

AMERICAN ASSOCIATION
OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS

AASHTO



GUIDE SPECIFICATION FOR **Service Life Design of Highway Bridges**

1st Edition | 2020



978-1-56051-741-2 | HBSLD-1



American Association of State Highway and Transportation Officials
555 12th Street NW, Suite 1000
Washington, DC 20004
202-624-5800 phone/202-624-5806 fax
www.transportation.org

© 2020 by the American Association of State Highway and Transportation Officials. All rights reserved. Duplication is a violation of applicable law.

Cover Photos: **Top Left and Bottom Right:** Stainless steel rebar for the new I-74 Mississippi River Bridge in the Quad Cities (Bettendorf, Iowa/Moline, Illinois). Courtesy Iowa Department of Transportation.

ISBN: 978-1-56051-741-2

Publication Code: HBSLD-1

© 2020 by the American Association of State Highway and Transportation Officials.
All rights reserved. Duplication is a violation of applicable law.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
555 12th Street, NW, Suite 1000
Washington, DC 20004

**EXECUTIVE COMMITTEE
2019–2020**

OFFICERS:

PRESIDENT: Patrick McKenna, Missouri*

VICE PRESIDENT: Victoria Sheehan, New Hampshire*

SECRETARY-TREASURER: Scott Bennett, Arkansas

EXECUTIVE DIRECTOR: Jim Tymon, Washington, D. C.

REGIONAL REPRESENTATIVES:

REGION I: Vacant
Diane Gutierrez-Scaccetti, New Jersey

REGION II: Melinda McGrath, Mississippi
Russell McMurry, Georgia

REGION III: Mark Lowe, Iowa
Craig Thompson, Wisconsin

REGION IV: Kyle Schneweis, Nebraska
James Bass, Texas

IMMEDIATE PAST PRESIDENT: Carlos Braceras, Utah

***Elected at the 2019 Annual Meeting in St. Louis, Missouri**

AASHTO COMMITTEE ON BRIDGES AND STRUCTURES, 2019

CARMEN E.L. SWANWICK, *Chair*

SCOT BECKER, *Vice Chair*

JOSEPH L. HARTMANN, Federal Highway Administration, *U.S. DOT Liaison*

PATRICIA J. BUSH, *AASHTO Liaison*

ALABAMA, William “Tim” Colquett, Eric J.

Christie,

Randall Mullins

ALASKA, Richard A. Pratt, Leslie Daughtery,

Elmer E. Marx

ARIZONA, David L. Eberhart, David Benton,

Pe-Shen Yang

ARKANSAS, Charles “Rick” Ellis, Michael Hill,

Joe Sartini

CALIFORNIA, Thomas A. Ostrom,

Gedmund Setberg, Dolores Valls

COLORADO, Michael Collins, Stephen Harelson,

Jessica Martinez

CONNECTICUT, Timothy D. Fields, Mary E. Baker

DELAWARE, Jason N. Hastings, Jason Arndt,

Craig A. Stevens

DISTRICT OF COLUMBIA, Konjit C. “Connie”

