal occupant impact velocity was 2.6 ft/s (0.8 m/s), and lateral occupant impact velocity was 3.3 ft/s (1.0 m/s) (pass).

  I. Occupant ridedown accelerations should satisfy the following:

  Longitudinal and Lateral Occupant Ridedown Accelerations – g's

Preferred	*Maximum*
15	*20*

  Results: Longitudinal ridedown acceleration was -0.7 g's, and lateral ridedown acceleration was 0.4 g's (pass).

- **Vehicle Trajectory**

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

  Results: The vehicle did not intrude into adjacent traffic lanes (pass).

  N. Vehicle trajectory behind the test article is acceptable.

  Results: The vehicle came to rest behind the sign support installation (pass).

In addition, the 1994 AASHTO Specification states:

"Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800 pound (816.5 kg) vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph (32 km/h to 97 km/h) does not exceed 16 fps (4.87 m/s), but preferably does not exceed 10 fps (3.05 m/s)…"

Results: Maximum change in velocity was 4.3 ft/s (1.3 m/s) (pass).

"To avoid vehicle undercarriage snagging, any substantial remains of a breakaway support, when it is broken away, should not project more than four inches (102 mm) above a 60-inch (1524 mm) chord aligned radially to the centerline of the highway and connecting any point, within the length of the chord, on the ground surface on one side of the support to a point on the ground surface on the other side."

Results: The height to the top of the lower portion of the base remaining in the ground was 3.3 in (85 mm) (pass).

The following supplemental evaluation factors and terminology, as presented in the FHWA memo entitled "Action: Identifying Acceptable Highway Safety Features," were used for visual assessment of test results:

- **Passenger Compartment Intrusion**
  1. Windshield Intrusion
     - a. <u>No windshield contact</u>
     - b. Windshield contact, no damage
     - c. Windshield contact, no intrusion
     - d. Device embedded in windshield, no significant intrusion
     - e. Complete intrusion into passenger compartment
     - f. Partial intrusion into passenger compartment
  2. Body Panel Intrusion — yes or <u>no</u>

- **Loss of Vehicle Control**
  1. Physical loss of control
  2. Loss of windshield visibility
  3. Perceived threat to other vehicles
  4. <u>Debris on pavement</u>

- **Physical Threat to Workers or Other Vehicles**
  1. Harmful debris that could injure workers or others in the area
  2. Harmful debris that could injure occupants in other vehicles

     If yes,

     Mass: 94.3 lb (42.8 kg)

     Speed: high or low

     Trajectory: traveled over vehicle

- **Vehicle and Device Condition**
  1. Vehicle Damage
     a. None
     b. Minor scrapes, scratches or dents
     c. Significant cosmetic dents
     d. Major dents to grill and body panels
     e. Major structural damage
  2. Windshield Damage
     a. None
     b. Minor chip or crack
     c. Broken, no interference with visibility
     d. Broken or shattered, visibility restricted but remained intact
     e. Shattered, remained intact but partially dislodged
     f. Large portion removed
     g. Completely removed
  3. Device Damage
     a. None
     b. Superficial
     c. Substantial, but can be straightened
     d. Substantial, replacement parts needed for repair
     e. Cannot be repaired

CHAPTER 4. SUMMARY AND CONCLUSIONS

SUMMARY OF TEST RESULTS

Test 417922-1 – *NCHRP Report 350* Test 3-60

The slip base sign support readily yielded to the vehicle as designed by slipping away at the base of the support. One leg of the dual support separated at the base and at the attachment to the sign panel. The sign panel remained near the impact point, and the support traveled along with the vehicle. The support fell against the roof and windshield of the vehicle, shattering the windshield, but neither the support nor the damage to the windshield restricted visibility. Maximum occupant compartment deformation was 2.0 in (52 mm). The vehicle remained upright during and after the collision period. Longitudinal occupant impact velocity was 3.0 ft/s (0.9 m/s), and lateral occupant impact velocity was 0.7 ft/s (0.2 m/s). Longitudinal ridedown acceleration was 0.6 g's, and lateral ridedown acceleration was 0.3 g's. The vehicle came to rest behind the initial location of the test article and did not intrude into adjacent traffic lanes. Maximum change in velocity was 4.7 ft/s (1.4 m/s). The height to the top of the lower base remaining in the ground was 3.3 in (85 mm).

Test 417922-2 – *NCHRP Report 350* Test 3-61

The slip base sign support readily yielded to the vehicle as designed by slipping away at the base of the support. One leg of the dual support separated at the base and at the attachment to the sign panel. The sign panel remained near the impact point, and the support traveled over the vehicle. No occupant compartment deformation occurred. The vehicle remained upright during and after the collision period. Longitudinal occupant impact velocity was 2.6 ft/s (0.8 m/s), and lateral occupant impact velocity was 3.3 ft/s (1.0 m/s). Longitudinal ridedown acceleration was -0.7 g's, and lateral ridedown acceleration was 0.4 g's. The vehicle came to rest behind the initial location of the test article and did not intrude into adjacent traffic lanes. Maximum change in velocity was 4.3 ft/s (1.3 m/s). The height to the top of the lower base remaining in the ground was 3.3 in (85 mm).

CONCLUSIONS

The extruded aluminum sign panel supported on dual schedule 80 pipe supports with triangular slip bases performed acceptably in accordance with *NCHRP Report 350* safety evaluation criteria for both a low speed and high speed impact, as shown in Tables 1 and 2, respectively.

Table 1. Performance Evaluation Summary for Test 417922-1, *NCHRP Report 350* Test 3-60.

Test Agency: Texas Transportation Institute	Test No.: 417922-1	Test Date: 05/10/02

<table>
<tr><th>NCHRP Report 350 3-60 Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td><u>Structural Adequacy</u>
B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</td><td>The slip base sign support readily yielded to the vehicle as designed by slipping away at the base of the support.</td><td>Pass</td></tr>
<tr><td><u>Occupant Risk</u>
D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td><td>One leg of the dual support separated at the base and at the attachment to the sign panel. The sign panel remained near the impact point, and the support traveled along with the vehicle. The support fell against the roof and windshield of the vehicle, shattering the windshield, but neither the support nor the damage to the windshield restricted visibility. Maximum occupant compartment deformation was 2.0 in (52 mm).</td><td>Pass</td></tr>
<tr><td>F. The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.</td><td>The vehicle remained upright during and after the collision period.</td><td>Pass</td></tr>
<tr><td>H. Occupant impact velocities should satisfy the following:<table><tr><th colspan="3">Occupant Velocity Limits (m/s)</th></tr><tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr><tr><td>Longitudinal</td><td>3</td><td>5</td></tr></table></td><td>Longitudinal occupant impact velocity was 3.0 ft/s (0.9 m/s), and lateral occupant impact velocity was 0.7 ft/s (0.2 m/s).</td><td>Pass</td></tr>
<tr><td>I. Occupant ridedown accelerations should satisfy the following:<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits (g’s)</th></tr><tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr><tr><td>Longitudinal and lateral</td><td>15</td><td>20</td></tr></table></td><td>Longitudinal ridedown acceleration was 0.6 g’s, and lateral ridedown acceleration was 0.3 g’s.</td><td>Pass</td></tr>
<tr><td><u>Vehicle Trajectory</u>
K. After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.</td><td>The vehicle did not intrude into adjacent traffic lanes.</td><td>Pass</td></tr>
<tr><td>N. Vehicle trajectory behind the test article is acceptable.</td><td>The vehicle came to rest behind the installation.</td><td>Pass</td></tr>
</table>

Table 2. Performance Evaluation Summary for Test 417922-2, *NCHRP Report 350* Test 3-61.

Test Agency: Texas Transportation Institute | Test No.: 417922-2 | Test Date: 05/10/02

NCHRP Report 350 3-61 Evaluation Criteria	Test Results	Assessment
<u>Structural Adequacy</u> B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	The slip base sign support readily yielded to the vehicle as designed by slipping away at the base of the support.	Pass
<u>Occupant Risk</u> D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.	One leg of the dual support separated at the base and at the attachment to the sign panel. The sign panel remained near the impact point and the support traveled over the vehicle. No occupant compartment deformation occurred.	Pass
F. The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.	The vehicle remained upright during and after the collision period.	Pass
H. Occupant impact velocities should satisfy the following: Occupant Velocity Limits (m/s) Component: Longitudinal; Preferred: 3; Maximum: 5	Longitudinal occupant impact velocity was 2.6 ft/s (0.8 m/s), and lateral occupant impact velocity was 3.3 ft/s (1.0 m/s).	Pass
I. Occupant ridedown accelerations should satisfy the following: Occupant Ridedown Acceleration Limits (g's) Component: Longitudinal and lateral; Preferred: 15; Maximum: 20	Longitudinal ridedown acceleration was -0.7 g's, and lateral ridedown acceleration was 0.4 g's.	Pass
<u>Vehicle Trajectory</u> 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
N. Vehicle trajectory behind the test article is acceptable.	The vehicle came to rest behind the installation.	Pass

CHAPTER 5. IMPLEMENTATION STATEMENT

Extruded aluminum sign panels up to 60 ft^2 (5.6 m^2) mounted on dual 2.5-in (64 mm) diameter schedule 80 pipe supports with triangular slip bases met *NCHRP Report 350* requirements and are considered suitable for implementation. Four universal pipe clamps, two on each support, should be used in field installations. Figures 1 through 6 show details of the tested configuration. Extruded aluminum sign panel details and specifications are found in TxDOT SMD (2-1) through SMD (2-4). Schedule 80 pipe support with triangular slip base details and specifications are found in TxDOT SMD (1-1) through SMD (1-5).

REFERENCES

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

2. *Standard Specifications for Structural Support for Highway Signs, Luminaires, and Traffic Signals*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 1994.

APPENDIX A. CRASH TEST PROCEDURES AND DATA ANALYSIS

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

ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

Each test vehicle was instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates; a triaxial accelerometer near the vehicle center of gravity (cg) to measure longitudinal, lateral, and vertical acceleration levels; and a back-up biaxial accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. These accelerometers were ENDEVCO® Model 2262CA piezoresistive accelerometers with a ±100g range.

The accelerometers are strain gage type with a linear millivolt output proportional to acceleration. Angular rate transducers are solid state, gas flow units designed for high-"g" service. Signal conditioners and amplifiers in the test vehicle increase the low level signals to a ±2.5 volt maximum level. The signal conditioners also provide the capability of an R-cal (resistive calibration) or shunt calibration for the accelerometers and a precision voltage calibration for the rate transducers. The electronic signals from the accelerometers and rate transducers are transmitted to a base station by means of a 15-channel, constant-bandwidth, Inter-Range Instrumentation Group (IRIG), FM/FM telemetry link for recording on magnetic tape and for display on a real-time strip chart. Calibration signals from the test vehicle are recorded before the test and immediately afterwards. A crystal controlled time reference signal is simultaneously recorded with the data. Wooden dowels actuate pressure-sensitive switches on the bumper of the impacting vehicle prior to impact to indicate the elapsed time over a known distance, and, thereby provide a measurement of impact velocity. The initial contact also produces an "event" mark on the data record to establish the instant of contact with the installation.

