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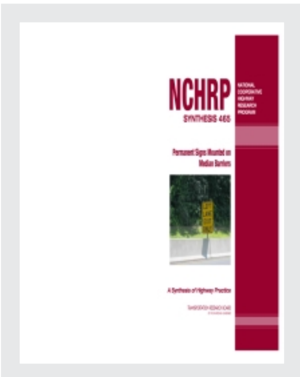

Permanent Signs Mounted on Median Barriers

DETAILS

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NCHRP SYNTHESIS 465

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Permanent Signs Mounted on Median Barriers

A Synthesis of Highway Practice

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Permanent Signs Mounted on Median Barriers

A Synthesis of Highway Practice

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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 communication 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.

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Cover figure: Permanent small sign support mounted on top of rigid median barrier.
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FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Tanya M. Zwahlen
Consultant
Transportation
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This report compiles and documents information regarding the current state of practice for mounting permanent signs on top of rigid median barriers throughout the United States. A primary objective of this research is to assess the extent to which barrier-mounted signs are used and the level of consideration some practices give to potential safety concerns. This report will be immediately useful to highway design practitioners.

Information used in this study was acquired through a review of the literature of state department of transportation standard plans specifications, as well as a review of national design policies, specifications, and guidelines. Information was also gathered through a survey of representatives in all states and select toll road authorities with potentially significant numbers of median-barrier-mounted signs.

Eric C. Lohrey, of ECL Engineering PLLC, Warrensburg, New York, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable with the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

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PERMANENT SIGNS MOUNTED ON MEDIAN BARRIERS

SUMMARY

The synthesis study was conducted to identify and report on the current state of practice for mounting permanent highway signs on top of rigid median barriers throughout the United States. Information related to design standards, guidelines, individual agency practices, and research was gathered and evaluated to assess the extent to which barrier-mounted signs are used and the level of consideration some practices give to potential safety concerns. The concept of a zone of intrusion (ZOI) is used to describe an area above and behind the face of a rigid barrier system where a substantial part of a vehicle can pass through during an impact event. If an object such as a sign support is attached to the barrier within the ZOI, it is likely to reduce the performance of the barrier during an impact.

National guidelines address some issues related to barrier-mounted sign supports. The AASHTO *Roadside Design Guide* is the primary national resource that directly addresses the barrier ZOI and identifies some options for reducing exposure of objects located in the zone, including moving the sign support to a location outside the ZOI or modifying the barrier configuration to reduce exposure of the sign support within the ZOI. However, there is limited guidance on how well specific rigid barriers accommodate attached sign supports and limited criteria for placing signs within the ZOI. Some of the data required to establish such guidelines are not available; thus, many barrier-mounted sign details are designed independently by individual agencies, with varying degrees of consideration for impact safety.

Forty-six state departments of transportation and five prominent toll road authorities submitted responses to a questionnaire distributed as part of the synthesis study. Results of the survey show that tens of thousands of barrier-mounted sign supports are currently installed in the United States and that transportation agencies use a wide variety of mounting details. Many of these signs are located within the barrier ZOI and could present a safety concern if a vehicle crashes into the host barrier in the vicinity of the sign support. This study identifies practices used throughout the nation for mounting sign supports on median barriers and methods used to reduce ZOI exposure. For large overhead sign supports, results show that lateral widening of the barrier cross-section in the vicinity of the supports is the most common technique for reducing ZOI exposure. For small sign supports, relocating or otherwise eliminating the need for a barrier-mounted sign support was reported as the most common technique for addressing ZOI concerns. Transportation agencies can use this review of existing practices to compare their practices with those of others and determine whether they need to revise their standards and policies to improve the overall safety of their divided highway networks.

Transportation agencies may benefit from research that aims to define ZOI characteristics for common barrier designs to identify which sign-mounting practices perform best. Performance evaluations can provide information on the safety issues associated with existing installations and the effectiveness of available treatments to mitigate ZOI exposure. In addition, new techniques for improving impact performance of sign/barrier com-

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binations need to be evaluated to ensure that sign functionality and driver expectancy are not compromised. Results of these research efforts can help transportation agencies evaluate their current practices and provide a basis for making improvements.

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CHAPTER ONE

INTRODUCTION

BACKGROUND

Median barriers are longitudinal barriers used to separate opposing traffic lanes on divided or limited-access highways. They are designed to contain and redirect errant vehicles that strike them on either side, and their performance requirements are identical to those for roadside barriers (AASHTO 2011). The most effective method of assessing barrier performance is by evaluating results of standardized full-scale crash tests. During these tests, the barrier must satisfy a number of requirements related to structural adequacy, occupant risk, and vehicle trajectory (Ross 1993; AASHTO 2009a). Individual barrier designs are typically designated as rigid, semi-rigid, or flexible, depending on the amount of lateral deflection that occurs during impact tests. Semi-rigid and flexible barriers allow some level of lateral displacement as they redirect an impacting vehicle, whereas rigid barriers remain essentially static during and after a design impact event.

The type of median barrier used for a particular highway section depends primarily on the width of the median, although other factors—such as traffic volume and percentage of truck traffic—may also be considered. Rigid barriers are more applicable for narrow medians because they are designed to prevent or minimize any encroachment of the barrier or the vehicle into opposing traffic lanes for events up to a specified level of impact severity. Although rigid median barriers are more costly to install initially, they offer the benefit of reduced maintenance and repair costs, making them more desirable for locations with high traffic volume or impact frequency.

These factors have triggered an increase in the use of rigid median barriers throughout the United States. Many divided highways have been expanded with additional traffic lanes added in the median space, significantly reducing median widths and creating the need for installation of rigid median barriers between the new opposing travel lanes. In other cases, traffic volumes have increased to the point where new or upgraded median barriers are necessary, and rigid types are selected for their low-deflection performance, longevity, and maintenance benefits.

Highway signing is an integral component of safe and efficient roadway networks. Signs provide drivers with vital information to assist with regulatory compliance, warnings of potential hazards, and navigation guidance. Regardless of the messages they convey, the physical configuration of signs can be separated into two basic categories: (1) overhead signs, which are suspended over the roadway by a cantilever, span, or bridge support structure; and (2) roadside signs, which are attached to ground-mounted supports adjacent to roadways.

Both types require at least one support anchored to the ground or another fixed object. The size, weight, and configuration of a sign support are typically determined by structural analysis of the load it must bear. The geographic region and the size of the sign are usually the primary factors that dictate the service loads used to design the required support. For example, larger sign panels require larger and heavier supports. Likewise, signs located in regions that experience high wind speeds require more substantial supports than the same size panels located in regions that have lower wind speeds. AASHTO specifications typically govern the structural design of highway sign supports; however, some agencies supplement or supersede the national specifications to better reflect conditions in their jurisdiction (AASHTO 2009b).

Overhead signs are suspended over a roadway by mounting them on a grade-separation structure (highway bridge) or by constructing a sign span or cantilever support. Although mounting overhead signs on grade-separation structures is preferred, most overhead signs need to be placed where no suitable highway bridge is available. Currently in the United States, all overhead sign supports are treated as fixed objects and, therefore, must be located outside the roadside clear zone or shielded with an appropriate crashworthy barrier (FHWA 2009; AASHTO 2009b, 2011). Figure 1 shows several configurations of overhead sign supports that are typical for divided highways with rigid median barriers. The full span shown in Figure 1*a* is often preferred, since a median-barrier-mounted support is not required. However, a full-width span is not possible in many locations; in those cases, median-barrier-mounted sign supports are necessary, as shown in Figure 1 *b*, *c*, and *d*.

Roadside signs are typically located on the right-hand side of travel lanes, where they are more easily recognized and understood by road users (FHWA 2009). U.S. drivers expect to find signs and messages on the right-hand

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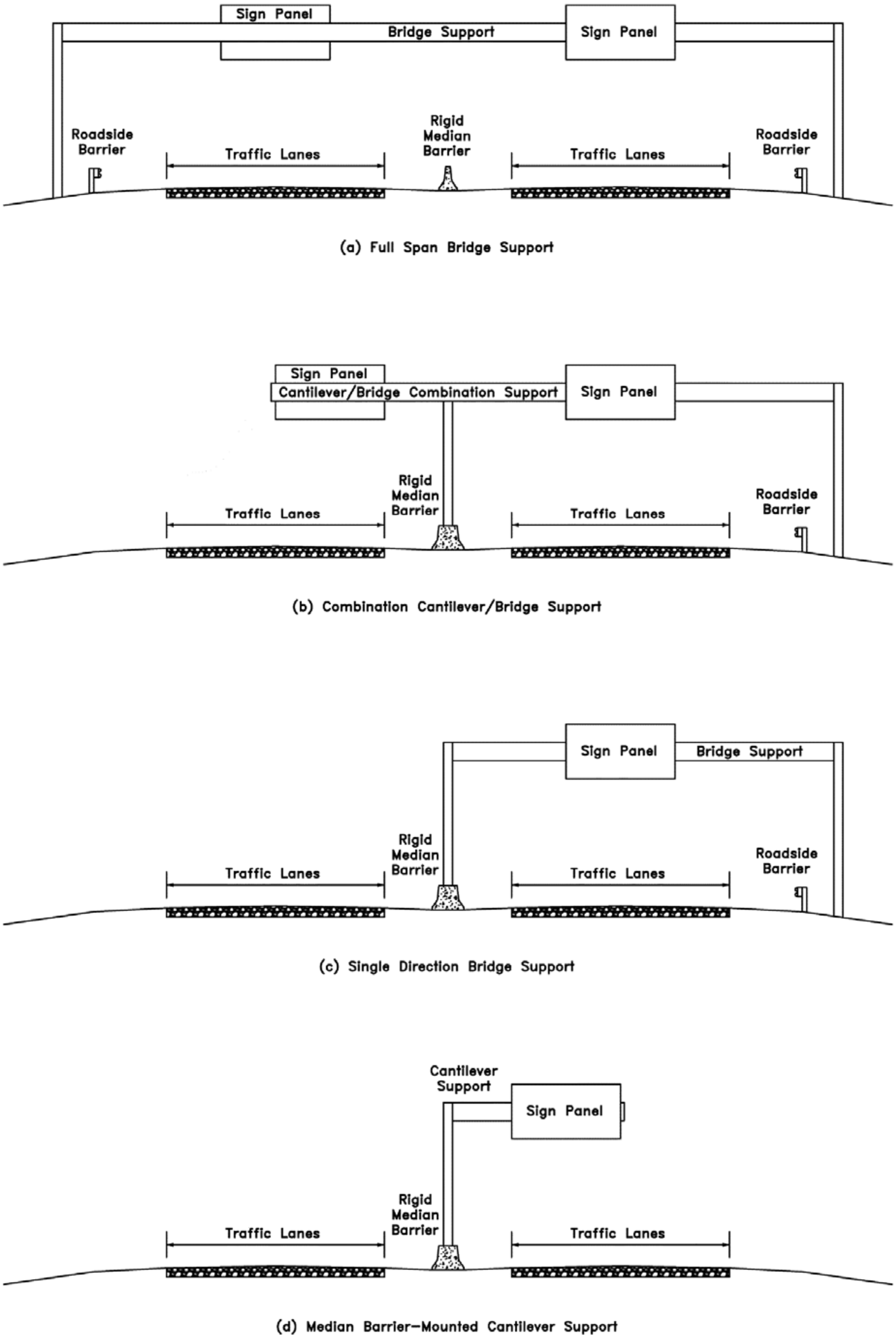

FIGURE 1 Typical overhead sign support configurations.