Eskender, Donald L. Cooney, Richard Kenney

FLORIDA, Sam Fallaha, William Potter,

Jeff A. Pouliotte

GEORGIA, Bill DuVall, Douglas D. Franks,

Steve Gaston

HAWAII, James Fu, Kevin Murata, John Williams

IDAHO, Matthew M. Farrar

ILLINOIS, Carl Puzey, Tim A. Armbrecht,

Jayne Schiff

INDIANA, Anne M. Rearick, Andrew Fitzgerald,

Stephanie Wagner

IOWA, James S. Nelson, Ahmad Abu-Hawash,

Michael Nop

KANSAS, Karen Peterson

KENTUCKY, Bart Asher, Andy Barber,

Marvin Wolfe

LOUISIANA, Zhengzheng “Jenny” Fu, Artur

D’Andrea, Chris Guidry

MAINE, Wayne L. Frankhauser, Jeff S. Folsom,

Michael H. Wight

MARYLAND, Maurizio Agostino, Jesse Creel,

Jeffrey Robert

MASSACHUSETTS, Alexander K. Bardow,

Joe Rigney

MICHIGAN, Matthew Chynoweth, Rebecca Curtis,

Richard E. Liptak

MINNESOTA, Kevin L. Western, Arielle Ehrlich,

Ed Lutgen

MISSISSIPPI, Justin Walker, Scott Westerfield

MISSOURI, Dennis Heckman, Greg E. Sanders

MONTANA, Stephanie Brandenberger,

Amanda Jackson, Dustin E. Rouse

NEBRASKA, Mark J. Traynowicz, Mark Ahlman,

Fouad Jaber

NEVADA, Jessen Mortensen, Troy Martin

NEW HAMPSHIRE, Robert Landry, David L. Scott

NEW JERSEY, Eddy Germain,

Xiaohua “Hannah” Cheng

NEW MEXICO, Shane Kuhlman, Kathy Crowell,

Jeff C. Vigil

NEW YORK, Richard Marchione, Brenda Crudele,

Ernest Holmberg

NORTH CAROLINA, Brian Hanks, Scott Hidden,

Girchuru Muchane

NORTH DAKOTA, Jon D. Ketterling,

Jason R. Thorenson

OHIO, Timothy J. Keller, Alexander B.C. Dettloff,

Jeffrey E. Syar

OKLAHOMA, Steven J. Jacobi, Walter L. Peters,

Tim Tegeler

OREGON, Albert Nako, Tanarat Potisuk

PENNSYLVANIA, Thomas P. Macioce,

Richard Runyen, Louis J. Ruzzi

PUERTO RICO, (Vacant)

RHODE ISLAND, Georgette K. Chahine,

Keith Gaulin

SOUTH CAROLINA, Terry B. Koon, Hongfen Li,

Jeff Sizemore

SOUTH DAKOTA, Steve Johnson, Dave Madden,

Todd S. Thompson

TENNESSEE, Ted A. Kniazewycz

TEXAS, Graham Bettis, Bernie Carrasco,
Jamie F. Farris
UTAH, Carmen E.L. Swanwick,
Cheryl Hersh Simmons, Rebecca Nix
VERMONT, Kristin M. Higgins, Jim Lacroix
VIRGINIA, Kendal R. Walus, Prasad L. Nallapaneni,
Andrew M. Zickler
WASHINGTON STATE, Mark A. Gaines,
Tony M. Allen, Bijan Khaleghi
WEST VIRGINIA, Tracy W. Brown, Ahmed Mongi
WISCONSIN, Scot Becker, Bill C. Dreher,
William L. Oliva
WYOMING, Michael E. Menghini, Jeff R. Booher,
Paul Cortez

MARYLAND TRANSPORTATION

AUTHORITY, James Harkness

MULTNOMAH COUNTY

TRANSPORTATION DIVISION,

Jon Henrichsen

NEW YORK STATE BRIDGE AUTHORITY,

William Moreau

TRANSPORTATION RESEARCH BOARD,

Waseem Dekelbab

U.S. ARMY CORPS OF ENGINEERS—

Phillip W. Sauser

U.S. COAST GUARD, Kamal Elnahal

U.S. DEPARTMENT OF AGRICULTURE—

FOREST SERVICE, John R. Kattell

ABBREVIATED TABLE OF CONTENTS

- Section 1—Introduction
- Section 2—Classification
- Section 3—General Design Guidelines
- Section 4—Concrete Structures
- Section 5—Steel Structures
- Section 6—Foundations and Retaining Walls
- Section 7—Renewable Elements
- Section 8—Life Cycle Cost Analysis
- Appendix A—Probabilistic Service Life Design Framework
- Appendix B—Case Studies

SECTION 1: INTRODUCTION

TABLE OF CONTENTS

1.1—BACKGROUND 1-1
1.2—OBJECTIVE 1-2
1.3—ORGANIZATION 1-2
1.4—DEFINITIONS..... 1-2
1.5—NOTATION 1-3
1.6—APPROACH 1-4
1.7—FUTURE SERVICE LIFE DESIGN IMPROVEMENTS 1-8
1.8—REFERENCES 1-8

