

1. Report No. TX-97/2924-3F	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle EVALUATION OF SIGN SUBSTRATES FOR USE WITH PLASTIC DRUMS		5. Report Date December 1996	
		6. Performing Organization Code	
7. Author(s) King K. Mak, Roger P. Bligh, and Wanda L. Menges		8. Performing Organization Report No. Research Report 2924-3F	
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135		10. Work Unit No.	
		11. Contract or Grant No. Study No. 7-2924	
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Transfer Office P. O. Box 5080 Austin, Texas 78763-5080		13. Type of Report and Period Covered Final Report: September 1995 - August 1996	
		14. Sponsoring Agency Code	
15. Supplementary Notes Research performed in cooperation with the Texas Department of Transportation. Research Study Title: Evaluation of Plastic Drum Specifications			
16. Abstract <p>The Texas Department of Transportation (TxDOT) is revising its Barricade and Construction Standard sheets. In support of this effort, an earlier study developed a proposed set of specifications to evaluate and qualify plastic drums for use in work zones. Various plastic drums obtained from manufacturers were submitted first to static tests then crash tested to validate those results. Research findings are being incorporated into the revision of the Barricade and Construction Standard sheets.</p> <p>This portion of the study pertains to the evaluation of various sign substrates for use with plastic drums. The objectives of this study are to (1) identify sign substrates suitable for use with plastic drums, including sign substrates that are currently in use and new sign substrates that could potentially be used with plastic drums, particularly sign substrates made from recycled materials; (2) evaluate the selected sign substrates for safety performance when used with plastic drums; and (3) analyze the test results and recommend sign substrates for use with plastic drums.</p> <p>The scope of the study included a survey of commercially available sign substrates that are currently used with plastic drums and candidate new sign substrates. The selected sign substrates were acquired from the manufacturers. Static and full-scale crash tests were then conducted to evaluate the safety performance of the selected sign substrates.</p>			
17. Key Words Plastic Drums, Signs, Work Zone Safety, Impact Performance.		18. Distribution Statement No restrictions. This document is available to the public through the NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161	
19. Security Classif (of this report) Unclassified	20. Security Classif (of this page) Unclassified	21. No of Pages 54	22. Price



# **EVALUATION OF SIGN SUBSTRATES FOR USE WITH PLASTIC DRUMS**

by

King K. Mak, P.E.  
Research Engineer

Roger P. Bligh, P.E.  
Assistant Research Engineer  
and

Wanda L. Menges  
Assistant Research Specialist

Research Report 2924-3F  
Research Study Number 7-2924  
Research Study Title: Evaluation of Plastic Drum Specifications

Sponsored by the  
Texas Department of Transportation

December 1996

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



## **DISCLAIMER**

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge of the project was King K. Mak, P.E. # 51502.

It is the policy of Texas Transportation Institute (TTI) and Texas A&M University not to endorse any specific manufacturers, trademarks, or products. However, it is necessary in the report to identify the specific plastic drums and sign substrates tested in the study. It should therefore be noted that the mention of specific manufacturers, trademarks, and products in the report does not constitute endorsement of such manufacturers, trademarks, or products by TTI or Texas A&M University.

## **ACKNOWLEDGMENT**

This study is sponsored by the Texas Department of Transportation (TxDOT). Mr. Lewis Rhodes is the Research Project Director for TxDOT, and the authors deeply appreciate his guidance and support.

## TABLE OF CONTENTS

	PAGE
LIST OF FIGURES .....	xi
LIST OF TABLES .....	xii
I. INTRODUCTION .....	1
1.1 BACKGROUND .....	1
1.2 OBJECTIVES AND SCOPE OF STUDY .....	2
II. STUDY APPROACH .....	3
2.1 SIGN SUBSTRATES .....	3
2.2 STATIC TEST PROCEDURES .....	4
2.3 FULL-SCALE CRASH TEST PROCEDURES .....	4
III. STUDY RESULTS .....	9
3.1 STATIC TEST RESULTS .....	9
3.2 FULL-SCALE CRASH TEST RESULTS .....	14
3.2.1 Safety Lite Fiberglass Sign Substrate (Test No. 429246-1) .....	14
3.2.2 U.S. Highway Products Survivor™ Fiberglass Reinforced Plastic Sign Substrate (Test No. 429246-2) .....	19
3.2.3 U.S. Highway Products FiberBrite™ Fiberglass Reinforced Plastic Sign Substrate (Test No. 429246-3) .....	19
3.2.4 Gopher Polyflex™ Polyethylene Sign Substrate (Test No. 429146-4) .....	20
3.2.5 International Plastics Fiberglass Reinforced Polycarbonate Sign Substrate (Test No. 429246-5) .....	20
3.2.6 International Plastics Duraplate™ Polycarbonate Sign Substrate (Test No. 429246-6) .....	21
3.2.7 Amsign Corp. 3004-H38 Aluminum Sign Substrate (Test No. 429246-7) .....	21
3.2.8 Amsign Corp. 5052-H38 Aluminum Sign Substrate (Test No. 429246-8) .....	22
3.2.9 Bent Manufacturing Two-Piece Traffic Cone (Test No. 429246-9) .....	22
3.2.10 TrafFix Two-Piece Traffic Cone (Test No. 429246-10) .....	22
3.2.11 U.S. Highway Products FiberBrite™ Fiberglass Reinforced Plastic Sign Substrate (Test No. 429246-11) .....	23
3.2.12 Bent Manufacturing Two-Piece Traffic Cone (Test No. 429246-12) .....	23
IV. SUMMARY OF FINDINGS .....	25
4.1 SIGN SUBSTRATES .....	25
4.2 TWO-PIECE TRAFFIC CONE .....	26

V. IMPLEMENTATION RECOMMENDATIONS ..... 27

APPENDIX A ..... 29

REFERENCES ..... 39



## LIST OF FIGURES

FIGURE		PAGE
1	Static test setup. ....	5
2	Deflected shape of sign panel specimen after static loading. ....	6
3	Static test of Gopher Sign Company Polyflex™ sign substrate. ....	12
4	Load-deflection behavior of various sign substrates. ....	13
5	Typical setup for sign substrate tests. ....	16
6	Typical setup for traffic cone tests. ....	17
7	Properties of vehicle used in testing. ....	18
A-1	Static test results for International Plastic Corporation's Fiberglass ....	30
A-2	Static test results for Gopher sign Company ....	31
A-3	Static test results for U.S. Highway Products ....	32
A-4	Static test results for U.S. Highway Products ....	33
A-5	Static test results for Safety Light fiberglass sign substrate ....	34
A-6	Static test results for Amsign Corp. ....	35
A-7	Static test results for Amsign Corp. ....	36
A-8	Static test results for International Plastics Corporation ....	37

**LIST OF TABLES**

<b>TABLE</b>		<b>PAGE</b>
1	Summary of static test results .....	11
2	List of crash tests conducted. ....	15

## SUMMARY

The Texas Department of Transportation (TxDOT) is in the process of revising its Barricade and Construction Standard sheets. This study was conducted in support of this effort. In earlier efforts under the study, researchers developed a proposed set of specifications to evaluate and qualify plastic drums for use in work zones. The proposed specifications provide a simple and inexpensive means of testing the plastic drums to make sure that they will perform in a predictable and satisfactory manner when impacted by errant vehicles. Static tests of various plastic drums submitted by manufacturers for consideration by TxDOT were conducted in accordance with the proposed specifications. The same plastic drums were then crash tested to validate the results of the static tests. Results of the research are being incorporated into the revision of the Barricade and Construction Standard sheets.

The portion of the study reported herein pertains to the evaluation of various sign substrates for use with plastic drums. The objectives of this study are to (1) identify sign substrates suitable for use with plastic drums, including sign substrates that are currently in use and new sign substrates that could potentially be used with plastic drums, particularly sign substrates made from recycled materials; (2) evaluate the selected sign substrates for safety performance when used with plastic drums; and (3) analyze the test results and recommend sign substrates for use with plastic drums.



# I. INTRODUCTION

## 1.1 BACKGROUND

Safety of work zones is a major area of concern since it is seldom possible to maintain a level of safety comparable to that of a normal highway not under construction. Proper traffic control is critical to the safety of work zones. However, traffic control devices themselves may pose a safety hazard when impacted by errant vehicles. It is therefore important to ensure that the traffic control devices used in the work zones meet certain safety performance standards and specifications. For the past few years, the Texas Department of Transportation (hereinafter referred to as TxDOT or the Department) has sponsored a number of studies at the Texas Transportation Institute (TTI) to assess the impact performance of various work zone traffic control devices, including plastic drums, sign substrates, barricades, and temporary sign supports (1-5).

The study reported herein is part of the continuing effort to evaluate work zone traffic control devices and pertains specifically to plastic drums and sign substrates for use with plastic drums. In previous studies on plastic drums and sign substrates, it was found that plastic drums posed little hazard to the impacting vehicle from the occupant risk standpoint due to their light weight and ready disengagement from the bases. The vehicle exhibited very stable behavior during impact with the plastic drums and did not appear to pose any potential threat to traffic in adjacent lanes. It was also determined that the flashing light units should be rigidly attached to the top of the plastic drums to avoid the possibility of the flashing light units being dislodged from the plastic drums and becoming projectiles.

Based on results of these studies, the Department developed proposed specifications for plastic drums. The proposed specifications outline the desired properties and characteristics of a plastic drum and specify certain dimensions and a series of static force tests a plastic drum must pass in order to be acceptable to TxDOT for purchase and use in work zones. These tests are intended as surrogates to the full-scale crash tests used to evaluate the safety performance of plastic drums. Full-scale crash testing is the best means to assess the safety performance of plastic drums, but it is also relatively expensive. Thus, a number of surrogate test procedures, which are less expensive to conduct, were developed and specified to provide a reliable indicator of the impact performance for the plastic drums. Commercially available plastic drums submitted by manufacturers for consideration by TxDOT were first evaluated with static tests in accordance with the proposed specifications. Investigators then subjected the same plastic drums to crash tests to validate the results of the static tests.

In addition, six sign substrates for use with plastic drums were evaluated: (1) plywood, (2) fiber-reinforced plastic (FRP), (3) polycarbonate, (4) 6 mm (0.24 in) thick plastic, (5) Medex, and (6) aluminum. Results of the crash tests indicate that the plywood and Medex sign substrates did not perform satisfactorily and are not recommended for use with plastic drums. The other four sign substrates performed satisfactorily and are considered acceptable for use with plastic drums. Additional sign substrates were evaluated in this study, the results of which are presented in this report.

## 1.2 OBJECTIVES AND SCOPE OF STUDY

The objectives of this study are as follows:

1. Identify sign substrates suitable for use with plastic drums, including sign substrates that are currently in use and new sign substrates that could potentially be used with plastic drums, particularly sign substrates made from recycled materials.
2. Evaluate the selected sign substrates for safety performance when used with plastic drums.
3. Analyze the test results and recommend sign substrates for use with plastic drums.

The scope of the study included a survey of commercially available sign substrates that are currently used with plastic drums and candidate new sign substrates. The selected sign substrates were acquired from the manufacturers. Static and full-scale crash tests were then conducted to evaluate the safety performance of the selected sign substrates.

Chapter II describes the sign substrates selected for evaluation. The test procedures for both static testing and full-scale crash testing are also presented in Chapter II. Chapter III summarizes the results of the tests. Chapter IV presents a summary of findings and recommendations.

## II. STUDY APPROACH

### 2.1 SIGN SUBSTRATES

Signs are often attached to plastic drums in work zones to delineate the edge of the work zone or curves in the roadway. These signs, which include Chevrons, arrow panels, and vertical panels, vary in size up to 457 mm × 610 mm. Full-scale crash testing has shown that conventional plywood sign blanks do not meet current safety impact criteria. During testing, the plywood sign blank has demonstrated a tendency for penetrating through the windshield of the impacting vehicle. To identify suitable alternatives and permit the continued use of signs mounted on plastic drums, a total of eight different sign substrates from five different manufacturers were tested and evaluated under this study. A description of the various sign substrates is given below.

