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Roger P. Bligh and Wanda L. Menges

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16. Abstract

Texas counties expressed a desire to the Texas Department of Transportation (TxDOT) to post advisory signs on the roadside to alert motorists when a burn ban is in effect. For obvious economic reasons, the preferred method of implementation is to append the burn ban notification signs to existing sign support structures already installed along Texas highways.

In support of this request, TxDOT sponsored this project to evaluate the impact performance of a Texas slip base sign support system with a lightweight, composite burn ban sign appended to the support below the primary sign at a mounting height less than 7 ft. The impact performance of the burn ban sign support configurations was evaluated through full-scale crash testing. The crash testing was performed in accordance with the requirements of *NCHRP Report 350*. The configuration selected for testing incorporated a 24 inch × 24 inch × 0.080 inch thick aluminum confirmation sign mounted at a height of 7 ft, with the burn ban signs mounted below.

Based on the satisfactory test results reported herein, the practice of appending a burn ban sign to an existing slip base sign support system is considered suitable for implementation.

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CRASH TESTING AND EVALUATION OF TXDOT BURN BAN SIGNS

by

Roger P. Bligh, P.E.
Research Engineer
Texas Transportation Institute

and

Wanda L. Menges
Research Specialist
Texas Transportation Institute

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data, and the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT), Federal Highway Administration (FHWA), The Texas A&M University System, or the Texas Transportation Institute. This report does not constitute a standard, specification, or regulation, and its contents are not intended for construction, bidding, or permit purposes. In addition, the above listed agencies assume no liability for its contents or use thereof. The names of specific products or manufacturers listed herein do not imply endorsement of those products or manufacturers. The engineer in charge of the project was Roger P. Bligh, P.E. (Texas, #78550).

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CHAPTER 1. INTRODUCTION

INTRODUCTION

Small roadside signs provide important information to motorists. The proximity of these signs to the edge of traveled way makes them susceptible to being struck by errant vehicles that inadvertently encroach onto the roadside. To reduce the hazard associated with these crashes, the sign supports are designed to "breakaway" from their foundation upon impact with a vehicle. The crashworthiness of a sign support system must be evaluated before the design can be used on the nation's highways. This evaluation is typically accomplished through full-scale vehicle crash testing.

National Cooperative Highway Research Program (NCHRP) Report 350 contains the recommended procedures for testing and evaluating sign supports and other roadside safety features *(1)*. This document contains the test matrices, impact conditions, evaluation criteria, and reporting requirements for assessing the impact performance of a breakaway support structure. If the design of a system is altered in response to changing needs in the highway environment, it may be necessary to reassess its compliance with current vehicle testing criteria.

BACKGROUND

It is not unusual for parts of Texas to experience hot, dry weather, particularly during the summer months. During periods of drought, Texas counties enact burn bans that prohibit any form of outside burning to help limit the risk of an uncontrolled fire. The counties expressed a desire to the Texas Department of Transportation (TxDOT) to post advisory signs on the roadside to alert motorists when a burn ban is in effect. For obvious economic reasons, the preferred method of implementation is to append the burn ban notification signs to existing sign support structures.

The most commonly used sign support system in Texas is the triangular slip base. It is a multi-directional breakaway design that uses three bolts tightened to a prescribed torque to clamp. One plate is attached to a rigid foundation and the other is attached to the bottom of the sign support through various methods. When the impact force applied by a vehicle exceeds the frictional clamping force, the upper plate "slips" relative to the lower plate and the support structure is "released" from its foundation. The released sign support system rotates over the impacting vehicle.

The Texas triangular slip base and its variations have been subjected to extensive crash testing and evaluation in accordance with *NCHRP Report 350* guidelines *(2,3,4,5,6)*. It has performed well in testing and has been used successfully in the field for many years.

TxDOT policy requires a minimum mounting height of 7 ft to the bottom of the sign panel. The Texas slip base system has traditionally been used for sign panels having an area greater than 10 square feet. Less expensive sign support systems, such as a wedge anchor system, are typically used for smaller sign areas of 10 square feet or less.

The current Texas slip base system utilizes two different types of support posts: a 2-7/8-inch outside diameter (O.D.), 10 British Wire Gage (BWG) steel tube that has a nominal wall thickness of 0.134 inches and a 55,000 psi minimum yield strength, and a 2-1/2-inch nominal diameter (2-7/8-inch O.D.), schedule 80 pipe that has a nominal wall thickness of 0.276 inches and a minimum yield strength of 46,000 psi. The 10 BWG tube support can be used for sign areas up to 16 square feet, while the schedule 80 pipe support can be used for larger sign areas up to 32 square feet.

There are many variables that can affect the impact performance of a slip base sign support system (and breakaway supports in general). These variables include but are not limited to the size and weight of the sign substrate, the sign mounting height, and the type of support post. As the size, weight, and mounting height of a sign panel increase, the center of mass and mass moment of inertia of the combined sign support system also increase. The released support system will rotate about its center of mass, and the higher the center of mass the higher the probability that an impacting vehicle can travel under the rotating support without secondary contact to the roof or windshield. Increasing the mass moment of inertia decreases the rotational velocity of the support structure after activation, which can give an impacting vehicle more time to travel under the support before any secondary contact occurs.

Appending a burn ban sign to an existing slip base sign support at a height less than 7 ft can effectively lower the center of mass (i.e., point of rotation) of the sign support system and possibly degrade its impact performance. Use of a lightweight sign substrate can minimize the effect of the secondary sign on the overall properties of the sign support system. However, given that this practice could be adopted statewide, TxDOT decided that further research of the proposed burn ban sign application was needed.

OBJECTIVES/SCOPE OF RESEARCH

The objective of this research was to evaluate the impact performance of a Texas slip base sign support system with a burn ban sign appended to the support below the primary sign at a mounting height less than 7 ft. The impact performance of the burn ban sign support configurations was evaluated through full-scale crash testing. The crash testing was performed in accordance with the requirements of *NCHRP Report 350*.

To minimize the effect of the burn ban signs on the inertia properties of the sign support system, a lightweight aluminum composite material was chosen as the sign substrate. Two different sizes of burn ban signs were considered: a 24 inch × 24 inch sign and a 30 inch × 36 inch sign. The smaller 24 inch × 24 inch sign is intended to simply communicate that a burn ban is in effect. The larger 30 inch × 36 inch sign would additionally indicate the name of the county when needed.

As discussed earlier, the Texas slip base system is used with a wide range of signs on two different types of supports. To qualify the burn ban sign for use on most if not all slip base support systems installed across the state, the research plan included identifying and testing the most critical sign configuration. If successful, the burn ban sign could then be used on the tested configuration as well as any less critical configurations.

The most critical configuration would be the system incorporating the smallest, lightest primary sign, because the appended burn ban sign would have more influence on the overall inertia properties (e.g., center of mass) of that system. A review of district practices by the Traffic Operations Division noted that some districts were using the Texas slip base for all small signs, even those having an area less than 10 square feet. The motivation behind this practice was to reduce inventory associated with multiple types of supports and simplify maintenance training and operations. This being the case, the smallest, lightest sign panel used with the Texas slip base support is a 24 inch × 24 inch aluminum confirmation sign.

The practice of using small confirmation signs on slip base supports raised some concerns. Researchers at the Texas Transportation Institute (TTI) are not aware of any crash testing of slip base supports with signs this small. The center of mass (i.e., point of rotation) of such a system would be significantly lower than those associated with most of the tested systems. The lower point of rotation could cause secondary contact with the roof and/or windshield that would not occur with systems incorporating larger sign panels. Thus, a secondary objective was to investigate the impact performance of the Texas slip base with sign panels having an area as small as 4 square feet.

The remaining chapters of this report describe the full-scale crash testing and evaluation of different sign support configurations with burn ban signs attached below the primary sign, and present recommendations regarding implementation and future work.

CHAPTER 2. CRASH TEST PROCEDURES

TEST FACILITY

The TTI Proving Ground is a 2000-acre complex of research and training facilities located 10 miles northwest of the main campus of Texas A&M University. The site, formerly an Air Force base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for construction and testing of the sign supports evaluated under this project was the edge of an out-of-service aircraft parking apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5 ft × 15 ft blocks nominally 8 to 12 inches deep. The apron is over 50 years old, and the joints have some displacement but are otherwise flat and level.

CRASH TEST CONDITIONS

The recommended test matrix for breakaway support structures, such as the Texas slip base, consists of two tests:

> ***NCHRP Report 350*** **test designation 3-60**: This test involves an 1808-lb passenger vehicle (820C) impacting the support structure at a nominal speed of 22 mi/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, as well as occupant risk.
>
> ***NCHRP Report 350*** **test designation 3-61**: This test involves an 1808-lb passenger vehicle (820C) impacting the support structure at a nominal speed of 62 mi/h and an angle ranging from 0-20 degrees. The test is intended to evaluate vehicle and test article trajectory and occupant risk.

Researchers performed both the low-speed and high-speed tests on a slip base system with a 24 inch × 24 inch burn ban sign attached below a 24 inch × 24 inch confirmation sign. However, only the high-speed test was performed during subsequent evaluation of slip base systems with 30 inch × 36 inch burn ban signs, as the high-speed test proved to be the more critical test.

All crash test, data analysis, and evaluation and reporting procedures followed under this project were in accordance with guidelines presented in *NCHRP Report 350*. Appendix A presents brief descriptions of these procedures.

EVALUATION CRITERIA

The crash tests performed under this project 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 tests reported herein.

CHAPTER 3. CRASH TESTS ON 24 INCH × 24 INCH BURN BAN SIGN

TEST ARTICLE

Figure 3.1 and Figure 3.2 show details of the test installation used for evaluation of the 24 inch × 24 inch burn ban sign. The support post was a 2-1/2-inch diameter (2.875-inch O.D.) schedule 80 steel pipe with a minimum specified yield strength of 46,000 psi. This support was considered to be more critical in terms of evaluating occupant compartment deformation associated with secondary contact with the roof and windshield because of its greater mass and lower center of mass compared to the same system mounted on a 10 BWG steel tube. A 24 inch × 24 inch × 0.080 inch thick aluminum sign panel was attached to the schedule 80 support using two 2-1/2-inch sign bracket mounting clamps and 15/16-inch diameter × 1 inch long bolts. The mounting height to the bottom of the confirmation sign was 7 ft.

A 24 inch × 24 inch × 0.080 inch thick lightweight composite burn ban sign panel was attached to the schedule 80 support in the same manner as the confirmation sign using two sign bracket mounting clamps spaced 18 inches apart. The composite sign consisted of a high-density polyethylene (HDPE) core sandwiched between two outer sheets of 0.010-inch thick, 5052 aluminum. A 3-inch offset was used between the two sign panels, making the mounting height to the bottom of the burn ban sign 4 ft-9 inches.

The upper slip base assembly consists of an integral collar and triangular base plate cast from American Society for Testing and Materials (ASTM) A536 Grade 65-45-12 ductile iron. The 0.535-inch thick collar is perpendicular to the base plate and has a 2.93-inch diameter hole to accept the 2.875 O.D. pipe support. Additional details of the slip base casting can be found in Figure 3.2.

To help prevent the pipe from rotating inside the collar during service and the casting from slipping off the pipe during an impact, the slip base assembly is secured to the end of the schedule 80 pipe using three 0.625-inch diameter set screws equally spaced around the perimeter of the collar and torqued to 65 ft-lb using a torque wrench with an Allen head adaptor.

The lower slip base plate was welded to a 36-inch length of 3-inch nominal diameter schedule 40 pipe. The pipe stub was embedded in a 12-inch diameter × 42-inch deep concrete footing installed in *NCHRP Report 350* standard soil. The distance from the ground surface to the top face of the lower triangular slip plate was 3.5 inches. The triangular slip base was oriented such that the upstream side was perpendicular to the direction of impact. A 30 gauge galvanized steel keeper plate was placed between the upper and lower slip plates. A washer was placed between the bolt keeper plate and upper slip plate to reduce the contact area between the plates. The two slip plates were clamped together using three 0.625 inch diameter × 2.5-inch long, ASTM A325 bolts that were tightened to a prescribed torque of 40 ft-lb. High strength washers were used under both the head and nut of each bolt. Photographs of the completed sign support installation are shown in Figure 3.3.

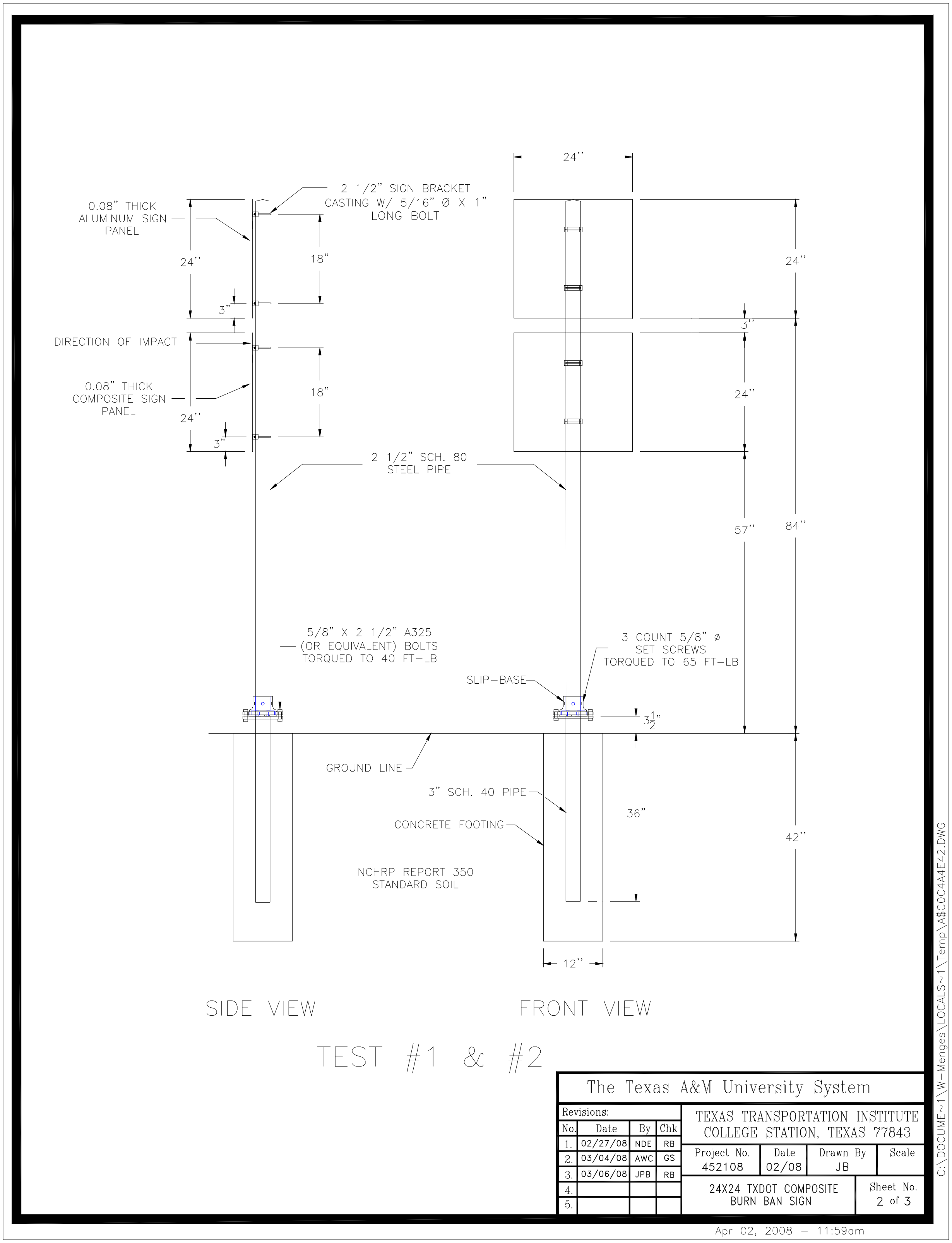


Figure 3.1. Details of the TxDOT 24 inch × 24 inch Burn Ban Sign Installation.

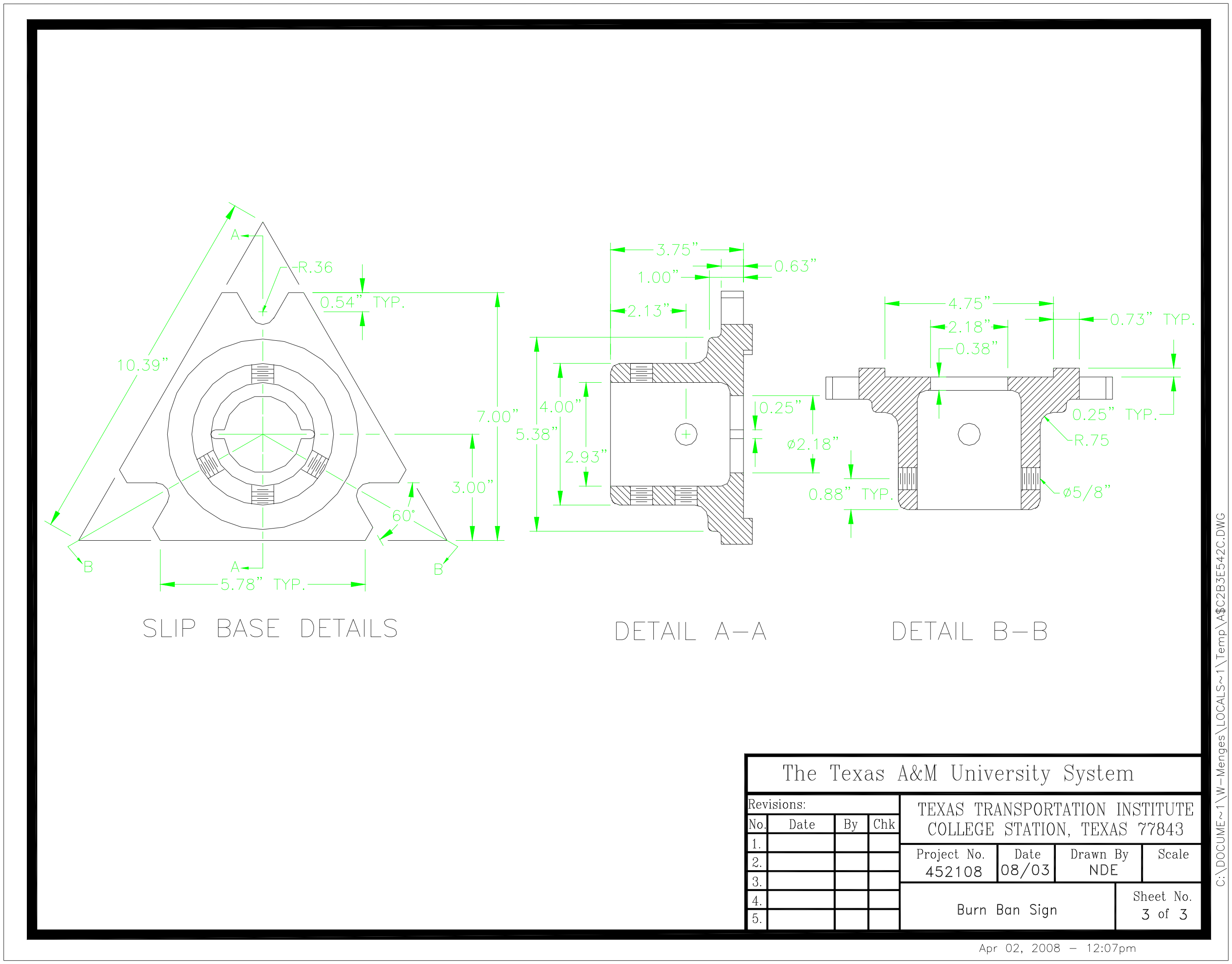


Figure 3.2. Details of the Slip Base Used in Tests 452108-1 and 2.

Figure 3.3. Test Article/Installation before Test 452108-1 and 2.

TEST 452108-1 (*NCHRP REPORT 350* TEST 3-60) ON THE SCHEDULE 80 STEEL PIPE SUPPORT WITH 24 INCH × 24 INCH TXDOT BURN BAN SIGN

Test Vehicle

A 1995 Geo Metro, shown in Figures 3.4 and 3.5, was used for the crash test. Test inertia weight of the vehicle was 1784 lb, and its gross static weight was 1953 lb. The height to the lower edge of the vehicle bumper was 15.75 inches, and the height to the upper edge of the vehicle bumper was 20.25 inches. Figure B1 in Appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a 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 morning of March 5, 2008. A total of 0.8 inches of rainfall was recorded three days prior to the test. Moisture content of the *NCHRP Report 350* standard soil in which the sign support system was installed was 8.6 percent. Weather conditions at the time of testing were as follows: Wind speed: 16 mi/h; Wind direction: 190 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 60^{o}F; Relative humidity: 59 percent.

Test Description

The 1995 Geo Metro, traveling at an impact speed of 21.7 mi/h, impacted the 2-1/2-inch diameter schedule 80 support 6 inches from the vehicle centerline offset to the driver's side. At 0.012 s, the support began to move toward the field side, and the front bumper was crushed to the front edge of the hood. The top slip plate began to move at 0.054 s, and the support lost contact with the lower slip plate at 0.066 s. The support began to rotate counterclockwise in front of the vehicle at 0.069 s. At 0.241 s, the vehicle lost contact with the support while traveling forward at a speed of 17.6 mi/h. As the vehicle continued forward, the top of the sign panel contacted the top of the windshield at 0.405 s, and the support remained in this position until the vehicle went out of view of the camera. Figure C1 in Appendix C shows sequential photographs of the test period.

Damage to Test Installation

Damage to the sign support installation is shown in Figures 3.6 and 3.7. The base showed no movement in the ground. The keeper plate and one bolt remained at the base, one bolt came to rest 12.5 ft downstream of impact, and the third was resting 57.5 ft downstream of impact. The sign panels and support came to rest under the vehicle, which came to rest 92.5 ft downstream from the point of impact.

Figure 3.4. Vehicle/Installation Geometrics for Test 452108-1.

Figure 3.5. Vehicle before Test 452108-1.

Figure 3.6. After Impact Trajectory Path for Test 452108-1.

Figure 3.7. Installation after Test 452108-1.

Vehicle Damage

Figures 3.8 and 3.9 show the damage to the exterior and interior of the vehicle, respectively. The front bumper, hood, radiator, and radiator support were deformed. The windshield was cracked near the roof line, but there was no hole. Maximum exterior crush to the vehicle was 6.3 inches on the front of the vehicle at a point 6 inches left (toward the driver side) of centerline. No occupant compartment deformation occurred. Exterior crush and occupant compartment measurements are shown in Appendix B, Tables B1 and B2, respectively.

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 5.6 ft/s (1.7 m/s) at 0.415 s, the highest 0.010-s occupant ridedown acceleration was 0.2 *g* from 0.440 to 0.450 s, and the maximum 0.050-s average acceleration was -3.0 *g* between 0.018 and 0.068 s. In the lateral direction, the occupant impact velocity was 0.7 ft/s (0.2 m/s) at 0.415 s, the highest 0.010-s occupant ridedown acceleration was 0.2 *g* from 0.428 to 0.438 s, and the maximum 0.050-s average acceleration was -0.4 *g* between 0.062 and 0.112 s. Figure 3.10 presents these data and other pertinent information from the test. Figures D1 through D4 in Appendix D present vehicle angular displacements and accelerations versus time traces.

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.*

Result: The slip base sign support with 24 inch × 24 inch burn ban sign readily activated by slipping away at the base as designed. (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.*

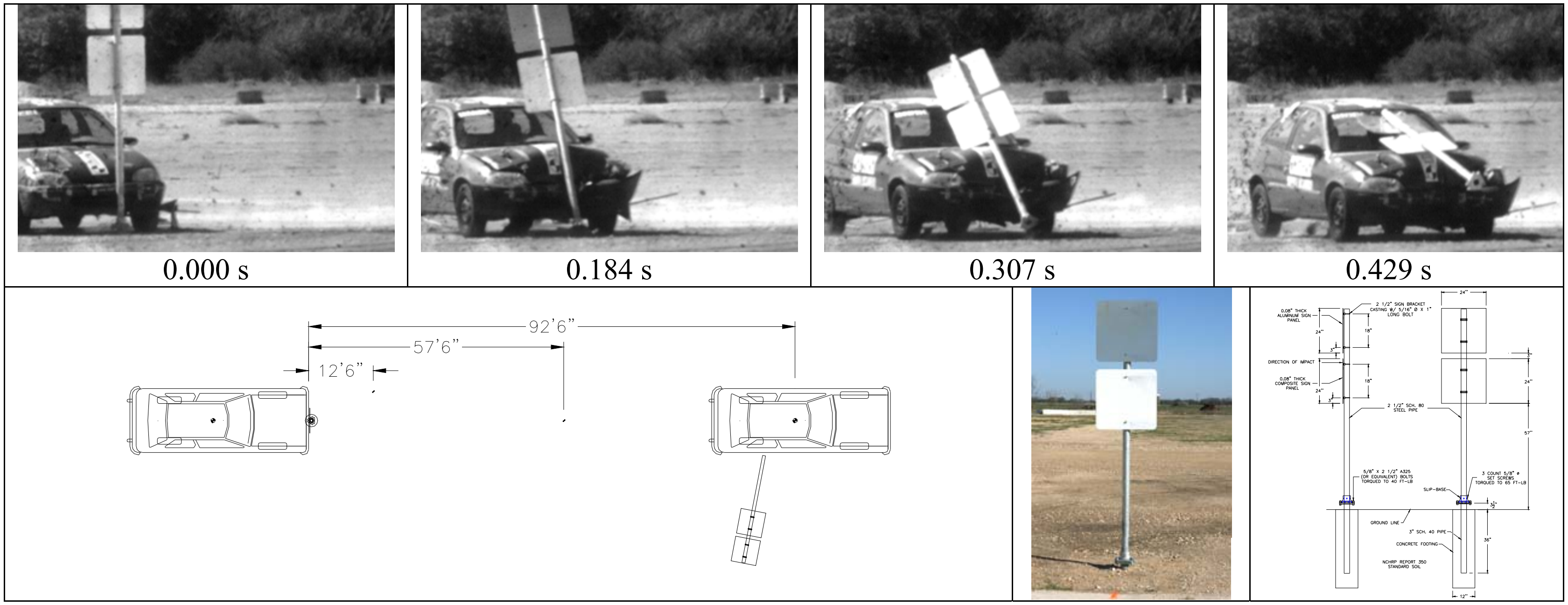
Result: The detached sign support traveled with the vehicle and came to rest under the vehicle. The support did not penetrate nor show potential for penetrating the vehicle, or to present undue hazard to others in the area. No occupant compartment deformation occurred. (PASS)

Figure 3.8. Vehicle after Test 452108-1.