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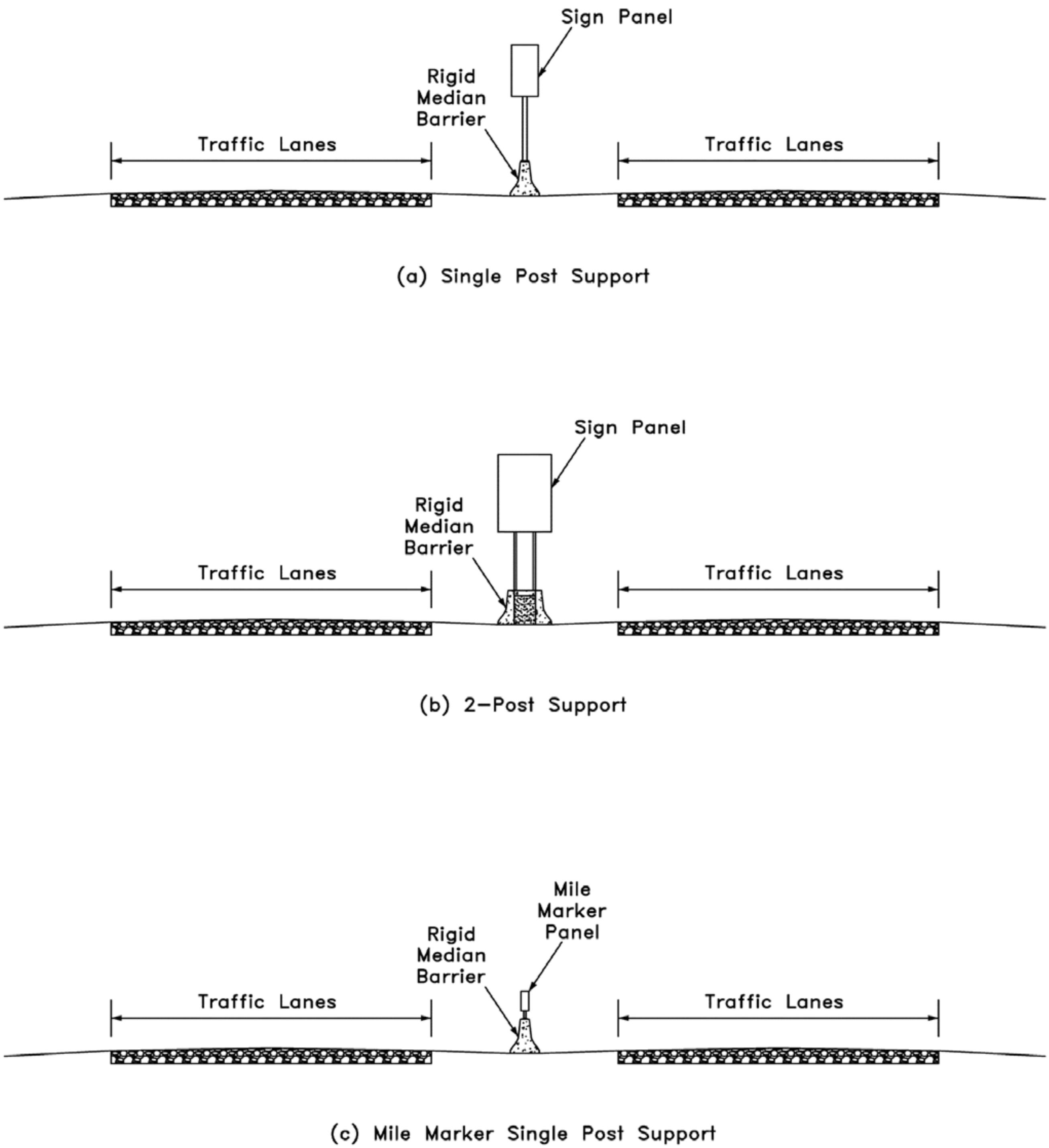

FIGURE 2 Typical small barrier-mounted sign supports.

side, as they travel on the right side of the road. However, in some circumstances it is necessary to place signs on the left-hand side. When this occurs on divided highway sections with rigid median barriers, supports for these signs often must be mounted on top of the barrier. Figure 2 shows several configurations for this type of sign installation. Most rigid barriers are relatively narrow, with room for only one or two closely spaced vertical supports. Because of this restriction, a majority of these signs are in the small sign category [panel area less than 50 ft^2 (5 m^2)] (AASHTO 2009b).

Mounting both overhead and small signs on top of rigid median barriers can enable transportation agencies to convey important messages to drivers when no other appropriate sign locations are available. The support bases are elevated above the pavement surface, which can provide benefits for maintenance operations such as street sweeping, mowing,

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and snow removal. Additionally, barrier-mounted supports may be less likely than ground-mounted roadside signs to be struck and damaged by errant vehicles, which reduces repair costs, particularly for nuisance hits.

Although these installations provide some benefits, there are safety issues associated with the widespread use of median-barrier-mounted signs, especially the potential for increasing the consequences of vehicle impacts into the barrier in the vicinity of a sign support. One concern is that a sign support can diminish barrier performance by creating a snag point that could inhibit the smooth redirection and stability of the vehicle as it is being captured or contained by the rigid barrier. Vehicle snagging during a barrier impact can increase the risk of injury to occupants. An additional safety consideration is that all or part of the barrier-mounted sign structure could become dislodged during an impact event, and these loose components could create a secondary hazard for other motorists. Narrow medians are particularly susceptible to this hazard because of the close proximity of high-speed travel lanes in opposite directions.

Barrier research and crash testing have identified potential problems with the safety performance of various barrier designs when objects, such as sign supports, are attached in the vicinity of the impact location (Keller 2003; Caldwell 2011). Many factors and design details of both the barrier system and the sign support affect crash performance of the median structure. Some sign/barrier combinations may perform satisfactorily during crash tests, whereas others may be unacceptable, based on standardized evaluation criteria. Although there has been some research and crash testing of specific combinations, limited guidance is available to highway designers, who often must specify safe and adequate systems for their projects.

We need to evaluate the state of current practice in order to assess and prioritize needs for improved guidance and research that will advance the quality of future practices. This synthesis study was conducted to address these needs through an information-gathering and -organizing process that presents the available information in a usable reference for future work.

SCOPE

The synthesis study focuses on critical topics within the wide range of issues and circumstances related to the subject matter. First, the study considers only *barrier-mounted sign use in the United States*. Information was gathered from state departments of transportation (DOTs) and select toll road authorities whose jurisdictions are entirely within the United States. Although information on practices in other countries is valuable, most of the applicable design and performance specifications and guidelines are issued by U.S.-based government authorities.

Second, the study considers only *permanent barriers and signs*. Design guidelines and specifications for highway features differ for permanent applications and temporary or work-zone applications. In general, permanent features are subject to more stringent standards and performance requirements because they are in service for substantially longer periods of time and, therefore, have greater exposure to traffic and environmental conditions. This study focuses on permanent barrier-mounted sign installations, which are considered to have a design life of 10 years or more.

Third, the study focuses on *rigid barriers used in median applications*. In permanent median applications, signs are mounted on or attached to vehicle barriers. Roadside barriers typically have clear space behind them that can be used for sign supports, so they do not usually need to be mounted directly on top of the barrier. Also, concern about flying debris during an impact is not as critical for roadside barriers, as there are no traffic lanes on the other side. Likewise, only rigid barriers are included in the study because they are used in narrow medians, where space limitations are likely to require that any signs be mounted directly on top of the barrier. The vast majority of rigid median barriers currently in use are constructed of reinforced concrete, and designs vary considerably with respect to width, height, and cross-sectional shape. These characteristics affect the barriers' impact response and level of performance.

Differences and similarities in design details and component properties among agencies are identified for both overhead and small signs mounted on top of or within rigid median barriers. The scope of the study does not include very small, self-supported panels, such as delineators, reflectors, or mile markers less than 0.5 ft^2 (0.05 m^2) in panel area that do not have a separate support or post component. These lightweight barrier attachments are not considered to be sign structures. On the other hand, barrier-mounted mile markers supported by a vertical post (as shown in Figure 2*c*) are included in the study.

To maintain its focus on the wide variety of applicable sign structures, the study does not include other barrier-mounted highway features, such as luminaire poles, electronic equipment poles, railings, fences, and screens. However, many issues addressed in this study apply to those structures as well, and similarities are identified where applicable.

STUDY APPROACH

The primary objectives of this synthesis study are to locate, assemble, and document available information pertaining to agency practices for use of permanent highway signs mounted on rigid median barriers. Information was gathered using the following methods:

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- Literature review of state DOT standard plans and specifications to identify current practices in use throughout the United States.
- Literature review of national design policies, specifications, and guidelines to assess their adequacy.
- Literature review of completed and ongoing research efforts directed at evaluating and solving known problems associated with median-barrier-mounted sign installations.
- Review and analysis of responses to a comprehensive survey questionnaire that was prepared and sent to all state DOTs and to select toll road authorities with potentially significant numbers of median-barrier-mounted signs.

The questionnaire was published electronically on a specialized website that provides survey services to NCHRP. Invitations to participate in the survey were sent to all voting members of the AASHTO Subcommittee on Design; respondents either personally prepared their agency's response or assigned it to be completed by appropriate personnel within their agency. The questions and responses are intended to estimate the extent of use of barrier-mounted signs throughout the United States, classify standard design details for common types of installations, and identify practices used to improve performance.

The information gathered from all these methods has been evaluated and organized as a reference for highway design practitioners. Chapter two provides a summary of pertinent design criteria that are currently available and in use. Chapter three summarizes the results of the survey questionnaire and identifies common practices among the agencies that participated. Chapter four describes testing and research that have been conducted to define zones of intrusion (ZOIs) and to evaluate impact performance of specific sign/barrier combinations. Chapter five offers conclusions regarding the state of practice and recommendations for research to improve existing resources. The report as a whole can be used by transportation agencies to promote successful practices, avoid known problems, and supplement their own design policies.

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CHAPTER TWO

SIGN AND BARRIER DESIGN CRITERIA AND GUIDELINES

Issues related to mounting signs on rigid median barriers are discussed, to varying degrees, in a number of pertinent national highway design specifications, policies, manuals, and guidelines. These documents provide a wealth of information to highway designers and other practitioners, and promote sound and consistent application of the latest technology throughout the national transportation infrastructure. In general, their contents have developed over many years and are revised on a regular basis in the form of supplements and new editions. This evolutionary process ensures that the latest editions incorporate recent research results and evaluations from users in the field.

On the national level, the use and placement of highway signs is addressed extensively in the following documents:

- FHWA *Manual of Uniform Traffic Control Devices* (MUTCD) (FHWA 2009)
- AASHTO *Roadside Design Guide* (RDG) (AASHTO 2011)
- AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* (LTS) (AASHTO 2009b).

These documents are valuable references for highway designers and provide a foundation for individual transportation agencies to develop policies that meet their needs. The following is a brief overview of the sections of the documents that relate to the use of permanent signs mounted on rigid median barriers.

SIGN USAGE AND PLACEMENT

The MUTCD is the national standard for all traffic control devices, including signs, installed on any roadway open to public travel in the United States (FHWA 2009). The 2009 edition sets minimum standards and provides guidance on practices intended to ensure uniformity across the nation. Part 2 addresses signs, which are classified by function; the primary categories are regulatory, warning, and guide signs. All three classes of signs may be mounted on either overhead or roadside supports.

Overhead signs are typically used on multilane divided highways where some degree of lane-use control is needed and in locations where adequate space is not available on the roadside. If a sign cannot be mounted on a grade-separation structure (bridge), a separate support structure, such as those shown in Figure 1, is required. The minimum height of an overhead sign panel is 17 ft (5.2 m), measured from the pavement surface to the bottom of the sign. The minimum lateral offset from the edge of the shoulder (or, if no shoulder exists, from the edge of the pavement) to the near edge of the vertical support is 6 ft (1.8 m) (FHWA 2009). Because breakaway or yielding supports are not applicable to overhead sign supports, they must be shielded with a longitudinal barrier (crash cushion) if they are located within the roadway clear zone (FHWA 2009; AASHTO 2009b, 2011).

Roadside signs should be located on the right-hand side of the roadway where they are easily recognized and understood by road users (FHWA 2009). However, standardization of sign position cannot always be attained in practice; in some circumstances, it is necessary to place signs on the left-hand side of a travel way. These circumstances include the following:

1. To enhance conspicuity by placing identical signs on both sides of the roadway.
2. On some curves to the right, where sign visibility on the left-hand side is significantly better than that the right-hand side.
3. On multilane roads, where traffic in a lane to the right might obstruct the driver's view to the right.
4. On left exit ramps.
5. At median openings.
6. At the beginning of divided highway sections.
7. For preferential and managed lanes; for example, high-occupancy vehicle (HOV) lanes.

When any of these circumstances occur on a divided highway section with a rigid median barrier, it is usually necessary to mount the sign on top of the barrier. In some cases, small signs can be mounted on an existing feature, such as a luminaire pole or an overhead sign support; how-

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ever, the availability of existing structures at desired placement locations is typically very limited (AASHTO 2011).

It is *not* recommended to place ground-mounted breakaway supports on each side of a median barrier, creating a two-post sign that straddles the barrier. This configuration inhibits the proper function of both the barrier and the breakaway support because of the unpredictable interaction of these systems when struck by a vehicle. In addition, components of the sign that are detached by an impact can impose a secondary hazard to traffic traveling on either side of the barrier.

It is also *not* recommended to install breakaway supports on top of median barriers. This issue is addressed on the FHWA Roadway Departure Safety website (FHWA 2013) as follows:

Q: Should we use breakaway bases for sign and light poles mounted on concrete median barriers?

A. No, breakaway bases should not be used. Mounting any pole on top of a median barrier should be avoided because trucks will lean over the barrier upon impact and hit whatever is on top. A rigid pole may or may not break off, but there is no safety advantage in making it easier for the pole to break away and fly into the opposing travel lanes.

The potential for a pole being struck by the box of the truck can be minimized by making the barrier wider. If you transition to a vertical face and/or taper the width of the barrier, you can provide additional offset to the pole. The point is to minimize the potential for broken poles to fly into the opposite roadway. Larger passenger vehicles as well as their occupants may contact objects on top of barriers under severe impact conditions.