The multiplex of data channels, transmitted on one radio frequency, is received and demultiplexed onto separate tracks of a 28-track, (IRIG) tape recorder. After each test, the data are played back from the tape machine and digitized. A proprietary software program (WinDigit) converts the analog data from each transducer into engineering units using the R-cal and pre-zero values at 10,000 samples per second, per channel. WinDigit also provides Society of Automotive Engineers (SAE) J211 class 180 phaseless digital filtering and vehicle impact velocity.

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

The Test Risk Assessment Program (TRAP) uses the data from WinDigit to compute occupant compartment impact velocities, time of occupant compartment impact after vehicle impact, and the highest 10-ms average ridedown acceleration. WinDigit calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact.

ANTHROPOMORPHIC DUMMY INSTRUMENTATION

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver's position of each 820C vehicle. The dummy was uninstrumented.

PHOTOGRAPHIC INSTRUMENTATION AND DATA PROCESSING

Photographic coverage of the test included two high-speed cameras: one behind the test article at a 45 degree angle to the vehicle path; and a second placed to have a field of view perpendicular to and aligned with the installation and vehicle path. A flash bulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked Motion Analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A BetaCam, a VHS-format video camera and recorder, and still cameras were used to record and document conditions of the test vehicle and installation before and after each test.

TEST VEHICLE PROPULSION AND GUIDANCE

Each test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A two-to-one speed ratio between the test and tow vehicle was used for the high-speed test. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site at which time brakes on the vehicle were activated to bring it to a safe and controlled stop.

APPENDIX B. TEST VEHICLE PROPERTIES AND INFORMATION

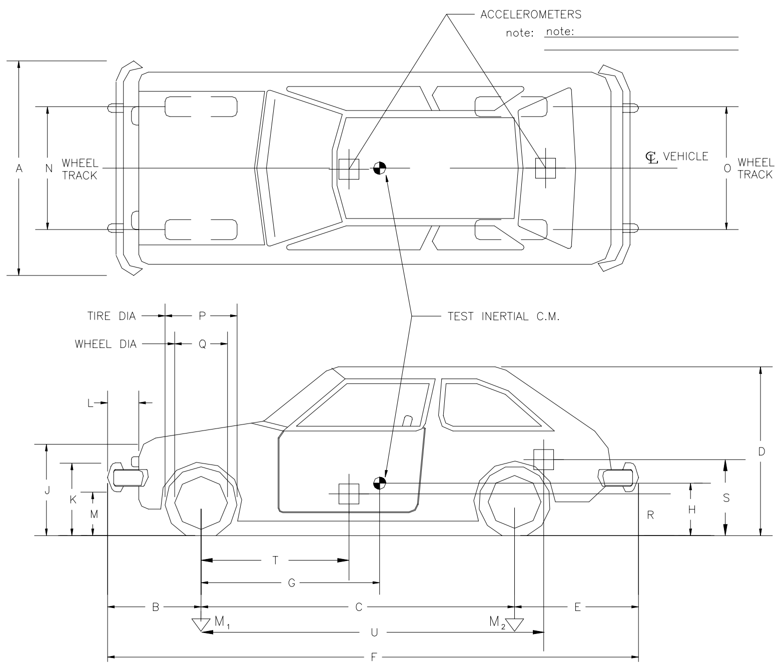
DATE: 05/10/02 TEST NO.: 417922-1 VIN NO.: 2C1MR2267X6709012

YEAR: 1998 MAKE: Geo MODEL: Metro

TIRE INFLATION PRESSURE: ______ ODOMETER: 53884 TIRE SIZE: P155 80R13

MASS DISTRIBUTION (kg) LF 257 RF 245 LR 161 RR 157

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL

ENGINE CID: 1.0 L

TRANSMISSION TYPE:

__ AUTO

X MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 74 kg

SEAT POSITION: driver

GEOMETRY – (mm)

A	1450	E	560	J	610	N	1380	R	400
B	730	F	3655	K	525	O	1365	S	555
C	2365	G	917.2	L	160	P	570	T	975
D	1430	H		M	400	Q	365	U	2445

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	498	502	536
M_2	313	318	358
M_T	811	820	894

Figure 23. Vehicle Properties for Test 417922-1.

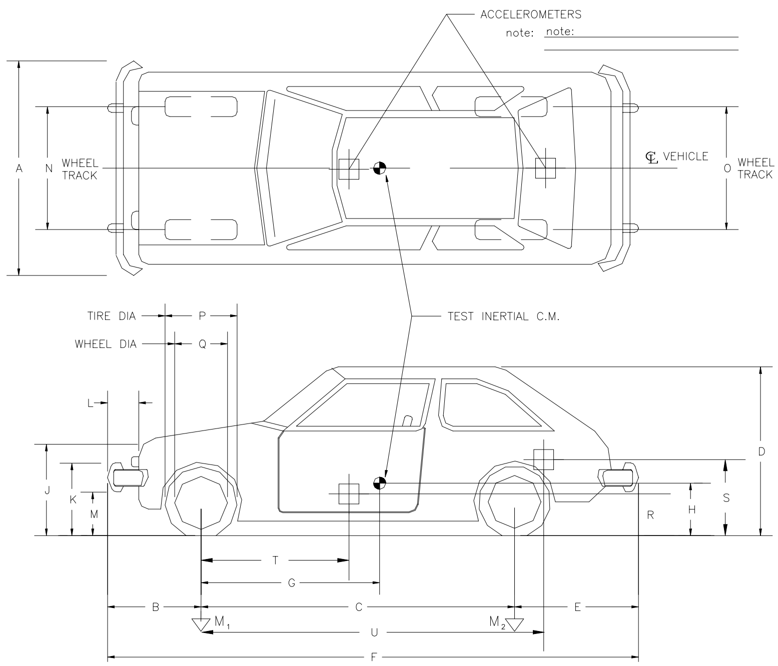
DATE: 05/10/02 TEST NO.: 417922-2 VIN NO.: 2C1MR2261V6763533

YEAR: 1997 MAKE: Geo MODEL: Metro

TIRE INFLATION PRESSURE: ______ ODOMETER: 47012 TIRE SIZE: P155 80R13

MASS DISTRIBUTION (kg) LF 257 RF 240 LR 164 RR 159

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL

ENGINE CID: 1.0 L

TRANSMISSION TYPE:

__ AUTO

X MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: driver

GEOMETRY – (mm)

A	1450	E	560	J	610	N	1380	R	400
B	730	F	3655	K	525	O	1365	S	555
C	2365	G	931.6	L	160	P	570	T	950
D	1430	H		M	400	Q	365	U	2450

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	496	497	533
M_2	301	323	363
M_T	797	820	896

Figure 24. Vehicle Properties for Test 417922-2.

Table 3. Exterior Crush Measurements for Test 417922-1.

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								

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

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

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

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

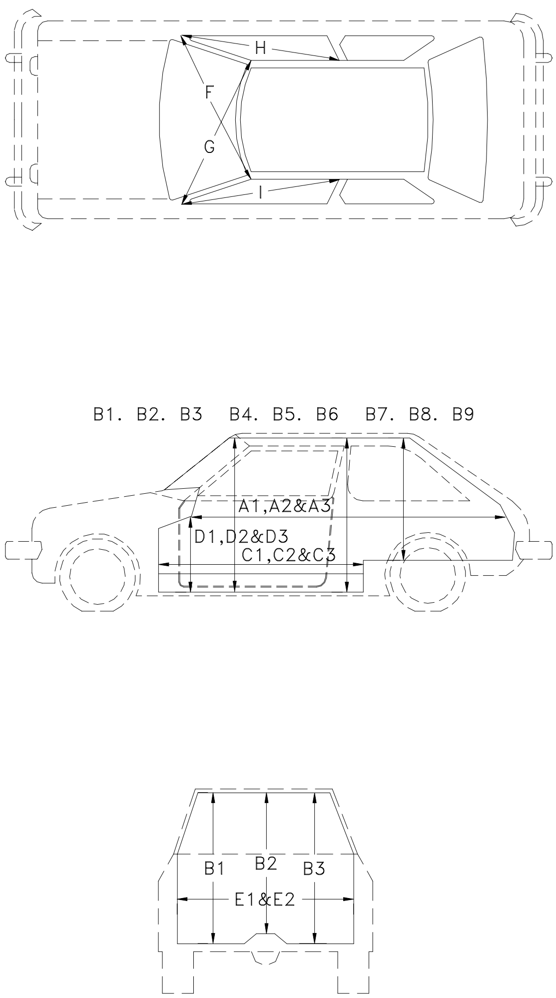
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Table 4. Occupant Compartment Measurements for Test 417922-1.

S m a l l   C a r

O c c u p a n t   C o m p a r t m e n t   D e f o r m a t i o n



	BEFORE	AFTER
A1	1426	1426
A2	1997	1997
A3	1410	1410
B1	895	890
B2	930	878
B3	892	890
B4	907	901
B5	896	860
B6	910	903
B7	761	761
B8		
B9	765	765
C1	559	559
C2	705	705
C3	555	555
D1	235	235
D2	130	130
D3	234	234
E1	1218	1218
E2	1181	1181
F	1213	1213
G	1213	1213
H	1000	1000
I	1000	1000
J	1200	1200

Table 5. Exterior Crush Measurements for Test 417922-2.

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front of hood	750	120	600	10	20	100	90	40	0	-30

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

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

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

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

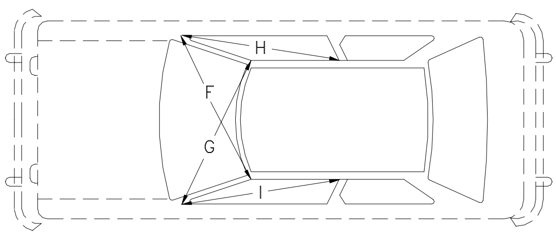
***Measure and document on the vehicle diagram the location of the maximum crush.

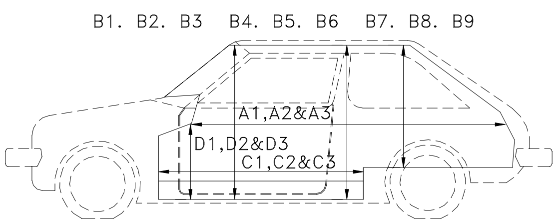
Note: Use as many lines/columns as necessary to describe each damage profile.

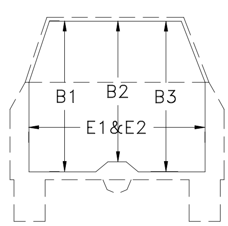
Table 6. Occupant Compartment Measurements for Test 417922-2.

