

# CONSTRUCTION HANDBOOK FOR BRIDGE TEMPORARY WORKS



2nd Edition | 2017

CHTBW-2 | ISBN 978-1-56051-641-5

AMERICAN ASSOCIATION  
OF STATE HIGHWAY AND  
TRANSPORTATION OFFICIALS

**AASHTO**



**Documents**

Document Sharing Hub



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](http://www.transportation.org)

Cover photo: Utah 4500 South Bridge over I-215. Its temporary staging area for first self-propelled modular transporter move in Salt Lake City, Utah, September 7, 2007. Photo provided by the Utah DOT.

© 2017 by the American Association of State Highway and Transportation Officials. All rights reserved. Duplication is a violation of applicable law.

# **AASHTO EXECUTIVE COMMITTEE**

**2016–2017**

## **Voting Members**

### ***OFFICERS:***

PRESIDENT: David Bernhardt, Maine\*

VICE PRESIDENT: John Schroer, Tennessee\*

SECRETARY-TREASURER: Carlos Braceras, Utah

EXECUTIVE DIRECTOR: Bud Wright, Washington, D. C.

### ***REGIONAL REPRESENTATIVES:***

REGION I: Leslie Richards, Pennsylvania  
Pete Rahn, Maryland

REGION II: Charles Kilpatrick, Virginia  
James Bass, Texas

REGION III: Randall S. Blankenhorn, Illinois  
Patrick McKenna, Missouri

REGION IV: Carlos Braceras, Utah  
Mike Tooley, Montana

***IMMEDIATE PAST PRESIDENT:*** vacant

**\*Elected at the 2016 Annual Meeting in Boston, Massachusetts**

## **Nonvoting Members**

Executive Director: Bud Wright, Washington, DC

This page is intentionally left blank.

## HIGHWAY SUBCOMMITTEE ON BRIDGES AND STRUCTURES, 2016

GREGG FREDRICK, *Chair*

BRUCE V. JOHNSON, *Vice Chair*

JOSEPH L. HARTMANN, Federal Highway Administration, *Secretary*

PATRICIA J. BUSH, *AASHTO Liaison*

**ALABAMA**, Eric J. Christie, William “Tim”  
Colquett, Randall B. Mullins

**ALASKA**, Richard A. Pratt

**ARIZONA**, David B. Benton, David L.  
Eberhart, Pe-Shen Yang

**ARKANSAS**, Charles “Rick” Ellis

**CALIFORNIA**, Susan Hida, Thomas A.  
Ostrom, Dolores Valls

**COLORADO**, Behrooz Far, Stephen  
Harelson, Jessica Martinez

**CONNECTICUT**, Timothy D. Fields

**DELAWARE**, Barry A. Benton, Jason  
Hastings

**DISTRICT OF COLUMBIA**, Donald L.  
Cooney, Konjit C. “Connie” Eskender,  
Richard Kenney

**FLORIDA**, Sam Fallaha, Dennis William  
Potter, Jeff Pouliotte

**GEORGIA**, Bill DuVall, Steve Gaston

**HAWAII**, James Fu

**IDAHO**, Matthew Farrar

**ILLINOIS**, Tim A. Armbrecht, Carl Puzey

**INDIANA**, Anne M. Rearick

**IOWA**, Ahmad Abu-Hawash, Norman L.  
McDonald

**KANSAS**, Mark E. Hoppe, John P. Jones

**KENTUCKY**, Mark Hite, Marvin Wolfe

**LOUISIANA**, Arthur D’Andrea, Paul Fossier,  
Zhengzheng “Jenny” Fu

**MAINE**, Jeffrey S. Folsom, Wayne  
Frankhauser, Michael Wight

**MARYLAND**, Earle S. Freedman, Jeffrey L.  
Robert, Gregory Scott Roby

**MASSACHUSETTS**, Alexander K. Bardow,  
Thomas Donald, Joseph Rigney

**MICHIGAN**, Matthew Jack Chynoweth,  
David Juntunen

**MINNESOTA**, Arielle Ehrlich, Kevin  
Western

**MISSISSIPPI**, Austin Banks, Justin Walker,  
Scott Westerfield

**MISSOURI**, Dennis Heckman, Scott  
Stotlemeyer

**MONTANA**, Kent M. Barnes, David F.  
Johnson

**NEBRASKA**, Mark Ahlman, Fouad Jaber,  
Mark J. Traynowicz

**NEVADA**, Troy Martin, Jessen Mortensen

**NEW HAMPSHIRE**, David L. Scott, Peter  
Stamnas

**NEW JERSEY**, Xiaohua “Hannah” Cheng,  
Nagnath “Nat” Kasbekar, Eli D. Lambert

**NEW MEXICO**, Ted L. Barber, Raymond M.  
Trujillo, Jeff C. Vigil

**NEW YORK**, Wahid Albert, Richard  
Marchione

**NORTH CAROLINA**, Brian Hanks, Scott  
Hidden, Thomas Koch

**NORTH DAKOTA**, Terrence R. Udland

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

**OKLAHOMA**, Steven Jacobi, Walter Peters

**OREGON**, Bruce V. Johnson, Tanarat  
Potisuk, Hormoz Seradj

**PENNSYLVANIA**, James M. Long, Thomas  
P. Macioce, Lou Ruzzi

**PUERTO RICO**, (Vacant)

**RHODE ISLAND**, Georgette Chahine

**SOUTH CAROLINA**, Barry W. Bowers,  
Terry B. Koon, Jeff Sizemore

**SOUTH DAKOTA**, Steve Johnson

**TENNESSEE**, John S. Hastings, Wayne J.  
Seeger

**TEXAS**, Bernie Carrasco, Jamie F. Farris,  
Gregg A. Freeby

**U.S. DOT**, Joseph L. Hartmann

**UTAH**, Carmen Swanwick, Cheryl Hersh  
Simmons, Joshua Sletten

**VERMONT**, James LaCroix, Wayne B.  
Symonds

**VIRGINIA**, Prasad L. Nallapaneni, Kendal R.  
Walus

**WASHINGTON**, Tony M. Allen, Thomas E.  
Baker, Bijan Khaleghi

**WEST VIRGINIA**, Ahmed Mongi, Billy  
Varney

**WISCONSIN**, Scot Becker, William C.  
Dreher, William Olivia

**WYOMING**, Paul G. Cortez, Gregg C.  
Frederick, Michael E. Menghini

**GOLDEN GATE BRIDGE, HIGHWAY  
AND TRANSPORTATION DISTRICT**,  
Kary H. Witt

**MDTA, Dan Williams**

**N.J. TURNPIKE AUTHORITY**, Richard J.  
Raczynski

**N.Y. STATE BRIDGE AUTHORITY**,  
Jeffrey Wright

**PENN. TURNPIKE COMMISSION**, James  
Stump

**U.S. ARMY CORPS OF ENGINEERS—  
DEPARTMENT OF THE ARMY**,  
Phillip W. Sauser, Christopher H.  
Westbrook

**U.S. COAST GUARD**, Kamal Elnahal

**U.S. DEPARTMENT OF  
AGRICULTURE—FOREST  
SERVICE**, John R. Kattell

**KOREA, Eui-Joon Lee, Sang-Soon Lee**

**SASKATCHEWAN**, Howard Yea  
**TRANSPORTATION RESEARCH BOARD**,  
Waseem Dekelbab

# CONSTRUCTION HANDBOOK FOR BRIDGE TEMPORARY WORKS

## TABLE OF CONTENTS

### SECTION 1—INTRODUCTION

|                                |     |
|--------------------------------|-----|
| 1.1—SCOPE .....                | 1-1 |
| 1.2—DEFINITIONS .....          | 1-1 |
| 1.3—RELATED PUBLICATIONS ..... | 1-2 |

