NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 155

FREEWAY GUIDE SIGN REPLACEMENT: POLICIES AND CRITERIA

TRANSPORTATION RESEARCH BOARD
National Research Council

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FREEWAY GUIDE SIGN REPLACEMENT: POLICIES AND CRITERIA

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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NOTE: The Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation
Research Board

This synthesis will be of interest to traffic engineers, planners, and others interested in making sure that motorists' needs for directional information on freeways are being met. Information is provided on policies and procedures used by states in evaluating freeway guide signs and replacing those that are outdated or deteriorated.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

Many signs on freeways and other controlled-access highways have exceeded their service life and are no longer serving motorists' needs. This report of the Transportation Research Board describes the policies, procedures, and criteria used by states for freeway sign evaluation and replacement programs.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation depart-

ments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

ACKNOWLEDGMENTS

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Special appreciation is expressed to Hugh W. McGee, Bellomo-McGee, Inc., Vienna, Va., who was responsible for the collection of the data and the preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Karl J. Brodtman, Project Engineer, Division of Research and Demonstration, New Jersey Department of Transportation; Arthur C. Geurts, Safety Studies Engineer, Utah Department of Transportation; W. Scott Wainwright, Assistant Chief, Traffic Engineering Division, Montgomery County Department of Transportation; James E. Weaver, Highway Engineer, Office of Traffic Operations, Federal Highway Administration; and William L. Williams, Engineer, National Highway Institute, Federal Highway Administration.

Richard A. Cunard, Engineer of Traffic and Operations, Transportation Research Board, assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

FREEWAY GUIDE SIGN REPLACEMENT: POLICIES AND CRITERIA

SUMMARY

It is roughly estimated that there are some 150,000 guide signs on the nation's freeways and expressways. This does not include guide signs on the approaches to these facilities nor the specific service signs. At an average installation cost of $800 per sign panel, this represents an investment of about $120,000,000 for a device that is a critical component of the safe and efficient operation of freeways and expressways. Motorists rely on legible, unambiguous, and informative signs to help them navigate through the highway system and guide them to their destination.

With an average service life of 15 years, many of the guide signs on freeways and expressways are in need of rehabilitation or replacement. Because all states and local jurisdictions who must maintain these signs will need to refurbish or replace guide signs, this synthesis has been prepared to provide the latest information on principles, materials, and procedures for this process. The synthesis deals primarily with the guide sign panel and does not discuss the sign support systems. Specific topics include replacement programs, inventories and inspection, sign face and substrate materials, service life, refurbishing procedures, and illumination of signs.

Information provided in this synthesis draws on published literature and discussions and visits with the states of Alabama, California, Georgia, Kansas, Maryland, Michigan, Pennsylvania, and Virginia. Two regional workshops sponsored by the Federal Highway Administration in February 1990 also provided useful information on current state practices.

The following points serve as a summary of major findings:

- All states have some semblance of a program for identifying and programming guide sign replacement projects on a statewide basis. The level of formality and sophistication varies, however. Some wait until the roadway is being rehabilitated, whereas others continually inspect for deficient signs, rate their deficiency, and rank them for improvement priority.
- A majority of the states do not have a comprehensive sign inventory program that includes the freeway guide signs. Thus far, the initial effort and expense involved in logging all the signs and the continuing maintenance of the data file have been obstacles for having a sign inventory. However, recent advancements in the technology for collecting the data, such as video-disc systems, and in micro- and minicomputer hardware and software systems are likely to encourage states to implement integrated inventories.

- Formal inspection of freeway guide signs should occur at regular intervals based on agency experiences. An inspection should be done during both night and day and include the physical condition of the sign and the support system.
- Inspection of signs can be accomplished using a human-observation technique. However, observers should be trained to relate their visual observation to luminance levels established by retro-reflectometers. In the near future, a mobile system should be available for accurate and relatively quick and inexpensive measurement of the retro-reflectivity condition of signs.
- There is no consensus among the states as to which retro-reflective sheeting materials are preferred for either the sign background or legend. For the background, all three types (FP-85 types of II, II-A, and III-A) of retro-reflective sheetings are being used. Porcelain enamel nonreflective backgrounds are still being used with lighted signs, although this is becoming less frequent. For the legends, either type III-A or reflective buttons are being used by a majority of the states, with a preference for Type III-A sheeting, especially if dew is a common situation.
- The vast majority of substrate material for guide signs is aluminum, either extruded or sheet. States using either cite favorable economics as the reason, although extruded aluminum appears to provide a more durable substrate and is less subject to bending. Plywood is still used by a few states with complete satisfaction. Fiberglass-reinforced plastics are still mostly experimental, but with further development should become a viable alternative substrate.
- A fully deteriorated sign panel can either be replaced or refurbished using a sheet overlay procedure. There is a difference of opinion as to the effectiveness of the overlay technique, however. The comparative cost of overlay versus total replacement is an area for further research.
- Recent research findings on the needs of the elderly indicate that sign letter size on guide signs should be based on 20/40 visual acuity and, subsequently, may require larger letter size. This is an area for further research.
- Illuminated overhead guide signs have longer detection and legibility distances than do fully reflectorized signs without illumination. However, several states are eliminating the illumination, especially when they use high-performance retro-reflective sheeting for both the background and legend. The elimination of illumination should be based on an engineering evaluation and should not be done under any of the following conditions: (a) the visibility distance is less than 1200 ft, (b) the horizontal curvature is less than 800 ft, (c) the sign contains an action message, such as EXIT ONLY, or (d) the sign is not fully reflectorized.

CHAPTER ONE

INTRODUCTION

Guide signing is a critical component of the safe and efficient operation of the nation's freeways and expressways. Motorists rely on legible, unambiguous, and informative signs to help them navigate through the highway system and guide them to their destinations. In a 1972 study of the problem of erratic maneuvers at freeway exits, Taylor and McGee (*1*) found that 52 percent of the observed erratic maneuvers, such as crossing over the gore, backing up on the mainline or ramps, etc., were attributed to guide sign deficiencies such as inappropriate sign legend, insufficient advance signing, and inadequate sign visibility. Deficient guide signing can also lead to inefficient operations, with motorists selecting wrong exits and driving excessive miles. The issues of required sign size, letter/symbol size, illumination, and levels of retro-reflectivity have become a concern because of the ever-increasing population of elderly drivers who require larger and brighter signs (*2–4*).

The nation's freeway and expressway system is aging and much of it is in need of rehabilitation. This is also true for guide signs, many of them having reached and exceeded their useful life. Unfortunately, too many freeway and expressway guide signs are in poor condition, as shown in Figure 1. Because all states need to refurbish or replace guide signs, this synthesis has been prepared to provide the latest information on principles, materials, and procedures for this process.

This synthesis draws on information obtained from the literature and from discussions with selected state highway officials. During this project on-site interviews were conducted with representatives of the states of Alabama, California, Georgia, Kansas, Maryland, Michigan, Pennsylvania, and Virginia. In addition, the Federal Highway Administration (FHWA) sponsored two regional workshops on all aspects of signing in February 1990; freeway guide sign replacement was one of the topics discussed (*5*).

This synthesis focuses on standard static interchange guide signs on freeways and expressways. It concentrates on the guide signs themselves, both roadside and overhead. Sign illumination is discussed only in the context of nighttime sign visibility. Current practices on designing, fabricating, and erecting sign structures are not included.

Topics covered in this synthesis include:

- Guide sign replacement program
- Inventory and inspection
- Sign materials
- Sign detection and legibility
- Sign service life
- Sign refurbishing
- Sign illumination

Readers should be aware of a related synthesis, *Maintenance Management of Street and Highway Signs* (*6*). It deals with all types of signing and focuses on various aspects of a sign maintenance program—inventory, facilities, equipment, personnel, costs, and control. Also, an FHWA report entitled "Retroreflectivity of Roadway Signs for Adequate Visibility: A Guide" (*7*) is a good primer on retro-reflective sheeting for signs.

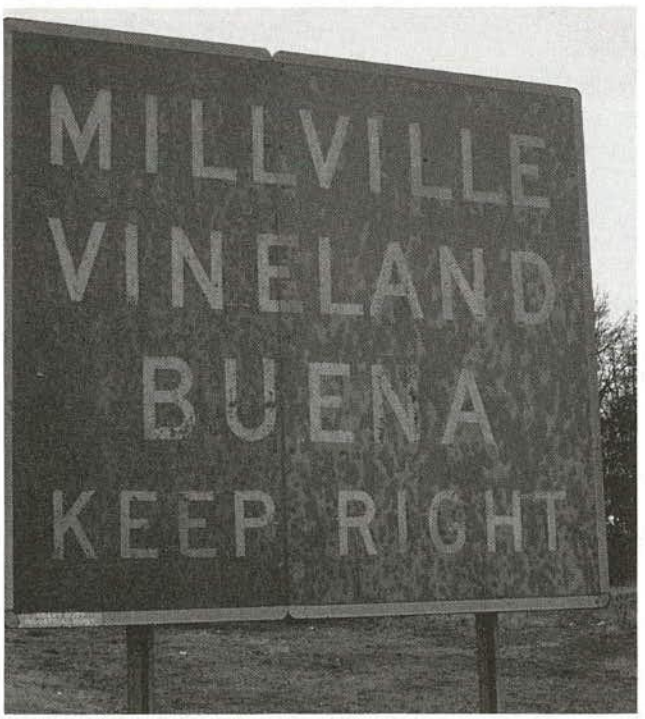


FIGURE 1 Examples of deteriorated guide signs.

CHAPTER TWO

FREEWAY GUIDE SIGN REPLACEMENT PROGRAM

As determined from the state interviews, freeway guide signs can be changed in a number of ways, namely:

- Portions or all of the sign legend, such as the destination, can be changed to reflect change in policy, routes, etc.
- The entire sign assembly can be replaced in connection with a freeway rehabilitation project. Typically, whenever a freeway is being widened, the reconstruction project calls for all new signing.
- Badly deteriorated portions of the legend or the background can be repaired or replaced completely.
- Badly deteriorated signs can be refurbished or replaced.

Modifications resulting from the third and fourth changes typically are the responsibility of the highway maintenance division of a highway or transportation department. Ideally, they follow as a product of an overall sign maintenance and improvement program within the department. A simplified generic program is illustrated by Figure 2. The program consists of the following elements:

- Inventory—a data base of what is there.
- Inspection—a routine inspection program to assess the condition of the sign.
- Replacement Decision—a process or criterion for determining when a sign should be improved.
- Project Identification—a determination of the scope of the necessary improvement.
- Priority Programming—a process for establishing priorities and an improvement schedule.
- Project Implementation—an improvement made by either in-house forces or by contract.

Although this process may, in fact, be followed to varying levels of sophistication by all states, the state interviews and the literature review identified few formalized complete programs for freeway guide signs. Of the states interviewed, Michigan had a process most similar to that identified above. As with all states, in Michigan, sign improvement programs have to compete with other construction and maintenance projects for limited funding. Therefore, to upgrade to and maintain an acceptable level of sign performance, Michigan policy makers determined that a systematic methodology of identifying signing needs and establishing project priorities was essential. The elements of the program, originally developed for a five-year freeway guide sign replacement plan, are as follows:

- Inspection and Evaluation—A night sign review was undertaken by a three-member team of Reflective Systems Unit personnel. With a hand-held spotlight, the evaluation team inspected each sign for cracking, dirt accumulation, inadequate retro-reflectivity, and adherence to the American Association of State Highway and Transportation Officials (AASHTO) "Yellow Book" (*8*) safety criteria. Figure 3 shows the form used, to which the following explanations apply:

  "Yellow Booked"—safety features, such as breakaway sign supports, guardrail, and clear zone requirements, were noted.

  "Up to Current Standards"—conformance to current federal and state sign standards for legend size and colors; use of symbols and exit numbering.

  "Drive By, Stop Inspection, Cross Road Signing"—signs on the mainline and the crossroads were rated on a scale of 1 to 4 for both retro-reflectivity and cracked sheeting. A 1 indicated that the sign was in such bad condition that it could not be seen. A 2 indicated that the sign was legible from only a short distance, had large cracks in the sheeting, or the sheeting was torn. A 3 indicated that the sign exhibited some slight cracking of the sheeting but was good enough to last a few years. A 4 indicated replacement was not required at that time.
- Priority Setting—Average daily traffic volume and the date of last upgrading were added to the data from the form for each interchange and route section. A numerical value was determined, with nearly equal priority given to all factors. The numerical values for each interchange in the segment were then added together and divided by the number of interchanges to determine a numerical value for the entire segment. The segments were then ranked numerically to determine the projects that required upgrading first.
- Selection of Projects—Costs to upgrade, including new structure supports, were determined. Then, knowing the amount of money the department could spend each year, the number of projects was determined and the approximate year for each project was identified. Final selection of projects was established by categories (i.e., Interstate, US, and M route projects) by funding and by location within the state.

Michigan's goal has been to upgrade approximately 200 miles of freeway signing per year.

SIGN INVENTORY

Knowing what is out on the road is a key component of a good maintenance program. This is particularly true for signing, because an up-to-date inventory:

. . .provides the basis for decisions relative to:

- Identification of deficient signs
- Development of priorities for maintenance needs
- Scheduling of maintenance efforts
- Continued surveillance of maintenance activities (*6*).

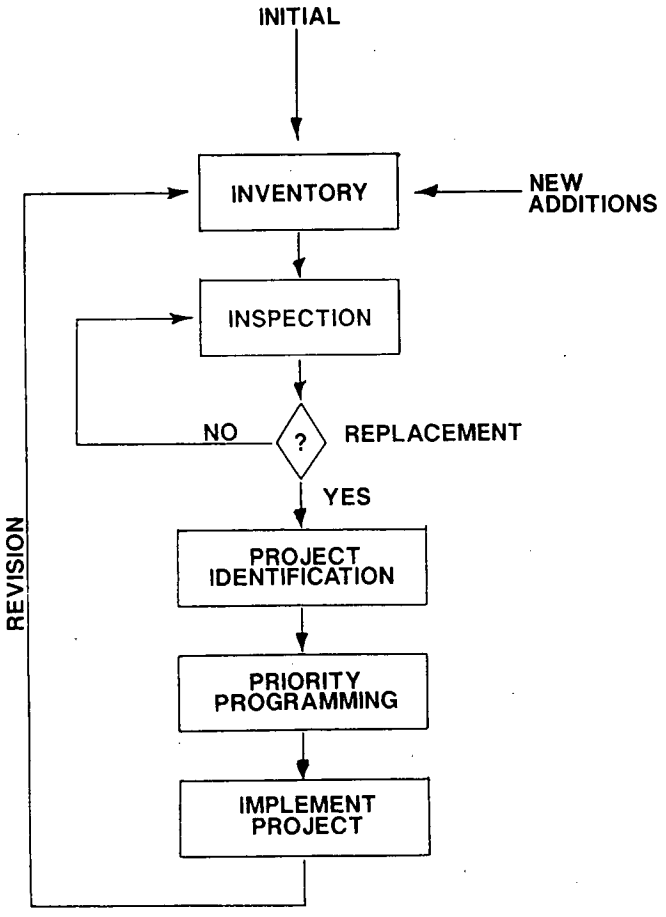


FIGURE 2 Sign maintenance management program.