The use of small median-barrier-mounted signs is generally limited to locations where they are critical for safety. These signs may include those in the regulatory and warning classes, and they are typically recommended only where the safety benefit of the sign outweighs its potential hazard. For example, the following common signs might meet these criteria:

- "No U Turn" and other signs used for barrier openings.
- Preferential and managed lane signs; for example, for HOV lanes.
- "Reduce Speed Ahead."
- "Slippery When Wet."
- Chevrons.
- Post-supported mile markers.

Panel sizes for median-barrier-mounted signs are limited by lateral clearances to other highway elements. The MUTCD provides standards and guidelines for placement of roadside signs; however, those specifically applicable to barrier-mounted signs are limited. This issue is addressed primarily in Chapter 2G, Preferential and Managed Lane Signs (FHWA 2009). The following are pertinent excerpts from this chapter:

Section 2G.03 Regulatory Signs for Preferential Lanes—General, and also appears in **Section 2G.08, Warning Signs on Median Barriers for Preferential Lanes:**

Guidance: The edges of Preferential Lane regulatory (and Warning) signs that are post-mounted on a median barrier should not project beyond the outer edges of the barrier, including in areas where lateral clearance is limited.

Option: Where lateral clearance is limited, Preferential Lane regulatory (and Warning) signs that are post-mounted on a median barrier and that are 72 inches or less in width may be skewed up to 45 degrees in order to fit within the barrier width or may be mounted higher, such that the vertical clearance to the bottom of the sign, light fixture, or structural support, whichever is lowest, is not less than 14 feet above any portion of the pavement and shoulders.

Standard: Where lateral clearance is limited, Preferential Lane regulatory (and Warning) signs that are post-mounted on a median barrier and that are wider than 72 inches shall be mounted with a vertical clearance that complies with the provisions of Section 2A.18 for overhead mounting.

Although these provisions do not apply to all barrier-mounted signs, they provide general guidance for panel width and height restrictions that are unique to this application. The following three general recommendations can be summarized from the available sources:

1. Panel edges are to be located as far as possible from travel lanes.
2. The sign panel may not be wider than the width of the barrier, unless it is skewed or raised to a minimum height of 14 ft (4.3 m).
3. Panels wider than 72 in. (1.8 m) must be mounted at the same height as overhead signs.

TYPES OF RIGID MEDIAN BARRIERS AND THE ZONE OF INTRUSION

A variety of rigid median barrier designs are in widespread use throughout the United States. Many of the designs have remained essentially unchanged for many years, while others have been developed more recently. Current crash performance criteria for barriers are contained in the AASHTO *Manual for Assessing Safety Hardware* (MASH) (AASHTO 2009a). However, a majority of the barriers in service today have been crash-tested and accepted in accordance with

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NCHRP Report 350 (Ross et al. 1993; FHWA 2013). Individual barrier designs meet specific test levels in the crash performance criteria, which define the level of containment provided by the barrier system. In general, the higher test levels contain and redirect heavier vehicles. The more common rigid median barriers have passed *NCHRP Report 350* Test Level 4 (TL-4) or TL-5 (AASHTO 2011). Table 1 identifies some of the more common rigid median barrier designs and shows their overall height and test level.

TABLE 1
COMMON RIGID MEDIAN BARRIER DESIGNS

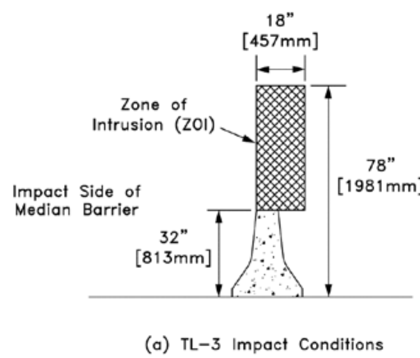
Barrier Description	Height (mm)	Test Level[a]
F-Shape Median Barrier, Designation SGM10a	32 [813]	TL-4
F-Shape Median Barrier, Designation SGM10b	42 [1,067]	TL-5
NJ-Shape Median Barrier, Designation SGM11a	32 [813]	TL-4[b]
NJ-Shape Median Barrier, Designation SGM11b	42 [1,067]	TL-5
Tall-Wall Median Barrier, Designation SGM12	42 [1,067]	TL-5
Single-Slope Median Barrier	32 [813]	TL-4
Single-Slope Median Barrier	42 [1,067]	TL-5
Vertical Wall Median Barrier	32 [813]	TL-4

[a]In accordance with *NCHRP Report 350* and/or AASHTO MASH testing criteria.
[b]32-in. (813-mm) NJ-shape barrier failed TL-4 testing per AASHTO MASH criteria (AASHTO 2011).

Barriers that satisfy TL-4 test conditions can contain and redirect vehicles up to and including a single-unit box truck weighing approximately 17,650 lbs (8000 kg), traveling at 50 mph (80 kph), and impacting the barrier at 15 degrees. Barriers that satisfy TL-5 test conditions are able to contain and redirect vehicles up to and including a tractor-van trailer truck weighing approximately 79,400 lbs (36,000 kg), traveling at 50 mph (80 kph), and impacting the barrier at 15 degrees. For more details on impact testing criteria, see *NCHRP Report 350* (Ross 1993) and MASH (AASHTO 2009a).

Measured from the surface of the adjacent pavement to the top of the barrier, nominal height values include a provision for a 3-in. (76-mm) pavement overlay. Because overall height is critical to a barrier's structural capacity and performance, its height may be extended if thick overlays are anticipated or increased vehicle containment capacity is desired at existing installations. Height extensions must be structurally connected to the host barrier. In addition to higher structural capacity, taller barriers reduce the ZOI, which is defined as the region measured above and beyond (behind) the face of the barrier system where an impacting vehicle or any major part of the system may extend during an impact (AASHTO 2011). If an object is located in the ZOI, it will be struck by part of an impacting vehicle if the impact point on the barrier is in the vicinity of the object. ZOI is analogous to the lateral distance behind a flexible or semi-rigid barrier, defined by the lateral dynamic deflection that occurs during a standardized crash into the barrier. For these systems, the lateral distance defines the "working width" that is needed for the barrier to function; placement of fixed objects within the working width behind the barrier is generally not recommended.

Figure 3 illustrates the general configuration of the ZOI for a 32-in. (813-mm) high safety-shape barrier and TL-3 and TL-4 impact conditions (AASHTO 2011). However, these are based on limited crash test and research data. The amount of intrusion above and behind a barrier system is directly related to its height and profile, as well as the vehicle's size, speed, and angle of impact (AASHTO 2011). For a particular barrier design, truck impacts have significantly larger ZOI areas than those created by passenger vehicle impacts. TL-4 and TL-5 barriers may have some level of ZOI for passenger vehicle impacts, as well. For example, a 32-in. (813-mm) high (or higher) TL-4 barrier may have a significant ZOI for TL-3-level passenger vehicle impacts. This may become a concern if sign supports are mounted on the barrier and positioned within its ZOI for a wide range of impact conditions that are likely to occur at the installation location.



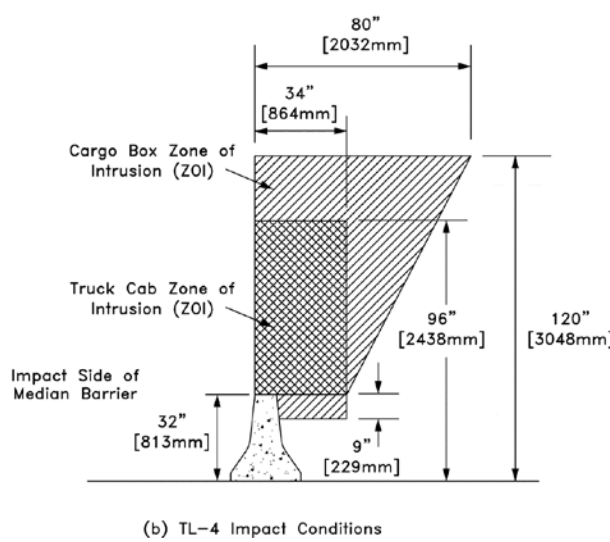


FIGURE 3 Zone of intrusion (ZOI) for 32-in. sloped-face concrete barrier [adapted from AASHTO (2011)].

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In many cases, the effective test level of the barrier is questionable in the vicinity of a sign support that is mounted within a ZOI. For example, a normally rated TL-4 barrier may effectively be reduced to TL-2 where a sign is mounted within the ZOI, because the support could cause failure of standard TL-3 and TL-4 tests at that location along the barrier. This is a particular concern when performance is reduced for passenger car impacts, which are more common events and potentially cause greater occupant risk. Because barriers are not typically crash-tested with mounted sign supports, the degradation in performance caused by the sign is often overlooked. Additionally, detached elements of the sign could cause failure of a standardized crash test, as this is an evaluation criterion that considers potential for secondary hazards caused by debris flying into adjacent traffic lanes.

Overhead signs require substantially larger and heavier support structures owing to the heavier loads they must bear. They are considered fixed objects, because they are not likely to be displaced even with the most extreme impact-loading conditions. Small signs vary considerably in size and mounting height, so the size and weight of their supports typically vary to match the magnitude of environmental loading. On the high end of the range, supports that carry relatively large signs may also act as true fixed objects during typical impact conditions. On the small end of the range, supports are less robust and may deform, deflect, or detach during a vehicle impact, even if they are not designed as a breakaway feature.

Although not included in the scope of this synthesis study, luminaire and equipment support poles are often mounted on top of rigid median barriers and may present similar concerns for ZOI impacts. As with signs, this type of installation should not use breakaway supports because of the risk a downed pole might present to opposing traffic (AASHTO 2011). Because all barrier-mounted features have potential for reducing impact performance, consideration of crashworthiness during the design process may help minimize adverse effects associated with barrier attachments.

TECHNIQUES FOR REDUCING ZONE OF INTRUSION EXPOSURE

This section includes practices that attempt to reduce the consequences of impacts involving structural supports located within a barrier's ZOI. Some of these techniques are described in the national design guidelines cited earlier; others were identified in responses to the survey questionnaire. Techniques vary from relatively minor incidental treatments to extensive modifications of the barrier in the vicinity of sign supports. They may apply to either overhead or small sign supports with varying degrees of practicality and effectiveness.

- **Eliminate the need for a separate sign support by locating the sign where it can be supported by an existing bridge structure, luminaire pole, or other sign support.** Where possible, this treatment is preferred and encouraged in the AASHTO RDG; it reduces the number, and thus exposure, of supports located in the ZOI (AASHTO 2011).
- **Widen the barrier cross-section laterally in the vicinity of the sign support.** This treatment has the effect of placing the support farther away from the traffic face of the barrier and removing it from the ZOI, or at least reducing the extent to which it impinges on the ZOI. Recommended maximum flare rates may be followed on both approach sides where the barrier transitions from its normal width to the widened section (AASHTO 2011).
- **Vertically taper the top of the barrier profile in the vicinity of the sign support.** This treatment was identified from responses to the survey questionnaire. It gradually raises the height of the barrier on both sides of the sign support to reduce the ZOI of a vehicle impacting from either direction.
- **Transition to a different type of barrier in the vicinity of the sign support.** For example, transition from safety-shape barrier to vertical wall at the support location and then back to safety-shape on both sides. This treatment is also intended to reduce the size of the ZOI at the support location. Vertical wall barriers have a reduced ZOI compared with other barriers of the same overall height (AASHTO 2011).
- **Modify the barrier by attaching a metal beam rail to the traffic face in the vicinity of the sign support.** As shown in Chapter 6, Figure 6-12 of the AASHTO RDG, the New York State DOT designed and tested a box beam attached near the top of the upper face of a typical safety-shape barrier to limit vehicle climb and improve performance (Phillips and Bryden 1984; AASHTO 2011).
- **Chamfer or round off sharp edges of the sign support.** This treatment was identified from responses to the survey questionnaire; it can be used to reduce the potential for snagging of the impacting vehicle. Reduced snagging may help reduce the severity of the primary impact as well as the likelihood that the sign structure will become dislodged and present a secondary hazard to adjacent traffic.
- **Limit projection height of sign support anchor bolts.** This treatment can also be used to reduce the potential for snagging of the impacting vehicle, reducing the severity of the primary impact and the likelihood that the sign structure will become dislodged and present a secondary hazard to adjacent traffic (Caldwell 2011).
- **Provide extra strengthening of the sign support beyond that required to resist wind loads.** This treatment was identified from responses to the survey questionnaire and applies primarily to small sign supports. It can be used to reduce the likelihood of the sign becoming dislodged during a ZOI impact and creating secondary hazards to adjacent traffic.

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CHAPTER THREE

EXISTING SIGN AND BARRIER COMBINATIONS

The primary objective of the synthesis study was to gather, compile, and disseminate information describing current practices for mounting permanent signs on rigid median barriers throughout the United States. A majority of the information was gathered from responses to a survey questionnaire that was distributed to all voting members of the AASHTO Subcommittee on Design, which includes representation from all 50 state DOTs and the District of Columbia DOT. In addition, invitations to participate in the survey were sent to 11 toll road authorities that manage turnpikes and other divided highway networks. The survey questionnaire is provided in Appendix A.