Before Test

After Test

Figure 3.9. Interior of Vehicle for Test 452108-1.



General Information	
Test Agency	Texas Transportation Institute
Test No.	452108-1
Date	2008-03-05
Test Article	
Type	Sign Support
Name	TxDOT Slip Base with Burn Ban Sign
Installation Height (ft)	7 ft to bottom of top sign
Material or Key Elements	2-1/2-inch schedule 80 pipe support with slip base and two 24 x 24 inch aluminum sign panels
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Designation	820C
Model	1995 Geo Metro
Mass (lb)	
Curb	1762
Test Inertial	1784
Dummy	169
Gross Static	1953

Impact Conditions	
Speed (mi/h)	21.7
Angle (deg)	0
Exit Conditions	
Speed (mi/h)	17.6
Angle (deg)	0
Occupant Risk Values	
Impact Velocity (ft/s)	
Longitudinal	5.6
Lateral	0.7
THIV (km/h)	6.2
Ridedown Accelerations (*g*)	
Longitudinal	0.2
Lateral	0.2
PHD (*g*)	0.3
ASI	0.26
Max. 0.050-s Average (*g*)	
Longitudinal	-3.0
Lateral	-0.4
Vertical	-1.3

Test Article Debris Scatter (ft)	
Laterally Left	12.5
Laterally Right	0
Vehicle Damage	
Exterior	
VDS	12FL4
CDC	12FLEN3
Max. Exterior Vehicle Crush (inches)	6.3
Interior	
OCDI	FL0000000
Max. Occupant Compartment Deformation (inches)	0
Post-Impact Behavior	
(during 1.0 sec after impact)	
Max. Yaw Angle (deg)	-1
Max. Pitch Angle (deg)	1
Max. Roll Angle (deg)	-1

Figure 3.10. Summary of Results for *NCHRP Report 350* Test 3-60 on the Schedule 80 Steel Pipe Support with 24 inch × 24 inch TxDOT Burn Ban Sign.

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

Result: The 820C vehicle remained upright and stable throughout the collision period. (PASS)

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

Longitudinal and Lateral Occupant Impact Velocity – m/s

Preferred	*Maximum*
3 [9.8 ft/s]	*5* [16.8 ft/s]

Result: Longitudinal occupant impact velocity was 5.6 ft/s, and lateral occupant impact velocity was 0.7 ft/s. (PASS)

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

Longitudinal and Lateral Occupant Ridedown Accelerations – g

Preferred	*Maximum*
15	*20*

Result: Longitudinal ridedown acceleration was 0.2 *g*, and lateral occupant ridedown acceleration was 0.2 *g*. (PASS)

Vehicle Trajectory

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

Result: The 820C vehicle did not intrude into adjacent traffic lanes. (PASS)

N. *Vehicle trajectory behind the test article is acceptable.*

Result: The vehicle came to rest 92.5 ft downstream (behind) the test installation. (PASS)

The following supplemental evaluation factors and terminology, as presented in the Federal Highway Administration (FHWA) memo entitled "ACTION: Identifying Acceptable Highway Safety Features," were used for visual assessment of test results *(7)*. Factors underlined below pertain to the results of the crash test reported herein.

Passenger Compartment Intrusion

1. *Windshield Intrusion*
    - *a. No windshield contact*
    - *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 *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*

[✓ No threat to others in area.]

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 452108-2 (*NCHRP REPORT 350* TEST 3-61) ON THE SCHEDULE 80 STEEL PIPE SUPPORT WITH 24 INCH × 24 INCH TXDOT BURN BAN SIGN

Test Vehicle

A 1998 Geo Metro, shown in Figures 3.11 and 3.12, was used for the crash test. Test inertia weight of the vehicle was 1812 lb, and its gross static weight was 1980 lb. The height to the lower edge of the vehicle bumper was 15.75 inches, and the height to the upper edge of the vehicle bumper was 20.25 inches. Figure B2 in Appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a 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 March 5, 2008. A total of 0.8 inches of rainfall was recorded three days prior to the test. Moisture content of the *NCHRP Report 350* standard soil in which the sign support system was installed was 8.6 percent. Weather conditions at the time of testing were as follows: Wind speed: 13 mi/h; Wind direction: 180 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 72°F; Relative humidity: 41 percent.

Test Description

The 1998 Geo Metro, traveling at an impact speed of 62.6 mi/h, impacted the 2-1/2-inch diameter schedule 80 support 6 inches from the vehicle centerline offset to the driver's side. At 0.005 s, the support began to move toward the field side, and the front bumper was crushed to the front edge of the hood. The top slip plate began to move at 0.012 s, and the support lost contact with the lower slip plate at 0.020 s. At 0.081 s, the vehicle lost contact with the support while traveling at a speed of 61.1 mi/h. As the vehicle continued forward, both sign panels contacted the roof just above the windshield at 0.108 s. The pipe support contacted the roof at 0.113 s and began to crush the roof at 0.118 s. At 0.187 s, the pipe support lost contact with the roof of the vehicle. Figure C2 in Appendix C shows sequential photographs of the test period.

Damage to Test Installation

Damage to the installation is shown in Figures 3.13 and 3.14. The base showed no movement in the ground. The keeper plate came to rest 28.5 ft downstream from impact and 30 inches to the right of centerline. One bolt remained at the base, one bolt came to rest 12.5 ft downstream of impact, and the third was resting 51 ft downstream of impact. The confirmation sign panel separated from the support came to rest near the support and confirmation sign panel, which came to rest 150 ft downstream from impact.

Figure 3.11. Vehicle/Installation Geometrics for Test 452108-2.

Figure 3.12. Vehicle before Test 452108-2.

Figure 3.13. After Impact Trajectory Path for Test 452108-2.

Figure 3.14. Installation after Test 452108-2.

Figure 3.14. Installation after Test 452108-2.

Vehicle Damage

Damage to the vehicle is shown in Figure 3.15. The front bumper, grill, hood, radiator, and radiator support were deformed. Maximum exterior crush in the frontal plane at the front bumper was 9.8 inches. The windshield was shattered downward from the roofline, but there was no loss of visibility. Two small cuts were noted in the roof, the largest measuring 0.6 × 1.6 inches. The roof was deformed downward a maximum of 5.1 inches on the exterior of the vehicle and deformed into the occupant compartment 5.0 inches. Photographs of the interior of the vehicle are shown in Figure 3.16. Exterior crush and occupant compartment measurements are shown in Appendix B, Tables B3 and B4, respectively.

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 5.2 ft/s at 0.443 s, the highest 0.010-s occupant ridedown acceleration was 0.4 *g* from 0.444 to 0.454 s, and the maximum 0.050-s average acceleration was -3.1 *g* between 0.001 and 0.051 s. In the lateral direction, the occupant impact velocity was 2.3 ft/s at 0.443 s, the highest 0.010-s occupant ridedown acceleration was 0.7 *g* from 0.844 to 0.854 s, and the maximum 0.050-s average acceleration was -0.6 *g* between 0.026 and 0.076 s. Figure 3.17 presents these data and other pertinent information from the test. Figures D5 through D8 in Appendix D present vehicle angular displacements and accelerations versus time traces.

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.

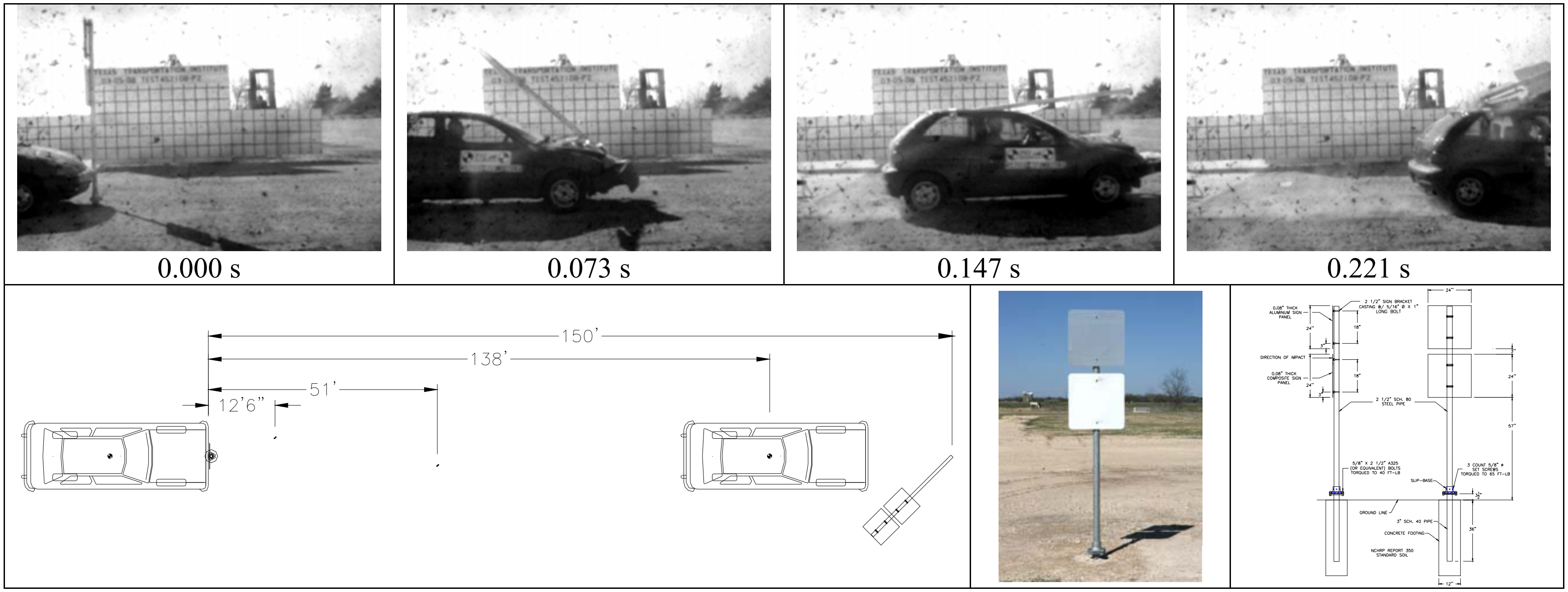
Result: The slip base sign support system with 24 inch × 24 inch burn ban sign readily activated by slipping away at the base as designed. (PASS)

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.

Figure 3.15. Vehicle after Test 452108-2.

Figure 3.16. Interior of Vehicle for Test 452108-2.



General Information	
Test Agency	Texas Transportation Institute
Test No.	452108-2
Date	2008-03-05
Test Article	
Type	Sign Support
Name	TxDOT Slip Base with Burn Ban Sign
Installation Height (ft)	7 ft to bottom of top sign
Material or Key Elements	2-1/2-inch schedule 80 pipe support with slip base and two 24x24 inch aluminum sign panels
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Designation	820C
Model	1998 Geo Metro
Mass (lb)	
Curb	1773
Test Inertial	1812
Dummy	168
Gross Static	1980

Impact Conditions	
Speed (mi/h)	62.6
Angle (deg)	0
Exit Conditions	
Speed (mi/h)	61.1
Angle (deg)	0
Occupant Risk Values	
Impact Velocity (ft/s)	
Longitudinal	5.2
Lateral	2.3
THIV (km/h)	6.2
Ridedown Accelerations (*g*)	
Longitudinal	0.4
Lateral	0.7
PHD (*g*)	0.7
ASI	0.26
Max. 0.050-s Average (*g*)	
Longitudinal	-3.1
Lateral	-0.6
Vertical	-1.2

Test Article Debris Scatter (ft)	
Laterally Left	1.0
Laterally Right	2.5
Vehicle Damage	
Exterior	
VDS	12FL4
CDC	12FLEN3
Max. Exterior Vehicle Crush (inches)	9.8
Interior	
OCDI	FL0200000
Max. Occupant Compartment Deformation (inches)	5.0
Post-Impact Behavior	
(during 1.0 sec after impact)	
Max. Yaw Angle (deg)	-6
Max. Pitch Angle (deg)	3
Max. Roll Angle (deg)	-3

Figure 3.17. Summary of Results for *NCHRP Report 350* Test 3-61 on the Schedule 80 Steel Pipe Support with 24 inch × 24 inch TxDOT Burn Ban Sign.

Result: The detached sign support traveled with the vehicle and came to rest along the path of the vehicle. The support did not penetrate nor show potential for penetrating the vehicle, or to present undue hazard to others in the area. Maximum occupant compartment deformation was 5.0 inches in the roof area. (PASS)

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

Result: The 820C vehicle remained upright and stable during and after the collision event. (PASS)

I. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity – m/s	
Preferred	*Maximum*
3 [9.8 ft/s]	*5* [16.8 ft/s]

Result: Longitudinal occupant impact velocity was 5.2 ft/s, and lateral occupant impact velocity was 2.3 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations – g	
Preferred	*Maximum*
16	*20*

Result: Longitudinal ridedown acceleration was 0.4 *g*, and lateral ridedown acceleration was 0.7 *g*. (PASS)

Vehicle Trajectory

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

Result: The vehicle did not intrude into adjacent traffic lanes. (PASS)

N. Vehicle trajectory behind the test article is acceptable.

Result: The vehicle came to rest behind the test installation. (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. Factors underlined below pertain to the results of the crash test reported herein.

Passenger Compartment Intrusion

1. *Windshield Intrusion*
    - *a. No windshield contact*
    - *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* [✓ *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*

[✓ No threat to others in area.]

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. CRASH TESTS ON 30 INCH × 36 INCH BURN BAN SIGN

TEST ARTICLE

Figure 4.1 and Figure 4.2 show details of the test installation used for evaluation of the 30 inch x 36 inch burn ban sign. The type of support post differed in the two tests. In test 452018-3, the support was a 2-1/2-inch diameter (2.875-inch O.D.) schedule 80 steel pipe with a minimum specified yield strength 46,000 psi. This support was initially considered to be the more critical of the two supports in terms of evaluating occupant compartment deformation associated with secondary contact with the roof and windshield because of its greater mass and lower center of mass. In test 452018-4, the support was a 2-7/8-inch outside diameter (O.D.), 10 British Wire Gage (BWG) steel tube with a 55,000 psi minimum yield strength. Because of its lower mass moment of inertia, this support will have a greater rotational velocity, which could possibly result in a higher impact force at a point more forward on the vehicle.

In both tests, a 24 inch × 24 inch × 0.080 inch thick aluminum sign panel was attached to the support using two 2-1/2-inch sign bracket mounting clamps and 15/16-inch diameter × 1-inch long bolts. The mounting height to the bottom of the confirmation sign was 7 ft.

A 30 inch wide × 36 inch tall × 0.080 inch thick lightweight composite burn ban sign panel was attached to the support in the same manner as the confirmation sign using two sign bracket mounting clamps spaced 18 inches apart. The composite sign consisted of a high-density polyethylene (HDPE) core sandwiched between two outer sheets of 0.010-inch thick, 5052 aluminum. A 3-inch offset was used between the two sign panels, making the mounting height to the bottom of the burn ban sign 3 ft-9 inches.

The upper slip base assembly consists of an integral collar and triangular base plate cast from ASTM A536 Grade 65-45-12 ductile iron. The 0.535-inch thick collar is perpendicular to the base plate and has a 2.93-inch diameter hole to accept the 2.875 O.D. support. Additional details of the slip base casting can be found in Figure 4.2.

To help prevent the pipe from rotating inside the collar during service and the casting from slipping off the pipe during an impact, the slip base assembly is secured to the end of the schedule 80 pipe using three 0.625-inch diameter set screws equally spaced around the perimeter of the collar and torqued to 65 ft-lb using a torque wrench with an Allen head adaptor.

The lower slip base plate was welded to a 36-inch length of 3-inch nominal diameter schedule 40 pipe. The pipe stub was embedded in a 12-inch diameter × 42-inch deep concrete footing installed in *NCHRP Report 350* standard soil. The distance from the ground surface to the top face of the lower triangular slip plate was 3.5 inches. The triangular slip base was oriented such that the upstream side was perpendicular to the direction of impact. A 30 gauge galvanized steel keeper plate was placed between the upper and lower slip plates. A washer was placed between the bolt keeper plate and upper slip plate to reduce the contact area between the plates. The two slip plates were clamped together using three 0.625-inch diameter × 2.5-inch long, ASTM A325 bolts that were tightened to a prescribed torque of 40 ft-lb. High strength washers were used under both the head and nut of each bolt. Photographs of the completed sign support installations for tests 452108-3 and 452108-4 are shown in Figure 4.3.

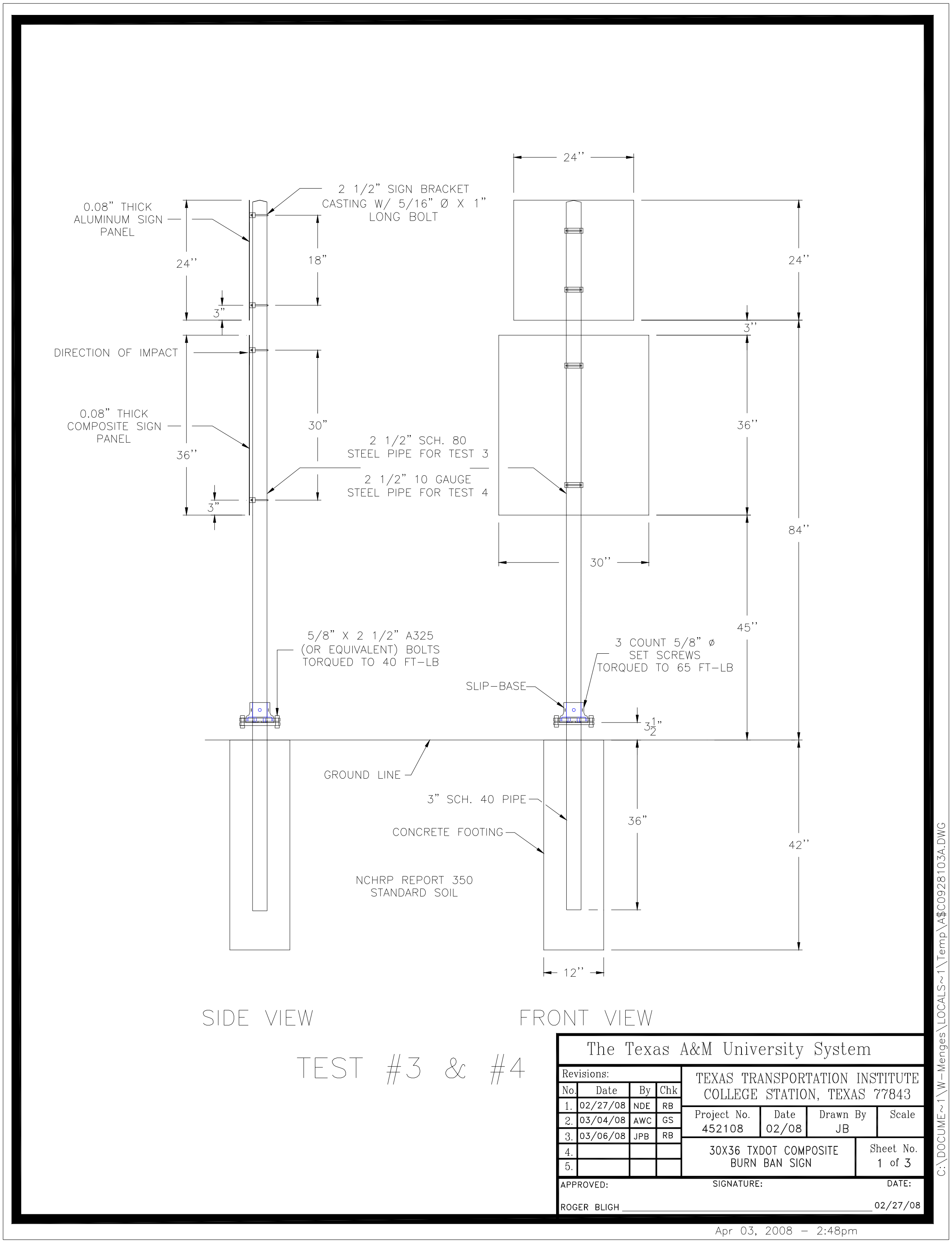


Figure 4.1. Details of the TxDOT 30 inch × 36 inch Burn Ban Sign Installation.

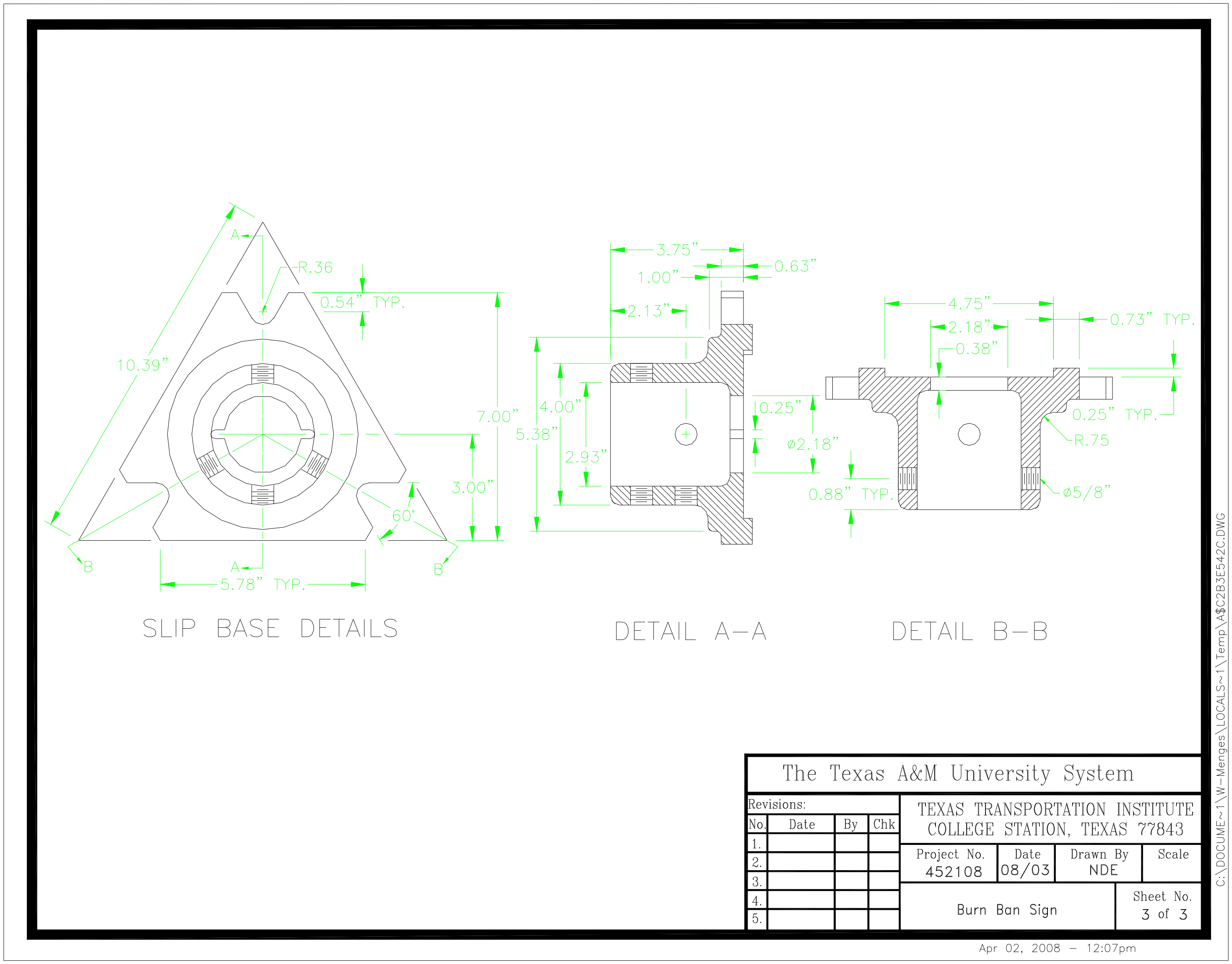


Figure 4.2. Details of the Slip Base Used in Tests 452108-3 and 4.

Figure 4.3. Test Article/Installation before Test 452108-3 and 4.

TEST 452108-3 (*NCHRP REPORT 350* TEST 3-61) ON THE SCHEDULE 80 STEEL PIPE SUPPORT WITH 30 INCH × 36 INCH TXDOT BURN BAN SIGN

Test Vehicle

A 1997 Geo Metro, shown in Figures 4.4 and 4.5, was used for the crash test. Test inertia weight of the vehicle was 1865 lb, and its gross static weight was 2035 lb. The height to the lower edge of the vehicle bumper was 15.75 inches, and the height to the lower edge of the vehicle bumper was 20.25 inches. Figure B3 in Appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a 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 morning of March 24, 2008. A total of 1.3 inches of rainfall was recorded six days prior to the test. Moisture content of the *NCHRP Report 350* standard soil in which the sign support system was installed was 8.9 percent. Weather conditions at the time of testing were as follows: Wind speed: 3-6 mi/h; Wind direction: 80 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 56^{o}F; Relative humidity: 36 percent.

Test Description

The 1997 Geo Metro, traveling at an impact speed of 62.0 mi/h, impacted the 2-1/2-inch diameter schedule 80 support 6 inches from the vehicle centerline offset to the driver's side. Shortly after contact, the support began to deform/move toward the field side. At 0.009 s, the top slip plate began to move, and the support lost contact with the lower slip plate at 0.0660 s. The support began to rotate counterclockwise in front of the vehicle at 0.019 s. At 0.060 s, the vehicle lost contact with the support while traveling at a speed of 58.3 mi/h. As the vehicle continued forward, the upper sign panel contacted the roof at 0.090 s. The support lost contact with the vehicle at 0.170 s. Figure C3 in Appendix C shows sequential photographs of the test period.

Damage to Test Installation

Damage to the installation is shown in Figures 4.6 and 4.7. The base showed no movement in the ground. The keeper plate and bolts came to rest near the base. The 30 inch × 36 inch burn ban sign panel separated from the support and came to rest 58 ft downstream of impact and 28 ft to the left of centerline. The 24 inch × 24 inch confirmation sign panel and support came to rest 149 ft downstream of and directly in line with the point of impact. The brakes on the vehicle were applied 160 ft behind the test installation, and the vehicle subsequently came to rest 322 ft downstream from impact.

Figure 4.4. Vehicle/Installation Geometrics for Test 452108-3.

Figure 4.5. Vehicle before Test 452108-3.