An extensive discussion of sign inventory programs and procedures can be found in Synthesis 157 (*6*). Some additional information particularly related to freeway guide signing is provided here.

As noted previously, not many states have a comprehensive statewide sign inventory program. A survey of the states in 1990 by Bellomo-McGee, Inc. as part of NCHRP Project 5-11 revealed that only 15 states have some semblance of a sign inventory.

The limited interviews for this synthesis confirmed that most states do not have a statewide inventory of signs. The survey and interviews also indicated that the existence of an inventory can vary within a state agency. In at least two states individual districts had sign inventories when no inventories existed at the central office for the entire state. This situation reflects the current status of sign inventories. Many states have not yet implemented statewide inventories because of the considerable expense in conducting the initial inventory and structuring the computer data base system.

As discussed in Synthesis 157 (*6*), a number of computer-based inventory systems have been developed. At the microcomputer level, most of the programs are based on either a data base management software or spreadsheet software. Some agencies have developed their own, and others have acquired off-the-shelf public-domain or proprietary software. Information about the existence and availability of sign inventory microcomputer programs can be obtained from the Center for Microcomputers in Transportation (McTrans) at the University of Florida. Under development by the FHWA is a system that goes beyond typical sign inventories. This system is called the Sign Management System (SMS). The SMS is a microcomputer-based system that will use sign deterioration models to estimate the life of the sign and predict when the sign should be inspected for possible replacement. This will assist highway agencies to locate deficient signs, use limited maintenance funds more efficiently, and project sign maintenance budget needs. The data base management portion of the SMS has been completed. Currently, the software allows a sign inventory to be created and the age and condition of individual signs to be tracked. The SMS is particularly useful for guide signs, because up to three lines of legend, each containing up to 120 characters, can be entered into the inventory. The predictive version of the SMS is expected to be completed in the fall of 1991.

Agencies having a sign inventory find guide signs pose data entry problems, especially if the message (i.e., destinations, etc.) is to be included. One Virginia DOT district uses a spreadsheet program to inventory its Interstate guide signs. Figure 4 shows a sample of how the data for a guide sign are formatted.

The Idaho Transportation Department has one of the most comprehensive statewide inventory systems. The file is on a mainframe computer located in department headquarters but is updated from terminals located in the district offices. It is an on-line accounting of each sign on Idaho Transportation Department's highways. Information about the sign, such as size, material, color, location, orientation, etc., is on the inventory. Also, each sign record has additional work-history records linked to it for all past work done on the sign.

Figure 5 shows a sample page from a sign status report, one of many reports that can be generated. An entry for a guide sign is blocked off. Reading across the first row the data elements are:

- 883000023—a record number
- 001010—route number
- 1.600—mile point
- 542811005—sign catalog number used for ordering
- E1-1—MUTCD sign number
- 132—width in inches
- 132—height in inches
- G901—G for ground mount, 9 for off pavement edge right, 01—for east direction
- 02—sign substrate material (02 is extruded aluminum)
- 02—sign color (02 is green and white)
- 04—sign face type (04 is for high-intensity removable legend or reflective background)

The second row data elements are:

- SGN 03—a work code indicating the sign was replaced with a new identification
- 19—reason work performed, in this case a safety improvement
- 04/01/86—the date of work
- X3 95 PARM PAY1—the legend in an abbreviated form; full message is "Exit 3, RT 95(symbol), Parma, Payette, 1 mile"
- 25—post-type code (25 is "breaksafe H-Beam")
- 2—number of posts.

Freeway Sign Evaluation

ROUTE INTERCHANGE

AGE OF SIGNS				
YELLOW BOOKED	NO		SOME	YES
UP TO CURRENT SIGN STANDARDS	NO	SOME	MOST	YES
OVERLAYED		YES		NO
HIGH INTENSITY ON ENG. GRADE		YES		NO
HIGH INTENSITY ON HIGH INTENSITY		YES		NO
DRIVE BY				
REFLECTIVITY	1	2	3	4
CRACKING	1	2	3	4
STOP INSPECTION				
REFLECTIVITY	1	2	3	4
CRACKING	1	2	3	4
CROSS ROAD SIGNING				
REFLECTIVITY	1	2	3	4
CRACKING	1	2	3	4
SIGN STANDARDS	NO	SOME	MOST	YES
CANTILEVERS	NO			YES
YELLOW BOOK	NO	SOME	OK	

(1) VERY BAD
(2) NEEDS REPLACEMENT NOW
(3) GOOD BUT WILL NEED REPLACEMENT
(4) GOOD FOR 1, 2, 3 YEARS

FIGURE 3 Sign inspection form used by Michigan.

The file for each sign is updated every time there is some type of maintenance activity or the sign is modified in any way.

Idaho Transportation Department feels that a correct and current sign inventory is important for the following reasons:

- To know if a sign is missing so that it can be replaced. (Knock-down and theft of signs sometimes go unnoticed.)
- History of sign installation and maintenance performed are important to sign and post material evaluations.
- A correct and detailed historical record is a must for any tort case filed against the state.
- Various types of reports are required for management and the public.

NORTHBOUND I-95
SANDSTON RESIDENCY

MP	TEXT	L/R	STRU-STD	STD.NO.	COLOR CODE	W"	H"	SQ.FT.	INSPECTION COMMENTS DATE	G	F	R	INSTALLATION/ REPLACEMENT DATE
	73 PARHAM RD EXITS 1/2 MI.			E1-1	C-7								
	HOSPITAL	R		D9-2	C-12	24	24	4.00					
82.71	LODGING SECOND RIGHT	R	2 I-BEAM	GEN.SERV.	C-12								
82.82	FOOD SECOND RIGHT	R	2 I-BEAM	GEN.SERV.	C-12								
82.89	EXIT 35B	OH		E5-1b	C-7	90	60	37.50					
	W. PARHAM RD. SECOND RIGHT			E1-3	C-7								
	EXIT 35A	OH		E5-1b	C-7	90	60	37.50					
	E. PARHAM RD. NEXT RIGHT			E1-3	C-7								
82.97	GAS SECOND RIGHT	R	2 I-BEAM	GEN.SERV.	C-12								
83.00	MILE 83 (MISSING)	R	U-POST	D10-5	C-7	12	36	3.00					
83.13	EXIT 35A	OH		E5-1b	C-7	90	60	37.50					
	PARHAM RD. EAST DIA ARROW			E6-1	C-7								
83.17	EXIT DIA ARROW	R	I-BEAM	E5-1	C-7	96	60	40.00					
83.25	MERGE FROM RIGHT	R	GM	W4-1	C-8	48	48	16.00					
83.30	HOSPITAL	R	WP	D9-2	C-12	24	24	4.00					
83.38	BLANK PANEL	OH		E1-5	C-7								
	295 TO 64 NORFOLK.CHARLOTVLE. 1 MILE			E1-1	C-7								
	EXIT 35B	OH		E5-1b	C-7	90	60	37.50					
	73 WEST,PARHAM RD. DIA ARROW			E6-1	C-7								
83.49	EXIT DIA. ARROW	R	WP	E5-1	C-7	96	60	40.00					
83.58	MERGE FROM RIGHT	R	I-BEAM	W4-1	C-8	48	48	16.00					
83.90	NORTH 95	R	GM	ASSEMBLY									
84.00	MILE 84	R	U-POST	D10-5	C-7	12	36	3.00					
84.29	BLANK PANEL	OH		E1-5	C-7								
	295 TO W. 64 CHARLOTVLE. SEC. RT.			E1-1	C-7								

FIGURE 4 Guide sign inventory format used by a Virginia Department of Transportation district.

PGM: HTR05010 SEMI-ANNUAL SIGN STATUS REPORT DATE: 04/10/90
GD-00653 DISTRICT 3, AS OF 04/10/90 PAGE: 2

KEY # WORK:CODE	SEGMENT REASON	MILE PT DATE	IC# LEG	CATALOG	SGN NO	WID	HGT	AS POST:	LOC. TYPE	MAT NO	CL LN	FCE
883000013	001010	1.000		544105240	D10-5	012	024		G802	01	02	07
SGN 01	17	05/05/78		1					23	1		
893000010	001010	1.000		544105240	D10-5	012	024		G901	01	02	05
SGN 03	12	09/22/88							23	1		
PST 01	12	09/22/88										
883000014	001010	1.020		542910450	E10-5	156	144	DA	G802	02	03	01
SGN 01	13	11/28/84	F	X376B F X376A					25	2		
883000015	001010	1.020		610000200	E10-5B	060	036	DB	G802	01	99	05
SGN 03	30	08/02/85	MCDONALD'S							0		
883000016	001010	1.020		610000200	E10-5B	060	036	DC	G802	01	99	05
SGN 03	21	08/03/88	KOPPER KITCHEN							0		
893000011	001010	1.020		610000200	E10-5B	060	036	DD	G802	01	99	05
SGN 01	13	10/24/88	WENDY'S							0		
883000019	001010	1.420		545580482	I-5B	048	024		G901	01	00	05
SGN 07	99	01/14/87							05	1		
883000021	001010	1.600		544951486	D5-1	048	024		G802	01	03	05
SGN 01	19	04/01/86	OREGON ST REST AREA						01	3		
883000020	001010	1.600		542321905	E2-101	090	036		G901	02	02	04
SGN 03	19	04/01/86	NX X 8 MILES						25	0		
883000022	001010	1.600		544994247	D9-4	024	024		G901	01	03	05
PST 01	19	04/01/86	C						25	0		
883000023	001010	1.600		542811005	E1-1	132	132		G901	02	02	04
SGN 03	19	04/01/86	X3 95 PARM PAY1						25	2		
883000024	001010	2.000		544105240	D10-5	012	024		G901	01	02	05
SGN 01	04	09/16/86	2						23	1		
883000026	001010	2.140		542870605	E-7	096	060		G802	02	02	01
SGN 01	06	10/28/81	ONTARIO3 BAKER77						02	1		
883000025	001010	2.140		542910187	E10-1	084	048		G901	02	03	05
SGN 01	13	03/00/73	G-F-L NXT RT						02	2		
883000027	001010	2.280		541021580	R2-1B	048	060		G802	04	00	05
SGN 03	04	11/22/89	65						26	1		
PST 02	09	11/22/89										

GUIDE SIGN ENTRY

FIGURE 5 Sample of sign status report from Idaho Department of Transportation sign inventory.

Finally, advancements in the technologies of geographic information systems (GIS) (*36*), video imagery, laser disk storage, and computer-aided drafting (CAD) software hold promise for more comprehensive, accurate, and affordable inventory and data base management systems for signs and all other roadway elements. Connecticut and Minnesota are developing state-of-the-art highway information systems based on these technologies.

SIGN INSPECTION PROCEDURES

A freeway guide sign inspection program should include checking for the following items (all items may not be checked during any specific inspection, e.g., the support system may be checked separately):

FIGURE 6 Prototype mobile retro-reflectivity measurement system.

- Condition of the sign face (e.g., major cracking, delamination, missing letters, discoloration, etc.).
- Vandalism, such as spray paint, bullet holes, etc.
- Excessive dirt or grime.
- Poor retro-reflectivity of any part of the sign.
- Structural integrity and condition of the support system.
- Adequacy of the message in terms of legibility and/or appropriateness.

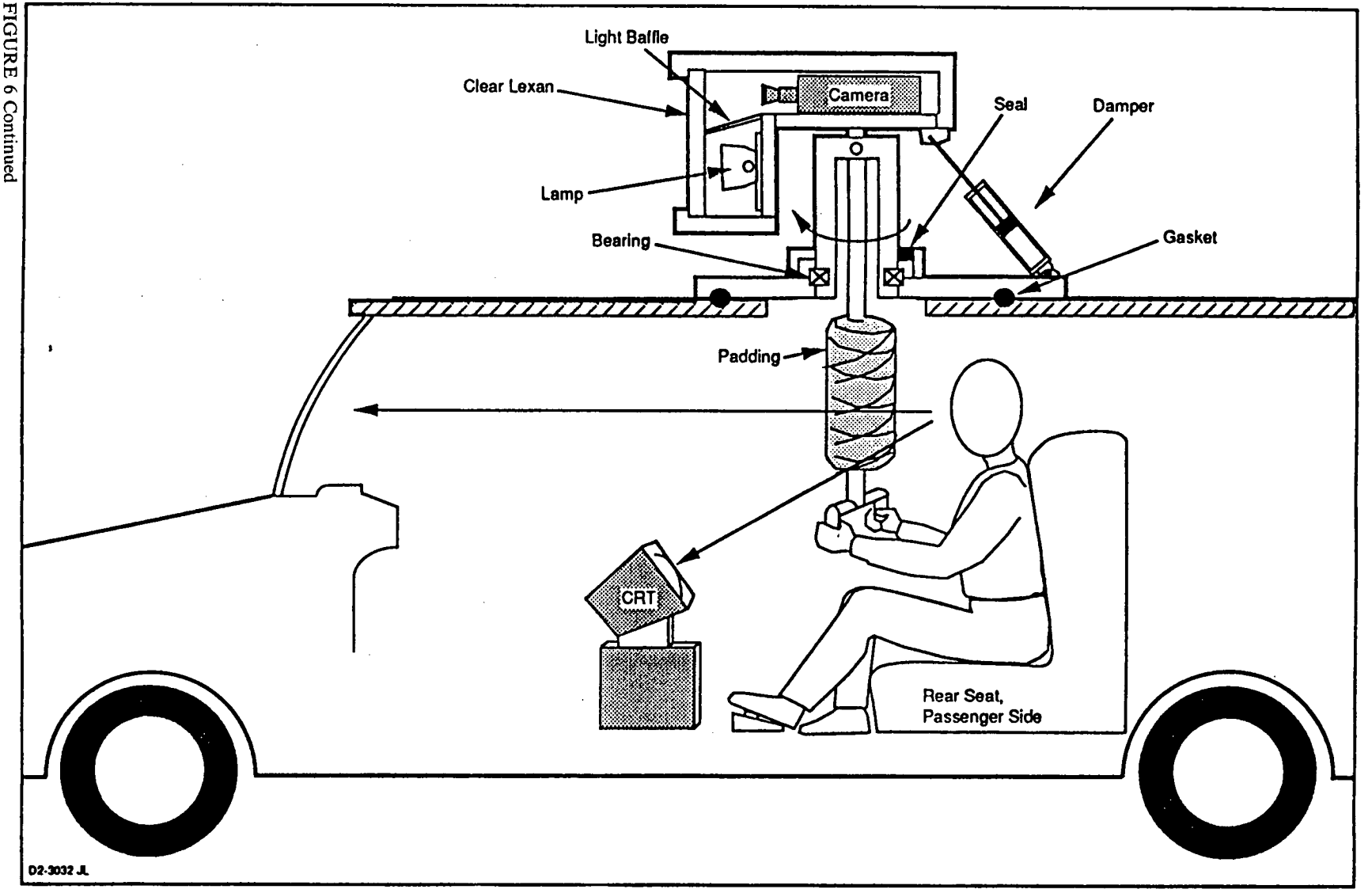
There are several inspection methods for retro-reflectivity that involve human observations, measuring instruments, and a combination of both. These are discussed in references *7* and *9*. The most prevalent method for inspecting freeway guide signs appears to be the human-observer method. Some states indicated that portable retro-reflectometers are used to supplement observations, especially for special studies.