Small Car

Occupant Compartment Deformation

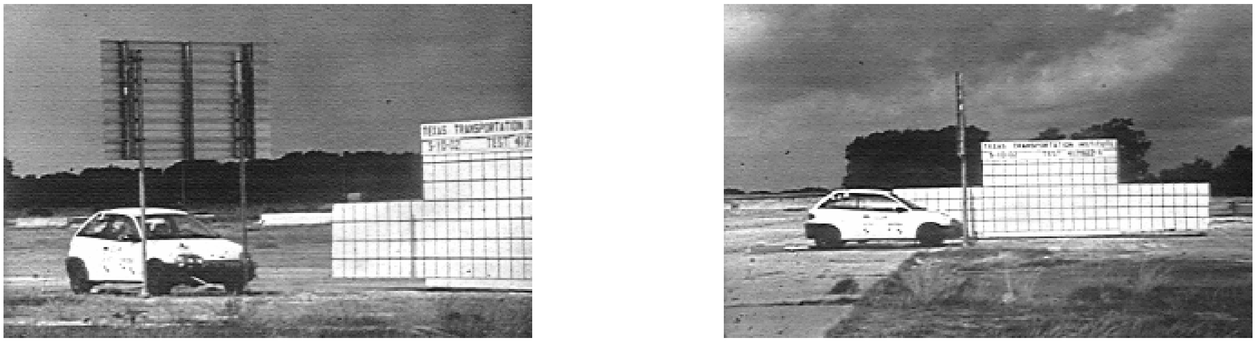




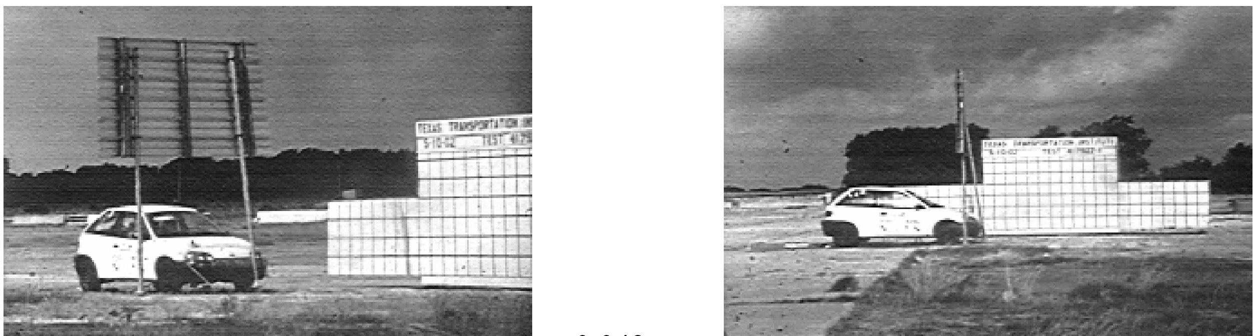


	BEFORE	AFTER
A1	1416	1416
A2	1990	1990
A3	1413	1413
B1	892	892
B2	911	911
B3	890	890
B4	910	910
B5	892	892
B6	917	917
B7	771	771
B8		
B9	771	771
C1	569	569
C2	715	715
C3	558	558
D1	245	245
D2	132	132
D3	245	245
E1	1216	1216
E2	1178	1178
F	1212	1212
G	1212	1212
H	1000	1000
I	1000	1000
J	1200	1200

APPENDIX C. SEQUENTIAL PHOTOGRAPHS



0.000 s



0.043 s

0.086 s

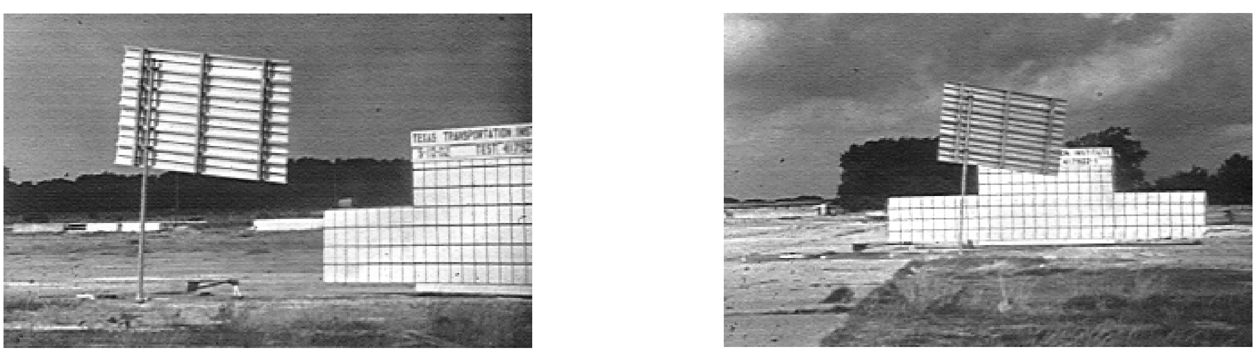
0.257 s

Figure 25. Sequential Photographs for Test 417922-1 (Oblique and Perpendicular Views).

0.428 s

0.684 s

1.027 s



1.497 s

Figure 25. Sequential Photographs for Test 417922-1 (Oblique and Perpendicular Views) (Continued).

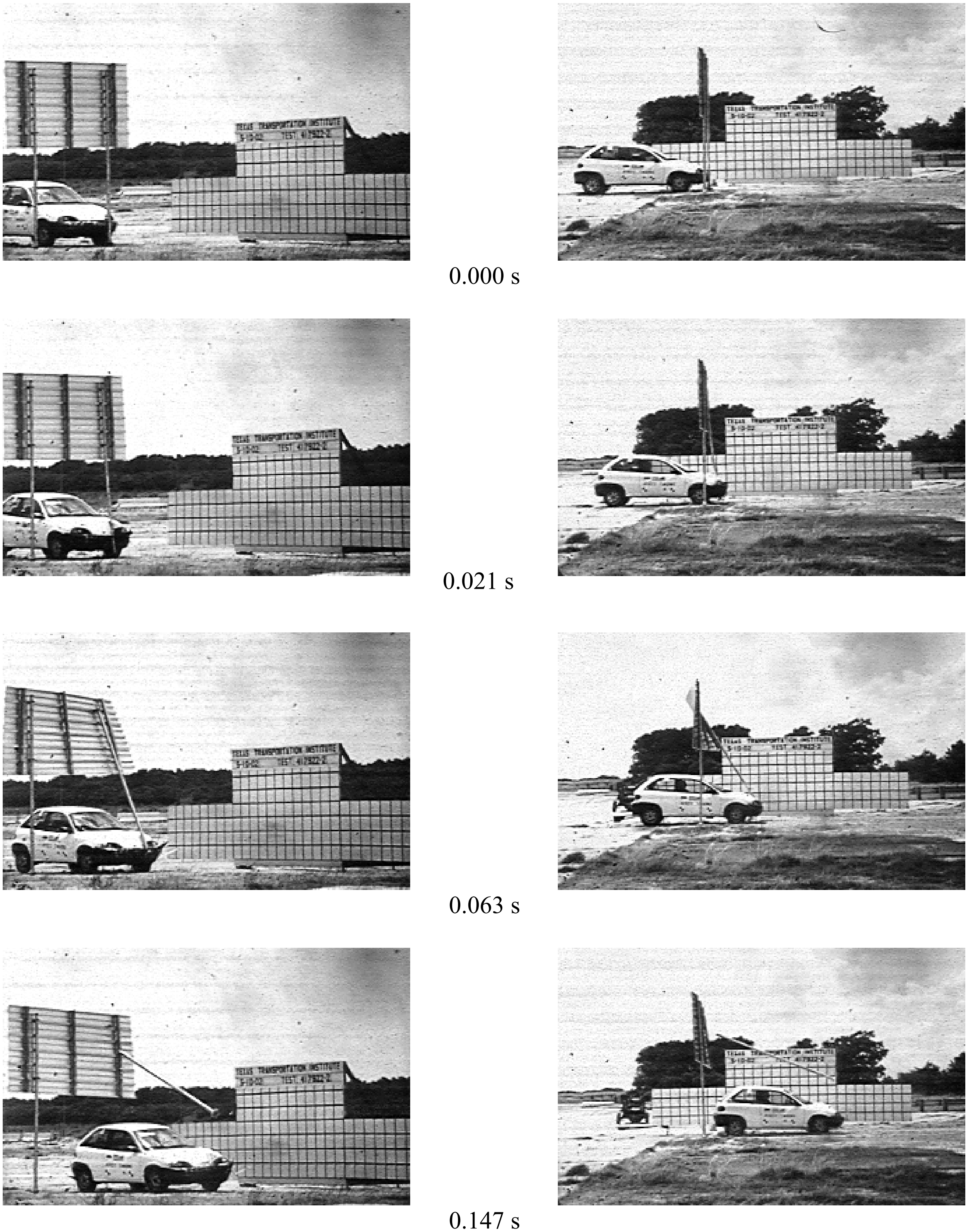
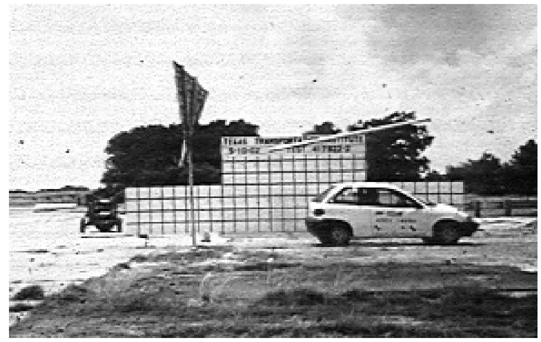
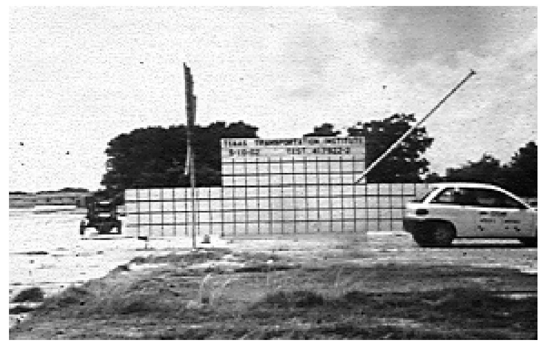


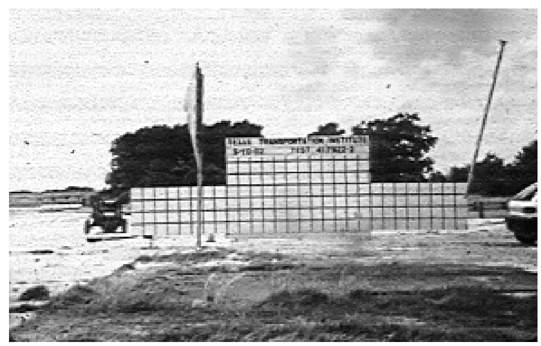
Figure 26. Sequential Photographs for Test 417922-2 (Oblique and Perpendicular Views).