### SECTION 2—FALSEWORK

|                                                  |      |
|--------------------------------------------------|------|
| 2.1—MATERIALS AND MANUFACTURED COMPONENTS .....  | 2-1  |
| 2.1.1—Structural Steel .....                     | 2-1  |
| 2.1.1.1—Quality of Steel .....                   | 2-1  |
| 2.1.1.2—Dimensional Tolerances .....             | 2-1  |
| 2.1.1.3—Conditioning of Salvaged Steel .....     | 2-1  |
| 2.1.1.4—Welding .....                            | 2-4  |
| 2.1.2—Wood .....                                 | 2-8  |
| 2.1.3—Manufactured Components .....              | 2-10 |
| 2.2—FOUNDATIONS .....                            | 2-12 |
| 2.2.1—Shallow Foundations .....                  | 2-12 |
| 2.2.2—Deep Foundations .....                     | 2-15 |
| 2.2.3—Protection of the Foundation .....         | 2-18 |
| 2.3—CONSTRUCTION .....                           | 2-19 |
| 2.3.1—General .....                              | 2-19 |
| 2.3.2—Wood Construction .....                    | 2-21 |
| 2.3.3—Vertical Shoring Systems .....             | 2-22 |
| 2.3.4—Cable Bracing .....                        | 2-24 |
| 2.3.5—Bridge Deck Falsework .....                | 2-25 |
| 2.3.6—Traffic Openings .....                     | 2-28 |
| 2.4—LOADING .....                                | 2-30 |
| 2.4.1—Loads During Falsework Erection .....      | 2-30 |
| 2.4.2—Concrete Placement .....                   | 2-30 |
| 2.4.3—Load Redistribution .....                  | 2-31 |
| 2.4.4—Other Conditions .....                     | 2-32 |
| 2.5—INSPECTION .....                             | 2-32 |
| 2.5.1—General .....                              | 2-32 |
| 2.5.2—Vertical Take-Up .....                     | 2-32 |
| 2.5.3—Inspection During Concrete Placement ..... | 2-32 |
| 2.5.4—Inspection After Concrete Placement .....  | 2-33 |

### SECTION 3—FORMWORK

|                                    |      |
|------------------------------------|------|
| 3.1—INTRODUCTION .....             | 3-1  |
| 3.2—FORM COMPONENTS .....          | 3-1  |
| 3.2.1—Sheathing .....              | 3-2  |
| 3.2.2—Structural Supports .....    | 3-6  |
| 3.2.3—Form Accessories .....       | 3-9  |
| 3.3—LOADS .....                    | 3-13 |
| 3.4—FORMWORK TYPES .....           | 3-15 |
| 3.4.1—Job-Built Formwork .....     | 3-15 |
| 3.4.2—Modular Formwork .....       | 3-15 |
| 3.4.3—Stay-in-Place Formwork ..... | 3-16 |
| 3.4.4—Gang Forms .....             | 3-16 |
| 3.4.5—Plate-Girder Forms .....     | 3-18 |
| 3.4.6—Traveling Forms .....        | 3-19 |
| 3.5—CONSTRUCTION .....             | 3-20 |

|                                                                                     |      |
|-------------------------------------------------------------------------------------|------|
| 3.6—FORM MAINTENANCE .....                                                          | 3-22 |
| 3.6.1—Stripping.....                                                                | 3-22 |
| 3.6.2—Cleaning and Release Agent Application.....                                   | 3-22 |
| 3.6.3—Handling and Storage.....                                                     | 3-22 |
| 3.6.4—Coatings and Agents .....                                                     | 3-23 |
| SECTION 4—TEMPORARY RETAINING STRUCTURES                                            |      |
| 4.1—INTRODUCTION.....                                                               | 4-1  |
| 4.2—CLASSIFICATIONS .....                                                           | 4-1  |
| 4.2.1—Wood Sheathing.....                                                           | 4-4  |
| 4.2.2—Soldier Piles .....                                                           | 4-5  |
| 4.2.3—Steel Sheet Piles .....                                                       | 4-7  |
| 4.2.4—Tangent Piles.....                                                            | 4-7  |
| 4.3—SELECTION OF COFFERDAM SCHEME.....                                              | 4-8  |
| 4.4—RELATIVE COSTS.....                                                             | 4-10 |
| 4.5—SELECTION OF SUPPORT METHOD.....                                                | 4-10 |
| 4.6—SEALING AND BUOYANCY CONTROL.....                                               | 4-10 |
| 4.7—SEEPAGE CONTROL .....                                                           | 4-11 |
| 4.8—PROTECTION .....                                                                | 4-15 |
| 4.9—CONSTRUCTION .....                                                              | 4-15 |
| 4.9.1 Wood Sheet Cofferdam.....                                                     | 4-15 |
| 4.9.2—Soldier Pile/Wood Lagging cofferdam .....                                     | 4-17 |
| 4.9.3—Steel Sheet Pile Cofferdam .....                                              | 4-18 |
| 4.9.4—Soil and Rock Anchors.....                                                    | 4-19 |
| 4.9.5—Soil Nail Walls.....                                                          | 4-23 |
| 4.9.6—Internal Bracing.....                                                         | 4-24 |
| APPENDICES                                                                          |      |
| APPENDIX A—SECTION PROPERTIES OF STANDARD DRESSED (S4S) AND ROUGH SAWN LUMBER ..... | A-1  |
| APPENDIX B—FALSEWORK AND FORMWORK DESIGN EXAMPLES .....                             | B-1  |
| Example 1—Slab Falsework with Overhang Bracket.....                                 | B-1  |
| Example 2—Needle Beam .....                                                         | B-7  |
| Example 3—Pier Cap Vertical Formwork .....                                          | B-12 |
| Example 4—Wind Load on Falsework .....                                              | B-18 |
| Example 5—Falsework Cable Bracing .....                                             | B-24 |
| Example 6—Falsework Loading in Longitudinal Direction .....                         | B-28 |
| Example 7—Falsework Internal Cable Bracing .....                                    | B-33 |
| APPENDIX C—RECOMMENDED THICKNESSES OF WOOD LAGGING .....                            | C-1  |
| APPENDIX D—STEEL SHEET PILE DATA .....                                              | D-1  |
| REFERENCES .....                                                                    | R-1  |