The human-observation method, although subjective and dependent on the experience of the inspectors, is viewed as adequate by many state highway departments. In fact, in 1986, the Washington State Department of Transportation sponsored a study to assess the accuracy of using human observers to evaluate traffic sign retro-reflectivity. In the study, observers were trained to rate warning and STOP sign retro-reflectivity, first in a dark gymnasium and then from a stationary car on a section of road. After the training, the observers evaluated signs under actual highway conditions. The observer sign ratings and the retro-reflectometer sign ratings were incorporated into separated models for determining whether or not to replace a sign based on the sign condition. The observer replacement decisions were then compared with the retro-reflectometer replacement decisions. The researcher reported that trained observers made correct sign replacement decisions on 74 percent of the warning signs and 75 percent of the STOP signs they inspected. "Correctness" was judged against the sign rating calculated using a retro-reflectometer. Inspection of freeway guide signs was not evaluated specifically in the study (*9*).

A visual subjective inspection method using a spotlight has been used effectively by Mississippi. In this method a 200,000-candlepower spotlight (known as a Q-Beam) is flickered across the face of the sign as the survey crew drives along the road during daylight hours. Although the method works best during cloudy days, even during sunny days the light beam is bright enough to indicate whether the sign still has sufficient retro-reflectivity. Mississippi DOT uses this inexpensive instrument (about $30 to $50) in its annual sign inspection program, which includes overhead and roadside guide signs.

For the states interviewed, visual inspection was the most prevalent technique followed. The use of a retro-reflectometer

FIGURE 6 Continued



for large guide signs, especially those overhead, was found to be too time consuming for routine inspections. However, a prototype mobile system for measuring the retro-reflectance of traffic signs has been developed. The system was developed by EKTRON Applied Imaging, Inc. under a recently completed National Cooperative Highway Research Program study. Testing and evaluation of the system is being conducted by the FHWA. The van-mounted system (shown in Figure 6a) uses a video camera to record the sign images, a xenon flash as a source of light, and a personal computer to analyze and store the retro-reflected sign images. Figure 6b shows a schematic illustration of the components. The system allows measurement of the average retro-reflectance of the sign legend and background during daylight, at speeds up to 50 mph, and can be built from commercially available components.

During sign inspections, the structural components should be inspected as well. Although a visual inspection can identify severe corrosion and loose or broken bolts and fasteners, nondestructive inspection, using ultrasound equipment, is necessary to detect fractures in anchor bolts or other critical members. After experiencing failures with two cantilever structures, the Michigan Department of Transportation inspected all of the state's 1200 cantilevered highway signs and replaced 10 when inspectors using the ultrasound equipment found loose or defective anchor bolts.

The adequacy and/or appropriateness of the sign legend should also be evaluated during the sign inspection. Sign messages should comply with the *Manual on Uniform Traffic Control Devices* (MUTCD) (*10*) (e.g., not have too many supplemental destinations tacked on).

Various policies were identified regarding the frequency of inspection. Some states claim that they inspect their freeway guide signs twice a year, once during the day and once at night. Alabama stated that it requires two senior-level engineers from division offices to conduct semiannual visual inspection. Other states, noting that guide signs have longer service lives and are less prone to vandalism and general deterioration, feel a three- to four-year inspection cycle is sufficient.

CHAPTER THREE

SIGN MATERIALS

Roadway signs consist of two components, the sign face and the sign panel or substrate. Results of studies and state practices for these two components are discussed in this chapter.

SIGN FACE MATERIAL

In the context of this synthesis, which focuses on freeway/expressway interchange guide signs, the sign face consists of the background and the legend (or copy), which includes the destinations, route names and symbols, exit number, directional arrows, and the border. The legend can also include route markers such as the Interstate shield or state and local route markers, black-on-yellow EXIT ONLY panels, and other special messages. In conformance with the sign color designations in the MUTCD (*10*), the background color for guide signs is green, except for motorist services signs, which have blue backgrounds, and recreational and cultural interest area signs, which have brown backgrounds. Borders, arrows, destinations, and route names are white. Other legend items, including the Interstate shield, state route markers, and special messages, could include other colors.

Sign faces can be fully reflectorized, meaning both the background and the legend and border are made of retro-reflective material, or partially reflectorized, in which case only the legend and border are made of retro-reflective material and the background is an opaque porcelain enamel-coated material. As specified in the MUTCD, overhead signs made of non-retro-reflective background must be illuminated.

The types of retro-reflective sheeting and their specifications for retro-reflection, color, and other parameters are contained in several "national" standards, including:

- "Federal Specification L-S-300C," a General Services Administration specification.
- "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects-FP-85" (*11*), for projects under the direct administration of the FHWA.
- "M268—Retroreflective Sheeting for Traffic Control," an AASHTO guide specification.
- "D4956—Standard Specification for Retroreflective Sheeting for Traffic Control," an American Society of Testing and Materials specification.

Also, all states have specifications that are for the most part identical to one of the above national specifications. All of the specifications are the same except for variations in typology and minor differences in certain parameters.

In FP-85 (*11*), four types of retro-reflective sheeting are specified for permanent roadway signs. They are:

- Type II and Type II-A, enclosed-lens sheeting, which is known as engineering and super-engineering grade, respectively.
- Type III-A, encapsulated-lens sheeting and Type III-B, prismatic or cube-corner sheeting, both known as high-intensity or high-performance-grade.

Figure 7a shows the cross-section design for enclosed-lens sheeting and Figure 7b shows the design for encapsulated-lens sheeting. A cross section of prismatic (cube-corner) sheeting is shown in Figure 8.

Although Type III-B is recognized, it is not currently being manufactured. However, in a memorandum dated November 3, 1989, the Federal Lands Highway Program Administration authorized Type III-C, Cube Corner Prismatic Retroreflective Element Material. This material is similar to Type III-B in that it derives its retro-reflective characteristics using micro-prism or cube-corner material.

Another material is the prismatic-type sheeting known as Diamond Grade™ sheeting. This new product has not yet been classified; it is essentially the same type of material as Types III-B and III-C but with much higher retro-reflectivity levels.

Table 1 lists the five types of retro-reflective sheeting specified in FP-85 and the Diamond Grade™, each with its purchase specification value for retro-reflectivity in terms of specific intensity per unit area (SIA) for white, green, and blue sheeting at the 0.2° observation and −4° entrance angles.

All of these sheetings can be and are used for the background, legend, and border except that, to provide adequate contrast between the legend/border and background, the background sheeting should not be a higher-order-type sheeting than that used for the legend/border (i.e., Type II sheeting would not be used for the legend/border if Type II-A or Type III sheeting was used for the background). Table 2 shows the contrast ratios (i.e., luminance ratio, which is equal to legend divided by background luminance) provided by various combinations of retro-reflective sheetings. The first column of values is based on the minimum SIA values specified in FP-85. The second column consists of those values measured by the Ontario Ministry of Transportation in weatherometer tests after 1000 hr of exposure (*12*).

When retro-reflective sheeting is used for the legend, the message is applied in one of three methods:

- Direct or reverse screen process—Ink processed through a screen with the message; rarely used for freeway-type guide signs.
- Demountable copy—Individual characters cut out from the sheeting, applied to aluminum substrate, and attached to sign panel with screws, bolts, or, most commonly, rivets.
- Direct applied copy—Individual characters cut out from the sheeting, attached to the sign panel, and secured with the adhesive on the back of the sheeting.

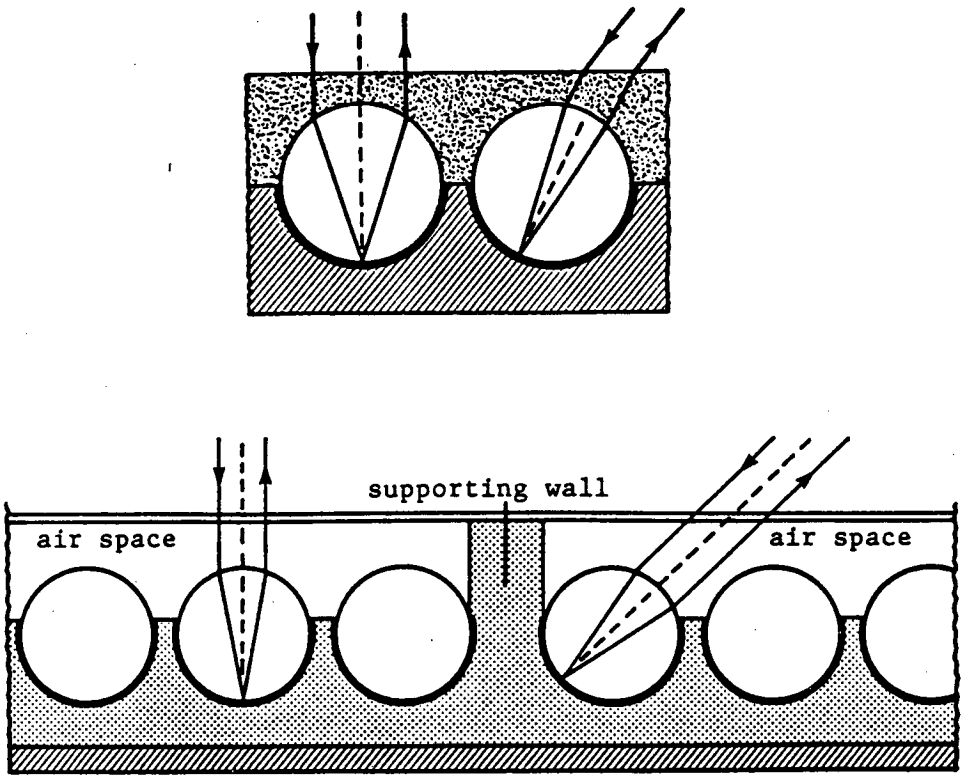
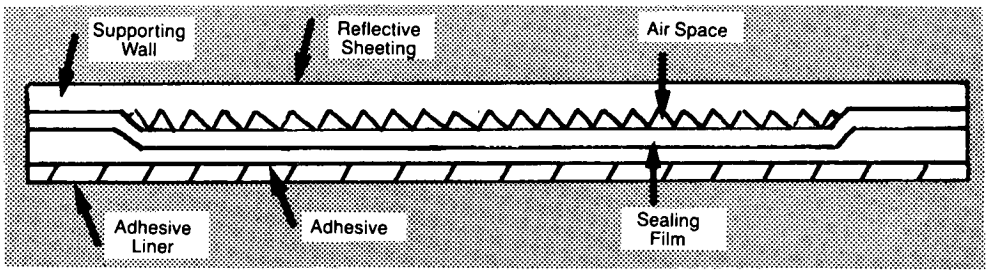


FIGURE 7 Cross-section view of two types of retro-reflective sheeting.



CUBE CORNER SHEETING

FIGURE 8 Cross section of prismatic sheeting.

TABLE 1
MINIMUM SIA VALUES FOR VARIOUS TYPES OF RETROREFLECTIVE SHEETING

Sheeting Type	White	Green	Blue
Type II	70	9	4
Type II-A	140	30	10
Type III-A	250	45	20
Type III-B	250	45	20
Type III-C	250	35	20
Diamond Grade™	800	75	43

Typology and SIA values are from FP-85 (*11*) except for Diamond Grade, which is from manufacturer.

Several states use circular prismatic retro-reflectors housed in aluminum frames to form the copy. Identified as acrylic plastic characters in FP-85 (*11*), the characters consist of embossed aluminum frames, cut in the shape of the character, in which prismatic retro-reflectors are installed. Individual characters (i.e., letters, numbers, symbols, borders, etc.) are fastened to the sign panel with screws or, more commonly, rivets. Figure 9 shows a sign made with this "button copy" method.

In 1988, Bellomo-McGee, Inc. conducted a study of alternative reflective sheetings for the Kansas Department of Transportation (*13*). The study included a survey of state practices concerning a number of signing issues. Table 3 shows the responses that were given to the question: "What is your policy regarding the use of different sheeting grades for freeway guide signs?"

TABLE 2

CONTRAST RATIOS FOR COMBINATIONS OF RETRO-REFLECTIVE SHEETING TYPES

White Legend	Green Background	Contrast Ratio[a] Per FP-85	Contrast Ratio[b]
Type II	Type II	7.8	7.4
Type II-A	Type II	15.6	9.5
Type III-A	Type II	27.8	19.0
Type II-A	Type II-A	4.8	3.3
Type III-A	Type II-A	8.3	--
Type III-A	Type III-A	5.6	5.0

[a]Minimum purchase SIA specification value (at 0.2° observation and entrance angle) for white sheeting divided by SIA value for green sheeting

[b]As measured in weatherometer tests with an observation angle of 0.2° and an entrance angle of -4° after 1000 hr of exposure (*12*).

FIGURE 9 Example of guide sign with circular prismatic retro-reflectors.

In one of several studies of freeway guide signs by the Texas State Department of Highways and Public Transportation (TSDH&PT), Jones and McNees (*14*) surveyed 65 traffic engineers attending the 1982 TSDH&PT Traffic Engineering Conference. Figures 10 and 11 show the results of their opinions regarding the use of the various materials for rural and urban areas, respectively. (Many of the sheeting combinations the engineers were asked to consider were not being used in Texas, so the preferences expressed were not necessarily based on experience.)

For a large guide sign replacement project, Oregon switched to removable encapsulated-lens reflective sheeting legends after experiencing problems with the reflector buttons at dew point temperatures. At the dew point, the moisture covering the reflector buttons reduced the reflectivity of the reflector-button legend more severely than it did the encapsulated-lens sheeting background. Consequently, the light reflected by the sheeting washed out the legend, which was reflecting a lesser amount of light (*15*).

Based on interviews with state officials and comments made at the two regional FHWA sign workshops held in February 1990, the states are using all combinations of retro-reflective sheeting and button reflectors. There appears to be a trend away from signs made of button copy on porcelain nonreflective background to fully reflectorized guide signs, with a majority using Type III sheeting, at least for the legend.

SUBSTRATE MATERIAL

The substrate or panels are commonly made from one of five materials:

- Aluminum sheet
- Extruded aluminum
- Laminated aluminum honeycomb panels
- Plywood sheet
- Fiberglass-reinforced plastic (FRP)

Of these, sheet and extruded aluminum are the most commonly used. Figure 12 shows the back of two guide signs, one made with sheet aluminum and another with extruded aluminum. Neither the literature review nor discussions with state officials identified any formal benefit-cost comparison for the two. Pennsylvania's decision to use sheet aluminum was based on a cost analysis, although no documentation is available. There appears to be advantages for using each type. Extruded aluminum provides a more rigid sign panel without the need for elaborate stiffeners and braces. Sheet aluminum is less costly, at least for fabrication, is adaptable to special sign sizes, and results in fewer seams on large signs.

Ohio is one state that is using Extrusheet panels for its guide signs. In this case, extrusions are spot welded to the sheet aluminum. (Ohio has experimented with using commercially available high-bond tape instead of spot welds; this system has performed satisfactorily so far.) Figure 13, extracted from Ohio's standard construction drawings, shows side and cross-section views of the 12-in. and 18-in. panels; 24-in. panels are also made.