SECTION 3: GENERAL DESIGN GUIDELINES

TABLE OF CONTENTS

3.1—SERVICE LIFE CONSIDERATIONS IN THE DESIGN PROCESS 3-1

3.2—DESIGN FOR SERVICE LIFE 3-1

 3.2.1—Planning 3-1

 3.2.2—Global Design 3-3

 3.2.2.1—Interaction of Bridge Components..... 3-3

 3.2.2.2—Plan for Component Replacement 3-4

 3.2.2.3—Total Bridge Service Life 3-5

 3.2.3—Deterioration Experience 3-5

 3.2.3.1—Drainage..... 3-5

 3.2.3.2—Decks 3-6

 3.2.3.3—Joints and Bearings 3-7

 3.2.3.4—Concrete Structures..... 3-9

 3.2.3.5—Structural Steel 3-12

 3.2.3.6—Foundations and Retaining Walls 3-15

 3.2.3.7—Utilities and Appurtenances..... 3-17

3.3—GENERAL DURABILITY CONSIDERATIONS 3-18

 3.3.1—Drainage..... 3-18

 3.3.2—Deck Detailing 3-19

 3.3.3—Joints 3-20

 3.3.3.1—Effect of Joints on Other Bridge Components 3-20

 3.3.3.2—Jointless Bridges 3-20

 3.3.4—Bearings 3-21

 3.3.5—Utilities and Appurtenances 3-21

 3.3.6—Wildlife 3-22

 3.3.7—Access and Inspection..... 3-22

 3.3.8—Construction and Preservation 3-22

3.4—DOCUMENTATION 3-22

 3.4.1—Service Life Design Report..... 3-22

 3.4.2—Need for Preservation Plan 3-23

3.5—REFERENCES 3-24

SECTION 4: CONCRETE STRUCTURES

TABLE OF CONTENTS

4.1—DETERIORATION MECHANISMS AND COMMON MITIGATION APPROACHES 4-1

 4.1.1—Chloride-Induced Corrosion 4-1

 4.1.2—Carbonation-Induced Corrosion..... 4-1

 4.1.3—Freeze–Thaw Attack 4-2

 4.1.4—Alkali–Aggregate Reaction..... 4-2

 4.1.5—Sulfate Attack 4-2

 4.1.6—Abrasion..... 4-2

 4.1.7—Preservice Cracking 4-2

4.2—MATERIAL-LEVEL PROTECTION STRATEGIES 4-3

 4.2.1—General Requirements..... 4-3

 4.2.2—Freeze–Thaw Attack 4-4

 4.2.3—Sulfate Attack 4-5

 4.2.4—Corrosion 4-5

 4.2.4.1—General 4-5

 4.2.4.2—Concrete Cover 4-6

 4.2.4.2.1—Assumptions and Limitations 4-6

 4.2.4.2.1a—Analysis Approach..... 4-6

 4.2.4.2.1b—Target Service Life 4-7

 4.2.4.2.1c—Influence of Cracking 4-8

 4.2.4.2.1d—Reinforcement 4-8

 4.2.4.2.1e—Surface Treatments 4-9

 4.2.4.2.1f—Wearing Surfaces 4-9

 4.2.4.2.2—Cover Requirements 4-10

4.3—OTHER PROTECTION STRATEGIES..... 4-15

 4.3.1—Surface Sealers..... 4-15

 4.3.2—Detailing 4-16

 4.3.3—Special Provisions for Decks 4-20

 4.3.3.1—Overlays..... 4-20

 4.3.3.2—Waterproofing Membranes 4-20

 4.3.3.3—Concrete Curing 4-21

4.4—CONCRETE DURABILITY TESTING..... 4-22

4.5—REFERENCES 4-22

SECTION 5: STEEL STRUCTURES

TABLE OF CONTENTS

5.1—DETERIORATION MECHANISMS 5-1
 5.1.1—Corrosion 5-1
 5.1.2—Fatigue 5-1
5.2—PROTECTION STRATEGIES 5-2
 5.2.1—Corrosion Protection 5-2
 5.2.1.1—General 5-2
 5.2.1.2—Considerations for Uncoated Weathering Steel 5-4
 5.2.2—Fatigue Design 5-5
5.3—DETAILING 5-6
 5.3.1—Members 5-6
 5.3.1.1—Corrosion Prevention 5-6
 5.3.1.2—Fatigue Resistance 5-10
 5.3.2—Drainage 5-11
5.4—REFERENCES 5-11
APPENDIX 5A 5-13

