



ROADSIDE DESIGN GUIDE

4th Edition 2011



AMERICAN ASSOCIATION OF
STATE HIGHWAY AND
TRANSPORTATION OFFICIALS

AASHTO
THE VOICE OF TRANSPORTATION



ROADSIDE DESIGN GUIDE

4th Edition 2011



AMERICAN ASSOCIATION OF
STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
AASHTO
THE VOICE OF TRANSPORTATION



American Association of State Highway and Transportation Officials
444 North Capitol Street, NW, Suite 249
Washington, DC 20001

202-624-5800 phone/202-624-5806 fax

www.transportation.org

© 2011 by the American Association of State Highway and Transportation Officials. All rights reserved.
Duplication is a violation of applicable law. Cover photographs courtesy of Washington DOT and Missouri DOT.

Publication Code: RSDG-4

ISBN: 978-1-56051-509-8

Executive Committee 2010–2011

Officers

President: Susan Martinovich, P.E., NEVADA
Vice President: Kirk Steudle, P.E., MICHIGAN
Secretary/Treasurer: Carlos Braceras, UTAH

Immediate Past President: *Vacant*

Regional Representatives

REGION I

George N. Campbell, Jr., NEW HAMPSHIRE
Beverley K. Swaim-Staley, MARYLAND

REGION II

Mike Hancock, KENTUCKY
Robert St. Onge, SOUTH CAROLINA

REGION III

Thomas K. Sorel, MINNESOTA
Vacant

REGION IV

Amadeo Saenz, Jr., TEXAS
Francis G. Ziegler P.E., NORTH DAKOTA

Non-Voting Members

Executive Director: John Horsley, AASHTO

Task Force for Roadside Safety

Region 1

Delaware	Drew Boyce
Maryland	Teri Soos
New Hampshire	Keith A. Cota (Chair)
New York	Richard D. Wilder

Region 2

Alabama	Steven Walker (Vice-Chair)
Georgia	Ben Buchan
Mississippi	Steve Reeves
Louisiana	Paul Fossier

Region 3

Iowa	David Little
Kansas	Rod Lacy
Missouri	Joe Jones
Ohio	Michael Bline

Region 4

Idaho	Damon Allen
South Dakota	Bernie Clocksin
Texas	Aurora (Rory) Meza
California	Kevin Herritt

Subcommittee on Bridges and Structures Representatives

Region 1:	Jiten K. Soneji, Delaware
Region 2:	Vacant
Region 3:	Vacant
Region 4:	Vacant

Others

FHWA	Nick Artimovich (Secretary), Frank Julian, Ken Opiela, Richard Albin
TRB	Charles Niessner
Ontario	Joe Bucik, Mark Ayton
AASHTO Liaison	Keith M. Platte

Highway Subcommittee on Design

VACANT, Chair

RICHARD LAND, California, Vice Chair

DAVID A. NICHOL, FHWA, Secretary

KEITH M. PLATTE, AASHTO, Staff Liaison

ALABAMA, William Adams,
Rex Bush, Carey Kelley

ALASKA, Mark Neidhold,
Robert A. Campbell

ARIZONA, Mary Viparina

ARKANSAS, Michael Fugett,
Phillip L. McConnell

CALIFORNIA, Terry L. Abbott

COLORADO, Jeffrey Wassenaar

CONNECTICUT, Michael W. Lonergan,
James H. Norman, Timothy M. Wilson

DELAWARE, Michael F. Balbierer,
James M. Satterfield

DISTRICT OF COLUMBIA,
Said Cherifi, Zahra Dorriz,
Allen Miller

FLORIDA, James Mills, David O'Hagan,
Frank Sullivan

GEORGIA, James "Ben" Buchan,
Russell McMurry, Brent Story

HAWAII, Julius Fronda

IDAHO, Loren D. Thomas,
Nestor Fernandez

ILLINOIS, Scott E. Stitt

INDIANA, Jeff Clanton,
Merril E. Dougherty, John E. Wright

IOWA, Michael J. Kennerly,
David L. Little, Deanna Maifield

KANSAS, James O. Brewer, Robert Lacy

KENTUCKY, Keith Caudill,
Bradley S. Eldridge, Jeff D. Jasper

LOUISIANA, Nicholas Kalivoda III,
David S. Smith, Chad Winchester

MAINE, Bradford P. Foley

MARYLAND, Kirk G. McClelland

MASSACHUSETTS, Stanley Wood, Jr.