Plywood is used for guide sign substrate by at least two states, Wyoming and Utah; others may use it as well, but no survey data exist on this item. Those who use it cite its ability to withstand bullet shots and versatility in fabrication as two advantages over aluminum. Comparative costs are subject to the wide fluctuations in aluminum costs.

To date, the use of FRP has been experimental, with both good and bad performance cited by state representatives at the FHWA sign workshops. The Ohio Department of Transportation has been evaluating FRP since 1977 and reports (*16*) the following:

- FRP of 0.135-in. thickness is used in place of 0.080-in. and 0.100-in.-thick aluminum.
- The sign fabrication process is the same as for aluminum except that FRP does not need to be deburred after shearing and punching as aluminum does. More care must be taken when

TABLE 3
STATES' PREFERENCE FOR SHEETING TYPES (*13*)

Legend	Background	No. of States
Buttons	Type II	7
Buttons	Type III	10
Demountable, Type II	Type II	1
Demountable, Type II	Type III	2
Demountable, Type III	Type II	7
Demountable, Type III	Type III	14
Direct Applied, Type II	Type II	7
Direct Applied, Type III	Type III	20

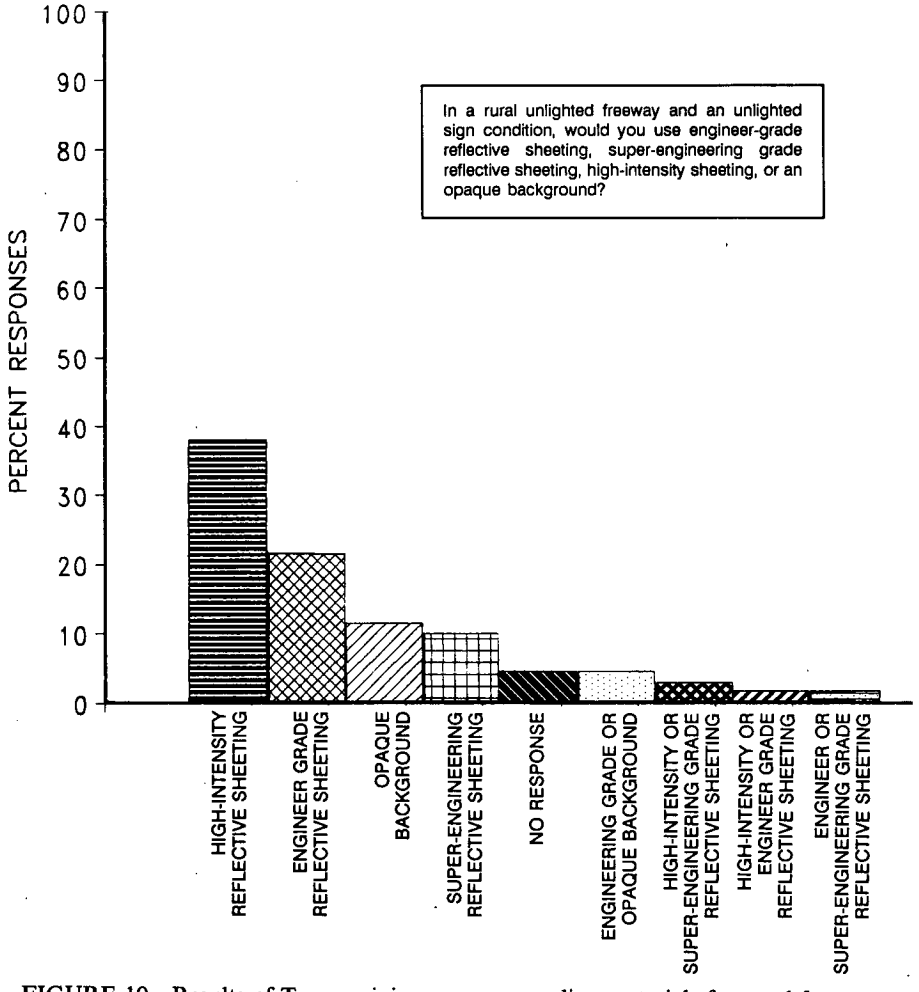


FIGURE 10 Results of Texas opinion survey regarding materials for rural freeway guide signs.

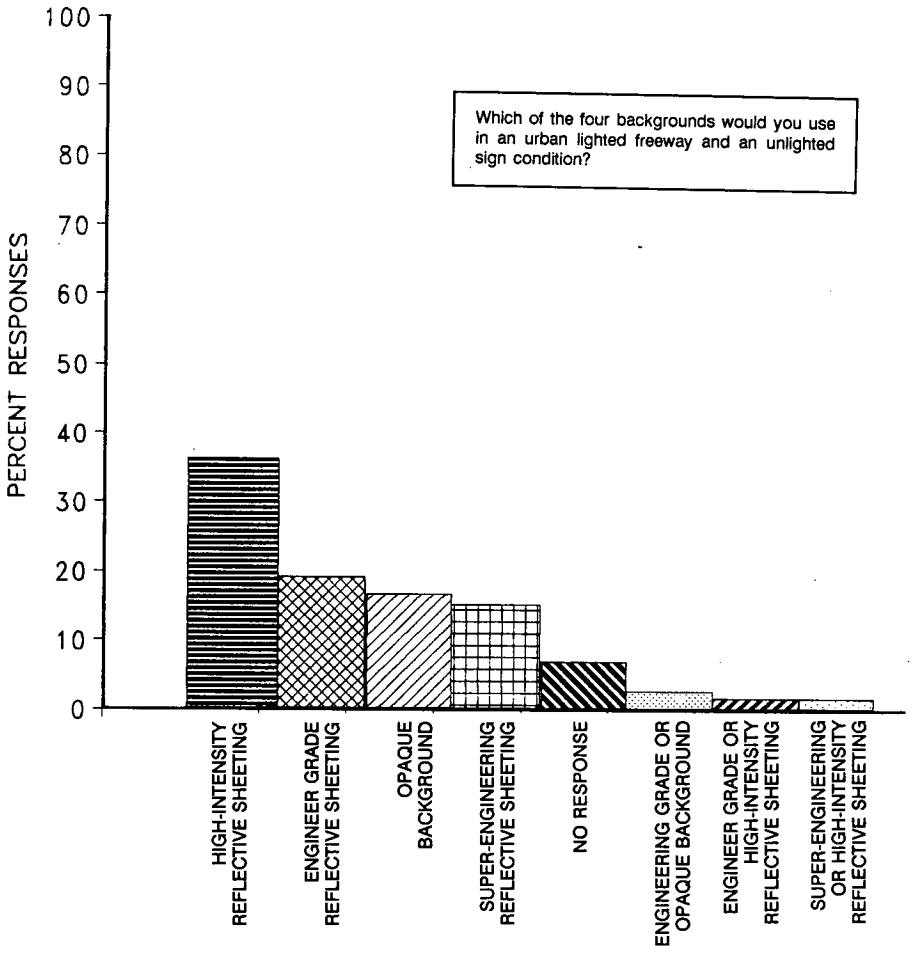


FIGURE 11 Results of Texas opinion survey regarding materials for urban freeway guide signs.

trimming the sheeting around the edges with FRP blanks, because the trimming knives have a tendency to dig in to the FRP.

- Undamaged FRP signs can be reclaimed in the same manner as aluminum signs, by grinding off the old sign face. However, damaged signs are not repairable, and FRP has little value for recycling purposes (a reason why it is less susceptible to theft).
- During the handling, fabrication, and recycling (sanding) process, slivers of the material can get into workers' hands and into the screens, and the dust can be inhaled. These problems, however, are controllable.
- FRP signs are more susceptible to fracture from high winds and from blows by equipment such as mowers.
- When overlaying large guide signs made with extruded aluminum the Ohio DOT uses 0.075-in. FRP or 0.040-in. aluminum for the substrate. Both materials have performed well, although it appears to be more critical that the rivets not be located too close to the edge of the FRP panels (minimum distance of 1½ in. is recommended). The FRP has a tendency to shear from around the rivets to the edge of the panel.

The Ohio DOT concluded that FRP provides a feasible alternative to aluminum as a substrate for flat sheet signs, although it is not as versatile a material as aluminum and requires more care and attention to detail when installed in the field.

In 1978, the Pennsylvania Department of Transportation (PennDOT) evaluated various types of sign materials for freeway and expressway guide signs in an effort to minimize annual signing costs. Up to that time it used laminated panels composed of a honeycomb material sandwiched between aluminum sheeting with extruded aluminum trim on all four edges and a porcelain finish on the face. PennDOT evaluated alternative materials, including sheet and extruded aluminum, because the honeycomb substrate panels were expensive, were nonreflective, and their projected 20-year service life was not being realized. It concluded that a 30 percent annual savings could be achieved for large guide signs by switching to signs with aluminum substrate and using encapsulated-lens background sheeting. It cited the fact that the aluminum sheeting and the hardware fasteners could be salvaged and recycled as another reason for their use. It also recommended that "button copy" be used for the legend except on smaller signs, such as EXIT gore signs, where direct-applied encapsulated-lens sheeting should be used (*17*). However, in recent years PennDOT has been using fully reflectorized Type III sheeting for its guide signs.

In guide sign refurbishing (discussed more thoroughly later in this synthesis) a common practice is to use overlays. The substrate material for this process is predominantly sheet aluminum, although plywood and plastics are used as well.

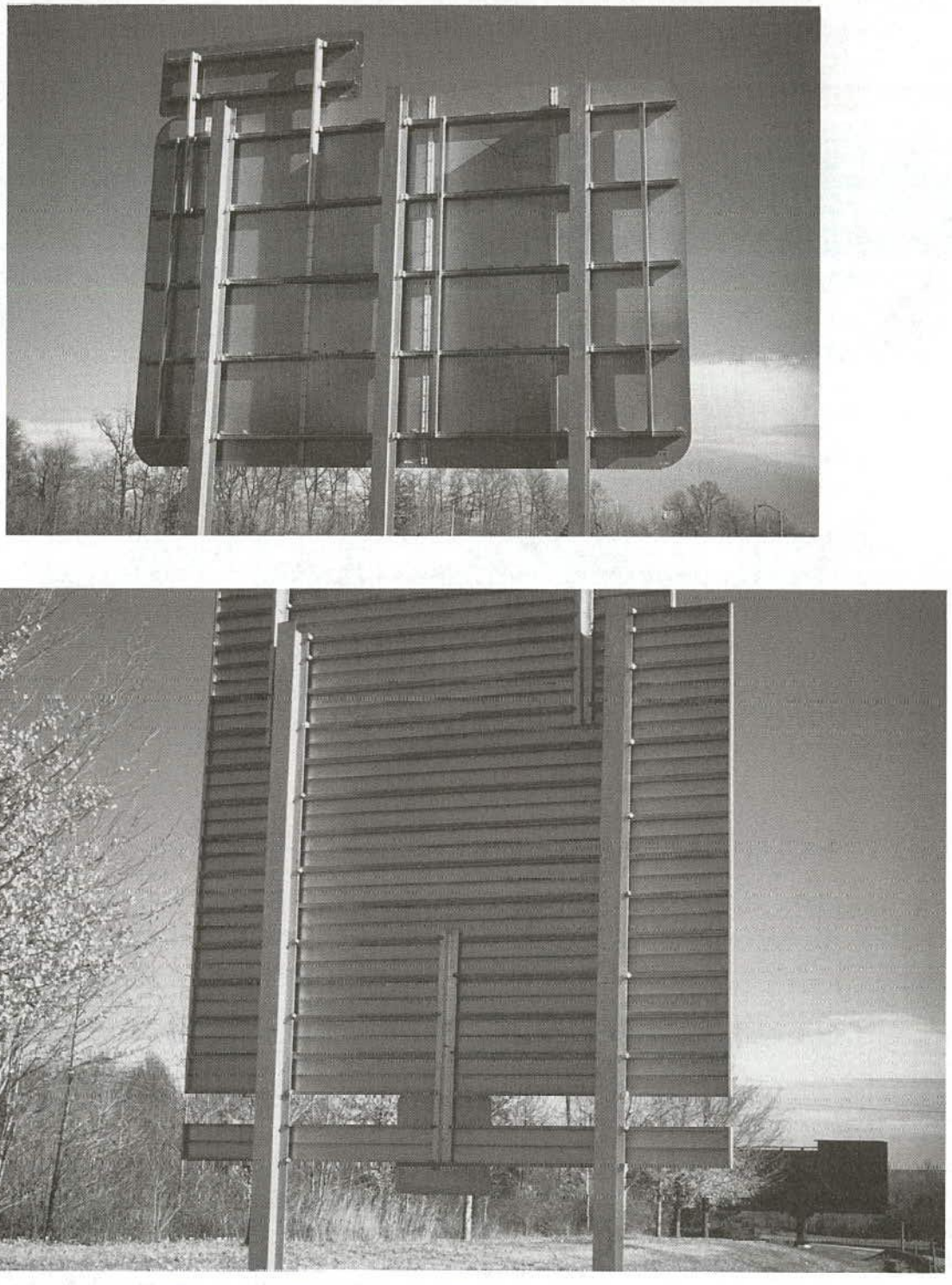


FIGURE 12 Freeway guide signs made with sheet and extruded aluminum substrate.