Figure 4.6. After Impact Trajectory Path for Test 452108-3.

Figure 4.7. Installation after Test 452108-3.

Vehicle Damage

Figures 4.8 and 4.9 show the damage to the exterior and interior of the vehicle, respectively. The front bumper, hood, radiator, and radiator support were deformed. The windshield was cracked near the roof line, but there was no hole. Maximum exterior crush in the frontal plane at the front bumper was 6.0 inches at a point, 6 inches to the left (toward the driver's side) of centerline. Maximum occupant compartment deformation was 5.6 inches in the roof area. Exterior crush and occupant compartment measurements are shown in Appendix B, Tables B5 and B6, respectively.

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 3.9 ft/s (1.2 m/s) at 0.516 s, the highest 0.010-s occupant ridedown acceleration was -0.2 *g* from 0.956 to 0.966 s, and the maximum 0.050-s average acceleration was -2.5 *g* between 0.000 and 0.050 s. In the lateral direction, the occupant impact velocity was 1.6 ft/s (0.5 m/s) at 0.516 s, the highest 0.010-s occupant ridedown acceleration was 0.2 *g* from 0.638 to 0.648 s, and the maximum 0.050-s average acceleration was -0.5 *g* between 0.130 and 0.180 s. Figure 4.10 presents these data and other pertinent information from the test. Figures D9 through D12 in Appendix D present vehicle angular displacements and accelerations versus time traces.

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.

Result: The slip base sign support with 30 inch × 36 inch burn ban sign readily activated by slipping away at the base as designed. (PASS)

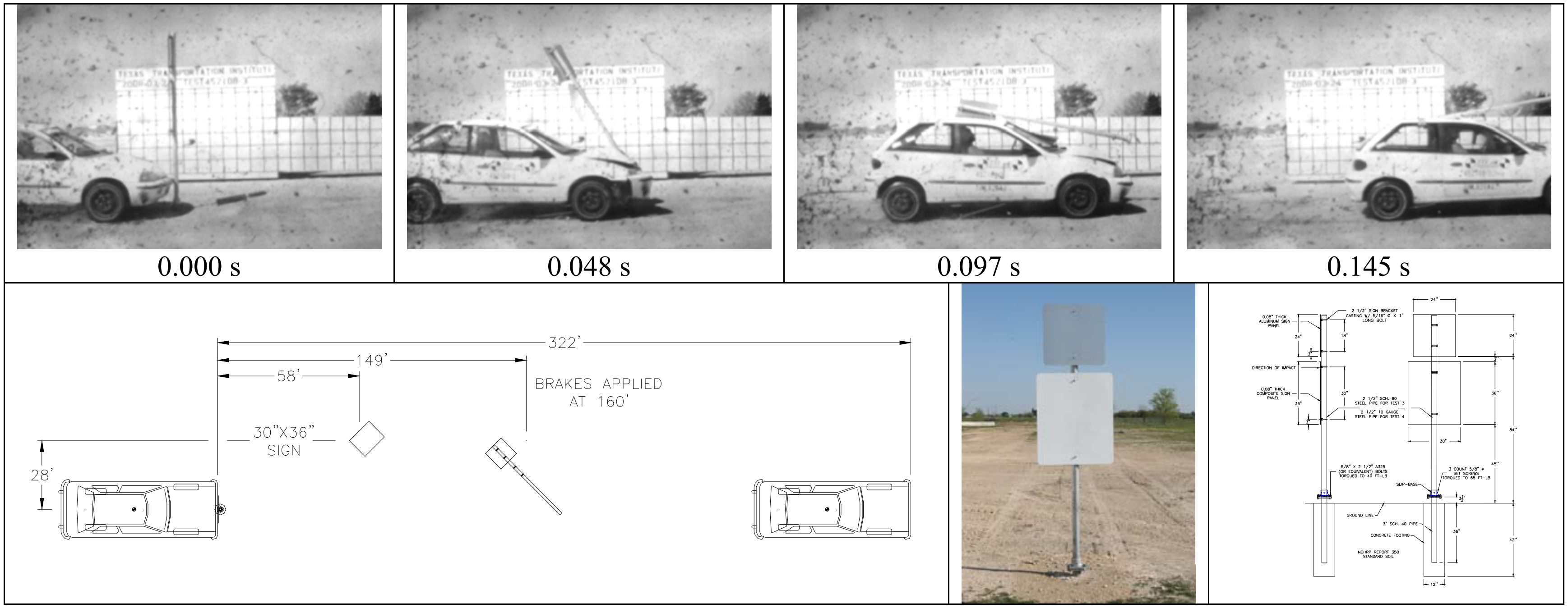
Occupant Risk

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.

Result: The detached sign support traveled with the vehicle and came to rest along the vehicle path. The support did not penetrate nor show potential for penetrating the vehicle, or to present undue hazard to others in the area. The sign panel and support deformed the roof 5.6 inches into the occupant compartment. (PASS)

Figure 4.8. Vehicle after Test 452108-3.

Figure 4.9. Interior of Vehicle for Test 452108-3.



General Information	
Test Agency	Texas Transportation Institute
Test No.	452108-3
Date	2008-03-24
Test Article	
Type	Sign Support
Name	TxDOT Slip Base with Burn Ban Sign
Installation Height (ft)	7 ft to bottom of top sign
Material or Key Elements	2-1/2-inch schedule 80 pipe support with slip base, one 24 x 24 inch sign panel, and one 30 x 36 inch sign panel
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Designation	820C
Model	1997 Geo Metro
Mass (lb)	
Curb	1876
Test Inertial	1865
Dummy	170
Gross Static	2035

Impact Conditions	
Speed (mi/h)	62.0
Angle (deg)	0
Exit Conditions	
Speed (mi/h)	58.3
Angle (deg)	0
Occupant Risk Values	
Impact Velocity (ft/s)	
Longitudinal	3.9
Lateral	1.6
THIV (km/h)	4.8
Ridedown Accelerations (*g*)	
Longitudinal	-0.2
Lateral	0.2
PHD (*g*)	0.3
ASI	0.21
Max. 0.050-s Average (*g*)	
Longitudinal	-2.5
Lateral	-0.5
Vertical	1.1

Test Article Debris Scatter (ft)	
Laterally Left	28.0
Laterally Right	0
Vehicle Damage	
Exterior	
VDS	12FL4
CDC	12FLEN3
Max. Exterior Vehicle Crush (inches)	5.9
Interior	
OCDI	FL0200000
Max. Occupant Compartment Deformation (inches)	5.6
Post-Impact Behavior (during 1.0 sec after impact)	
Max. Yaw Angle (deg)	-2
Max. Pitch Angle (deg)	2
Max. Roll Angle (deg)	-2

Figure 4.10. Summary of Results for *NCHRP Report 350* Test 3-61 on the Schedule 80 Steel Pipe Support with 30 inch × 36 inch TxDOT Burn Ban Sign.

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

Result: The 820C vehicle remained upright and stable throughout the collision period. (PASS)

J. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity – m/s

Preferred	*Maximum*
3 [9.8 ft/s]	*5* [16.8 ft/s]

Result: Longitudinal occupant impact velocity was 3.9 ft/s, and lateral occupant impact velocity was 1.6 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations – g

Preferred	*Maximum*
17	*20*

Result: Longitudinal ridedown acceleration was -0.2 *g*, and lateral occupant ridedown acceleration was 0.2 *g*. (PASS)

Vehicle Trajectory

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

Result: The 820C vehicle did not intrude into adjacent traffic lanes. (PASS)

N. Vehicle trajectory behind the test article is acceptable.

Result: The vehicle came to rest 322 ft downstream (behind) the test installation. (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. Factors underlined below pertain to the results of the crash test reported herein.

Passenger Compartment Intrusion

1. Windshield Intrusion
   - *a. No windshield contact*
   - *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* *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*

[✓ No threat to others in area.]

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 452108-4 (*NCHRP REPORT 350* TEST 3-61) ON THE 10 GAUGE STEEL PIPE SUPPORT WITH 30 INCH × 36 INCH TXDOT BURN BAN SIGN

Test Vehicle

A 1998 Geo Metro, shown in Figures 4.11 and 4.12, was used for the crash test. Test inertia weight of the vehicle was 1812 lb, and its gross static weight was 1989 lb. The height to the lower edge of the vehicle bumper was 15.75 inches, and the height to the upper edge of the vehicle bumper was 20.25 inches. Figure B4 in Appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a 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 March 24, 2008. A total of 1.3 inches of rainfall was recorded six days prior to the test. Moisture content of the *NCHRP Report 350* standard soil in which the sign support system was installed was 8.9 percent. Weather conditions at the time of testing were as follows: Wind speed: 9-10 mi/h; Wind direction: 180 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 64^{o}F; Relative humidity: 27 percent.

Test Description

The 1998 Geo Metro, traveling at an impact speed of 62.1 mi/h, impacted the 2-7/8-inch O.D., 10 BWG steel tube support 6 inches from the vehicle centerline offset to the driver's side. Shortly after contact, the support began to move toward the field side, and the front bumper was crushed to the front edge of the hood. The top slip plate began to move at 0.004 s, and the support lost contact with the lower slip plate at 0.017 s. At 0.063 s, the vehicle lost contact with the support while traveling at a speed of 61.9 mi/h. As the vehicle continued forward, both sign panels contacted the roof just above the windshield at 0.089 s, and the support contacted the roof at 0.097 s. At 0.175 s, the support lost contact with the roof of the vehicle. Figure C4 in Appendix C shows sequential photographs of the test period.

Damage to Test Installation

Damage to the installation is shown in Figures 4.13 and 4.14. The base showed no movement in the ground. The keeper plate and bolts came to rest near the base. The 30 inch × 36 inch burn ban sign panel separated from the support and came to rest 71 ft downstream of impact and 9 ft to the left. The 24 inch × 24 inch confirmation sign panel and support came to rest 213 ft downstream of impact and 4 ft to the left of centerline. The vehicle came to rest 466 ft downstream and 37 ft to the left of the point of impact.

Figure 4.11. Vehicle/Installation Geometrics for Test 452108-4.

Figure 4.12. Vehicle before Test 452108-4.

Figure 4.13. After Impact Trajectory Path for Test 452108-4.

Figure 4.14. Installation after Test 452108-4.

Vehicle Damage

Damage to the vehicle is shown in Figure 4.15. The front bumper, grill, hood, radiator, and radiator support were deformed. Maximum exterior crush in the frontal plane at the front bumper was 5.9 inches. The windshield was shattered downward from the roofline, but there was no loss of visibility. The roof was deformed downward a maximum of 5.5 inches on the exterior of the vehicle and deformed into the occupant compartment 4.8 inches. Photographs of the interior of the vehicle are shown in Figure 4.16. Exterior crush and occupant compartment measurements are shown in Appendix B, Tables B7 and B8, respectively.

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 3.3 ft/s at 0.673 s, the highest 0.010-s occupant ridedown acceleration was -0.2 *g* from 0.914 to 0.924 s, and the maximum 0.050-s average acceleration was -1.5 *g* between 0.000 and 0.050 s. In the lateral direction, the occupant impact velocity was 0.0 ft/s at 0.673 s, the highest 0.010-s occupant ridedown acceleration was 0.3 *g* from 0.760 to 0.770 s, and the maximum 0.050-s average acceleration was -0.4 *g* between 0.128 and 0.178 s. Figure 4.17 presents these data and other pertinent information from the test. Figures D13 through D16 in Appendix D present vehicle angular displacements and accelerations versus time traces.

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.

Result: The slip base with 2-7/8 inch O.D., 10 BWG steel tube sign support with 30 inch × 36 inch burn ban sign readily activated by slipping away at the base as designed. (PASS)

Occupant Risk

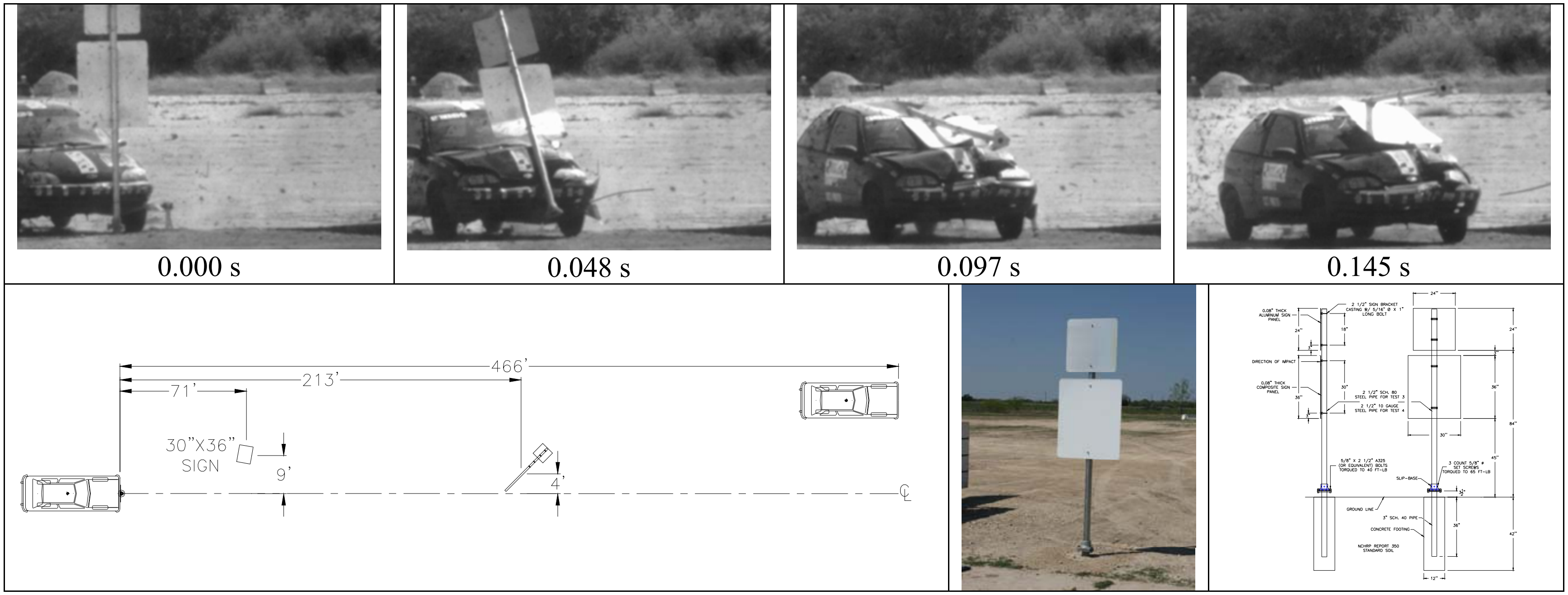
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.

NOTE:
Still photographs were taken after vehicle was removed from test site. Movement jarred the windshield loose from the top of the windshield/roof frame.

Figure 4.15. Vehicle after Test 452108-4.

NOTE: Photographs were taken after vehicle was removed from test site.
Movement jarred the windshield loose from the top of the windshield/roof frame.

Figure 4.16. Interior of Vehicle for Test 452108-4.



General Information	
Test Agency	Texas Transportation Institute
Test No.	452108-4
Date	2008-03-24
Test Article	
Type	Sign Support
Name	TxDOT Slip Base with Burn Ban Sign
Installation Height (ft)	7 ft to bottom of top sign
Material or Key Elements	2-7/8-inch O.D., 10 BWG tube support with slip base, one 24x24 inch sign panel, and one 30x36 inch sign panel
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Designation	820C
Model	1998 Geo Metro
Mass (lb)	
Curb	1772
Test Inertial	1812
Dummy	170
Gross Static	1989

Impact Conditions	
Speed (mi/h)	62.1
Angle (deg)	0
Exit Conditions	
Speed (mi/h)	61.9
Angle (deg)	0
Occupant Risk Values	
Impact Velocity (ft/s)	
Longitudinal	3.3
Lateral	0.0
THIV (km/h)	3.9
Ridedown Accelerations (*g*)	
Longitudinal	-0.2
Lateral	0.3
PHD (*g*)	0.3
ASI	0.13
Max. 0.050-s Average (*g*)	
Longitudinal	-1.5
Lateral	-0.4
Vertical	-0.7

Test Article Debris Scatter (ft)	
Laterally Left	9.0
Laterally Right	0
Vehicle Damage	
Exterior	
VDS	12FL4
CDC	12FLEN3
Max. Exterior Vehicle Crush (inches)	5.9
Interior	
OCDI	FL0200000
Max. Occupant Compartment Deformation (inches)	4.8
Post-Impact Behavior	
(during 1.0 sec after impact)	
Max. Yaw Angle (deg)	3
Max. Pitch Angle (deg)	2
Max. Roll Angle (deg)	2

Figure 4.17. Summary of Results for *NCHRP Report 350* Test 3-61 on the 10 Gauge Steel Pipe Support with 30 inch × 36 inch Burn Ban Sign.

Result: The detached sign support traveled with the vehicle and came to rest along the vehicle path. The support did not penetrate nor show potential for penetrating the vehicle, or to present undue hazard to others in the area. The sign panel and support deformed the roof 4.8 inches into the occupant compartment. (PASS)

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

Result: The 820C vehicle remained upright and stable during and after the collision event. (PASS)

K. Occupant impact velocities should satisfy the following:

Longitudinal and Lateral Occupant Impact Velocity – m/s

Preferred	*Maximum*
3 [9.8 ft/s]	*5* [16.8 ft/s]

Result: Longitudinal occupant impact velocity was 3.3 ft/s, and lateral occupant impact velocity was 0.0 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations – g

Preferred	*Maximum*
18	*20*

Result: Longitudinal ridedown acceleration was -0.2 *g*, and lateral ridedown acceleration was 0.3 *g*. (PASS)

Vehicle Trajectory

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

Result: The 820C vehicle did not intrude into adjacent traffic lanes. (PASS)

N. Vehicle trajectory behind the test article is acceptable.

Result: The vehicle came to rest behind the test installation. (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. Factors underlined below pertain to the results of the crash test reported herein.

Passenger Compartment Intrusion

1. *Windshield Intrusion*
    - *a. No windshield contact*
    - *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* [✓ *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*

[✓ No threat to others in area.]

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 5. SUMMARY AND CONCLUSIONS

SUMMARY OF TEST RESULTS

Schedule 80 Steel Pipe Support with 24 inch × 24 inch Burn Ban Sign

Two tests were performed on a slip base sign support system with a 2-1/2-inch nominal diameter schedule 80 steel pipe support, a 24 inch × 24 inch × 0.080 inch thick aluminum confirmation sign mounted at a height of 7 ft, and a 24 inch × 24 inch × 0.080 composite burn ban sign mounted at a height of 4 ft-9 inches.

In the low-speed test, the support readily activated by slipping away at the base as designed. The released sign support traveled with the vehicle and came to rest under the vehicle. The support did not penetrate nor show potential for penetrating the vehicle or to present undue hazard to others in the area. No occupant compartment deformation occurred. The 820C vehicle remained upright and stable throughout the collision period. Occupant risk factors were within the preferred limits specified in *NCHRP Report 350*. The vehicle came to rest 92.5 ft downstream (behind) the test installation and did not intrude into adjacent traffic lanes.

In the high-speed test, the support also readily activated by slipping away at the base as designed. The released sign support traveled with the vehicle and came to rest along the path of the vehicle. The support did not penetrate nor show potential for penetrating the vehicle or to present undue hazard to others in the area. Maximum occupant compartment deformation was 5.0 inches in the roof area resulting from secondary contact with the released sign support system. The 820C vehicle remained upright and stable during and after the collision event. Again, occupant risk factors were with the preferred limits specified in *NCHRP Report 350*. The vehicle came to rest behind the test installation and did not intrude into adjacent traffic.

After analyzing the results of the testing on the slip base sign support system with 24 inch x 24 inch x 0.080 composite burn ban sign, the researchers determined that the high-speed test was the more critical test. Therefore, only this test was performed on the remaining burn ban sign support configurations that were evaluated.

Schedule 80 Steel Pipe Support with 30 inch × 36 inch Burn Ban Sign

In a high-speed test (*NCHRP Report 350* Test 3-61) of a slip base sign support system with a 2-1/2-inch nominal diameter schedule 80 steel pipe support, a 24 inch × 24 inch × 0.080 inch thick aluminum confirmation sign mounted at a height of 7 ft, and a 30 inch × 36 inch × 0.080 inch composite burn ban sign mounted at a height of 3 ft-9 inches, the system readily activated by slipping away at the base as designed. The released sign support traveled with the vehicle and came to rest along the vehicle path. The support did not penetrate nor show potential for penetrating the vehicle or to present undue hazard to others in the area. The sign panel and support deformed the roof 5.6 inches into the occupant compartment. The 820C vehicle remained upright and stable throughout the collision period. Occupant risk factors were within the preferred limits specified in *NCHRP Report 350*. The 820C vehicle came to rest 322 ft downstream (behind) the test installation and did not intrude into adjacent traffic lanes.

10 Gauge Steel Pipe Support with 30 inch × 36 inch Burn Ban Sign

In a high-speed test (*NCHRP Report 350* Test 3-61) of a slip base sign support system with a 2-7/8-inch outside diameter, 10 BWG steel tube support, a 24 inch × 24 inch × 0.080 inch thick aluminum confirmation sign mounted at a height of 7 ft, and a 30 inch × 36 inch × 0.080 inch composite burn ban sign mounted at a height of 3 ft-9 inches, the system readily activated by slipping away at the base as designed. The released sign support traveled with the vehicle and came to rest along the vehicle path. The support did not penetrate nor show potential for penetrating the vehicle or to present undue hazard to others in the area. The sign panel and support deformed the roof 4.8 inches into the occupant compartment. The 820C vehicle remained upright and stable during and after the collision event. Occupant risk factors were within the preferred limits specified in *NCHRP Report 350*. The 820C vehicle came to rest behind the test installation and did not intrude into adjacent traffic lanes.

CONCLUSIONS

As summarized in Tables 5.1 through 5.4, the slip base sign support systems with attached burn ban signs satisfied the impact performance evaluation criteria of *NCHRP Report 350*.

In the three high-speed tests performed on different burn ban sign configurations, secondary contact of the sign support system with the roof resulted in substantial deformation of the occupant compartment ranging in magnitude from 4.8 inches to 5.6 inches. These deformation levels are less than the 6-inch roof deformation threshold established by FHWA based on accepted testing of various breakaway sign support and luminaire poles. However, they are significantly greater than roof deformations typically associated with impacts of slip base sign support systems.

After examination of the test results, the extent of roof deformation is primarily attributed to the use of a slip base with a small, 4 square foot aluminum confirmation sign rather than the addition of the burn ban signs to these systems. It was concluded that the small size and light weight of the confirmation sign substrate decreased the height of the center of mass and mass moment of inertia of the support system. This adversely influenced the trajectory of the support post and increased the severity of interaction with the vehicle by lowering the point of rotation and increasing the rotational velocity of the released support post.

Historically, and primarily due to economic considerations, slip base sign supports have only been used for larger sign panels (e.g., area greater than 10 square feet). With an increase in the size of the sign panel, there is a corresponding increase in the sign panel weight and length of the support post, both of which tend to increase the height of the center of mass and mass moment of inertia. This increases the height of the point of rotation and decreases the rate of rotation of the released support, which tends to shift the point of secondary contact further rearward on the vehicle and decrease the severity of this contact. In tests of the Texas slip base with a 16 square foot plywood sign panel mounted at a height of 7 ft from the ground to the bottom of the sign, the released sign support system rotated above the impacting vehicle without any secondary contact at all *(3,4)*.

A recent review of district practices by the Traffic Operations Division noted that some districts were using the Texas slip base for all small signs, even those having an area less than 10 square feet. The motivation behind this practice was to reduce inventory associated with multiple types of supports and simplify maintenance training and operations. Thus, the smallest, lightest sign panel being used with the Texas slip base support is a 24 inch × 24 inch aluminum confirmation sign. Until this project, TTI researchers were not aware of any crash testing of slip base supports with signs this small.

Although the slip base support with 24 inch × 24 inch aluminum confirmation sign was found to satisfy *NCHRP Report 350* impact performance requirements, it may be appropriate to limit the minimum sign area on slip base supports to achieve a reduction in occupant compartment deformation caused by secondary contact of the released support system with the roof of the impacting vehicle. It is recommended that an expanded investigation using engineering modeling and full-scale crash testing be undertaken to more fully examine the performance limits of slip base sign supports in terms of sign panel size, mass, and mounting height. The compatibility of other vehicle types (e.g., pickup truck) with the slip base with small signs could also be evaluated.

Table 5.1. Performance Evaluation Summary for *NCHRP Report 350* Test 3-60 on the Schedule 80 Steel Pipe Support with 24 inch × 24 inch Burn Ban Sign.

Test Agency: Texas Transportation Institute　Test No.: 452108-1　Test Date: 2008-03-05

***NCHRP Report 350* Test 3-60 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy		
B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The 2-1/2-inch diameter schedule 80 steel sign support with 24 inch × 24 inch burn ban sign readily activated by slipping away at the base as designed.	Pass
Occupant Risk D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*	The detached sign support traveled with the vehicle and came to rest under the vehicle. The support did not penetrate nor show potential for penetrating the vehicle or to present undue hazard to others in the area. 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 820C vehicle remained upright and stable throughout the collision period.	Pass
H. *Occupant impact velocities should satisfy the following:* *Occupant Velocity Limits (m/s)* *Component* / *Preferred* / *Maximum* *Longitudinal* / *3 [9.8 f/s]* / *5 [16.8 ft/s]*	Longitudinal occupant impact velocity was 5.6 ft/s, and lateral occupant impact velocity was 0.7 ft/s.	Pass
I. *Occupant ridedown accelerations should satisfy the following:* *Occupant Ridedown Acceleration Limits (g)* *Component* / *Preferred* / *Maximum* *Longitudinal and lateral* / *15* / *20*	Longitudinal ridedown acceleration was 0.2 *g*, and lateral occupant ridedown acceleration was 0.2 *g*.	Pass
Vehicle Trajectory K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*	The vehicle did not intrude into adjacent traffic lanes.	Pass
N. *Vehicle trajectory behind the test article is acceptable.*	The vehicle came to rest 92.5 ft downstream (behind) the test installation.	Pass

Table 5.2. Performance Evaluation Summary for *NCHRP Report 350* Test 3-61 on the Schedule 80 Steel Pipe Support with 24 inch × 24 inch Burn Ban Sign.