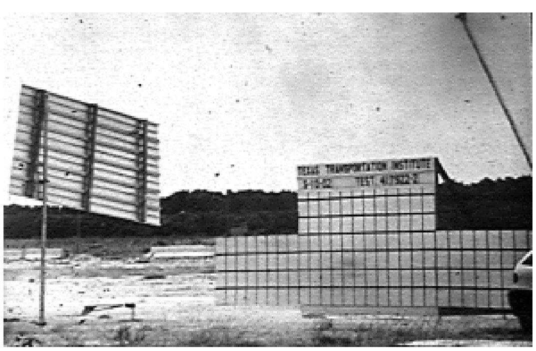
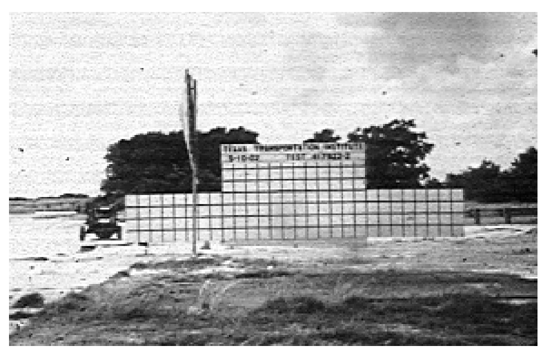
0.231 s

0.315 s

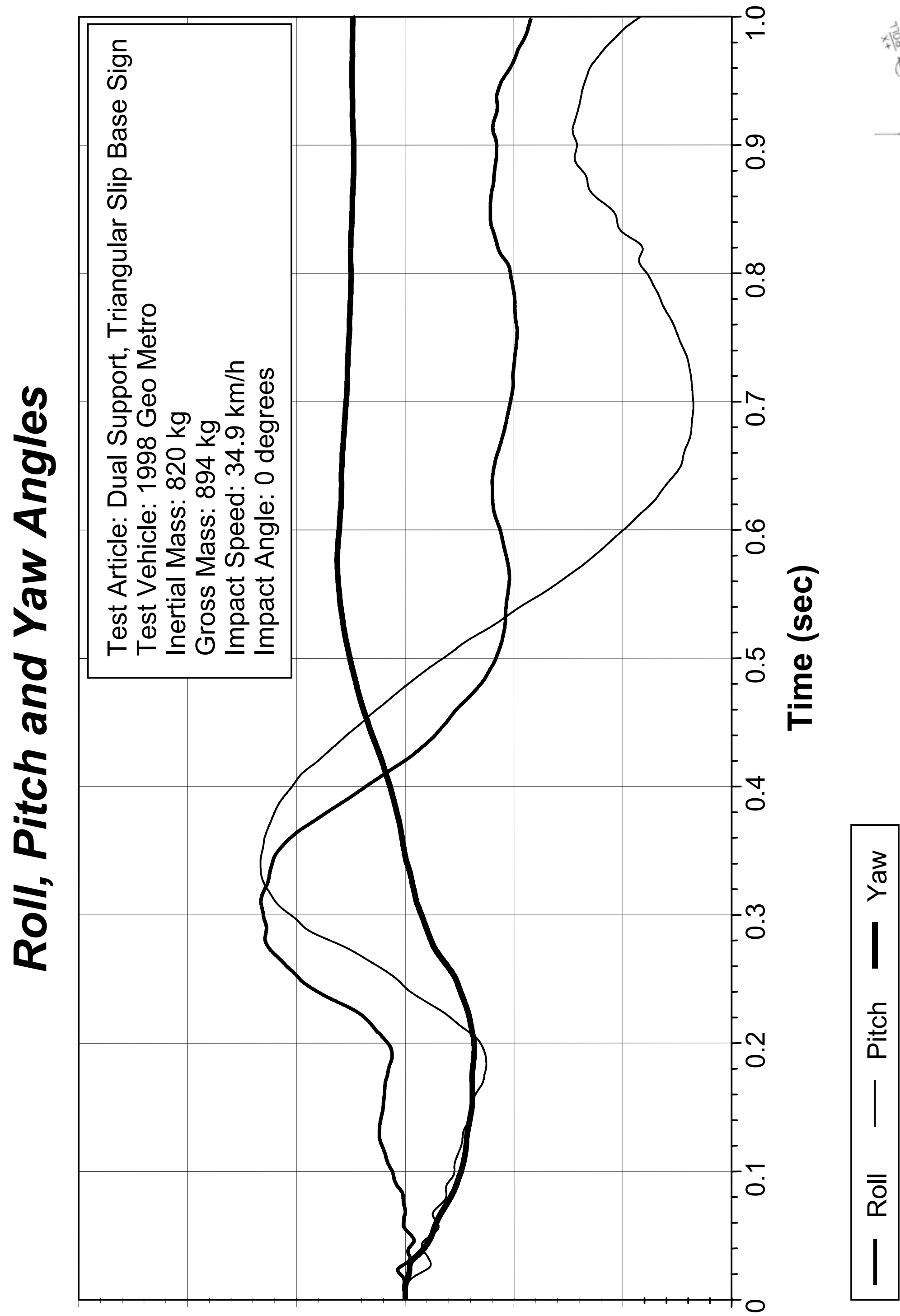
0.399 s

0.525 s

Figure 26. Sequential Photographs for Test 417922-2 (Oblique and Perpendicular Views) (Continued).

APPENDIX D. VEHICLE ANGULAR DISPLACEMENTS AND ACCELERATIONS



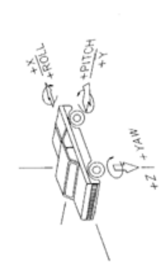


Figure 27. Vehicular Angular Displacements for Test 417922-1.

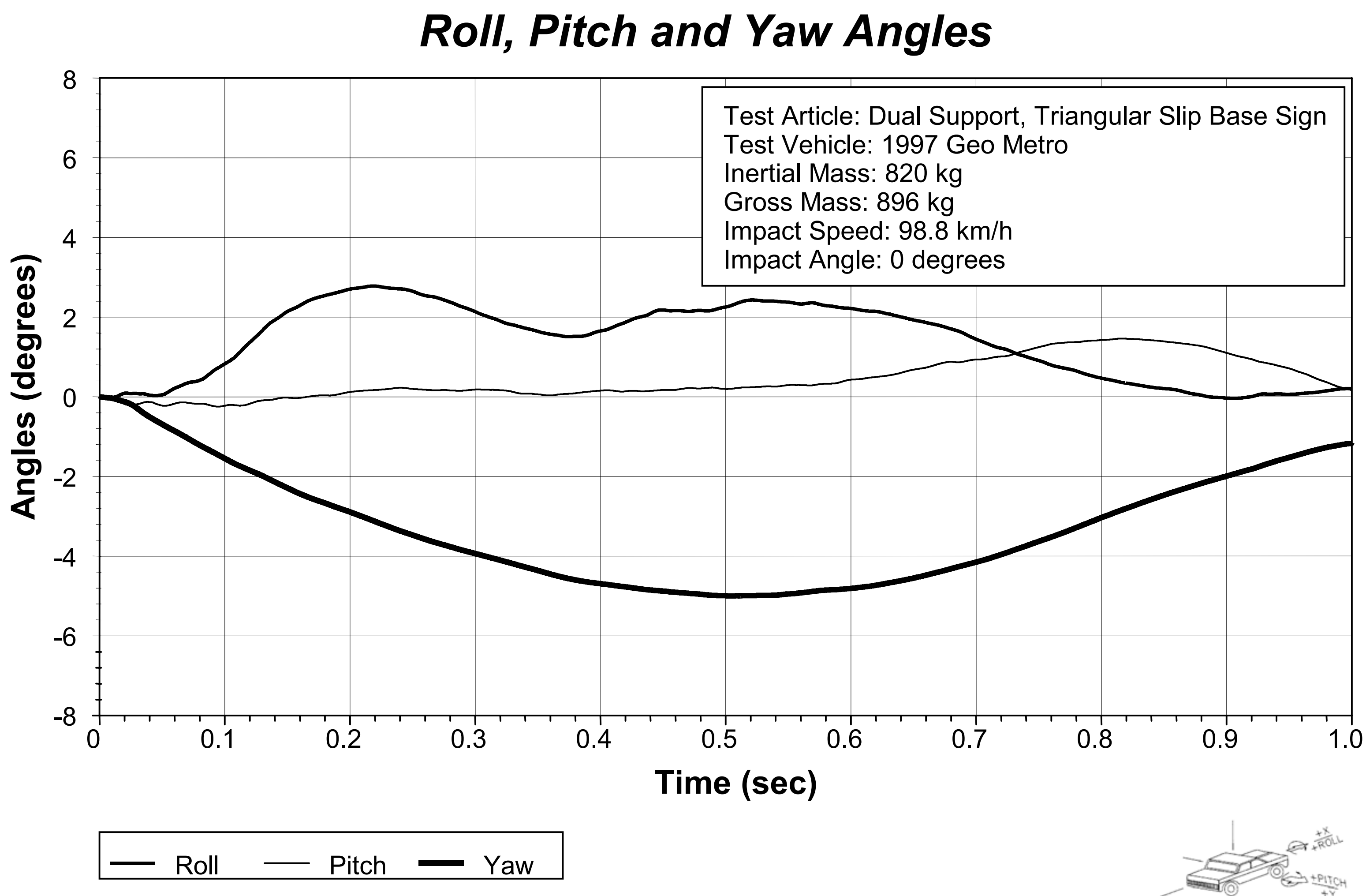


Figure 28. Vehicular Angular Displacements for Test 417922-2.

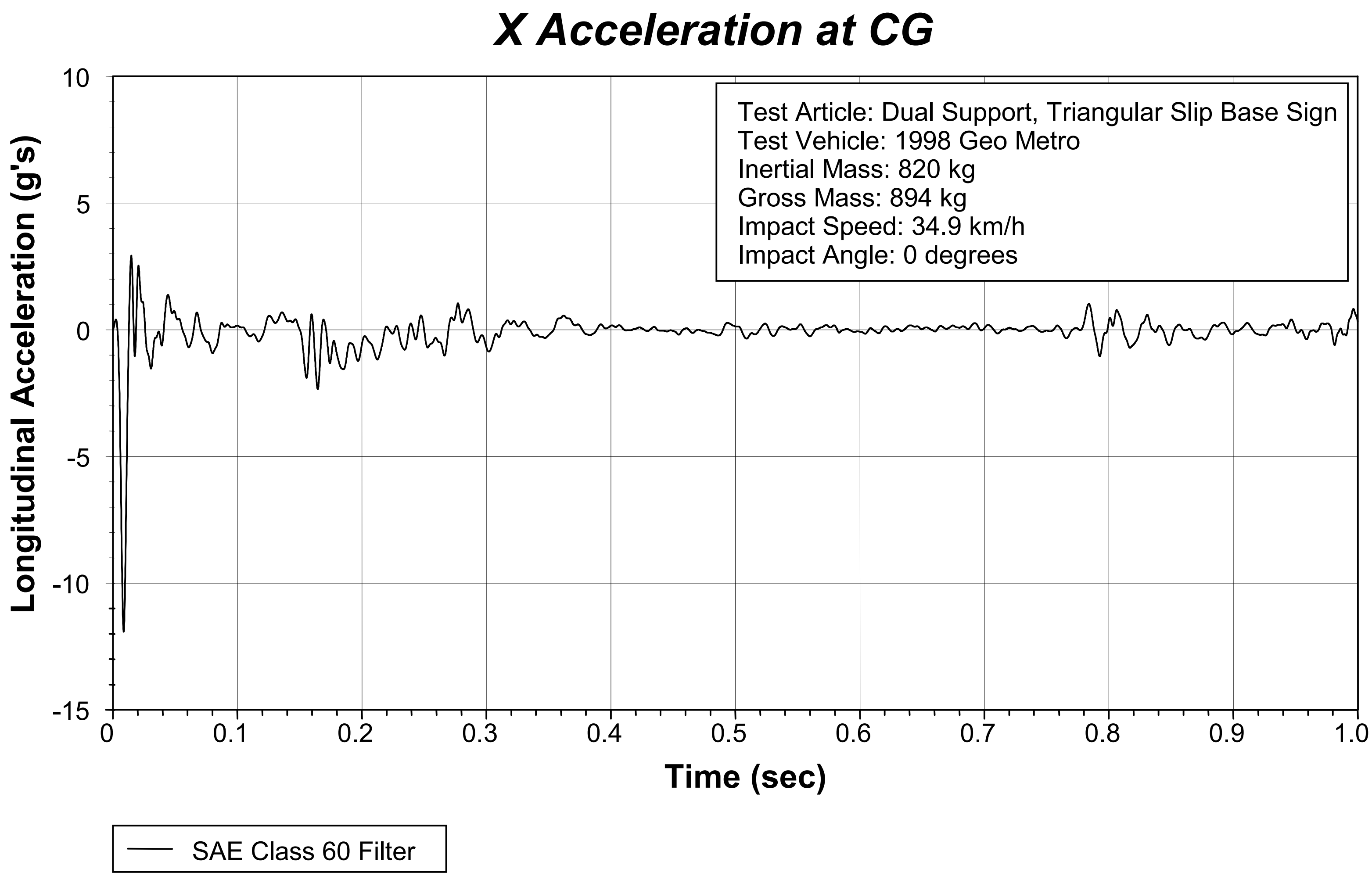


Figure 29. Vehicle Longitudinal Accelerometer Trace for Test 417922-1 (Accelerometer Located at Center of Gravity).