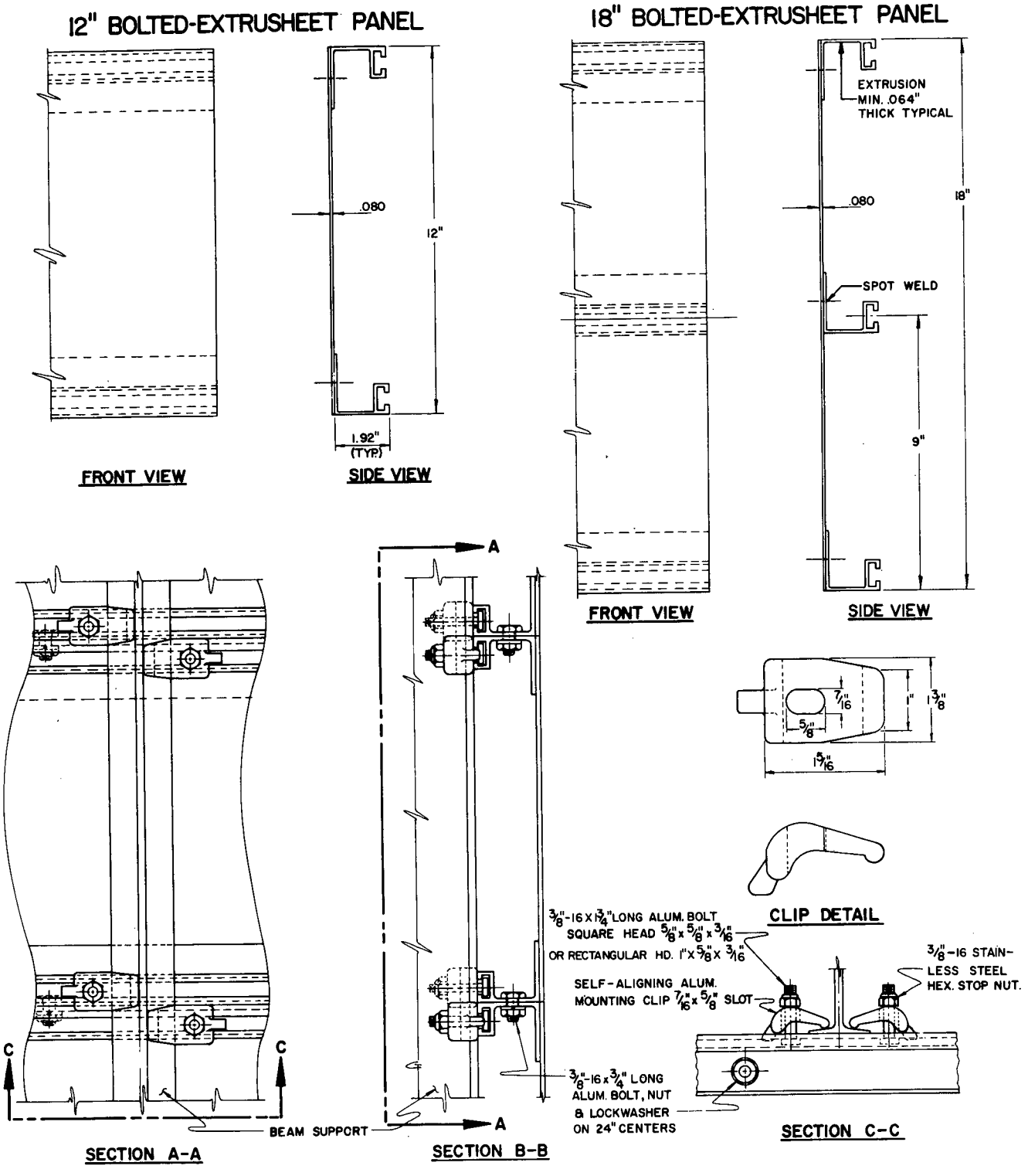


FIGURE 13 Construction drawings of 12-in. and 18-in. aluminum-bolted Extrusheet panel signs (Ohio).

CHAPTER FOUR

SIGN SERVICE LIFE

The service life of a guide sign can be defined as the time during which the sign provides the required legibility distance for all or a vast majority of drivers under normal operating conditions, which includes periods of reduced visibility conditions. Sign failure can result from loss of a sufficient level of retro-reflectivity (primarily with the legend, but also with the background), loss of sufficient contrast, or a loss of color, all from the natural deterioration of the sign material or from vandalism. There is no national standard for the minimum level of retro-reflectivity, however. Sign detection and legibility, as they relate to sign retro-reflectivity and contrast levels, will be discussed later in the synthesis.

Agencies that have kept data or have evaluated the service life of their signs report the following for various materials:

- In 1977, New York State DOT established a 12-year service life expectancy for the reflective buttons in the button copy-type sign. Laboratory tests showed that the brightness remained nearly constant for about 12 years, then rapidly decreased, until, at 14 years, it stabilized well below the New York State DOT specification. Its brightness specification for new button material is a specific intensity of 9.4 candela per foot-candle (c/ft-c). Using a subjective evaluation rating scale, it determined that failure occurred at 6 c/ft-c (*18*).
- In a survey of states conducted for the Kansas DOT (*13*), the following service lives were reported by the responding states: (a) Enclosed-Lens Sheeting—8 years and (b) Encapsulated-Lens Sheeting—11 years.

These service life figures apply to all signs.

In the Kansas DOT study, a life-cycle cost analysis was performed to compare the costs of overlaying an overhead guide sign with Type II versus Type III-A sheetings. A life-cycle cost analysis evaluates the cost differences, considering the different service life, the initial costs, the maintenance costs, and the time value of money. Using the "equivalent uniform annual cost" economic analysis method, the following data were reported for a 10-ft-x-15-ft overhead sign:

	Type II	Type III-A
Total Initial Cost	$671	$1,040
Sheeting Service Life	10 years	15 years
Adjusted Equivalent Uniform Annual Cost	$102	$92

Assuming that the more expensive Type III sheeting lasted five years longer than the Type II sheeting, the Type III sheeting would be more economical over its service life (*13*).

- In a 1977 study, the Idaho Department of Transportation estimated 15 years for the average life of ground-mounted freeway guide signs, and 20 years for overhead guide signs. The signs were nonreflective porcelain backgrounds, with both Type II sheeting and button copy. The reasons cited for the long life of freeway guide signs are: (a) The substrate and background materials are more durable, (b) the signs are large and are located on routes having higher traffic volumes, two factors that would discourage vandalism, and (c) the signs are set back farther from the travelway, making them more difficult to be hit by thrown missiles and errant vehicles (*19*).

The FHWA is sponsoring a study entitled "Sign Service Life," which is attempting to identify factors that cause retro-reflectivity deterioration and to develop an equation that could be used to predict retro-reflectivity levels at different ages and eventual service life. The results of that study were not available at this writing.

Signs may also need to be replaced for reasons unrelated to the end of their legibility service life as described at the beginning of this section. These reasons include theft, vandalism to the structural components, knockdown, or changes in signing standards. Additional study is needed to develop life-cycle costs for the replaced signs that account for these other replacement factors. Such an expanded life-cycle cost would lead to better comparisons between sheeting types, substrate, and supports.

CHAPTER FIVE

SIGN DETECTABILITY AND LEGIBILITY

Two factors considered in the selection of material for a sign background and legend are the detection distance and legibility distance provided by the specific material or combination of materials. Sign detection occurs when a motorist sees that a sign is ahead without being able to read its legend. Aside from the visual capabilities of the driver, guide sign detection is a function of its size and its external contrast (i.e., the contrast between the sign and surrounding visual background) or, at night, its luminance or brightness. A sign's conspicuity can affect its detectability. A formal definition of conspicuity is "the quality of an object or a light source to appear prominent in the surroundings" (*20*). A more conspicuous sign can be detected with higher probability at a longer distance. Nighttime conspicuity can be increased by providing brighter signs (i.e., signs using retro-reflective material of higher SIA).

Sign legibility occurs when a motorist is able to distinguish the letters, symbols, and words, thereby reading the sign. Sign legibility distance is a function of many factors, including the size and spacing of the letters and symbols, the internal contrast of the legend against the background, and the luminance or brightness of the legend. For nighttime legibility, increasing the legend luminance will increase the legibility distance up to a maximum value if illumination uniformity is maintained. Figure 14 shows this relationship as developed by Allen many years ago (*21*). A more thorough discussion of the principles of guide sign detectability and legibility can be found in references *22* and *4*. This section focuses on studies that examined these issues as they relate to the selection of sign face material and sign design.

The Texas State Department of Highways and Public Transportation has been evaluating this and other issues related to guide signs for several years. In one of the studies, McNees and Jones (*23*) determined the legibility distances for several sign combinations. Opaque sign backgrounds and backgrounds with all types of retro-reflective sheetings were used in combination with button-removable and Type III retro-reflective legend. Both illuminated and nonilluminated signs were studied. The researchers concluded:

1. When considering sign lighting, legibility distance, and driver variability, [encapsulated-lens (Type III-A) retro-reflective] sheeting with [encapsulated-lens] stick-on [legend], opaque background with button [legend], and [Type II retro-reflective] sheeting with button [legend] are all acceptable combinations for freeway guide signs.
2. Background materials for signs have a more significant effect on sign legibility than does legend material.

In recent years, more attention has been given to the issue of elderly drivers and how they are being accommodated within current design practices. This topic was the focus of a congressionally mandated study conducted by the Transportation Research Board (TRB) in 1986, and its results and findings are published in *Transportation in an Aging Society* (*2*). D.J. Mace, the expert the TRB panel charged to examine traffic signs, provided several relevant observations from the literature:

- Letter height for signs is based on the assumption that an inch-high letter is visible from 50 ft, which assumes a visual acuity of roughly 20/25. However, 40 percent of the drivers between 65 and 74 do not see that well; through age 75, the 95th percentile for acuity is close to 20/40.
- The older driver is at a greater disadvantage reading signs at night because of poorer acuity under low illumination. Citing the work of Sivak et al. (*24, 3*), he noted that older drivers (62 to 79) had a legibility distance only 65 to 77 percent that of drivers 18 to 24 years old.

The study (*2*) recommended an increase in the current design of letter height based on the assumption that an inch-high letter can be read at 40 ft rather than 50 ft. If a minimum legibility distance of 900 ft is assumed (commonly used in determining letter size for Interstate guide signs), this revised standard would result in 22.5-in. letters rather than 18-in. letters. Recognizing the cost implications of the resulting larger signs, it also recommended that sign performance be improved through increased conspicuity and multiple signs. Sign conspicuity can be enhanced by using Type III retro-reflective sheeting, especially in urbanized areas where visual clutter occurs (*25*).

On an Interstate freeway signing upgrade project in Oregon, it was reported (*15*) that 13½-in. uppercase and 10-in. lowercase letters were reduced to 8-in. and 6-in. letters. However, upon receiving numerous complaints that it was difficult to read the signs at freeway speeds, the letter sizes subsequently were returned to the original size.

North Carolina is experimenting with larger letter sizes on guide signs, specifically in consideration of the needs of the elderly. For the guide signs at freeway-to-freeway interchanges, the Interstate shield size has been increased from 36 in. to 48 in. and the letter size from 16-in. uppercase, 12-in. lowercase to 20 and 15 in. Figure 15 shows three guide sign panels with the larger letter sizes used on the two outside signs. The state is expanding this procedure to other selected sections of its Interstate system. No formal evaluation is planned. It was noted, however, that the larger-size legend increases the sign panel by a factor of 1.5, which in turn substantially increases the cost of the total sign and support system.

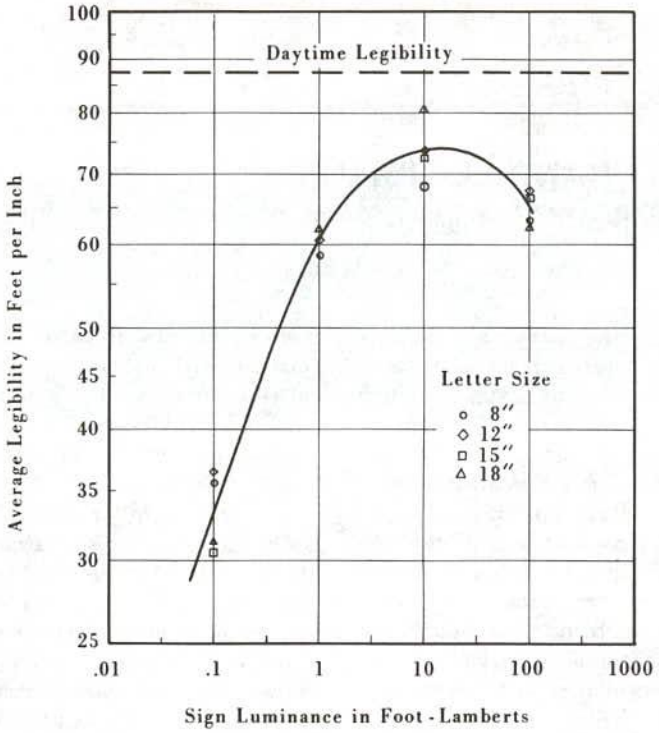


FIGURE 14 Legibility related to sign luminance. White legend on black background (*21*).

FIGURE 15 Example of larger letter sizes.

CHAPTER SIX

REFURBISHING

There are different methods for refurbishing existing overhead signs, depending on the existing sign material. These methods include:

- Total replacement
- Overlay panels
- Commercial overlay
- Cleaning and recoating porcelain panels

The interviews with the selected states and the comments made at the FHWA sign workshops (*5*) revealed a difference of opinion as to which method of sign refurbishing is most cost-effective. Some preferred the overlay procedure, whereas others prefer total sign replacement. The different preferences are related to a certain extent to the state's sign shop capabilities and to whether this work is done by contract or by the state's own forces. For example, George (*15*) reported on a large sign replacement program for sections of the Interstate system in Oregon. The contract specification called for an overlay of 0.10-in. aluminum covered with encapsulated-lens reflective sheeting. Reflector buttons were to be used for the legend. The project involved 33,000 ft^2 of guide sign refurbishing and 13,000 ft^2 of new guide signs. However, instead of applying the overlay, the contractor requested and was allowed to substitute totally new signs. Also, the copy material was changed to encapsulated-lens sheeting. As a result of this experience, Oregon has concluded that, for large projects, replacing signs is more cost-effective and is preferred to an overlaying operation in the field.

Overlaying is preferred by the Virginia Department of Transportation. In 1984, Shepard (*26*) reviewed the sign overlay procedures used by the various districts within Virginia. He examined the costs, manpower, time, and quality of the product for 13 sign refurbishing projects around the state. Of those projects, six involved refurbishing in the field with overlay panels attached with rivets, one involved attaching overlay panels in the field with rivets and adhesive, five involved the use of a commercial overlay, and one the replacement of the entire sign. Figure 16 is a plot of the total cost/ft^2 for the refurbishing procedures. Several noteworthy findings were reported:

- The use of overlay panels, fabricated in the shop with directly applied copy and attached in-place in the field using rivets, was found to be the most cost-effective. Figure 17 shows two steps in this overlay procedure.
- Both 0.063-in. and 0.080-in.-thick aluminum panel sheets were used and found satisfactory.
- Applying adhesive to the old panel required extra care in handling and aligning the panels and was deemed not worth the additional time and cost.
- The overlay panels tended to produce signs with wavy surfaces—especially at the rivet locations—that cause "hot spots" at night. This was not considered to be a significant problem and did not diminish the visibility and legibility of the sign.
- A commercial overlay is a panel of reflective sheeting on a thin, semi-rigid aluminum backing coated with a pressure-sensitive adhesive. It is applied directly over an old panel after the copy has been removed, using a rubber roller or soft cloth. No rivets are used. Extra care and time was required to apply the material, but satisfactory results were obtained.

Shepard's study (*26*) also included a survey of other states' practices and preferences. Asked: "How are your guide signs refurbished?" 45 states responded as follows:

- They are replaced—13 percent
- Overlay panels are attached in the field—51 percent
- Commercial overlay—2 percent
- Combination of 1 and 2—34 percent

The results of the responses of 45 states reporting to Shepard's questionnaire are presented in Appendix A for some of the questions related to refurbishing.

Pennsylvania has found that overlays should not be used if the existing panel consists of honeycomb material between two aluminum sheets. Water seeps into the honeycomb area through the rivet or bolt holes and the old panel quickly deteriorates. Although the overlay technique is used for some situations, PennDOT's policy is to replace the entire sign.

Region 5 of the FHWA reported on sign rejuvenation techniques used by some states and local highway departments in that region (*27*). It reported that Wisconsin initially experienced a "wavy sign face" when 0.030-in.-thick aluminum sheets were used for overlay. This was eliminated by using 0.060-in. aluminum placed horizontally across the existing panel. Further experimentation revealed that an acceptable overlay method was to remove the existing sign, bolt stiffeners to its back, and then place a 0.030-in. overlay on the front. The wave problem was corrected, and removing the sign allowed easier installation.