Test Agency: Texas Transportation Institute Test No.: 452108-2 Test Date: 2008-03-05

<table>
<tr><th>NCHRP Report 350 Test 3-61 Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td>Structural Adequacy</td><td></td><td></td></tr>
<tr><td>B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</td><td>The 2-1/2-inch diameter schedule 80 steel pipe sign support with 24 inch × 24 inch burn ban sign readily activated by slipping away at the base as designed.</td><td>Pass</td></tr>
<tr><td>Occupant Risk
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td><td>The detached sign support traveled with the vehicle and came to rest along the path of the vehicle. The support did not penetrate nor show potential for penetrating the vehicle or to present undue hazard to others in the area. Maximum occupant compartment deformation was 5.0 inches in the roof area.</td><td>Pass</td></tr>
<tr><td>F. The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.</td><td>The 820C vehicle remained upright and stable during and after the collision event.</td><td>Pass</td></tr>
<tr><td>H. Occupant impact velocities should satisfy the following:
<table>
<tr><th colspan="3">Occupant Velocity Limits (m/s)</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal</td><td>3 [9.8 f/s]</td><td>5 [16.8 ft/s]</td></tr>
</table></td><td>Longitudinal occupant impact velocity was 5.2 ft/s, and lateral occupant impact velocity was 2.3 ft/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)</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and lateral</td><td>15</td><td>20</td></tr>
</table></td><td>Longitudinal ridedown acceleration was 0.4 g, and lateral ridedown acceleration was 0.7 g.</td><td>Pass</td></tr>
<tr><td>Vehicle Trajectory
K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.</td><td>The vehicle 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 test installation.</td><td>Pass</td></tr>
</table>

Table 5.3. Performance Evaluation Summary for *NCHRP Report 350* Test 3-61 on the Schedule 80 Steel Pipe Support with 30 inch × 36 inch Burn Ban Sign.

Test Agency: Texas Transportation Institute Test No.: 452108-3 Test Date: 2008-03-24

<table>
<tr><th><i>NCHRP Report 350</i> Test 3-61 Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td><u>Structural Adequacy</u></td><td></td><td></td></tr>
<tr><td>B. <i>The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</i></td><td>The 2-1/2-inch diameter schedule 80 sign support with 30 inch × 36 inch burn ban sign readily activated by slipping away at the base as designed.</td><td>Pass</td></tr>
<tr><td><u>Occupant Risk</u>
D. <i>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.</i></td><td>The detached sign support traveled with the vehicle and came to rest along the vehicle path. The support did not penetrate nor show potential for penetrating the vehicle or to present undue hazard to others in the area. The sign panel and support deformed the roof 5.6 inches into the occupant compartment.</td><td>Pass</td></tr>
<tr><td>F. <i>The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.</i></td><td>The 820C vehicle remained upright and stable throughout the collision period.</td><td>Pass</td></tr>
<tr><td>H. <i>Occupant impact velocities should satisfy the following:</i>
<table>
<tr><td colspan="3"><i>Occupant Velocity Limits (m/s)</i></td></tr>
<tr><td><i>Component</i></td><td><i>Preferred</i></td><td><i>Maximum</i></td></tr>
<tr><td><i>Longitudinal</i></td><td><i>3</i> [9.8 f/s]</td><td><i>5</i> [16.8 ft/s]</td></tr>
</table></td><td>Longitudinal occupant impact velocity was 3.9 ft/s, and lateral occupant impact velocity was 1.6 ft/s.</td><td>Pass</td></tr>
<tr><td>I. <i>Occupant ridedown accelerations should satisfy the following:</i>
<table>
<tr><td colspan="3"><i>Occupant Ridedown Acceleration Limits (g)</i></td></tr>
<tr><td><i>Component</i></td><td><i>Preferred</i></td><td><i>Maximum</i></td></tr>
<tr><td><i>Longitudinal and lateral</i></td><td><i>15</i></td><td><i>20</i></td></tr>
</table></td><td>Longitudinal ridedown acceleration was -0.2 <i>g</i>, and lateral occupant ridedown acceleration was 0.2 <i>g</i>.</td><td>Pass</td></tr>
<tr><td><u>Vehicle Trajectory</u>
K. <i>After collision, it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.</i></td><td>The 820C vehicle did not intrude into adjacent traffic lanes.</td><td>Pass</td></tr>
<tr><td>N. <i>Vehicle trajectory behind the test article is acceptable.</i></td><td>The vehicle came to rest 322 ft downstream (behind) the test installation.</td><td>Pass</td></tr>
</table>

Table 5.4. Performance Evaluation Summary for *NCHRP Report 350* Test 3-61 on the 10 Gauge Steel Pipe Support with 30 inch × 36 inch Burn Ban Sign.

Test Agency: Texas Transportation Institute   Test No.: 452108-4   Test Date: 2008-03-24

<table>
<tr><th><i>NCHRP Report 350</i> Test 3-61 Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td><u>Structural Adequacy</u></td><td></td><td></td></tr>
<tr><td>B. <i>The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</i></td><td>The 2-1/2-inch diameter 10 gauge steel pipe sign support with 30 inch × 36 inch burn ban sign readily activated by slipping away at the base as designed.</td><td>Pass</td></tr>
<tr><td><u>Occupant Risk</u>
D. <i>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.</i></td><td>The detached sign support traveled with the vehicle and came to rest along the vehicle path. The support did not penetrate nor show potential for penetrating the vehicle or to present undue hazard to others in the area. The sign panel and support deformed the roof 4.8 inches into the occupant compartment.</td><td>Pass</td></tr>
<tr><td>F. <i>The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.</i></td><td>The 820C vehicle remained upright and stable during and after the collision event.</td><td>Pass</td></tr>
<tr><td>H. <i>Occupant impact velocities should satisfy the following:</i>
<table>
<tr><td colspan="3"><i>Occupant Velocity Limits (m/s)</i></td></tr>
<tr><td><i>Component</i></td><td><i>Preferred</i></td><td><i>Maximum</i></td></tr>
<tr><td><i>Longitudinal</i></td><td><i>3</i> [9.8 f/s]</td><td><i>5</i> [16.8 ft/s]</td></tr>
</table></td><td>Longitudinal occupant impact velocity was 3.3 ft/s, and lateral occupant impact velocity was 0.0 ft/s.</td><td>Pass</td></tr>
<tr><td>I. <i>Occupant ridedown accelerations should satisfy the following:</i>
<table>
<tr><td colspan="3"><i>Occupant Ridedown Acceleration Limits (g)</i></td></tr>
<tr><td><i>Component</i></td><td><i>Preferred</i></td><td><i>Maximum</i></td></tr>
<tr><td><i>Longitudinal and lateral</i></td><td><i>15</i></td><td><i>20</i></td></tr>
</table></td><td>Longitudinal ridedown acceleration was -0.2 <i>g</i>, and lateral ridedown acceleration was 0.3 <i>g</i>.</td><td>Pass</td></tr>
<tr><td><u>Vehicle Trajectory</u>
K. <i>After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.</i></td><td>The 820C vehicle did not intrude into adjacent traffic lanes.</td><td>Pass</td></tr>
<tr><td>N. <i>Vehicle trajectory behind the test article is acceptable.</i></td><td>The vehicle came to rest behind the test installation.</td><td>Pass</td></tr>
</table>

CHAPTER 6. IMPLEMENTATION STATEMENT

Texas counties expressed a desire to TxDOT to post advisory signs on the roadside to alert motorists when a burn ban is in effect. For obvious economic reasons, the preferred method of implementation is to append the burn ban notification signs to existing sign support structures already installed along Texas highways.

In support of this request, TxDOT sponsored this project to evaluate the impact performance of a Texas slip base sign support system with a burn ban sign appended to the support below the primary sign at a mounting height less than 7 ft. The impact performance of the burn ban sign support configurations was evaluated through full-scale crash testing. The crash testing was performed in accordance with the requirements of *NCHRP Report 350*.

To qualify the burn ban sign for use on most if not all slip base support systems installed across the state, the research plan included identifying and testing the most critical sign configuration. The configuration selected for testing incorporated a 24 inch × 24 inch × 0.080 inch thick aluminum confirmation sign mounted at a height of 7 ft, with the burn ban signs mounted below.

Two different sizes of burn ban signs were considered: a 24 inch × 24 inch sign and a 30 inch × 36 inch sign. The smaller 24 inch × 24 inch sign is intended to simply communicate that a burn ban is in effect. The larger 30 inch × 36 inch sign will additionally indicate the name of the county when needed.

Based on the satisfactory test results reported herein, the practice of appending a burn ban sign to an existing slip base sign support system is considered suitable for implementation. The burn ban signs should be fabricated from 0.080-inch thick lightweight composite sheeting consisting of a high-density polyethylene (HDPE) core sandwiched between two thin outer sheets of aluminum and should be no larger than 30 inches × 36 inches in size.

The burn ban signs may be attached to any slip base sign support system having a primary sign panel that is 24 inches × 24 inches or larger mounted at a height of 7 ft or greater from the ground to the bottom of the sign. Both the 2-1/2-inch nominal diameter schedule 80 steel pipe support and 2-7/8-inch outside diameter, 10 BWG steel tube support are acceptable support post options. The mounting height of the burn ban sign should not be less than 3 ft-9 inches from the ground to the bottom of the bottom of the composite sign. Further details for mounting composite burn ban signs to slip base sign support systems are presented in Figure 6.1 and 6.2.

It should be noted that slip base sign supports have traditionally been used for signs having an area of 10 square feet or more. However, some districts are now using the Texas slip base with signs as small as 4 square feet. In full-scale tests of this configuration, secondary contact of the released sign support system with the roof resulted in roof deformation ranging in magnitude from 4.8 inches to 5.6 inches. While this level of deformation is considered acceptable by FHWA, it is significantly greater than roof deformations typically associated with impacts of slip base sign support systems that use larger sign panels. It is recommended that additional research be performed to more fully understand the performance limits of slip base sign supports in terms of sign panel size, mass, and mounting height, and determine whether or not a minimum sign area should be established for slip base support. The compatibility of other vehicle types (e.g., pickup truck) with the slip base with small signs could also be evaluated.

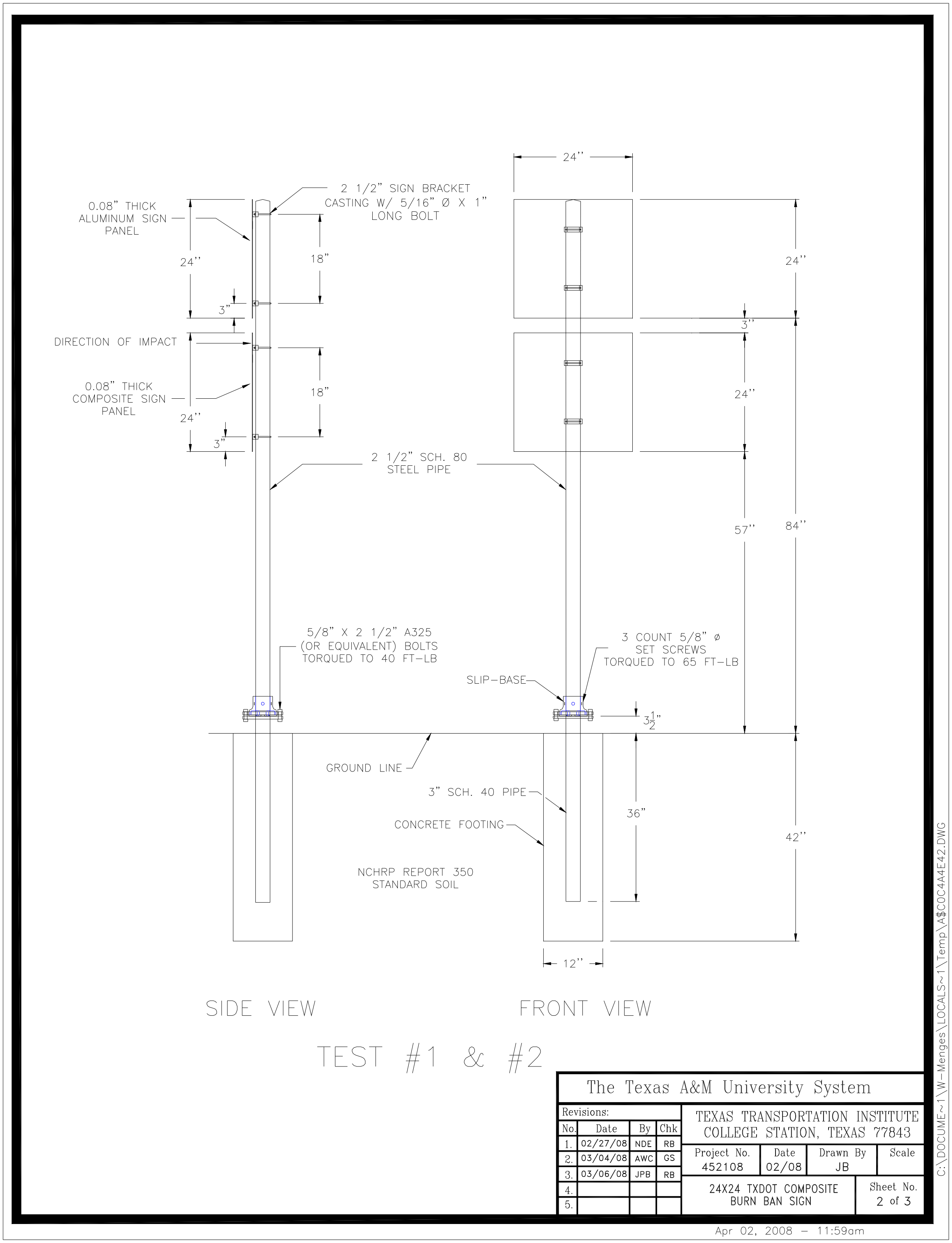


Figure 6.1. Details of 24 inch × 24 inch Burn Ban Sign Mounted to Texas Slip Base.

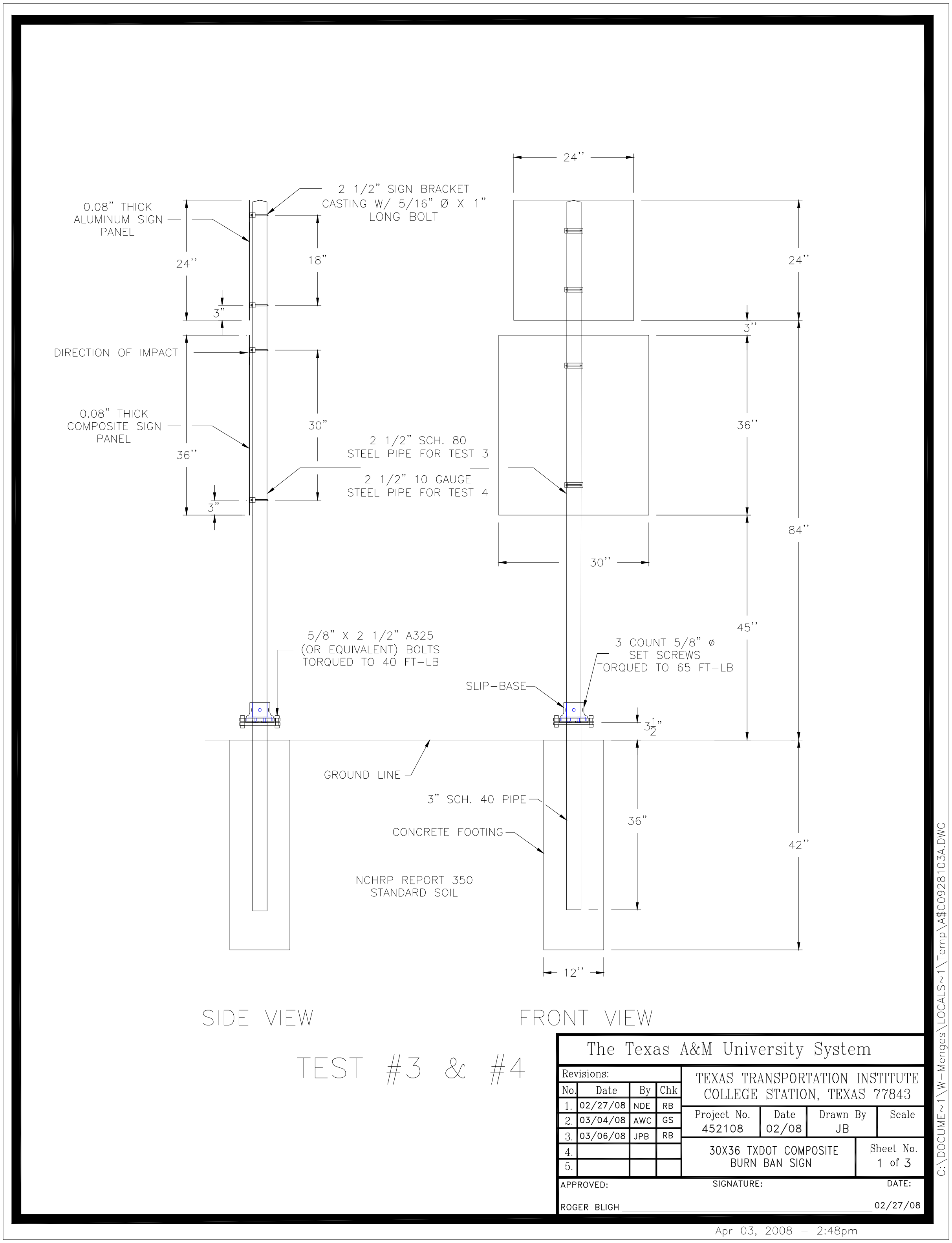


Figure 6.2. Details of 30 inch × 36 inch Burn Ban Sign Mounted to Texas Slip Base.

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2. R.P. Bligh, H.E. Ross, Jr., W.L. Menges, and S.K. Schoeneman. *Development and Evaluation of New Small Sign Support Systems*. Report No. 7-1971. Texas Transportation Institute, Texas A&M University, College Station, Texas, April 2001.

3. R.P. Bligh and W.L. Menges. *NCHRP Report 350 Testing of the Southwest Pipe Sign Support*. Report No. 405481. Texas Transportation Institute, Texas A&M University, College Station, Texas, June 1996.

4. R.P. Bligh, A.G. Arnold, and W.L. Menges. *Safety Performance Evaluation of Southwest Pipn Sign Support Systems in Weak Soil*. Report No. 405851-1F. Texas Transportation Institute, Texas A&M University, College Station, Texas, February 1997.

5. R.P. Bligh, D.L. Bullard, Jr., W.L. Menges, and S.K. Schoeneman. *Testing and Evaluation of Slip Base Sign Supports*. Report No. 0-1792-5. Texas Transportation Institute, Texas A&M University, College Station, Texas, May 2001.

6. R.P. Bligh, C.E. Buth, W.L. Menges, and B.G. Butler. *Evaluation of Design and Retrofit Concepts for Slip-Base Sign Support Systems*. Report No. 3911-S. Texas Transportation Institute, Texas A&M University, College Station, Texas, February 2001.

7. Federal Highway Administration Memorandum from the Director, Office of Engineering, entitled: “ACTION: Identifying Acceptable Highway Safety Features,” dated July 25, 1997.

APPENDIX A. CRASH TEST AND DATA ANALYSIS PROCEDURES

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

ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

The 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 (c.g.) to measure longitudinal, lateral, and vertical acceleration levels; and a backup 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 $\underline{+}100$ *g* 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 $\underline{+}2.5$ volt maximum level. The signal conditioners also provide the capability of a resistive calibration (R-cal) or shunt calibration for the accelerometers and a precision voltage calibration for the rate transducers. The electronic signals from the accelerometers and rate transducers are transmitted to a base station by means of a 15-channel, constant bandwidth, Inter-Range Instrumentation Group (I.R.I.G.), FM/FM telemetry link for recording and for display. 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 to 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 a TEAC® instrumentation data recorder. After the test, the data are played back from the TEAC® recorder 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 the 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-millisecond (ms) average ridedown acceleration. WinDigit calculates change in vehicle velocity at the end of a given impulse period. In addition, WinDigit computes maximum average accelerations over 50-ms intervals in each of the three directions. 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 the 820C vehicle. The dummy was uninstrumented. Use of a dummy in the 2000P vehicle is optional according to *NCHRP Report 350*, and there was no dummy used in the tests with the 2000P vehicle.

PHOTOGRAPHIC INSTRUMENTATION AND DATA PROCESSING

Photographic coverage of the test included three high-speed cameras: one overhead with a field-of-view perpendicular to the ground and directly over the impact point; one placed behind the installation at an angle; and a third placed to have a field-of-view parallel to and aligned with the installation at the downstream end. A flash bulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked Motion Analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A mini-DV camera and still cameras were used to record and document conditions of the test vehicle and installation before and after the test.

TEST VEHICLE PROPULSION AND GUIDANCE

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2-to-1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time the vehicle’s brakes were activated to bring it to a safe and controlled stop.

APPENDIX B. TEST VEHICLE PROPERTIES AND INFORMATION

Vehicle Inventory Number: 765

Date: 2008-03-05 Test No.: 452108-1 VIN No.: 2CIMR226256722856

Year: 1995 Make: Geo Model: Metro

Tire Inflation Pressure: 32 psi Odometer: 137178 Tire Size: ____

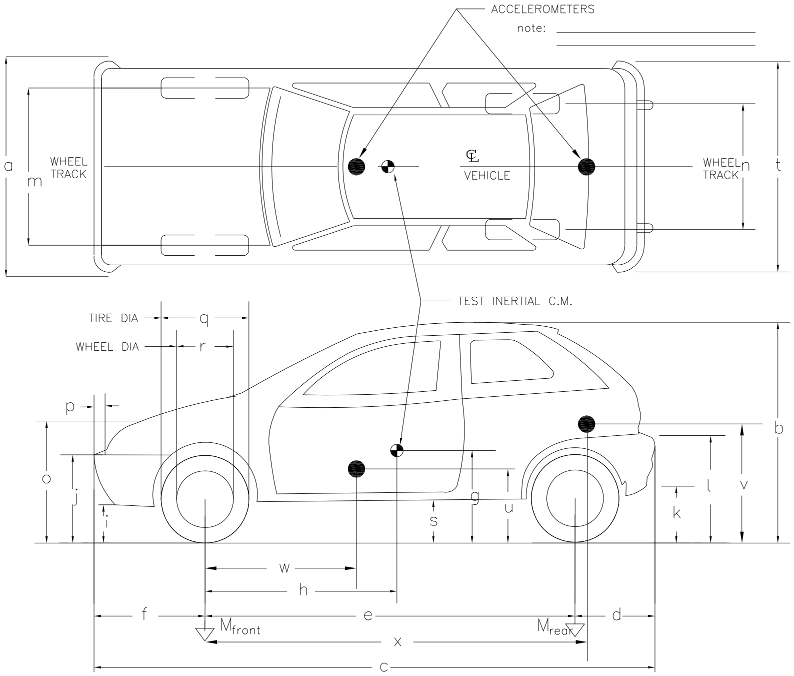
Describe any damage to the vehicle prior to test: ____

● Denotes accelerometer location.

NOTES: ____

Engine Type: 3 cylinder
Engine CID: ____
Transmission Type:
___ Auto or _x_ Manual
_x_ FWD ___ RWD ___ 4WD
Optional Equipment:

Dummy Data:
Type: 95th Percentile Male
Mass: 169 lb
Seat Position: Front Passenger



Geometry: inches

a	62.6	f	31.1	k	11.8	p	4.7	u	16.5
b	55.9	g		l	25.8	q	22.4	v	21.6
c	147.8	h	36.8	m	54.5	r	14.5	w	37.4
d	23.6	i	15.7	n	53.5	s	12.0	x	95.3
e	93.1	j	20.3	o	25.6	t	60.2		

Wheel Center Ht Front 10.2 Wheel Center Ht Rear 10.8

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1400	M_{front}	1069	1078	1157
Back	1235	M_{rear}	692	706	796
Total	2590	M_{Total}	1761	1784	1953

Mass Distribution:
lb: LF: 560 RF: 518 LR: 360 RR: 346

Figure B1. Vehicle Properties for Test 452108-1.

Table B1. Exterior Crush Measurements for Test 452108-1.

Vehicle Inventory Number: 765

Date: 2008-03-05 Test No.: 452108-1 VIN No.: 2CIMR226256722856

Year: 1995 Make: Geo Model: Metro

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 inches ________	
≥ 4 inches ________	

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	Front bumper	3.9	6.3	11.8	-1.6	1.2	2.4	6.3	2.0	0.8	5.9
	All measurements										
	in inches										

[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.

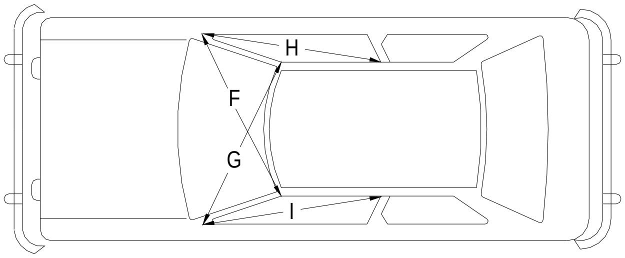
Note: Use as many lines/columns as necessary to describe each damage profile.

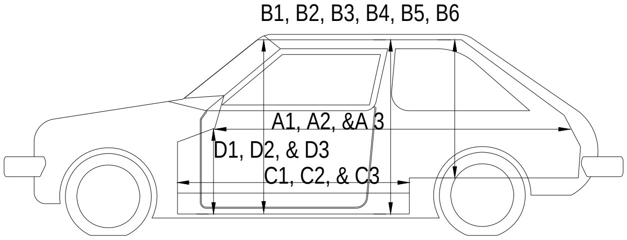
Table B2. Occupant Compartment Measurements for Test 452108-1.