- Two aluminum substrates were obtained from Amsign Corporation. One was fabricated from a virgin aluminum alloy (5052), while the other was composed of a recycled aluminum alloy (3004). Both panels had a thickness of 2.03 mm, a yield strength of 276 MPa and a tensile strength of approximately 296 MPa. The 5052 virgin aluminum had a 4 percent ductility, while the 3004 recycled aluminum had a ductility of 5-6 percent.
- A 3.81 mm thick fiberglass panel was acquired from Safety Light.
- Gopher Sign Company supplied a recycled plastic sign panel with the trade name Polyflex™. This product is a 3.18 mm thick extruded sheet made from 100 percent post-consumer high-density polyethylene (HDPE), which is obtained from sources such as milk bottles. The manufacturer reported it to be flexible and shatterproof down to temperatures as low as -70 degrees Fahrenheit.
- Two different fiber-reinforced plastic (FRP) sign substrates were furnished by U.S. Highway Products, Inc. The Survivor™ sign panel is a high-gloss pigmented polyester fiberglass reinforced composite with ultraviolet (UV) stabilizers for weatherability. It has three layers of continuous-strand fiberglass and four layers of chop-strand fiberglass with a total minimum fiberglass content of 40 percent by weight. The Survivor™ is 3.61 mm thick and has a tensile strength of 137.9 MPa. The second product, known as Fiber-Brite™, is an FRP sign panel made with acrylic modified and UV-stabilized thermoset polyester resins. It is 3.43 mm thick and has a tensile strength of 68.9 MPa. Both panels are reported to have thermal stability over a wide temperature range.
- International Plastics Corporation (IPC) provided three different sign substrates. The Duraplate™ panel is made from 100 percent recycled plastic. This polycarbonate substrate is 3.9 mm and has a tensile strength of 67.5 MPa. The second product was a fiberglass reinforced polycarbonate panel that has a thickness of 4.06 mm. The third sign panel supplied by IPC was an acrylonitrile butadiene styrene terpolymer (ABS) coextrusion that had a thickness of 6.9 mm. Investigators did not receive this

product in time to incorporate it into the full-scale crash test program, but it was included in the static load testing for comparison purposes.

With the exception of the IPC fiberglass reinforced polycarbonate, all sign panels measured 457 mm × 610 mm. The IPC fiberglass reinforced polycarbonate panels measured 381 mm × 546 mm.

## **2.2 STATIC TEST PROCEDURES**

Each sign blank was mounted horizontally to a rigid table in a cantilever fashion. Two 13-mm diameter holes were drilled in each sign blank to match the hole spacing required for attachment of the panel to a plastic drum. The distance from the rigid support to the centerline of the mounting holes was 457 mm for the IPC fiberglass reinforced polycarbonate and 508 mm for all other sign substrates. The distance from the centerline of the holes to the free edge of the panel was 45 mm for all sign panels.

A 5-mm grid was mounted behind the sign panel and leveled with the rigid table. The initial vertical deflection at the free edge of the sign panel was measured and recorded. Two eye bolts with washers on each side were attached to the sign panel through the drilled mounting holes. A cable was attached between the two eye bolts to permit attachment of weights. The weight of the eye bolts and cable assembly was 0.54 kg. The deflection after attaching the eye bolt and cable assembly was measured and recorded. Individual weights weighing 1.33 kg each were then attached to the cable. The vertical deflection was measured and recorded after the addition of each weight. Researchers stopped testing when cracking or failure of the sign panel was observed or when the deflected shape of the panel was close to vertical. The horizontal distance from the support to the free end of the deflected sign blank was measured and recorded at the end of each test. Still photographs taken at selected intervals were used to visually record each test.

Figure 1 shows photographs of the static test setup. The final deflected shape of one of the test specimens after loading is shown in Figure 2.

## **2.3 FULL-SCALE CRASH TEST PROCEDURES**

Investigators conducted a total of 12 full-scale crash tests, nine of which were on various sign substrates mounted on plastic drums; the remaining three tests were on tall plastic traffic cones. The test procedures were in accordance with guidelines set forth in National Cooperative Highway Research Program (NCHRP) Report 350 (6). All the 12 tests were conducted under test level 3 (TL-3) conditions and corresponded to test designation 3-71 under NCHRP Report 350 (i.e., an 820-kg passenger car impacting the traffic control device head on with the center front of the vehicle at a nominal impact speed and angle of 100 km/h and 0 degree).



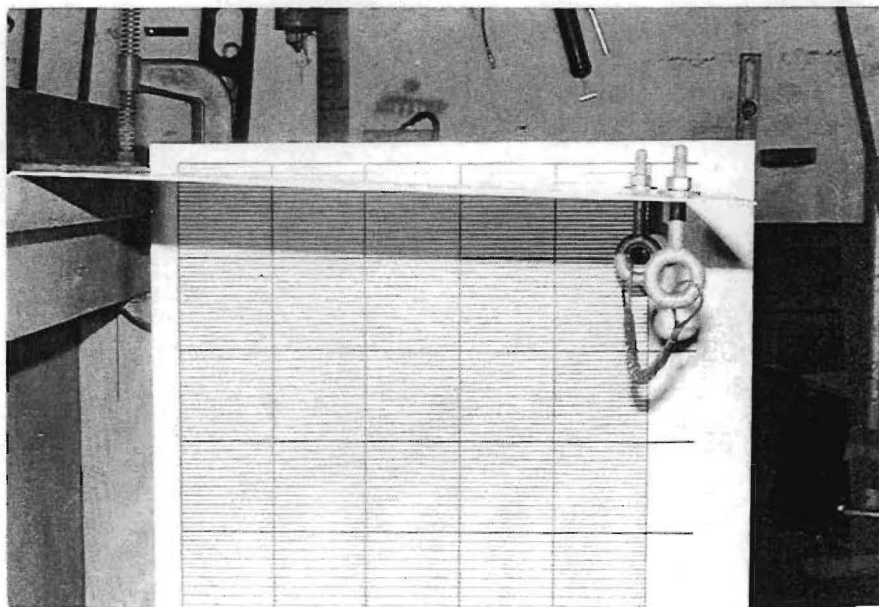
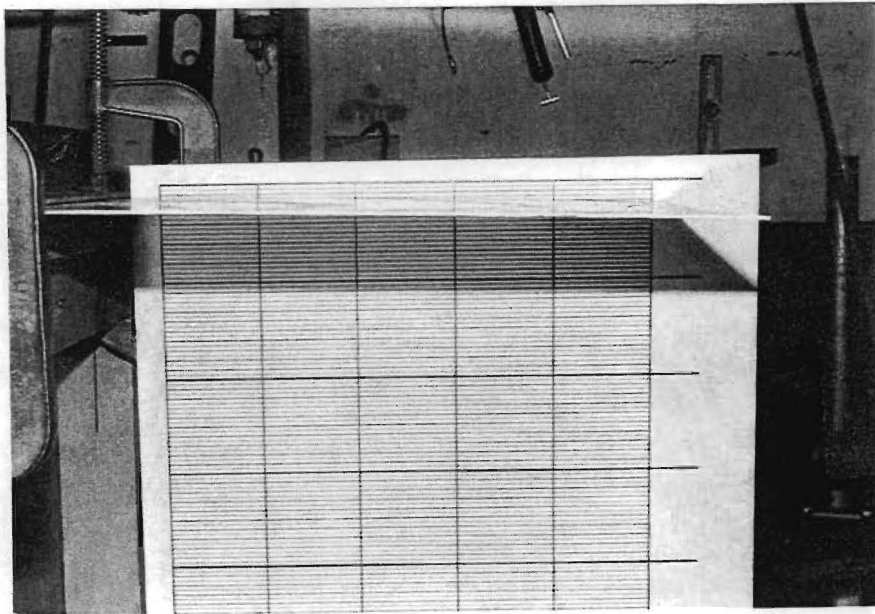


Figure 1. Static test setup.

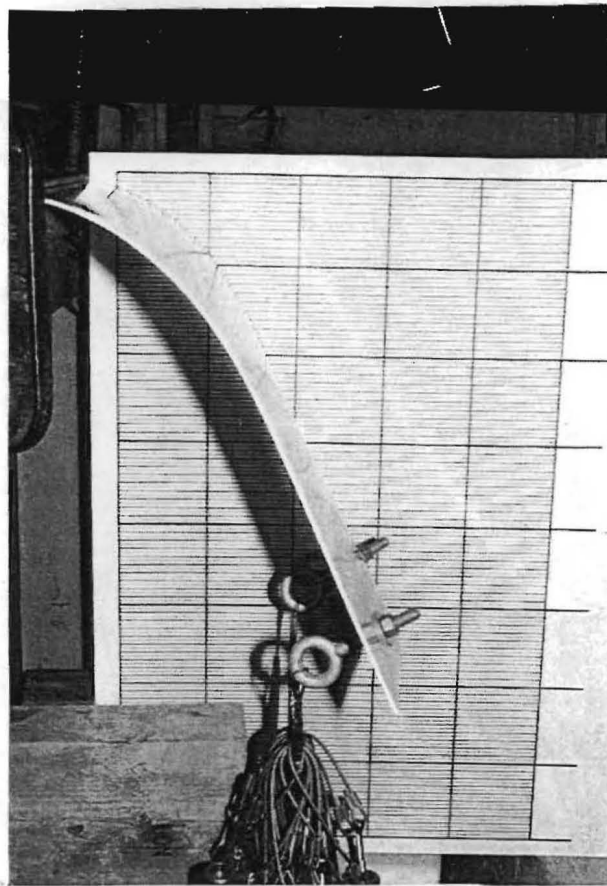
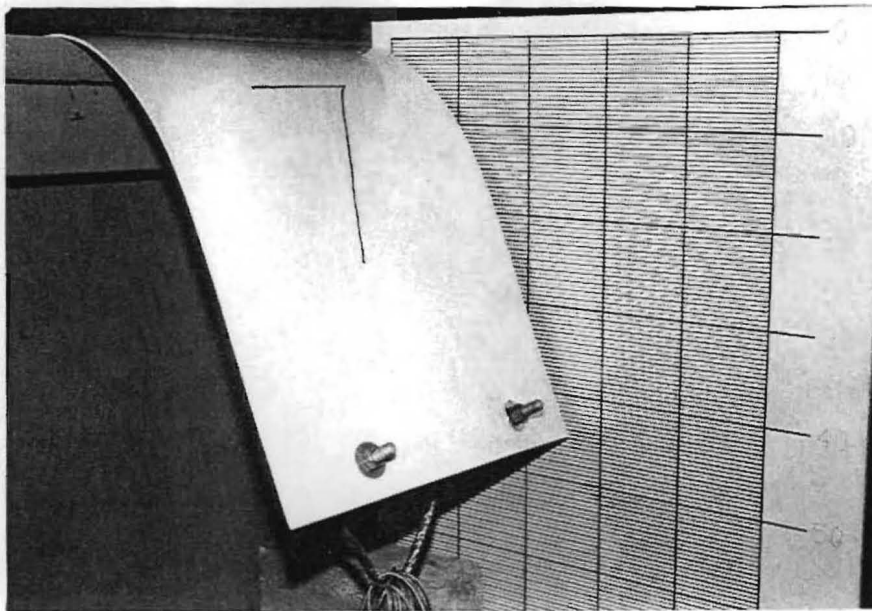


Figure 2. Deflected shape of sign panel specimen after static loading.

Previous crash tests with plastic drums and cones indicated that the level of acceleration experienced by the test vehicle in impacts with plastic drums was extremely low, and electronic instrumentation would offer little useful information. Thus, the test vehicle was not instrumented. Also, the test vehicles exhibited very stable behavior during previous impacts with plastic drums and did not appear to pose any potential rollover threat. It was therefore decided to use a driver for the test vehicle instead of using the cable tow and guidance system to minimize the turnaround time between tests. The biggest threat to the driver would be glass fragments if the windshield shattered from impact with a sign panel. A shield constructed from heavy gauge wire mesh was installed to protect the driver from glass fragments. Also, a five-point seat belt system restrained the test vehicle driver, who wore a crash helmet with a face shield.

The photographic coverage for the tests included two video camcorders, one positioned at a right angle to the path of the vehicle and the other at a 45-degree angle. High-speed film was also used for the first seven tests (test nos. 429246-1 through 429246-7). The tests were documented with video and 35-mm still cameras, including before and after shots of the test vehicle, plastic drums and sign substrates, and the debris patterns.