Region 5 also reported on Illinois DOT's experiences with three overlay techniques: (a) riveted overlays with overlapping joints, (b) riveted overlays with butt joints, and (c) commercial overlays. The riveted overlays consisted of 0.063-in.-thick, 4-ft-wide aluminum panels. As did other states, Illinois experienced waviness but felt it had an insignificant effect on sign legibility or appearance. Commercial overlays were used for the legend in some cases. Mixed results were obtained with the commercial overlays because they peeled at the nonoverlapped edges of the background overlays after six months.

Experimentation in Texas in 1979 demonstrated that thermal-setting polyester, thermal-setting polyvinylidene fluoride, and air-dry polyvinylidene fluoride are excellent coating materials for refurbishing existing deteriorated porcelain alumi-

num sign panels at approximately half the cost of a new sign panel (*28*). Later testing showed that deteriorated porcelain-enameled extrusions can be refurbished satisfactorily with all types of retro-reflective sheeting applied directly to the porcelain extrusions without the use of an overlay face sheet (*29*).

Texas also reported on a successful refurbishing/modification by cleaning (*29*). In the El Paso area district, the legend on 20 overhead signs had to be revised. At the sign shop the porcelain signs were refurbished and modified as follows:

- Sign legend was removed.
- Sign blank was washed with soap and water.
- Sign blank was scrubbed with floor polisher and powdered chlorinated cleaner.
- Sign blank was rinsed and mopped dry.
- New copy was attached to the sign blank.

Figures 18 through 25 show the process of refurbishing the porcelain signs. This operation was done within one day for each sign. The absence of one guide sign for that amount of time was not considered a problem. The cost to refurbish a sign was approximately one-tenth of the cost of a new sign installed by contract. However, this method proved satisfactory only for signs experiencing deterioration found in an arid climate.

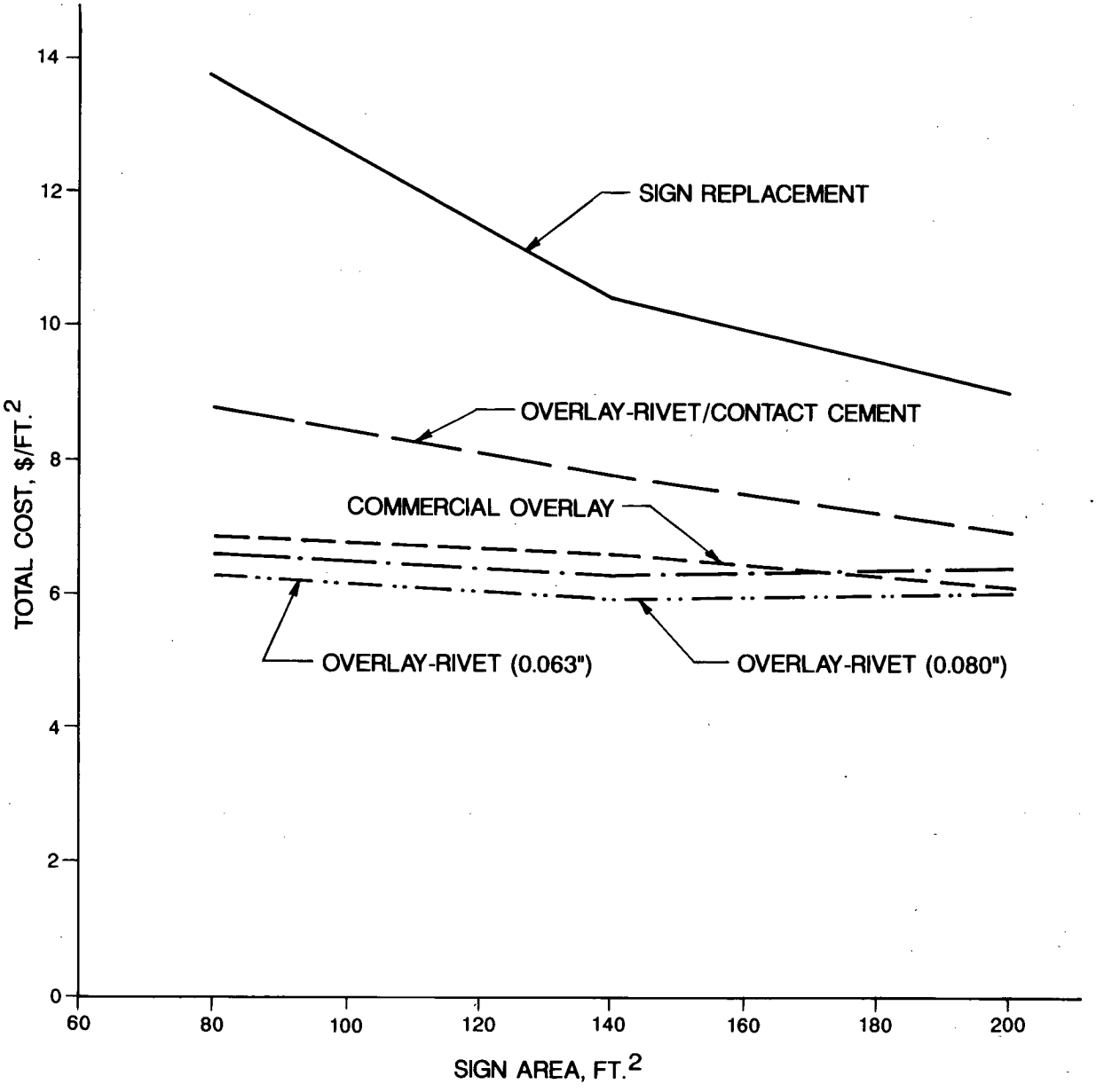


FIGURE 16 Comparative cost of sign refurbishing.

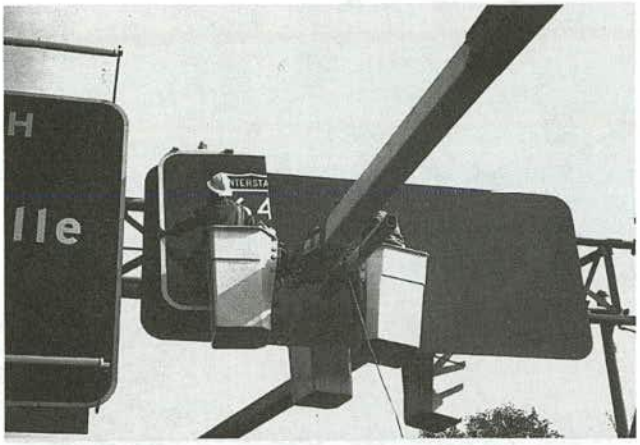


FIGURE 17 Illustration of overlay method of sign refurbishing.

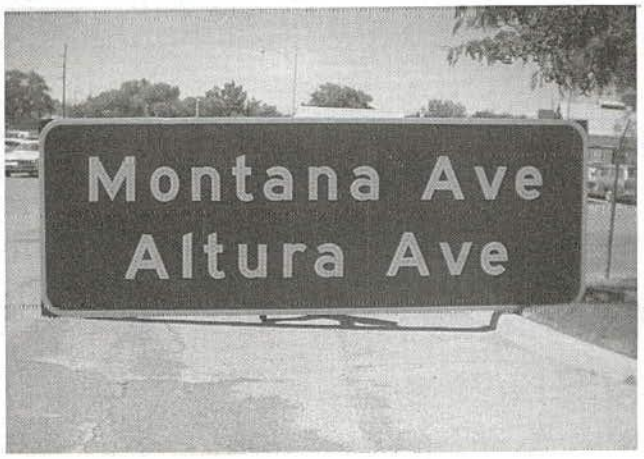


FIGURE 18 Sign as removed from sign bridge with original text.

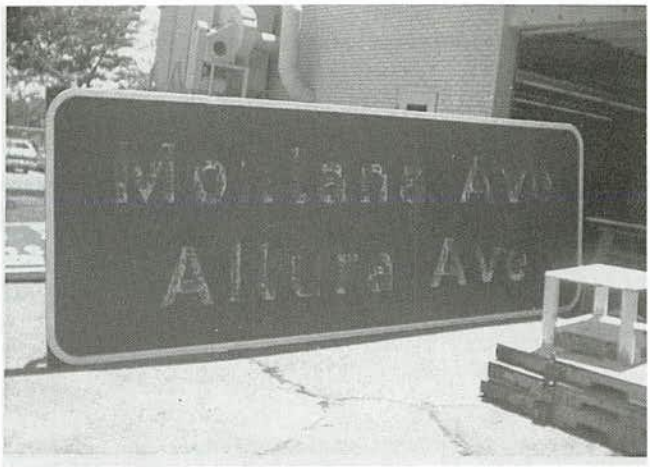


FIGURE 19 Sign with text removed.

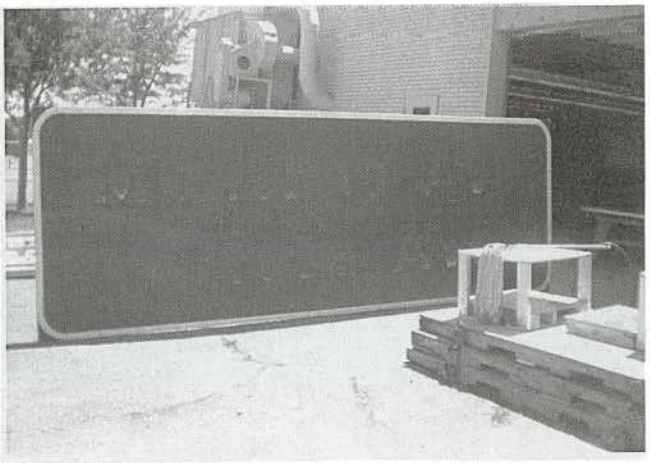


FIGURE 20 Sign blank washed with soap and water.

FIGURE 21 Sign blank scrubbed with floor polisher and powdered chlorinared cleaner.

FIGURE 22 Sign blank rinsed and mopped dry.

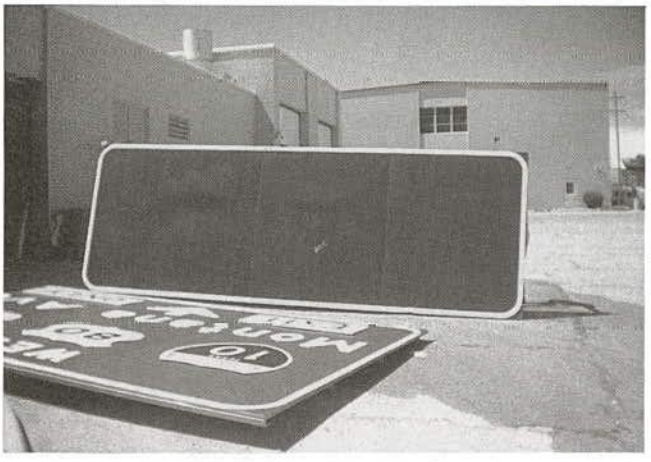


FIGURE 23 Sign blank after drying.

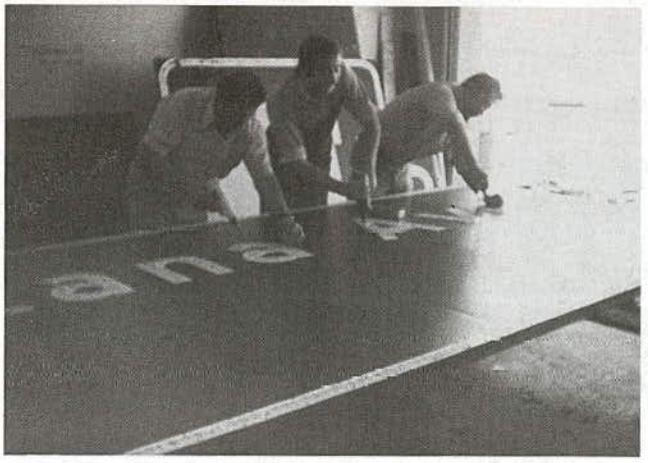


FIGURE 24 New text being applied to sign blank.

FIGURE 25 Sign with new text.

CHAPTER SEVEN

SIGN ILLUMINATION

In Section 2A-16, Illumination and Reflectorization, of the MUTCD (*10*), it is stated that "[a]ll overhead sign installations should be illuminated where an engineering study shows that reflectorization will not perform effectively." Further, in Section 2E-6, Reflectorization or Illumination, it is stated:

> . . .In general, where there is no serious interference from extraneous light sources, reflectorized signs will usually be adequate. However, on expressways where much driving at night is done with low beam headlights, the amount of headlight illumination incident to an overhead sign display is relatively small. Therefore, all overhead sign installations should normally be illuminated. The type of illumination chosen should provide effective and reasonably uniform illumination of the sign face and message.

Large monetary savings can accrue if sign lighting is eliminated. These include:

- Eliminating the cost of lighting fixtures.
- Eliminating the increased cost of the sign supports due to the sign lights.
- Reducing maintenance costs by not having to inspect, repair, and replace lights.
- Eliminating utility costs for electrical energy (*30*).

In their investigation of nighttime visibility of overhead guide signs, Stein et al. (*31, 32*) conducted an extensive life-cycle cost analysis of sign materials and lighting. In comparing two 165-ft^2 signs, one with a non-retro-reflective, porcelain enamel background and a button copy legend and the other with both encapsulated-lens legend and background, they found the present worth cost of the fully reflectorized sign without illumination to be $5,300 versus $11,000 for the illuminated non-retro-reflective sign.

Three surveys provide relevant information about states' policies on overhead sign illumination. In 1987, Hajjiri and Michalopoulos (*33*) of the University of Minnesota surveyed 54 states and other agencies about their practices regarding overhead sign illumination and reflectorization. Of the 44 responding, 23 stated that they do not always require illumination of overhead signs. To the question: "Do you illuminate overhead guide signs that have reflectorized high intensity (Type III) backgrounds?" 19 of 36 responding replied, "no." When asked: "Do you illuminate signs with high intensity legend only?" 19 of 34 responded, "no." Appendix B provides the full results of the survey.

In a survey of the states conducted for the Kansas Department of Transportation (*13*), 16 of 35 states responding stated that they do not illuminate all of their overhead signs. In these states, overhead guide sign illumination is generally reserved for urban areas, situations with restricted visibility distance, and for high-volume freeway interchanges.

The consensus from the eight state interviews conducted during the preparation of this synthesis is that all the states are trying to minimize the number of signs that will have external illumination. With the use of fully reflectorized signs, especially with Type III sheeting, the interviewees see less need for illumination. However, before illumination is removed, turned off, or not included in the original installation, an engineering evaluation of the situation should be made. Results of evaluations by several states concerning this issue are presented below.