MICHIGAN, Bradley C. Wiefelich

MINNESOTA, John M. Chiglo,
Mukhtar Thakur

MISSISSIPPI, John M. Reese,
Amy Mood, C. Keith Purvis

MISSOURI, David B. Nichols,
Kathryn P. Harvey

MONTANA, Paul R. Ferry,
Lesly Tribelhorn

NEBRASKA, James J. Knott,
Ted Watson

NEVADA, Paul Frost, Eric Glick,
Paul K. Sinnott

NEW HAMPSHIRE, Craig A. Green

NEW JERSEY, Richard Jaffe

NEW MEXICO,
Gabriela Contreras-Apodaca,
Joe S. Garcia

NEW YORK, Daniel D'Angelo

NORTH CAROLINA,
Deborah M. Barbour, Jay A. Bennett,
Art McMillan

NORTH DAKOTA, Roger Weigel

OHIO, Dirk Gross, Timothy McDonald

OKLAHOMA, Tim Tegeler

OREGON, David Joe Polly,
Steven R. Lindland

PENNSYLVANIA, Brian D. Hare

PUERTO RICO, Luis Santos,
José E. Santana-Pimentel

RHODE ISLAND, Robert Smith

SOUTH CAROLINA,
Rob Bedenbaugh, Mark Lester,
Mitchell D. Metts

SOUTH DAKOTA, Michael Behm,
Mark A. Leiferman

TENNESSEE, Michael Agnew,
Jeff C. Jones, Carolyn Stonecipher

TEXAS, Mark A. Marek

UTAH, Jesse Sweeten, Lisa Wilson

VERMONT, Kevin Marshia

VIRGINIA, Robert H. Cary,
Mohammad Mirshahi,
Barton A. Thrasher

WASHINGTON, Pasco Bakotich,
Terry L. Berends, Nancy Boyd,
Dave Olson

WEST VIRGINIA, Gregory Bailey,
Jason C. Foster

WISCONSIN, Jerry H. Zogg

WYOMING, Tony Laird

ASSOCIATE MEMBER—Bridge, Port, and Toll

NJ TURNPIKE AUTHORITY,
J. Lawrence Williams

PORT AUTHORITY OF NY AND NJ,
Scott D. Murrell

ASSOCIATE MEMBER—Federal

USDA FOREST SERVICE,
Ellen G. LaFayette

ASSOCIATE MEMBER— International

ALBERTA, Moh Lali

BRITISH COLUMBIA, Richard Voyer

KOREA, Chan-Su "Chris" Reem

ONTARIO, Joe Bucik

SASKATCHEWAN, Sukhy Kent

Table of Contents

PREFACE	xxvii
CHAPTER 1—AN INTRODUCTION TO ROADSIDE SAFETY	1-1
1.0 HISTORY OF ROADSIDE SAFETY	1-1
1.1 THE BENEFITS OF ROADSIDE SAFETY	1-1
1.2 STRATEGIC PLAN FOR IMPROVING ROADSIDE SAFETY	1-2
1.3 GUIDE CONTENT AND FORMAT	1-4
1.4 CRASH TESTING ROADSIDE SAFETY FEATURES AND HARDWARE	1-4
1.5 THE APPLICATION OF THIS GUIDE.....	1-6
CHAPTER 2—ECONOMIC EVALUATION OF ROADSIDE SAFETY	2-1
2.0 OVERVIEW	2-1
2.1 BENEFIT/COST ANALYSIS.....	2-1
2.1.1 Encroachments.....	2-2
2.1.2 Roadside Geometry.....	2-2
2.1.3 Crash Costs.....	2-2
2.2 BENEFIT/COST ANALYSIS PROGRAMS	2-2
2.3 IN-SERVICE PERFORMANCE EVALUATION.....	2-3
CHAPTER 3—ROADSIDE TOPOGRAPHY AND DRAINAGE FEATURES	3-1
3.0 OVERVIEW	3-1
3.1 THE CLEAR-ZONE CONCEPT.....	3-1
3.2 ROADSIDE GEOMETRY	3-4
3.2.1 Foreslopes	3-4
3.2.2 Backslopes.....	3-6
3.2.3 Transverse Slopes	3-6
3.2.4 Drainage Channels	3-8
3.3 APPLICATION OF THE CLEAR-ZONE CONCEPT.....	3-10
3.3.1 Recoverable Foreslopes.....	3-11
3.3.2 Non-Recoverable Foreslopes.....	3-11
3.3.3 Critical Foreslopes	3-11
3.3.4 Examples of Clear-Zone Application on Variable Slopes	3-11
3.3.5 Clear-Zone Applications for Drainage Channels and Backslopes	3-12
3.3.6 Clear Zone for Auxiliary Lanes and Freeway Ramps	3-12
3.4 DRAINAGE FEATURES	3-12
3.4.1 Curbs.....	3-13
3.4.2 Cross-Drainage Structures.....	3-13

3.4.2.1 Traversable Designs	3-14
3.4.2.2 Extension of Structure	3-14
3.4.2.3 Shielding	3-16
3.4.3 Parallel Drainage Features.....	3-16
3.4.3.1 Eliminate the Structure	3-16
3.4.3.2 Traversable Designs	3-16
3.4.3.3 Relocate the Structure.....	3-18
3.4.3.4 Shielding.....	3-19
3.4.4 Drop Inlets	3-19
3.5 EXAMPLES OF THE CLEAR-ZONE CONCEPT TO RECOVERABLE FORESLOPES	3-19
CHAPTER 4—SIGN, SIGNAL, AND LUMINAIRE SUPPORTS, UTILITY POLES, TREES, AND SIMILAR ROADSIDE FEATURES	4-1
4.0 OVERVIEW	4-1
4.1 ACCEPTANCE CRITERIA FOR BREAKAWAY SUPPORTS.....	4-2
4.2 DESIGN AND LOCATION CRITERIA FOR BREAKAWAY AND NON-BREAKAWAY SUPPORTS.....	4-2
4.3 SIGN SUPPORTS.....	4-4
4.3.1 Overhead Sign Supports	4-4
4.3.2 Large Roadside Sign Supports	4-4
4.3.3 Small Roadside Sign Supports.....	4-7
4.4 MULTIPLE POST SUPPORTS FOR SIGNS.....	4-10
4.5 LUMINAIRE SUPPORTS	4-10
4.5.1 Breakaway Luminaire Supports.....	4-10
4.5.2 High-Level Lighting Supports	4-12
4.6 TRAFFIC SIGNAL SUPPORTS	4-12
4.7 SUPPORTS FOR MISCELLANEOUS DEVICES	4-13
4.7.1 Railroad Crossing Warning Devices	4-13
4.7.2 Fire Hydrants	4-13
4.7.3 Mailbox Supports	4-13
4.8 UTILITY POLES.....	4-13
4.9 TREES	4-15
CHAPTER 5—ROADSIDE BARRIERS	5-1
5.0 OVERVIEW	5-1
5.1 PERFORMANCE REQUIREMENTS	5-1
5.1.1 FHWA Acceptance Letters	5-3
5.1.2 Standard Barrier Hardware Guide	5-3
5.2 BARRIER RECOMMENDATIONS.....	5-3
5.2.1 Roadside Geometry and Terrain Features.....	5-4
5.2.2 Roadside Obstacles	5-9
5.2.3 Bystanders, Pedestrians, and Bicyclists	5-10

5.2.4 Motorcycles and Barrier Design	5-10
5.3 TEST LEVEL SELECTION FACTORS	5-10
5.4 STRUCTURAL AND SAFETY CHARACTERISTICS OF ROADSIDE BARRIERS	5-11
5.4.1 Standard Sections of Roadside Barriers	5-11
5.4.1.1 Low-Tension Cable	5-13
5.4.1.2 High-Tension Cable.....	5-14
5.4.1.3 W-Beam (Weak Post)	5-14
5.4.1.4 Ironwood Aesthetic Guardrail	5-15
5.4.1.5 Box Beam (Weak Post)	5-15
5.4.1.6 Blocked-Out W-Beam (Strong Post)	5-16
5.4.1.7 Midwest Guardrail System (MGS).....	5-18
5.4.1.8 Proprietary W-Beam Guardrail Systems.....	5-20
5.4.1.8.1 Gregory Mini Spacer™ (GMS) Guardrail System	5-21
5.4.1.8.2 Trinity T-31™ Guardrail System	5-21
5.4.1.8.3 NU-GUARD™ 31 by Nucor Steel Marion, Inc.	5-22
5.4.1.9 Blocked-Out Thrie-Beam	5-23
5.4.1.9.1 Blocked-Out Thrie-Beam (Wood and Steel Strong Post)	5-23
5.4.1.9.2 Modified Thrie-Beam	5-23
5.4.1.9.3 Trinity T-39™ Guardrail System	5-24
5.4.1.10 Merritt Parkway Aesthetic Guardrail	5-25
5.4.1.11 Backed Timber Guardrail	5-26
5.4.1.12 Concrete Barriers	5-26
5.4.1.13 CUSHIONWALL® II Crash Cushion System.....	5-29
5.4.1.14 Stone Masonry Wall/Precast Masonry Wall	5-29
5.4.2 Long-Span Guardrail Systems	5-30
5.4.3 Transition Designs	5-31
5.5 SELECTION GUIDELINES	5-32
5.5.1 Barrier Performance Capability	5-32
5.5.2 Barrier Deflection Characteristics	5-33
5.5.3 Site Conditions	5-38
5.5.4 Compatibility	5-38
5.5.5 Life-Cycle Costs	5-38
5.5.6 Maintenance	5-38
5.5.6.1 Routine Maintenance	5-38
5.5.6.2 Crash Maintenance	5-38
5.5.6.3 Material and Storage Requirements	5-39
5.5.6.4 Simplicity of Barrier Design	5-39
5.5.7 Aesthetic and Environmental Considerations	5-39
5.5.8 Field Experience	5-39