A total of 51 completed responses to the survey questionnaire were received: 46 from state DOTs and five from toll road authorities. Because the response rate from toll road authorities (five of 11 surveyed) was low for statistical significance, some of the data analyses apply only to DOT responses. Corresponding data received from the toll road authorities are discussed in the commentary.

The information received varied greatly among the agencies. One agency reported having no barrier-mounted sign installations at all, while several reported having more than 1,300 within their jurisdictions. Many agencies provided access to standard plans, specifications, photos, and other information related to their practices. These materials and the questionnaire answers have been reviewed and compiled, and the results are summarized in this chapter.

RIGID BARRIER TYPES AND USAGE

The vast majority of rigid median barrier designs are constructed of reinforced concrete, with varying height, width, and cross-sectional shape. Because this study focuses on high-speed, median-divided highways, only TL-3 and higher rated rigid barriers are included in the data-gathering process. For this range of test levels, four basic cross-sectional barrier shapes are in widespread use: New Jersey safety-shape, F-shape, single-slope, and vertical wall. These shapes have been in use for many years, and their geometric details are available in AASHTO publications (AASHTO 1995, 2011).

For median applications, the minimum width at the base is typically 24 in. (610 mm); however, the width can be increased as needed to provide increased protection for objects in the ZOI or to provide increased capacity for impact loading. Many agencies have set a standard width to meet the needs of their highway networks. Where extra-wide median barrier is needed, typical practice is to install back-to-back half-sections with earth backfill and a concrete cap between the sections. Figure 2b offers a general view of this configuration.

The minimum nominal height for all four basic barrier shapes is 32 in. (813 mm) for TL-3/TL-4 ratings. Traditionally, this allows for up to 3 in. (76 mm) of pavement overlay adjacent to the barrier, making the overall minimum height 29 in. (737 mm) (AASHTO 2011). Raising the barrier section height is the primary means of increasing capacity. Forty-two inch (1,067 mm) high concrete barrier has been established as the minimum nominal height that satisfies TL-5 impact conditions. A number of ultra-high-capacity barriers have been developed to satisfy specific agency needs. Higher barriers are also used to provide a glare screen to block light from oncoming traffic.

Figure 4 shows results from Question 2 of the survey, which asked agencies to identify all types of rigid median barriers currently in use in their divided highway network. New Jersey (NJ) and F-shape (FS) are the most common shapes, followed by single-slope (SS) and then vertical wall (VW). The most common nominal barrier heights are 32 in. (813 mm) and 42 in. (1,067 mm). The data do not include the quantity or mileage of each system installed in the United States; however, they indicate the distribution of quantities currently in service.

For rigid barriers, height is the primary factor that affects ZOI for TL-3 and higher impact conditions. In general, higher barriers reduce vehicle roll during an impact and thus reduce the size of the ZOI by limiting overhang of the upper portions of the vehicle over the barrier. The shape of the barrier's face has some effect on ZOI, and this effect likely varies with overall height. However, definitive relationships between barrier shape and ZOI have not yet been established.

OVERHEAD SIGN SUPPORTS

Figure 1 showed the typical configurations of overhead sign supports on divided highways. For the purpose of obtain-

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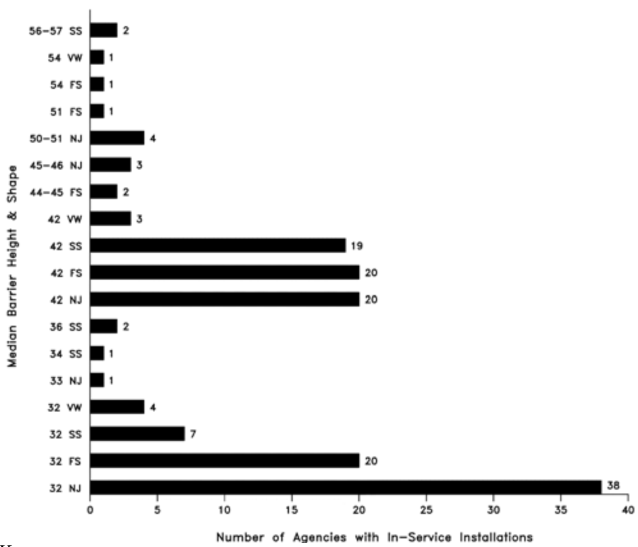
ing information on median-barrier-mounted applications, the survey questionnaire did not differentiate between span/bridge and cantilever supports. Question 3 of the survey asked agencies approximately how many existing overhead sign supports, mounted within or on top of rigid median barriers, are installed throughout their agency's total divided highway network. The intent was to provide a general indication of quantities rather than precise values, as the level of detail in roadway inventory systems varies considerably among agencies. In addition, there is a wide range in the size of divided highway networks among the agencies. Table 2 shows the results from the 46 DOTs that responded to the survey questionnaire. Twenty-one of the 46 DOTs (45.7%) and one of the five toll road authorities reported having at least 100 overhead sign supports mounted within or on top of rigid median barriers.



Key:
Number—Nominal barrier height in inches
NJ—New Jersey safety-shape
FS—F-shape
SS—Single slope
VW—Vertical wall

FIGURE 4 Rigid median barrier usage by height and shape.

TABLE 2
NUMBER OF EXISTING OVERHEAD SIGN SUPPORTS MOUNTED ON RIGID MEDIAN BARRIERS

No. of Supports in DOTs Total Divided Highway Network	No. of DOTs	Percent of Total DOTs
300+	12	26.1
100–299	9	19.6
10–99	11	23.9
Less than 10	6	13.0
None	1	2.2
Unknown	7	15.2

Thirty-two of the 51 total agencies that responded reported availability of either standard or project-specific construction plans. These plans have some common features, but details vary considerably. A majority of agencies use round pipe supports, and a majority of those use a relatively large single-pipe support mounted within or on top of the barrier. Figure 5*a* shows photos of large single-pipe supports. Other round pipe designs use two pipe supports connected by lighter diagonal members to form the basis for a truss support structure. The truss support creates a larger ZOI in the longitudinal direction because it consists of two rigid supports spaced a short distance apart in the longitudinal direction. Figure 5*b* shows photos of truss configurations. Structural square tube sections are less common; examples are shown in Figure 5*c*.

A review of plans submitted with the survey questionnaire shows that approximately half of the agencies build foundations for overhead sign supports as an integral component of the barrier, which is formed to match the barrier profile on each side of the support. The remaining agencies construct the support foundation in between precast barrier half-sections, which transition to standard barrier over tapered sections on both longitudinal sides of the support. Flare rates for the tapered sections are typically a minimum of 1:20; several agencies specify 1:30 or more gradual taper rates. Widening the median barrier section in the vicinity of fixed objects is one method of reducing exposure within the ZOI, whether the widening is required to accommodate the foundation or done solely for safety improvement.

Question 8 of the survey questionnaire listed six design characteristics that can be used to improve the safety performance of overhead median-barrier-mounted sign supports and asked the agencies which they have used for installations in their highway networks. Respondents were asked to check all that apply. Table 3 presents the results from the 46 DOTs that responded to this question.

Responses from the five toll road authorities that completed this question followed a similar distribution—lateral widening of the barrier cross-section in the vicinity of a sign support was the most common design characteristic incorporated into installations within their jurisdictions. Several agencies commented that lateral widening is often required to accommodate foundations for overhead supports, and safety benefits were not the primary motive. A review of the plans that were submitted shows that the minimum lateral offset distance from the top face of the barrier to the outside edge of the support ranges from 0 in. (0 mm) to 18 in. (457 mm). Two agencies specify a minimum offset distance of 16 in. (406 mm) and 18 in. (457 mm), specifically to place the support farther away from the face of the barrier to improve ZOI impact performance. Some respondents noted that widening the barrier also reduces the inside shoulder width, which may be a concern in very narrow medians. Designers often have to weigh benefits and consequences of conflicting treatments.

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(*a*) Single pipe overhead sign supports

(*b*) Truss with two closely spaced vertical supports

(*c*) Structural square tube vertical supports

FIGURE 5 Examples of typical overhead sign supports from survey responses.

Ten agencies reported vertical tapering of the top of the barrier profile in the vicinity of the sign support. This treatment is more applicable to barriers less than 42 in. (1,067 mm) in height. One agency noted that it uses this treatment at locations where existing conditions do not allow widening of the barrier. Another agency uses the practice in conjunc-

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tion with the next treatment in the list: transitioning to a different type of barrier in the vicinity of sign supports. For appropriate conditions, this agency transitions from 32-in. (813-mm) high F-shape to 54-in. (1,372-mm) high vertical wall over a length of 15 ft (4.6 m). The barrier remains 24 in. (610 mm) wide, with zero offset between the face of the barrier and the edge of the support base plate, because it is located 54 in. (1,372 mm) above the pavement surface. Sixteen agencies reported using transitions to a different type of barrier at overhead sign support locations.

TABLE 3
DESIGN CHARACTERISTICS USED TO IMPROVE SAFETY PERFORMANCE OF MEDIAN BARRIER-MOUNTED OVERHEAD SIGN SUPPORTS

Method and Description	No. of DOTs	Percent of Total DOTs
LATERAL WIDENING OF THE BARRIER CROSS-SECTION IN THE VICINITY OF THE SIGN SUPPORT: This treatment is typically used to move the support laterally farther from the traffic face of the barrier to remove it from, or reduce the severity of its position within, the zone of intrusion (ZOI).	30	65.2
ELIMINATING THE NEED FOR A SIGN SUPPORT BY MOVING THE SIGN LOCATION SUCH THAT IT IS SUPPORTED BY AN EXISTING STRUCTURE (BRIDGE, LUMINAIRE, OTHER SIGN SUPPORT, ETC.):	24	52.2
TRANSITIONING TO A DIFFERENT TYPE OF BARRIER IN THE VICINITY OF THE SIGN SUPPORT: For example, transitioning from safety-shape barrier to vertical wall at the support location, and then back to safety shape. This treatment is also intended to reduce the ZOI at the support location.	15	32.6
VERTICAL TAPERING OF THE TOP OF THE BARRIER PROFILE IN THE VICINITY OF THE SIGN SUPPORT: This treatment gradually raises the height of the barrier on both sides of the sign support in an effort to reduce the ZOI of an impacting vehicle in the vicinity of the support.	9	19.6
MODIFYING THE BARRIER BY ATTACHING A METAL BEAM RAIL TO THE TRAFFIC FACE OF THE BARRIER IN THE VICINITY OF THE SIGN SUPPORT: This type of treatment is also intended to reduce the ZOI at the support location.	5	10.9
OTHER: Treatments that have been incorporated into existing installations that are intended to improve safety performance of a barrier/sign support installation.	3	6.5
NONE or UNKNOWN: No known treatments have been incorporated into existing installations that are intended to improve safety performance of a barrier/sign support installation.	9	19.6

Five agencies reported attaching metal beam rail to the traffic face of the barrier in the vicinity of sign supports to reduce vehicle climb during impact and thereby reduce the size of the ZOI. This treatment is shown in Chapter 6, Figure 6-12 of the AASHTO *Roadside Design Guide* and is used extensively in at least one state to increase protection against impacting bridge piers that are immediately behind rigid barriers. Its use at sign support locations is more limited, although five agencies have reported using it. One agency noted that this treatment is in its toolbox of options but has not yet been installed in the jurisdiction. Another agency reported placing precast barrier sections on each longitudinal side of a support, then bridging the gap with metal beam rail attached on the lateral sides of the barrier. However, this was an isolated case.

Twenty-seven agencies reported eliminating the need for new sign supports by changing their location and mounting them on existing structures. This is a preferred treatment, and one agency noted that it is included in the analysis before installing any support in the median. Several agencies stated that they are phasing out median-barrier-mounted overhead sign supports unless no other option is available. Many prefer to span the entire roadway (both directions) with an overhead support where possible, as shown in Figure 1*a*.

The "Other" category was checked by four agencies, and they described combinations of raising the barrier, widening, and transitioning to a different barrier type in the vicinity of overhead sign supports. In the "None" category, comments primarily related to not allowing any median-barrier-mounted sign supports or not needing special treatments because the standard barrier is expected to be high enough to sufficiently reduce the ZOI.

SMALL BARRIER-MOUNTED SIGN SUPPORTS

Typical configurations of small barrier-mounted sign supports on divided highways were shown in Figure 2. To obtain information on median-barrier-mounted applications, the survey questionnaire did not differentiate among regulatory, advisory, guide, and mile marker sign functions. The primary criterion for including signs in this category is that they must be supported by a separate vertical support or post. Very small, lightweight, self-supported panels—such as some mile markers and barrier delineators—are not included because they are far less likely to affect crash performance of the host barrier. Panel sizes for this category of sign fall into the range of 1.0 ft^2 (0.1 m^2) to 49 ft^2 (4.5 m^2).