# CONSTRUCTION HANDBOOK FOR BRIDGE TEMPORARY WORKS

## LIST OF FIGURES

|                                                                                                                     |      |
|---------------------------------------------------------------------------------------------------------------------|------|
| Figure 2.1.1.4-1—Fillet Weld Profiles .....                                                                         | 2-7  |
| Figure 2.1.2-1—Shapes in which Knots Appear in Various Structural Members and Methods of Measurement ....           | 2-9  |
| Figure 2.1.2-2—Determination of Combined Slope of Gain.....                                                         | 2-9  |
| Figure 2.1.3-1—Frame and Braced Tower Buckling Modes.....                                                           | 2-11 |
| Figure 2.1.3-2—Adjustable Horizontal Shoring Beams Spanning between Bridge Piers and Temporary Timber<br>Bents..... | 2-11 |
| Figure 2.1.3-3—Adjustable Overhang Bracket for Precast Concrete Stringer .....                                      | 2-12 |
| Figure 2.2.1-1—Analysis of Plate Bearing Tests .....                                                                | 2-14 |
| Figure 2.2.2-1—Interpretation of Pile Load Test .....                                                               | 2-16 |
| Figure 2.2.2-2—Load Test Analysis where Downdrag Acts on Pile.....                                                  | 2-17 |
| Figure 2.2.3-1—Washout under Sill Support .....                                                                     | 2-18 |
| Figure 2.2.3-2—Sole Plate and Bracing Details for Falsework Supported on a Sloped Surface.....                      | 2-19 |
| Figure 2.3.1-1—Wood Cross-Bracing between Longitudinal Stringers.....                                               | 2-20 |
| Figure 2.3.1-2—Cantilevered Ledger Beam at Temporary Pile Bent .....                                                | 2-21 |
| Figure 2.3.3-1—Examples of Plan Bracing of Modular Frames .....                                                     | 2-23 |
| Figure 2.3.3-2—Bracing Detail for Screw Leg Supporting a Sloped Soffit .....                                        | 2-24 |
| Figure 2.3.4-1—Typical Installation of Wire Rope Slip .....                                                         | 2-25 |
| Figure 2.3.5-1—Bridge Deck Falsework.....                                                                           | 2-27 |
| Figure 2.3.6-1—Traffic Openings .....                                                                               | 2-29 |
| Figure 2.4.3-1—Deformation of Spans Subject to Post-Tensioning .....                                                | 2-31 |
| Figure 3.2-1—Formwork Components.....                                                                               | 3-1  |
| Figure 3.2.1-1—Plywood Sheathing for Horizontal Formwork .....                                                      | 3-2  |
| Figure 3.2.3-1—Form Ties .....                                                                                      | 3-10 |
| Figure 3.2.3-2—Coil Tie System.....                                                                                 | 3-12 |
| Figure 3.2.3-3—Exterior and Interior Formwork Hangers.....                                                          | 3-13 |
| Figure 3.3-1—Distribution of Concrete Pressure with Form Height.....                                                | 3-14 |
| Figure 3.3-2—Lateral Pressure of Concrete on Formwork for Various Temperatures .....                                | 3-14 |
| Figure 3.4.1-1—Job-Built Formwork .....                                                                             | 3-15 |
| Figure 3.4.4-1—Assembled Gang Form.....                                                                             | 3-17 |
| Figure 3.4.4-2—Gang Form for Wall Construction .....                                                                | 3-17 |
| Figure 3.4.5-1—Plate Girder Form Spanning between Two Supports .....                                                | 3-18 |
| Figure 3.4.5-2—Plate Girder Forms Used to Form a Bridge Pier .....                                                  | 3-19 |
| Figure 3.5-1—Vibration of Concrete.....                                                                             | 3-21 |
| Figure 3.5-2—Proper and Improper Securing Wedges .....                                                              | 3-21 |
| Figure 3.5-3—Proper and Improper Positioning Wedges .....                                                           | 3-21 |
| Figure 3.5-4—Proper and Improper Spacing of Walers.....                                                             | 3-22 |
| Figure 3.5-5—Proper and Improper Installation of Coil Bolt.....                                                     | 3-22 |
| Figure 4.2-1—Typical Cofferdams .....                                                                               | 4-2  |
| Figure 4.2-2—Internally Braced Cofferdam Systems .....                                                              | 4-2  |
| Figure 4.2-3—Self-Supporting and Externally Anchored Cofferdam Systems.....                                         | 4-3  |
| Figure 4.2.1-1—Types of Wood Sheet Piling .....                                                                     | 4-4  |
| Figure 4.2.2-1—Louver Effect for Wood Lagging.....                                                                  | 4-5  |
| Figure 4.2.2-2—Steel Soldier Piles .....                                                                            | 4-6  |
| Figure 4.2.2-3—Concrete In-Fill between Soldier Piles.....                                                          | 4-6  |
| Figure 4.2.2-4—Wood Lagging to Front Flange .....                                                                   | 4-6  |
| Figure 4.2.3-1—Typical Steel Sheet-Piling Sections .....                                                            | 4-7  |
| Figure 4.2.4-1—Typical Pile Arrangements.....                                                                       | 4-8  |
| Figure 4.7-1—Penetration of Sheeting Required to Prevent Piping in Isotropic Sand .....                             | 4-12 |
| Figure 4.7-2—Penetration of Sheeting Required to Prevent Piping in Stratified Sand .....                            | 4-13 |
| Figure 4.9.1-1—Wood Sheeting Systems.....                                                                           | 4-16 |
| Figure 4.9.1-2—Sheet Pile Driving Procedure.....                                                                    | 4-16 |
| Figure 4.9.2-1—Soldier Pile Retained with Soil Anchors.....                                                         | 4-18 |

|                                                                                                   |      |
|---------------------------------------------------------------------------------------------------|------|
| Figure 4.9.4-1—Sheet Pile Installation.....                                                       | 4-23 |
| Figure 4.9.6-1—Typical Framing Arrangements .....                                                 | 4-25 |
| Figure 4.9.6-2—Typical Connection for an Inclined Brace and Horizontal Wale .....                 | 4-26 |
| Figure 4.9.6-3—Typical Wale and Anchor Rod Details .....                                          | 4-26 |
| Figure B-1—Slab Falsework with Overhang Bracket .....                                             | B-2  |
| Figure B-2—Load–Deflection Curve for Steel Overhang Bracket.....                                  | B-6  |
| Figure B-3—Needle Beam for Slab Overhang .....                                                    | B-8  |
| Figure B-4—Pier Cap on Friction Collar .....                                                      | B-13 |
| Figure B-5—Falsework Tower Elevation.....                                                         | B-18 |
| Figure B-6—Falsework Towers with Internal Cable Bracing .....                                     | B-24 |
| Figure B-7—Tower Reactions.....                                                                   | B-25 |
| Figure B-7A—Stability .....                                                                       | B-25 |
| Figure B-7B—Stability.....                                                                        | B-27 |
| Figure B-8—Falsework Bents .....                                                                  | B-28 |
| Figure B-8A—Span AB .....                                                                         | B-29 |
| Figure B-8B—Span BC .....                                                                         | B-30 |
| Figure B-8C—Span CD.....                                                                          | B-30 |
| Figure B-8D—Span DE.....                                                                          | B-31 |
| Figure B-8E—Span EF.....                                                                          | B-31 |
| Figure B-8F—Span FG .....                                                                         | B-32 |
| Figure B-8G—Span GH .....                                                                         | B-32 |
| Figure B-8H—Bent H .....                                                                          | B-32 |
| Figure B-9—Falsework with Internal Cable Bracing .....                                            | B-35 |
| Figure B-9A—Cable A.....                                                                          | B-39 |
| Figure B-9B—Cable B .....                                                                         | B-40 |
| Figure B-10—Sag.....                                                                              | B-42 |
| Figure D-1—Normal Interlock Swing is at Least 10 Degrees on Arch Web and Straight Web Shapes..... | D-2  |
| Figure D-2—Steel Sheet Piling Interlocks in the Normal Position .....                             | D-3  |
| Figure D-3—Steel Sheet Piling Interlocks in the Reverse Position (not recommended).....           | D-3  |

## CONSTRUCTION HANDBOOK FOR BRIDGE TEMPORARY WORKS

### LIST OF TABLES

|                                                                                                       |      |
|-------------------------------------------------------------------------------------------------------|------|
| Table 2.1.1.1-1—Early ASTM Steel Specifications.....                                                  | 2-1  |
| Table 2.1.1.3-1—Permitted Variations in Cross Section for W, HP, S, M, C, and MC Shapes.....          | 2-2  |
| Table 2.1.1.3-2—Permitted Variations in Straightness W and HP Shapes .....                            | 2-3  |
| Table 2.1.1.3-3—Permitted Variations in Straightness C, M, C, MC, L, T, Z, and Bulb Angle Shapes..... | 2-3  |
| Table 2.1.1.4-1—Matching Filler Metal Requirements.....                                               | 2-5  |
| Table 2.1.1.4-2—Preferred Analysis of Carbon Steel for Good Weldability .....                         | 2-5  |
| Table 2.1.1.4-3—Weld Profile Schedule.....                                                            | 2-6  |
| Table 2.1.1.4-4—Weld Profile Tolerance .....                                                          | 2-6  |
| Table 2.3.6-1—Falsework Depth and Span Relationship .....                                             | 2-30 |
| Table 3.2.1-1—Grade-Use Guide for Plyform Sheathing .....                                             | 3-3  |
| Table 3.2.1-2—Recommended Maximum Pressures on Plyform .....                                          | 3-4  |
| Table 3.2.1-3—Section Properties for Plyform Class I and Class II and Structural I Plyform.....       | 3-5  |
| Table 3.2.1-4—Design Stresses for Plyform.....                                                        | 3-5  |
| Table 3.2.1-5—Formulas for Safe Support Spacings of Joists and Ledgers.....                           | 3-6  |
| Table 3.2.2-1—Beam Formulas .....                                                                     | 3-8  |
| Table 4.9.4-1—Typical Equipment for Construction of Tiebacks .....                                    | 4-20 |
| Table A-1—Section Properties of Standard Dresses (S4S) Lumber .....                                   | A-1  |
| Table A-2—Section Properties of Rough Sawn Lumber.....                                                | A-3  |
| Table B-1—Velocity Pressure Exposure Coefficient .....                                                | B-19 |
| Table B-2—Velocity Pressure at Each Height Zone .....                                                 | B-20 |
| Table B-3—Wind Pressure at Each Falsework Height Zone .....                                           | B-21 |
| Table B-4—Wind Load per Tower for Each Height Zone .....                                              | B-22 |
| Table B-5—Loads from Stringers (kips) .....                                                           | B-35 |
| Table B-6—Post Reactions (lbf) .....                                                                  | B-40 |
| Table B-7—Summary pf Stresses (psi) .....                                                             | B-41 |
| Table B-8—Summary of Stresses (psi) .....                                                             | B-42 |
| Table B-9—Sag and Offset Distances.....                                                               | B-43 |
| Table C-1—Recommended Thickness of Wood Lagging for Various Soil Types .....                          | C-1  |
| Table D-1—Standard Sheet Piling .....                                                                 | D-4  |
| Table D-2—H-Pile Properties .....                                                                     | D-6  |

