ASCE Manuals and Reports on Engineering Practice No. 130

Second Edition

Waterfront Facilities Inspection and Assessment





Waterfront Facility Inspection Committee

Edited by
Noah J. Elwood, P.E., BC.PE, BC.OE

ASCE

COPRI ASCE
COASTS, OCEANS, PORTS AND RIVERS INSTITUTE

Waterfront Facilities Inspection and Assessment

Other Titles of Interest

Design of Marine Facilities: Engineering for Port and Harbor Structures, by John W. Gaythwaite (ASCE Press 2016). Gaythwaite provides the essential reference for civil and structural engineers designing port and harbor structures for all types of marine facilities. (ISBN 978-0-7844-7993-3)

Planning and Design Guidelines for Small Craft Harbors, Third Edition, by the Task Committee on Marinas 2020 (ASCE/COPRI 2012). MOP 50 provides new, state-of-the-art guidelines for the planning, design, and development of small craft harbors. (ISBN 978-0-7844-7649-9)

Managing Water in River and Reservoir Systems: Water Resources, Institutional Practices, and Constructed Infrastructure in Texas, by Ralph A. Wurbs (ASCE Press 2024). Author Ralph A. Wurbs provides an overview of effective river and reservoir system water management, discussing the collaborative endeavors of international, federal, interstate, state, river basin, and local agencies, private sector enterprises, and the water management community, using the state of Texas as a case study. (ISBN 978-0-7844-8538-5)

Mooring of Ships to Piers and Wharves, by the Mooring Analysis Task Committee; edited by John W. Gaythwaite (ASCE/COPRI 2014). MOP 129 provides guidelines for the determination of safe mooring design practices for vessels at fixed piers and wharves in ports and harbors. (ISBN 978-0-7844-7842-4)

Sea Level Rise and Coastal Infrastructure: Predictions, Risks, and Solutions, edited by Bilal M. Ayyub and Michael S. Kearney (ASCE/COPRI 2012). CDRM 6 analyzes the challenges posed by rising sea levels and climate change. Using a risk analysis and management framework, this report focuses on various aspects of sea level rise, including associated risks and socioeconomic impacts. (ISBN 978-0-7844-7651-2)

ASCE Manuals and Reports on Engineering Practice No. 130

Waterfront Facilities Inspection and Assessment

Second Edition

Edited by
Noah J. Elwood, P.E., BC.PE, BC.OE

Sponsored by
the Waterfront Facility Inspection Committee of the
Technical Committee on Ports and Harbors of the Coasts, Oceans,
Ports, and Rivers Institute of the American Society of Civil Engineers





Published by the American Society of Civil Engineers

Library of Congress Cataloging-in-Publication Data

Names: Elwood, Noah J., editor. | Coasts, Oceans, Ports and Rivers Institute (American Society of Civil Engineers). Waterfront Facility Inspection Committee, sponsoring body.
Title: Waterfront facilities inspection and assessment / edited by Noah J. Elwood, P.E., BC.PE, BC.OE ; sponsored by the Waterfront Facility Inspection Committee of the Technical Committee on Ports and Harbors of the Coasts, Oceans, Ports, and Rivers Institute of the American Society of Civil Engineers.
Description: Second edition. | Reston, Virginia : American Society of Civil Engineers, 2025. | Series: ASCE manuals and reports on engineering practice ; no. 130 | Includes bibliographical references and index.
Identifiers: LCCN 2025006928 | ISBN 9780784416358 (soft cover) | ISBN 9780784486160 (PDF)
Subjects: LCSH: Harbors--Inspection--United States. | Hydraulic structures--Inspection--United States.
Classification: LCC TC223 .W38 2025
LC record available at https://lccn.loc.gov/2025006928

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191-4382
www.asce.org/bookstore | ascelibrary.org

Any statements expressed in these materials are those of the individual authors and do not necessarily represent the views of ASCE, which takes no responsibility for any statement made herein. No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE. The materials are for general information only and do not represent a standard of ASCE, nor are they intended as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document. ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefor. The information contained in these materials should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing such information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

ASCE and American Society of Civil Engineers—Registered in US Patent and Trademark Office.