Question 11 asked agencies approximately how many permanent, small sign supports mounted on top of rigid median barriers are installed throughout their total divided highway network. The intent was to elicit a general indication of quantities rather than precise values, as the level of

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detail in roadway inventory systems varies considerably among agencies. Table 4 shows the results from the 46 DOTs that responded to the survey questionnaire. There is far less certainty about the number of small barrier-mounted signs compared with overhead sign supports. Because of the large number of small signs, they are more likely to be overlooked in roadway inventory systems, whereas overhead signs are more likely to be cataloged and inspected on a regular basis. Thirteen of the 46 DOTs (28.3%) and two of the five toll road authorities reported having at least 100 small sign supports mounted on top of rigid median barriers. Two of the five toll road authorities reported having fewer than 10, and one reported having between 10 and 99.

TABLE 4
NUMBER OF EXISTING SMALL SIGN SUPPORTS MOUNTED ON RIGID MEDIAN BARRIERS

No. of Supports in Agency's Total Divided Highway Network	No. of DOTs	Percent of Total DOTs
1,000+	6	13.0
500–999	3	6.5
100–499	4	8.7
10–99	5	10.9
Less than 10	2	4.3
None	7	15.2
Unknown	19	41.3

Twenty-six of the 51 agencies that responded made their standard or project-specific construction plans available. Review of the drawings showed that details of supports vary considerably among agencies; however, they generally fall into two primary categories:

1. Flat base plate mounted to the top horizontal surface of the median barrier with vertical anchor bolts. Physical sizes of support components vary considerably among the agencies that responded to the survey questionnaire. Component size ranges and typical sizes are provided here:

   Base plate thickness: 1/4 in. (6.3 mm) to 1 in. (25.4 mm); 5/8 in. (15.9 mm) typical.

   Base plate width: 4 in. (102 mm) to 7 in. (178 mm); 6 in. (152 mm) typical.

   Base plate length: 6 in. (152 mm) to 28 in. (711 mm).

   Round pipe support: 2.5 in. Schedule 40 to 4 in. Schedule 40.

   Square tube support: 1.75 in. x 1.75 in. Perforated to 4 in. x 4 in. x 3/8 in. Structural tube.

2. Saddle-style base plate that is bent to straddle the top of the barrier with various anchor bolt configurations: horizontal bolts that extend through the barrier, with nuts on both sides; horizontal expansion or adhesive anchor bolts extending into the barrier from both sides; or a combination of horizontal and vertical anchor bolts. Component size ranges and typical sizes are provided here:

   Base plate thickness: 1/4 in. (6.3 mm) to 3/4 in. (19 mm); 1/2 in. (15.9 mm) typical.

   Base plate width at top: 6 in. (152 mm) to 8 in. (203 mm); 6 in. (152 mm) typical.

   Base plate length: 6 in. (152 mm) to 38 in. (965 mm).

   Round pipe support: 2.5 in. Schedule 40 to 4 in. Schedule 80.

   Square tube support: 2 in. x 2 in. Perforated to 6 in. x 4 in. x 3/8 in. Structural tube.

Figure 6 shows typical details of primary configurations used for small sign supports. Figure 6*a* shows the flat base plate type with the post welded directly to it, while Figure 6*b* shows this type with a sleeve welded to the base plate. This is common for relatively light perforated square tube supports, in which the post is inserted into the sleeve and secured with bolts that extend through the post and sleeve. Figure 6*c* shows general details of a saddle-style base plate that wraps over the top of the barrier and is secured with horizontal bolts. Some of the larger saddle-style bases include vertical anchor bolts that attach the top of the saddle to the barrier in addition to horizontal bolts. A majority of agencies that provided plans specify the use of chemical adhesive anchors for vertical bolts that secure base plates to existing barriers. Adhesive anchor bolt diameters range from 1/2 in. (13 mm) to 1 in. (25 mm), and adhesive specifications typically reference those they have in place for a variety of other applications. In general, adhesive anchors must be installed in strict conformance with the manufacturer's recommendations, and they are intended to develop the full strength of the steel bolt material that is specified. Less reliable expansion or wedge anchors are used by some agencies for applications using 1/2 in. (13 mm) to 3/4 in. (19 mm) anchor bolts for generally smaller signs compared with those using adhesive anchor bolts.

Material sizes of the base plate, post, and anchor bolts vary significantly, depending on the size and height of the supported sign panel. The perforated sleeve and post design shown in Figure 6b is used for smaller and lower signs, which include mile markers. Larger and higher signs use one of the base types shown in Figure 6, a and c. All the agencies that provided details of their supports use steel posts, and

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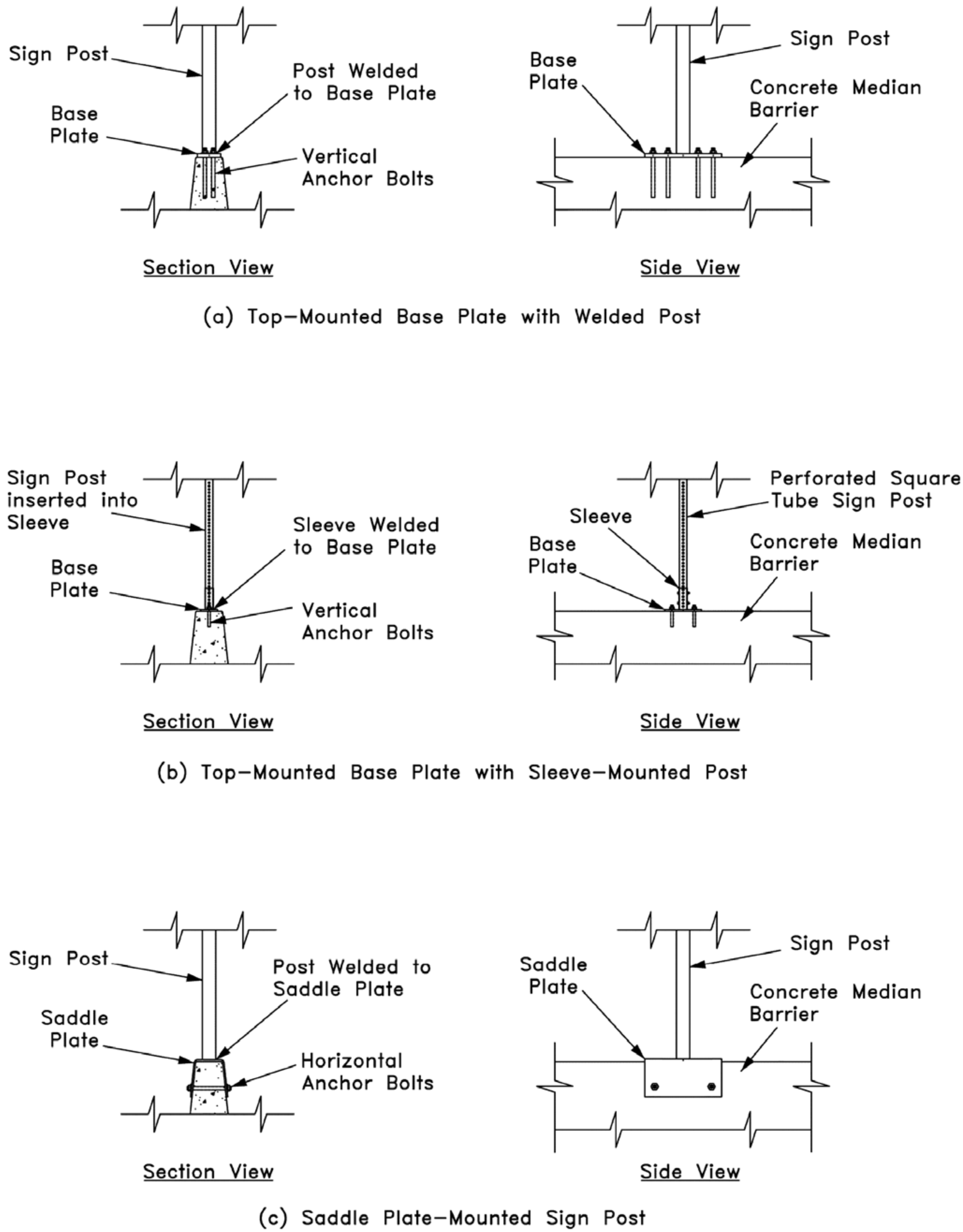

FIGURE 6 Typical details of small sign supports mounted on rigid median barriers.

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the types and sizes of posts cover a wide range, as shown in Table 5. U-channel and perforated square tubes are the lightest, and the weight range progresses up through various structural shapes. The heaviest post identified is a 6 in. x 4 in. x 3/8 in. structural square tube; it is used to support a 49 ft^2 (4.5 m^2) sign panel with a 14 ft (4.3 m) minimum mounting height, measured from the pavement surface to the bottom of the panel.

TABLE 5
RANGE IN SIZE OF SUPPORTS FOR SMALL SIGNS MOUNTED ON RIGID MEDIAN BARRIERS

Support Description	Weight per Unit Length (lb/ft)	Mass per Unit Length (kg/m)
2-lb U-Channel	2.00	2.98
1.75" x 1.75" Perforated Square Tube	2.09	3.11
2" x 2" Perforated Square Tube	2.44	3.63
3-lb U-Channel	3.00	4.48
2.5" x 2.5" Perforated Square Tube	3.14	4.69
3" x 3" x 1/8" Structural Square Tube	4.75	7.07
2.5" Schedule 40 Round Pipe	5.80	8.63
3" Schedule 40 Round Pipe	7.58	11.28
4" x 3" x 3/16" Structural Square Tube	8.15	12.12
W6 x 9 I-Beam	9.00	13.39
3.5" Schedule 40 Round Pipe	9.12	13.57
4" Schedule 40 Round Pipe	10.79	16.05
W6 x 12 I-Beam	12.00	17.85
4" Schedule 80 Round Pipe	14.98	22.28
4" x 4" x 3/8" Structural Square Tube	17.27	25.69
6" x 4" x 3/8" Structural Square Tube	22.37	33.28

Figures 7 and 8 show examples of various sizes and configurations of small sign supports mounted on rigid median barriers. These examples represent some of the post sizes shown in Table 5. Heavier posts are shown in Figure 7, and examples of significantly lighter perforated square tube supports are shown in Figure 8. Because the perforated square tube supports are typically used for mile markers, they are found in more existing installations throughout the United States than the nonperforated post types. When mile markers are placed every 0.1 mi (0.16 km) along a highway section, the number of installations adds up to significantly greater numbers than other types of signs that normally have larger panels.

When signs are mounted within the barrier ZOI, post weight and structural characteristics of the base anchorage may have an effect on impact response. A heavier post with a more substantial anchorage design is more likely (though not certain) to behave as a fixed object in response to passenger car impacts. In such cases, the primary concern is the risk of injury for occupants of the impacting vehicle if it snags on the support. Lighter posts may fully or partially yield during a ZOI impact and may or may not completely detach from the barrier. In these cases, risk to occupants of the impacting vehicle may be reduced; however, debris from the detached sign may pose a risk to adjacent traffic. Whether the support remains fixed or yields during an impact is influenced by both the structural integrity of the support and the impact conditions (vehicle size and weight, speed, and impact angle).

Question 16 of the survey questionnaire listed 10 design characteristics that can be used to improve the safety performance of small median-barrier-mounted sign supports and asked which ones the agencies have used in their highway networks. Respondents were asked to check all that apply. Table 6 shows the results from the 46 DOTs.

The survey shows that fewer of these treatments are used for small sign supports compared with those used for overhead supports. Treatments that require modifications to the barrier at the sign location are typically expensive and impractical to be incorporated at a large number of small sign locations. At least one agency indicated that it has a barrier design that is wider at the top than its standard design, specifically for use where barrier-mounted signs will be installed in the future. However, this agency noted that it discourages the practice of mounting objects on top of barriers unless there are no other options. Using a wider barrier also allows the use of wider sign panels while still conforming to the MUTCD recommendation that sign panels be no wider than the barrier.

Ten agencies reported the use of breakaway supports for barrier-mounted signs; however, none of the plans provided in response to the questionnaire showed details of breakaway supports on top of barriers. The photo in Figure 7*a* is the only item received that shows a breakaway support for this application.

Some agencies reported making relatively minor modifications to supports with the intent of improving impact safety performance. Removing sharp edges and reducing the projection height of anchor bolts can reduce snagging of an impacting vehicle. Crash testing has shown that some horizontal anchor bolts used in saddle bases project off the side face of the barrier far enough to cut into and tear vehicle bodies during an impact event (Caldwell 2011). Six agencies reported extra strengthening of the support to reduce the likelihood that it would be dislodged. This practice could reduce the number of designs an agency needs to detail and maintain, by having one support design for a wide range of panel sizes.

