ROADSIDE DESIGN GUIDE

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Preface

This *Roadside Design Guide* was developed by the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Design through the Technical Committee for Roadside Safety (TCRS) under the chairmanship of Keith Cota, P.E. This book presents a synthesis of current information and operating practices related to roadside safety and is written in dual units—metric and U.S. Customary. This edition supersedes the 2006 AASHTO publication, which included the update of the Median chapter.

The roadside is defined as that area beyond the traveled way (i.e., driving lanes) and the shoulder (if any) of the roadway itself. Consequently, roadside delineation, shoulder surface treatments, and similar on-roadway safety features are not extensively discussed. Although safety can best be served by keeping motorists on the road, the focus of this guide is on safety treatments that minimize the likelihood of serious injuries when a driver does run off the road.

A second noteworthy point is that this book is a guide. It is not a standard, nor is it a design policy. It is intended to be used as a resource document from which individual highway agencies can develop standards and policies. Although much of the material in the guide can be considered universal in its application, several recommendations are subjective in nature and may need modification to fit local conditions. However, it is important that significant deviations from the guide be based on operational experience and objective analysis.

To be consistent with AASHTO's *A Policy on Geometric Design of Highways and Streets*, design speed has been selected as the basic speed parameter to be used in this guide. However, because the design speed often is selected based on the most restrictive physical features found on a specific project, reasonable and prudent drivers may exceed that speed for a significant percentage of a project length. There will be other instances in which roadway conditions will prevent most motorists from driving as fast as the design speed. Because roadside safety design is intended to minimize the consequences of a motorist leaving the roadway inadvertently, the designer should consider the speed at which encroachments are most likely to occur when selecting an appropriate roadside design standard or feature.

The 2011 edition of the AASHTO *Roadside Design Guide* has been updated to include hardware that has met the evaluation criteria contained in the National Cooperative Highway Research Program (NCHRP) *Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features* and begins to detail the most current evaluation criteria contained under the *Manual for Assessing Safety Hardware*, 2009 (MASH). For the most part, roadside hardware tested and accepted under older guidelines that are no longer applicable has been included in this edition.

The TCRS is currently working through a National Cooperative Highway Research Program (NCHRP) research project to update the Roadside Safety Analysis Program (RSAP) with the development of a "window-friendly" version. The RSAP update will be "beta" tested in 2011 and is expected to be available through AASHTO in early 2012, and will be available through a link on the web-based format of this publication.

As mentioned, design values are presented in this document in both metric and U.S. Customary units. The relationship between these values is neither an exact (i.e., soft) conversion nor a completely rationalized (i.e., hard) conversion. The metric values are those that would have been used had the guide been presented exclusively in metric units, while the U.S. Customary values are those that would have been used if the guide had been presented exclusively in U.S. Customary units. Therefore, the user is advised to work entirely in one system and not to attempt to convert directly between the two.

The reader is cautioned that roadside safety policy, criteria, and technology is a rapidly changing field of study. Changes in the roadside safety field are certain to occur after this document is published. Efforts should be made to incorporate the appropriate current design elements into the project development. Comments from users of this guide about suggested changes or modifications that result from further developmental work or hands-on experience will be appreciated. All such comments should be addressed to the American Association of State Highway and Transportation Officials, Engineering Program, 444 North Capitol Street NW, Suite 249, Washington, DC 20001.

Chapter 1
An Introduction to Roadside Safety

1.0 HISTORY OF ROADSIDE SAFETY

Roadside safety design, as one component of total highway design, is a relatively recent concept. Most of the highway design fundamentals were established by the late 1940s. Additional refinements were made in the 1950s and 1960s with the development of the Interstate system. These components included horizontal alignment, vertical alignment, hydraulic design, and sight distance to name some of the more common highway design elements. These elements have been revised and refined over the years through experience and research. However, the highway design components themselves have remained about the same for several decades.

Roadside safety design did not become a much discussed aspect of highway design until the late 1960s, and it was the decade of the 1970s before this type of design was regularly incorporated into highway projects. The purpose of this guide is to present the concepts of roadside safety to the designer in such a way that the most practical, appropriate, and cost-effective roadside design can be accomplished for each project.

