Contents

PREFACE

CHAPTER 1 THE BRIDGE PROGRAM AND BRIDGE NEEDS
  1.1 The Status of the Nation's Highways and Bridges:
      Conditions and Performance  1
  1.2 The National Bridge Inventory (NBI) and Other Programs  7
  1.3 Bridge Management Systems: An Overview  10
  1.4 Recording and Coding Policies  13
  1.5 Priority Ranking  22
  1.6 Systemwide Analysis of Bridges  41
  1.7 FHWA Ongoing Programs  42
      References  49

CHAPTER 2 COST EFFECTIVENESS ANALYSIS AND SERVICE LIFE ESTIMATES
  2.1 Project-Level Analysis  51
  2.2 Cost Effectiveness of Evaluation Method  61
  2.3 Analytical Models  64
  2.4 Sensitivity Analysis of Economic Model: Example  74
  2.5 Incremental Benefit/Cost Ratio  77
  2.6 Bridge Deterioration Studies and Service Life Estimates  91
  2.7 Needs Prediction Models  101

References  xiii
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.8</td>
<td>Network Level Analysis</td>
<td>111</td>
</tr>
<tr>
<td>2.9</td>
<td>Overview of FHWA Philosophy</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>121</td>
</tr>
<tr>
<td>CHAPTER 3</td>
<td>ASSESSMENT OF BRIDGE DEFICIENCIES</td>
<td>123</td>
</tr>
<tr>
<td>3.1</td>
<td>Inspection Policies and Procedures</td>
<td>123</td>
</tr>
<tr>
<td>3.2</td>
<td>Bridge Systems, General Overview</td>
<td>127</td>
</tr>
<tr>
<td>3.3</td>
<td>Defects and Definitions</td>
<td>146</td>
</tr>
<tr>
<td>3.4</td>
<td>Inspection of Bridge Members</td>
<td>152</td>
</tr>
<tr>
<td>3.5</td>
<td>Procedures for Detecting Defects and Deterioration</td>
<td>158</td>
</tr>
<tr>
<td>3.6</td>
<td>Assessment of Deficiencies Below the Waterline</td>
<td>187</td>
</tr>
<tr>
<td>3.7</td>
<td>Full-Scale Testing</td>
<td>190</td>
</tr>
<tr>
<td>3.8</td>
<td>Current Practice</td>
<td>192</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>196</td>
</tr>
<tr>
<td>CHAPTER 4</td>
<td>STRUCTURAL CAPACITY ANALYSIS</td>
<td>203</td>
</tr>
<tr>
<td>4.1</td>
<td>Overall Structure Adequacy Appraisal</td>
<td>203</td>
</tr>
<tr>
<td>4.2</td>
<td>Specifications for Checking Capacities of Existing Bridges</td>
<td>205</td>
</tr>
<tr>
<td>4.3</td>
<td>Allowable Stress Design (ASD)</td>
<td>211</td>
</tr>
<tr>
<td>4.4</td>
<td>Load Factor Design (Strength Design)</td>
<td>215</td>
</tr>
<tr>
<td>4.5</td>
<td>Design Examples, Steel Beams: Load Factor</td>
<td>222</td>
</tr>
<tr>
<td>4.6</td>
<td>Design Examples, Concrete Superstructure: Load Factor Method</td>
<td>227</td>
</tr>
<tr>
<td>4.7</td>
<td>Special Considerations for Bridge Foundations</td>
<td>232</td>
</tr>
<tr>
<td>4.8</td>
<td>Design Example, Substructure Capacity Analysis Timber Pile Foundations</td>
<td>234</td>
</tr>
<tr>
<td>4.9</td>
<td>Assessment of Trusses and Truss Members</td>
<td>237</td>
</tr>
<tr>
<td>4.10</td>
<td>Design Example 4–5, Truss Bridge</td>
<td>241</td>
</tr>
<tr>
<td>4.11</td>
<td>Prestressed Concrete</td>
<td>249</td>
</tr>
<tr>
<td>4.12</td>
<td>Special Considerations for Columns</td>
<td>258</td>
</tr>
<tr>
<td>4.13</td>
<td>Design Example 4–7, Capacity Analysis: Pile Foundations and Spread Footings</td>
<td>262</td>
</tr>
<tr>
<td>4.14</td>
<td>Two-Girder Steel Bridges: Capacity Analysis and Rating</td>
<td>269</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>284</td>
</tr>
<tr>
<td>CHAPTER 5</td>
<td>METHODS OF STRENGTHENING EXISTING BRIDGES</td>
<td>286</td>
</tr>
<tr>
<td>5.1</td>
<td>Background and Objectives</td>
<td>286</td>
</tr>
<tr>
<td>5.2</td>
<td>Bridges in Need of Strengthening: Statistical Data</td>
<td>288</td>
</tr>
<tr>
<td>5.3</td>
<td>Composite Action Between Deck and Beams</td>
<td>292</td>
</tr>
<tr>
<td>5.4</td>
<td>Increasing the Strength of Bridge Members</td>
<td>305</td>
</tr>
<tr>
<td>5.5</td>
<td>Increasing the Geotechnical Capacity of Bridge Foundations</td>
<td>321</td>
</tr>
<tr>
<td>5.6</td>
<td>Strengthening Critical Connections</td>
<td>332</td>
</tr>
<tr>
<td>5.7</td>
<td>Modification of Transverse Stiffness</td>
<td>335</td>
</tr>
</tbody>
</table>
5.8 The Use of Posttensioning to Improve Strength 349
5.9 Design Example 5–3, Posttensioning of Steel Beam Bridge 363
5.10 Design Example 5–4, Strengthening of Truss Members 371
5.11 Design Example 5–5, Transverse Stiffness Effects 374
5.12 Design Example 5–6, Addition of Steel Cover Plates 378
5.13 Design Example 5–7, Prestressed Precast Box Beams 381
5.14 Further Considerations of Posttensioning 384
5.15 Epoxy-Bonded Steel Plates 393
5.16 Strengthening Steel Beams by Testing Existing Steel 398
References 399