### III. STUDY RESULTS

#### 3.1 STATIC TEST RESULTS

The researchers performed static load tests on eight different sign substrates to investigate their force-deflection characteristics. Two tests were conducted on each type of substrate for a total of 16 static load tests. The primary purpose of the static testing was to compare the relative stiffness of the different sign substrates. Although a particular substrate may exhibit satisfactory impact performance, it may lack sufficient stiffness to be functional as a sign panel. If a sign substrate is too flexible, it may adversely affect the reflectivity and/or legibility of the sign.

As discussed in Chapter II, the static load testing was continued until cracking or failure of the sign panel was observed or the deflected shape of the panel was close to vertical. Given the large loads that were applied and the associated large deflections, it was necessary to establish a load limit at which the deflections of the different sign substrates could be compared. Two different loads were evaluated to establish an appropriate threshold: (1) the force generated on the 457 mm × 610 mm sign blank by a 96.5 km/h design wind speed which is used in the design of small sign supports, and (2) the force required to cause the plastic drum to tip over or slide on its base.

For a 96.5 km/hr design wind speed, the associated wind pressure on the sign panel is 575 Pa. Using the appropriate drag coefficient and sign panel area, the computed wind force being applied to the sign panel is 18.3 kg. When this resultant force is adjusted from the centroid of the sign panel to the top of the sign to correspond with the load procedure followed in the static testing, a force of 9.1 kg is obtained.

To evaluate the second load case, the results of horizontal tip tests were used. Under a previous research study (4), horizontal tip tests were conducted as part of an evaluation of a draft specification for plastic drums. The purpose of the testing was to determine the force required to cause a drum to tip over or slide on its base for a prescribed amount of ballast. The results indicated that the horizontal force applied to the top of the drum necessary to cause the drum to tip over or slide ranged from 10.2 kg to 13.6 kg. When the maximum force of 13.6 kg applied to the top of the drum is adjusted to an equivalent force applied at the top of the sign panel that generates the same overturning moment, a value of 5.4 kg is obtained.

Since the overturning force is less than that obtained from the wind load analysis, a value of 5.4 kg was used as a threshold value for one means of comparison of the static load test data obtained for the different sign substrates. Table 1 shows a summary of the static test results. The table contains a description of the test specimen, including manufacturer, substrate type, weight, and thickness. Results contained in the table include initial deflection of the sign panel under its own weight and the deflection of the sign panel under a load of 5.4 kg applied near the top of the panel. Individual plots of the load-deflection response of each type of sign substrate are presented in Figures A-1 through A-8 in Appendix A.

As shown in Table 1, the most flexible sign substrate was the recycled high-density polyethylene panel provided by Gopher Sign Company. This panel deflected as much as 148 mm

under its own weight and 479 mm at a load of 5.4 kg. Figure 3 shows the final deflected shape of this panel for an applied load of only 5.9 kg. This product appears to be too flexible to be of any practical use as a sign substrate on plastic drums.

The stiffest sign substrates were the two aluminum products supplied by Amsign Corporation. Both the recycled and virgin aluminum alloys had an initial deflection of only 9 mm and an average deflection of 138 mm at a load of 5.4 kg. Although the ABS acrylic panel provided by International Plastics Corporation had a slightly larger initial deflection than the aluminum products, the deflection measured at a load of 5.4 kg was very similar. Figure 4 shows the load-deflection behavior of the various substrates from which the relative stiffness of each product can be inferred.

As discussed above, investigators conducted two static load tests for each type of substrate. It should be noted that, with one exception, the results of both tests correlated very well and indicated similar behavior. However, the fiberglass sign panels supplied by Safety Light showed dramatically different results. As shown in Table 1, there is a 70 percent difference in the amount of deflection observed at a load of 5.4 kg for the two tests (tests 9 and 10) that were conducted on the fiberglass substrate. This difference in behavior is also illustrated in the load-deflection plots of these two tests (see Figure A-5).

It is possible that the stiffness of some of these sign panels can be increased to limit deflections caused by wind loads or passing vehicles. The most obvious means of increasing the stiffness is by increasing the thickness of the panel. However, since a change in thickness will increase both the stiffness and the weight of the panel, it is recommended that any variations be evaluated through full-scale crash testing to ensure that the impact performance is not adversely affected.

Table 1. Summary of static test results.

Manufacturer	Substrate	Test No.	Weight (kg)	Thickness (mm)	Deflection (mm)		Comments
					Initial	@ 5.4 kg load	
International Plastics Corp.	Fiberglass Reinforced Polycarbonate <sup>a</sup>	1	1.18	4.1	40	151	cracking @ 53 kg
		2	1.18	4.0	35	153	
	ABS Acrylic	15	1.96	7.0	13	135	
		16	1.93	6.9	17	149	
Gopher Sign Company	Recycled HDPE (Polyflex)	3	0.79	3.1	148	479	
		4	0.79	3.1	133	477	
U.S. Highway Products	Fiberglass Reinforced Plastic (Fiber-Brite)	5	1.36	3.5	40	258	
		7	1.39	3.4	40	258	
	Fiberglass Reinforced Plastic (Survivor)	6	1.30	3.4	35	253	visible cracks, failure @ 26 kg
		8	1.32	3.4	30	238	visible cracks, failure @ 26 kg
Safety Light	Fiberglass	9	1.53	3.7	50	307	
		10	1.70	3.9	30	180	
Amsign Corporation	Recycled Aluminum (3004-H38)	11	1.42	2.0	9	137	
		12	1.42	2.0	9	138	
	Virgin Aluminum (5052-H38)	13	1.42	2.0	9	137	
		14	1.45	2.0	8	142	

<sup>a</sup> Dimensions of panel were 382 mm × 544 mm; all others were 456 mm × 609 mm

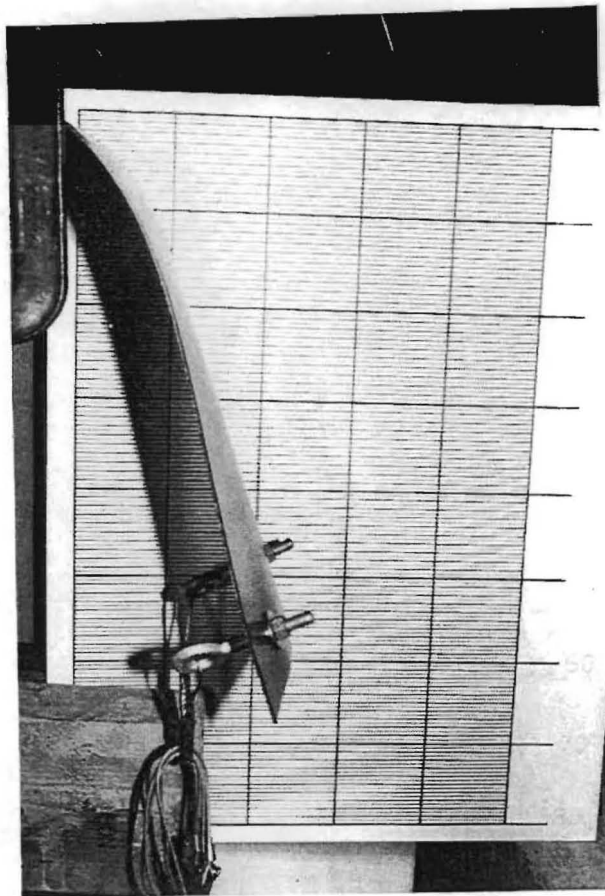
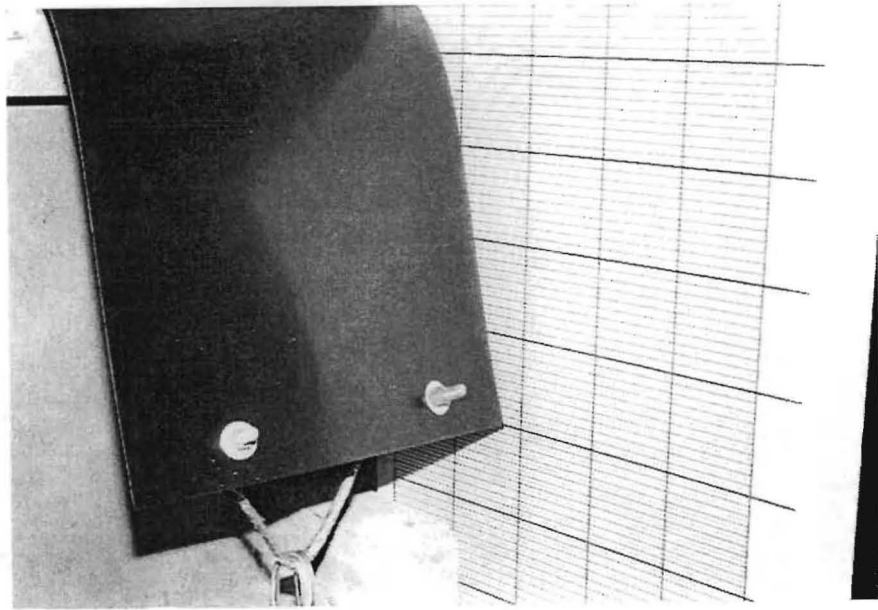


Figure 3. Static test of Gopher Sign Company Polyflex™ sign substrate.



### Various Substrates

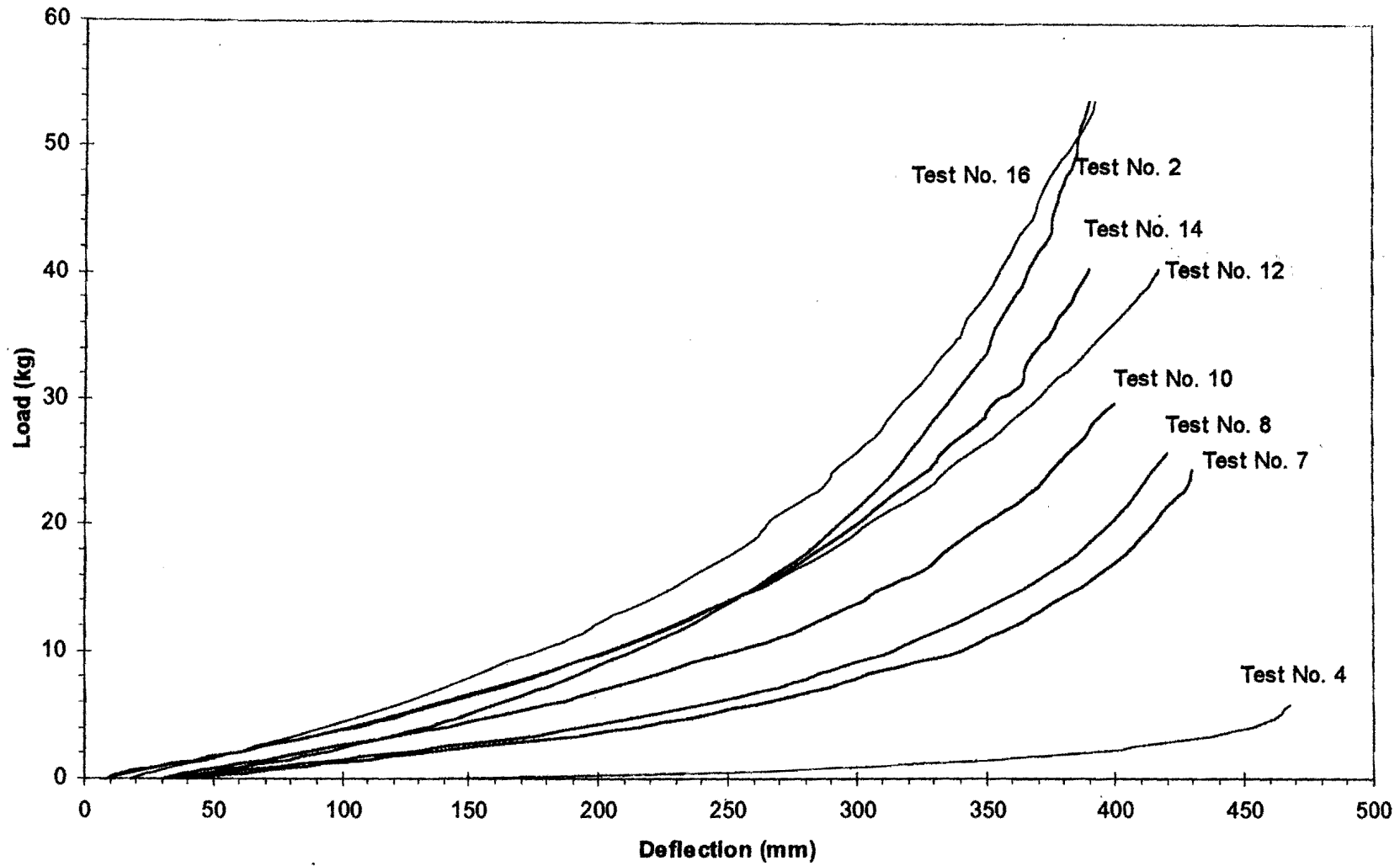


Figure 4. Load-deflection behavior of various sign substrates.