1.1 THE BENEFITS OF ROADSIDE SAFETY

Roadside design might be defined as the design of the area outside the traveled way. Some have referred to this aspect of highway design as off-pavement design. A question commonly asked revolves around whether spending resources off the pavement is really beneficial given the limited nature of infrastructure funds. Perhaps some statistics can bring the potential of crash reduction and roadside safety into focus.

In 2009, 33,808 people died in motor vehicle traffic crashes in the United States—the lowest number of deaths since 1950 *(7)*. During the same time period, the number of vehicle-kilometers [vehicle-miles] of travel each year has increased by approximately six and one half times from 0.7 (0.5) billion to 4.8 (3.0) billion. Consequently, the traffic fatality rate per 100 million vehicle-kilometers [vehicle-miles] of travel has decreased approximately 85 percent from 4.58 (7.38) in 1950 to 0.71 (1.13) in 2009 (the latest year available for data on vehicle-kilometers [vehicle-miles] of travel). Figure 1-1 shows the number of fatalities and fatality rate from 1950 to 2009.

This significant reduction is due to several factors. Motor vehicles are much safer today than they have been in the past. Protected passenger compartments, padded interiors, occupant restraints, and airbags are some features that have added to passenger safety during impact situations. Roadways have been made safer through improvements in features such as horizontal and vertical alignments, intersection geometry, traversable roadsides, roadside barrier performance, and grade separations and interchanges. Drivers are more educated about safe vehicle operation as evidenced by the increased use of occupant restraints and a decrease in driving under the influence of alcohol or drugs. All these contributing factors have reduced the motor vehicle fatality rate.

Unfortunately, roadside crashes still account for far too great a portion of the total fatal highway crashes. In 2008, 23.1 percent of the fatal crashes were single-vehicle, run-off-the-road crashes. These figures mean that the roadside environment comes into play in a very significant percentage of fatal and serious-injury crashes.

Figure 1-1. Motor Vehicle Crash Deaths and Deaths Per 100 Million Vehicle Miles Traveled, 1950–2008 ***(6)***

1.2 STRATEGIC PLAN FOR IMPROVING ROADSIDE SAFETY

According to the Insurance Institute for Highway Safety (IIHS) and Highway Loss Data Institute (HLDI), the proportion of motor vehicle deaths involving collisions with fixed objects has fluctuated between 19 and 23 percent since 1979 *(4)*. Almost all fixed-object crashes involve only one vehicle and occur in both urban and rural areas. Figure 1-2 shows the percentage distribution of fixed-object fatalities by the object struck in 2008. Trees were by far the most common object struck, accounting for approximately half of all fixed-object fatal crashes. Utility poles were the second most common objects struck, accounting for 12 percent of all fixed object crashes, followed by traffic barriers with 8 percent. Furthermore, for 2008, 18 percent of fixed-object crashes involved vehicles that rolled over, while 18 percent involved occupant ejection. More detailed crash statistics are available from the following website at http://www.nhtsa.gov/FARS.

In 1967, the American Association for State Highway Officials (AASHO; currently the American Association for State Highway and Transportation Officials [AASHTO]) released its *Highway Design and Operational Practices Related to Highway Safety (1)*, the first official report that focused attention on hazardous roadside elements and suggested appropriate treatment for many of them. This guide, also known as the AASHTO "Yellow Book," was revised and updated in 1974 with the introduction of the forgiving roadside concept. In 1989, AASHTO published the first edition of the *Roadside Design Guide*.

In 1998, AASHTO approved their Strategic Highway Safety Plan *(3)*, which provides objectives and strategies for keeping vehicles on the roadway and for minimizing the consequences when a vehicle does encroach on the roadside. The National Cooperative Highway Research Program (NCHRP) also has published a series of guides, called the NCHRP Report 500 *(9)*, to assist state and local agencies in their efforts to reduce injuries and fatalities in targeted emphasis areas. These guides correspond to the emphasis areas outlined in AASHTO's Strategic Highway Safety Plan. The Strategic Highway Safety Plan and associated NCHRP Report 500 guides are available from the AASHTO website at http://safety.transportation.org/guides.aspx.