CHAPTER 6 RETROFIT PROCEDURES AND ANALYSIS 406
6.1 Background 406
6.2 Adding or Replacing Members 407
6.3 Retrofit to Provide Continuity 409
6.4 Integral Conversions (Retrofitting) 419
6.5 Design Example 6–1: Modification of Simple Spans 426
6.6 Seismic Resistance of Bridges: General Principles 430
6.7 AASHTO Requirements for Seismic Design 435
6.8 Bridge Eligibility and Evaluation for Seismic Retrofitting 447
6.9 Capacity/Demand Ratio Analysis 452
6.10 Seismic Retrofitting Concepts and Details 469
6.11 Design Example 6–2: Seismic Retrofit 485
6.12 Development of Column Vulnerability Rating 510
6.13 Simplified Restrainer Analysis, CalTrans Method 514
References 518

CHAPTER 7 GENERAL REPAIR METHODS 522
7.1 Repair of Concrete Elements 522
7.2 Repair of Prestressed Concrete 532
7.3 Repair of Steel Members 550
7.4 The Use of Welding to Repair Cracks in Steel Members 566
7.5 Increasing the Fatigue Strength of Welded Joints 580
7.6 Repair of Accidental Damage 584
7.7 Repair of Timber Members 589
References 589

CHAPTER 8 REPAIR OF SUPERSTRUCTURES 591
8.1 Concrete Bridge Decks—Typical Conditions and Repairs 591
8.2 Long-Term Programs for Salt-Contaminated Bridge Decks 596
8.3 Wearing Surfaces 599
8.4 Steel Beams and Girders—Problems and Repairs 601
8.5 Prestressed Concrete Beams 621
8.6 Deck Joints 630
8.7 Bearing Assemblies 639
8.8 Curbs, Sidewalks, and Railings 648
8.9 Geometric Deficiencies 649
8.10 Effects of Overload on Deterioration of Concrete Bridges 654
References 663

CHAPTER 9 REPAIR OF SUBSTRUCTURES 665
9.1 Substructure and Foundation Requirements 665
9.2 Scour at Bridge Sites 668
9.3 Collision Damage 678
9.4 Problems Caused by Foundation Settlement 690
9.5 The Option of Strengthening 700
9.6 Substructures Below the Waterline: Problems and Deterioration 705
9.7 Substructure Below the Waterline: Procedures to Arrest Deterioration 708
9.8 General Repair Techniques 715
References 726

CHAPTER 10 REHABILITATION OF SPECIAL BRIDGES 729
10.1 Trusses, Problems and Repair Procedures 729
10.2 Examples of Truss Repairs 746
10.3 Arch Bridges 751
10.4 Grid and Orthotropic Decks 762
10.5 Suspension Bridges 769
10.6 Steel Railroad Bridges 795
10.7 Movable Bridges 807
References 816

CHAPTER 11 THE REPLACEMENT OPTION 818
11.1 The Rationale of Analysis: Replacement Versus Repair and Strengthening 818
11.2 Repair and Replacement Resulting from Damage of Steel Members 826
11.3 Partial Replacement of Steel Members 833
11.4 Replacement of Prestressed Concrete Beams 838
11.5 Replacement of Deck Joints 842
11.6 Replacement of Bearings 844
11.7 Redecking and Widening 846
11.8 Overview of Replacement Systems 851