5.6 PLACEMENT RECOMMENDATIONS	5-39
5.6.1 Barrier Offset	5-40
5.6.2 Terrain Effects	5-43
5.6.2.1 Curbs	5-43
5.6.2.1.1 Curb/Guardrail Combinations for Strong-Post W-Beam Guardrail.....	5-44
5.6.2.1.2 Crash Tested Curb/Guardrail Combinations.....	5-45
5.6.2.2 Slopes	5-46
5.6.3 Flare Rate	5-48
5.6.5 Grading for Terminals.....	5-59
5.6.6 Guardrail Placed in a Radius	5-60
5.6.7 Guardrail Posts in Rigid Foundations	5-61
5.6.7.1 Guardrail Posts in Rock Formations.....	5-61
5.6.7.2 Guardrail Posts in Mow Strips	5-61
5.7 UPGRADING SYSTEMS	5-66
5.7.1 Structural Inadequacies	5-66
5.7.2 Design/Placement Inadequacies	5-66
5.7.3 Establishing Priorities of Upgrading Needs	5-66
CHAPTER 6—MEDIAN BARRIERS	6-1
6.0 OVERVIEW	6-1
6.1 PERFORMANCE REQUIREMENTS	6-1
6.2 GUIDELINES FOR MEDIAN BARRIER APPLICATION	6-1
6.3 PERFORMANCE LEVEL SELECTION PROCEDURES	6-3
6.4 STRUCTURAL AND SAFETY CHARACTERISTICS OF MEDIAN BARRIERS	6-3
6.4.1 Crashworthy Median Barrier Systems	6-3
6.4.1.1 Weak-Post W-Beam Median Barrier.....	6-5
6.4.1.2 Low-Tension Cable Barrier	6-5
6.4.1.3 High-Tension Cable Barrier	6-6
6.4.1.4 Box-Beam Median Barrier	6-9
6.4.1.5 Blocked-Out W-Beam (Strong Post)	6-9
6.4.1.6 Blocked-Out Thrie-Beam (Strong Post)	6-10
6.4.1.7 Modified Thrie-Beam Median Barrier	6-10
6.4.1.8 Concrete Barrier	6-11
6.4.1.9 Quickchange® Moveable Barrier System	6-14
6.4.2 End Treatments	6-14
6.4.3 Transitions	6-16
6.5 SELECTION GUIDELINES	6-16
6.5.1 Barrier Performance Capability	6-16
6.5.2 Barrier Deflection Characteristics	6-16
6.5.3 Compatibility	6-16

6.5.4 Costs	6-17
6.5.5 Maintenance	6-17
6.5.6 Aesthetic and Environmental Considerations	6-17
6.5.7 Field Experience	6-17
6.6 PLACEMENT RECOMMENDATIONS	6-17
6.6.1 Terrain Effects	6-17
6.6.1.1 Median Section I.....	6-18
6.6.1.2 Median Section II.....	6-18
6.6.1.3 Median Section III.....	6-19
6.6.2 Fixed Objects within the Median	6-20
6.7 UPGRADING SYSTEMS	6-21
CHAPTER 7—BRIDGE RAILINGS AND TRANSITIONS	7-1
7.0 OVERVIEW	7-1
7.1 PERFORMANCE REQUIREMENTS.....	7-1
7.2 GUIDELINES	7-2
7.3 APPROPRIATE TEST LEVEL SELECTION CONSIDERATIONS.....	7-2
7.4 CRASH-TESTED RAILINGS	7-2
7.4.1 NCHRP 350 TL-1 through TL-4 Bridge Railings.....	7-4
7.4.2 MASH TL-5 and TL-6 Bridge Railings	7-5
7.5 SELECTION GUIDELINES.....	7-6
7.5.1 Railing Performance	7-6
7.5.2 Compatibility.....	7-7
7.5.3 Costs	7-7
7.5.4 Field Experience	7-7
7.5.5 Aesthetics	7-7
7.5.6 Protective Screening at Overpasses.....	7-7
7.6 PLACEMENT RECOMMENDATIONS	7-8
7.6.1 Considerations for Urban and Low-Volume Roads.....	7-8
7.7 UPGRADING OF BRIDGE RAILINGS.....	7-10
7.7.1 Identification of Potentially Obsolete Systems	7-10
7.7.2 Upgrading Systems.....	7-11
7.7.2.1 Concrete Retrofit (Safety Shape or Vertical)	7-11
7.7.2.2 W-Beam or Thrie-Beam Retrofits.....	7-12
7.7.2.3 Metal Post-and-Beam Retrofits	7-13
7.8 TRANSITIONS.....	7-14
CHAPTER 8—END TREATMENTS	8-1
8.0 OVERVIEW	8-1
8.1 PERFORMANCE REQUIREMENTS.....	8-1

8.1.1 FHWA Acceptance Letters	8-2
8.1.2 Guide to Standardized Barrier Hardware	8-2
8.2 ANCHORAGE DESIGN CONCEPTS	8-2
8.3 TERMINAL DESIGN CONCEPTS.....	8-3
8.3.1 Compatibility of Terminals with Flexible and Semi-Rigid Barrier Systems	8-3
8.3.2 Performance Characteristics of Terminals.....	8-4
8.3.2.1 Energy-Absorbing vs. Non-Energy-Absorbing Terminals	8-4
8.3.2.2 Flared versus Tangent Terminals	8-4
8.3.2.3 Length-of-Need Point	8-4
8.3.3 Site Grading Considerations for Terminals	8-4
8.3.3.1 Advance Grading.....	8-5
8.3.3.2 Adjacent Grading	8-5
8.3.3.3 Runout Distance Grading	8-6
8.3.4 Terminals.....	8-7
8.3.5 Terminals for Cable Barrier Systems	8-7
8.3.5.1 Three-Strand Cable Terminal.....	8-7
8.3.5.2 Terminals for High-Tension Cable Barrier Systems.....	8-8
8.3.6 Terminals for W-Beam Guardrail Systems	8-9
8.3.6.1 Buried-in-Backslope Terminal	8-10
8.3.6.2 Flared W-Beam Terminals	8-11
8.3.6.2.1 Eccentric Loader Terminal (ELT)	8-11
8.3.6.2.2 Modified Eccentric Loader Terminal (MELT)	8-12
8.3.6.2.3 Flared Energy-Absorbing Terminal (FLEAT™)	8-12
8.3.6.2.4 Slotted Rail Terminal (SRT-350™)	8-12
8.3.6.2.5 X-Tension™ Guardrail End Terminal	8-13
8.3.6.3 Tangent W-Beam Terminals	8-14
8.3.6.3.1 Extruder Terminal (ET-Plus™).....	8-14
8.3.6.3.2 Sequential Kinking Terminal (SKT-350™)	8-15
8.3.6.3.3 X-Tension™ Guardrail Terminal	8-16
8.3.6.4 Terminals for 787-mm [31-in.] Height Steel Beam Guardrail Systems	8-16
8.3.6.5 Median Terminals	8-16
8.3.6.5.1 Brakemaster® 350.....	8-16
8.3.6.5.2 Crash Cushion Attenuating Terminal (CAT-350™).....	8-18
8.3.6.5.3 FLEAT Median Terminal (FLEAT-MT™)	8-18
8.3.6.5.4 X-Tension™ Median Attenuator System (X-MAS).....	8-18
8.3.7 Terminals for Box-Beam Guardrail.....	8-19
8.3.7.1 Wyoming Box-Beam End Terminal (WY-BET™)	8-20
8.3.7.2 Bursting Energy Absorbing Terminal (BEAT™)	8-20
8.4 CRASH CUSHION DESIGN CONCEPTS	8-21