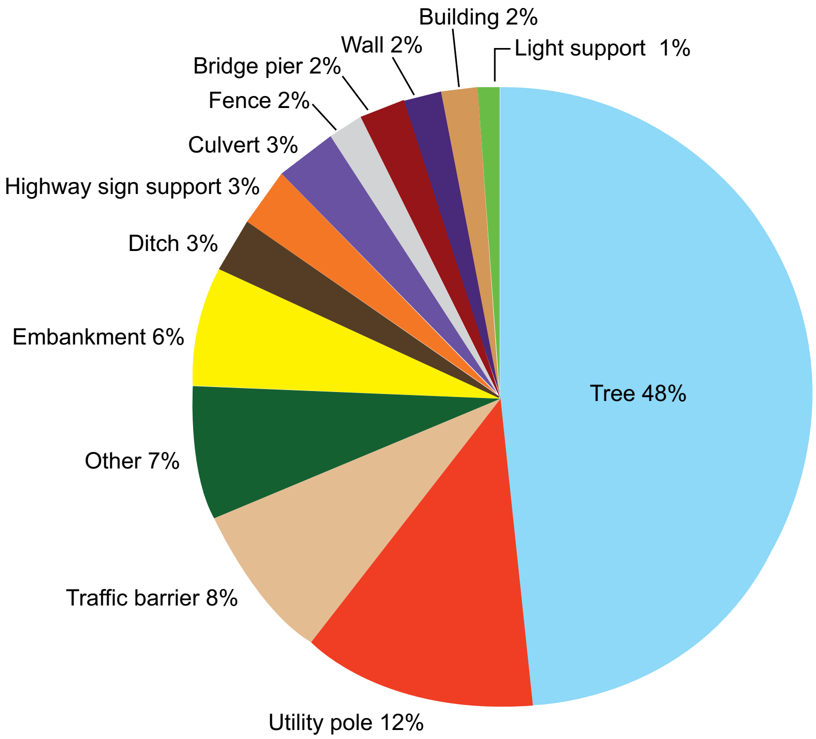

Figure 1-2. Percent Distribution of Fixed-Object Fatalities by Object Struck, 2008 *(4)*

For roadside design, Volumes 3, 6, and 8 of NCHRP Report 500 address collisions with trees in hazardous locations, run-off-the-road collisions, and the reduction of collisions involving utility poles.

A vehicle will leave the roadway and encroach on the roadside for many reasons, including the following:

- Driver fatigue
- Driver distractions or inattention
- Excessive speed
- Driving under the influence of drugs or alcohol
- Crash avoidance
- Adverse roadway conditions, such as ice, snow, or rain
- Vehicle component failure
- Poor visibility

Regardless of the reason for a vehicle leaving the roadway, a roadside environment free of fixed objects and with stable, flattened slopes enhances the opportunity for motorists to regain control of their vehicles and reduce crash severity. The forgiving roadside concept allows for errant vehicles leaving the roadway and supports a roadside design in which the serious consequences of such incidents are reduced.

Through decades of experience and research, the application of the forgiving roadside concept has been refined to the point where roadside design is an integral part of the transportation design process. Design options for reducing roadside obstacles, in order of preference, are as follows:

1. Remove the obstacle.
2. Redesign the obstacle so it can be safely traversed.
3. Relocate the obstacle to a point where it is less likely to be struck.
4. Reduce impact severity by using an appropriate breakaway device.
5. Shield the obstacle with a longitudinal traffic barrier designed for redirection or use a crash cushion.
6. Delineate the obstacle if the previous alternatives are not appropriate.

One on-roadway safety feature that is becoming more prevalent nationwide on facilities experiencing a significant number of run-off-the-road crashes is the use of rumble strips to supplement pavement edge lines. These indentations in the roadway shoulders alert motorists through noise and vibration that their vehicles have departed the traveled way and afford them an opportunity to return to and remain on the roadway safely. Several transportation agencies have reported significant reductions in single-vehicle crashes after installing shoulder rumble strips.

1.3 GUIDE CONTENT AND FORMAT

This guide replaces the Third Edition of AASHTO's *Roadside Design Guide* (2006) *(2)*. This publication can be considered a companion document for such current publications as *A Policy on Geometric Design of Highways and Streets* and *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*. There also are several research publications and additional reference literature at the end of each chapter.

Chapter 2 discusses methods for selecting appropriate alternative roadside safety enhancements, including the use of benefit/cost analysis to determine a ranking of alternatives in the absence of better local information. The Roadside Safety Analysis Program (RSAP) offers an example of one methodology for accomplishing a benefit/cost analysis of various alternatives.