Nineteen agencies reported eliminating the need for new sign supports by moving the signs and mounting them on existing structures nearby. This is a preferred treatment. One agency noted that it attaches signs to luminaire poles on or

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(*a*) Breakaway support

(*b*) Saddle base plate support

(*c*) Saddle base plate with round pipe supports

(*d*) Top-mounted base plate with structural square tube support

FIGURE 7 Examples of small sign supports from survey responses.

between median barrier sections to eliminate the need for additional supports. Several agencies stated that they either prohibit or are phasing out median-barrier-mounted sign supports unless no other option is available.

Five agencies checked the "Other" category. Three stated that they raise the mounting height of sign panels to reduce the likelihood of their being struck by trucks. One stated that it specifies a minimum mounting height of 14 ft (4.3 m) in its standards. In

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(*a*) Top plate-mounted sleeve and perforated square tube support

(*b*) Top plate-mounted angle and perforated square tube support

(*c*) Adjustable angle-mounted angle and perforated square tube support

FIGURE 8 Examples of small sign supports from survey responses.

the "None" category, comments primarily related to not needing special treatments because the standard barrier is presumed to be high enough to sufficiently reduce the ZOI or the agency simply does not allow median-barrier-mounted sign supports.

The five toll road authorities that responded to the survey questionnaire reported using some of the same practices used by DOTs. Three of the five reported that their preferred practice for both overhead and small sign supports

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TABLE 6

DESIGN CHARACTERISTICS USED TO IMPROVE SAFETY PERFORMANCE OF SMALL MEDIAN BARRIER-MOUNTED SIGN SUPPORTS

Method and Description	No. of DOTs	Percent of Total DOTs
ELIMINATING THE NEED FOR A SIGN SUPPORT BY MOVING THE SIGN LOCATION SUCH THAT IT IS SUPPORTED BY AN EXISTING STRUCTURE (BRIDGE, LUMINAIRE, OTHER SIGN SUPPORT, ETC.):	17	37.0
LATERAL WIDENING OF THE BARRIER CROSS-SECTION IN THE VICINITY OF THE SIGN SUPPORT: This treatment is typically used to move the support laterally farther from the traffic face of the barrier to remove it from, or reduce the severity of its position within, the zone of intrusion (ZOI).	11	23.9
USE OF BREAKAWAY SIGN SUPPORTS: Although this treatment is not typically recommended for barrier-mounted signs, there may be locations for which a designer determines that the benefits outweighed the risks for a unique situation.	10	21.7
VERTICAL TAPERING OF THE TOP OF THE BARRIER PROFILE IN THE VICINITY OF THE SIGN SUPPORT: This treatment gradually raises the height of the barrier on both sides of the sign support in an effort to reduce the ZOI of an impacting vehicle in the vicinity of the support.	6	13.0
TRANSITIONING TO A DIFFERENT TYPE OF BARRIER IN THE VICINITY OF THE SIGN SUPPORT: For example, transitioning from safety-shape barrier to vertical wall at the support location, and then back to safety shape. This treatment is also intended to reduce the ZOI at the support location.	6	13.0
LIMIT PROJECTION HEIGHT OF ANCHOR BOLTS: This treatment may be used to reduce snagging of the impacting vehicle, which may reduce the severity of the primary impact, as well as reduce the likelihood of the sign structure becoming dislodged.	5	10.9
EXTRA STRENGTHENING OF THE SIGN SUPPORT BEYOND THAT REQUIRED TO RESIST WIND LOADS: This treatment may be used to reduce the likelihood of the sign structure becoming dislodged during a ZOI impact, and therefore reduce the potential for creating secondary hazards.	5	10.9
CHAMFER OR ROUND OFF SHARP EDGES OF THE SIGN SUPPORT: This treatment may be used to reduce snagging of the impacting vehicle, which may reduce the severity of the primary impact, as well as reduce the likelihood of the sign structure becoming dislodged.	2	4.3
MODIFYING THE BARRIER BY ATTACHING A METAL BEAM RAIL TO THE TRAFFIC FACE OF THE BARRIER IN THE VICINITY OF THE SIGN SUPPORT: This type of treatment is also intended to reduce the ZOI at the support location.	1	2.2
OTHER: Treatments that have been incorporated into existing installations that are intended to improve safety performance of a barrier/sign support installation.	5	10.9
NONE or UNKNOWN: No known treatments have been incorporated into existing installations that are intended to improve safety performance of a barrier/sign support installation.	16	34.8

is to eliminate the need for barrier-mounted sign supports by moving the signs. Two toll road authorities reported having 500 to 999 small sign supports installed on rigid median barriers within their jurisdiction. Although details were not provided, it is assumed that these are primarily mile marker signs. Two toll road authorities reported that they use signing standards from their state DOT and follow the same practices for addressing the ZOI.

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CHAPTER FOUR

TESTING AND RESEARCH

This chapter provides a summary of past and current research related to the safety performance of barrier-mounted sign supports. Although there have not been a large number of studies on this topic, several projects include results of full-scale crash tests and computational analyses that were conducted to quantify the size and shape of ZOIs or to evaluate the effect on safety performance of objects mounted within the ZOI. Some of the earlier studies did not specifically address sign supports; however, they identified the consequences of placing fixed objects on top of or directly behind rigid barriers, thereby establishing the concept of the zone of intrusion. Subsequent research has evaluated the effects of a greater variety of barrier-mounted appurtenances, including sign supports, and has provided a better understanding of which practices have greater potential for compromising safety performance.

EARLY RESEARCH

One early study by the New York State DOT focused on circular concrete bridge piers located directly behind half-section NJ safety-shape barriers (Phillips 1984). Although the term ZOI had had not yet been established, full-scale crash tests showed that piers located behind the barrier caused rollover of a 4,500-lb (2,041-kg) sedan impacting at 25 degrees and approximately 60 mph (97 kph). The piers were clearly located in the ZOI for that particular combination of barrier design and impact conditions. The researchers went on to design a modification to the barrier in which box-beam guardrail extends along the face of the barrier in front of the piers. This modification significantly reduced vehicle climbing during impact and kept the vehicle from hitting the piers with enough force to destabilize its trajectory. The result was much smoother redirection of the vehicle, with significantly less pitch and roll. Survey responses indicated that the box-beam treatment is still used by a few agencies, and it is shown as a design option for reducing ZOI exposure in the AASHTO *Roadside Design Guide* (AASHTO 2011).

The term ZOI was first used by researchers from the Midwest Roadside Safety Facility (MwRSF), who conducted a study to develop guidelines for placement and design of various attachments on or near traffic barriers (Keller 2003). The project included an extensive review of previous crash tests of different types of barriers to evaluate the extent of vehicle intrusion observed above and behind the barriers for Test Level 2, 3, and 4 impact conditions. The ZOI configurations focused on the areas into which substantial structural components of the impacting vehicle extended during an impact event. Zones that were intruded by relatively weak external components of the vehicle (such as mirrors) were not considered to be critical to defining the ZOI, because they yield under low loads and would not cause significant deceleration forces if they struck an object mounted on or near the barrier. Structural components of the vehicle that snag on barrier attachments are likely to cause high deceleration forces and occupant compartment deformation, which are primary evaluation criteria for assessing safety performance. Results of the crash test analyses were used to establish ZOI diagrams for various barrier types and impact conditions. These diagrams were subsequently included in the RDG to illustrate the concept of ZOI and provide preliminary guidelines for addressing objects located in the ZOI (AASHTO 2011). The report also identifies a range of attachments that might be located within a traffic barrier ZOI, including overhead and small sign supports (Keller et al. 2003).

MORE RECENT RESEARCH

MwRSF conducted a series of full-scale crash tests to evaluate the practice of placing luminaire poles on top of and behind 32-in. (813-mm) high single-slope concrete barriers to evaluate their effects on safety for both occupants of the impacting vehicle and adjacent traffic (Wiebelhaus et al. 2008). Although the project focused on luminaire poles rather than sign supports, the results are directly applicable to evaluating safety issues related to ZOI impacts. Two of the three tests were conducted on a top-of-barrier-mounted luminaire pole. *NCHRP Report 350* Test No. 4-11 consisted of a 4,430-lb (2,009-kg) pickup truck hitting the barrier at a speed of 61.7 mph (99.3 kph) and an angle of 23.4 degrees. *NCHRP Report 350* Test No. 4-12 consisted of a 17,605-lb (7,985-kg) single-unit truck hitting the barrier at a speed of 50.4 mph (81.0 kph) and an angle of 15.6 degrees. For Test No. 4-11, the 2000P vehicle was adequately contained and redirected by the barrier, and all applicable performance evaluation criteria were met. However, the front hood of the vehicle made significant contact with the pole, which likely increased damage to the vehicle compared with the same impact conditions without the pole mounted on the barrier.

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For Test No. 4-12, the 8000S vehicle was adequately contained and redirected by the barrier, and all applicable performance evaluation criteria were met. However, the pole was fractured and dislodged from its base plate and came to rest behind and parallel to the barrier. This could have caused a hazard to adjacent traffic if the barrier had been used for a narrow median application, with traffic present on both sides and narrow inside shoulders.

A subsequent ZOI study for the Florida DOT included an analysis using LS-DYNA simulation that was performed to investigate the ZOI of an *NCHRP Report 350* 2000P pickup truck impacting a 40-in. (1,016-mm) high F-shape rigid barrier (Reid and Sicking 2010). For TL-3 impact conditions [62 mph (100 kph), 25 degrees], the simulation predicted the lateral dimension of the ZOI to be 5 in. (127 mm). A majority of the intrusion was from the front hood of the 2000P vehicle, because it extended just over the 40 in. (1,016 mm) barrier height. The researchers suggested that some intrusion can be expected at almost all impact speeds; however, they concluded that the ZOI for this barrier design was inconsequential compared with that of a 32-in. (813-mm) high rigid barrier, in which a significant amount of vehicle structure will overhang the barrier.

The California DOT conducted a full-scale crash test on a permanent small sign support mounted on a 36-in. (914-mm) high, single-slope concrete median barrier (Caldwell 2011). The sign support was a 4-in. (102-mm) diameter steel post welded to a 3/8-in. (10-mm) thick saddle-style base plate with horizontal through-bolts securing the support assembly to the barrier. Impact conditions in the test were in compliance with *NCHRP Report 350*, Test 3-11 [2000P pickup truck, 62 mph (100 kph), 25 degrees]. The barrier successfully redirected the vehicle. However, a significant portion of the vehicle structure impacted the sign support, including the front hood, which was pushed into the windshield toward the driver. The hood penetrated the windshield, causing significant occupant compartment deformation. In addition, the horizontal bolts securing the sign support caused a jagged slice down the side of the vehicle as a result of its sustained contact with the barrier. The sign support was bent toward downstream of the impact. Because of the substantial damage to the vehicle, the occupant risk for this test was deemed unacceptable. It was also noted that the excessive amount of debris could have become a hazard to oncoming traffic. On the basis of these test results, the saddle-mounted sign support is not considered crashworthy in accordance with *NCHRP Report 350* evaluation criteria. The researchers recommended improving performance by modifying the barrier in one or more of the following ways: increase the height of the barrier, increase the width of the barrier, or attach the sign panel directly to the barrier with no support post.

A project to design and conduct full-scale crash testing of a sign support assembly mounted on portable concrete traffic barrier was completed by the Texas A&M Transportation Institute (Williams and Menges 2011). Although this type of concrete barrier is unanchored, some of the results may be valuable for evaluation of rigid barrier as well, especially as available crash test data for any type of barrier-mounted sign supports are limited. In addition, the test was conducted in accordance with *The Manual for Assessing Safety Hardware*; the availability of MASH test results is also compared with those for *NCHRP Report 350* (Ross et al. 1993; AASHTO 2009a). The barrier used for the project is a freestanding, 33-in. (838-mm) high safety-shape, composed of 30-ft (9.1-m) sections. The sign support connection consisted of a 6 x 2 x 1/4 in. (152 x 51 x 6.3 mm) x 72 in. (1,829 mm) long structural steel tube mounted horizontally on top of the barrier. A 3-in. (76-mm) diameter x 4.5-in. (114-mm) high collar was welded to the steel tube, and a 2.5-in. (64-mm) diameter signpost was inserted into the collar and secured with a ½-in. (13-mm) diameter bolt. The sign support design was intended to limit movement of the adjacent barrier sections and thus improve performance. (See the project report for specific details of the test article.) MASH Test 3-11 was selected as the critical test, owing to likely interaction between the pickup truck and the sign support. Results of the test met all the applicable MASH evaluation criteria. The maximum dynamic deflection of the barrier was 3.9 ft (1.2 m), which would not have occurred with a rigid barrier installation. Lateral movement of the barrier may have allowed less snagging on the sign support than would have occurred with a rigid barrier of the same height.