Photocopies and permissions. Permission to photocopy or reproduce material from ASCE publications can be requested by sending an email to permissions@asce.org or by locating a title in the ASCE Library (https://ascelibrary.org) and using the "Permissions" link.

Errata: **Errata, if any, can be found at https://dx.doi.org/10.1061/9780784486160.**

Disclaimer: The publisher has provided alt-text for the EPUB version of this book.

Copyright © 2025 by the American Society of Civil Engineers.
All Rights Reserved.

ISBN 978-0-7844-1635-8 (soft cover)
ISBN 978-0-7844-8616-0 (PDF)
ISBN 978-0-7844-8617-7 (ePub)

Manufactured in the United States of America.
29 28 27 26 25 1 2 3 4 5

MANUALS AND REPORTS ON ENGINEERING PRACTICE

(As developed by the ASCE Technical Procedures Committee, July 1930, and revised March 1935, February 1962, and April 1982)

A manual or report in this series consists of an orderly presentation of facts on a particular subject, supplemented by an analysis of limitations and applications of these facts. It contains information useful to the average engineer in his or her everyday work, rather than findings that may be useful only occasionally or rarely. It is not in any sense a "standard," however, nor is it so elementary or so conclusive as to provide a "rule of thumb" for nonengineers.

Furthermore, material in this series, in distinction from a paper (which expresses only one person's observations or opinions), is the work of a committee or group selected to assemble and express information on a specific topic. As often as practicable, the committee is under the direction of one or more of the Technical Divisions and Councils, and the product evolved has been subjected to review by the Executive Committee of the Division or Council. As a step in the process of this review, proposed manuscripts are often brought before the members of the Technical Divisions and Councils for comment, which may serve as a basis for improvement. When published, each manual shows the names of the committees by which it was compiled and indicates clearly the several processes through which it has passed in review, so that its merit may be definitely understood.

In February 1962 (and revised in April 1982), the Board of Direction voted to establish a series titled "Manuals and Reports on Engineering Practice," to include the manuals published and authorized to date, future Manuals of Professional Practice, and Reports on Engineering Practice. All such manual or report material of the Society would have been refereed in a manner approved by the Board Committee on Publications and would be bound, with applicable discussion, in books similar to past manuals. Numbering would be consecutive and would be a continuation of present manual numbers. In some cases of joint committee reports, bypassing of journal publications may be authorized.

A list of available Manuals of Practice can be found at https://ascelibrary.org/page/books/s-mop.

CONTENTS

CONTRIBUTORS ..... **xvii**

BLUE-RIBBON PANEL ..... **xxi**

ACKNOWLEDGMENTS ..... **xxiii**

PREFACE ..... **xxv**

1. INTRODUCTION **1**
- 1.1 Intent of This Manual 1
- 1.2 Importance of Inspections 2
- 1.3 How to Use This Manual 2
- 1.4 Assessment Limitations 3
- 1.5 Significant Changes and Owner's Responsibilities 4
- 1.6 Limits of Inspection 5
- 1.7 Terminology 5
- 1.8 Organization 6

2. STANDARDS OF PRACTICE **9**
- 2.1 Type and Frequency of Inspections 9
  - 2.1.1 General 9
  - 2.1.2 Routine Inspections 12
  - 2.1.3 Structural Repair or Upgrade Design Inspections 15
  - 2.1.4 New Construction Inspections 16
  - 2.1.5 Baseline Inspections 17
  - 2.1.6 Due Diligence Inspections 17
  - 2.1.7 Special-Purpose Inspections 18
  - 2.1.8 Repair Construction Inspections 19
  - 2.1.9 Postevent Inspections 20

2.2 Selection of the Proper Inspection Type 25
2.3 Service Life Modeling: Purpose and Value 25
2.4 Minimum Qualifications of Inspection Personnel 26
2.4.1 General 26
2.4.2 Project Manager 28
2.4.3 Team Leader 28
2.4.4 Team Members 28
2.5 Element-Level Damage Ratings 28
2.5.1 Timber Elements 29
2.5.2 Steel Elements 29
2.5.3 Reinforced Concrete Elements 29
2.5.4 Prestressed Concrete Elements 29
2.5.5 Mooring System Elements 29
2.5.6 Fender System Elements 29
2.5.7 Fiber-Reinforced Polymer Composite Systems 29
2.5.8 Utility Systems 67
2.6 Overall System Ratings 67
2.6.1 General 67
2.6.2 Condition Assessment Ratings 68
2.6.3 Postevent Damage Ratings 70
2.7 Recommended Action Guidelines 71
2.7.1 Repair Priority 71