Chapter 3 discusses the clear-zone concept. It gives some relative clear-zone values from which design guidance may be derived, as well as examples of the application of the clear-zone values. The chapter also includes a discussion of the treatment of drainage features.

Chapter 4 provides information on the use of sign and Luminaire supports within the roadside environment. Both small and large signs are included and criteria for breakaway and non-breakaway supports are presented. The chapter concludes with discussions of miscellaneous roadside features, such as mailbox supports, utility poles, and trees.

Chapters 5, 6, 7, and **8** provide information on various barrier systems and crash cushions. Chapter 5 discusses roadside barriers, Chapter 6 provides information for median barriers, Chapter 7 provides information on appropriate bridge railings, and Chapter 8 offers the latest state-of-the-practice information on barrier end treatments and crash cushions.

Chapter 9 discusses the application of the roadside safety concept for the temporary conditions found in construction or maintenance work zones. For example, the chapter contains information on clear zones in a work zone, temporary barriers, truck-mounted attenuators, and temporary traffic control devices.

Chapter 10 discusses the application of roadside safety in an urban environment. Although much of the information presented in this guide applies to rural high-speed facilities, this chapter offers information on urban roadside practices.

Chapter 11 provides information on mailboxes and mailbox turnout design.

Chapter 12 discusses the application of the roadside safety concept on very low-volume roads and streets.

1.4 CRASH TESTING ROADSIDE SAFETY FEATURES AND HARDWARE

This publication has numerous references to crash-testing criteria and crash-tested hardware. The intended implication of referring to a device as crash-tested is that the hardware was tested to the applicable criteria in existence at the time of the full-scale crash testing. Although full-scale crash testing subjects roadside safety devices to severe vehicular impact conditions, the testing cannot duplicate every roadside condition or vehicular impact situation. The testing provides for an acceptable level of performance under idealized conditions. However, every roadside device or installation has limitations dictated by physical laws, the crashworthiness of vehicles, and the limitation of resources. Some actual crashes may have impact situations that are more severe than the design impact conditions the testing was intended to replicate. In such crashes, the consequences could be beyond the expected severity suggested by the crash test results.

AASHTO's *Manual for Assessing Safety Hardware* (MASH) *(8)* contains the current recommendations for testing and evaluating the safety performance of highway features and hardware, including longitudinal barriers, terminals, crash cushions, work zone elements, and breakaway structures. MASH contains revised criteria for safety evaluation of virtually all permanent and temporary highway safety features, based primarily on changes in the vehicle fleet, and replaces the guidelines outlined in NCHRP Report 350 *(7)*.

MASH presents specific test level (TL) impact conditions for conducting vehicle crash tests. The specified test conditions include vehicle mass [weight], impact speed, approach angle, and point of impact on the safety feature. Standard test vehicle types are defined for small passenger cars (1100C), pickup trucks (2270P), single-unit van trucks (10,000S), tractor/van-type trailer units (36,000V), and tractor/tanker trailer units (36,000T). The design impact test conditions for each type of roadside hardware have been established to reflect the vast majority of real-world crash conditions. The specific MASH test conditions and evaluation criteria for each type of roadside device are summarized in the chapters that address that type of device. Table 1-1 shows the test matrix for traffic barrier systems as an example.

Table 1-1. Example of MASH Test Matrix for Traffic Barrier Systems *(8)*

Test Level	Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight kg [lb]	Speed km/h [mph]	Angle Degree
1	1100C (Passenger Car) 2270P (Pickup Truck)	1,100 [2,420] 2,270 [5,000]	50 [31] 50 [31]	25 25
2	1100C (Passenger Car) 2270P (Pickup Truck)	1,100 [2,420] 2,270 [5,000]	70 [44] 70 [44]	25 25
3	1100C (Passenger Car) 2270P (Pickup Truck)	1,100 [2,420] 2,270 [5,000]	100 [62] 100 [62]	25 25
4	1100C (Passenger Car) 2270P (Pickup Truck) 10000S (Single Unit Truck)	1,100 [2,420] 2,270 [5,000] 10,000 [22,000]	100 [62] 100 [62] 90 [56]	25 25 15
5	1100C (Passenger Car) 2270P (Pickup Truck) 36000V (Tractor/Van Trailer)	1,100 [2,420] 2,270 [5,000] 36,000 [79,300]	100 [62] 100 [62] 80 [50]	25 25 15
6	1100C (Passenger Car) 2270P (Pickup Truck) 36000T (Tractor/Tanker Trailer)	1,100 [2,420] 2,270 [5,000] 36,000 [79,300]	100 [62] 100 [62] 80 [50]	25 25 15