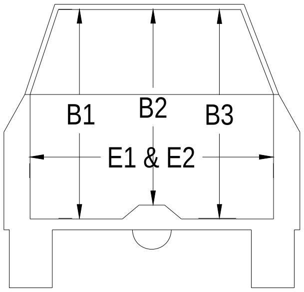
Vehicle Inventory Number: 765

Date: 2008-03-05 Test No.: 452108-1 VIN No.: 2CIMR226256722856

Year: 1995 Make: Geo Model: Metro







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	56.7	56.7
A2	79.1	79.1
A3	56.2	56.2
B1	37.9	37.9
B2	35.4	35.4
B3	37.8	37.8
B4	34.8	34.8
B5	35.3	35.3
B6	34.8	34.8
C1	22.0	22.0
C2	----	----
C3	22.0	22.0
D1	9.6	9.6
D2	3.7	3.7
D3	9.4	9.4
E1	47.8	47.8
E2	46.4	46.4
F	47.6	47.6
G	47.6	47.6
H	40.6	40.6
I	40.6	40.6
J*	47.2	47.2

*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

Vehicle Inventory Number: 760

Date: 2008-03-05 Test No.: 452108-2 VIN No.: 2C1MR2263W6717581

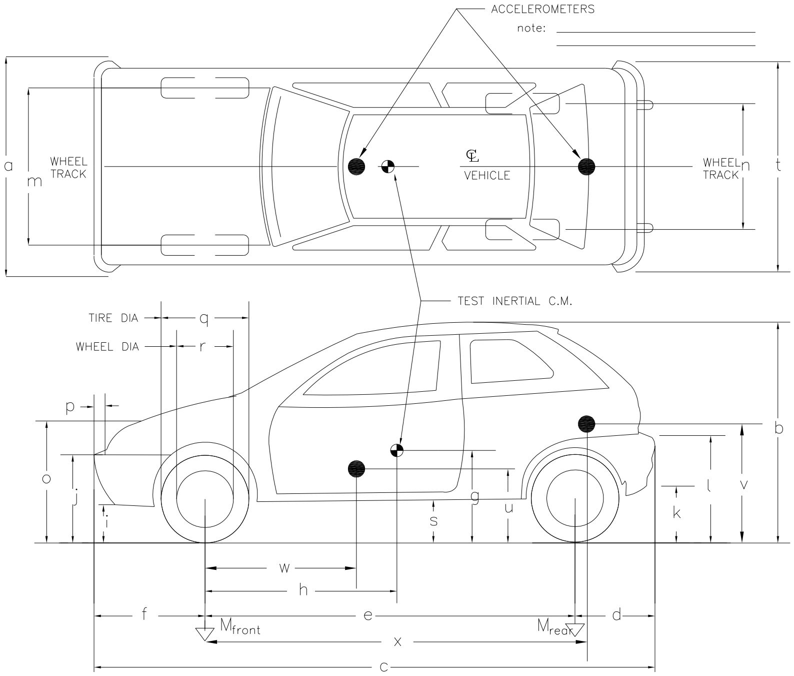
Year: 1998 Make: Chevrolet Model: Metro

Tire Inflation Pressure: 32 psi Odometer: 175399 Tire Size: 155/80R13

Describe any damage to the vehicle prior to test:

● Denotes accelerometer location.

NOTES:



Engine Type: 3 cylinder
Engine CID: 1 liter
Transmission Type:
____ Auto or ____ Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:

Dummy Data:
Type: 95th Percentile Male
Mass: 168 lb
Seat Position: Passenger

Geometry: inches

a	62.6	f	31.1	k	11.8	p	4.7	u	16.5
b	55.9	g		l	25.8	q	22.4	v	21.6
c	147.8	h	36.8	m	54.5	r	14.5	w	37.4
d	23.6	i	15.7	n	53.5	s	12.0	x	95.3
e	93.1	j	20.3	o	25.6	t	60.2		

Wheel Center Ht Front 10.2 Wheel Center Ht Rear 10.8

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1400	M_{front}	1109	1120	1202
Back	1235	M_{rear}	664	692	778
Total	2590	M_{Total}	1773	1812	1980

Mass Distribution:
lb: LF: 578 RF: 542 LR: 370 RR: 322

Figure B2. Vehicle Properties for Test 452108-2.

Table B3. Exterior Crush Measurements for Test 452108-2.

Vehicle Inventory Number: 760

Date: 2008-03-05 Test No.: 452108-2 VIN No.: 2C1MR2263W6717581

Year: 1998 Make: Chevrolet Model: Metro

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

Note: Measure 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	Front bumper	3.9	9.8	11.8	6.3	7.1	9.8	8.3	4.7	3.5	6.3
	All measurements										
	in inches										

[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.

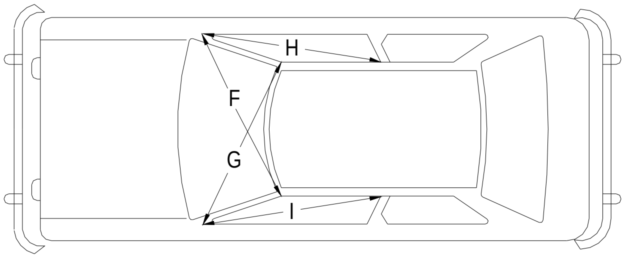
Note: Use as many lines/columns as necessary to describe each damage profile.

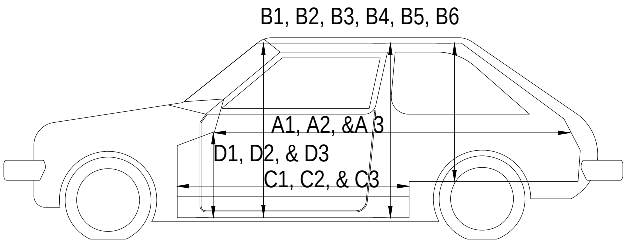
Table B4. Occupant Compartment Measurements for Test 452108-2.

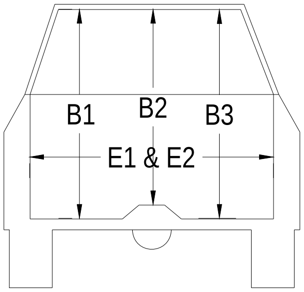
Vehicle Inventory Number: 760

Date: 2008-03-05
Test No.: 452108-2
VIN No.: 2C1MR2263W6717581

Year: 1998
Make: Chevrolet
Model: Metro







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	56.7	56.7
A2	78.8	78.8
A3	56.3	56.3
B1	38.0	36.8
B2	35.5	32.9
B3	37.6	37.4
B4	34.8	29.8
B5	35.1	30.1
B6	34.8	32.9
C1	22.0	22.0
C2	----	----
C3	22.0	22.0
D1	9.5	9.5
D2	4.4	4.4
D3	9.6	9.6
E1	47.8	47.8
E2	46.3	46.3
F	47.6	47.6
G	47.6	47.6
H	40.6	40.6
I	40.6	40.6
J*	47.2	47.2

*Lateral area across the cab from
driver's side kickpanel to passenger's side kickpanel.

Vehicle Inventory Number: 766

Date: 2008-03-24 Test No.: 452108-3 VIN No.: 2C1MR2291V6709028

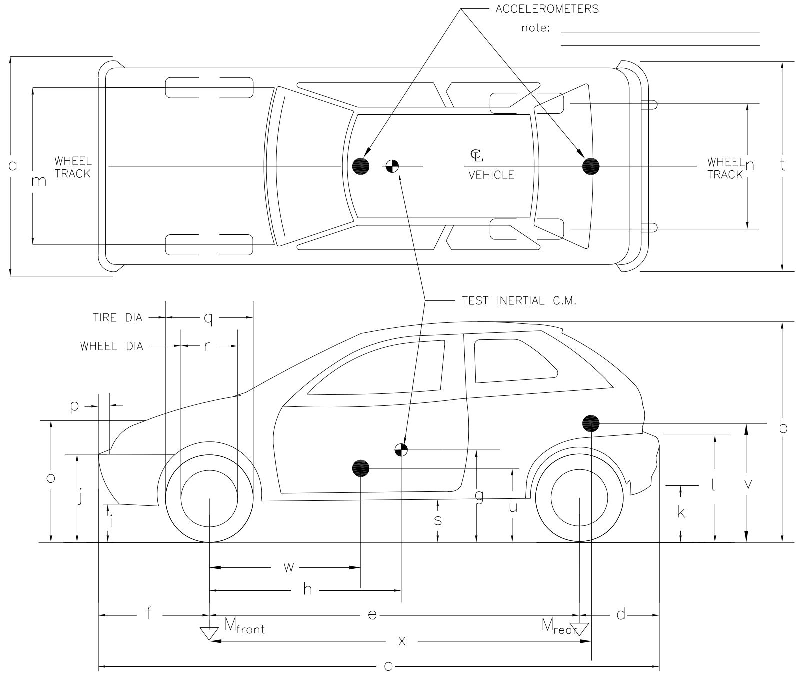
Year: 1997 Make: Chevrolet Model: Metro

Tire Inflation Pressure: 32 psi Odometer: 159411 Tire Size: 155 80R13

Describe any damage to the vehicle prior to test: ______

● Denotes accelerometer location.

NOTES: ______



Engine Type: 4 cylinder
Engine CID: 1.3 liter
Transmission Type:
x Auto or ____ Manual
x FWD ____ RWD ____ 4WD
Optional Equipment: ______

Dummy Data:
Type: 95th percentile male
Mass: 170 lb
Seat Position: ______

Geometry: inches

a	62.6	f	31.1	k	11.8	p	4.7	u	16.5
b	55.9	g		l	25.8	q	22.4	v	21.6
c	147.8	h	32.9	m	54.5	r	14.5	w	37.4
d	23.6	i	15.7	n	53.5	s	12.0	x	95.3
e	93.1	j	20.3	o	25.6	t	60.2		

Wheel Center Ht Front 10.2 Wheel Center Ht Rear 10.8

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1433	M_{front}	1208	1206	1292
Back	1234	M_{rear}	668	659	743
Total	2623	M_{Total}	1876	1865	2035

Mass Distribution:
lb: LF: 595 RF: 611 LR: 333 RR: 326

Figure B3. Vehicle Properties for Test 452108-3.

Table B5. Exterior Crush Measurements for Test 452108-3.

Vehicle Inventory Number: 766

Date: 2008-03-24 Test No.: 452108-3 VIN No.: 2C1MR2291V6709028

Year: 1997 Make: Chevrolet Model: Metro

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 inches ________	
≥ 4 inches ________	

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	Front bumper	5.9	5.9	15.7	0.6	1.6	5.1	5.5	3.5	1.6	-3.9
	All measurements										
	in inches										

[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.

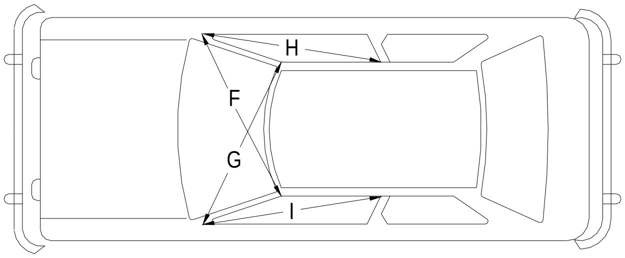
Note: Use as many lines/columns as necessary to describe each damage profile.

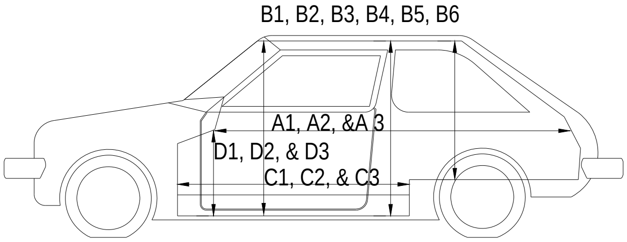
Table B6. Occupant Compartment Measurements for Test 452108-3.

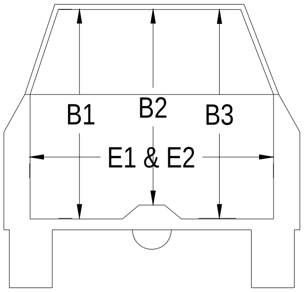
Vehicle Inventory Number: 766

Date: 2008-03-24 Test No.: 452108-3 VIN No.: 2C1MR2291V6709028

Year: 1997 Make: Chevrolet Model: Metro







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	56.8	56.8
A2	79.1	79.1
A3	56.1	56.1
B1	37.8	34.6
B2	35.0	30.3
B3	37.6	36.8
B4	34.7	29.1
B5	34.9	29.8
B6	34.7	31.3
C1	21.8	21.6
C2	----	----
C3	21.6	21.6
D1	9.2	9.2
D2	3.7	3.7
D3	9.4	9.4
E1	47.8	47.8
E2	46.5	46.5
F	47.2	47.2
G	47.2	47.2
H	40.6	40.6
I	40.6	40.6
J*	47.2	47.2

*Lateral area across the cab from
driver's side kickpanel to passenger's side kickpanel.

Vehicle Inventory Number: 734

Date: 2008-03-24 Test No.: 452108-4 VIN No.: 2C1MR1160W6705754

Year: 1998 Make: Chevrolet Model: Metro

Tire Inflation Pressure: 32 psi Odometer: 105744 Tire Size: 155 80R13

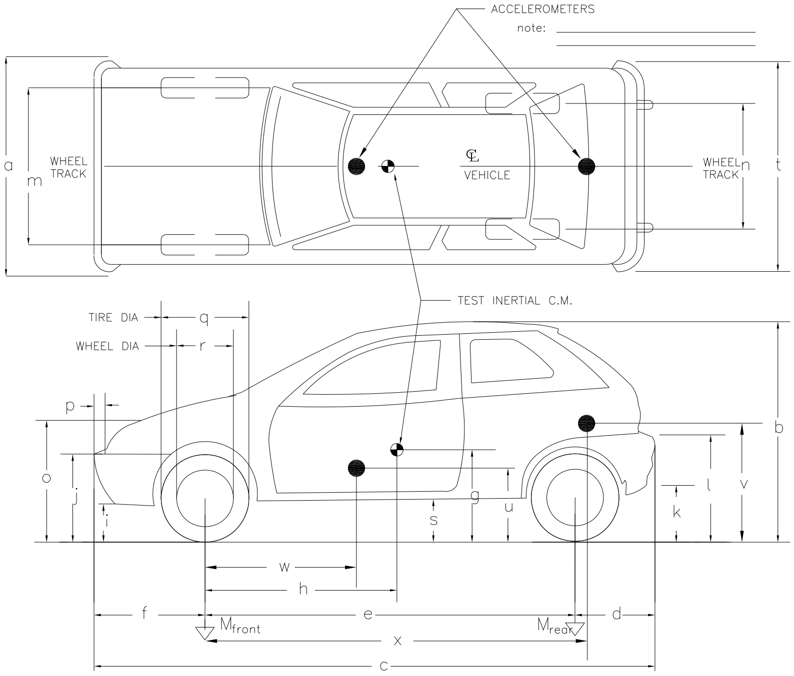
Describe any damage to the vehicle prior to test:

● Denotes accelerometer location.

NOTES:

Engine Type: 3 cylinder
Engine CID: 1 liter
Transmission Type:
____ Auto or x Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:

Dummy Data:
Type: 95th percentile male
Mass: 170 lb
Seat Position: Front passenger



Geometry: inches

a	62.6	f	31.1	k	11.8	p	4.7	u	16.5
b	55.9	g		l	25.8	q	22.4	v	21.6
c	147.8	h	49.4	m	54.5	r	14.5	w	37.4
d	23.6	i	15.7	n	53.5	s	12.0	x	95.3
e	93.1	j	20.3	o	25.6	t	60.2		

Wheel Center Ht Front 10.2 Wheel Center Ht Rear 10.8

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1400	M_{front}	1102	1116	1204
Back	1235	M_{rear}	670	696	785
Total	2590	M_{Total}	1772	1812	1989

Mass Distribution:
lb: LF: 580 RF: 536 LR: 361 RR: 335

Figure B4. Vehicle Properties for Test 452108-4.

Table B7. Exterior Crush Measurements for Test 452108-4.

Vehicle Inventory Number: 734

Date: 2008-03-24 Test No.: 452108-4 VIN No.: 2C1MR1160W6705754

Year: 1998 Make: Chevrolet Model: Metro

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 inches ________	
≥ 4 inches ________	

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	Front bumper	5.9	5.9	15.7	1.2	2.0	5.5	5.5	3.9	2.0	-7.1
	All measurements										
	in inches										

[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.

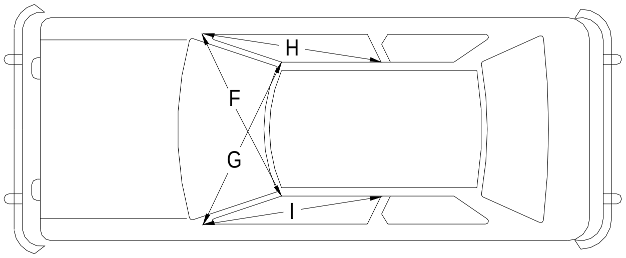
Note: Use as many lines/columns as necessary to describe each damage profile.

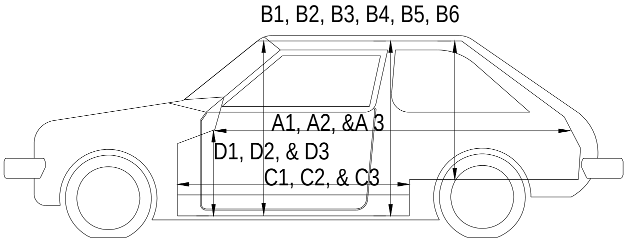
Table B8. Occupant Compartment Measurements for Test 452108-4.

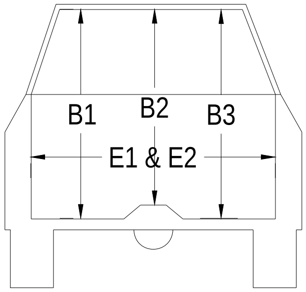
Vehicle Inventory Number: 734

Date: 2008-03-24 Test No.: 452108-4 VIN No.: 2C1MR1160W6705754

Year: 1998 Make: Chevrolet Model: Metro





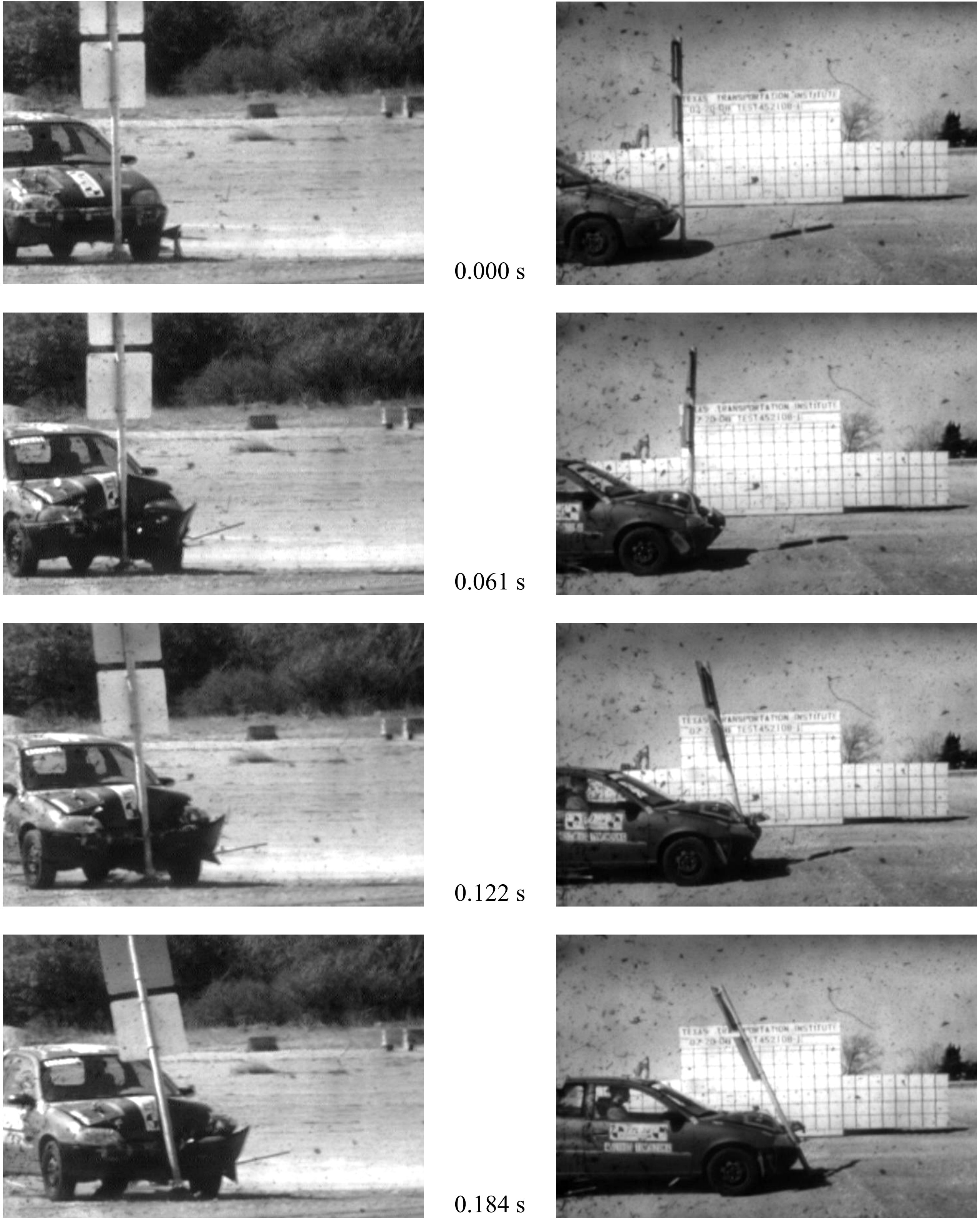


OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	56.6	56.6
A2	79.1	79.1
A3	56.1	56.1
B1	37.9	33.7
B2	35.4	30.6
B3	37.8	37.0
B4	35.0	31.1
B5	35.2	31.4
B6	35.0	33.2
C1	22.4	22.4
C2	----	----
C3	22.4	22.4
D1	9.6	9.6
D2	3.5	3.5
D3	9.4	9.4
E1	47.8	47.8
E2	46.3	46.3
F	47.2	47.2
G	47.2	47.2
H	40.6	40.6
I	40.6	40.6
J*	47.2	47.2

*Lateral area across the cab from
driver's side kickpanel to passenger's side kickpanel.

APPENDIX C. SEQUENTIAL PHOTOGRAPHS



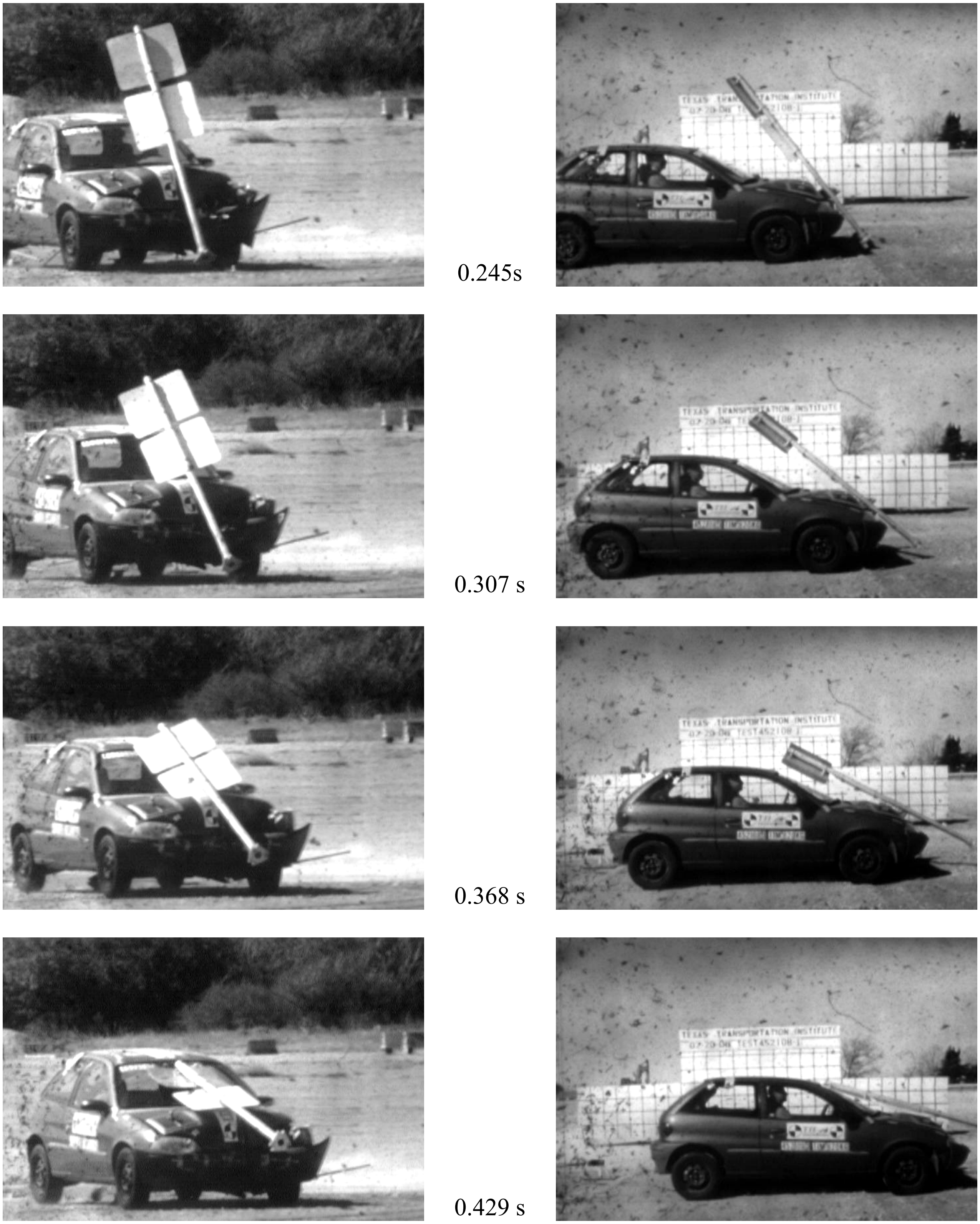
0.000 s

0.061 s

0.122 s

0.184 s

Figure C1. Sequential Photographs for Test 452108-1 (Oblique and Perpendicular Views).