8.4.1 Design Principles	8-22
8.4.1.1 Work-Energy Principle.....	8-22
8.4.1.2 Conservation of Momentum Principle.....	8-22
8.4.2 Crash Cushions Based on Work-Energy Principle	8-23
8.4.2.1 Sacrificial Crash Cushions.....	8-23
8.4.2.1.1 Thrie-Beam Bullnose Guardrail System	8-24
8.4.2.1.2 ABSORB 350®.....	8-24
8.4.2.1.3 Advanced Dynamic Impact Extension Module (ADIEM™).....	8-25
8.4.2.1.4 Bursting Energy Absorbing Terminal–Single Sided Crash Cushion (BEAT-SSCC™) System	8-25
8.4.2.1.5 Bursting Energy Absorbing Terminal–Bridge Pier (BEAT-BP™) System	8-26
8.4.2.1.6 QuadTrend® 350	8-27
8.4.2.1.7 Narrow Connecticut Impact Attenuation System (NCIAS).....	8-27
8.4.2.2 Reusable Crash Cushions	8-28
8.4.2.2.1 QuadGuard® Family	8-28
8.4.2.2.2 Universal TAU-II® Family	8-29
8.4.2.2.3 Trinity Attenuating Crash Cushion (TRACC™) Family.....	8-30
8.4.2.2.4 QUEST® Crash Cushion	8-30
8.4.2.3 Low-Maintenance and/or Self-Restoring Crash Cushions.....	8-31
8.4.2.3.1 Compressor™ Attenuator	8-31
8.4.2.3.2 EASI-CELL® Cluster	8-32
8.4.2.3.3 Hybrid Energy Absorbing Reusable Terminal (HEART™).....	8-32
8.4.2.3.4 QuadGuard Elite	8-33
8.4.2.3.5 QuadGuard Low-Maintenance Cartridge (LMC)	8-34
8.4.2.3.6 Reusable Energy-Absorbing Crash Terminal (REACT 350®)	8-34
8.4.2.3.7 Smart Cushion Innovations 100GM and 70GM (SCI-100GM and SCI-70GM).....	8-35
8.4.3 Crash Cushions Based on Conservation of Momentum Principle	8-36
8.4.4 Miscellaneous Crash Cushions and End Treatments for Concrete Barriers	8-41
8.4.4.1 Sloped Concrete End Treatment.....	8-42
8.4.4.2 Buried Concrete Barrier Terminal	8-42
8.4.4.3 Dragnet	8-42
8.4.4.4 Ground Retractable Automotive Barrier (GRAB-300®).....	8-43
8.4.4.5 Gravel-Bed Attenuator	8-44
8.4.4.6 STOPGATE®.....	8-44
8.4.4.7 Florida Low-Profile Barrier Terminal	8-45
8.4.5 Crash Cushion Selection Guidelines	8-45
8.4.5.1 Site Characteristics.....	8-45
8.4.5.2 Crash Cushion Structural and Safety Characteristics	8-45
8.4.5.3 Costs	8-47
8.4.5.4 Maintenance Characteristics.....	8-47

8.4.5.5 Selection Criteria	8-50
8.4.5.6 Inclusion Area.....	8-50
8.4.6 Placement Recommendations.....	8-51
8.5 DELINEATION OF END TREATMENTS.....	8-51

CHAPTER 9—TRAFFIC BARRIERS, TRAFFIC CONTROL DEVICES, AND OTHER SAFETY FEATURES FOR WORK ZONES 9-1

9.0 OVERVIEW	9-1
9.1 THE CLEAR-ZONE CONCEPT IN WORK ZONES.....	9-2
9.1.1 Application of the Clear-Zone Concept in Work Zones	9-2
9.2 TRAFFIC BARRIERS.....	9-2
9.2.1 Temporary Longitudinal Barriers	9-2
9.2.1.1 Test-Level Requirements.....	9-3
9.2.1.2 Portable Concrete Barriers	9-3
9.2.1.2.1 Iowa Temporary Concrete Barrier.....	9-4
9.2.1.2.2 Rockingham Precast Concrete Barrier.....	9-6
9.2.1.2.3 J-J Hooks Portable Concrete Barrier	9-6
9.2.1.2.4 Modified Virginia DOT Portable Concrete Barrier	9-7
9.2.1.2.5 California K-Rail Portable Concrete Barrier for Semi-Permanent Installations.....	9-8
9.2.1.2.6 GPLINK® Pre-Cast Temporary Concrete Barrier.....	9-9
9.2.1.2.7 Georgia Temporary Concrete Barrier	9-9
9.2.1.2.8 Idaho 6.1-m [20-ft] New Jersey Portable Barrier.....	9-10
9.2.1.2.9 Oregon Pin-and-Loop Barrier	9-11
9.2.1.2.10 Ohio DOT 3-m [10-ft] Long New Jersey Profile Temporary Concrete Barrier.....	9-12
9.2.1.2.11 New York DOT Portable Concrete Barrier.....	9-12
9.2.1.2.12 Iowa DOT Tie-Down Steel H-Section Temporary Barrier	9-13
9.2.1.2.13 Quick-Bolt F-Shaped Concrete Safety Barrier	9-14
9.2.1.2.14 Texas X-Bolt F-Shaped Concrete Safety Barrier.....	9-14
9.2.1.2.15 Texas Single Slope Concrete Barrier (SSCB)	9-15
9.2.1.2.16 Minimizing Deflection.....	9-16
9.2.1.2.17 Restricted Sites.....	9-19
9.2.1.3 Other Concrete Barriers	9-19
9.2.1.3.1 Quickchange® Barrier System.....	9-19
9.2.1.3.2 Low-Profile Barrier System	9-20
9.2.1.3.3 Florida Low-Profile Barrier System.....	9-20
9.2.1.4 Other Barriers	9-20
9.2.1.4.1 Water-Filled Barriers	9-20
9.2.1.4.2 Steel Barriers	9-21
9.2.2 End Treatments.....	9-22
9.2.3 Transitions.....	9-23