This page is intentionally left blank.

## ABBREVIATIONS

|        |                                                                    |
|--------|--------------------------------------------------------------------|
| AASHTO | American Association of State Highway and Transportation Officials |
| ACI    | American Concrete Institute                                        |
| AISC   | American Institute of Steel Construction                           |
| AIISI  | American Iron and Steel Institute                                  |
| AITC   | American Institute of Timber Construction                          |
| ANSI   | American National Standards Institute                              |
| APA    | American Plywood Association                                       |
| ASCE   | American Society of Civil Engineers                                |
| ASTM   | American Society for Testing and Materials                         |
| AWS    | American Welding Society                                           |
| BOCA   | Building Officials & Code Administrators                           |
| FHWA   | Federal Highway Administration                                     |
| NAVFAC | Naval Facilities Engineering Command                               |
| NDS    | National Design Specifications for Wood Construction               |
| NFPA   | National Forest Products Association                               |
| OSHA   | Occupational Safety and Health Administration                      |
| PCI    | Precast/Prestressed Concrete Institute                             |
| SSFI   | Scaffolding, Shoring and Forming Institute                         |
| UBC    | Uniform Building Code                                              |

## GENERAL NOTATION

|     |                        |
|-----|------------------------|
| in. | inches                 |
| ft  | feet                   |
| plf | pounds per linear foot |
| psi | pounds per square inch |
| ksi | kips per square inch   |
| psf | pounds per square foot |
| ksf | kips per square foot   |
| tsf | tons per square foot   |
| pcf | pounds per cubic foot  |
| fps | feet per second        |
| hr  | hour                   |

| SI* (MODERN METRIC) CONVERSION FACTORS                               |                            |                         |                             |                   |                                       |                             |             |                            |                      |
|----------------------------------------------------------------------|----------------------------|-------------------------|-----------------------------|-------------------|---------------------------------------|-----------------------------|-------------|----------------------------|----------------------|
| APPROXIMATE CONVERSIONS TO SI UNITS                                  |                            |                         |                             |                   | APPROXIMATE CONVERSIONS FROM SI UNITS |                             |             |                            |                      |
| Symbol When You Know                                                 |                            | Multiply by             | To Find                     | Symbol            | Symbol When You Know                  |                             | Multiply by | To Find                    | Symbol               |
| <b>LENGTH</b>                                                        |                            |                         |                             |                   | <b>LENGTH</b>                         |                             |             |                            |                      |
| in.                                                                  | inches                     | 25.4                    | millimeters                 | mm                | mm                                    | millimeters                 | 0.039       | inches                     | in.                  |
| ft                                                                   | feet                       | 0.305                   | meters                      | m                 | m                                     | meters                      | 3.28        | feet                       | ft                   |
| yd                                                                   | yards                      | 0.914                   | meters                      | m                 | m                                     | meters                      | 1.09        | yards                      | yd                   |
| mi                                                                   | miles                      | 1.61                    | kilometers                  | km                | km                                    | kilometers                  | 0.621       | miles                      | mi                   |
| <b>AREA</b>                                                          |                            |                         |                             |                   | <b>AREA</b>                           |                             |             |                            |                      |
| in. <sup>2</sup>                                                     | square inches              | 645.2                   | square millimeters          | mm <sup>2</sup>   | mm <sup>2</sup>                       | square millimeters          | 0.0016      | square inches              | in. <sup>2</sup>     |
| ft <sup>2</sup>                                                      | square feet                | 0.093                   | square meters               | m <sup>2</sup>    | m <sup>2</sup>                        | square meters               | 10.764      | square feet                | ft <sup>2</sup>      |
| yd <sup>2</sup>                                                      | square yards               | 0.836                   | square meters               | m <sup>2</sup>    | m <sup>2</sup>                        | square meters               | 1.195       | square yards               | yd <sup>2</sup>      |
| ac                                                                   | acres                      | 0.405                   | hectares                    | ha                | ha                                    | hectares                    | 2.47        | acres                      | ac                   |
| mi <sup>2</sup>                                                      | square miles               | 2.59                    | square kilometers           | km <sup>2</sup>   | km <sup>2</sup>                       | square kilometers           | 0.386       | square miles               | mi <sup>2</sup>      |
| <b>VOLUME</b>                                                        |                            |                         |                             |                   | <b>VOLUME</b>                         |                             |             |                            |                      |
| fl oz                                                                | fluid ounces               | 29.57                   | milliliters                 | mL                | mL                                    | milliliters                 | 0.034       | fluid ounces               | fl oz                |
| gal                                                                  | gallons                    | 3.785                   | liters                      | L                 | L                                     | liters                      | 0.264       | gallons                    | gal                  |
| ft <sup>3</sup>                                                      | cubic feet                 | 0.028                   | cubic meters                | M <sup>3</sup>    | M <sup>3</sup>                        | cubic meters                | 35.71       | cubic feet                 | ft <sup>3</sup>      |
| yd <sup>3</sup>                                                      | cubic yards                | 0.765                   | cubic meters                | m <sup>3</sup>    | m <sup>3</sup>                        | cubic meters                | 1.307       | cubic yards                | yd <sup>3</sup>      |
| NOTE: Volumes greater than 1000 l shall be shown in m <sup>3</sup> . |                            |                         |                             |                   |                                       |                             |             |                            |                      |
| <b>MASS</b>                                                          |                            |                         |                             |                   | <b>MASS</b>                           |                             |             |                            |                      |
| oz                                                                   | ounces                     | 28.35                   | grams                       | g                 | g                                     | grams                       | 0.035       | ounces                     | oz                   |
| lb                                                                   | pounds                     | 0.454                   | kilograms                   | kg                | kg                                    | kilograms                   | 2.202       | pounds                     | lb                   |
| T                                                                    | short tons (2000 lb)       | 0.907                   | megagrams (or "metric ton") | Mg (or "T")       | Mg (or "T")                           | megagrams (or "metric ton") | 1.103       | short tons (2000 lb)       | T                    |
| <b>TEMPERATURE (exact)</b>                                           |                            |                         |                             |                   | <b>TEMPERATURE (exact)</b>            |                             |             |                            |                      |
| °F                                                                   | Fahrenheit temperature     | 5(F-32)/9 or (F-32)/1.8 | Celsius temperature         | °C                | °C                                    | Celsius temperature         | 1.8C + 32   | Fahrenheit temperature     | °F                   |
| <b>ILLUMINATION</b>                                                  |                            |                         |                             |                   | <b>ILLUMINATION</b>                   |                             |             |                            |                      |
| fc                                                                   | foot-candles               | 10.76                   | lux                         | lx                | lx                                    | lux                         | 0.0929      | foot-candles               | fc                   |
| fl                                                                   | foot-lamberts              | 3.426                   | candela/m <sup>2</sup>      | cd/m <sup>2</sup> | cd/m <sup>2</sup>                     | candela/m <sup>2</sup>      | 0.2919      | foot-Lamberts              | fl                   |
| <b>FORCE AND PRESSURE OR STRESS</b>                                  |                            |                         |                             |                   | <b>FORCE AND PRESSURE OR STRESS</b>   |                             |             |                            |                      |
| lbf                                                                  | poundforce                 | 4.45                    | newtons                     | N                 | N                                     | newtons                     | 0.225       | poundforce                 | lbf                  |
| lbf/in. <sup>2</sup>                                                 | poundforce per square inch | 6.89                    | kilopascals                 | kPa               | kPa                                   | kilopascals                 | 0.145       | poundforce per square inch | lbf/in. <sup>2</sup> |

\* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

## PREFACE

This Construction Handbook has been developed for use by contractors and construction engineers involved in bridge construction on Federal-aid highway projects. This document may also be of interest to falsework design engineers, and supplements information found in the *Guide Design Specifications for Bridge Temporary Works*.<sup>(1)</sup> The content is construction-oriented, focusing primarily on standards of material quality and means and methods of construction. The Handbook contains chapters on falsework, formwork, and temporary retaining structures. For more in-depth discussion on a particular topic, related literature and references are identified.

The revisions to this 2nd Edition of the AASHTO *Construction Handbook for Bridge Temporary Works* have been primarily editorial and organizational. The tables and references were updated and the content of the appendices were evaluated and updated as appropriate.

The Construction Handbook was revised under NCHRP Project 20-07/Task 294 by Wiss, Janney, Elstner Associates, Inc. (WJE), Northbrook, IL. John F. Duntemann was the Principal Investigator. This project was directed by the NCHRP Task Group, which consisted of the following representatives:

Arthur W. D'Andrea, *Louisiana Department of Transportation*  
Richard W. Dunne, *Michael Baker Jr., Inc.*  
Shoukry Elnahal, *Massachusetts Department of Transportation*  
Matthew Farrar, *Idaho Transportation Department*  
Kenneth F. Hurst, *Kansas Department of Transportation (Retired)*  
Paul V. Liles, Jr., *Georgia Department of Transportation*  
Carmen Swanwick, *Utah Department of Transportation*  
Sheila Rimal Duwadi, *Federal Highway Administration*  
Jeffrey Ger, *Federal Highway Administration*  
Waseem Dekelbab, *Transportation Research Board*  
Danna Powell, *Transportation Research Board*

The original Handbook was developed under FHWA Contract No. DTFH61-91-C-00088. The project was directed by the Scaffolding, Shoring, and Forming Task Group of the FHWA, which consisted of the following representatives:

Ian M. Friedland, *Transportation Research Board*  
James M. Stout, *California Department of Transportation*  
Donald Flemming, *Minnesota Department of Transportation*  
Nick Yaksich, *Associated General Contractors*  
Kent Starwalt, *American Road and Transportation Builders Association*  
Ramon Cook, *The Burke Company*  
Robert Desjardins, *Cianbro Corp.*  
Richard F. Hoffman, *McLean Contracting*

Robert T. Ratay, *Consulting Engineer*  
Sheila Rimal Duwadi, *Federal Highway Administration*  
James R. Hoblitzell, *Federal Highway Administration*  
Donald W. Miller, *Federal Highway Administration*  
William S. Cross, *Federal Highway Administration*

Special recognition is extended to Robert G. Lukas and Safdar Gill, Ground Engineering Consultants, Inc.; Robert T. Ratay, Consulting Engineer; and Flora A. Calabrese, Noah J. Fehrenbacher, Raymond H.R. Tide, Penny S. Sympson, and Holly L. Ryan of Wiss, Janney, Elstner Associates, Inc. for their review comments, assistance with the research, and preparation of this document.

## INTRODUCTION

### 1.1—SCOPE

This Construction Handbook has been developed for use by contractors and construction engineers involved in bridge construction on Federal-aid highway projects. This document may also be of interest to falsework design engineers and supplements information found in the *Guide Design Specifications for Bridge Temporary Works* and *AASHTO LRFD Bridge Construction Specifications*.<sup>(1,2)</sup> The content is construction-oriented, focusing primarily on standards of material quality and means and methods. This Handbook contains sections on falsework, formwork, and temporary retaining structures. For more in-depth discussion on a particular topic, related literature and references are identified.

It is paramount that the contractor identifies the specific critical condition where an existing or new bridge segment is at its weakest state for each of the possible loading and support conditions. The loads could include normal highway traffic. Experience has shown that catastrophic failures are often caused by support and loading conditions overlooked by the project team.

**Section Two—Falsework** identifies material standards, the assessment and protection of foundations, construction-related topics, loading considerations, and inspection guidelines. Methods for *in situ* testing of foundations are identified. General guidelines regarding timber construction, proprietary shoring systems, cable bracing, bridge deck falsework, and traffic openings are also discussed.

**Section Three—Formwork** identifies and describes the various components and formwork types commonly used in bridge construction. Information on load considerations and design nomographs are provided. General guidelines relating to formwork construction and form maintenance are also discussed.

**Section Four—Temporary Retaining Structures** focuses primarily on cofferdams and their application to bridge construction. As indicated by the section title, however, general topics relating to a wide range of temporary retaining structures are also addressed. Specific topics include classification of construction types, relative costs, sealing and buoyancy control, seepage control, and protection. The construction of timber sheet pile cofferdams, soldier pile and wood lagging cofferdams, and steel sheet pile cofferdams is reviewed. Methods of internal bracing and soil and rock anchorage are also discussed.

**Appendices**—Section properties of standard dressed and rough lumber, bridge deck falsework and braced falsework design examples, recommended thicknesses for wood lagging, and steel sheet pile data are included as appendices. Definitions and related publications are identified below.

### 1.2—DEFINITIONS

For the purpose of this manual, the following definitions apply. These definitions are not intended to be exclusive, but are generally consistent with the common usage of these terms.

**Falsework**—Temporary construction work used to support the permanent structure until it becomes self-supporting. Falsework would include steel or timber beams, girders, columns, piles and foundations, and any proprietary equipment, including modular shoring frames, post shores, and adjustable horizontal shoring.

**Shoring**—A component of falsework such as horizontal, vertical, or inclined support members. For the purpose of this document, this term is used interchangeably with falsework.

**Formwork**—A temporary structure or mold used to retain plastic or fluid concrete in its designated shape until it hardens. Formwork must have enough strength to resist the fluid pressure exerted by plastic concrete and any additional fluid pressure effects generated by vibration. Surcharge pressure from screeds and workmen must also be supported.

**Cofferdam**—A temporary watertight enclosure that allows construction of the permanent structure under dry conditions or in wet conditions until a basal seal coat is placed.

### 1.3—RELATED PUBLICATIONS

American Association of State Highway and Transportation Officials. *Guide Design Specifications for Bridge Temporary Works*. Second Edition. Washington, DC, 2017.

American Association of State Highway and Transportation Officials. *AASHTO LRFD Bridge Construction Specifications*. Third Edition with 2010, 2011, 2012, 2014, 2015, and 2016 Interim Revisions. Washington, DC, 2010.

American Association of State Highway and Transportation Officials. *AASHTO LRFD Bridge Design Specifications*. Seventh Edition with 2015 and 2016 Interim Revisions. Washington, DC, 2014.

American Association of State Highway and Transportation Officials. *Standard Specifications for Highway Bridges*. 17th Edition. Washington, DC, 2002.

American Association of State Highway and Transportation Officials. *Steel Bridge Erection Guide Specification*. NSBA. Washington, DC, 2014.

California Department of Transportation. *California Falsework Manual*. 34th Revision. Division of Structures, Caltrans, Sacramento, CA, July 2010.