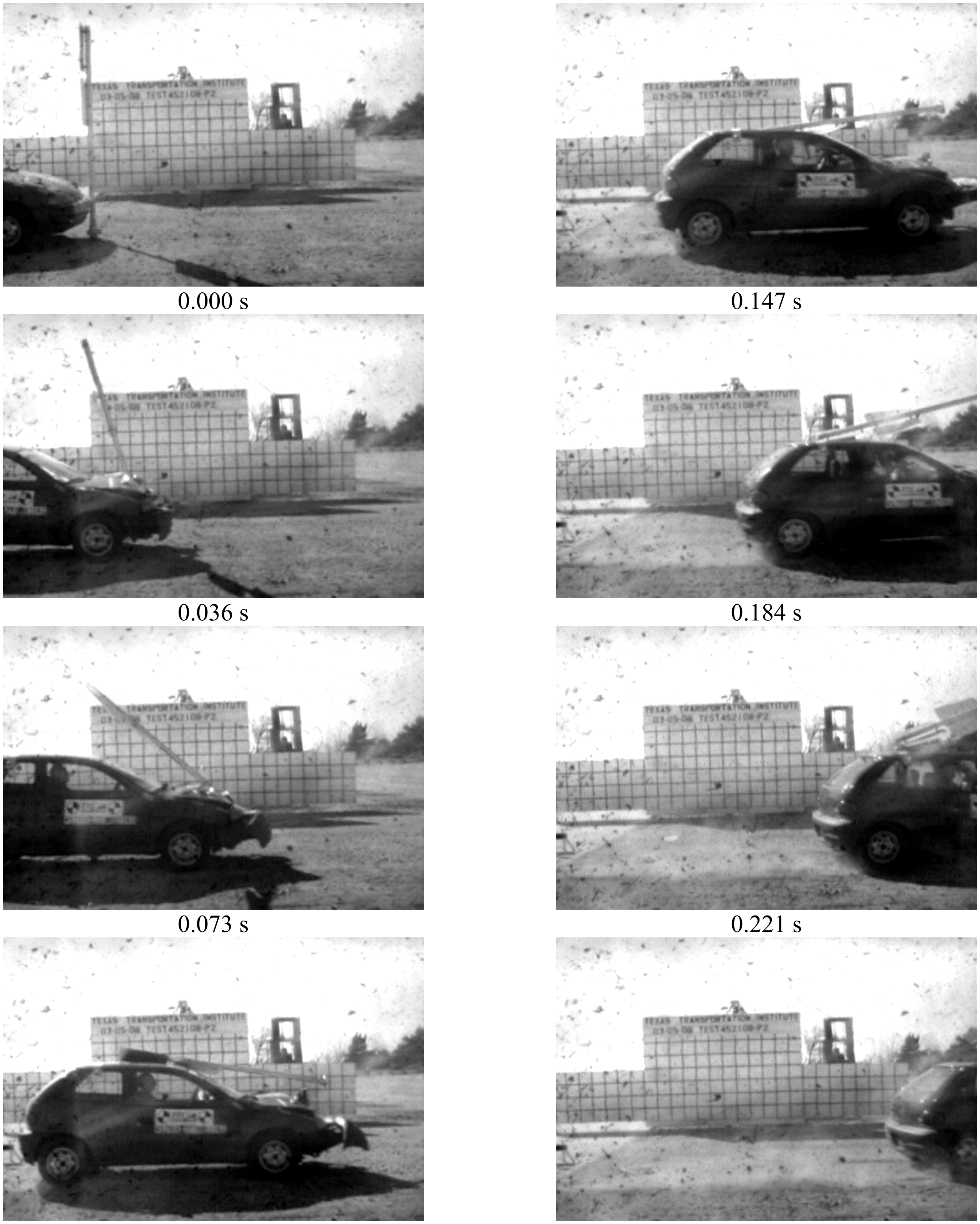
0.245s

0.307 s

0.368 s

0.429 s

Figure C1. Sequential Photographs for Test 452108-1 (Oblique and Perpendicular Views) (continued).



0.000 s

0.036 s

0.073 s

0.110 s

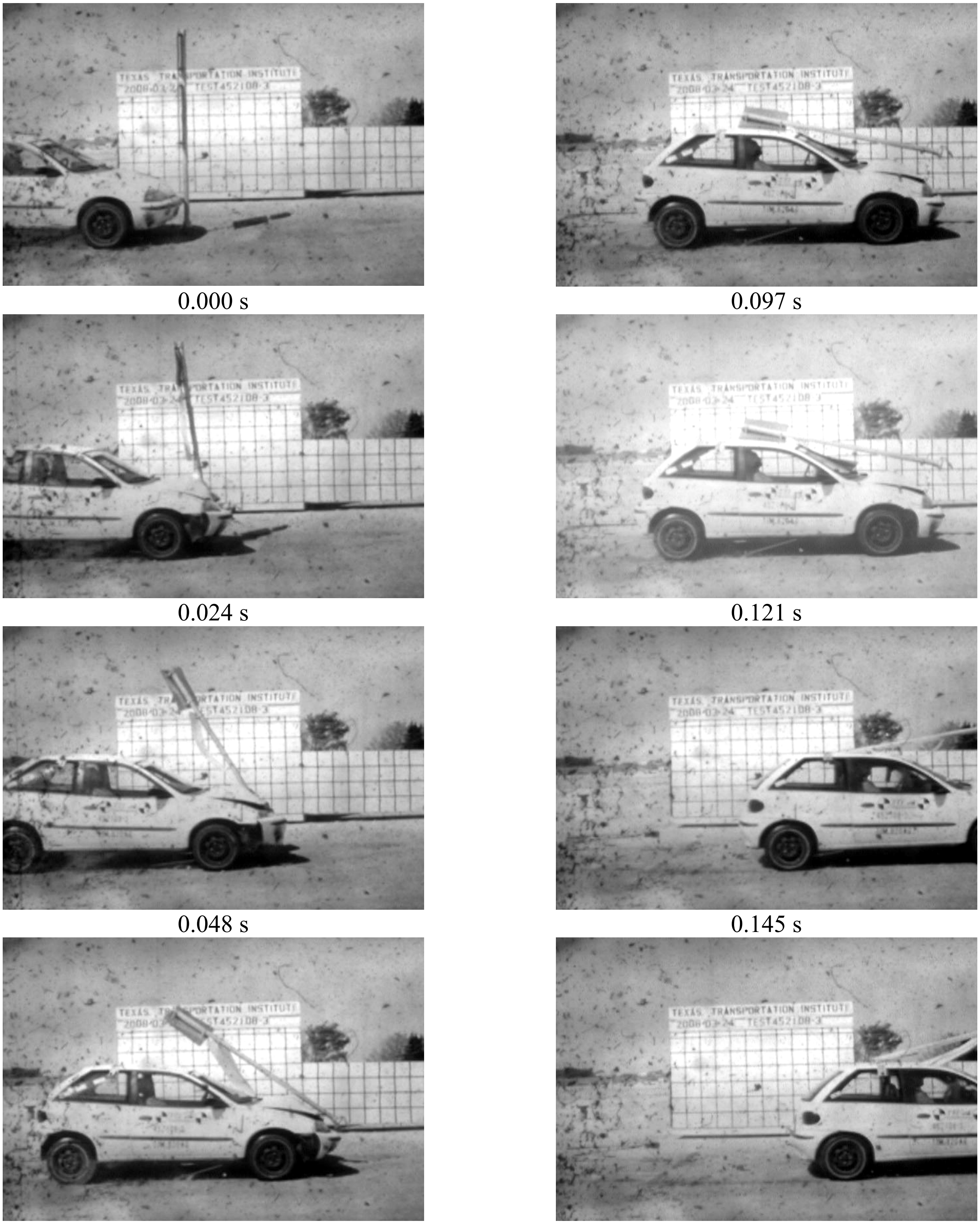
0.147 s

0.184 s

0.221 s

0.258 s

Figure C2. Sequential Photographs for Test 452108-2 (Perpendicular View).



0.000 s

0.024 s

0.048 s

0.072 s

0.097 s

0.121 s

0.145 s

0.170 s

Figure C3. Sequential Photographs for Test 452108-3 (Perpendicular View).

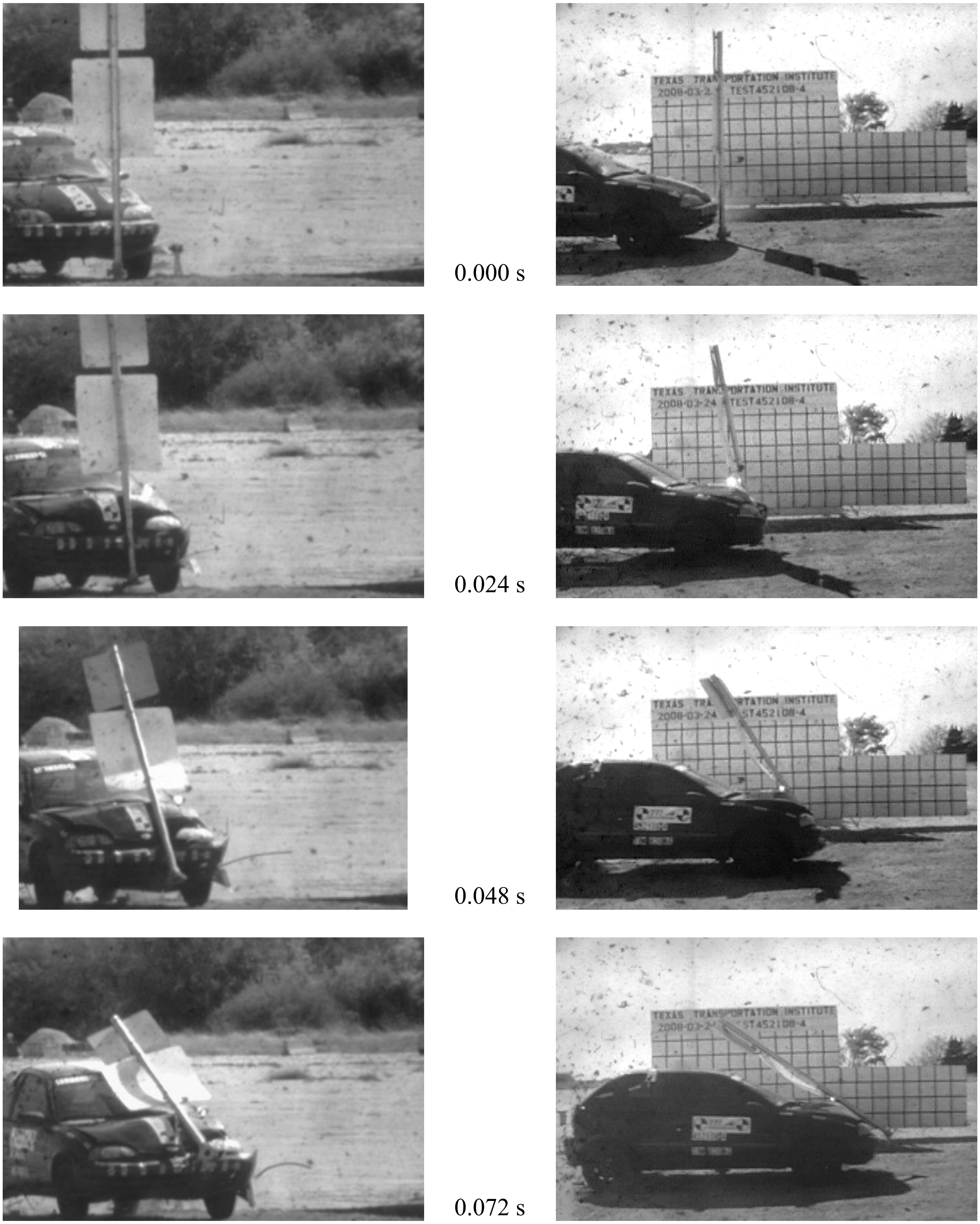
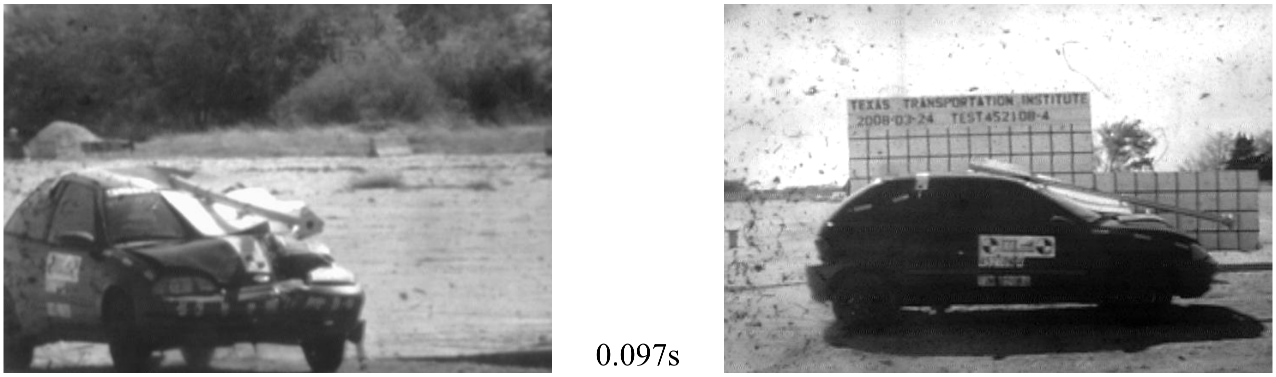
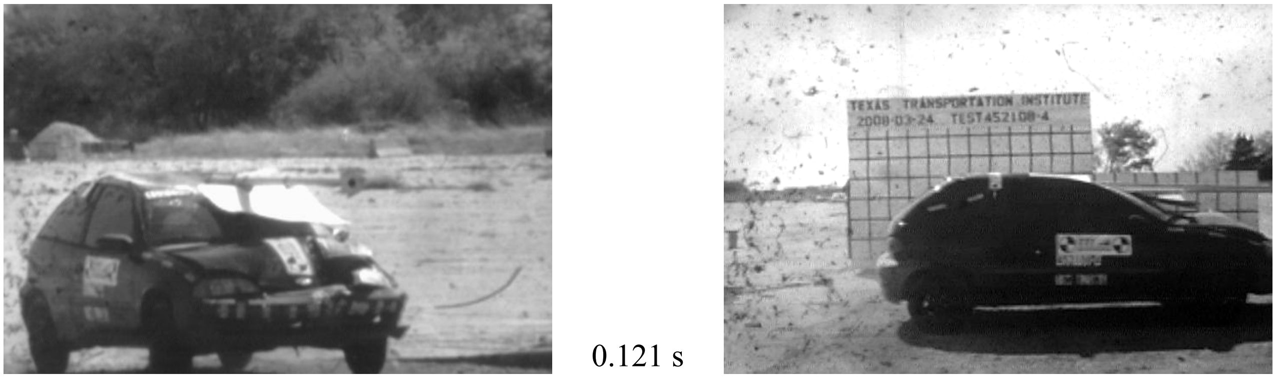


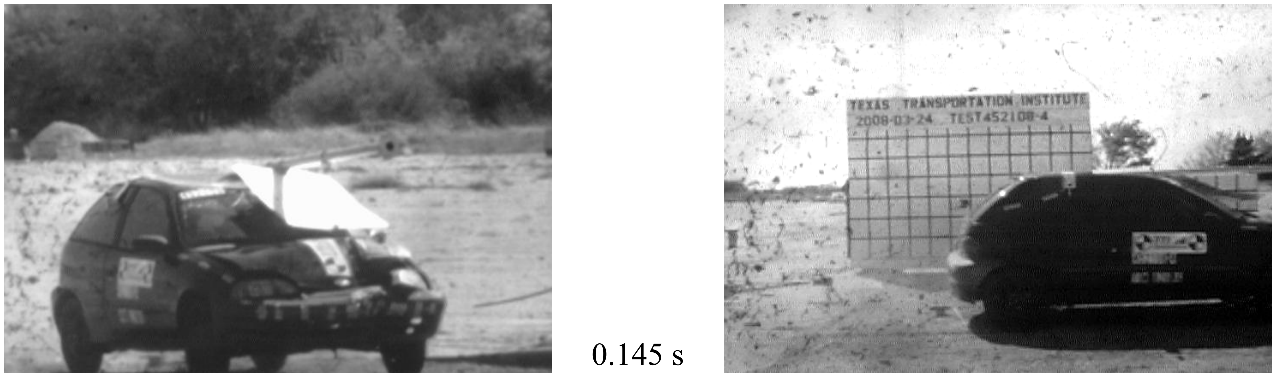
Figure C4. Sequential Photographs for Test 452108-4 (Oblique and Perpendicular Views).



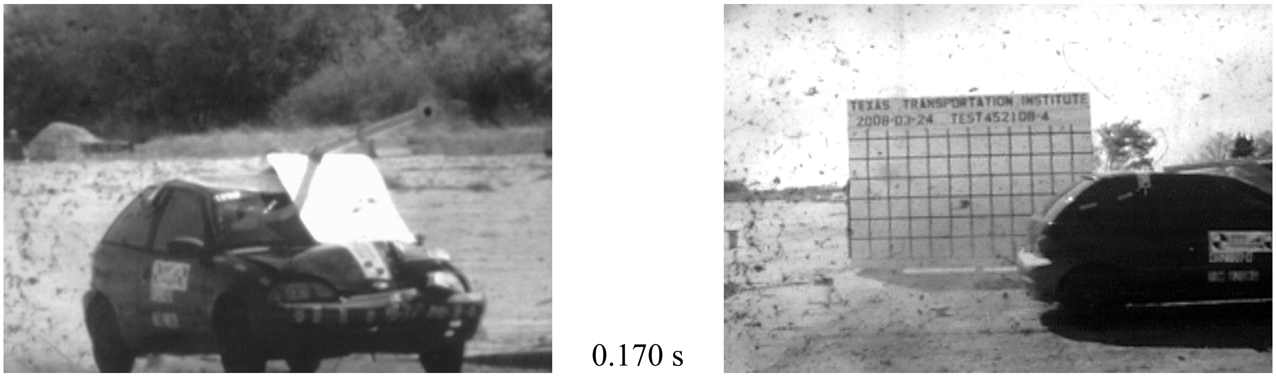
0.097s



0.121 s



0.145 s



0.170 s

Figure C4. Sequential Photographs for Test 452108-4 (Oblique and Perpendicular Views) (continued).

APPENDIX D. VEHICLE ANGULAR DISPLACEMENTS AND ACCELERATIONS

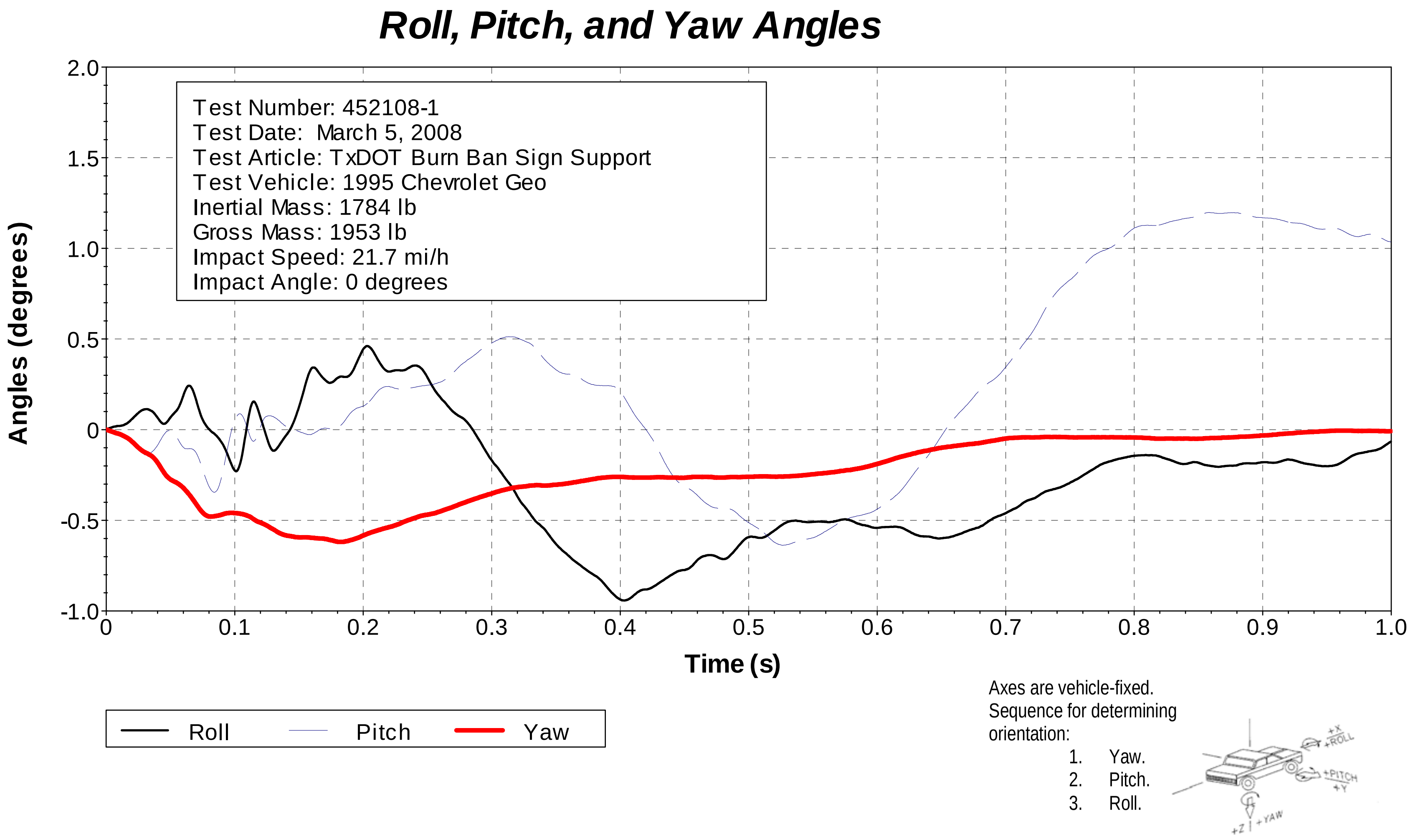


Figure D1. Vehicle Angular Displacements for Test 452108-1.

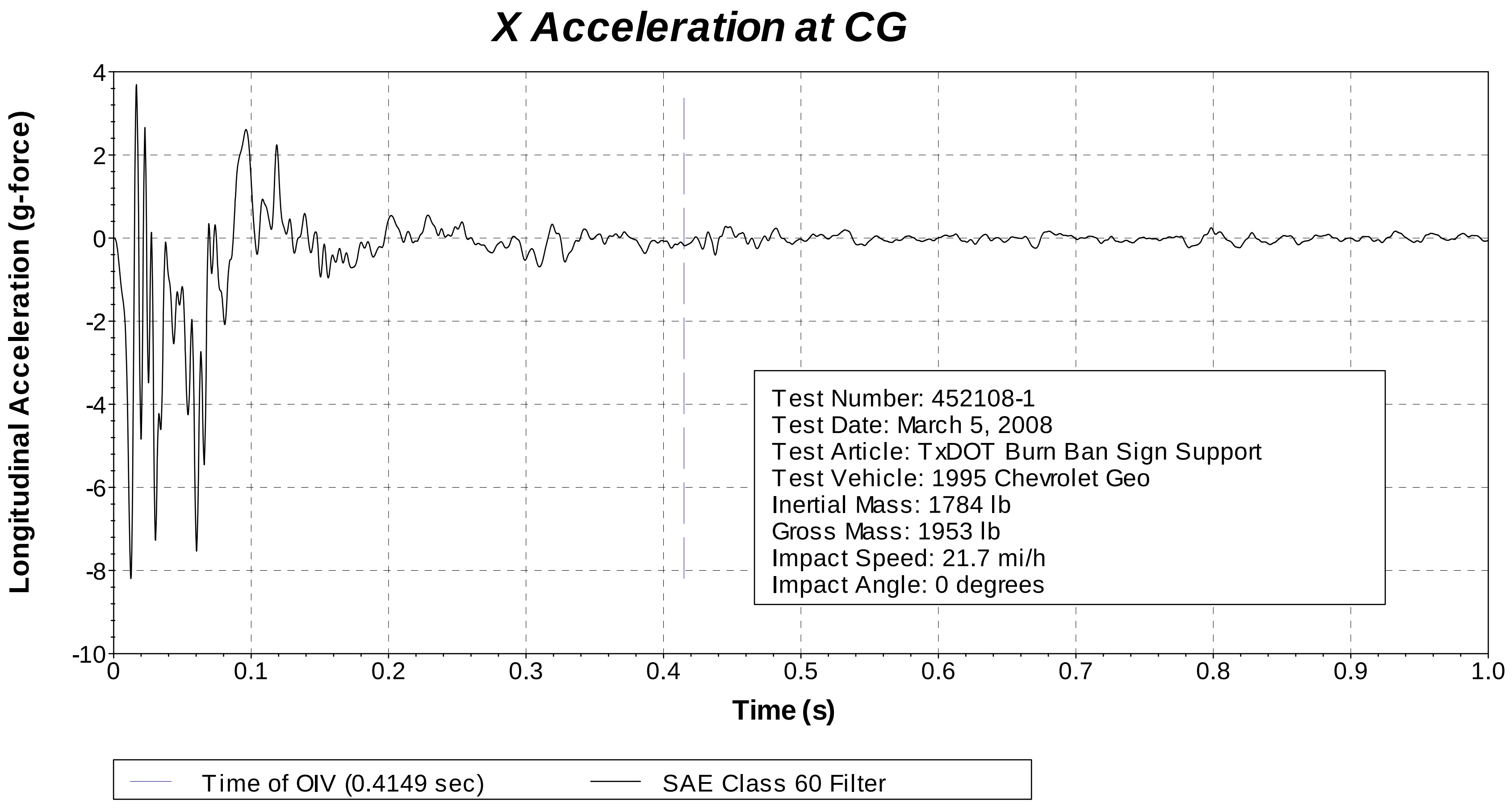


Figure D2. Vehicle Longitudinal Accelerometer Trace for Test 452108-1 (Accelerometer Located at Center of Gravity).