Federal Highway Administration (FHWA) policy requires that all roadside appurtenances such as traffic barriers, barrier terminals and crash cushions, bridge railings, sign and light pole supports, and work zone hardware used on the National Highway System (NHS) meet the performance criteria contained in NCHRP Report 350 or MASH. The FHWA website identifies all such hardware and includes copies of FHWA acceptance letters for each of them at http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/. In addition, information on roadside hardware can be found on the Task Force 13's website located at http://aashtotf13.org.

According to the AASHTO/FHWA Joint Implementation Plan *(5)*, all safety hardware accepted prior to adoption of MASH and using criteria contained in NCHRP Report 350 may remain in place and may continue to be manufactured and installed. Safety hardware installed on new construction and reconstruction projects shall be those accepted under NCHRP Report 350 or MASH. Agencies are encouraged to upgrade existing highway safety hardware that has not been accepted under NCHRP Report 350 or MASH either during reconstruction or resurfacing, rehabilitation, or restoration (3R) projects or when the system is damaged beyond repair. Highway safety hardware not accepted under NCHRP Report 350 or MASH with no suitable alternatives available may remain in place and may continue to be installed. The AASHTO/FHWA Joint Implementation Plan for MASH is available at the FHWA website at http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/.

1.5 THE APPLICATION OF THIS GUIDE

This publication is intended to present information on the latest state-of-the-practice in roadside safety. The concepts, designs, and philosophies presented in the following chapters cannot, and should not, be included in their totality on every single project. Each project is unique and offers an individual opportunity to enhance that particular roadside environment from a safety perspective.

The guidelines presented in this publication are mostly applicable to new construction or major reconstruction projects. These projects, which often include significant changes in horizontal or vertical alignment, offer the greatest opportunity for implementing many of the roadside safety enhancements presented in this document. For 3R projects, the primary emphasis is generally placed on the roadway itself to maintain the structural integrity of the pavement. It will be generally necessary to selectively incorporate roadside safety guidelines on 3R projects only at locations where the greatest safety benefit can be realized. Because of the scope of 3R projects and the limited nature of most rehabilitation programs, the identification of areas that offer the greatest safety enhancement potential is critical. Crash reports, site investigations, and maintenance records offer starting points for identifying these locations.

The amount of monetary resources available for all roadside safety enhancements is limited. The objective of designers is to maximize roadside safety on a system-wide basis using the available funds. Accomplishing this objective means addressing those specific roadside features that can contribute the most to the safety enhancement of an individual highway project. If including the highest level of roadside design criteria is routinely required in each highway design project—regardless of cost or safety effectiveness—it is likely that system-wide safety may stay static or even may be degraded. This potential certainly will exist if other, more pressing roadside safety needs are not improved because funds were not judiciously applied to the most viable safety enhancement needs.

Given the fact that fixed objects and slope changes are introduced at varying points off the pavement edge, the enhancement of roadside safety involves selecting the "best" choice among several acceptable design alternatives. The experience gained from decades of selecting design alternatives, the research done on vehicle dynamics, and the technological advances in materials offers the potential for maintaining and enhancing one of the safest national transportation systems in existence.

This guide is intended to represent the spectrum of commonly available roadside design alternatives. In most cases, these alternatives have shown significant benefits in appropriately selected field conditions. Many of these roadside enhancements have, over time, demonstrated their ability in the field to improve roadside safety conditions. In many areas, this publication strives to give the advantages and disadvantages of roadside technology. With this information, designers can make more knowledgeable decisions about the best applications for individual projects. However, no attempt is made or implied to offer every single roadside enhancement design technique or technology.

Finally, this guide is not intended to be used as a standard or a policy statement. This document is made available to be a resource for current information in the area of roadside design. Agencies may choose to use this information as one reference on which to build the roadside design criteria best suited to their particular location and projects. Knowledgeable design, practically applied at the project level, offers the greatest potential for a continually improved transportation system.

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