3. SCOPE OF INSPECTION WORK 75
3.1 General 75
3.1.1 Structural Boundaries 75
3.1.2 Limits of Inspection 76
3.1.3 Definition of Underwater Inspection Levels of Effort 76
3.2 Routine Inspections 79
3.2.1 Objectives 79
3.2.2 Methods of Inspection and Documentation 79
3.2.3 Methods of Inspection for Steel Components 85
3.2.4 Methods of Inspection for Concrete Components 87
3.2.5 Methods of Inspection for Timber Components 88
3.2.6 Methods of Inspection for Masonry Components 89
3.2.7 Methods of Inspection for Polymer Composite Components 90
3.2.8 Methods of Inspection for Slope Protection 91
3.2.9 Methods of Inspection for Mudline 92
3.2.10 Methods of Inspection for Mooring Hardware and Fender Systems 93
3.2.11 Methods of Inspection for Anchors and Chains 94
3.2.12 Methods of Inspection for Buoys 95
3.2.13 Methods of Inspections for Utility Systems 95

3.2.14 Evaluation and Rating 96
3.2.15 Recommendations 97
3.3 Repair or Upgrade Design Inspections 97
3.3.1 Objectives 97
3.3.2 Methods of Inspection and Documentation 98
3.3.3 Inspection of Buried Elements 100
3.3.4 Recommendations 100
3.4 New Construction Inspections 100
3.4.1 Objectives 100
3.4.2 Method of Inspection and Documentation 100
3.4.3 Methods of Inspection for Steel Components 101
3.4.4 Methods of Inspection for Concrete, Timber, Masonry, and Polymer Composite Components 102
3.4.5 Methods of Inspection for Slope Protection 102
3.4.6 Methods of Inspections for Mudline 103
3.4.7 Evaluation and Rating 103
3.4.8 Recommendations 103
3.5 Baseline Inspections 104
3.5.1 Objectives 104
3.5.2 Method of Inspection and Documentation 104
3.5.3 Recommendations 105
3.6 Due Diligence Inspections 106
3.6.1 Objectives 106
3.6.2 Methods of Inspection and Documentation 106
3.6.3 Recommendations 107
3.7 Special-purpose Inspections 107
3.7.1 Objectives 107
3.7.2 Methods of Inspection and Documentation 107
3.7.3 Recommendations 108
3.8 Repair Construction Inspections 108
3.8.1 Objectives 108
3.8.2 Methods of Inspection and Documentation 108
3.8.3 Recommendations 109
3.9 Postevent Inspections 109
3.9.1 Objectives 109
3.9.2 Methods of Inspection and Documentation 110
3.9.3 Ratings and Recommendations 111
Reference 111

4. SERVICE LIFE ESTIMATION 113
4.1 General 113
4.2 Importance of Accurate Estimations 115
4.3 State of the Art 115
4.4 Deterioration Zones 116

4.5 Concrete Facilities 118
4.5.1 Sampling 118
4.5.2 Laboratory Testing and Analysis 121
4.5.3 Service Life Modeling 123
4.6 Steel Facilities 124
4.6.1 Background 124
4.6.2 Variation in Published Unprotected Steel Corrosion Rates 126
4.6.3 Data Summary 130
4.6.4 Corrosion Protection Systems 130
4.6.5 Original Service Life Calculation 132
4.6.6 Remaining Service Life Calculation 133
4.7 Timber Facilities 135
4.7.1 Background 135
4.7.2 Sampling 135
4.7.3 Laboratory Testing and Analysis 138
4.7.4 Service Life Estimation 138
4.8 Polymer Composite Materials 140
4.8.1 Background 140
4.8.2 Sampling and Testing 141
4.8.3 Service Life Estimation 142
References 145