Duntemann, J. F., N. S. Anderson, and A. Longinow. *Synthesis of Falsework, Formwork, and Scaffolding for Highway Bridge Structures* (FHWA-RD-91-062). Federal Highway Administration, Washington, DC, November 1991.

FHWA. *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects* (FP-03). Washington, DC, 2003.

FHWA. *Certification Program for Bridge Temporary Works* (FHWA-RD-93-033). Federal Highway Administration, Washington, DC, 1993.

## FALSEWORK

### 2.1—MATERIALS AND MANUFACTURED COMPONENTS

Details of design which are permitted to be selected by the contractor shall conform to the *Guide Design Specifications for Bridge Temporary Works*.

#### 2.1.1—Structural Steel

##### 2.1.1.1—Quality of Steel

ASTM A709 steel grades greater than grade 36 are generally not recommended for falsework design. The *Guide Design Specifications for Bridge Temporary Works* <sup>(1)</sup> permits the use of higher grades of steel conforming to other specifications, provided the grade of steel can be identified. Identification is the contractor's responsibility. If steel properties are unknown and test samples are not taken, steel can generally be assumed to be ASTM A709 Grade A36. For reference, some of the more common steel designations predating ASTM A709 Grade A36 are provided in Table 2.1.1.1-1.

Table 2.1.1.1-1—Early ASTM Steel Specifications <sup>(3)</sup>

| Date      | Specification | ASTM Requirement |                                          |                                             |
|-----------|---------------|------------------|------------------------------------------|---------------------------------------------|
|           |               | Remark           | Tensile Strength,<br>lb/in. <sup>2</sup> | Minimum Yield Point,<br>lb/in. <sup>2</sup> |
| 1924–1931 | ASTM A7       | Structural Steel | 55,000 to 65,000                         | ½ T.S. or not less than 30,000              |
|           |               | Rivet Steel      | 46,000 to 56,000                         | ½ T.S. or not less than 25,000              |
|           | ASTM A9       | Structural Steel | 55,000 to 65,000                         | ½ T.S. or not less than 30,000              |
|           |               | Rivet Steel      | 46,000 to 56,000                         | ½ T.S. or not less than 25,000              |
| 1939–1948 | ASTM A7-A9    | Structural Steel | 60,000 to 72,000                         | ½ T.S. or not less than 33,000              |
| 1939–1949 | ASTM A141-39  | Rivet Steel      | 52,000 to 62,000                         | ½ T.S. or not less than 28,000              |

Note: Copyright © American Institute of Steel Construction. Reprinted with permission. All rights reserved.

##### 2.1.1.2—Dimensional Tolerances

Rolling structural shapes and plates involves such factors as roll wear, subsequent roll dressing, temperature variations, etc., which cause the finished product to vary from published profiles. Mill dimensional tolerances are identified in ASTM A6. <sup>(4)</sup> This information is provided in Tables 2.1.1.3-1 through 2.1.1.3-3 for general reference.

##### 2.1.1.3—Conditioning of Salvaged Steel

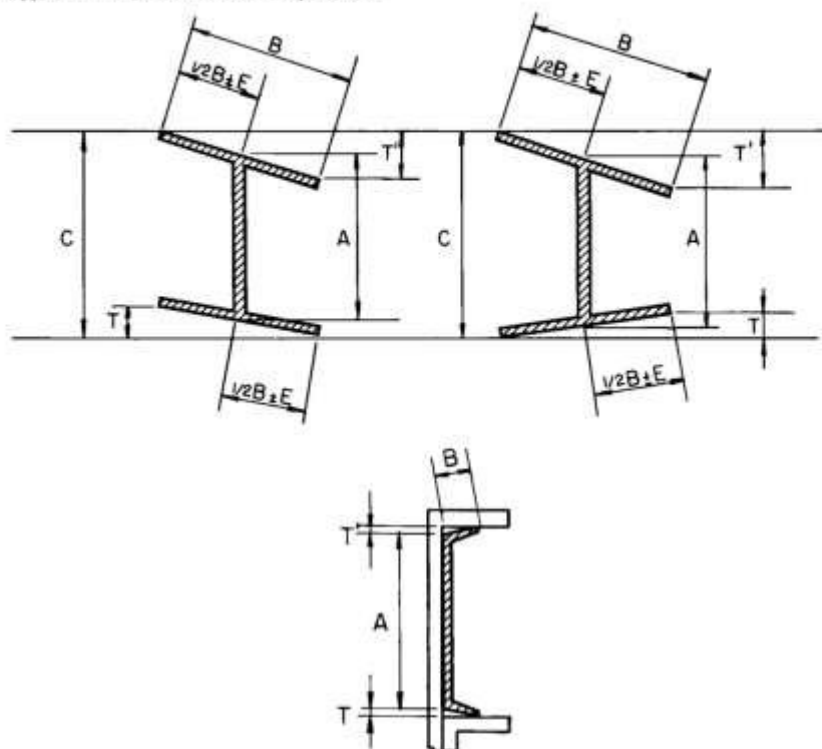
ASTM A6 also provides guidelines for plates, structural shapes, and steel sheet piling, as follows (references made to Section 9 refer to that section in ASTM A6):

**Plate Conditioning**—The grinding of plates by the manufacturer or processor to remove imperfections on the top or bottom surface shall be subject to the limitations that the area ground is well faired without abrupt changes in contour and the grinding does not reduce the thickness of the plate by: (1) more than 7 percent under the nominal thickness for plates ordered to weight per square foot or mass per square meter, but in no case more than 1/8 in.; or (2) below the permissible minimum thickness for plates ordered to thickness in inches or millimeters.

Table 2.1.1.3-1—Permitted Variations in Cross Section for W, HP, S, M, C, and MC Shapes <sup>(4)</sup>

NOTE: 1—*A* is measured at center line of web for S, M, and W and HP shapes; at back of web for C and MC shapes. Measurement is overall for C shapes under 3 in. *B* is measured parallel to flange. *C* is measured parallel to web.

NOTE: 2—Where "...," there is no requirement.