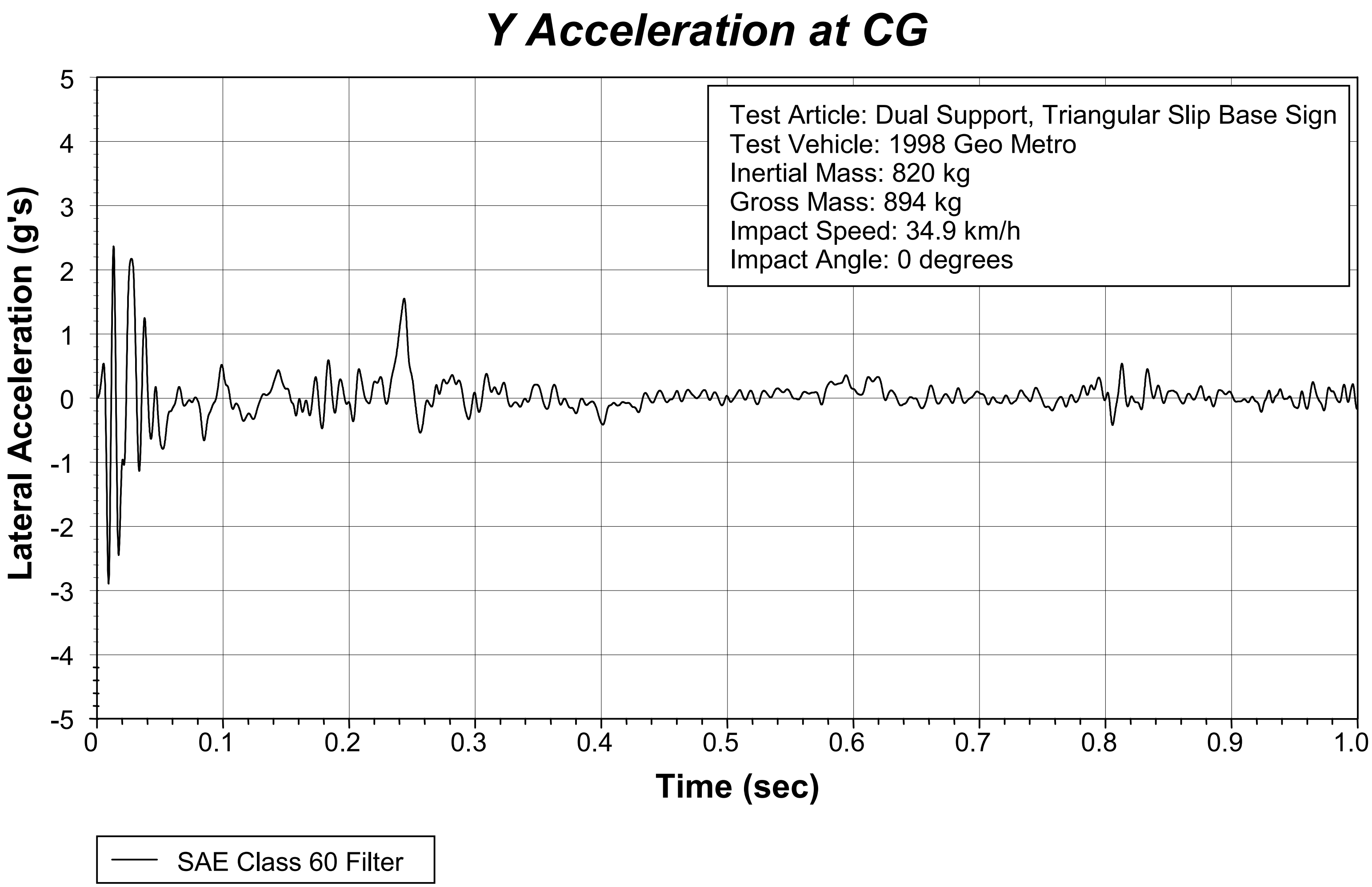


Figure 30. Vehicle Lateral Accelerometer Trace for Test 417922-1 (Accelerometer Located at Center of Gravity).

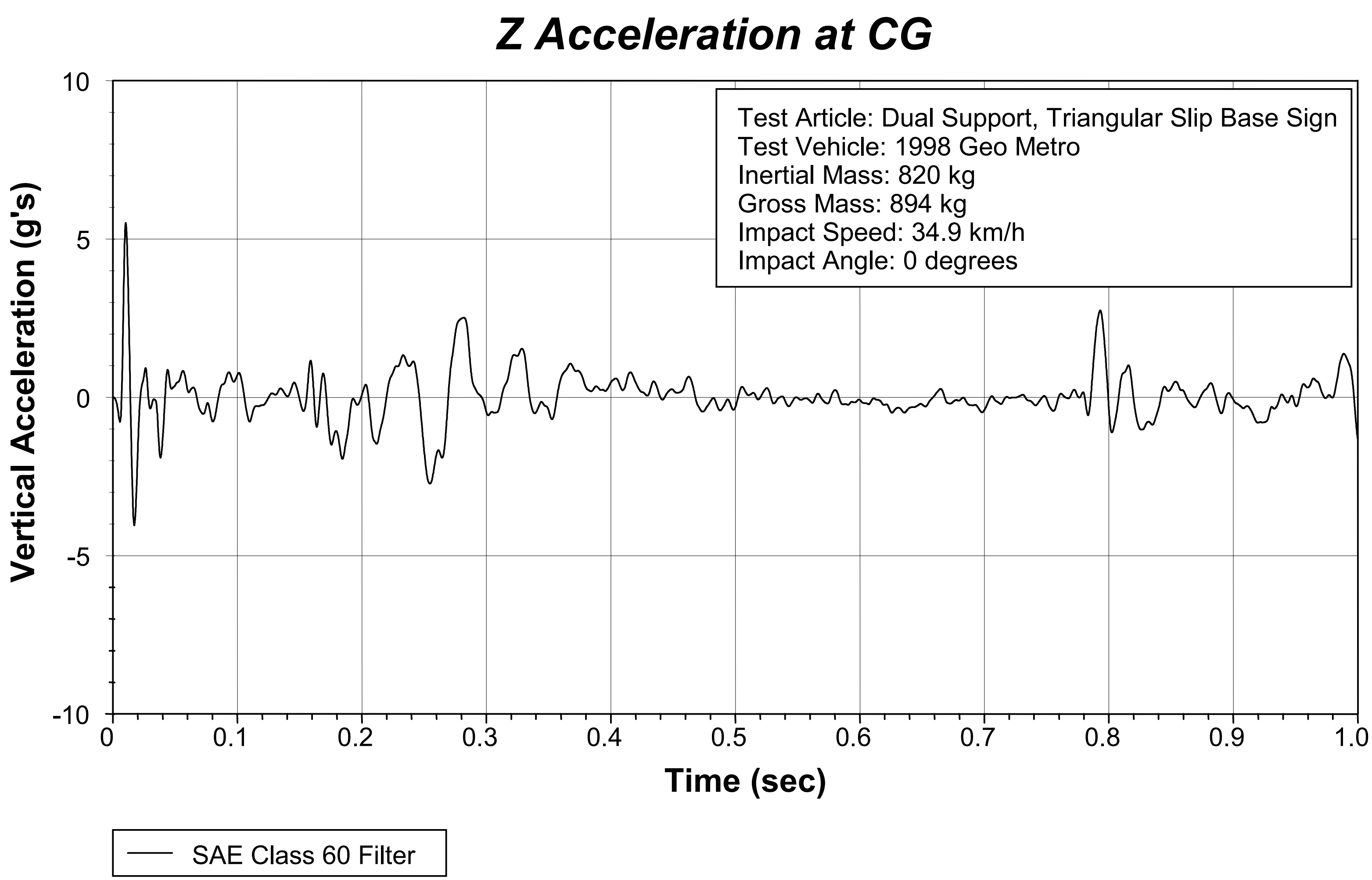


Figure 31. Vehicle Vertical Accelerometer Trace for Test 417922-1 (Accelerometer Located at Center of Gravity).