SECTION 6: FOUNDATIONS AND RETAINING WALLS

TABLE OF CONTENTS

6.1—GENERAL.....	6-1
6.1.1—Quality Assurance/Quality Control.....	6-2
6.1.2—Drainage.....	6-2
6.2—FOUNDATIONS.....	6-2
6.2.1—Spread Footings.....	6-2
6.2.1.1—Deterioration Environment.....	6-2
6.2.1.2—Protection Strategies.....	6-3
6.2.2—Driven Piles.....	6-4
6.2.2.1—Deterioration Environment.....	6-4
6.2.2.2—Protection Strategies.....	6-6
6.2.2.2.1—Steel Piles.....	6-6
6.2.2.2.2—Concrete Piles.....	6-8
6.2.3—Micropiles.....	6-9
6.2.3.1—Deterioration Environment.....	6-9
6.2.3.2—Protection Strategies.....	6-9
6.2.4—Drilled Shafts.....	6-10
6.2.4.1—Deterioration Environment.....	6-10
6.2.4.1.1—Lack of Adequate Concrete Cover.....	6-10
6.2.4.1.2—Soft Bottom.....	6-10
6.2.4.1.3—Preservice Cracking.....	6-10
6.2.4.2—Protection Strategies.....	6-11
6.2.4.2.1—Integrity Testing.....	6-12
6.3—RETAINING WALLS.....	6-13
6.3.1—Nongravity Cantilever Walls.....	6-13
6.3.1.1—Deterioration Environment.....	6-13
6.3.1.2—Protection Strategies.....	6-14
6.3.2—Anchored Walls.....	6-14
6.3.2.1—Deterioration Environment.....	6-14
6.3.2.2—Selection of P_f Value.....	6-15
6.3.2.3—Protection Strategies.....	6-16
6.3.3—Soil Nails.....	6-17
6.3.3.1—Deterioration Environment.....	6-17
6.3.3.2—Selection of P_f Value.....	6-17
6.3.3.3—Protection Strategies.....	6-17
6.3.3.3.1—Minimum Grout Cover ($P_f=0$).....	6-18
6.3.3.3.2—Sacrificial Steel with Minimum Grout Cover ($P_f=1$).....	6-19
6.3.3.3.3—Grout-Filled Corrugated Plastic Sheath Encapsulation ($P_f=2$).....	6-20
6.3.4—Mechanically Stabilized Earth (MSE) Walls.....	6-21
6.3.4.1—Deterioration Environment.....	6-21
6.3.4.1.1—Select Granular Soils for Reinforced Fill.....	6-21
6.3.4.1.2—Electrochemical Properties of Soils for Metallic Reinforcement.....	6-22
6.3.4.1.3—Electrochemical Properties of Fills for Geosynthetic Reinforcement.....	6-23
6.3.4.1.4—Selection of P_f Value.....	6-23
6.3.4.2—Protection Strategies.....	6-24
6.3.4.2.1—MSE Facing.....	6-24
6.3.4.2.2—Steel Reinforcements.....	6-25
6.3.4.2.3—Geosynthetic Reinforcements.....	6-26
6.4—APPROACH EMBANKMENTS.....	6-28
6.5—REFERENCES.....	6-29

SECTION 7: RENEWABLE ELEMENTS

TABLE OF CONTENTS

7.1—JOINTS 7-1
 7.1.1—Joint Systems 7-1
 7.1.2—Jointless Systems 7-2
 7.1.3—Detailing for Replacement 7-3
 7.1.4—Joint Inspection and Maintenance 7-3
7.2—BEARINGS 7-3
 7.2.1—Bearing Types 7-4
 7.2.2—Service Life Performance 7-5
 7.2.3—Corrosion Protection 7-5
 7.2.4—Design for Replacement 7-6
 7.2.5—Bearing Maintenance 7-6
7.3—RAILINGS AND BARRIERS 7-6
7.4—ROADWAY APPROACH SLABS 7-6
7.5—REFERENCES 7-7