9.2.3.1 Portable Concrete Barrier Steel Plate Transition	9-23
9.2.3.2 F-Shaped Portable Concrete Barrier to Low-Profile Barrier Transition	9-24
9.2.4 Applications	9-24
9.3 Crash Cushions.....	9-25
9.3.1 Stationary Crash Cushions.....	9-25
9.3.1.1 Sand-Filled Plastic Barrels.....	9-25
9.3.1.2 QuadGuardD™ CZ System	9-26
9.3.1.3 REACT® 350 CZ	9-26
9.3.2 Truck- and Trailer-Mounted Attenuators (TMAs).....	9-27
9.3.2.1 Test-Level Selection for TMAs	9-29
9.3.2.2 Placement	9-29
9.3.2.2.1 Buffer Distance	9-29
9.3.2.2.2 Mass of a Shadow Vehicle	9-30
9.3.2.2.3 Delineation.....	9-30
9.3.2.3 Crashworthy TMAs	9-30
9.4 TRAFFIC CONTROL DEVICES	9-32
9.4.1 Channelizing Devices	9-33
9.4.1.1 Test-Level Evaluation Criteria.....	9-33
9.4.1.2 Cones and Tubular Markers	9-33
9.4.1.3 Vertical Panels.....	9-34
9.4.1.4 Drums	9-35
9.4.1.5 Barricades	9-35
9.4.1.6 Longitudinal Channelizing Devices.....	9-37
9.4.2 Signs and Supports.....	9-38
9.4.2.1 Long- and Intermediate-Term Work-Zone Sign Supports.....	9-38
9.4.2.2 Wheeled Portable Sign Supports	9-38
9.4.2.3 Short-Term Work-Zone Sign Supports	9-38
9.4.2.4 Trailer-Mounted Devices	9-39
9.4.2.5 Warning Lights.....	9-40
9.5 OTHER WORK-ZONE FEATURES.....	9-40
9.5.1 Glare Screens	9-40
9.5.2 Pavement Edge Drop-Offs	9-41
CHAPTER 10—ROADSIDE SAFETY IN URBAN OR RESTRICTED ENVIRONMENTS	10-1
10.0 OVERVIEW.....	10-1
10.1 EVALUATION OF CRITICAL URBAN ROADSIDE LOCATIONS.....	10-2
10.1.1 Evaluation of Individual Sites.....	10-2
10.1.2 Design Speed and Functional Use.....	10-3
10.1.3 Targeted Design Approach for High-Risk Urban Roadside Corridors.....	10-3
10.1.3.1 Obstacles in Close Proximity to Curb Face or Lane Edge	10-3

10.1.3.2 Lane Merge Locations	10-4
10.1.3.3 Driveway Locations	10-5
10.1.3.4 Intersection Locations	10-6
10.2 ROADSIDE FEATURES FOR URBAN AND RESTRICTED AREAS.....	10-7
10.2.1 Common Urban Roadside Features	10-7
10.2.1.1 Curbs.....	10-7
10.2.1.2 Shoulders.....	10-8
10.2.1.3 Channelization and Medians	10-8
10.2.1.4 Gateways	10-8
10.2.1.5 Roadside Grading	10-9
10.2.1.6 Pedestrian Facilities	10-9
10.2.1.7 Bicycle Facilities.....	10-11
10.2.1.8 Parking	10-12
10.2.2 Safe Placement of Roadside Objects	10-12
10.2.2.1 Mailboxes	10-12
10.2.2.2 Street Furniture.....	10-13
10.2.2.3 Vertical Roadside Treatments and Their Hardware	10-13
10.2.2.3.1 Utility Poles	10-14
10.2.2.3.2 Lighting and Visibility	10-14
10.2.2.3.3 Sign Posts and Roadside Hardware	10-14
10.2.3 Placement of Landscaping, Trees, and Shrubs.....	10-15
10.2.4 Use of Roadside Barriers.....	10-16
10.2.4.1 Barrier Warrants.....	10-17
10.2.4.2 Barriers to Protect Adjacent Land Use	10-17
10.2.4.3 Common Urban Barrier Treatments	10-17
10.2.4.3.1 Roadside and Median Barriers.....	10-17
10.2.4.3.2 Crash Cushions.....	10-17
10.2.4.3.3 Pedestrian Restraint Systems	10-18
10.3 DRAINAGE	10-18
10.4 URBAN WORK ZONES.....	10-19
CHAPTER 11—ERECTING MAILBOXES ON STREETS AND HIGHWAYS.....	11-1
11.0 OVERVIEW	11-1
11.1 MAILBOXES.....	11-1
11.2 GENERAL PRINCIPLES AND GUIDELINES.....	11-3
11.2.1 Regulations	11-3
11.2.2 Mail Stop and Mailbox Location	11-4
11.2.3 Mailbox Turnout Design	11-6
11.2.4 Mailbox Support and Attachment Design.....	11-8

11.3 U.S. POSTAL SERVICE GUIDANCE AND MODEL MAILBOX REGULATION	11-17
11.3.1 U.S. Postal Service Guidance.....	11-17
11.3.2 Model Mailbox Regulation	11-17
11.3.2.1 Scope	11-17
11.3.2.2 Location	11-17
11.3.2.3 Structure	11-18
11.3.2.4 Shoulder and Parking Area Construction.....	11-18
11.3.2.5 Removal of Nonconforming or Unsafe Mailboxes	11-18
CHAPTER 12—ROADSIDE SAFETY ON LOW-VOLUME ROADS AND STREETS	12-1
12.0 OVERVIEW.....	12-1
12.1 STRATEGIES.....	12-2
12.2 SIGNING, MARKING, AND DELINEATION.....	12-2
12.3 CLEAR ZONE	12-3
12.4 SLOPES AND DITCHES.....	12-4
12.5 DRAINAGE STRUCTURES	12-4
12.7 ROADSIDE BARRIERS.....	12-6
12.8 BRIDGES	12-7
GLOSSARY.....	G-1
INDEX	I-1

List of Figures

CHAPTER 1

Figure 1-1. Motor Vehicle Crash Deaths and Deaths Per 100 Million Vehicle Miles Traveled, 1950–2008.....	1-2
Figure 1-2. Percent Distribution of Fixed-Object Fatalities by Object Struck, 2008.....	1-3

CHAPTER 3

Figure 3-1. Roadway Geometry Features.....	3-5
Figure 3-2. Clear Zone for Non-Recoverable Parallel Foreslope	3-6
Figure 3-3. Suggested Design for Transverse Slopes.....	3-7
Figure 3-4. Median Transverse Slope Design	3-7
Figure 3-5. Alternate Designs for Drains at Median Openings.....	3-8
Figure 3-6. Preferred Cross Sections for Channels with Abrupt Slope Changes	3-9
Figure 3-7. Preferred Cross Sections for Channels with Gradual Slope Changes.....	3-10
Figure 3-8. Design Criteria for Safety Treatment of Pipes and Culverts	3-15
Figure 3-9. Safety Treatment for Cross-Drainage Culvert.....	3-15
Figure 3-10. Inlet and Outlet Design Example for Parallel Drainage	3-17
Figure 3-11. Alternate Location for a Parallel Drainage Culvert	3-18
Figure 3-12. Safety Treatment for Parallel Drainage Pipe	3-18

CHAPTER 4

Figure 4-1. Breakaway Support Stub Height Measurements.....	4-3
Figure 4-2. Wind and Impact Loads on Roadside Signs.....	4-5
Figure 4-3. Impact Performance of a Multiple-Post Sign Support	4-5
Figure 4-4. Multidirectional Coupler	4-6
Figure 4-5. Typical Unidirectional Slip Base	4-6
Figure 4-6. Slotted Fuse Plate Design.....	4-6
Figure 4-7. Perforated Fuse Plate Design	4-7
Figure 4-8. Unidirectional Slip Base for Small Signs	4-9
Figure 4-9. Multidirectional Slip Base for Small Signs	4-9
Figure 4-10. Oregon 3-Bolt Slip Base	4-10
Figure 4-11. Example of a Cast Aluminum Frangible Luminaire.....	4-11
Figure 4-12. Example of a Luminaire Slip Base Design	4-11
Figure 4-13. Example of a Frangible Coupling Design	4-11
Figure 4-14. Prototype Breakaway Design for Utility Poles	4-15