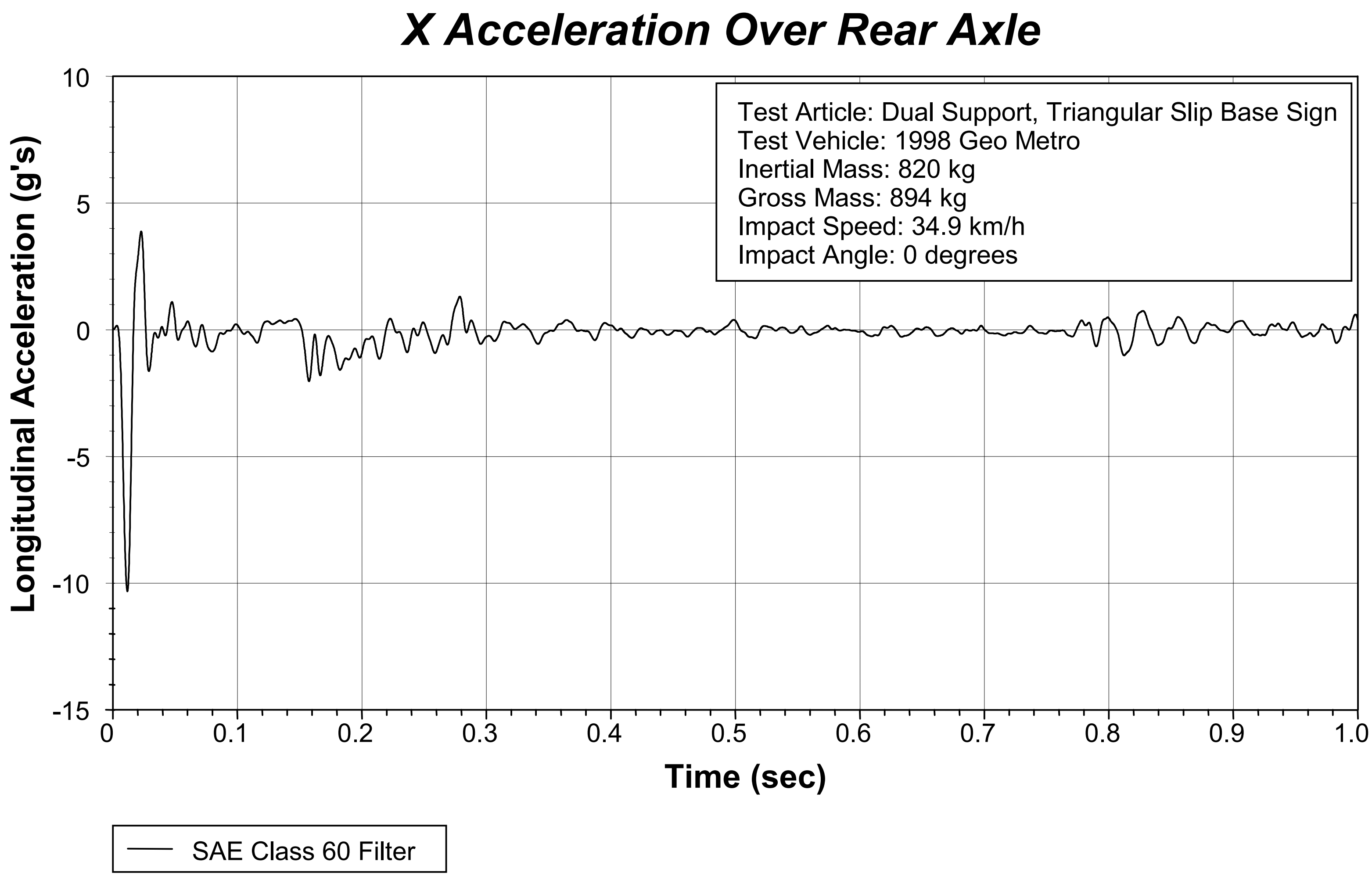


Figure 32. Vehicle Longitudinal Accelerometer Trace for Test 417922-1 (Accelerometer Located over Rear Axle).

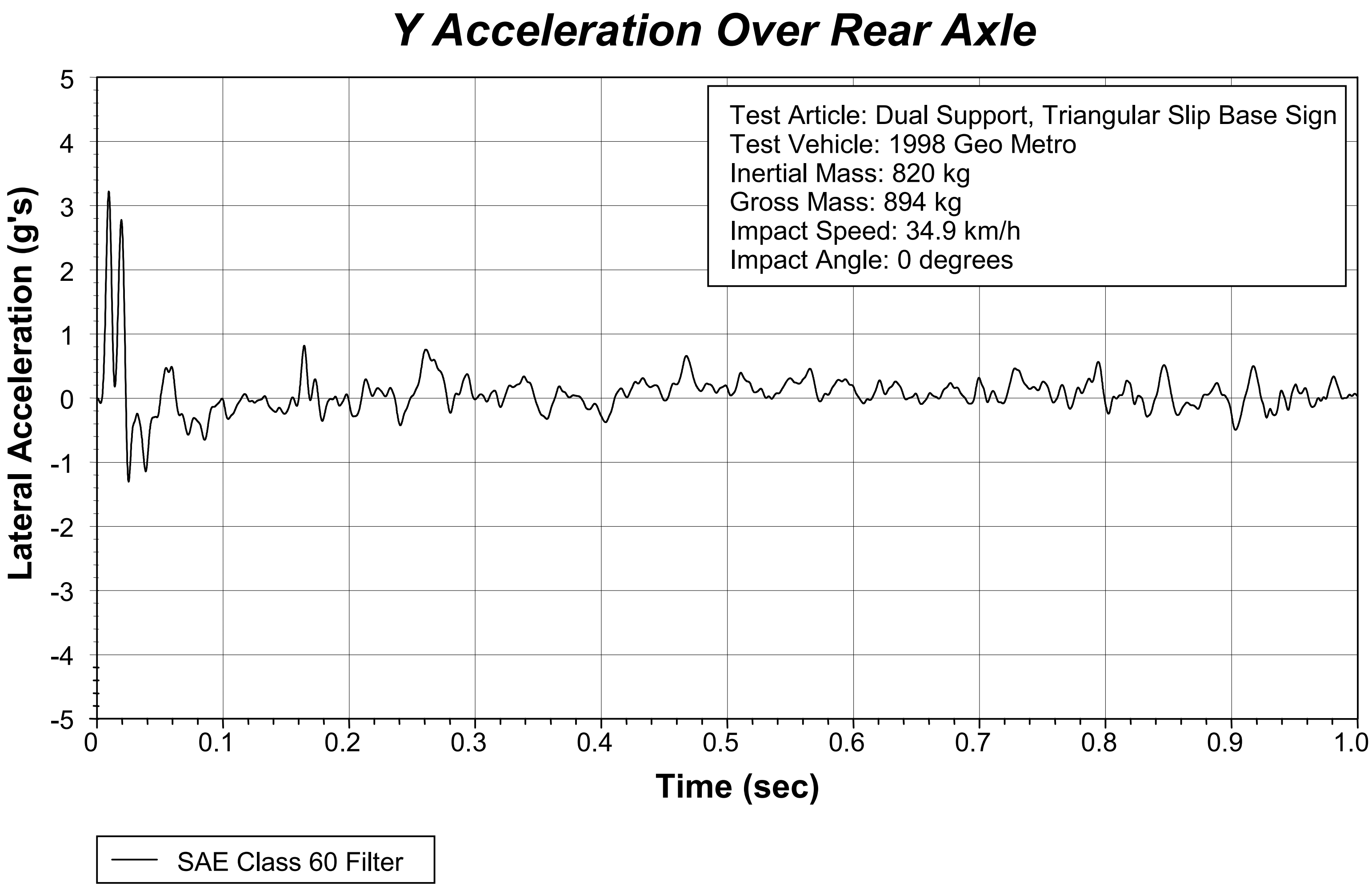


Figure 33. Vehicle Lateral Accelerometer Trace for Test 417922-1 (Accelerometer Located over Rear Axle).

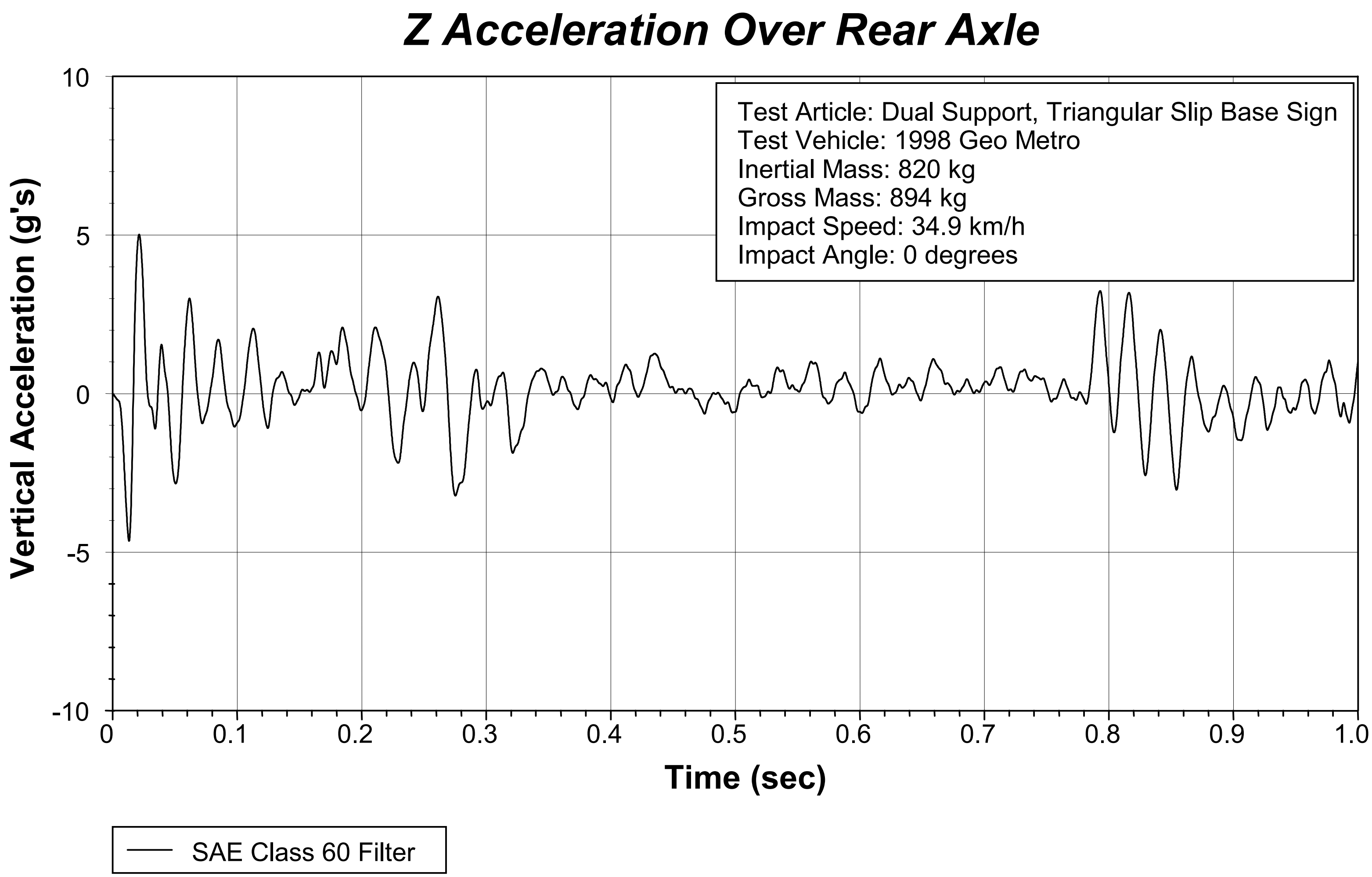


Figure 34. Vehicle Vertical Accelerometer Trace for Test 417922-1
(Accelerometer Located over Rear Axle).