5. DOCUMENTATION AND REPORTING 149
5.1 General 149
5.2 Routine Inspection Report 150
5.2.1 Executive Summary 150
5.2.2 Introduction 151
5.2.3 Existing Conditions or Observations 151
5.2.4 Evaluation and Assessment 152
5.2.5 Recommendations 152
5.2.6 Appendixes 153
5.3 Documentation 153
5.3.1 Field Notes 153
5.3.2 Photographs and Video 154
5.3.3 Calculations 155
5.3.4 Cost Estimates 155
5.3.5 Other Documentation 155
5.4 Electronic Record Keeping 155
5.4.1 Spreadsheets 156
5.4.2 Databases 156
5.4.3 Basic Architecture of the Inspection Database 156
5.4.4 Reporting Data 157
5.4.5 Trends 157

5.4.6 Dashboards 158
5.4.7 Digital Twins 158
5.5 Data Comparison over Time 159

6. ADMINISTRATIVE CONSIDERATIONS AND PLANNING 161
6.1 Request for Proposals and Agreements 161
6.1.1 Defining Owner Requirements 162
6.1.2 Owner Considerations for Project Control and Risk Management 163
6.1.3 Other Supporting Information 164
6.2 Insurance 165
6.2.1 Commercial General Liability and Property Damage Insurance 165
6.2.2 Automobile Liability and Physical Damage 166
6.2.3 Workers' Compensation Insurance 166
6.2.4 Longshoremen and Harbor Workers' Insurance 166
6.2.5 Jones Act Maritime Insurance 167
6.2.6 Marine Protection and Indemnity Insurance 167
6.2.7 Professional Liability Insurance (Errors and Omissions) 167
6.2.8 Contractor's Pollution Liability 168
6.2.9 Vessel Pollution Insurance 168
6.2.10 Railroad Protective Insurance 168
6.3 Indemnity 169
6.4 Certificates of Insurance 169
6.5 Permitting 169
6.6 Notice to Proceed 170

APPENDIX A: SPECIAL CONSIDERATIONS FOR SPECIFIC STRUCTURE TYPES AND SYSTEMS 171
A.1 Introduction 171
A.2 Open-Piled Structures 171
A.2.1 General 171
A.2.2 Timber Structures 172
A.2.3 Concrete Structures 177
A.2.4 Steel Structures 182
A.2.5 Polymer Composite Structures and Elements 186
A.3 Relieving Platforms 187
A.3.1 General 187
A.3.2 Typical Components and Problem Areas 188
A.4 Walls and Retaining Structures 191
A.4.1 General 191
A.4.2 Common Types of Walls and Retaining Structures 192
A.4.3 Typical Components and Problem Areas 194

A.5 Revetments 205
A.5.1 General 205
A.5.2 Typical Components and Problem Areas 206
A.6 Caissons, Cofferdams, and Cellular Structures 207
A.6.1 General 207
A.6.2 Typical Components and Problem Areas 208
A.7 Floating Structures 212
A.7.1 General 212
A.7.2 Typical Components and Problem Areas 213
A.8 Mooring Hardware and Fender Systems 217
A.8.1 General 217
A.8.2 Typical Components and Problem Areas 218
A.9 Mooring Buoy Systems 226
A.9.1 General 226
A.9.2 Typical Components and Problem Areas 227
A.10 Wave Screens and Attenuators 232
A.10.1 General 232
A.10.2 Typical Components and Problem Areas 232
A.11 Waterfront Security Barriers 236
A.11.1 General 236
A.11.2 Typical Components and Problem Areas 236
A.12 Coatings and Cathodic Protection Systems 238
A.12.1 General 238
A.12.2 Typical Components and Problem Areas 238
A.13 Marina and Small Craft Harbor Components 243
A.13.1 General 243
A.13.2 Typical Components and Problem Areas 245
A.14 Gangways 250
A.14.1 General 250
A.14.2 Typical Components and Problem Areas 252
A.15 Boat Ramps 254
A.15.1 General 254
A.15.2 Typical Components and Problem Areas 255
A.16 Marine Railways 256
A.16.1 General 256
A.16.2 Typical Components and Problem Areas 257
A.17 Bull Rails, Ladders, and Safety Features 257
A.17.1 General 257
A.17.2 Typical Components and Problem Areas 258
A.18 Crane Rails, Trenching, and Cables 259
A.18.1 Crane Rails 259
A.18.2 Trenching and Cables 260
A.18.3 Typical Components and Problem Areas 261