## 3.2 FULL-SCALE CRASH TEST RESULTS

This study included 12 crash tests, a list of which is shown in Table 2. The first eight tests (test nos. 429246-1 through 429246-8) pertained to the eight different sign substrates selected for evaluation, one test for each sign substrate. Tests 9 and 10 (test nos. 429246-9 and 429246-10) involved two-piece traffic cones submitted by two different manufacturers to the Department for consideration. Test 11 (test no. 429246-11) involved a retest of a recycled fiber-reinforced plastic (FRP) sign panel damaged in a previous test (test no. 429246-3) to assess if the damaged sign panel could manage multiple impacts. The last test (test no. 429246-12) involved a retest of a two-piece traffic cone previously tested (test no. 429246-9), but with two weighted bases to evaluate the effect of using more than one weighted base.

Figure 5 shows photographs of a typical setup for tests of sign substrates mounted on plastic drums. The sign panel was mounted on top of a plastic drum with two 13 mm × 25 mm bolts. The bolt holes were field drilled to fit the hole spacing of the plastic drum. The plastic drum had either a sand-filled base or a plain base ballasted with sandbags to a weight of 23 kg.

Photographs showing a typical setup for tests of two-piece traffic cones are shown in Figure 6. The two-piece traffic cone is intended as a substitute for plastic drums for delineation of work zones. The purported advantage of two-piece traffic cones over plastic drums is reduced sight restriction due to the smaller cross-section of the cone. Two different manufacturers have submitted two-piece traffic cones to the Department for consideration. The purpose of these crash tests is to evaluate the impact performance of these two-piece traffic cones.

All 12 crash tests were conducted under test level 3 (TL-3) conditions and corresponded to test designation 3-71 under NCHRP Report 350 (i.e., an 820-kg passenger car impacting the traffic control device head on with the center front of the vehicle at a nominal impact speed and angle of 100 km/h and 0 degree). The vehicle used for all 12 tests was a 1991 Ford Festiva, as shown in Figure 6. Test inertial weight of the vehicle was 820 kg, and the gross static weight was 898 kg, which included the weight of the driver. The height to the bottom of the bumper was 355 mm and to the top was 510 mm. Figure 7 gives additional information on the vehicle. There was no instrumentation used during these tests.

Brief descriptions of the tests are presented in the following subsections.

### 3.2.1 Safety Lite Fiberglass Sign Substrate (Test No. 429246-1)

The first test was on a fiberglass sign substrate manufactured by Safety Lite. The sign panel measured 610 mm × 460 mm × 3.81 mm and weighed 1.58 kg. The sign panel was attached to the top of a Traffix 220 HDPE plastic drum with two 13 mm × 25 mm bolts. The plastic drum had a sand-filled base ballasted to a weight of 23 kg. The height to the top of the sign panel as tested was 1.56 m.

Table 2. List of crash tests conducted.

Test No.	Sign Substrate/ Test Article	Plastic Drum	Comments
429246-1	Safety Lite fiberglass sign substrate	TrafFix 220 HDPE with sand-filled base	
429246-2	U.S. Highway Products Survivor recycled FRP* sign substrate	TrafFix 220 HDPE LW with sand-filled base	
429246-3	U.S. Highway Products FiberBrite recycled FRP* sign substrate	TrafFix 220 LDPE with sand-filled base	
429246-4	Gopher Polyflex polyethylene sign substrate	Flex-O-Lite LDPE with sandbags	
429246-5	International Plastics Duraplate fiberglass reinforced polycarbonate sign substrate	TrafFix with sandbags	
429246-6	International Plastics Duraplate polycarbonate sign substrate	TrafFix 220 LDPE with sandbags	
429246-7	Amsign Corp. 3004-H38 Aluminum sign substrate	Flex-O-Lite 1500 with sandbags	
429246-8	Amsign Corp. 5052-H38 Aluminum sign substrate	TrafFix 220 HDPE with sandbags	
429246-9	Bent Manufacturing two-piece traffic cone	N/A	
429246-10	TrafFix two-piece traffic cone	N/A	
429246-11	U.S. Highway Products FiberBrite recycled FRP* sign substrate	Flex-O-Lite LDPE with sandbags	The sign panel was previously tested in test no. 429245-3. The plastic drum was previously used in test no. 429246-4.
429246-12	Bent Manufacturing two-piece traffic cone	N/A	The traffic cone was previously tested in test no. 429246-9 and installed with two weighted bases.

Notes: \* FRP - Fiber-reinforced Plastic. N/A = Not applicable.



Figure 5. Typical setup for sign substrate tests.



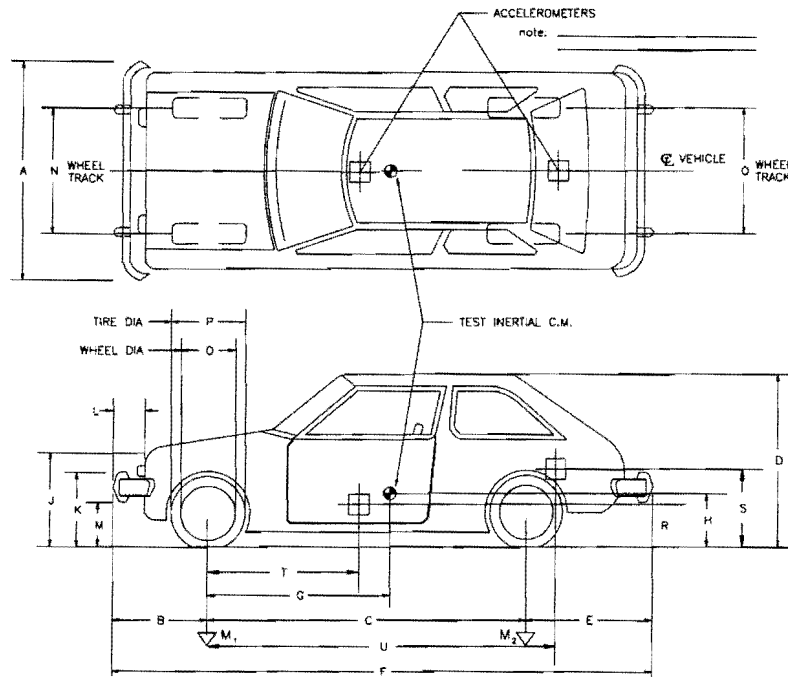
Figure 6. Typical setup for traffic cone tests.

DATE: 8-16-96 TEST NO.: 429246-1 thru 12 VIN NO.: KNJPT06H8M6123693  
 YEAR: 1991 MAKE: Ford MODEL: Festiva  
 TIRE INFLATION PRESSURE: \_\_\_\_\_ ODOMETER: 146575 TIRE SIZE: 145 SR12

MASS DISTRIBUTION (kg) LF 297 RF 276 LR 122 RR 125

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:

No Instrumentation



ACCELEROMETERS  
 note: \_\_\_\_\_  
 ENGINE TYPE: 4 CYL  
 ENGINE CID: 1.3 L  
 TRANSMISSION TYPE:  
 AUTO  
 MANUAL  
 OPTIONAL EQUIPMENT:  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 DUMMY DATA:  
 TYPE: \_\_\_\_\_  
 MASS: \_\_\_\_\_  
 SEAT POSITION: \_\_\_\_\_

GEOMETRY - (mm)

A <u>1665</u>	E <u>565</u>	J <u>740</u>	N <u>1405</u>	R <u>N/A</u>
B <u>665</u>	F <u>3510</u>	K <u>510</u>	O <u>1390</u>	S <u>N/A</u>
C <u>2280</u>	G _____	L <u>120</u>	P <u>530</u>	T <u>N/A</u>
D <u>1430</u>	H _____	M <u>355</u>	Q <u>330</u>	U <u>N/A</u>

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M <sub>1</sub>	<u>569</u>	<u>573</u>	_____
M <sub>2</sub>	<u>288</u>	<u>247</u>	_____
M <sub>T</sub>	<u>856</u>	<u>820</u>	_____

Figure 7. Properties of vehicle used in testing.

As the vehicle impacted the plastic drum, the drum body deformed and separated from the base. The sign panel slapped the hood and contacted the front of the windshield wipers. The drum body with the attached sign panel wrapped around the front of the vehicle and rode along with the vehicle until the vehicle was braked to a stop. The top of the sign panel was scraped. There were 45-mm long stress cracks 10 mm above the attachment bolts on the rear side of the sign panel. The hood of the vehicle was scratched and the windshield was slightly cracked in the lower center. Review of the videotape and high-speed film showed that the sign panel contacted the windshield wiper, which then contacted and cracked the windshield. There was no intrusion into the occupant compartment and the vision of the driver was not adversely affected by the slight cracking of the windshield. This test is judged to have met all evaluation criteria set forth in NCHRP Report 350.

### **3.2.2 U.S. Highway Products Survivor™ Fiberglass Reinforced Plastic Sign Substrate (Test No. 429246-2)**

The second test was on a fiberglass reinforced plastic sign substrate manufactured by U.S. Highway Products with the trade name of Survivor. The sign panel measured 610 mm × 460 mm × 3.18 mm and weighed 1.25 kg. The sign panel was attached to the top of a Traffix 220 HDPE LW plastic drum with two 13 mm × 25 mm bolts. The plastic drum had a sand-filled base ballasted to a weight of 23 kg. The height to the top of the sign panel as tested was 1.58 m.

As the vehicle impacted the plastic drum, the drum body deformed and separated from the base. The sign panel slapped the hood. The drum body with the attached sign panel wrapped around the front of the vehicle and rode along with the vehicle until the vehicle was braked to a stop. The top of the sign panel was scratched, and there were 25 mm long cracks on the rear of the panel 10 mm above the attachment bolts. There were two unmeasurable dents on the front of the hood of the vehicle. The sign panel did not contact the windshield and there was no intrusion into the occupant compartment. This test is judged to have met all evaluation criteria set forth in NCHRP Report 350.

### **3.2.3 U.S. Highway Products FiberBrite™ Fiberglass Reinforced Plastic Sign Substrate (Test No. 429246-3)**

The third test was on a fiberglass reinforced plastic sign substrate, also manufactured by U.S. Highway Products, with the trade name of FiberBrite. The sign panel measured 610 mm × 460 mm × 3.28 mm and weighed 1.22 kg. The sign panel was attached to the top of a Traffix 220 LDPE (low density polyethylene) plastic drum with two 13 mm × 25 mm bolts. The plastic drum had a sand-filled base ballasted to a weight of 23 kg. The height to the top of the sign panel as tested was 1.56 m.

As the vehicle impacted the plastic drum, the drum body deformed and separated from the base. The sign panel slapped the hood. The drum body with the attached sign panel wrapped around the front of the vehicle and rode along with it until the vehicle was braked to a stop. The top of the sign panel was scraped and dented. There were cracks on the rear of the sign panel 10 mm above the attachment bolts, 45 mm long on the left and 35 mm long on the right. The hood of the vehicle was scraped. The sign panel did not contact the windshield and there was no intrusion into the

occupant compartment. The researchers judged this test to have met all evaluation criteria set forth in NCHRP Report 350.

#### **3.2.4 Gopher Polyflex™ Polyethylene Sign Substrate (Test No. 429146-4)**

The fourth test was on a high-density polyethylene plastic sign substrate manufactured by Gopher Sign Company, with the trade name of Polyflex. The sign panel measured 610 mm × 450 mm × 3.12 mm and weighed 0.8 kg. The sign panel was attached to the top of a Flex-O-Lite LDPE plastic drum with two 13 mm × 25 mm bolts. The plastic drum had a plain base and was ballasted with sandbags to a weight of 23 kg. The height to the top of the sign panel as tested was 1.54 m.