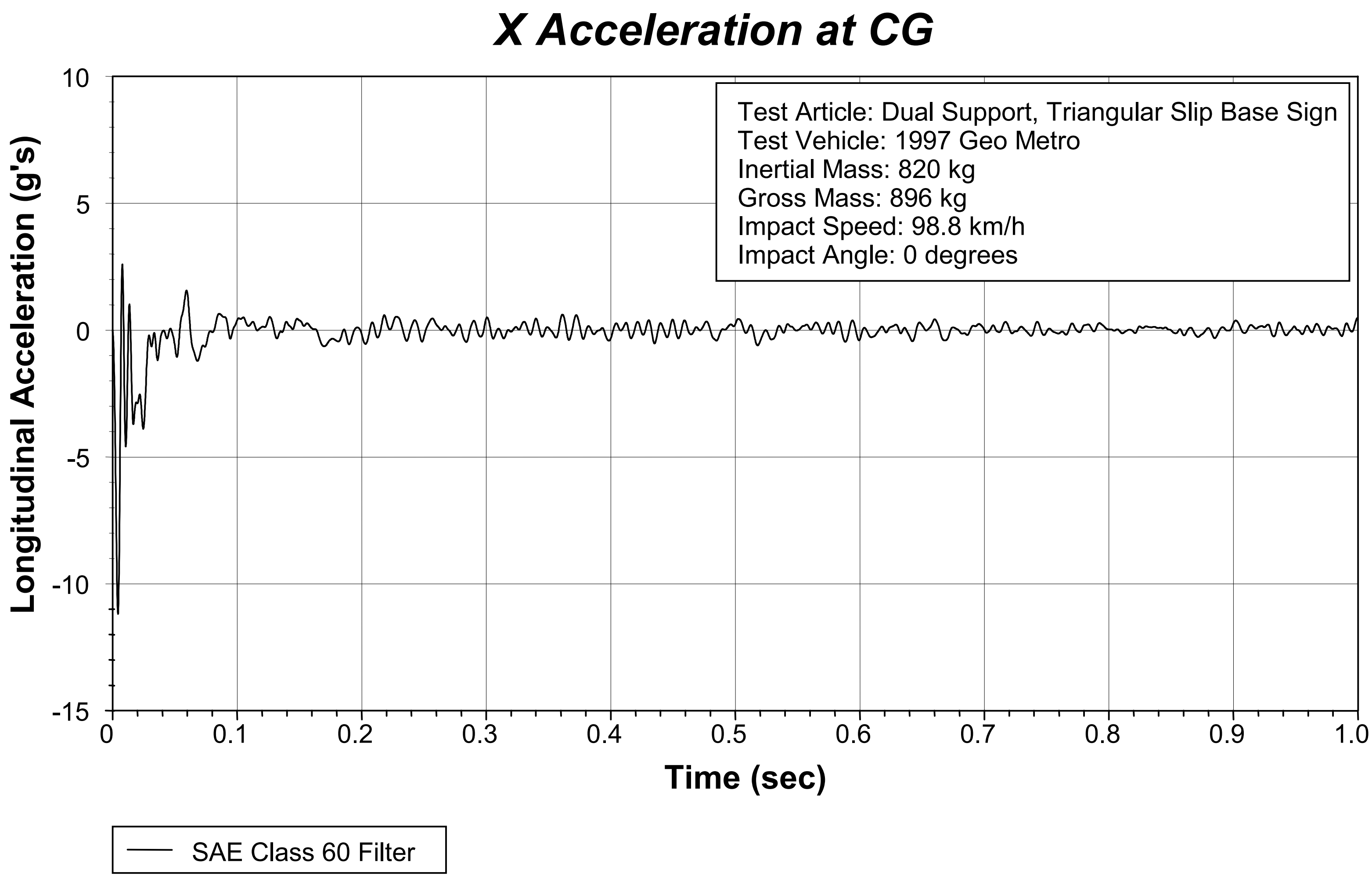


Figure 35. Vehicle Longitudinal Accelerometer Trace for Test 417922-2 (Accelerometer Located at Center of Gravity).

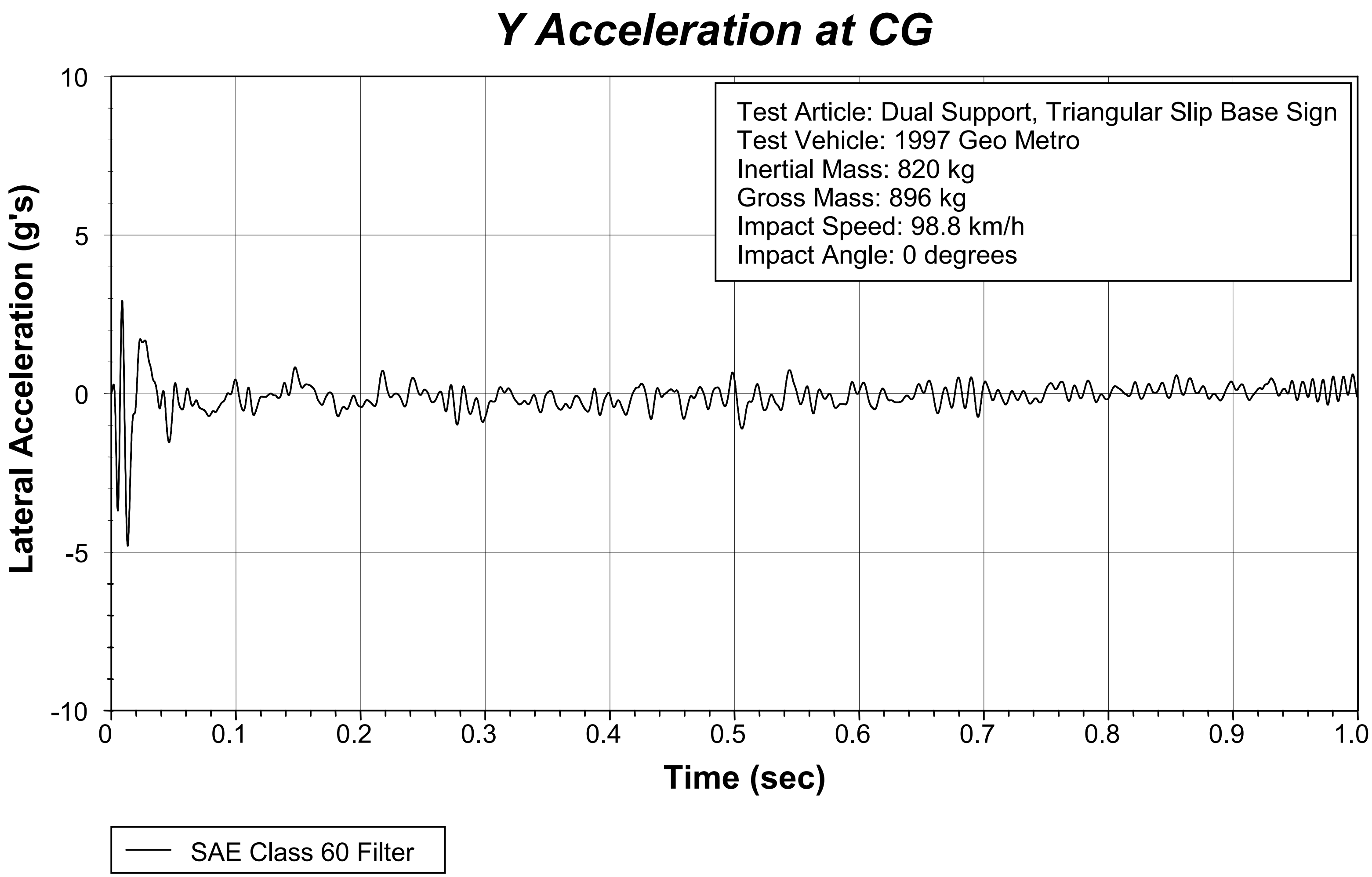


Figure 36. Vehicle Lateral Accelerometer Trace for Test 417922-2 (Accelerometer Located at Center of Gravity).

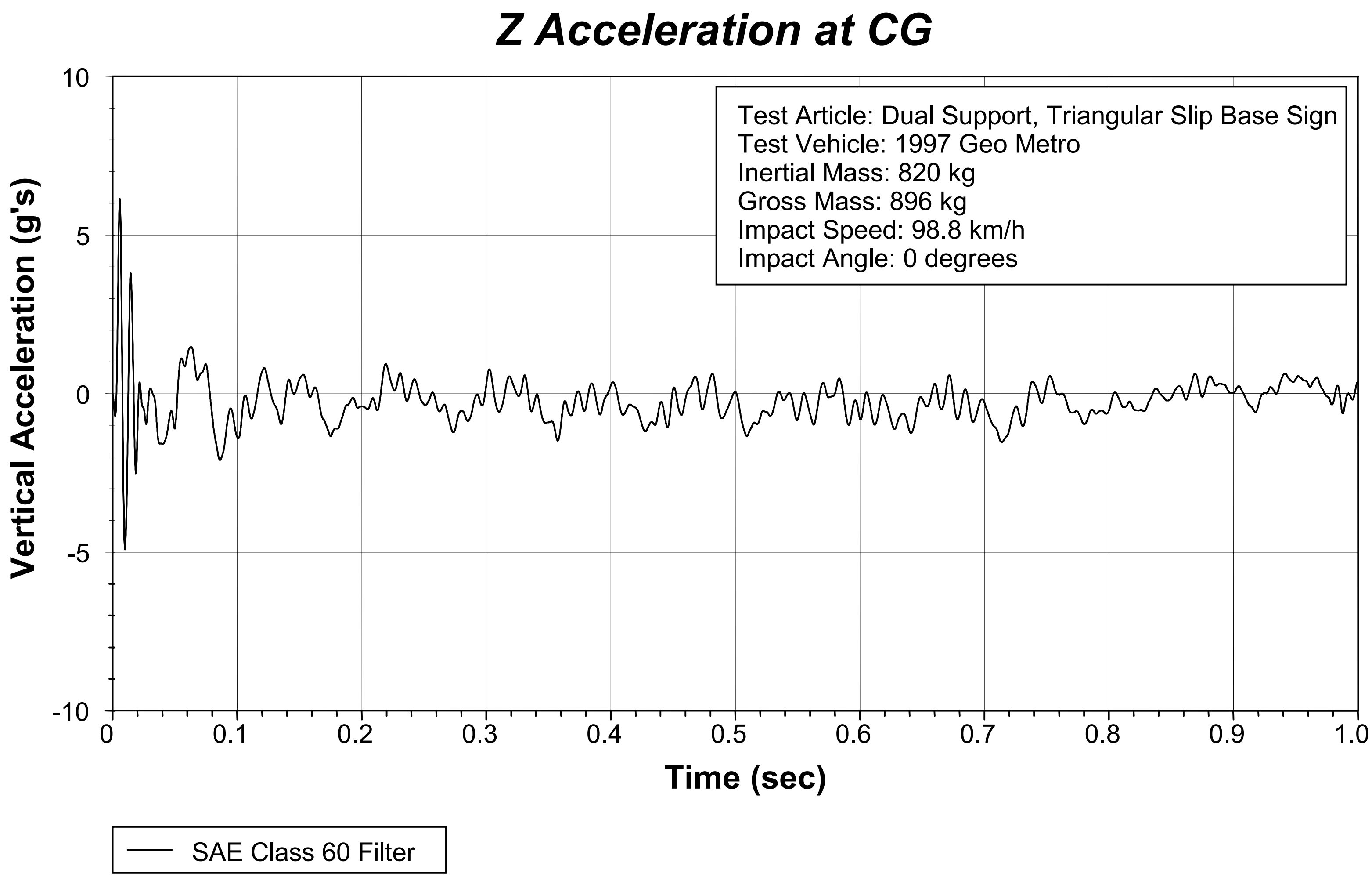


Figure 37. Vehicle Vertical Accelerometer Trace for Test 417922-2 (Accelerometer Located at Center of Gravity).