A.19 Waterfront Utility Systems 263
A.19.1 General 263
A.19.2 Typical Components and Problem Areas 264
A.20 Anchors and Chains 267
A.20.1 General 267
A.20.2 Typical Components and Problem Areas 267
References 275

APPENDIX B: TYPES AND CAUSES OF DEFECTS 277
B.1 Introduction 277
B.2 Concrete Structures 277
B.2.1 Cracking 278
B.2.2 Corrosion of Reinforcing Steel 281
B.2.3 Chemical Attack 288
B.2.4 Mechanical and Other Types of Damage 293
B.3 Steel Structures 302
B.3.1 Steel Deterioration 302
B.3.2 Impact or Overload Damage 311
B.4 Timber Structures 312
B.4.1 Timber Deterioration 312
B.5 Masonry Structures 320
B.5.1 Erosion and Movement 321
B.5.2 Spalling 322
B.5.3 Splitting 322
B.5.4 Abrasion 322
B.5.5 Degradation of Mortar 323
B.5.6 Marine Borers 324
B.6 Polymer Composite Structural Components 324
B.6.1 Ultraviolet Deterioration 324
B.6.2 Material Incompatibility 325
B.6.3 Corrosion Damage 326
B.6.4 Swelling 326
B.6.5 Overstress Damage 326
B.7 Coating and Wrap Systems 328
B.7.1 Coatings 328
B.7.2 Wraps 329
B.8 Load Isolators and Bearings 330
B.9 Mudline Changes 331
B.9.1 Aggradation 332
B.9.2 Scour 332
B.9.3 Causes of Aggradation and Scour 333

APPENDIX C: OVERVIEW OF SPECIALIZED TECHNIQUES 335
C.1 Introduction 335
C.1.1 Qualifications for Specialized Techniques 336
C.1.2 Data Collection and Interpretation 336

C.2 Infrared Thermography 337
C.3 Ground-Penetrating Radar 340
C.4 Pile Integrity Testing 343
C.5 Seismic Refraction Testing 344
C.6 Acoustic Emission Testing 347
C.7 Steel Reinforcement Testing 348
C.8 Schmidt Hammer 350
C.9 Impact-Echo Testing 351
C.10 Windsor Probe Testing 352
C.11 Half-Cell Testing Corrosion Survey 353
C.12 Chloride Ion Testing 355
C.13 Timber Resistance Drill 356
C.14 Material Sampling 358
C.14.1 Concrete Sampling 359
C.14.2 Steel Testing 360
C.14.3 Timber Testing 361
C.15 Ultrasonic Testing 362
C.16 Liquid Penetrant Testing 364
C.17 Magnetic Particle Testing 367
C.17.1 Magnetic-Particle Test Methods and Implementation Procedures 368
C.17.2 Field Testing of Structures 369
C.18 Microbial-Induced Corrosion Testing 370
C.18.1 Sulfate-Reducing Bacteria Testing 370
C.18.2 Iron-Reducing Bacteria and Acid-Producing Bacteria Testing 373
C.18.3 Additional Microbial-Induced Corrosion Testing Methods 373
C.19 Structure-Monitoring Systems 374
C.19.1 Monitoring Systems 375
C.19.2 Strain Gauges 375
C.19.3 Applications of Monitoring Systems 377
C.20 Unknown Foundation Investigation 377
C.20.1 Surface Methods 379
C.20.2 Borehole Methods 380
C.21 Underwater Acoustic Imaging and Mudline Soundings 380
C.21.1 Mudline Sonar Data 381
C.21.2 Underwater Acoustic Imaging Data 384
C.22 Light Detection and Ranging 390
C.23 Robotic Inspection Aids 391
C.23.1 Unmanned Aerial Systems 392
C.23.2 Unmanned Underwater Vehicles 393
C.23.3 Other Robotic Inspection Aids 394
C.24 Digital Twins 395

C.25 Mooring Hardware Testing 397
C.25.1 Bolt Testing 398
C.25.2 Pull Testing 398
References 399

APPENDIX D: INSPECTION NOMENCLATURE 401
D.1 Data Collection Nomenclature 401
D.2 Reporting Nomenclature 410

GLOSSARY 411

INDEX 431