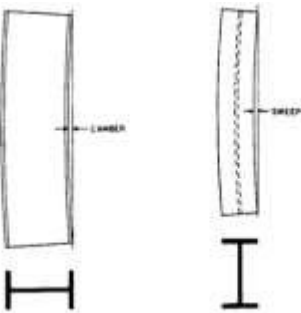
| Permitted Variations in Sectional Dimensions Given, in. |                            |                       |                        |                         |                        |                                                                                |                                                |                                                                                               |                                                                                                                 |                     |
|---------------------------------------------------------|----------------------------|-----------------------|------------------------|-------------------------|------------------------|--------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------|
| Shape                                                   | Section Nominal Sizes, in. | <i>A</i> , Depth      |                        | <i>B</i> , Flange Width |                        | <i>T</i> + <i>T'</i> <sup>A</sup><br>Flanges<br>Out-of-<br>Square <sup>B</sup> | <i>E</i> , Web<br>off Cen-<br>ter <sup>C</sup> | <i>C</i> , Maximum<br>Depth at<br>any Cross<br>Section<br>over Theo-<br>retical<br>Depth, in. | Permitted Variations<br>Over or Under Theoreti-<br>cal Web Thickness for<br>Thicknesses Given in<br>Inches, in. |                     |
|                                                         |                            | Over Theo-<br>retical | Under Theo-<br>retical | Over Theo-<br>retical   | Under Theo-<br>retical |                                                                                |                                                |                                                                                               | $\frac{3}{16}$ and<br>under                                                                                     | Over $\frac{3}{16}$ |
| W and HP                                                | Up to 12, incl             | $\frac{1}{8}$         | $\frac{1}{8}$          | $\frac{1}{8}$           | $\frac{3}{16}$         | $\frac{1}{4}$                                                                  | $\frac{3}{16}$                                 | $\frac{1}{4}$                                                                                 | ...                                                                                                             | ...                 |
|                                                         | Over 12                    | $\frac{1}{8}$         | $\frac{1}{8}$          | $\frac{1}{4}$           | $\frac{3}{16}$         | $\frac{3}{16}$                                                                 | $\frac{3}{16}$                                 | $\frac{1}{4}$                                                                                 | ...                                                                                                             | ...                 |
| S and M                                                 | 3 to 7, incl               | $\frac{3}{32}$        | $\frac{1}{16}$         | $\frac{1}{8}$           | $\frac{1}{8}$          | $\frac{1}{32}$                                                                 | $\frac{3}{16}$                                 | ...                                                                                           | ...                                                                                                             | ...                 |
|                                                         | Over 7 to 14, incl         | $\frac{1}{8}$         | $\frac{3}{32}$         | $\frac{1}{32}$          | $\frac{1}{32}$         | $\frac{1}{32}$                                                                 | $\frac{3}{16}$                                 | ...                                                                                           | ...                                                                                                             | ...                 |
| C and MC                                                | Over 14 to 24, incl        | $\frac{3}{16}$        | $\frac{1}{8}$          | $\frac{3}{16}$          | $\frac{3}{16}$         | $\frac{1}{32}$                                                                 | $\frac{3}{16}$                                 | ...                                                                                           | ...                                                                                                             | ...                 |
|                                                         | 1½ and under               | $\frac{1}{32}$        | $\frac{1}{32}$         | $\frac{1}{32}$          | $\frac{1}{32}$         | $\frac{1}{32}$                                                                 | ...                                            | ...                                                                                           | 0.010                                                                                                           | 0.015               |
|                                                         | Over 1½ to 3, excl         | $\frac{3}{16}$        | $\frac{1}{16}$         | $\frac{1}{16}$          | $\frac{1}{16}$         | $\frac{1}{32}$                                                                 | ...                                            | ...                                                                                           | 0.015                                                                                                           | 0.020               |
|                                                         | 3 to 7, incl               | $\frac{3}{32}$        | $\frac{1}{16}$         | $\frac{1}{8}$           | $\frac{1}{8}$          | $\frac{1}{32}$                                                                 | ...                                            | ...                                                                                           | ...                                                                                                             | ...                 |
|                                                         | Over 7 to 14, incl         | $\frac{1}{8}$         | $\frac{3}{32}$         | $\frac{1}{8}$           | $\frac{1}{32}$         | $\frac{1}{32}$                                                                 | ...                                            | ...                                                                                           | ...                                                                                                             | ...                 |
|                                                         | Over 14                    | $\frac{3}{16}$        | $\frac{1}{8}$          | $\frac{1}{8}$           | $\frac{3}{16}$         | $\frac{1}{32}$                                                                 | ...                                            | ...                                                                                           | ...                                                                                                             | ...                 |

<sup>A</sup> *T* + *T'* applies when flanges of channels are toed in or out. For channels  $\frac{1}{8}$  in. and under in depth, the permitted out-of-square is  $\frac{3}{16}$  in./in. of depth.

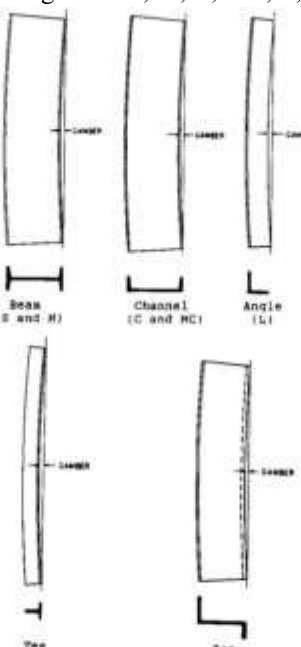
<sup>B</sup> Permitted variation is per inch of flange width for S, M, C, and MC shapes.

<sup>C</sup> Permitted variation of  $\frac{1}{16}$  in. max for sections over 426 lb/ft.

Notes—Reprinted, with permission, from ASTM A6/A6M-14 Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM, [www.astm.org](http://www.astm.org).

Table 2.1.1.3-2—Permitted Variations in Straightness W and HP Shapes <sup>(4)</sup>


| Positions for Measuring Camber and Sweep of W and HP Shapes                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                                       | Permitted Variation in Straightness, in.                                                                                                                                                                                                                    |
| Camber and sweep<br>When certain sections <sup>a</sup> with a flange width approximately equal to depth are specified in the order for use as columns:<br>Lengths of 45 ft and under<br>Lengths over 45 ft                                                                                                            | $\frac{1}{8} \times (\text{number of feet of total length}/10)^A$<br><br>$\frac{1}{8} \times (\text{number of feet of total length}/10)$ but not over $\frac{3}{8}$<br>$\frac{3}{8} + [\frac{1}{8} \times (\text{number of feet of total length} - 45)/10]$ |
| <sup>a</sup> Sections with a flange width less than 6 in., permitted variation for sweep, in. = $\frac{1}{8} \times (\text{number of feet of total length}/5)$ .                                                                                                                                                      |                                                                                                                                                                                                                                                             |
| <sup>b</sup> Applies only to:<br>8-in. deep sections 31 lb/ft and heavier,<br>10-in. deep sections 49 lb/ft and heavier,<br>12-in. deep sections 65 lb/ft and heavier,<br>14-in. deep sections 90 lb/ft and heavier,<br>16-in. deep sections 88 lb/ft and heavier, and<br>18-in. deep sections 135 lb/ft and heavier. |                                                                                                                                                                                                                                                             |
| For other sections specified in the order for use as columns, the permitted variation is subject to negotiation with the manufacturer.                                                                                                                                                                                |                                                                                                                                                                                                                                                             |

Table 2.1.1.3-3—Permitted Variations in Straightness S, M, C, MC, L, T, Z, and Bulb Angle Shapes <sup>(4)</sup>


| Positions for Measuring Camber of Shapes |                                   |                                                                                                                                                                                                           |
|------------------------------------------|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Variable                                 | Nominal Size, <sup>a</sup><br>in. | Permitted Variation, in.                                                                                                                                                                                  |
| Camber                                   | Under 3                           | $\frac{1}{8}$ in. in any 5 ft, or $\frac{1}{8} \times (\text{number of feet of total length}/5)$                                                                                                          |
|                                          | 3 and over                        | $\frac{1}{8} \times (\text{number of feet of total length}/5)$                                                                                                                                            |
| Sweep                                    | All                               | Due to the extreme variations in flexibility of these shapes, permitted variations for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved. |

<sup>a</sup> Greatest cross-sectional dimension.

Notes—Tables 2.1.1.3-2 and 2.1.1.3-3 were reprinted, with permission, from ASTM A6/A6M-14 Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM, [www.astm.org](http://www.astm.org).

The deposition of weld metal (see Section 9.5) following the removal of imperfections on the top or bottom surface of plates by chipping, grinding, or arc-air gouging shall be subject to the following limiting conditions:

- The chipped, ground, or gouged area shall not exceed 2 percent of the area of the surface being conditioned.
- After removal of any imperfections preparatory to welding, the thickness of the plate at any location shall not be reduced by more than 30 percent of the nominal thickness of the plate. (ASTM A131/A131M restricts the reduction in thickness to 20 percent maximum.)
- The deposition of weld metal (see Section 9.5) following the removal of injurious imperfections on the edges of plates by grinding, chipping, or arc-air gouging by the manufacturer or processor shall be subject to the limitation that, prior to welding, the depth of the depression, measured from the plate edge inward, is not more than the thickness of the plate or 1 in., whichever is less.

**Structural Shapes and Steel Sheet Piling Conditioning**—The grinding, or chipping and grinding, of structural size shapes, bar size shapes, and sheet piling by the manufacturer or processor to remove imperfections shall be subject to the limitations that the area ground is well faired without abrupt changes in contour and the depression does not extend below the rolled surface by more than (1)  $\frac{1}{32}$  in., for material less than  $\frac{3}{8}$  in. in thickness; (2)  $\frac{1}{16}$  in., for material  $\frac{3}{8}$  to 2 in. inclusive in thickness; or (3)  $\frac{1}{8}$  in., for material over 2 in. in thickness.