SECTION 8: LIFE CYCLE COST ANALYSIS

TABLE OF CONTENTS

8.1—LIFE CYCLE COST METHOD..... 8-1
 8.1.1—Approach..... 8-1
 8.1.2—Bridge LCCA Process..... 8-2
 8.1.3—Uncertainty 8-3
8.2—DESIGN ALTERNATIVES 8-3
8.3—PLANNING HORIZON 8-3
 8.3.1—Analysis Period 8-3
8.4—SCHEDULE OF COSTS 8-4
8.5—ESTIMATE OF COSTS 8-4
 8.5.1—Agency Costs 8-6
 8.5.2—User Costs 8-6
 8.5.3—Vulnerability Costs 8-7
8.6—LIFE CYCLE COSTS..... 8-7
 8.6.1—Present Value 8-7
 8.6.2—Total Life Cycle Cost..... 8-8
8.7—COMPARISON OF ALTERNATIVES 8-9
8.8—REFERENCES 8-9

APPENDIX A: PROBABILISTIC FRAMEWORK

TABLE OF CONTENTS

A1—METHODOLOGY.....	A-1
A1.1—Background.....	A-1
A1.2—Target Service Life	A-2
A1.3—Target Reliability Index	A-2
A2—CHLORIDE-INDUCED CORROSION	A-2
A2.1—Limit State Function	A-2
A2.2—Numerical Model	A-2
A2.3—Input Parameters	A-4
A2.3.1—Chloride Diffusion Parameters	A-4
A2.3.1.1—Chloride Migration Coefficient, D_{RCM}	A-5
A2.3.1.2—Aging Exponent, α	A-5
A2.3.1.3—Reference Time, t_0	A-6
A2.3.2—Temperature Parameters (k_e , b_e , T_{ref} , T_{real})	A-6
A2.3.2.1—Regression Variable, b_e	A-6
A2.3.2.2—Ambient Temperature, T_{real}	A-6
A2.3.2.3—Reference Temperature, T_{ref}	A-6
A2.3.3—Surface and Substitute Surface Parameters (C_S , $C_{S,\Delta x}$, Δx)	A-6
A2.3.3.1—Chloride Content at the Surface, C_S	A-9
A2.3.3.2—Chloride Content at the Substitute Surface, $C_{S,\Delta x}$	A-10
A2.3.3.3—Depth of the Convection Zone, Δx	A-10
A2.3.4—Reinforcement Parameters (C_{crit})	A-10
A2.3.5—Concrete Cover (c).....	A-10
A2.3.6—Initial Chloride Content (C_0).....	A-11
A3—REFERENCES	A-11

APPENDIX B: CASE STUDIES

TABLE OF CONTENTS

B1—BACKGROUND.....	B-1
B2—CASE STUDY 1	B-1
B2.1—Design as per AASHTO LRFD and State Bridge Design Specifications.....	B-1
B2.2—Identification of Exposure Classes	B-2
B2.3—Selected Locations	B-3
B2.4—Guide Specification Requirements for Each Exposure Class.....	B-3
B2.4.1—Case 1—Deicing Exposure	B-3
B2.4.2—Case 2—Marine Exposure	B-4
B2.4.3—Case 3—Rural/Nonaggressive Exposure	B-5
B3—CASE STUDY 2	B-7
B3.1—Design as per AASHTO LRFD and State Bridge Design Specifications.....	B-7
B3.2—Identification of Exposure Classes	B-7
B3.3—Selected Locations	B-8
B3.4—Guide Specification Requirements for Each Exposure Class.....	B-8
B3.4.1—Case 1—Deicing Exposure	B-8
B3.4.2—Case 2—Marine Exposure	B-10
B3.4.3—Case 3—Rural/Nonaggressive Exposure	B-11
B4—REFERENCES.....	B-11