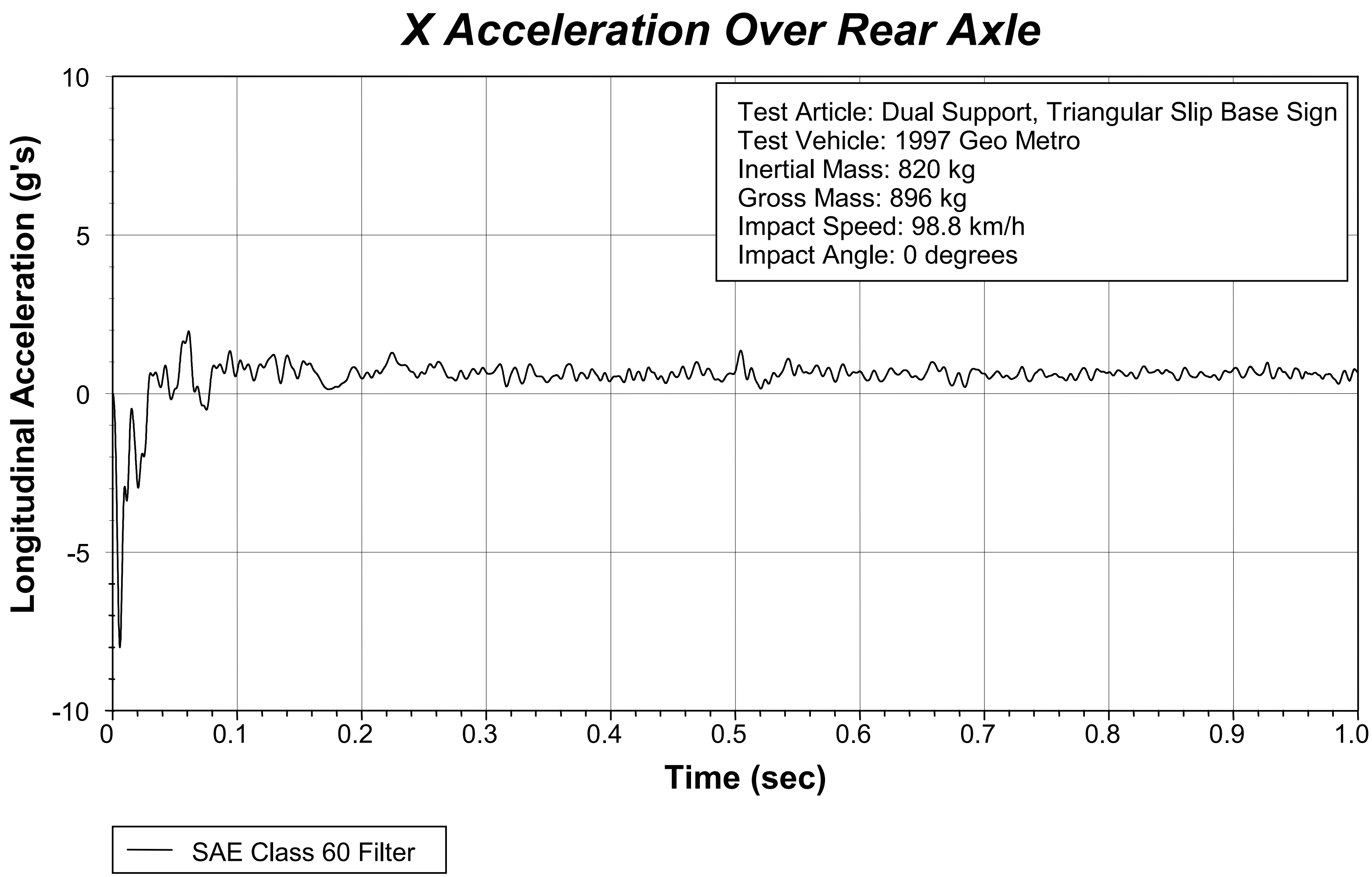


Figure 38. Vehicle Longitudinal Accelerometer Trace for Test 417922-2 (Accelerometer Located over Rear Axle).

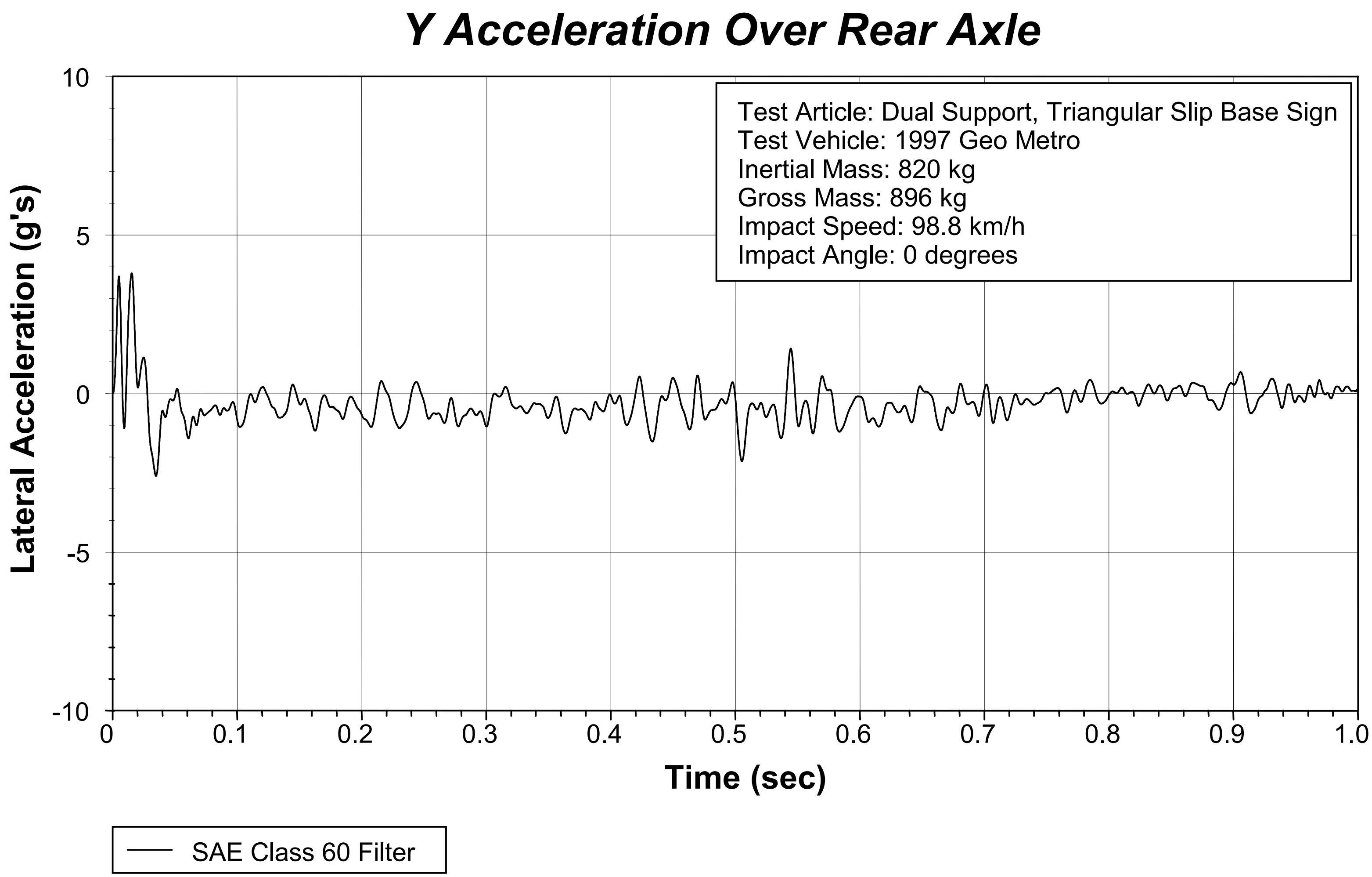


Figure 39. Vehicle Lateral Accelerometer Trace for Test 417922-2 (Accelerometer Located over Rear Axle).

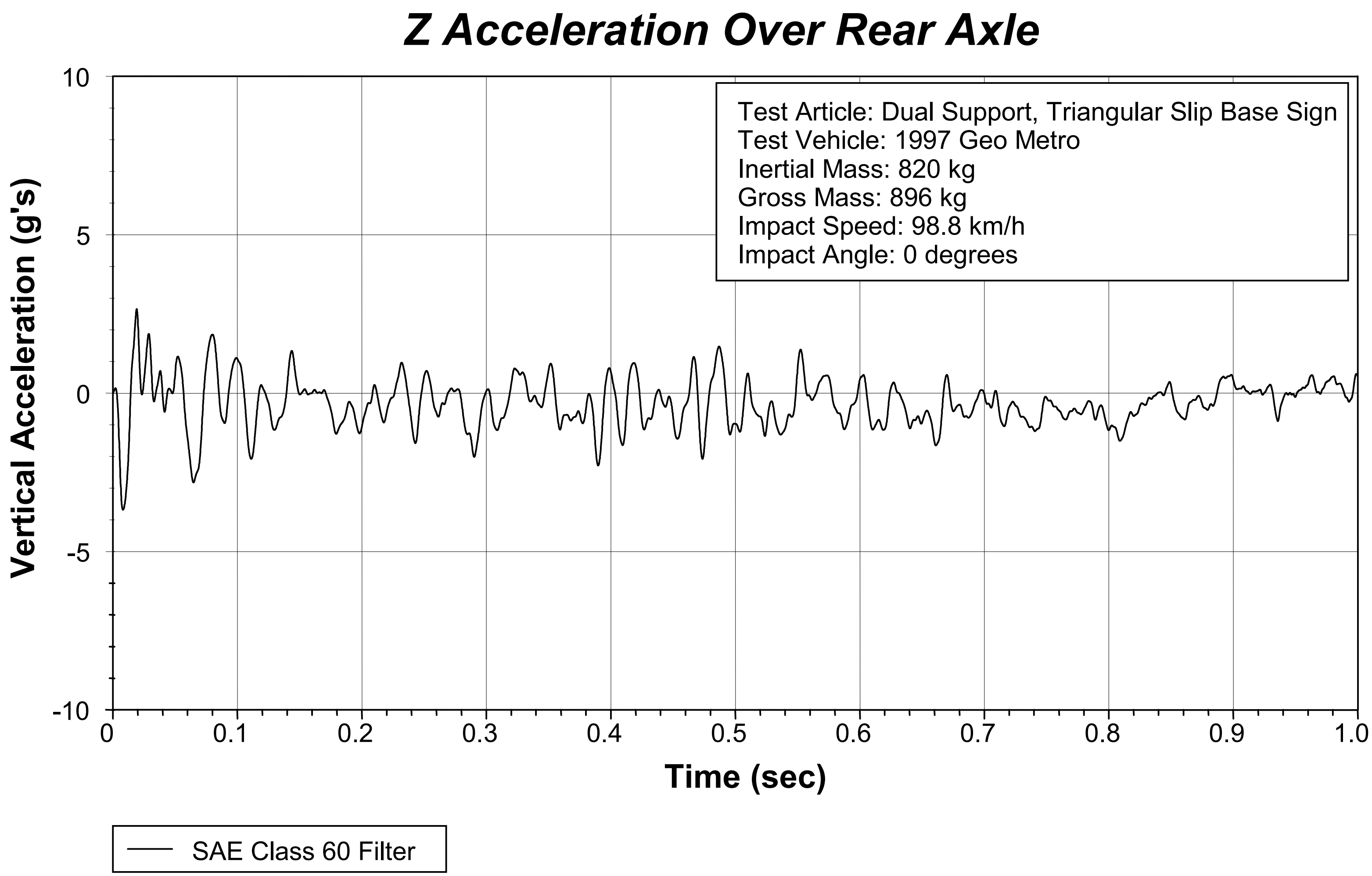


Figure 40. Vehicle Vertical Accelerometer Trace for Test 417922-2 (Accelerometer Located over Rear Axle).