Subsequently, the Texas A&M Transportation Institute completed a comprehensive research project sponsored by the Texas DOT that covers several aspects of signs mounted on concrete median barriers (Abu-Odeh et al. 2013). The project includes an assessment of current practices used by the Texas DOT, various types of analyses, and full-scale crash testing to identify crashworthy sign support designs and develop guidelines for their placement on permanent rigid barriers. In an effort to improve performance of a typical small sign support mounted on top of and within the ZOI of the barrier, six experimental design concepts were presented and evaluated as potential solutions. Evaluations included analytical analyses and computer simulations to assess both impact and environmental wind-loading levels on typical sign supports. The four highest ranked concepts were selected for further analyses, which included additional simulation and full-scale crash testing. The simulation indicated that all four concepts would pass MASH Test 3-11 test conditions, and they did. All the designs are rated for supporting sign panels up to 4 ft x 6 ft (1.2 m x 1.8 m) with a mounting height of 7 ft (2.1 m) measured from the pavement surface to the bottom of the sign panel. One of the concepts emerged as the preferred design; it consists of a 2.5-in. (64-mm) diameter Schedule 80 pipe support attached to a sliding base and chute that is mounted on top of the rigid barrier. The support assembly will move longitudinally

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with the base, sliding within the chute when load is applied by an impacting vehicle. Displacement of the post reduces snagging of the vehicle and thereby improves performance compared to that of a rigidly attached support post.

Although these are valuable findings, the literature search showed that these studies represent most of the limited research that has been conducted on ZOIs for rigid barriers and on the consequences of mounting rigid sign supports within the ZOI. However, much of the research has been conducted within the past few years, indicating that this subject is being recognized as a roadside safety issue worthy of further investigation. Furthermore, the most recent study described earlier hardware designs that are available to potentially alleviate safety concerns for new or retrofitted installations. More research and development may be needed to cover a wider range of applications, but it appears that research on barrier-mounted sign supports is increasing.

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CHAPTER FIVE

CONCLUSIONS AND RESEARCH NEEDS

This synthesis study was conducted to identify and report on the current state of practice for mounting permanent highway signs on top of or within rigid median barriers throughout the United States. Information related to design standards, guidelines, individual agency practices, and research was gathered and evaluated to assess the extent to which barrier-mounted signs are used and the level of consideration given to potential safety concerns with some practices. The concept of a zone of intrusion is used to describe an area above and behind the face of a rigid barrier system where a substantial part of a vehicle can pass through during an impact event. Fixed objects placed within a barrier ZOI have been shown to reduce the crashworthiness of the barrier in the vicinity of the object (Keller et al. 2003; Caldwell 2011). The size and shape of the ZOI varies among the wide variety of rigid median barriers currently in service throughout the nation. In addition, the ZOI configuration for a particular barrier design varies with impact conditions. For example, the width and height of the ZOI for a single-unit truck impact would be significantly greater than those for a pickup truck impact into the same barrier. Likewise, the ZOI for small passenger car impacts might be minimal, whereas it could be significant for vehicles with a higher center of gravity impacting the same barrier system. Thus, the ZOI is a varying characteristic that depends on barrier design and impact conditions.

CONCLUSIONS

The following conclusions can be drawn from this synthesis study, and the subsequent discussion provides further details and commentary.

- Currently, tens of thousands of sign supports are mounted on rigid median barriers installed throughout the United States.
- Existing national design guidelines identify some issues related to vehicle impact ZOI; however, limited specific guidance is available to address the wide range of barrier types and sign supports currently in use.
- A limited number of treatments, with varying degrees of effectiveness, have been used to reduce the severity of ZOI impacts with barrier-mounted sign supports.
- NJ safety-shape, F-shape, single-slope, and vertical wall are the most common rigid barrier shapes used in the United States. Barrier heights range from 32 in. (813 mm) to 57 in. (1,448 mm), with 32 in. (813 mm) and 42 in. (1067 mm) being the most common.
- For overhead sign supports mounted on median barriers, lateral widening of the barrier in the vicinity of the support is the most common treatment used to reduce the severity of ZOI impacts.
- A wide variety of post types and techniques are used to mount small sign supports on rigid median barriers; consequently, various degrees of yielding occur during ZOI impacts with the supports.
- Eliminating the need for a sign support by moving the sign is the most common ZOI remediation treatment for small sign supports mounted on rigid median barriers.
- Treatments that are specially intended to reduce ZOI exposure are used less often for small sign supports than for overhead sign supports mounted on rigid median barriers.

Responses from the survey questionnaire indicate that tens of thousands of barrier-mounted sign supports are currently installed in the United States. In most cases, these signs are essential to convey critical information to drivers; however, it is not essential that all of them be mounted on the median barrier. Many of these signs were installed before concerns over ZOI implications were identified, in the general belief that objects mounted on top of barriers were outside the vehicle impact zone and therefore not a safety concern. This study seeks to clarify the current national status of sign supports mounted on median barriers in order to begin the process of assessing the relative risks associated with their placement.

One of the issues presented in the problem statement for this study is that only limited guidelines are available to help highway designers assess the need for and then design barrier-mounted sign supports. Chapter two provides a summary of pertinent sections of national design manuals and guidelines that address this subject. In general, these documents identify ZOI issues and discourage the haphazard use of barrier-mounted signs with little regard for impact performance (FHWA 2009; AASHTO 2011). However, specific guidance is lacking on which rigid barrier types adequately accommodate attached sign supports when signs mounted within the ZOI might be deemed necessary. Some of the data required to establish these guidelines are not currently available; thus, many of these

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decisions must be made on a case-by-case basis by individual designers.

In addition to explaining the ZOI and its potential effects on barrier performance, the latest edition of the AASHTO *Roadside Design Guide* describes a number of treatments that can be used to reduce ZOI exposure (AASHTO 2011). These treatments—discussed in chapters two and three of this report—have been employed by transportation agencies to varying degrees. Because it is often impractical to locate a sign completely outside a barrier's ZOI for all impact conditions, these treatments can be effective in reducing intrusion at sign locations and thus reducing the severity of those impacts.

Responses to the survey questionnaire show that four rigid barrier shapes are used predominately throughout the United States: NJ safety-shape, F-shape, single slope, and vertical wall. The nominal height of these barriers ranges from 32 in. (813 mm) to 57 in. (1,448 mm), with 32 in. (813 mm) and 42 in. (1,067 mm) being the most common. For rigid barriers, height is the primary factor that affects the ZOI for TL-3 and higher impact conditions. In general, higher barriers reduce vehicle roll during an impact and thus reduce the size of the ZOI by limiting overhang of the upper portions of the vehicle over the barrier. The shape of the barrier's face has some effect on the ZOI; this effect likely varies with overall height. However, definitive relationships between shape and ZOI have not yet been established.

Responses to the survey questionnaire related to overhead sign supports showed that 22 of the 51 agencies reported having at least 100 overhead sign supports mounted within or on top of rigid median barriers. A majority use round pipe supports supported by foundations that are either built as an integral part of the barrier or constructed in between barrier half-sections. Lateral widening of the barrier cross-section is the most common technique used to reduce ZOI exposure for overhead sign supports. Often, widening the barrier in the vicinity of the support is needed to accommodate its foundation. Current guidelines recommend maximum lateral flare rates of the barrier for various applications to avoid abrupt bulges in the barrier (AASHTO 2011). A majority of the responding agencies try to eliminate the need for overhead sign supports in the median.

Information related to small sign supports mounted on median barriers is somewhat limited compared with information on overhead supports. Nineteen of the 51 responding agencies could not estimate the number of signs within their jurisdiction, while 15 agencies reported having at least 100, and six reported having more than 1,000. There is a wide variety of mounting configurations, and they vary significantly in level of structural integrity. Thin-walled tubular posts are used for very small signs, and many are expected to yield if struck during a ZOI impact. For larger signs, substantial structural members are used for supports; the heaviest are expected to act as true fixed objects under a wide range of ZOI impact conditions. Eliminating the need for barrier-mounted supports is the most common method of reducing ZOI exposure for small signs. Ten agencies reported having existing breakaway supports on barrier-mounted signs, but no details of these installations were provided, indicating that they may no longer be in use for new signs. Several agencies said they use higher barriers in urban areas, where barrier-mounted signs are more likely to be needed, and that barrier height sufficiently addresses their ZOI concerns.

RESEARCH NEEDS

ZOI crash testing and research for sign supports mounted on median barriers have increased in recent years. Earlier research established the ZOI concept and recognized it as a potential hazard for a variety of objects located on or near rigid barriers (Phillips and Bryden1984; Keller et al. 2003; Wiebelhaus et al. 2008). Subsequent research has used both computer simulation and full-scale crash testing to evaluate specific combinations of sign supports and barrier designs (Reid and Sicking 2010; Caldwell 2011; Williams and Menges 2011; Abu-Odeh et al. 2013). There is a need for additional design, testing, evaluation, and acceptance of sign support/barrier combinations that cover a wide range of barrier and sign configurations. A set of design options that covers a wide range of sign sizes and barrier types could ultimately be included in national guidelines, which could lead to standardization among transportation agencies.

Additionally, transportation agencies would benefit from research directed toward defining ZOI characteristics for common barrier designs with different shapes, widths, and heights. This information could be used to develop guidelines that suggest which barrier designs better accommodate sign supports mounted on them, based on safety performance. The results could also be used to establish minimum lateral offset distances from the face of the barrier to the edge of the sign support for common barriers. In addition, it would be beneficial to define acceptable and unacceptable levels of intrusion and identify components of the impacting vehicle that cause more occupant risk when they strike an object in the ZOI.

There may also be a need for performance evaluations to determine the extent of any safety problem associated with existing installations and to evaluate the effectiveness of current treatments used to mitigate ZOI exposure. These tests could also be used to evaluate the relative risks of sign versus no-sign design options. Information gathered from these studies would provide valuable input for cost/benefit analyses to identify cost-effective design options.

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Additionally, there may be a need to evaluate possible effects on driver expectations and behavior resulting from implementation of treatments intended to reduce ZOI exposure. Modifications to signs, supports, and locations might impair visual recognition and thus reduce their effectiveness in conveying vital information to drivers. This could be an important factor in evaluating the full range of safety issues related to median-barrier-mounted signs.

This synthesis study identified a wide variety of practices currently in use throughout the United States. Some designs incorporate treatments intended to improve the safety performance of sign supports mounted on median barriers, while others follow older standards that were in use before the concept of the ZOI was established. The study results indicate the need for additional research to help highway designers develop unique and standard details for mounting permanent signs on rigid median barriers.

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APPENDIX A

NCHRP Synthesis Topic 44-14 Survey Questionnaire

In order to increase capacity and improve safety, transportation agencies are increasing the use of rigid median barriers to separate opposing traffic lanes on divided highways. Due to limited space in the median, a variety of permanent highway signs are often mounted within or on top of rigid median barriers. These include large overhead sign support structures and relatively smaller single-post sign support structures. There are few specific details and guidelines for installing sign support structures on rigid median barriers. Rigid median barriers are typically constructed of concrete with varying height, width, and cross-sectional shape. As a result, many existing installations may be somewhat unique, having been designed on a case-by-case basis. This questionnaire is part of an effort in NCHRP Synthesis Topic 44-14 to gather relative information on agency practices for mounting permanent signs on rigid median barriers. We are interested in the input and opinions of all agencies, regardless of the number and type of installations previously used, or which currently exist, or are planned within their jurisdictions. Your valuable experience will help identify the range of techniques implemented and assist in determining potential needs for additional guidance in this area.

The questionnaire has 11 questions. Trial use in a survey pretest shows that the questionnaire can be easily completed within 20 minutes.

Please complete the questionnaire by March 8, 2013.

Disclaimer Statement: Answers provided in response to this NCHRP questionnaire will be compiled and presented anonymously, and the final report will be written in a manner that does not expose any owner agencies or their agents to liability concerns.

The following definitions are used in this questionnaire:

- **Breakaway:** A design feature that allows a sign support to yield, fracture, or separate near the base of the support on impact.
- **Overhead Sign:** A sign suspended over the roadway by either a cantilever or bridge support.
- **Sign Support:** Structural members, either horizontal or vertical, and anchoring components designed to carry the loads induced by attached signs.
- **Small Roadside Sign:** Roadside sign with sign area less than or equal to 5 m^2 (54 ft^2).
- **Zone of Intrusion (ZOI):** The region measured above and beyond/behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact. Further description and diagrams of ZOI are shown in the AASHTO *Roadside Design Guide*, 4th ed., 2009, Chapter 5.

If you have any questions, please contact the Principal Investigator, Eric C. Lohrey, P.E.

Email: Eric@ECLengineering.com Phone (518) 623-3457

Please identify your contact information. NCHRP will e-mail you a link to the online report when it is completed.