As the vehicle impacted the plastic drum, the drum body deformed and separated from the base. The separated drum body with the attached sign panel bounced up in the air and the sign panel slightly scraped the hood of the vehicle. The separated drum body with the attached sign panel then went over the vehicle and came to rest 50 m downstream from its original position. The top of the panel was scraped, but there were no stress cracks around the attachment bolts as in previous tests. The paint on the hood of the vehicle was scraped. The sign panel did not contact the windshield and there was no intrusion into the occupant compartment. This test is judged to have met all evaluation criteria set forth in NCHRP Report 350.

It should be noted, however, that the Polyflex sign panel is very flexible to the extent that the sign panel would not stay vertical even without any wind (i.e., the sign panel would bend by itself). The sign panel would flex considerably under windy conditions. This would pose a problem to the reflectivity of the reflective sheeting and the legibility of the sign. Thus, while the Polyflex sign substrate has acceptable impact performance, it is not considered acceptable from the serviceability or practicality standpoint and is not recommended for field use.

#### **3.2.5 International Plastics Fiberglass Reinforced Polycarbonate Sign Substrate (Test No. 429246-5)**

The fifth test was on a fiberglass reinforced polycarbonate sign substrate manufactured by International Plastics Corporation. The sign panel measured 550 mm × 380 mm × 4.01 mm and weighed 1.16 kg. The sign panel was attached to the top of a Traffix plastic drum with two 13 mm × 25 mm bolts. The plastic drum had a plain base and was ballasted with sandbags to a weight of 23 kg. The height to the top of the sign panel as tested was 1.52 m.

As the vehicle impacted the plastic drum, the drum body deformed and separated from the base. The separated drum body with the attached sign panel bounced up in the air and to the left. The separated drum body with the attached sign panel then went over the vehicle and came to rest 35.1 m downstream and 3.6 m to the right of its original position. The top corner of the sign panel was chipped, but there were no stress cracks around the attachment bolts. There was no damage to the vehicle. The sign panel did not contact the windshield, and there was no intrusion into the occupant compartment. This test is judged to have met all evaluation criteria set forth in NCHRP Report 350.



Note that this sign panel, as supplied by the manufacturer, was smaller than the standard size of 610 mm × 460 mm (differences of 60 mm in height and 80 mm in width). The nominal weight of a standard size panel would have weighed 1.56 kg, which is heavier than most of the other sign substrates tested. It is not clear what effect the smaller panel size might have on the impact performance of this sign substrate.

### **3.2.6 International Plastics Duraplate™ Polycarbonate Sign Substrate (Test No. 429246-6)**

The sixth test was on a polycarbonate sign substrate, also manufactured by International Plastics, with the trade name of Duraplate. The sign panel measured 610 mm × 455 mm × 3.86 mm and weighed 1.25 kg. The sign panel was attached to the top of a Traffix 220 LDPE plastic drum with two 13 mm × 25 mm bolts. The plastic drum had a plain base and was ballasted with sandbags to a weight of 23 kg. The height to the top of the sign panel as tested was 1.57 m.

As the vehicle impacted the plastic drum, the drum body deformed and separated from the base. The sign panel slapped the hood of the vehicle and shattered into multiple pieces. The separated drum body, with a 390-mm tall piece of sign panel still attached to the top, traveled with the vehicle until it was braked to a stop. There were six other pieces of the shattered sign panel, the largest measuring 265 mm × 130 mm. These pieces were scattered over a relatively wide area and could have posed a potential hazard to workers in the immediate area of the sign panel. There were no stress cracks around the attachment bolts. The hood of the vehicle was scraped.

The investigators consider the shattering of the sign panel upon impact undesirable because it could pose a potential hazard to workers in the immediate area of the sign panel. Thus, the use of this sign substrate is not recommended.

### **3.2.7 Amsign Corp. 3004-H38 Aluminum Sign Substrate (Test No. 429246-7)**

The seventh test was on a recycled aluminum sign substrate manufactured by Amsign Corp. from a 3004-H38 alloy. The sign panel measured 610 mm × 460 mm × 1.98 mm and weighed 1.48 kg. The sign panel was attached to the top of a Flex-O-Lite 1500 plastic drum with two 13 mm × 25 mm bolts. The plastic drum had a plain base and was ballasted with sandbags to a weight of 23 kg. The height to the top of the sign panel as tested was 1.57 m.

As the vehicle impacted the plastic drum, the drum body deformed and separated from the base. The sign panel slapped the hood of the vehicle. The separated drum body with the attached sign panel traveled with the vehicle until it slowed. The sign panel was scraped and bent and probably not reusable. The sign panel cut a hole in the top of the hood near the windshield. The sign panel did not contact the windshield, and there was no intrusion into the occupant compartment. This test is judged to have met all evaluation criteria set forth in NCHRP Report 350.

### **3.2.8 Amsign Corp. 5052-H38 Aluminum Sign Substrate (Test No. 429246-8)**

The eighth test was on a virgin aluminum sign substrate, also manufactured by Amsign Corp. from a 5052-H38 alloy. The sign panel measured 610 mm × 460 mm × 20.07 mm and weighed 1.48 kg. The sign panel was attached to the top of a Traffix 220 HDPE plastic drum with two 13 mm × 25 mm bolts. The plastic drum had a plain base and was ballasted with sandbags to a weight of 23 kg. The height to the top of the sign panel as tested was 1.57 m.

As the vehicle impacted the plastic drum, the drum body deformed and separated from the base. The sign panel slapped the hood and the lower windshield of the vehicle. The separated drum body and attached sign panel bounced to the right and came to rest 30.5 m downstream and 7.6 m to the right of its original position. The sign panel was only scraped. However, the windshield of the vehicle was shattered at the lower frame. The wire mesh shield prevented the sign panel from penetrating into the windshield and the occupant compartment, but glass fragments were found inside the occupant compartment.

This test is judged to be unsatisfactory due to impact of the sign panel with the windshield and the subsequent shattering of the windshield and the potential for penetration into the occupant compartment. However, previous tests with aluminum sign panels mounted on plastic drums have shown satisfactory impact performance, including the test with the recycled aluminum sign substrate (test no. 429246-7). Thus, the authors recommend further investigation into this matter.

### **3.2.9 Bent Manufacturing Two-Piece Traffic Cone (Test No. 429246-9)**

A two-piece traffic cone provided by Bent Manufacturing was evaluated in this crash test. The cone body measured 1100 mm in height with a diameter of 200 mm at the base, which tapered to a diameter of 100 mm near the top. A hook was built into the top of the cone, which measured 70 mm tall × 95 mm wide × 25 mm thick with a 15-mm diameter hole in the center. A base made of a rubber compound with measurements of 415 mm square and 50 mm high and weighing 6.81 kg, fits over the base of the cone body to provide the necessary stability.

As the vehicle impacted the traffic cone, the cone body deformed and pulled out of the base. The cone body then went underneath the vehicle and came to rest 27.4 m downstream and 4.6 m to the right of its original position. The weighted base was moved 5.1 m downstream. The cone received only minor scrapes and slight deformations. The vehicle sustained no damage. This test is judged to have met all evaluation criteria set forth in NCHRP Report 350.

### **3.2.10 Traffix Two-Piece Traffic Cone (Test No. 429246-10)**

A two-piece traffic cone manufactured by Traffix was evaluated in this crash test. The cone body measured 1210 mm in height with a diameter of 195 mm at the base, which tapered to a diameter of 100 mm near the top. A knob was built into the top of the cone body, which measured 135 mm tall and tapered downward from 85 mm to 35 mm in diameter. A base made of a rubber

compound with measurements of 450 mm square and 50 mm high and weighing 7.26 kg fits over the base of the cone body to provide the necessary stability.

As the vehicle impacted the traffic cone, the cone body deformed and pulled out of the base. The separated cone body then traveled with the vehicle until the vehicle was braked to a stop. The weighted base was moved 1.22 m downstream from its original position. The cone body was only scraped, and there was no damage to the vehicle. This test is judged to have met all evaluation criteria set forth in NCHRP Report 350.

### **3.2.11 U.S. Highway Products FiberBrite™ Fiberglass Reinforced Plastic Sign Substrate (Test No. 429246-11)**

In some sign substrate tests, investigators noted stress cracks in the back of the sign panels. A question was raised as to the reusability of these slightly damaged sign panels, which led to this particular crash test. In test no. 429245-3, a fiberglass reinforced plastic sign substrate manufactured by U.S. Highway Products with the trade name of FiberBrite was crash tested with satisfactory results. The sign panel sustained only minor scrapes and dents to the top, but there were stress cracks on the rear of the panel 10 mm above the attachment bolts, 45 mm long on the left and 35 mm on the right. The damaged sign panel was used in this test. The sign panel measured 610 mm × 460 mm × 3.28 mm and weighed 1.22 kg. The sign panel was attached to a Flex-O-Lite LDPE plastic drum previously used in test no. 429246-4 with two 13 mm x 25 mm bolts. The plain base was ballasted with sandbags weighing 23 kg. The height to the top of the sign panel as tested was 1.59 m.

As the vehicle impacted the plastic drum, the drum body deformed and separated from the base. The sign panel slapped the hood and the lower windshield of the vehicle. The separated drum body and attached sign panel bounced to the side and came to rest 38.1 m downstream from its original position. The top of the sign panel was scraped, but the stress cracks remained unchanged. Note that the windshield of the vehicle was previously shattered in test no. 429246-8. The slapping of the windshield by the sign panel in this test sent glass fragments into the occupant compartment, but the damage to the windshield did not appear to worsen. It should be borne in mind that the purpose of this test is to assess the reusability of a previously damaged sign panel and not its impact performance. Thus, the windshield of the test vehicle was not repaired prior to this test. The results of this test indicated that the stress cracks did not propagate further, and the damaged sign panel is acceptable for reuse.

### **3.2.12 Bent Manufacturing Two-Piece Traffic Cone (Test No. 429246-12)**

The two-piece traffic cone manufactured by Bent Manufacturing previously used in test no. 429246-9 was used in this test with two weighted bases. It has been observed in the field that the two-piece traffic cone is sometimes used with two weighted bases to keep the cone from toppling over from air current generated by passing traffic. The purpose of this test is to assess if the use of two weighted bases would adversely affect the impact performance of the traffic cone. The cone body measured 1100 mm in height with a diameter of 200 mm at the base, which tapered to a diameter of 100 mm near the top. A hook was built into the top of the cone, which measured 70 mm

tall × 95 mm wide × 25 mm thick with a 15-mm diameter hole in the center. The bases are made of a rubber compound with measurements of 415 mm square and 50 mm high and weighing 6.81 kg each.

As the vehicle impacted the traffic cone, the cone body deformed and pulled out of the bases. The separated cone body then traveled with the vehicle. The bottom base was moved 350 mm downstream from its original position. The top base rolled and came to rest 48.8 m downstream and 35.1 m to the left of its original position. The cone was only scraped, and no damage was done to the vehicle. This test is judged to have met all evaluation criteria set forth in NCHRP Report 350. The use of two weighted bases does not appear to adversely effect the impact performance of the two-piece traffic cone.

## IV. SUMMARY OF FINDINGS

Based on the results of the static tests and full-scale crash tests, the findings and recommendations are summarized as follows.

### 4.1 SIGN SUBSTRATES

Eight sign substrates were tested under this study, including:

- Safety Light's fiberglass sign substrate
- U.S. Highway Product's Survivor™ fiberglass reinforced plastic sign substrate
- U.S. Highway Product's Fiber-Brite™ fiberglass reinforced plastic sign substrate
- Gopher Sign Company's Polyflex™ high-density polyethylene sign substrate
- International Plastic Corporation's fiberglass reinforced polycarbonate sign substrate
- International Plastic Corporation's Duraplate™ polycarbonate sign substrate
- Amsign Corp. 3004-H38 recycled aluminum sign substrate
- Amsign Corp. 5052-H38 virgin aluminum sign substrate

Six of the eight sign substrates tested were judged to have satisfactory impact performance. The International Plastic's Duraplate™ polycarbonate sign panel shattered upon impact, which is considered undesirable since it could pose potential hazard to workers in the immediate area of the sign panel. The Amsign Corp. 5052-H38 virgin aluminum sign panel impacted and shattered the windshield, which is judged to be unsatisfactory due to the potential for penetration into the occupant compartment.

The Gopher Sign Company Polyflex™ high-density polyethylene sign substrate has acceptable impact performance, but is not considered acceptable from the serviceability or practicality standpoint since the sign panel is overly flexible to the extent that the sign panel would not stay vertical even without any wind (i.e., the sign panel would bend by itself and would flex considerably under windy conditions). This would pose a problem to the reflectivity of the reflective sheeting and the legibility of the sign.