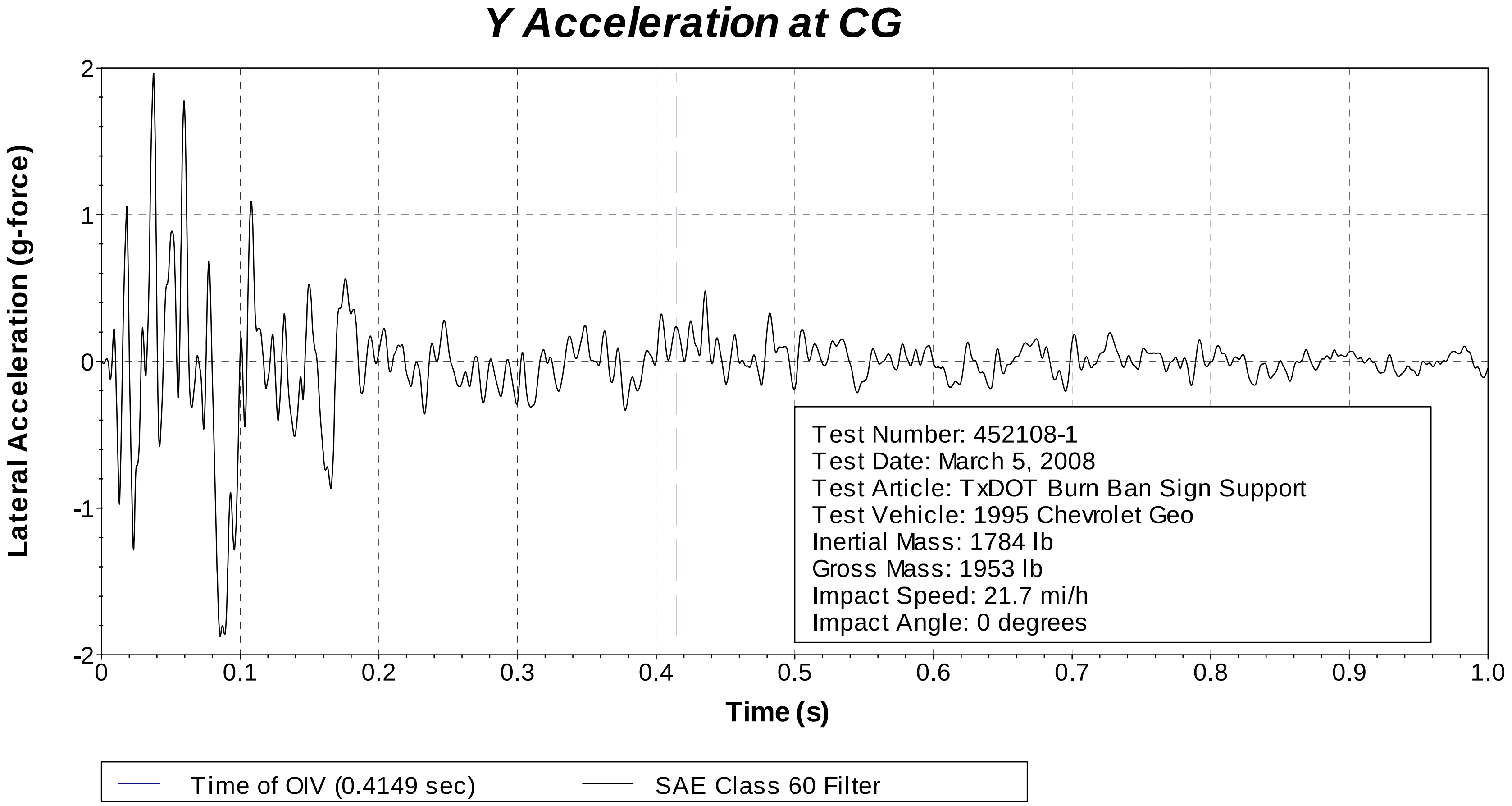


Figure D3. Vehicle Lateral Accelerometer Trace for Test 452108-1 (Accelerometer Located at Center of Gravity).

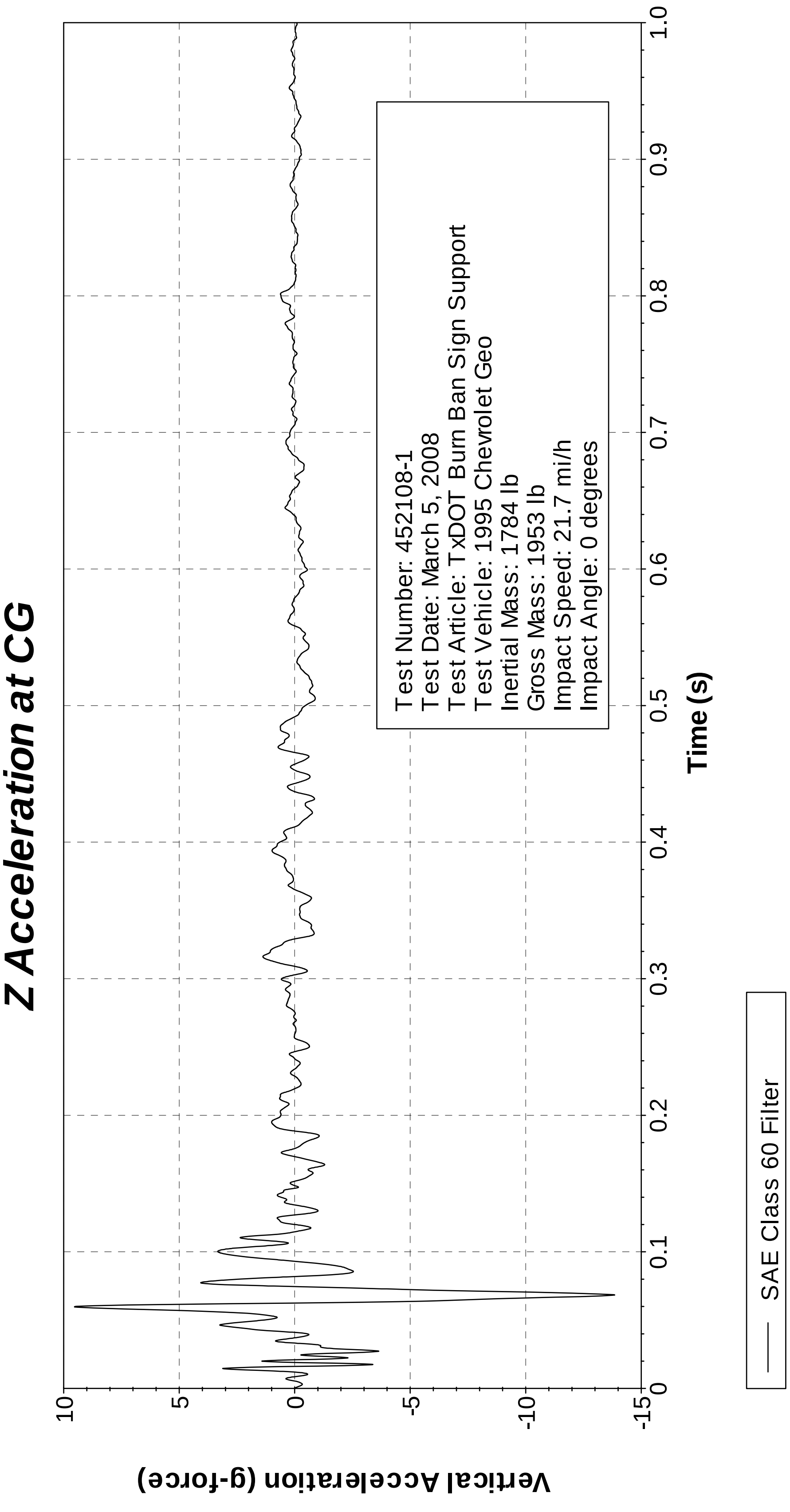


Figure D4. Vehicle Vertical Accelerometer Trace for Test 452108-1 (Accelerometer Located at Center of Gravity).

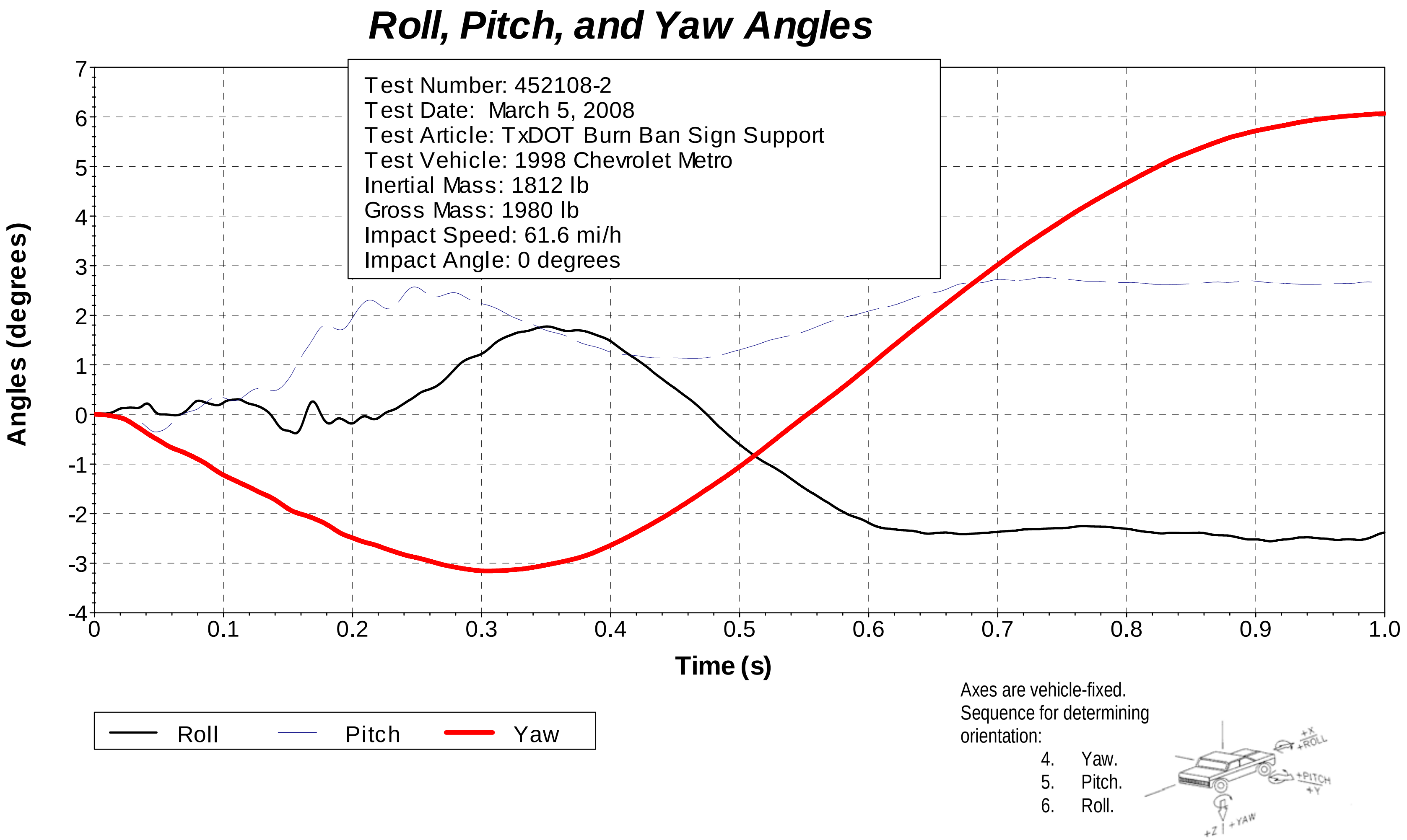


Figure D5. Vehicle Angular Displacements for Test 452108-2.

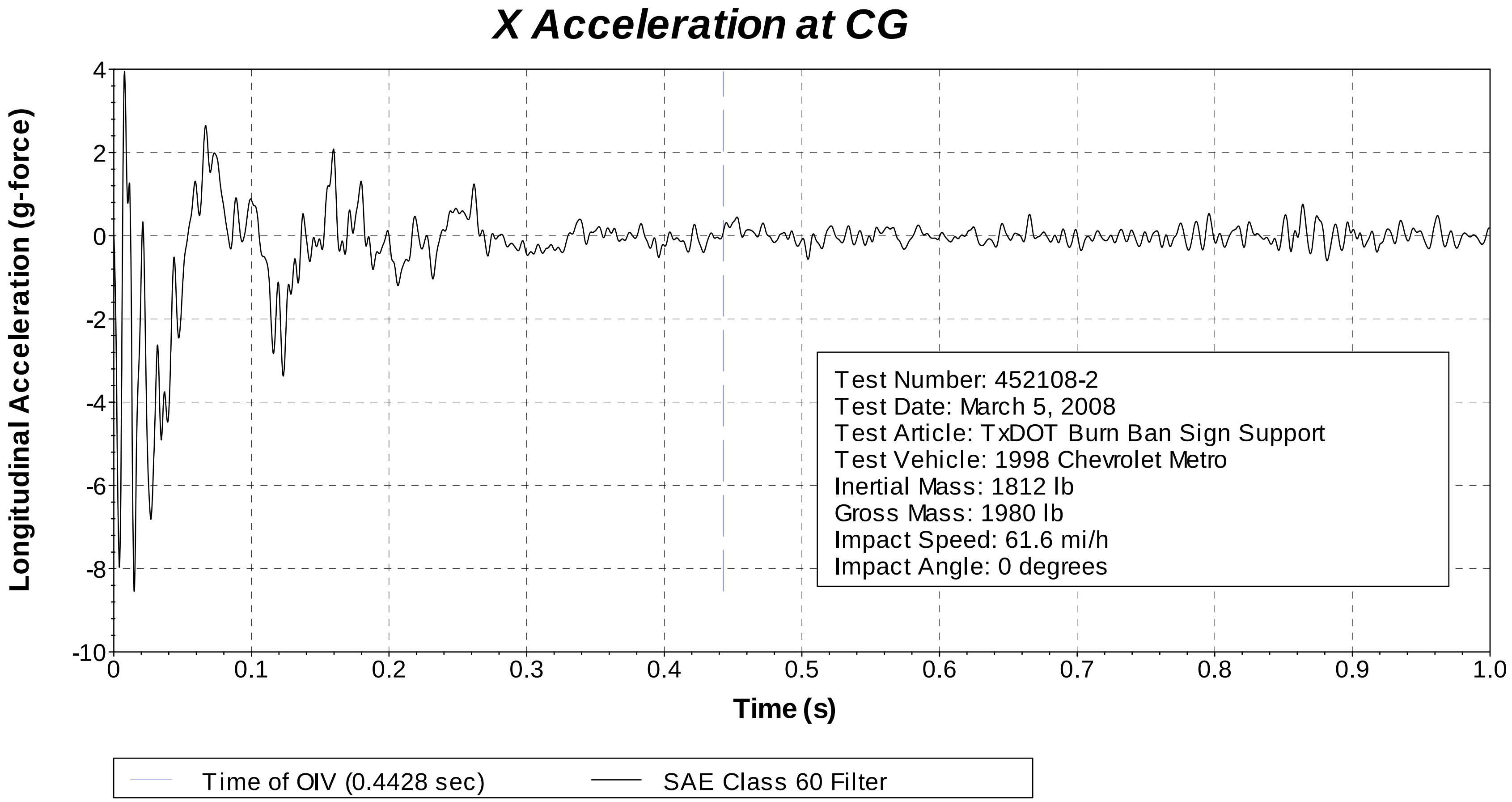


Figure D6. Vehicle Longitudinal Accelerometer Trace for Test 452108-2 (Accelerometer Located at Center of Gravity).

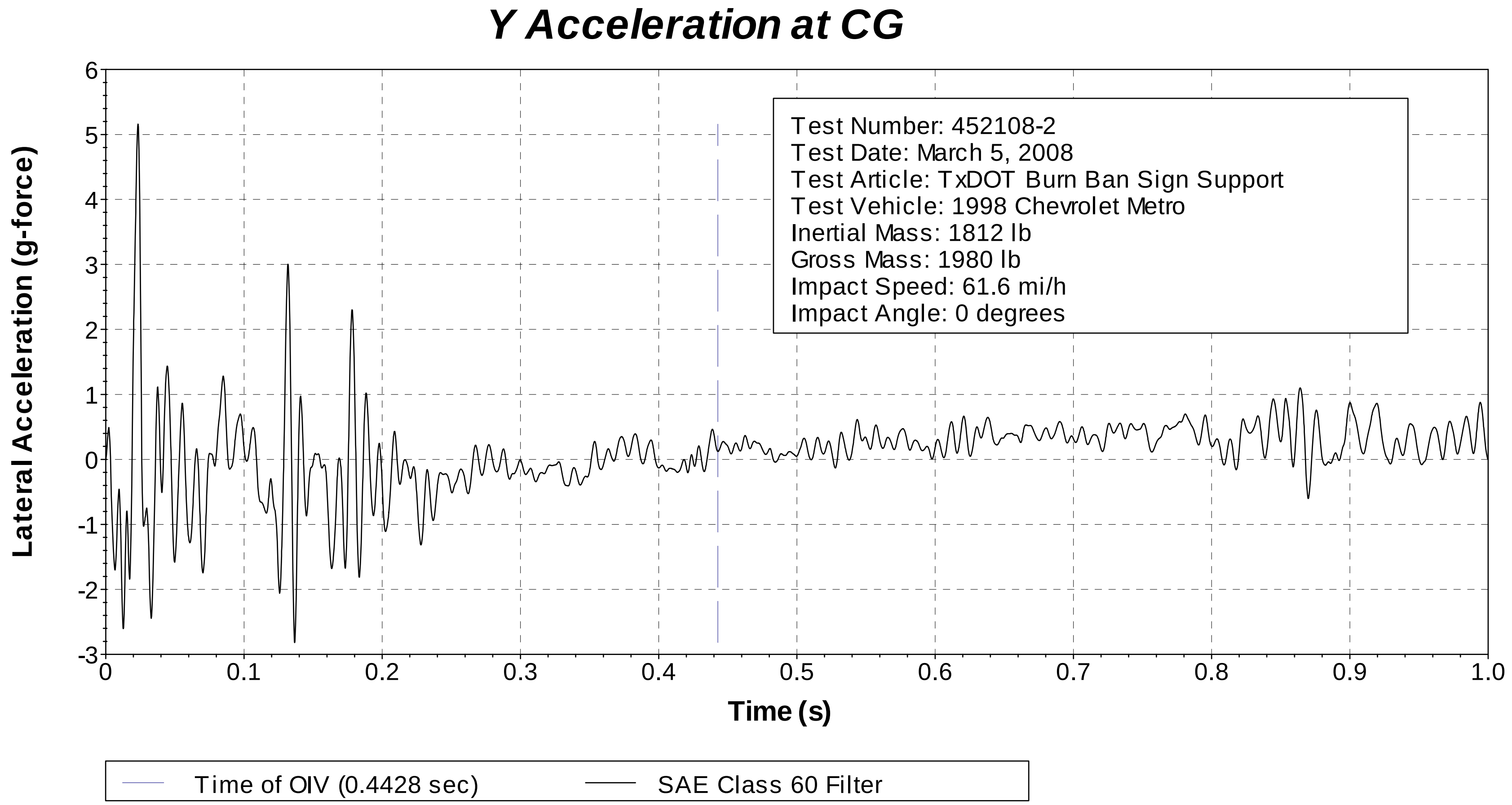


Figure D7. Vehicle Lateral Accelerometer Trace for Test 452108-2 (Accelerometer Located at Center of Gravity).

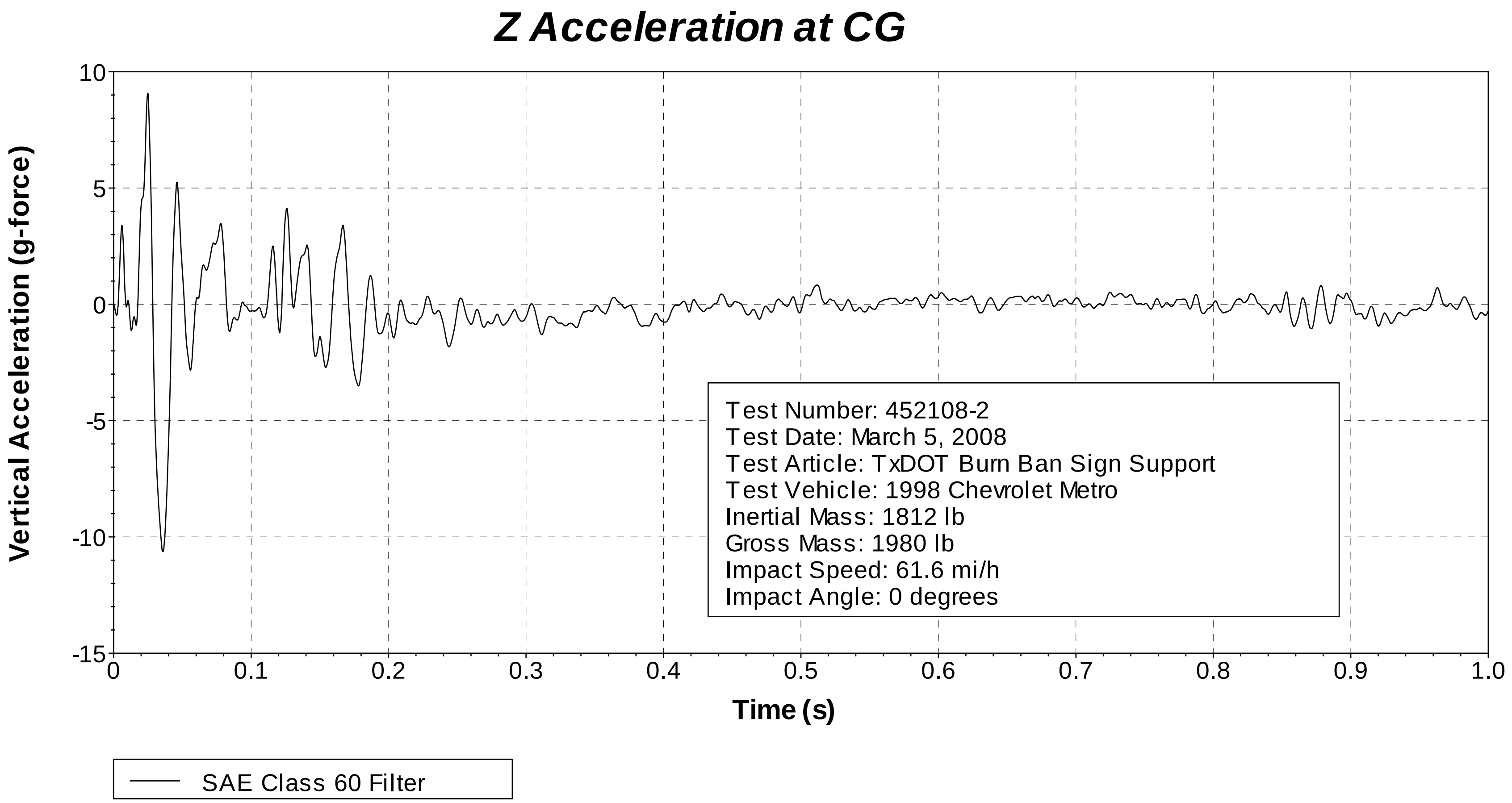


Figure D8. Vehicle Vertical Accelerometer Trace for Test 452108-2 (Accelerometer Located at Center of Gravity).

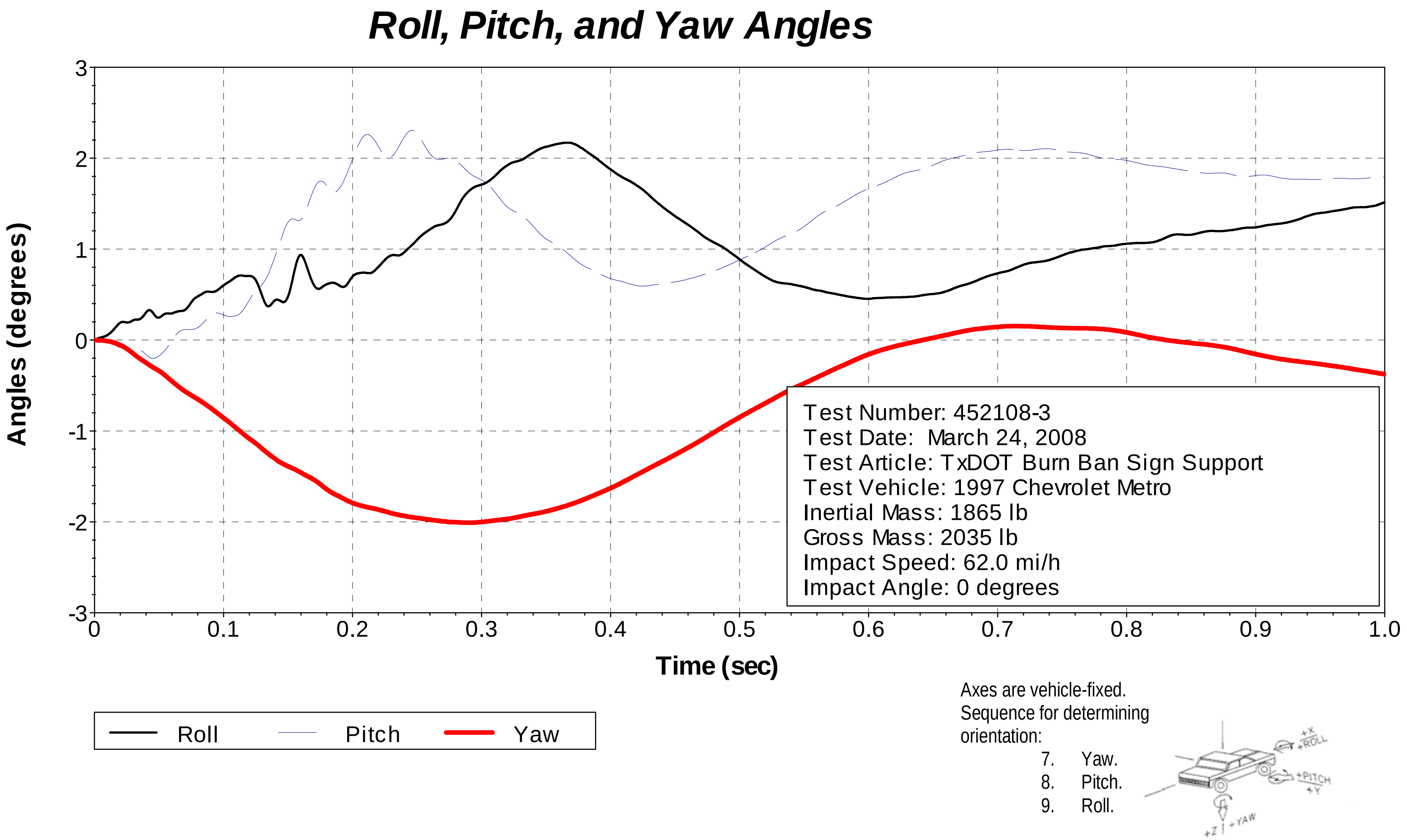


Figure D9. Vehicle Angular Displacements for Test 452108-3.