Agency: ______________________________

Address:______________________________

____

City:______________________________

State: ______________________________

ZIP: ______________________________

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Questionnaire Contact: ____

Position/Title: ____

In case of questions and for NCHRP to send you a link to the final report, please provide:

Tel:____

E-mail:____

Section 1: Types of Rigid Median Barriers

1. What types of rigid median barriers are currently in service within your agency's divided highway network?

- ☐ F-Shape Median Barrier, 813 mm [32 in.] High, (Designation SGM10a).
- ☐ F-Shape Median Barrier, 1,067 mm [42 in.] High, (Designation SGM10b).
- ☐ Safety(NJ)-Shape Median Barrier, 813mm [32 in.] High, (Designation SGM11a).
- ☐ Safety(NJ)-Shape Median Barrier, 1,067 mm [42 in.] High, (Designation SGM11b).
- ☐ Tall-Wall Median Barrier, 1,067 mm [42 in.] High, (Designation SGM12).
- ☐ Single-Slope Median Barrier, 813 mm [32 in.] High.
- ☐ Single-Slope Median Barrier, 1,067 mm [42 in.] High.
- ☐ Vertical Wall Median Barrier, 813 mm [32 in.] High.
- ☐ Vertical Wall Median Barrier, 1,067 mm [42 in.] High.
- ☐ Other, Description: ______________________________________ , Height:_______________.
- ☐ Other, Description: ______________________________________ , Height: _______________.

Section 2: Overhead Sign Supports Mounted within or on top of Rigid Median Barriers

Photo Example of an Overhead Sign Support Mounted within Rigid Median Barrier.

Note: The sign panel message has been purposely blanked out.

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2. ***Approximately*** how many existing overhead sign supports mounted within or on top of rigid median barriers are installed throughout your agency's total divided highway network? Please enter a number, if known ________________. If not, please estimate below.

   ☐ 300+

   ☐ 100–299

   ☐ 10–99

   ☐ Fewer than 10

   ☐ None

   ☐ Unknown

3. Does your agency have **current or past standard plans, specifications, and/or design guidelines** for construction of bridge or cantilevered overhead sign supports mounted within or on top of rigid median barriers?

   ☐ Yes

   ☐ No

   If yes to above, the project team would like to review these documents in order to compile and summarize common practices for the Synthesis Report. Please use one of the three (3) methods below to provide access to pertinent **current or past standard plans, specifications, and/or design guidelines** for construction of bridge or cantilevered overhead sign supports mounted within or on top of rigid median barriers.

   a) Please upload documents here. If the file size is too large or the documents are in multiple files, please e-mail them to the Principal Investigator. Thank you. *<upload option>*

   b) Or provide an Internet URL: ________________________________

   c) Or provide contact information for obtaining standards and/or guidelines (name and e-mail address or telephone number is sufficient).

   ____

4. Does your agency have any **project-specific plans and/or specifications** for completed/existing bridge or cantilevered overhead sign supports mounted within or on top of rigid median barriers?

   ☐ Yes

   ☐ No

   If yes to above, the project team would like to review these documents in order to compile and summarize common practices for the Synthesis Report. Please use one of the three (3) methods below to provide access to pertinent **project-specific plans and/or specifications** for existing overhead sign supports mounted within or on top of rigid median barriers.

   a) Please upload documents here. If the file size is too large or the documents are in multiple files, please e-mail them to the Principal Investigator. Thank you. *<upload option>*

   b) Or provide an Internet URL: ________________________________

   c) Or provide contact information for obtaining standards and/or guidelines (name and e-mail address or telephone number is sufficient).

   ____

5. Please identify which design characteristics below have been used within your agency's jurisdiction to improve crash safety performance of any existing overhead sign supports mounted within or on top of rigid median barriers. Please check all that apply.

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Design Characteristic	Comments
☐ **LATERAL WIDENING OF THE BARRIER CROSS-SECTION IN THE VICINITY OF THE SIGN SUPPORT:** This treatment is typically used to move the support laterally farther from the traffic face of the barrier to remove it from or reduce the severity of its position within the Zone of Intrusion (ZOI).	
☐ **VERTICAL TAPERING OF THE TOP OF THE BARRIER PROFILE IN THE VICINITY OF THE SIGN SUPPORT:** This treatment gradually raises the height of the barrier on both sides of the sign support in an effort to reduce the ZOI of an impacting vehicle in the vicinity of the support.	
☐ **TRANSITIONING TO A DIFFERENT TYPE OF BARRIER IN THE VICINITY OF THE SIGN SUPPORT:** For example, transitioning from safety-shape barrier to vertical wall at the support location and then back to safety-shape. This treatment is also intended to reduce the ZOI at the support location.	
☐ **MODIFYING THE BARRIER BY ATTACHING A METAL BEAM RAIL TO THE TRAFFIC FACE OF THE BARRIER IN THE VICINITY OF THE SIGN SUPPORT:** An example is shown in Chapter 6, Figure 6-12 of the AASHTO *Roadside Design Guide*, 4th edition, 2011. This type of treatment is also intended to reduce the ZOI at the support location.	
☐ **ELIMINATING THE NEED FOR A SIGN SUPPORT BY MOVING THE SIGN LOCATION SUCH THAT IT IS SUPPORTED BY AN EXISTING STRUCTURE (BRIDGE, LUMINAIRE, OTHER SIGN SUPPORT, ETC.):** This treatment is encouraged, where possible, in the AASHTO *Roadside Design Guide*, 4th ed., 2011.	
☐ **OTHER:** Treatments that have been incorporated into existing installations that are intended to improve safety performance of a barrier/sign support installation. Please describe.	
☐ **NONE or UNKNOWN:** No known treatments have been incorporated into existing installations that are intended to improve safety performance of a barrier/sign support installation.	

6. **Additional Information Sources:** Does your agency have any of the following materials available related to existing overhead sign supports mounted within or on top of rigid median barriers? Please check all that apply.

- ☐ Photos
- ☐ Highway Photo Log Images
- ☐ Asset Management/Inventory Data
- ☐ Installation Location Information (Route/Direction/Milepost or GPS)
- ☐ Accident Experience Information

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☐ Other Information (Please describe) ____________________

☐ None

If any item other than "None" is checked above, the project team would like to review this information in order to compile and summarize common practices for the Synthesis Report. Please use one of the three (3) methods below to provide access to pertinent **additional information sources** for existing overhead sign supports mounted within or on top of rigid median barriers.

a) Please upload documents here. If the file size is too large or the documents are in multiple files, please e-mail them to the Principal Investigator. Thank you. *<upload option>*

b) Or provide an Internet URL: ____________________

c) Or provide contact information for obtaining standards and/or guidelines (name and e-mail address or telephone number is sufficient).

____

Section 3: Permanent Small Roadside Sign Supports Mounted on Rigid Median Barriers

Photo Examples of Permanent Small Sign Supports Mounted on Rigid Median Barriers.

Note: The mileage marker sign panel has been purposely blanked out.

7. ***Approximately*** how many existing, permanent small sign supports mounted on top of rigid median barriers are installed throughout your agency's total divided highway network? Please **include** mile markers, or similar small signs, if they utilize a post or separate support. **Do not** include lightweight mile markers or delineators/reflectors that are typically self-supported (no post) and less than 0.05 m^2 [0.5 ft^2] in panel area.

Please enter a number, if known ____________. If not, please estimate below.

☐ 1000+

☐ 500–999

☐ 100–499

☐ 10–99

☐ Fewer than 10

☐ None

☐ Unknown

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8. Does your agency have **current or past standard plans, specifications, and/or design guidelines** for construction of permanent small sign supports mounted on top of rigid median barriers? These include mile markers or similar small signs that utilize a post or support.

☐ Yes

☐ No

If yes to above, the project team would like to review these documents in order to compile and summarize common practices for the Synthesis Report. Please use one of the three (3) methods below to provide access to pertinent **current or past standard plans, specifications, and/or design guidelines** for construction of permanent small sign supports mounted on top of rigid median barriers. These include mile markers or similar small signs that utilize a post or support.

a) Please upload documents here. If the file size is too large or the documents are in multiple files, please e-mail them to the Principal Investigator. Thank you. *<upload option>*

b) Or provide an Internet URL: ______________________________

c) Or provide contact information for obtaining **standards and/or guidelines** (name and e-mail address or telephone number is sufficient).

____

9. Does your agency have any **project-specific plans and/or specifications** for completed/existing permanent small sign supports mounted on top of rigid median barriers? These include mile markers or similar small signs that utilize a post or support.

☐ Yes

☐ No

If yes to above, the project team would like to review these documents in order to compile and summarize common practices for the Synthesis Report. Please use one of the three (3) methods below to provide access to **project-specific plans and/or specifications** for completed/existing permanent small sign supports mounted on top of rigid median barriers. These include mile markers or similar small signs that utilize a post or support.

a) Please upload documents here. If the file size is too large or the documents are in multiple files, please e-mail them to the Principal Investigator. Thank you. *<upload option>*

b) Or provide an Internet URL: ______________________________

c) Or provide contact information for obtaining **project-specific plans and/or specifications** (name and e-mail address or telephone number is sufficient).

____

10. Please identify which design characteristics below have been used within your agency's jurisdiction to improve crash safety performance of any existing small sign supports mounted on top of rigid median barriers. Please check all that apply.

Design Characteristic	Comments
☐ **VERTICAL TAPERING OF THE TOP OF THE BARRIER PROFILE IN THE VICINITY OF THE SIGN SUPPORT:** This treatment gradually raises the height of the barrier on both sides of the sign support in an effort to reduce the ZOI of an impacting vehicle in the vicinity of the support.	
☐ **LATERAL WIDENING OF THE BARRIER CROSS-SECTION IN THE VICINITY OF THE SIGN**	

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SUPPORT: This treatment is typically used to move the support laterally farther from the traffic face of the barrier to remove it from or reduce the severity of its position within the ZOI.

- [ ] **TRANSITIONING TO A DIFFERENT TYPE OF BARRIER IN THE VICINITY OF THE SIGN SUPPORT:** For example, transitioning from safety-shape barrier to vertical wall at the support location and then back to safety-shape. This is also a treatment that may reduce the ZOI at the support location.
- [ ] **MODIFYING THE BARRIER BY ATTACHING A METAL BEAM RAIL TO THE TRAFFIC FACE OF THE BARRIER IN THE VICINITY OF THE SIGN SUPPORT:** An example is shown in Chapter 6, Figure 6-12 in the AASHTO *Roadside Design Guide*, 4th ed., 2011. This type of treatment is also intended to reduce the ZOI at the support location.
- [ ] **USE OF BREAKAWAY SIGN SUPPORTS:** Although this treatment is not typically recommended for barrier-mounted signs, there may be locations for which a designer determined that the benefits outweighed the risks for a unique situation.
- [ ] **CHAMFER OR ROUND OFF SHARP EDGES OF THE SIGN SUPPORT:** This treatment may be used to reduce snagging of the impacting vehicle, which may reduce the severity of the primary impact as well as the likelihood of the sign structure becoming dislodged.
- [ ] **LIMIT PROJECTION HEIGHT OF ANCHOR BOLTS:** This treatment may be used to reduce snagging of the impacting vehicle, which may reduce the severity of the primary impact as well as the likelihood of the sign structure becoming dislodged.
- [ ] **EXTRA STRENGTHENING OF THE SIGN SUPPORT BEYOND THAT REQUIRED TO RESIST WIND LOADS:** This treatment may be used to reduce the likelihood of the sign support becoming dislodged during a ZOI impact and therefore reduce the potential for creating secondary hazards.
- [ ] **ELIMINATING THE NEED FOR A SIGN SUPPORT BY MOVING THE SIGN SUCH THAT IT IS SUPPORTED BY AN EXISTING STRUCTURE (BRIDGE, LUMINAIRE, OTHER SIGN SUPPORT, ETC.):** This treatment is encouraged, where possible, in the AASHTO *Roadside Design Guide*, 4th ed., 2011.
- [ ] **OTHER:** Treatments that have been incorporated into existing installations that are intended to improve safety performance of a barrier/sign support installation. Please describe.
- [ ] **NONE or UNKNOWN:** No known treatments have been incorporated into existing installations that are intended to improve safety performance of a barrier/sign support installation.

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11. **Additional Information Sources:** Does your agency have any of the following materials available related to existing small sign supports mounted on top of rigid median barriers? Please check all that apply.

- ☐ Photos
- ☐ Highway Photo Log Images
- ☐ Asset Management/Inventory Data
- ☐ Installation Location Information (Route/Direction/Milepost or GPS)
- ☐ Accident Experience Information
- ☐ Other Information (Please describe) ____________________
- ☐ None

If any item other than "None" is checked, the project team would like to review this information in order to compile and summarize common practices for the Synthesis Report. Please use one of the three (3) methods below to provide access to pertinent **additional information sources** for existing small sign supports mounted on top of rigid median barriers.

a) Please upload documents here. If the file size is too large or the documents are in multiple files, please e-mail them to the Principal Investigator. Thank you. *<upload option>*

b) Or provide an Internet URL: ____________________

c) Or provide contact information for obtaining pertinent **additional information** (name and e-mail address or telephone number is sufficient).

____

The survey questionnaire is complete! Thank you for your participation!

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Abbreviations used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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