The International Plastic Corporation's fiberglass reinforced polycarbonate sign substrate also has acceptable impact performance. However, the sign panel, as supplied by the manufacturer, was smaller than the standard size of 610 mm × 460 mm (differences of 60 mm in height and 80 mm in width). The nominal weight of a standard size panel would have weighed 1.56 kg, which is heavier than most of the other sign substrates tested. It is unsure what effect the smaller panel size might have on the impact performance of this sign substrate.

Stress cracks were noted on the rear of the sign panels, approximately 10 mm above the attachment bolts, for the Safety Light fiberglass sign substrate and U.S. Highway Product's Survivor™ and Fiber-Brite™ fiberglass reinforced plastic sign substrates. A question was raised as

to the reusability of these slightly damaged sign panels. A crash test was conducted with a damaged sign panel (U.S. Highway Product's Fiber-Brite™ fiberglass reinforced plastic sign substrate) and found that the stress cracks did not propagate any further.

#### **4.2 TWO-PIECE TRAFFIC CONE**

Two-piece traffic cones supplied by two manufacturers, Bent Manufacturing and Traffix, were crash tested to evaluate their impact performance. In both tests, the cone body readily separated from the base and traveled with the vehicle. The cone body sustained only minor scrapes, and there was no damage to the vehicle. The weighted base moved from its original position but did not pose any potential hazard to the driver or workers in the immediate vicinity of the traffic cone. Both tests were judged to have met all evaluation criteria set forth in NCHRP Report 350.

It has been observed in the field that the two-piece traffic cone is sometimes used with two weighted bases to keep the cone from toppling over from air current generated by passing traffic. A crash test was conducted on a two-piece traffic cone with two weighted bases to assess if the additional base would adversely affect the impact performance of the traffic cone. Again, the cone body readily pulled out of the bases and traveled with the vehicle. The bottom base was moved slightly while the top base rolled for some distance, but it did not pose any potential hazard to the driver or workers in the immediate vicinity of the traffic cone. The cone body was only scraped, and there was no damage to the vehicle. The test is judged to have met all evaluation criteria set forth in NCHRP Report 350. The use of two weighted bases does not appear to adversely effect the impact performance of the two-piece traffic cone.

## V. IMPLEMENTATION RECOMMENDATIONS

- Four of the eight sign substrates performed satisfactorily in crash tests and are recommended for field implementation, including the Safety Light fiberglass sign substrate, U.S. Highway Product's Survivor™ and Fiber-Brite™ fiberglass reinforced plastic sign substrates and the Amsign Corp. 3004-H38 recycled aluminum sign substrate.
- The impact performance of the International Plastic Corporation's Duraplate™ polycarbonate sign substrate was considered unsatisfactory and is not recommended for field implementation.
- The Gopher Sign Company Polyflex™ high-density polyethylene sign substrate has satisfactory impact performance but is not considered acceptable from the serviceability or practicality standpoint and is not recommended for field implementation.
- The International Plastic Corporation's fiberglass reinforced polycarbonate sign substrate has satisfactory impact performance, but the sign panel, as supplied by the manufacturer, was smaller than the standard size. Investigators are unsure what effect the smaller panel size might have on the impact performance of this sign substrate.
- The impact performance of the Amsign Corp. 5052-H38 aluminum sign substrate was judged to be unsatisfactory. However, previous tests with aluminum sign panels mounted on plastic drums have shown satisfactory impact performance, including the test with the recycled aluminum sign substrate, which has similar material properties. Further investigation into this matter is recommended prior to any decision on the field use of the aluminum sign substrate.
- The two-piece traffic cone performed satisfactorily and is recommended for field implementation. The use of two weighted bases does not appear to pose any safety problem and is considered acceptable for field use.





## **APPENDIX A**



**Fiberglass Reinforced Polycarbonate  
(International Plastics Corporation)**

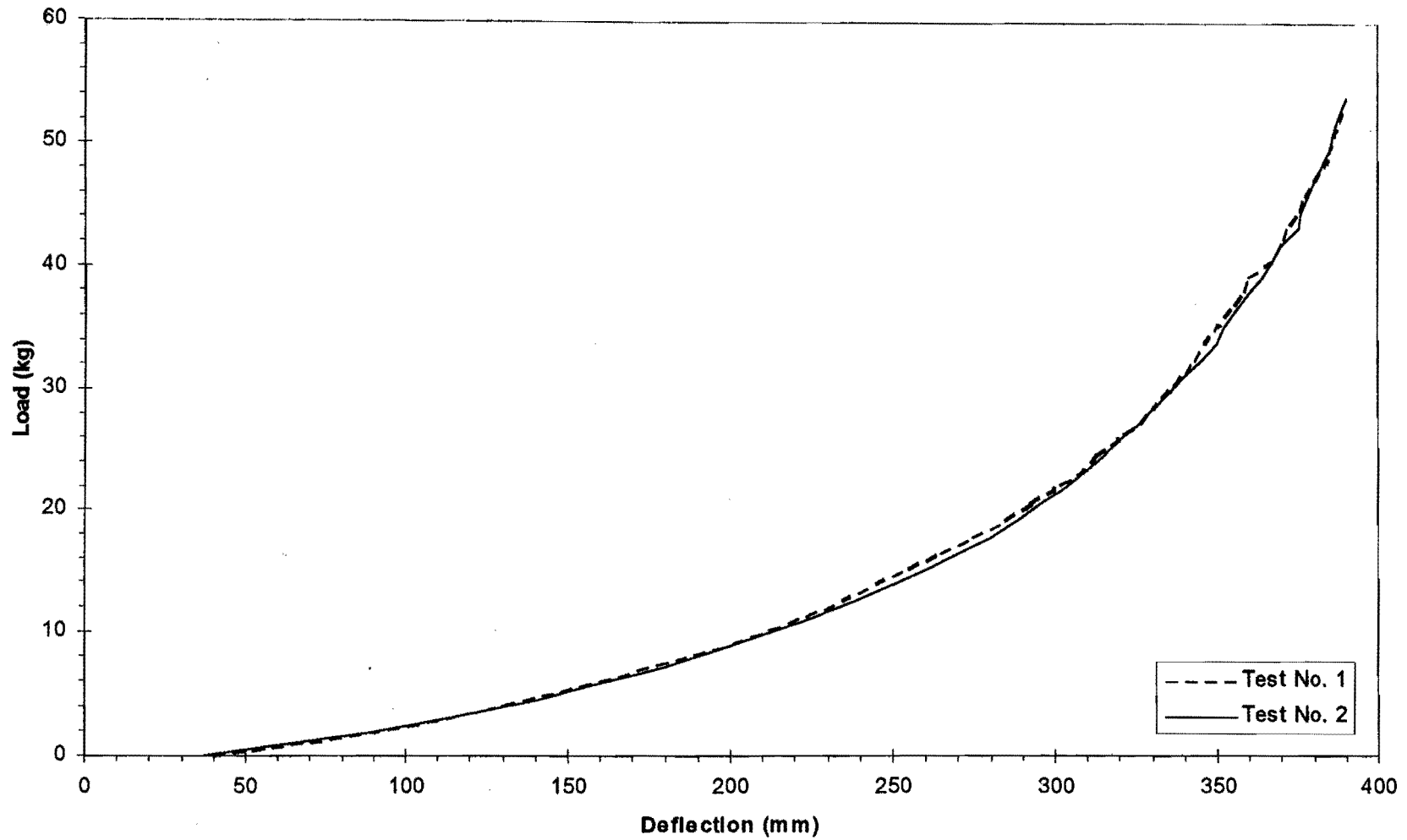


Figure A-1. Static test results for International Plastic Corporation fiberglass reinforced polycarbonate sign substrate.

**Recycled High Density Polyethylene (Polyflex)  
(Gopher Sign Company)**

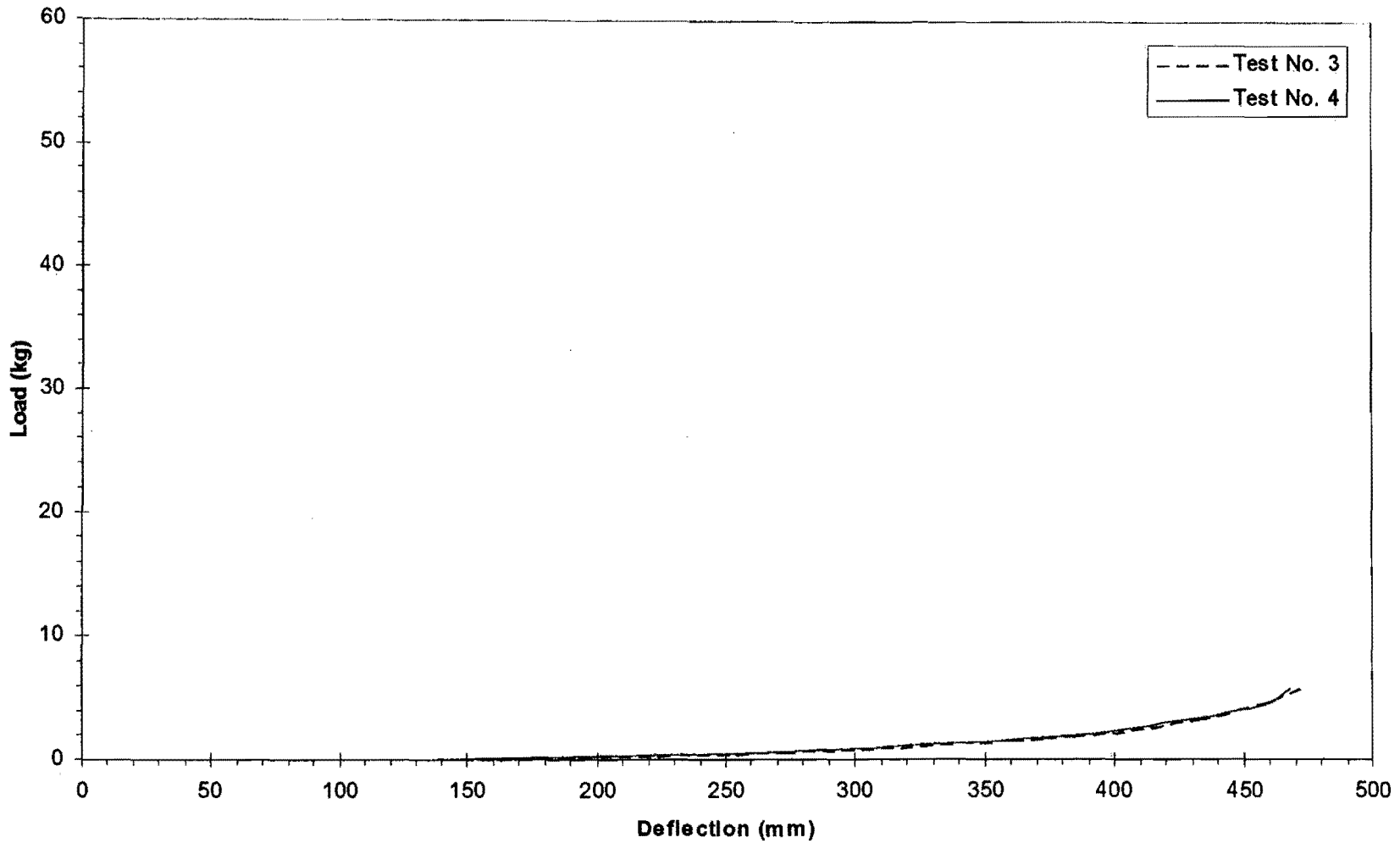


Figure A-2. Static test results for Gopher Sign Company recycled high-density polyethylene (Polyflex) sign substrate.