CHAPTER 5

Figure 5-1(a). Comparative Barrier Consideration for Embankments (Metric Units)	5-5
Figure 5-1(b). Comparative Barrier Consideration for Embankments (U.S. Customary Units)	5-6

Figure 5-2(a). Example Design Chart for Embankment Barrier Consideration Based on Fill Height, Slope, and Traffic Volume (Metric Units)	5-7
Figure 5-2(b). Example Design Chart for Embankment Barrier Consideration Based on Fill Height, Slope, and Traffic Volume (U.S. Customary Units)	5-7
Figure 5-3(a). Example Design Chart for Cost-Effective Barrier Consideration for Embankments Based on Traffic Speeds and Volumes, Slope Geometry, and Length of Slope (Metric Units)	5-8
Figure 5-3(b). Example Design Chart for Cost-Effective Barrier Consideration for Embankments Based on Traffic Speeds and Volumes, Slope Geometry, and Length of Slope (U.S. Customary Units)	5-8
Figure 5-4. Definition of Roadside Barriers	5-11
Figure 5-5. Three-Strand Cable Barrier	5-13
Figure 5-6. Weak-Post W-Beam Guardrail	5-14
Figure 5-7. Ironwood Aesthetic Guardrail	5-15
Figure 5-8. Weak-Post Box Beam Guardrail	5-16
Figure 5-9. Steel-Post W-Beam Guardrail with Wood Blockouts.....	5-16
Figure 5-10. Midwest Guardrail System (MGS)	5-18
Figure 5-11. Gregory Mini Spacer	5-21
Figure 5-12. Trinity T-31™ Guardrail System.....	5-22
Figure 5-13. NU-GUARD™-31 Guardrail System.....	5-22
Figure 5-14. Wood-Post Thrie-Beam Guardrail	5-23
Figure 5-15. Modified Thrie-Beam Guardrail.....	5-24
Figure 5-16. Trinity T-39™ Guardrail System.....	5-25
Figure 5-17. Merritt Parkway Aesthetic Guardrail	5-25
Figure 5-18. Backed Timber Guardrail.....	5-26
Figure 5-19. Low Profile Barrier	5-27
Figure 5-20. Constant Slope Barrier	5-27
Figure 5-21. 2,290-mm [90-in.] New Jersey Barrier	5-28
Figure 5-22. CushionWall® II System	5-29
Figure 5-23. Stone Masonry Wall.....	5-29
Figure 5-24. Precast Masonry Wall	5-30
Figure 5-25. Long-Span, Nested W-Beam Guardrail.....	5-31
Figure 5-26. Long-Span MGS.....	5-31
Figure 5-27. Zone of Intrusion for TL-2	5-35
Figure 5-28. Zone of Intrusion for TL-3 Concrete Barriers and Steel Tubular Rails on Curbs.....	5-36
Figure 5-29. Zone of Intrusion for TL-3 Combination and Timber Barriers	5-36
Figure 5-30. Zone of Intrusion for TL-3 Steel Tubular Rails Not on Curbs.....	5-37
Figure 5-31. Zone of Intrusion for TL-4 Barriers per NCHRP Report 350.....	5-37
Figure 5-32. Example Guardrail and Embankment Layout Sheet.....	5-40
Figure 5-33. Recommended Barrier Placement for Optimum Performance.....	5-41
Figure 5-34. MGS Placed at 1V:2H Slope Breakpoint.....	5-42
Figure 5-35(a). Example Laydown Curb for Use Offset from Guardrail	5-43
Figure 5-35(b). Example Laydown Curb near End Terminal.....	5-44

Figure 5-36. MGS Offset from Curb.....	5-45
Figure 5-37. Design Parameters for Vehicle Encroachments on Slopes.....	5-46
Figure 5-38. Recommended Barrier Location on 1V:6H.....	5-47
Figure 5-39. Approach Barrier Layout Variables	5-49
Figure 5-40(a). Example Design Chart for a Flared Roadside Barrier	5-52
Figure 5-40(b). Example Design Chart for a Flared Roadside Barrier Installation (U.S. Customary Units)	5-52
Figure 5-41(a). Example Design Chart for a Parallel Roadside Barrier Installation (Metric Units).....	5-53
Figure 5-41(b). Example Design Chart for a Parallel Roadside Barrier Installation (U.S. Customary Units)	5-53
Figure 5-42. Approach Barrier Layout for Opposing Traffic	5-54
Figure 5-43. Determination of Trailing End Guardrail Layout.....	5-54
Figure 5-44. Suggested Roadside Slopes for Approach Barriers	5-55
Figure 5-45. Example of Barrier Design for Bridge Approach.....	5-56
Figure 5-46. Example of Barrier Design for Bridge Piers.....	5-57
Figure 5-47. Example of Barrier Design for Non-Traversable Embankments	5-58
Figure 5-48. Example of Barrier Design for Fixed Object on Horizontal Curve	5-59
Figure 5-49. Example Field Installation with Terminal	5-60
Figure 5-50. Possible Solution to Intersection Side Road Near Bridge.....	5-60
Figure 5-51(a). Guardrail Post Details in Rock Formation (Metric Units).....	5-62
Figure 5-51(b). Guardrail Post Details in Rock Formation (U.S. Customary Units)	5-63
Figure 5-52(a). Guardrail Post Details in Mow Strip Applications (Metric Units).....	5-64
Figure 5-52(b). Guardrail Post Details in Mow Strip Applications (U.S. Customary Units)	5-65

CHAPTER 6

Figure 6-1. Guidelines for Median Barriers on High-speed, Fully Controlled-Access Roadways.....	6-2
Figure 6-2. Weak-Post W-Beam Median Barrier	6-5
Figure 6-3. Three-Strand Cable Median Barrier	6-6
Figure 6-4. Brifen Wire Rope Safety Fence	6-7
Figure 6-5. The Cable Safety System (CASS)	6-8
Figure 6-6. NU-CABLE™ High-Tension Cable System	6-8
Figure 6-7. Safence Cable Barrier System.....	6-8
Figure 6-8. Gibraltar Cable Barrier System.....	6-9
Figure 6-9. Box-Beam Median Barrier	6-9
Figure 6-10. Strong-Post W-Beam Median Barrier	6-10
Figure 6-11. Modified Thrie-Beam Median Barrier	6-11
Figure 6-12. New York Modification of Concrete Barrier.....	6-12
Figure 6-13. Concrete Safety-Shape Median Barrier	6-13
Figure 6-14. Single-Slope Concrete Median Barrier	6-13
Figure 6-15. Standard Quickchange® Moveable Barrier System	6-14
Figure 6-16. Barrier Termination at Permanent Openings	6-15

Figure 6-17. BarrierGate	6-15
Figure 6-18. Recommended Barrier Placement in Non-Level Medians	6-19
Figure 6-19. Example of a Split Median Barrier Layout	6-20
Figure 6-20. Suggested Layout for Shielding a Rigid Object in a Median	6-21