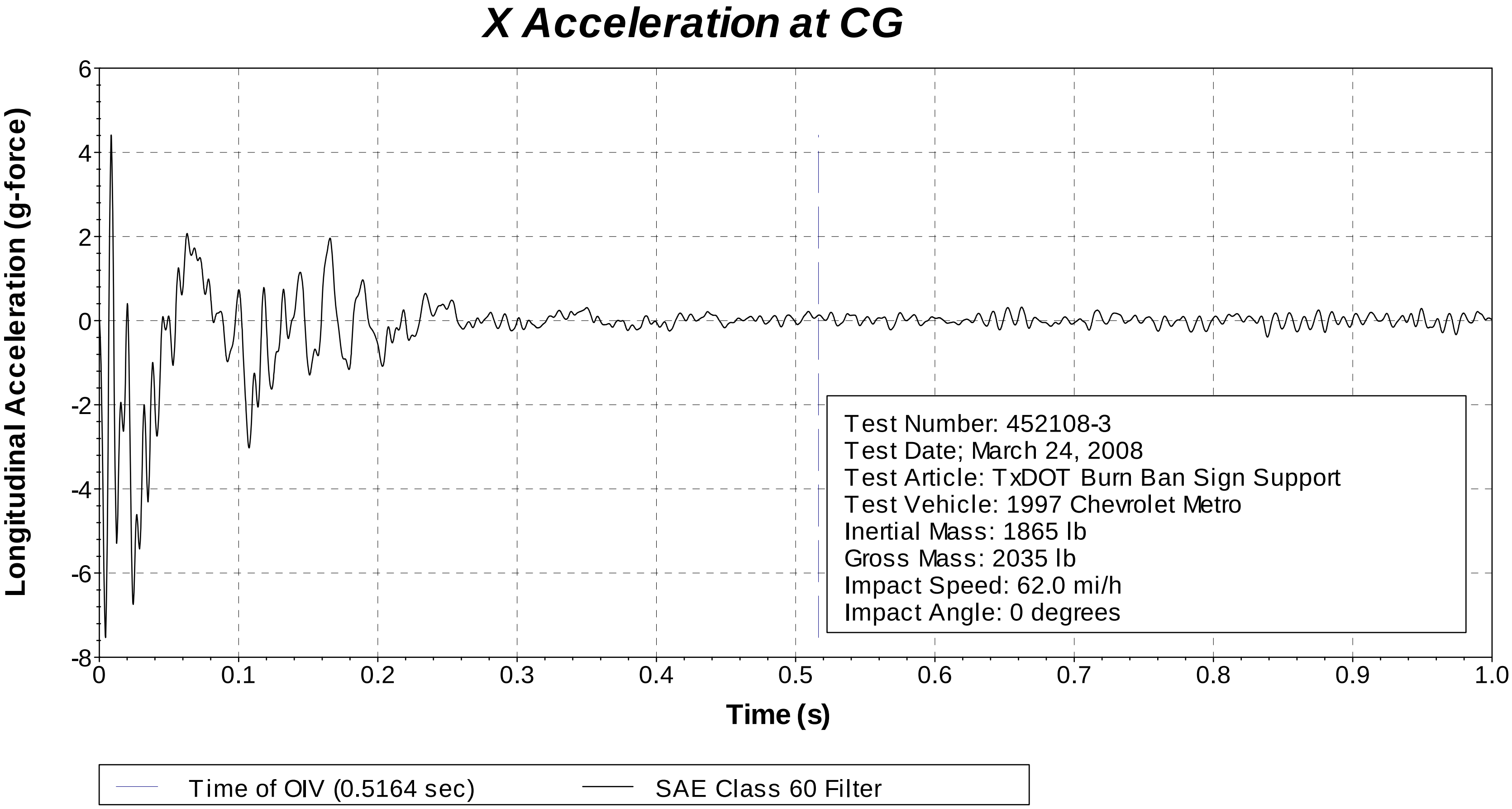


Figure D10. Vehicle Longitudinal Accelerometer Trace for Test 452108-3 (Accelerometer Located at Center of Gravity).

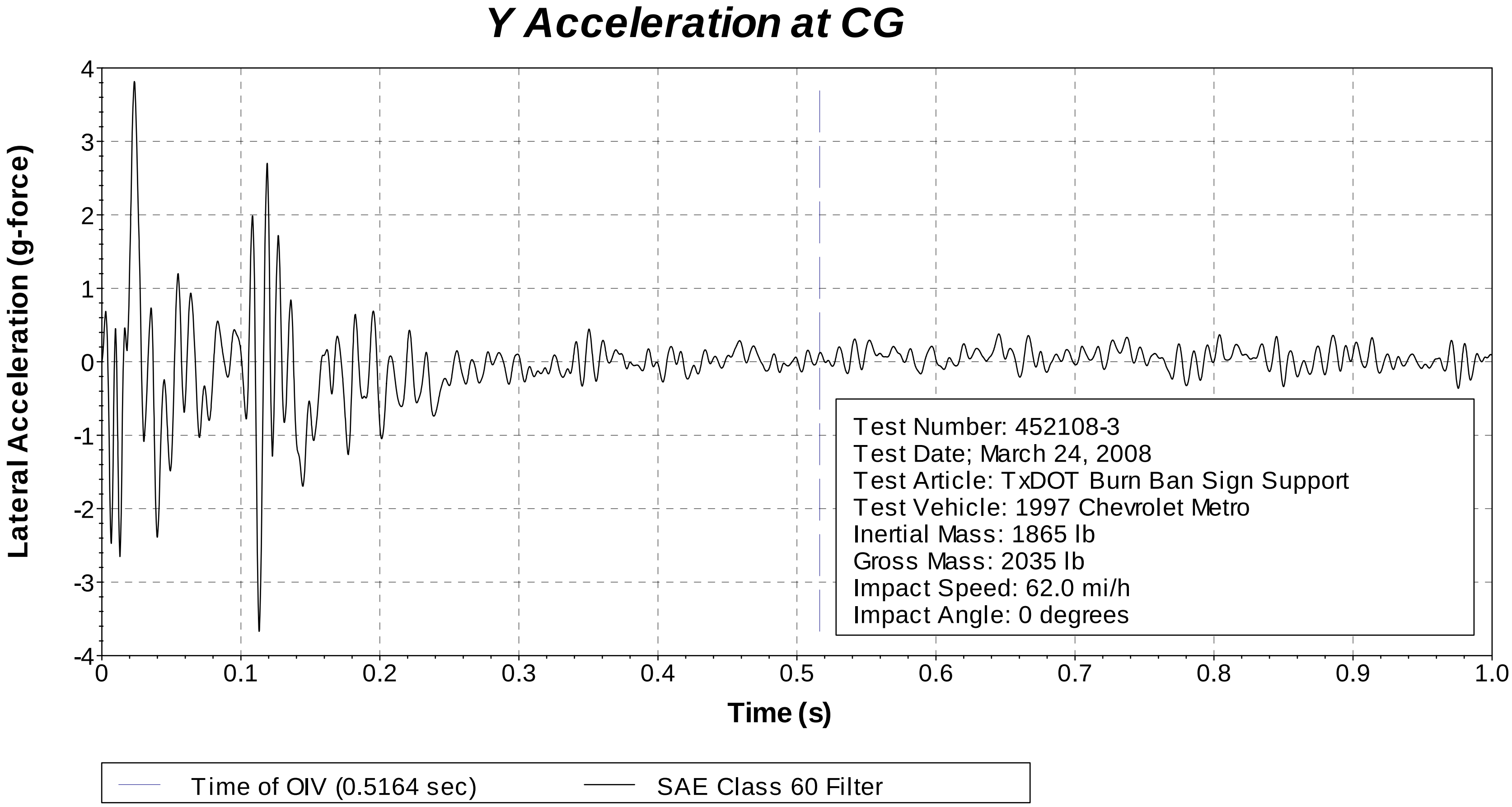


Figure D11. Vehicle Lateral Accelerometer Trace for Test 452108-3 (Accelerometer Located at Center of Gravity).

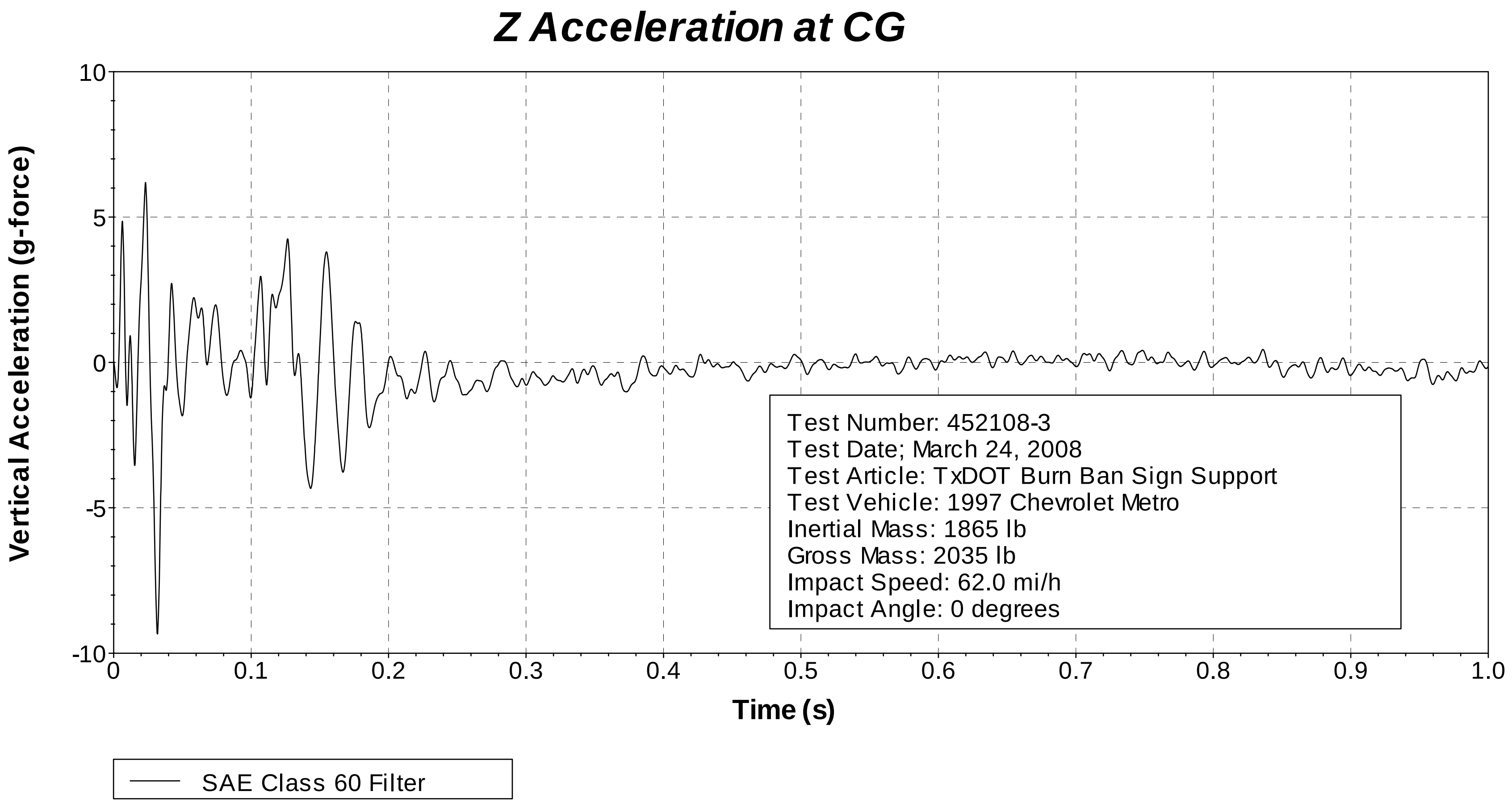


Figure D12. Vehicle Vertical Accelerometer Trace for Test 452108-3 (Accelerometer Located at Center of Gravity).

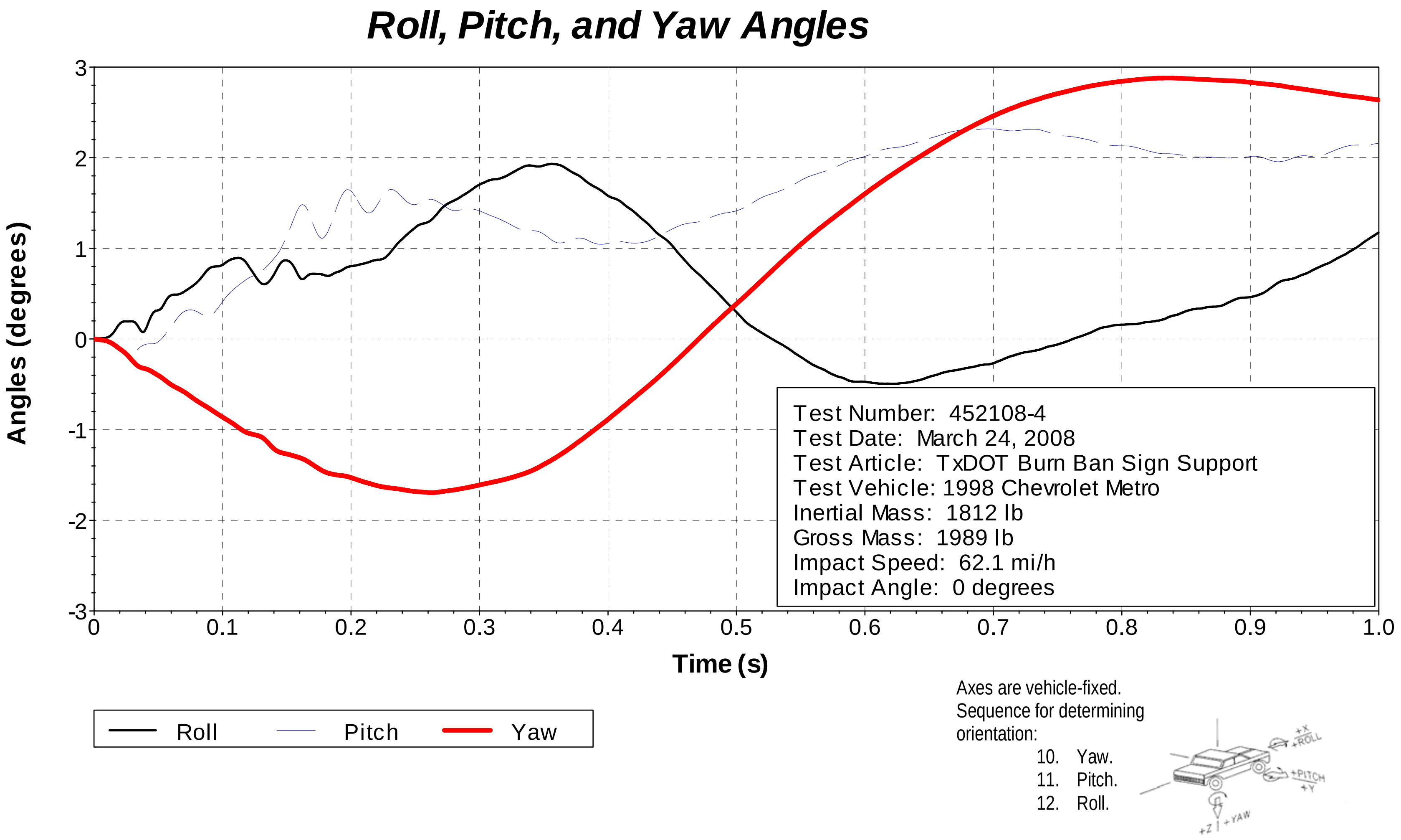


Figure D13. Vehicle Angular Displacements for Test 452108-4.

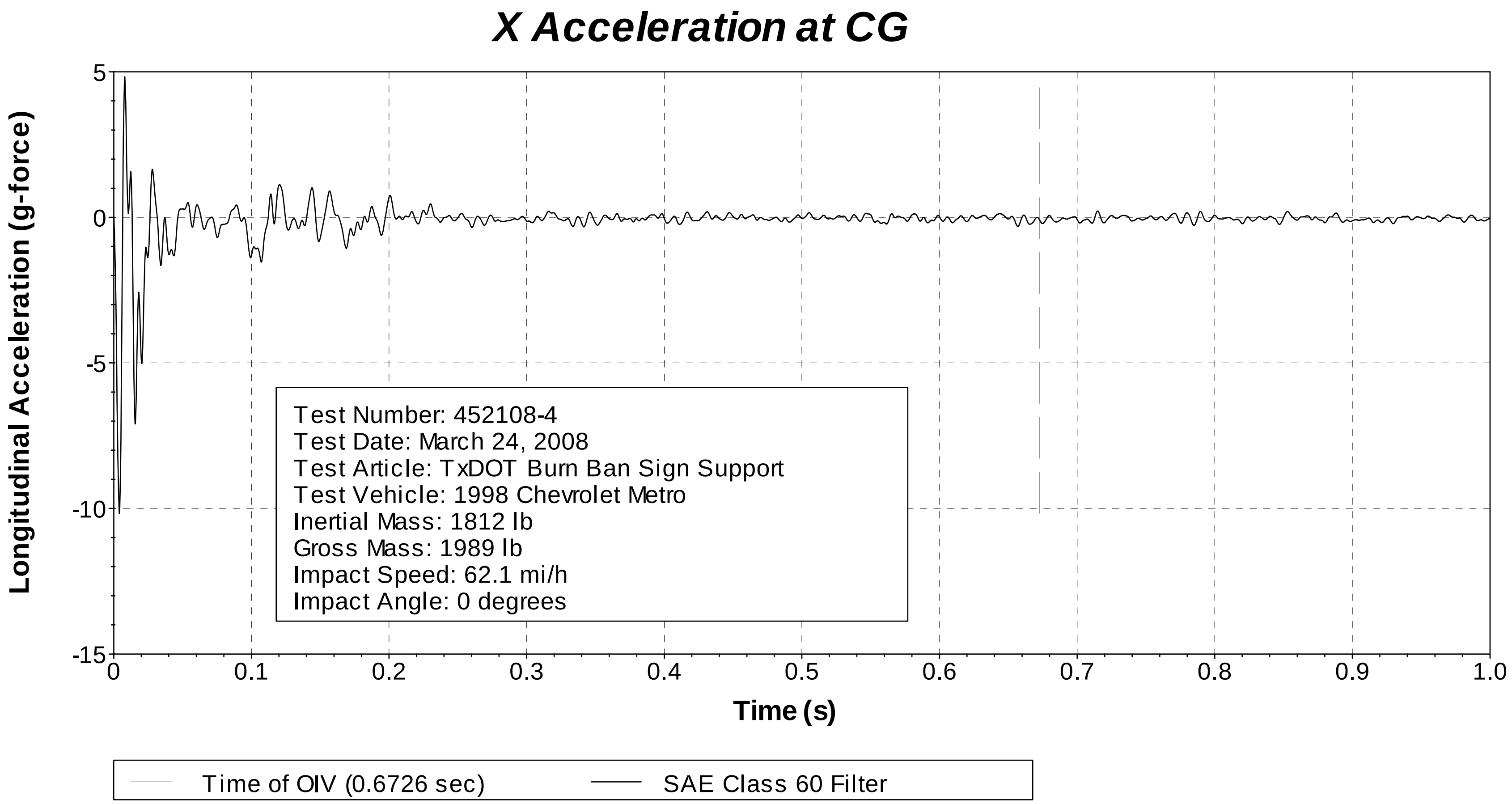


Figure D14. Vehicle Longitudinal Accelerometer Trace for Test 452108-4 (Accelerometer Located at Center of Gravity).

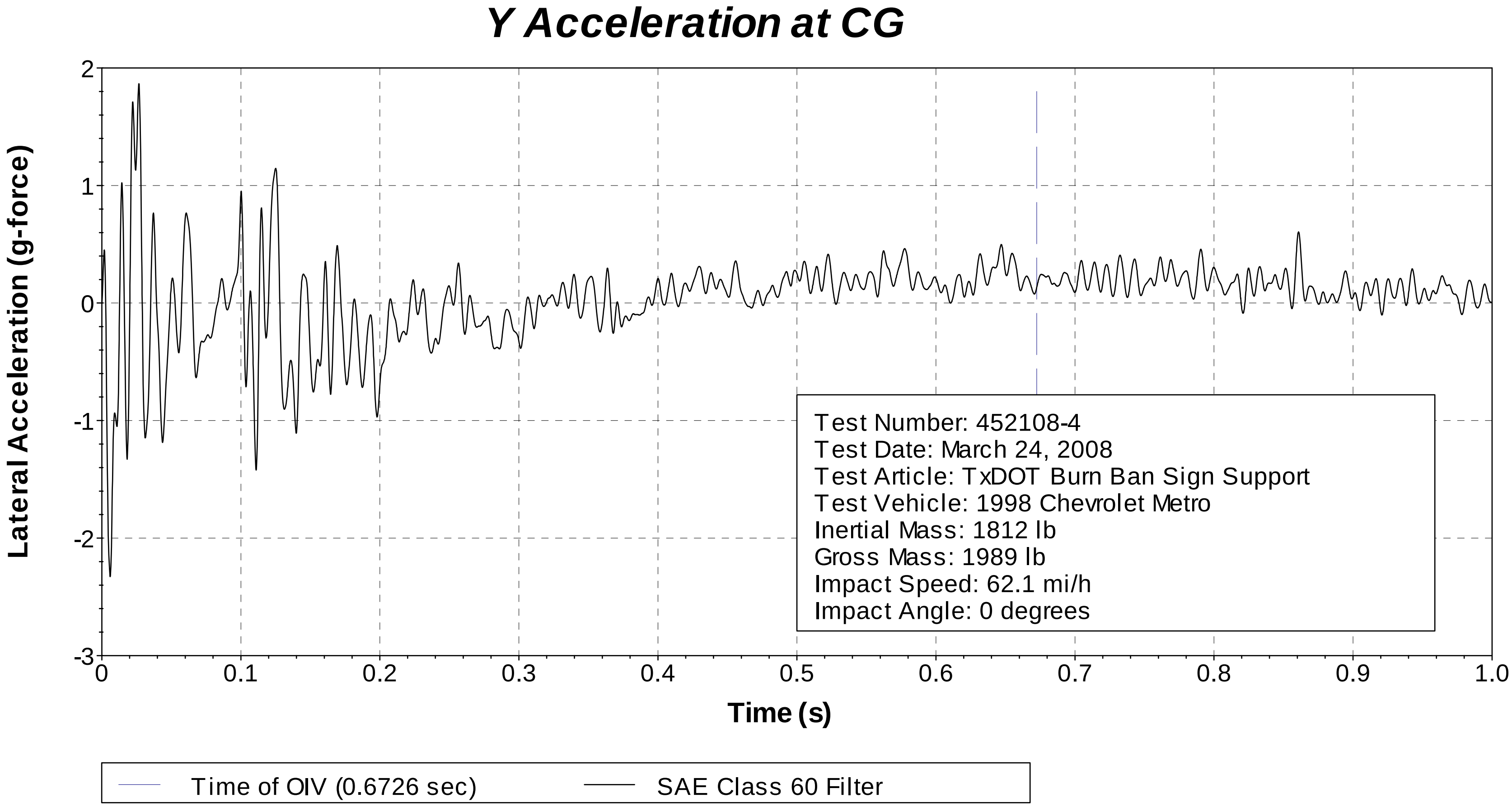


Figure D15. Vehicle Lateral Accelerometer Trace for Test 452108-4 (Accelerometer Located at Center of Gravity).

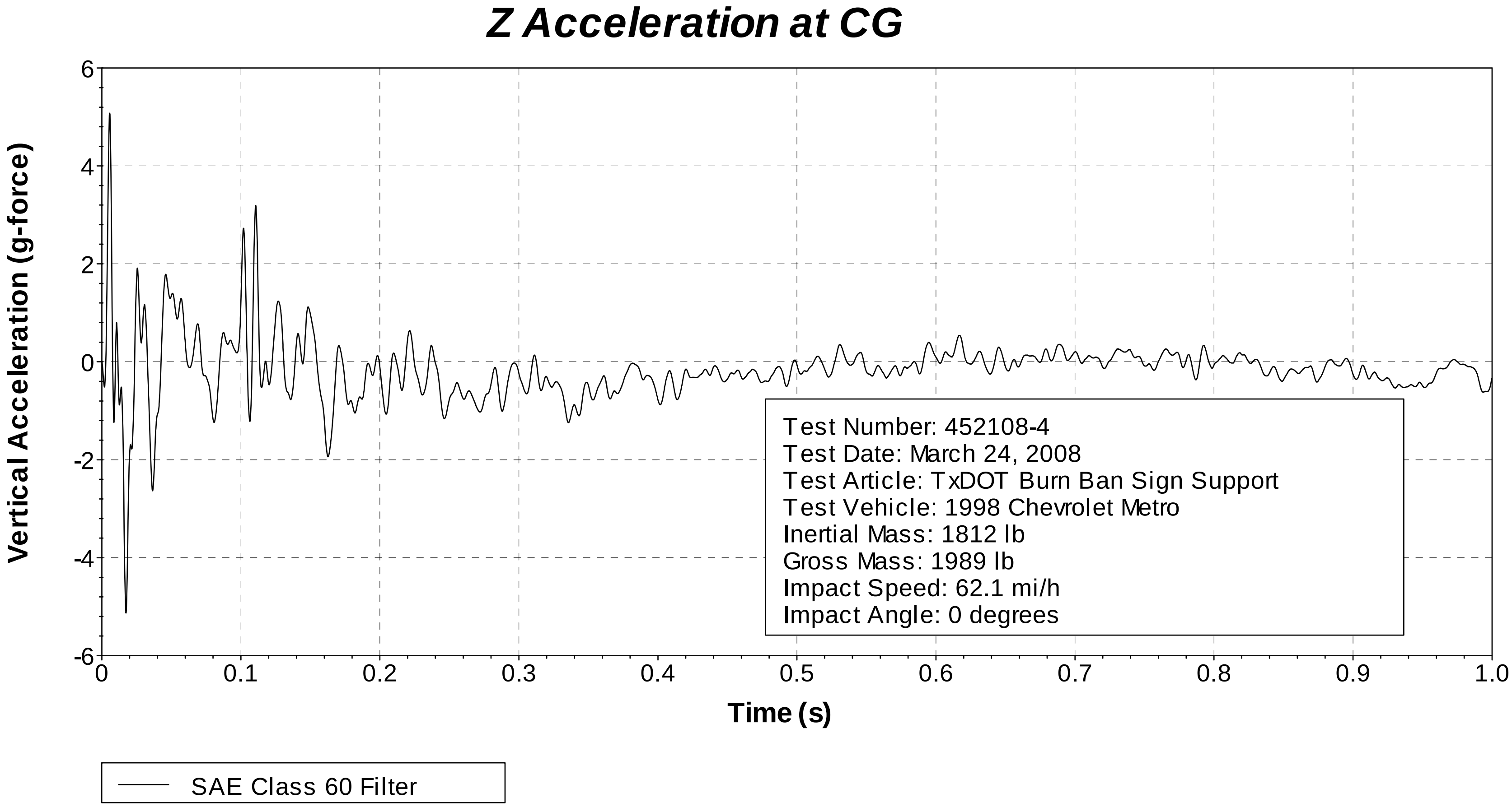


Figure D16. Vehicle Vertical Accelerometer Trace for Test 452108-4 (Accelerometer Located at Center of Gravity).