**Fiberglass Reinforced Plastic (Fiber Brite)  
(U.S Highway Products)**

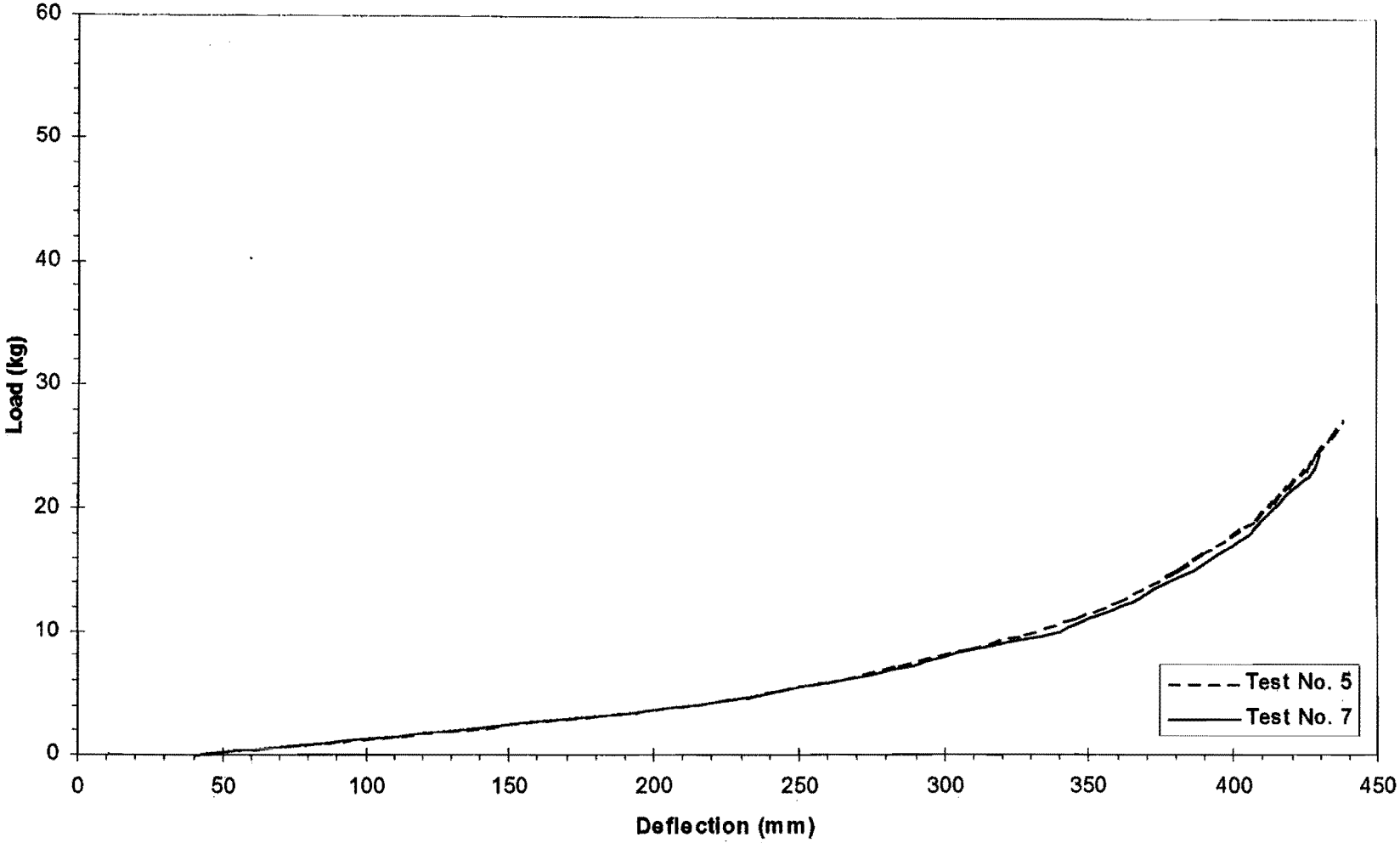


Figure A-3. Static tests results for U.S. Highway Products fiberglass reinforced plastic (Fiber Brite) sign substrate.

**Fiberglass Reinforced Plastics (Survivor)  
(U.S. Highway Products)**

34

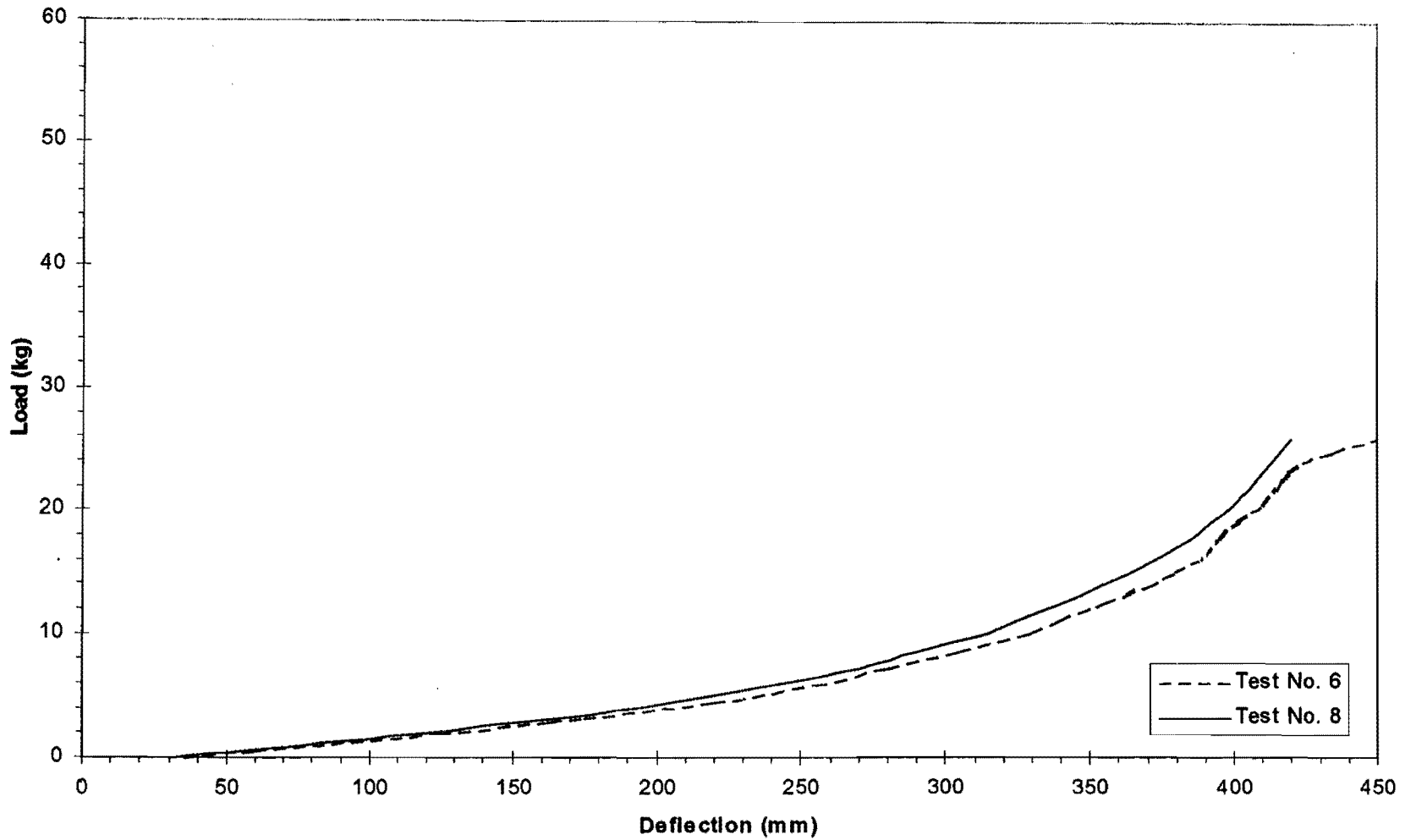


Figure A-4. Static tests results for U.S. Highway Products fiberglass reinforced plastic (Survivor) sign substrate.

### Fiberglass (Safety Light)

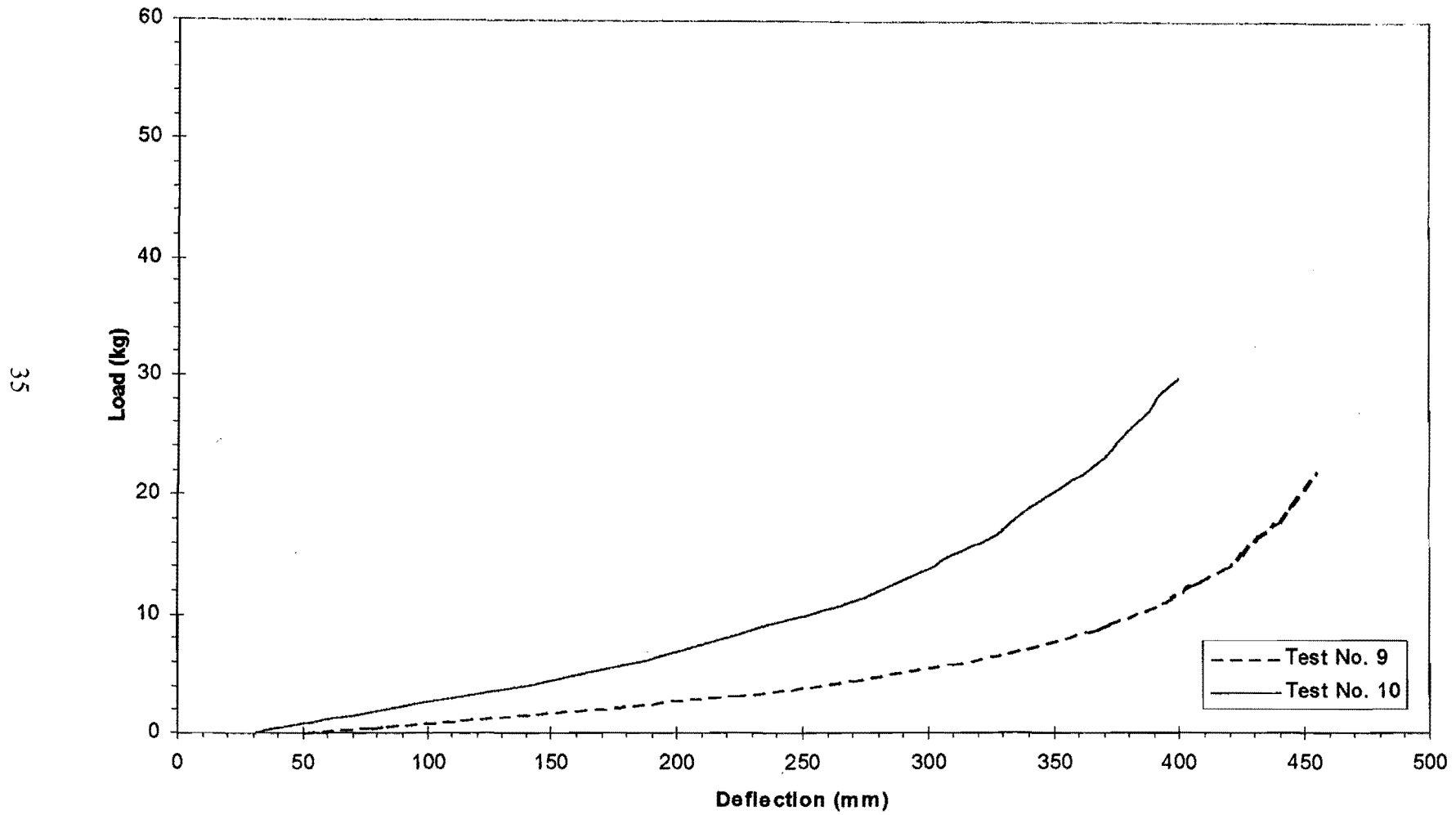


Figure A-5. Static test results for Safety Light fiberglass sign substrate.