CHAPTER 7

Figure 7-1. Curb Type Glu-Lam Timber Railing	7-4
Figure 7-2. Texas T-6 Railing	7-4
Figure 7-3. Wyoming Two-Tube Bridge Railing	7-5
Figure 7-4. Concrete F-Shaped Bridge Railing	7-5
Figure 7-5. 1,067-mm [42-in.] Tall Concrete Safety-Shaped Bridge Railing	7-6
Figure 7-6. Texas Type TT Railing	7-6
Figure 7-7. End Treatment for Traffic Railing on a Bridge in Low-Speed Situations	7-9
Figure 7-8. Terminating a Traffic Barrier on Bridge with End Terminal	7-10
Figure 7-9. Iowa Concrete Block Retrofit Bridge Railing	7-12
Figure 7-10. Delaware Thrie-Beam Retrofit	7-13
Figure 7-11. Metal Post-and-Beam Retrofit	7-14
Figure 7-12. Thrie-Beam Transition to Modified Concrete Safety Shape	7-15

CHAPTER 8

Figure 8-1. Trailing End W-Beam Guardrail Anchorage	8-3
Figure 8-2. Grading for Flared Guardrail Terminal	8-5
Figure 8-3. Grading for Tangent Guardrail Terminal	8-6
Figure 8-4. Three-Strand Cable Terminal	8-8
Figure 8-5. CASS™ Cable Terminal (CCT)	8-8
Figure 8-6. W-Beam Guardrail Anchored in Backslope	8-10
Figure 8-7. Eccentric Loader Terminal (ELT)	8-11
Figure 8-8. Modified Eccentric Loader Terminal (MELT)	8-12
Figure 8-9. Flared Energy-Absorbing Terminal (FLEAT™)	8-13
Figure 8-10. Slotted Rail Terminal (SRT-350™)	8-13
Figure 8-11. X-Tension Guardrail End Terminal	8-14
Figure 8-12. Extruder Terminal (ET-Plus™)	8-15
Figure 8-13. Sequential Kinking Terminal (SKT-350™)	8-16
Figure 8-14. Brakemaster® 350	8-17
Figure 8-15. Crash Cushion Attenuating Terminal (CAT-350™)	8-18
Figure 8-16. FLEAT Median Terminal (FLEAT-MT™)	8-19
Figure 8-17. X-Tension™ Median Attenuator System (X-MAS)	8-19
Figure 8-18. Wyoming Box-Beam End Terminal (WY-BET™)	8-20
Figure 8-19. Bursting Energy Absorbing Terminal (BEAT™)	8-21
Figure 8-20. Bullnose Guardrail System	8-24

Figure 8-21. ABSORB 350® Crash Cushion	8-25
Figure 8-22. Advanced Dynamic Impact Extension Module (ADIEM™)	8-25
Figure 8-23. Bursting Energy Absorbing Terminal–Single Sided Crash Cushion (BEAT-SSCC™) System	8-26
Figure 8-24. Bursting Energy Absorbing Terminal–Bridge Pier (BEAT-BP™) System.....	8-26
Figure 8-25. QuadTrend® 350	8-27
Figure 8-26. Narrow Connecticut Impact Attenuation System (NCAIS)	8-27
Figure 8-27. QuadGuard® Crash Cushion.....	8-29
Figure 8-28. TAU-II Crash Cushion.....	8-29
Figure 8-29. Trinity Attenuating Crash Cushion (TRACC™)	8-30
Figure 8-30. QUEST® Crash Cushion.....	8-30
Figure 8-31. Compressor Attenuator.....	8-32
Figure 8-33. Hybrid Energy Absorbing Reusable Terminal (HEART™)	8-33
Figure 8-34. QuadGuard Elite.....	8-33
Figure 8-35. QuadGuard Low-Maintenance Cartridge (LMC).....	8-34
Figure 8-36. Reusable Energy-Absorbing Crash Terminal (REACT 350®).....	8-35
Figure 8-37. Smart Cushion Innovations (SCI-100GM) Crash Cushion.....	8-35
Figure 8-38. Conservation of Momentum Principle.....	8-37
Figure 8-39. The Fitch Universal Barrel®	8-38
Figure 8-40. Suggested Layout for the Last Three Exterior Modules in an Inertial Barrier.....	8-38
Figure 8-41. Sand Barrel Array for Reverse-Direction Impacts	8-40
Figure 8-42. Sand Barrel Array Oriented Towards Approaching Traffic	8-41
Figure 8-43. Sloped Concrete End Treatment.....	8-42
Figure 8-44. Barrier Anchored in Backslope.....	8-43
Figure 8-45. Dagnet.....	8-43
Figure 8-46. Ground Retractable Automotive Barrier (GRAB-300®)	8-44
Figure 8-47. STOPGATE®	8-44

CHAPTER 9

Figure 9-1. Iowa Temporary Concrete Barrier.....	9-5
Figure 9-2. Rockingham Precast Concrete Barrier.....	9-6
Figure 9-3. J-J Hooks Portable Concrete Barrier	9-7
Figure 9-4. Modified Virginia DOT Portable Concrete Barrier	9-7
Figure 9-5. California K-Rail Portable Concrete Barrier	9-8
Figure 9-6. GPLINK® Pre-Cast Temporary Concrete Barrier	9-9
Figure 9-7. Georgia Temporary Concrete Barrier.....	9-10
Figure 9-8. Idaho 6.1-m [20-ft] New Jersey Portable Barrier	9-11
Figure 9-9. Oregon Pin-and-Loop Barrier	9-11
Figure 9-10. Ohio DOT 3-m [10-ft] Long New Jersey Profile Temporary Concrete Barrier	9-12
Figure 9-11. New York DOT Portable Concrete Barrier	9-13
Figure 9-12. Iowa DOT Tie-Down Steel H-Section Temporary Barrier.....	9-14

Figure 9-13. Quick-Bolt F-Shaped Concrete Safety Barrier	9-14
Figure 9-14. Texas X-Bolt F-Shaped Concrete Safety Barrier	9-15
Figure 9-15. Texas SSCB	9-16
Figure 9-16. TxDOT New Jersey-Shaped Portable Concrete Barrier Pinned-with-Stakes Design.....	9-17
Figure 9-17. Pinned F-Shaped Temporary Barrier	9-18
Figure 9-18. Quickchange® Barrier System.....	9-19
Figure 9-19. Low-Profile Barrier System	9-20
Figure 9-20. Water-Filled Barrier	9-21
Figure 9-21. Steel Barrier	9-22
Figure 9-22. Slope-End Treatment for Low-Profile Portable Concrete Barrier.....	9-23
Figure 9-23. Portable Concrete Barrier Steel Plate Transition	9-24
Figure 9-24. F-Shaped Portable Concrete Barrier to Low-Profile Barrier Transition.....	9-24
Figure 9-25. QuadGuard™ CZ System.....	9-26
Figure 9-26. REACT® 350 CZ System	9-27
Figure 9-27. TMA with Energy-Absorbing Cartridge	9-31
Figure 9-28. TMA with Telescoping Steel Frame and Cutter Assembly	9-31
Figure 9-29. TMA with Steel Frame and Burster or Kinker Assembly	9-31
Figure 9-30. TMA with Steel or Polyethylene Cylinder Assembly	9-32
Figure 9-31. Mobile Barrier Trailer	9-32
Figure 9-32. Traffic Cone	9-34
Figure 9-33. Portable Vertical Panel	9-34
Figure 9-34. Plastic Drums	9-35
Figure 9-35. Crashworthy Generic Type II Barricade	9-36
Figure 9-36. Crashworthy Generic Type III Barricade	9-37
Figure 9-37. Longitudinal Channelizing Device.....	9-37
Figure 9-38. Montana Wheeled Portable Sign Support.....	9-38
Figure 9-39. X-Base Sign Support	9-39