In 1978, PennDOT (*17*) evaluated the feasibility of: (a) using retro-reflective sign sheeting, either enclosed-lens or encapsulated-lens grade, as background material for selected overhead signs or (b) using nonreflective opaque, porcelain enamel backgrounds without external illumination. The study involved placing two sets of overhead signs at two sites on a freeway where 572 motorists were interviewed and photometric readings were taken. The photometric readings provided the following results regarding luminance contrast ratios:

- Nonreflective (porcelain enamel) background with button legend—140:1 contrast ratio because the background has negligible reflectivity.
- Enclosed-lens-grade sheeting background with button legend—14:1 contrast ratio.
- Encapsulated-lens-grade sheeting background with button legend—7:1 contrast ratio.
- Encapsulated-lens-grade sheeting for both background and legend—4:1 contrast ratio.

From the motorist interviews it was established that a majority preferred the unlighted, fully reflectorized signs with encapsulated-lens sheeting when they were compared with unlighted nonreflective or enclosed-lens-grade signs. However, their survey data revealed that 67 percent of the car drivers and 61 percent of the truck drivers interviewed preferred the illuminated nonreflective sign compared with the nonilluminated, fully reflectorized sign with encapsulated-lens sheeting.

PennDOT's economic analysis revealed that substantial savings could be realized by not illuminating the signs. It concluded that signs with the reflective backgrounds and legends used in the study could fully provide an acceptable level of service when not illuminated on freeway-type highways with a tangent section of a minimum of 1200 ft in length. (As an update, a PennDOT official was contacted to determine the agency's current policy regarding illumination. It has adopted the report recommendation and is illuminating new overhead guide signs only if there is less than 1200-ft visibility. It has been using Type III-A encapsulated-lens sheeting for both legend and background but is also experimenting with Type II-A-grade sheeting for the background. Type II-A material is believed to last as long as Type III-A, is less expensive, and provides a better contrast.)

One of several Texas studies on freeway guide signing found that there were no significant differences in legibility distances

whether the freeway signs were lighted or unlighted, stick-on copy or button copy, or opaque or reflective background. The study, considered preliminary, involved field evaluation of legibility distance using 37 test subjects (*29*).

Similar results were found in a sequel study conducted by McNees and Jones (*23, 34*). Sixteen overhead and ground-mount signs, with opaque and all types of retro-reflective sheeting material used for backgrounds in combination with button-removable and Type III-A reflective legend, were tested on two freeways. The measure of effectiveness was legibility distance as determined by subject drivers. As in the earlier study (*29*), no significant difference in legibility distance was found between lighted and unlighted signs of similar sign material. With regard to overhead guide sign illumination, McNees and Jones recommended that sign lights should be used where there is limited sight distance (less than 1100 ft) and horizontal curvature greater than 4°. Sign lights should also be used at major freeway splits where the total distance from the first guide sign to the existing ramp is less than 2000 ft and where signs are located in areas of high visual clutter.

In a 1988 report by Jones and McNees (*14*) for the TSDH&PT, the results of an eight-state questionnaire/telephone survey were as follows:

- Most state traffic engineers prefer and use Type III-A intensity sheeting when the signs are not lighted, but claim that their "lights out" policy does not consider sign material.
- Most states allow lights to be turned off provided the following conditions exist: (a) Critical sight distance is greater than 1200 ft, (b) horizontal curvature is greater than an 800-ft radius, or (c) sign does not contain any action message.
- Traffic engineers felt it was necessary to see the green background. Different states used different techniques to assure the visibility of the green background.

The most recent investigation of the visibility of illuminated versus nonilluminated overhead signs was that conducted by Stein et al. in 1988 (*31, 32*). Using laboratory studies involving static 35 mm slide presentations and an interactive driving simulator, the researchers found no statistical differences in the tested driver measures that would indicate illumination is required. They did show that green signs provide greater detection distances than black or gray signs and that, as signs become brighter, detection distances increase. However, the studies were conducted in a laboratory setting and have not been correlated to actual traffic conditions.

Hajjiri and Michalopoulos (*33*) conducted an extensive review of the literature as well as sending a questionnaire to 54 state and local agencies to define the most effective sign treatment (reflectorization and illumination) to be used for overhead guide signs for Minnesota. Based on the results of the survey and the findings of previous studies, they concluded that:

- Illuminated overhead guide signs with reflective backgrounds provide the maximum possible legibility and visibility compared with other sign treatments.
- Nonilluminated overhead guide signs with reflectorized legend only do not have adequate legibility and visibility.
- Nonilluminated overhead guide signs do not require letter heights to be increased.
- Any combination of retro-reflective materials will provide satisfactory legibility contrast ratios between legend and background.
- Nonilluminated reflective overhead guide signs that are susceptible to high-beam headlights or stream traffic lighting and that have a straight approach equal to or greater than the visibility recognition distance, have adequate luminance to provide the motorists proper service.
- The following conditions require external illumination of overhead guide signs: (a) heavy fog, (b) heavy dew, (c) heavy rain and snow, and (d) high ambient lighting conditions.

At least two agencies have examined alternative illumination systems for use when sign lighting is required. They are reported below.

As part of an extensive research program dealing with overhead sign materials, the TSDH&PT evaluated mercury vapor lighting fixtures (as a replacement for fluorescent lighting) and the need for sign illumination with different sign materials. In its 1979 evaluation (*28*) it concluded that based on the subjective evaluation of a committee, 100-watt mercury vapor units produced sufficient illumination for good target value, satisfactory uniformity, and good legibility. Legend washout was found to be a problem with most 250-watt mercury vapor units.

The committee also preferred a clear lamp to a color-corrected lamp for providing better color rendition and legibility. Sign materials studied included enamel background with button copy and combinations of engineering and high-intensity sheeting.

One of the most recent evaluations of alternative lighting systems was conducted by Upchurch and Bordin for the Arizona Department of Transportation in 1986 (*35*). Ten lighting systems incorporating five different light sources—fluorescent, mercury vapor, metal halide, high-pressure sodium, and low-pressure sodium—were field tested for 10 to 14 months. The comprehensive analysis consisted of luminance measurements; power consumption monitoring; lamp life and maintenance determination; legibility distance measurements; ratings of viewing comfort, lighting uniformity, and color rendition; and an economic analysis of initial and annual costs. The authors recommended the lighting system using a high-pressure sodium light source. Compared with the fluorescent system then in use in Arizona, it was found to use one-third as much electric power and have one-third of the annual owning and maintenance cost. Furthermore, it provided the best legibility distance of the systems tested.

CHAPTER EIGHT

SUMMARY AND CONCLUSIONS

The purpose of this synthesis was to identify how states are addressing a common need—refurbishing or replacing their outdated and deteriorated guide signs for freeways and expressways—and to identify results of research that would aid in this process. Based on information gleaned from the literature and interviews and discussions with selected state highway officials, the following points have evolved:

- All states have some semblance of a program for identifying and programming guide sign replacement projects. The level of their formality and sophistication varies, however. Some states wait until the roadway is being rehabilitated, whereas others continually inspect for deficient signs, rate their deficiency, and rank them for improvement priority.
- A majority of the states do not have a comprehensive sign inventory program that includes the freeway guide signs. Thus far, the initial effort and expense involved in logging all the signs and the continuing maintenance of the data file have been obstacles for having such a sign inventory. However, recent advancements in the technology for collecting the data, such as video-disc systems, and in micro- and minicomputer hardware and software systems are likely to encourage states to implement integrated sign inventories.
- Formal inspections of freeway guide signs should occur at regular intervals based on agency experiences. An inspection should be done during both night and day and include the physical condition of the sign and the support system.
- Inspection of signs can be accomplished using a human-observation technique. However, observers should be trained to relate their visual observation to luminance levels established by retro-reflectometers. The new mobile system should be available for making accurate and relatively quick and inexpensive measurement of the retro-reflectivity condition of signs.
- There is no consensus among the states as to which materials are preferred for either the sign background or legend. For the background, all three types (FP-85 types II, II-A, and III) of retro-reflective sheetings are being used. Porcelain enamel nonreflective backgrounds are still being used with lighted signs, although less frequently. For the legends, either Type III-A or reflective buttons are being used by a majority of the states, with a preference for Type III-A sheeting, especially if dew is a common situation.
- Most guide sign substrate material is either extruded or sheet aluminum. States using either cite favorable economics as the reason, although extruded aluminum appears to provide a more durable substrate and is less subject to bending. Plywood is still used satisfactorily by a few states. Fiberglass-reinforced plastics are still mostly experimental, but with further development should become a feasible alternative substrate.
- A fully deteriorated sign panel can either be replaced or refurbished using a sheet overlay procedure. There is a difference of opinion as to the effectiveness of the overlay technique, however. The comparative cost of overlay versus total replacement is an area for further research.
- Recent research findings on the needs of the elderly indicate that sign letter size on guide signs should be based on 20/40 visual acuity, a revision that may necessitate larger letter sizes. This area requires further research.
- Illuminated overhead guide signs have longer detection and legibility distances than do fully reflectorized signs without illumination. However, several states are eliminating illumination, especially when using high-performance retro-reflective sheeting for both the background and legend. The elimination of illumination should be based on an engineering evaluation and should not occur if any of the following conditions exist: (a) the visibility distance is less than 1200 ft, (b) horizontal curvature is less than 800 ft, (c) the sign contains an action message such as EXIT ONLY, or (d) the sign is not fully reflectorized.

Before any sign is refurbished or replaced, its legend should be reevaluated for appropriateness, clarity, and conformance with MUTCD requirements.

REFERENCES

1. Taylor, J.I. and H.W. McGee, *NCHRP Report 145: Improving Traffic Operations and Safety at Exit Gore Areas,* Highway Research Board, National Research Council, Washington, D.C. (1973) 120 pp.
2. Transportation Research Board, *Special Report 218: Transportation in an Aging Society: Improving Mobility and Safety for Older Persons,* Vol. 1, Committee Report and Recommendations, Transportation Research Board, National Research Council, Washington D.C. (1988) 125 pp.
3. Sivak, M., P.L. Olson, and L.A. Pastalan, "Effect of Driver's Age on Nighttime Legibility of Highway Signs," *Human Factors,* Vol. 23, No. 1 (1981) pp. 59–64.
4. Olson, P.L. "Minimum Requirements for Adequate Nighttime Conspicuity of Highway Signs," Report No. UMTRI-88-8, The University of Michigan Transportation Research Institute, Ann Arbor, Mich. (1988).
5. "Workshop on Field Inspection and Rehabilitation of Traffic Control Devices, Proceedings," Report No. FHWA-TS-90-048, Federal Highway Administration, Washington, D.C. (June 1990).
6. Cunard, R.A., *NCHRP Synthesis of Highway Practice 157: Maintenance Management of Street and Highway Signs,* Transportation Research Board, National Research Council, Washington, D.C. (September 1990) 134 pp.
7. McGee, H.W. and D.L. Mace, "Retroreflectivity of Roadway Signs for Adequate Visibility: A Guide," Report No. FHWA/DF-88/001, Federal Highway Administration, Washington, D.C. (November 1987).
8. *Highway Design and Operational Practices Related to Highway Safety,* 2nd ed., American Association of State Highway and Transportation Officials, Washington, D.C. (1974).
9. Lagergren, E.A., "Traffic Sign Retroreflectivity Measurements Using Human Observers," Report No. WA-RD 140.1, Washington State Department of Transportation, Olympia, Wash. (December 1987).
10. *Manual on Uniform Traffic Control Devices,* Federal Highway Administration, Washington, D.C. (1978).
11. U.S. Department of Transportation, Federal Highway Administration, "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects," (FP-85) U.S. Department of Transportation, Federal Highway Administration, Washington, D.C. (1985).
12. Harmelink, M.D., G. Hemsley, D. Duncan, R.W. Kuhk, and T. Titishov, "Evaluation of Reflectorized Sign Sheeting for Nonilluminated Freeway Overhead Guide Signs," in *Transportation Research Record 1010: Traffic Control Devices and Rail Highway Crossings,* Transportation Research Board, National Research Council, Washington, D.C. (1985) pp. 80–84.
13. "Reflective Sheeting Study," Bellomo-McGee, Inc., Vienna, Va. (January 1988).
14. Jones, H.D. and R.W. McNees, "Functionality of Guide Signs," Research Report No. 277-2F covering Target Value Study, Sign Lighting Guidelines and Executive Summary, Texas State Department of Highways and Public Transportation, Austin, Tex. (August 1988).
15. George, L.E., "Oregon's Sign Refinishing Project," *ITE Journal* (September 1987) pp. 45–46.
16. Roth, J.M., "Report on the Use of Fiberglass Reiforced Plastic as an Alternative to Aluminum in the Manufacture of Flat Sheet Highway Signs and Overlay Panels for Extrusheet Signs," Ohio Department of Transportation, Bureau of Traffic, Traffic Maintenance Section (June 30, 1988).
17. Bryan, N., Jr., D. Casner, R. Klotz, and H. Knisley, "A Limited Evaluation of Reflective and Non-Reflective Background for Overhead Signs," Research Project 75-19, Pennsylvania Department of Transportation, Harrisburg, Pa. (September 1978).
18. O'Connor, L.J. and E.D. McNaught, "Service Life of Button Sign Copy," Report NYSDOT-ERD-77-RR43, New York State Department of Transportation, Albany, N.Y. (April 1977).
19. "An Evaluation of Reflective Traffic Signs," Idaho Transportation Department, Division of Highways, Traffic Section (April 1977).
20. deVries-deMol, E.C. and P.C. Walraven, eds., *Roadsigns,* Publication CIE No. 74, International Commission on Illumination (1988).
21. Allen, T.M., "Night Legibility Distances of Highway Signs," in *Highway Research Board Bulletin No. 191: Night Visibility 1958,* Transportation Research Board, National Research Council, Washington, D.C. (1958) pp. 33–40.
22. Gordon, D.A., "Night Visibility of Overhead Guide Signs: A Review of the Literature," Report No. FHWA/RD-84/087, Federal Highway Administration, Washington, D.C. (October 1984).
23. McNees, R.W. and H.D. Jones, "Legibility of Freeway Guide Signs as Determined by Sign Materials," in *Transportation Research Record 1149: Visibility for Highway Guidance and Hazard Detection,* Transportation Research Board, National Research Council, Washington, D.C. (1987) pp. 22–31.
24. Sivak, M. and P.L. Olson, "Optimal and Minimal Luminance Characteristics for Retroreflective Highway Signs," in *Transportation Research Record 1027: Driver Information Needs and Visibility of Traffic Control Devices,* Transportation Research Board, National Research Council, Washington, D.C. (1985) pp. 53–57.
25. Mace, D.J., "Sign Legibility and Conspicuity," in *Special Report 218: Transportation in an Aging Society,* Vol. 2, Transportation Research Board, National Research Council, Washington, D.C. (1988) pp. 270–293.
26. Shepard, F.D., "Review of Sign Overlay Procedures in Virginia," in *Transportation Research Record 1019: Winter and Transit Bus Maintenance and Highway Maintenance Management,* Transportation Research Board, National Research Council, Washington, D.C. (1985) pp. 40–49. Full report under same title and author published as Report No. VHTRC 84-R27 by Virginia Highway and Transportation Research Council, Charlottesville, Va. (February 1984).