**Recycled Aluminum (3004-H38)  
(Amsign Corp.)**

36

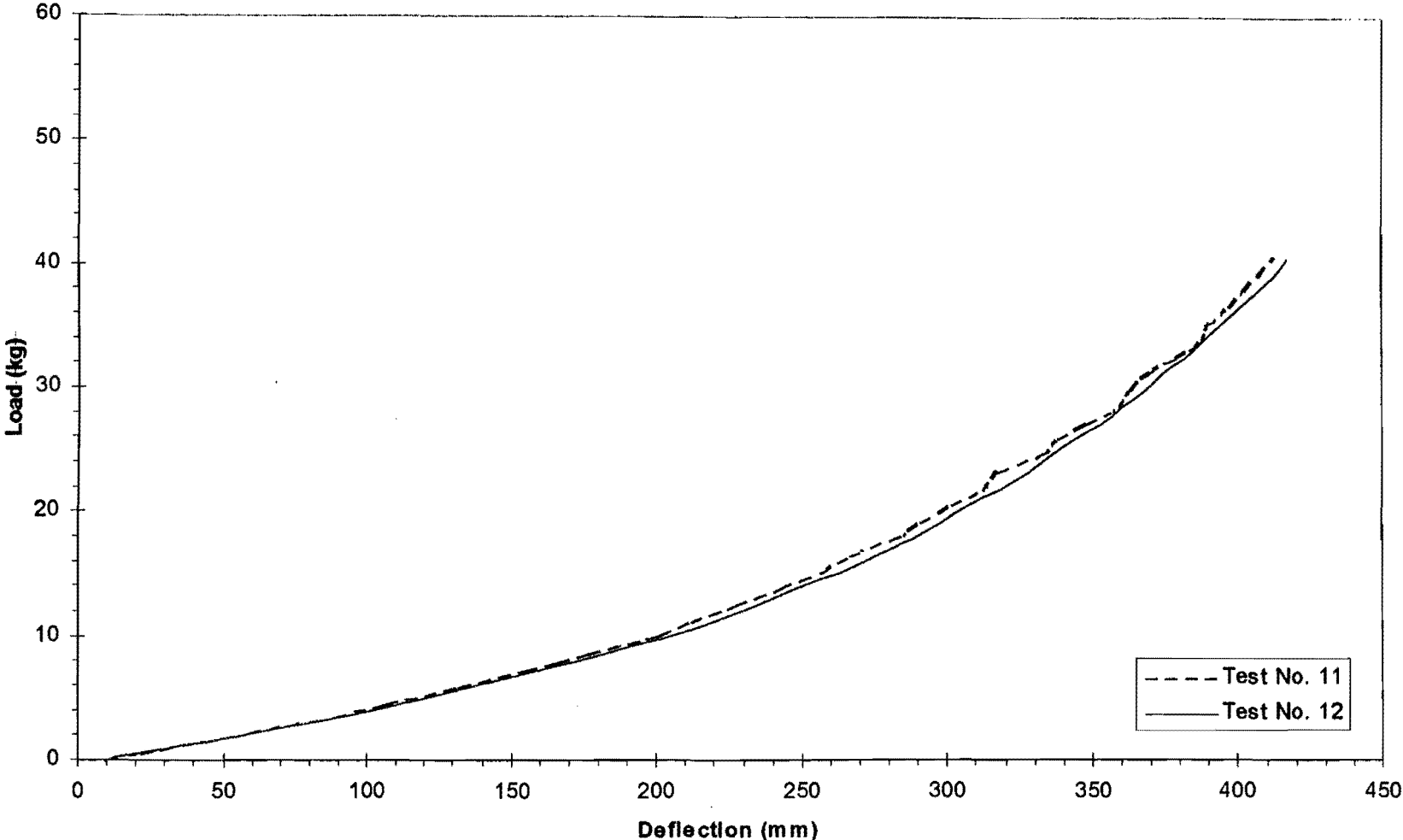


Figure A-6. Static test results for Amsign Corp. recycled aluminum (3004-H38) sign substrate.



**Virgin Aluminum (5052-H38)  
(Amsign Corp.)**

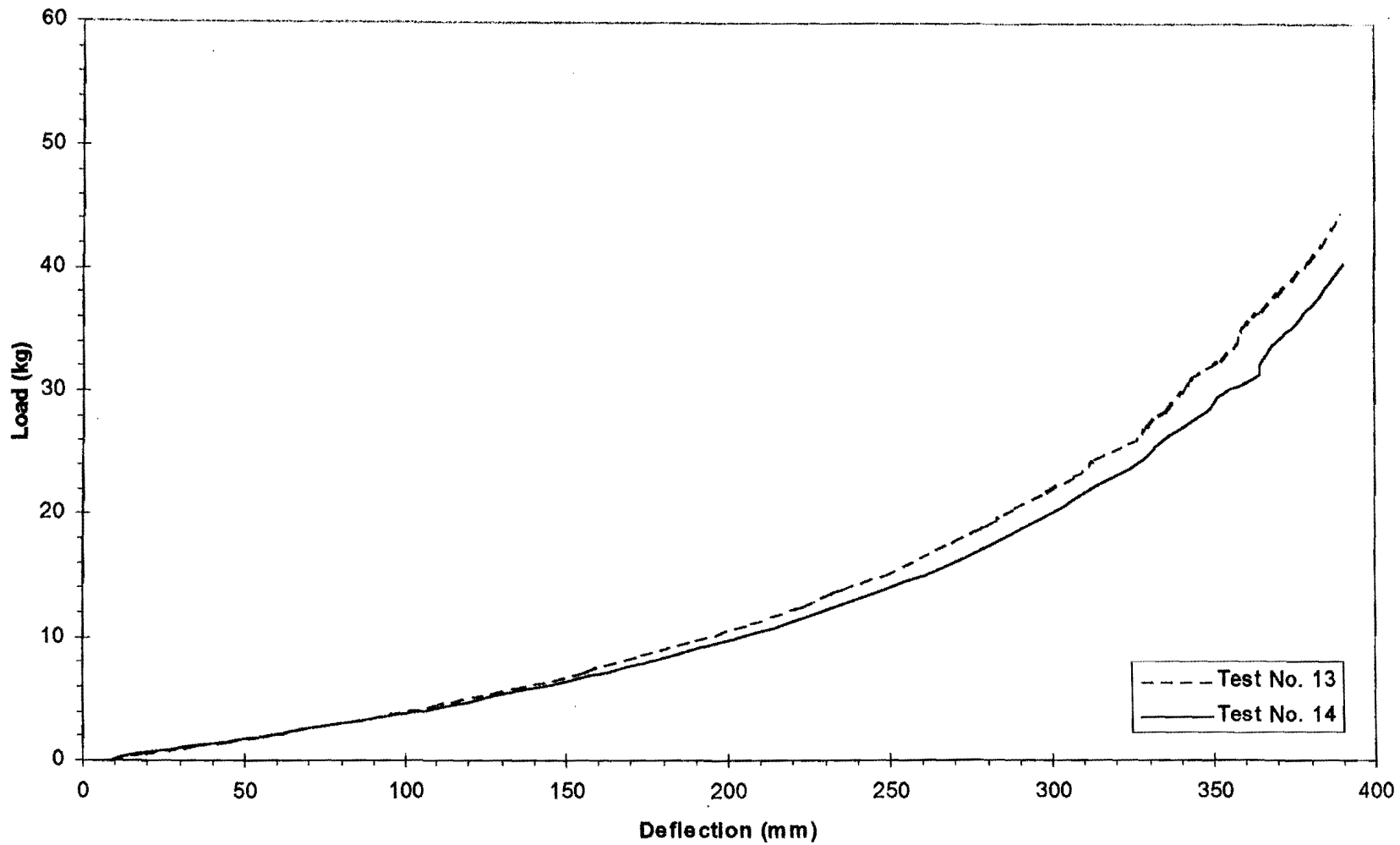


Figure A-7. Static test results for Amsign Corp.  
virgin aluminum (5052-H38) sign substrate.

**ABS Acrylic  
(International Plastics Corporation)**

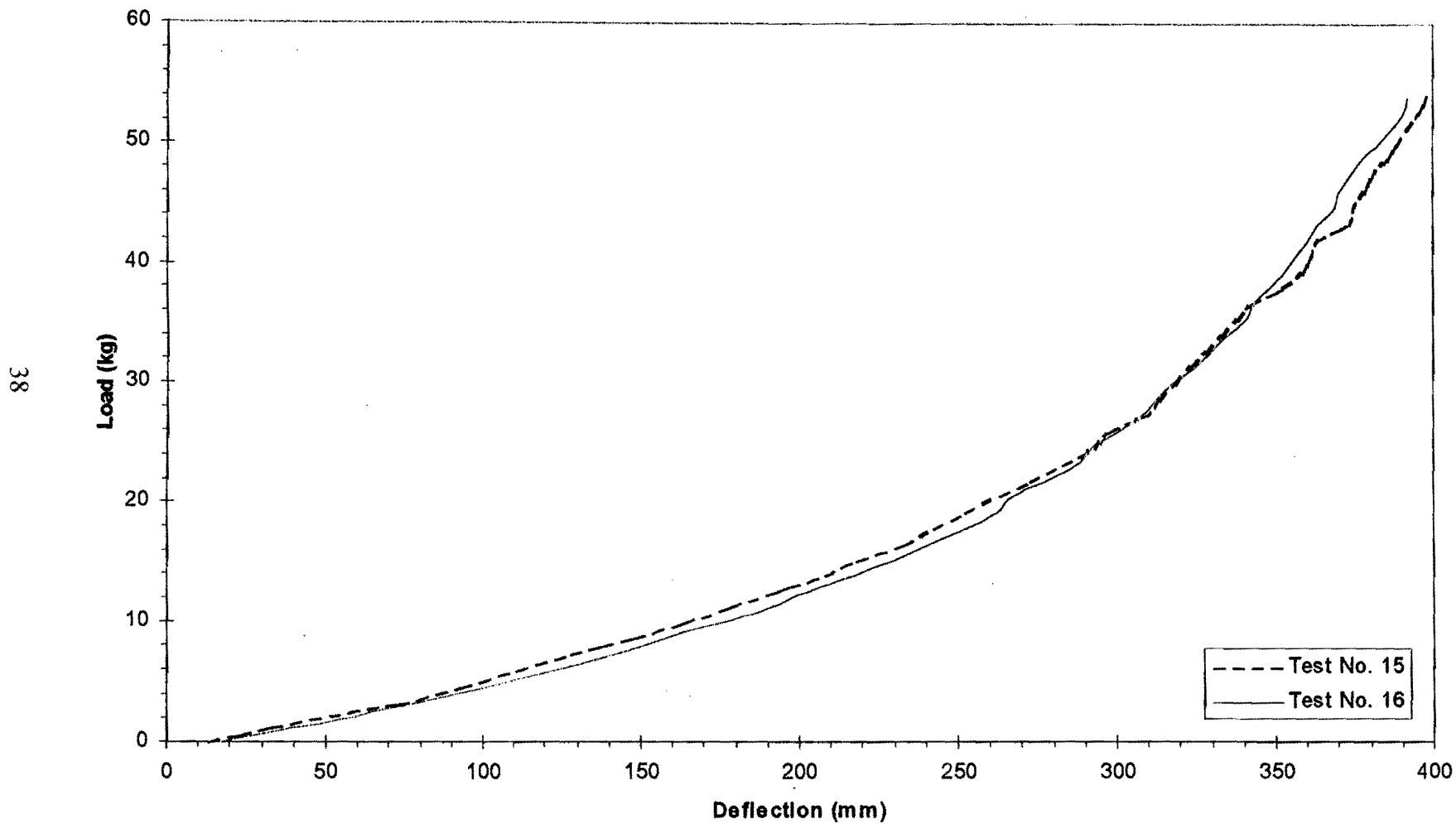


Figure A-8. Static test results for International Plastics Corporation  
ABS acrylic sign substrate.

## REFERENCES

1. K.K. Mak and W.L. Campise, "Testing and Evaluation of Traffic Control Devices for Use in Work Zones," Final Report, Project No. 9850B, Texas Transportation Institute, Texas A&M University, College Station, Texas, January 1990.
2. K.K. Mak and W.L. Campise, "Testing and Evaluation of Traffic Control Devices for Use in Work Zones," Final Report, Project No. 1917, Texas Transportation Institute, Texas A&M University, College Station, Texas, September 1990.
3. K.K. Mak, R.A. Zimmer, and W.L. Campise, "Testing and Evaluation of Traffic Control Devices," Final Report, Project No. 1938, Texas Transportation Institute, Texas A&M University, College Station, Texas, October 1991.
4. K.K. Mak and R.A. Zimmer, "Evaluation of Plastic Drum Specifications," Research Report 2924-2F, Texas Transportation Institute, Texas A&M University, College Station, Texas, September 1995.
5. K.K. Mak, R.P. Bligh, and W.L. Menges, "Evaluation of Work Zone Barricades and Temporary Sign Supports," Research Report 5388-1F, Texas Transportation Institute, Texas A&M University, College Station, Texas, February 1996.
6. H.E. Ross, Jr., D.L. Sicking, R.A. Zimmer, and J.D. Michie, "Recommended Procedures for the Safety Performance Evaluation of Highway Features," NCHRP Report 350, National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C., 1993.