CHAPTER 10

Figure 10-1. Lateral Offset for Objects at Horizontal Curves on Curbed Facilities.....	10-4
Figure 10-2. Enhanced Lateral Offsets at Merge Points.....	10-5
Figure 10-3. Enhanced Lateral Offsets at Driveways	10-6
Figure 10-4. Landscape and Rigid Object Placement for Buffer Strip Widths ≤1.2 m [4 ft]	10-10
Figure 10-5. Landscape and Rigid Object Placement for Buffer Strip Widths >1.2 m [4 ft]	10-10
Figure 10-6. A Transit Shelter Located Curbside	10-13

CHAPTER 11

Figure 11-1. Typical Single Mailbox Installations	11-2
Figure 11-2. Examples of Hazardous Single Mailbox Installations	11-2
Figure 11-3. Examples of Hazardous Multiple Mailbox Installations	11-3

Figure 11-4. Suggested Minimum Clearance Distance to Nearest Mailbox for Mail Stops at Intersections	11-5
Figure 11-5. Mailbox Turnout.....	11-7
Figure 11-6. Mailbox Support Hardware, Series A.....	11-10
Figure 11-7. Single and Double Mailbox Assemblies, Series A.....	11-11
Figure 11-8. Mailbox Support Hardware, Series B	11-12
Figure 11-9. Single and Double Mailbox Assemblies, Series B	11-13
Figure 11-10. Single and Double Mailbox Assemblies, Series C.....	11-14
Figure 11-11. Collection Unit on Auxiliary Lane (left) and Neighborhood Delivery and Collection Box Units.....	11-15
Figure 11-12. Plastic Mailbox with Integral Support.....	11-15
Figure 11-13. Vandal-Resistant Decorative Mailbox	11-16
Figure 11-14. Secure Mailboxes	11-16
Figure 11-15. Cantilever Mailbox Supports.....	11-19
Figure 11-16. Breakaway Cantilever/Swing-Away Mailbox Support	11-20

CHAPTER 12

Figure 12-1. Single Vehicle Roadway Departure Fatalities on Two Lanes, Undivided, Noninterchange, Nonconjunction Roads by Roadway Classification in 2009	12-2
Figure 12-2. Distribution of Single-Vehicle ROR Crashes between Tangent and Curved Sections	12-3
Figure 12-3. Reinforcing Steel Grate	12-5
Figure 12-4. Typical Low-Volume Rural Roadway.....	12-6
Figure 12-5. Typical Low-Volume Rural Bridge	12-7

List of Tables

CHAPTER 3

Table 3-1. Suggested Clear-Zone Distances in Meters (Feet) from Edge of Through Traveled Lane	3-2
Table 3-2. Horizontal Curve Adjustment Factor	3-4

CHAPTER 4

Table 4-1. Objectives and Strategies for Reducing Utility Pole Crashes.....	4-14
Table 4-2. Objectives and Strategies for Reducing Crashes with Trees.....	4-16

CHAPTER 5

Table 5-1(a). MASH Crash Test Matrix for Longitudinal Barriers	5-2
Table 5-1(b). NCHRP Report 350 Crash Test Matrix for Longitudinal Barriers	5-3
Table 5-2. Barrier Guidelines for Non-Traversable Terrain and Roadside Obstacles.....	5-9
Table 5-3. Roadside Barriers and NCHRP Report 350 Approved Test Levels.....	5-12
Table 5-4. MGS Design Applications with Pickup Truck Impact Performance	5-20
Table 5-5. Selection Criteria for Roadside Barriers	5-32
Table 5-6. Summary of Maximum Deflections	5-34
Table 5-7. Suggested Shy-Line Offset (L_s) Values	5-41
Table 5-8(a). Example Bumper Trajectory Data (Metric Units)	5-47
Table 5-8(b). Example Bumper Trajectory Data (U.S. Customary Units)	5-47
Table 5-9. Suggested Flare Rates for Barrier Design	5-48
Table 5-10(a). Suggested Runout Lengths for Barrier Design (Metric Units)	5-50
Table 5-10(b). Suggested Runout Lengths for Barrier Design (U.S. Customary Units)	5-50

CHAPTER 6

Table 6-1. Crashworthy Median Barrier Systems.....	6-4
--	-----

CHAPTER 7

Table 7-1. MASH Test Matrix for Bridge Railings.....	7-3
--	-----

CHAPTER 8

Table 8-1. Terminals for Cable Barrier Systems	8-7
Table 8-2. Terminals for W-Beam Guardrail Systems	8-9
Table 8-3. Terminals for Median W-Beam Guardrail Systems	8-17
Table 8-4. Terminals for Box-Beam Guardrail Systems	8-20
Table 8-5. Sacrificial Crash Cushions	8-23
Table 8-6. Reusable Crash Cushions	8-28
Table 8-7. Low-Maintenance and/or Self-Restoring Crash Cushions	8-31
Table 8-8. Sand Barrel Systems	8-37

Table 8-9. Sample Design Calculation for a Sand-Filled Barrel System.....	8-39
Table 8-10. Miscellaneous Crash Cushions and End Treatments.....	8-41
Table 8-11. Area Available for Crash Cushion Installation.....	8-46
Table 8-12. Comparative Maintenance Characteristics	8-48

CHAPTER 9

Table 9-1. Example of Clear-Zone Widths for Work Zones	9-2
Table 9-2. Temporary Longitudinal Barriers	9-3
Table 9-3. Crashworthy Portable Concrete Barriers.....	9-5
Table 9-4. Suggested Priorities for Application of Protective Vehicles and Truck-Mounted Attenuators	9-28
Table 9-5. Example of Guidelines for Spacing of Shadow Vehicles.....	9-30

CHAPTER 10

Table 10-1. Design Strategies for Curb Treatment	10-8
Table 10-2. Design Strategies for Channelized Islands and Medians.....	10-8
Table 10-3. Design Strategies for Gateways	10-9
Table 10-4. Design Strategies for Roadside Grading	10-9
Table 10-5. Design Strategies to Protect Pedestrians in Motor Vehicle Crashes	10-11
Table 10-6. Design Strategies for Bicycles	10-12
Table 10-7. Design Strategies for On-Street Parking	10-12
Table 10-8. Design Strategies for Urban Mailbox Use	10-12
Table 10-9. Design Strategies for Street Furniture Use	10-13
Table 10-10. Design Strategies for Vertical Roadside Treatment and Hardware	10-15

CHAPTER 11

Table 11-1. Suggested Guidelines for Lateral Placement of Mailboxes	11-6
---	------

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>.