27. "A Review of Sign Refurbishing Methods in Region 5," Federal Highway Administration, Region 5, Office of Traffic Operations (March 1, 1983).
28. Jones, H.D. and J.G. Raska, "Evaluation of Overhead Sign Background Materials and Mercury Vapor Sign Lights," Research Report No. 222-1, Texas State Department of Highways and Public Transportation, Austin, Tex. (February 1979).
29. Jones, H.D., J.G. Raska, and R.W. McNees, "Evaluation of Overhead Sign Background Materials and Mercury Vapor Sign Lights," Research Report 222-2F, Texas State Department of Highways and Public Transportation, Austin, Tex. (August 1983).
30. "Value Engineering Study of Sign Maintenance," Report No. FHWA-TS-78-223, Federal Highway Administration, Office of Research and Development, Implementation Division, Washington, D.C. (1978).
31. Stein, A.C., Z. Parseghian, R.W. Allen, and C.E. Wolf, "Overhead Guide Sign Visibility Factors—Vol. I," Report No. FHWA/RD-88-196, Federal Highway Administration, Washington D.C. (February 1989).
32. Stein, A.C., Z. Parseghian, R.W. Allen, and C.E. Wolf, "Overhead Guide Sign Visibility Factors, Vol. II: Appendixes," Report No. FHWA-RD-88-197, Federal Highway Administration, Washington D.C. (May 1989).
33. Hajjiri, S.A. and P.G. Michalopoulos, "Review of Current Practices for Illumination and Reflectorization of Overhead Signs," Report No. MN/RC-87/02, Minnesota Department of Transportation, St. Paul, Minn. (June 30, 1987).
34. Jones, H.D. and R.W. McNees, "Functionality of Guide Signs," Research Report No. 277-1 covering Lighting of Guide Signs—Legibility Study, Texas State Department of Highways and Public Transportation, Austin, Tex. (October 1987).
35. Upchurch, J.E. and J.T. Bordin, "Evaluation of Alternative Lighting Systems for Guide Sign Illumination," Report No. FHWA/AZ 86/200, College of Engineering and Applied Sciences, Arizona State University, Tempe, Ariz. (April 1986). See also Upchurch, J.E. and J.T. Bordin, "Evaluation of Alternative Sign-Lighting Systems To Reduce Operating and Maintenance Costs," in *Transportation Research Record 1111: Traffic Accident Analysis, Visibility Factors, and Motorist Information Needs,* Transportation Research Board, National Research Council, Washington, D.C. (1987) pp. 79–91.
36. Simkowitz, H.J., "GIS: Technology for Transportation," *Civil Engineering* (June 1989) pp. 72–75.

APPENDIX A
QUESTIONNAIRE DATA FROM SURVEY FOR VIRGINIA TRANSPORTATION RESEARCH COUNCIL

1. How are your guide signs refurbished? (45 states reporting)
   A. They are replaced 13%
   B. Overlay panels are attached in the field 51%
   C. Other method of overlaying; 3M System-5 or other commercial overlay 2%
   D. Comments: 47% are experimenting with System-5

2. How is sign overlaid? (45 states)
   A. In place on posts 58%
   B. Lowered to ground 16%
   C. Taken to shop 7%
   D. Other 19%
      contractor option 4%
      combination A & B 7%
      combination A & C 2%
      combination B & C 2%
      combination A, B, & C 4%

3. How is overlay panel attached to original sign? (37 states)
   A. Rivets 87%
      Size: 1/8" 48%
      3/16" 39%
      1/4" 9%
      5/16" 4%
      Spacing: 6" to 8" 18%
      6" to 12" 9%
      8" to 10" 4%
      12" 9%
      18" 17%
      24" 4%
      Variable 9%
   B. Rivet plus adhesive 5%
   C. Other methods 8%

4. What type of material is used for overlay panels? (42 states)
   A. Aluminum 94% (includes System-5)
   B. Wood 2%
   C. Other 2%
   Aluminum or wood 2%

5. What type of reflective sheeting is used on overlay panels? (45 states)
   A. Encapsulated lens 51%
   B. Engineering grade 24%
   C. Encapsulated lens or engineering grade 17%
   D. Other 8%
      Prismatic button copy 25%
      Encapsulated copy and engineering-grade background 50%
      Opaque porcelain enamel 25%

6. What is the thickness of the overlay panel on:
   A. Small signs (2' to 4' wide) (28 states)
      .032 4%
      .040 36%
      .050 5%
      .060 to .063 42%
      .080 13%
   B. Medium (4' to 8' wide) (34 states)
      .040 29%
      .050 6%
      .060 to .063 47%
      .080 18%
   C. Large (8' + wide) (33 states)
      .040 30%
      .050 3%
      .063 46%
      .080 21%
   D. States using same thickness for all sign sizes: 22 states
   E. States using different thickness for different size signs: 3 states

7. What is the width of the overlay panel (40 states)
   A. 2 ft 8%
   B. 3 ft 8%
   C. 4 ft 74%
   D. Different widths 10%

8. What method do you use to join panels? (43 states)
   A. Butt joint 77%
   B. Overlap 14%
   C. Butt and overlap 9%

9. What type of letters do you use? (44 states)
   A. Demountable 30%
   B. Direct applied 43%
   C. Demountable or direct applied 23%
   D. Button 4%

10. Where are letters laid out? (39 states)
    A. In shop 59%
    B. In field 21%
    C. Shop and/or field 18%
    D. Other (prison) 2%

11. If laid out in the field do you: (27 states)
    A. Drill through existing holes from rear of sign? 19%
    B. Measure from drawing? 33%
    C. Measure from original sign? 22%
    D. Measure from drawing or original sign? 15%
    E. Other 11%

12. What problems do you find are related to work methods and handling of overlay installation? (45 states)
    A. Care in handling, damage in transport, etc. 13%
    B. Traffic control and safety, equipment in field, height of sign, etc. 13%
    C. Wind blowing panels while erecting 7%
    D. Waviness and wrinkling of signs 4%
    E. Assuring squareness, sizing, etc. 4%
    F. No problem and no problem with proper precaution 59%

13. What problems do you find with the final appearance of the overlay (34 states)
    A. Legibility 9%
    B. Durability 3%
    C. Hot spots 29%
    D. None 53%
    E. Other 6%

Overlay Fabrication

		Hot Spots	No Problem
Overlay thickness	0.032	1*	0*
	0.040	5	6
	0.050	0	1
	0.060-.063	4	8
	0.080	0	6
Rivet size	1/8 in.	4	6
	3/16 in.	2	4
	1/4 in.	0	2
	5/16 in.	0	1
Rivet spacing	6 to 8 in.	1	3
	6 to 12 in.	1	1
	8 to 10 in.	0	1
	12 in.	1	7
	18 in.	3	2

*Numbers state using

APPENDIX B
RESULTS OF SURVEY ON ILLUMINATION AND REFLECTORIZATION OF OVERHEAD GUIDE SIGNS FOR MINNESOTA DOT

In order to make recommendations to the Minnesota DOT, in addition to the literature, 54 states/agencies were queried to provide information on overhead guide signs. Forty-five were received and analyzed. The answers provided and their interpretation are presented along with the questions in this section as follows:

1. Do you illuminate overhead guide signs that have reflectorized high-intensity (HI) backgrounds?
   Yes 17 No 19
   Responses to this question are distributed almost equally. Thus, a decision cannot be made.

2. Do you illuminate signs with HI legend only?
   Yes 15 No 19
   Same argument as above.

3. If signs are illuminated, does your state use:
   Fully reflectorized signs with
   HI background 26
   Engineering-grade (EG) background 10
   Reflectorized legend only with:
   HI legend 10
   Button copy 9
   The total responses exceed the number of agencies that responded to this particular question. This is because some states use more than one signing material.

   It can be seen that the usage of fully reflectorized signs when sign illumination is eliminated is high compared with the usage of signs with reflectorized legend only. Furthermore, high-intensity sheeting is more widely used than other reflectorized materials.

4. What priority does your state assign to providing reflectorized background?
   Low 7 Medium 1 High 37
   This shows that provision of reflectorized background is given high priority by the states.

5. Based on your experience, what critical messages require sign illumination?
   Agencies' opinions regarding critical messages that require sign illumination are itemized in the following table:

Critical Messages that Require Sign Illumination	Number of Agencies
All overhead signs	15
Action signs (e.g., gore EXIT lane drops, draw bridges, tunnels)	10
All signs in urban areas at major intersections and where high ambient lighting exists	2
All major destinations	1
Expressway overhead guide signs	1
Any requiring down arrow for lane designation (2D-8, MUTCD)	1
Full through signs if arrow required (optimal lane splits such as Fig. 2-29, MUTCD)	1
None	9

In this case, the views of the agencies concerning critical messages that require sign illuminated are biased by their signing policies.

6. Based on your experience, what are the conditions that require sign background to be reflectorized as well as illuminated?
   Agencies' opinions regarding the conditions that require sign background to be reflectorized as well as illuminated are shown in the following table:

Conditions that Require Sign Background to Be Reflectorized as Well as Illuminated	Number of Agencies
All overhead guide signs	11
All major intersections	1
Possibly when power fails	1
If weather is a major source of power failure, then all overhead guide signs are illuminated	1
Safety, maintenance of sign is hard then sign background is reflectorized	2
Sign is inadequately visible, highway lighting is in place	1
Background lighting obscures the legend of the sign	1
All overhead guide signs require HI plus illumination when a tangent sight distance of 1200 ft does not exist	1
Urban overhead guide signs with ambient source	2
Most overhead locations on controlled-access highway generally require reflectorized legend on opaque background	1
If sign is illuminated, sign background can be either reflectorized or nonreflectorized	4
If EG is used, signs are illuminated in areas prone to heavy fog	1
When roadway alignment does not allow vehicle headlights to illuminate sign	1
None	11

7. Based on your experience, the visibility and legibility of signs with button copy on opaque background under frost and dew formation is rated as:
   Poor 8 Good 15 Excellent 5
   The total number of responses is insufficient to arrive at a concrete conclusion concerning the performance of signs with button copy on opaque background under frost and dew formation.

8. Based on your experience, the visibility and legibility of signs with HI on opaque background under frost and dew formation is rated as:
   Poor 16 Good 8 Excellent 2
   The total number of responses is insufficient to arrive at a concrete conclusion concerning the performance of signs with HI legend on opaque background under frost and dew formation.

9. Based on your experience, does the roadway lighting have a detrimental effect on sign visibility and legibility?
   With sign illumination? Yes 2 No 40
   Without sign illumination? Yes 12 No 31
   If yes, please explain what detrimental effect and how you have solved it.
   The majority of the states concurred that roadway lighting has no detrimental effect on sign visibility and legibility irrespective of sign illumination. It is of interest to study the problems that the rest of the states have experienced and how they have solved them. The experienced problems and the solutions proposed by those states are as follows:

   Glare
   Paint portions of the glass refractor.
   Position luminaries at least 50 ft away from overhead signs.
   Illuminate the sign with the same type of lighting used on the roadway.

   Shadow
   Do not install street lighting units directly behind overhead guide signs.

   Reduction in contrast
   Illuminate the sign.

   Reduction in target value
   Illuminate the sign.

   Darkening of sign face
   High-pressure sodium (HPS) lighting tends to darken the sign face. As a solution, illuminate the sign.

   The California Department of Transportation replied that roadway lighting is not a problem, whereas heavy background lighting, such as downhill approach to an interchange with a major shopping center, can be detrimental to either illuminated or nonilluminated overhead signs.

10. If sign illumination is eliminated, does it require letter heights to be increased? If yes, specify change.
    Yes 0 No 39

Based on the responses, it can be concluded that is sign illumination is eliminated, it does not require letter heights to be increased.

11. Do you require illumination of overhead sign:
    a. Always? Yes 21 No 23
    b. In addition to roadway lighting at sign? Yes 20 No 16
    c. In addition to ambient lighting near sign? Yes 20 No 16
    d. On horizontal curves with particular radii of curvature? Yes 14 No 19
    e. On vertical curves with particular stopping distance or headlight sight distance? Yes 11 No 22
    f. Under some local weather conditions? Yes 9 No 21

In order to interpret the responses to these questions, it would be more useful to look at the response of states that always require illumination separately from the states that do not.

Responses of states that always require illumination:
    b. In addition to roadway lighting at sign Yes 13 No 1
    c. In addition to ambient lighting near sign Yes 13 No 1
    d. On horizontal curves with particular radii of curvature Yes 9 No 1
    e. On vertical curves with particular stopping sight distance or headlight sight distance Yes 8 No 2
    f. Under some local weather conditions Yes 8 No 2

Under the umbrella of the responses, it can be seen that the conditions listed above dictate illumination of overhead signs.

Responses of states that do not require illumination:
    b. In addition to roadway lighting at sign Yes 7 No 15
    c. In addition to ambient lighting near sign Yes 7 No 15
    d. On horizontal curves with particular radii of curvature Yes 5 No 18
    e. On vertical curves with particular stopping sight distance or headlight sight distance Yes 3 No 20
    f. Under some local weather conditions Yes 1 No 19

In this case, these states do not require illumination either because it is their state policy not to illuminate signs or for other reasons beyond the scope of this questionnaire.

12. Based on your experience, is the visibility and legibility of signs erected on straight segments of unlighted roadway sufficient to provide motorists proper service if:
    a. Sign is *not* illuminated but fully reflectorized? Yes 35 No 4
    b. Sign is *illuminated* and fully reflectorized? Yes 38 No 2
    c. Sign is *not* illuminated but has reflectorized legend only? Yes 10 No 19
    d. Sign is *illuminated* with reflectorized legend only? Yes 27 No 5

Based on the responses, the listed sign treatment can be arranged for this particular condition of roadway lighting in the following descending order:

1. *Sign is illuminated and fully reflectorized.*
2. *Sign is illuminated with reflectorized legend only.*
3. *Sign is not illuminated but is fully reflectorized.*
4. *Sign is not illuminated but has reflectorized legend only.*

14. In your opinion which is most important for guide signs:
    a. Target value
    b. Legibility
    c. Conspicuity

As defined below:

Target value:	Attention-getting value of the sign (i.e., you are aware of the presence or existence of something).
Legibility:	Ease of reading the words and shapes of the messages.
Conspicuity:	Quality that makes it obvious that the object is a sign (i.e., you can read and understand the message conveyed).

The responses to this question are shown in the following table:

	Number of Responses			
	Rank 1	Rank 2	Rank 3	Overall Rank
Target Value	10	11	19	3
Legibility	26	9	6	1
Conspicuity	9	19	15	2

Based on the responses, legibility is more important than conspicuity or target value for overhead guide signs.

15. Are you considering any changes in your signing OH practice (i.e., lighting, reflectorizing)? If so, what are you considering?
The majority of states are not considering any changes in their signing OH practice.

In summary, the following conclusions can be drawn from the study conducted through the questionnaire:

1. *On straight segments of lighted/unlighted roadway, illuminated and fully reflectorized overhead guide signs, compared with other sign treatments, provide the best service for motorists in terms of visibility and legibility.*
2. *On straight segments of lighted/unlighted roadway, signs that are not illuminated and only have a reflectorized legend do not provide the motorist acceptable visibility and legibility.*
3. *Irrespective of sign illumination, roadway lighting has no detrimental effect on sign visibility and legibility.*
4. *If sign illumination is eliminated, letter heights need not be increased.*
5. *Legibility is more important than conspicuity or target value.*

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