The deposition of weld metal (see Section 9.5) following removal of imperfections that are greater in depth than the limits listed above shall be subject to the following limiting conditions:

- The total area of the chipped or ground surface of any piece prior to welding shall not exceed 2 percent of the total surface area of that piece.
- The reduction of thickness of the material resulting from removal of imperfections prior to welding shall not exceed 30 percent of the nominal thickness at the location of the imperfection, nor shall the depth of depression prior to welding exceed  $1\frac{1}{4}$  in. in any case except as noted in Section 9.3.2.3.
- The deposition of weld metal (see Section 9.5) following grinding, chipping, or arc-air gouging of the toes of angles, beams, channels, and zees and the stems and toes of tees shall be subject to the limitation that, prior to welding, the depth of the depression, measured from the toe inward, is not more than the thickness of the material at the base of the depression or  $\frac{1}{2}$  in., whichever is less.
- The deposition of weld metal (see Section 9.5) and grinding to correct or build up the interlock of any sheet piling section at any location shall be subject to the limitation that the total surface area of the weld not exceed 2 percent of the total surface area of the piece.

#### 2.1.1.4—Welding

Most of the ASTM-specification construction steels can be welded without special precautions or procedures. The weld electrode should have properties matching those of the base metal. When properties are comparable, the deposited weld metal is referred to as “matching” weld metal. Table 2.1.1.4-1 provides matching weld metal for many of the common ASTM-designated structural steels. In general, welding of unidentified structural steel is not recommended unless weldability is determined.

Most of the readily available structural steels are suitable for welding. Welding procedures can be based on specified steel chemistry because most mill lots are usually below the maximum specified limits. Table 2.1.1.4-2 shows the ideal chemistry for carbon steels.

Guidance with respect to workmanship, qualification, and inspection of weldable steel can be obtained from the *Structural Welding Code—Steel, ANSI/AWS D1.1M:2010*<sup>(5)</sup>. Acceptable and unacceptable fillet weld profiles prescribed by D1.1/D1.1M are illustrated in Figures 2.1.1.4-1(a) and (b) and Tables 2.1.1.4-3 and 2.1.1.4-4.

Table 2.1.1.4-1—Matching Filler Metal Requirements <sup>(5)</sup>

| Group | Base Metal Steel Specification <sup>c</sup>                                       | Welding Process <sup>ab</sup>       |                                    |                               |                                                       |
|-------|-----------------------------------------------------------------------------------|-------------------------------------|------------------------------------|-------------------------------|-------------------------------------------------------|
|       |                                                                                   | Shielded Metal Arc Welding (SMAW)   | Submerged Arc Welding (SAW)        | Gas Metal Arc Welding (GMAW)  | Flux Cored Arc Welding (FCAW)                         |
| I     | ASTM A36, A53 Grade B, A500, A501, A529, A570 Grades 40, 45, and 50 A709 Grade 36 | AWS A5.1 or A5.5 E60XX or E70XX     | AWS A5.17 or A5.23 F6X or F7X-EXXX | AWS A5.18 ER70S-X             | AWS A5.20 E5XT-X and E7XT-X (except -2, -3, -10, -GS) |
| II    | ASTM A242, <sup>d</sup> A572 Grades 42 and 50 A588 A709 Grades 50 and 50W         | AWS A5.1 or A5.5 E70XX <sup>e</sup> | AWS A5.17 or A5.23 F7X-Exxx        | AWS A5.18 ER70S-X             | AWS A5.20 E7XT-X (except -2, -3, -10, -GS)            |
| III   | ASTM A572 Grades 60 and 65                                                        | AWS A5.5 E80XX <sup>e</sup>         | AWS A5.23 F8X-EXXX <sup>f</sup>    | AWS A5.28 ER80S <sup>f</sup>  | AWS A5.29 E8XT <sup>f</sup>                           |
| IV    | ASTM A514 (over 2 1/2 in. thick) A709 Grades 100 and 100W (2 1/2 in. and under)   | AWS A505 E100XX <sup>e</sup>        | AWS 5.23 F8X-EXXX <sup>f</sup>     | AWS A5.28 ER100S <sup>f</sup> | AWS A5.29 E10XT <sup>f</sup>                          |
| V     | ASTM A514 (2 1/2 in. and under), A709 Grades 100 and 100W (2 1/2 in. and under)   | AWS A505 E110XX <sup>e</sup>        | AWS 5.23 F11X-EXXX <sup>f</sup>    | AWS A5.28 ER110S <sup>f</sup> | AWS A5.29 E11XT <sup>f</sup>                          |

Notes:

a. When welds are to be stress relieved, the deposited weld metal shall not exceed 0.05 percent vanadium.

b. See ANSI/AWS D1.1/D1.1M Section 4.20 for electroslag and electrogas weld metal requirements.

c. In joints involving base metals of two different groups, low-hydrogen filler metal electrodes applicable to the lower strength group metal may be used. The low-hydrogen processes shall be subject to the technique requirements applicable to the higher strength group.

d. Special welding materials and procedures may be required to match the notch toughness of base metal or for atmospheric corrosion and weathering characteristics.

e. Low hydrogen classifications only.

f. Deposited weld metal shall have a minimum impact strength of 20j ft-lb at 0°F when Charpy V-notch specimens are used. This requirement is applicable only to bridges.

g. *ANSI/AWS D1.1/D1.1M:2010, Structural Welding Code—Steel*, Table 3.1, reproduced with permission of the American Welding Society (AWS), Miami, Florida.Table 2.1.1.4-2—Preferred Analysis of Carbon Steel for Good Weldability <sup>(6)</sup>

| Element    | Normal Range (%) |
|------------|------------------|
| Carbon     | 0.06–0.25        |
| Manganese  | 0.35–0.80        |
| Silicon    | 0.10 max         |
| Sulfur     | 0.035 max        |
| Phosphorus | 0.030 max        |

Courtesy of the James F. Lincoln Arc Welding Foundation

Table 2.1.1.4-3—Weld Profile Schedule <sup>(5)</sup>

| Weld Type              | Joint Type              |                                      |                              |                                      |                     |                         |
|------------------------|-------------------------|--------------------------------------|------------------------------|--------------------------------------|---------------------|-------------------------|
|                        | Butt                    | Corner—Inside                        | Corner—Outside               | T-Joint                              | Lap                 | Butt with Shelf Bar     |
| Groove<br>(CJP or PJP) | See ANSI/AWS D1.1/D1.1M | See ANSI/AWS D1.1/D1.1M <sup>b</sup> | See ANSI/AWS D1.1/D1.1M      | See ANSI/AWS D1.1/D1.1M <sup>b</sup> | N/A                 | See ANSI/AWS D1.1/D1.1M |
|                        | Schedule A              | Schedule B                           | Schedule A                   | Schedule B                           | N/A                 | See Note C              |
| Fillet                 | N/A                     | Figure 2.1.1.4-1(a)                  | Figure 2.1.1.4-1(b)          | Figure 2.1.1.4-1(a)                  | Figure 2.1.1.4-1(a) | N/A                     |
|                        | N/A                     | Schedule C                           | Schedule C or D <sup>d</sup> | Schedule C                           | Schedule C          | N/A                     |

Notes:

a. Schedules A through D are given in Table 2.1.1.4-4.

b. For reinforcing fillet welds required by design, the profile restrictions apply to each weld, butt, and fillet, separately.

c. Welds made using shelf bars and welds between horizontal bars of unequal thickness are exempt from R and C limitations.

d. See Figure 2.1.1.4-1(b) for a description of where Schedule C and D apply.

e. *ANSI/AWS D1.1/D1.1M:2010, Structural Welding Code—Steel*, Table 5.9, reproduced with permission of the American Welding Society (AWS), Miami, Florida.Table 2.1.1.4-4—Weld Profile Tolerance <sup>(5)</sup>

| Schedule A ( $t$ = thickness of thicker plate joints for CJP; $t$ = throat size for PJP)                                          |           |                        |           |            |
|-----------------------------------------------------------------------------------------------------------------------------------|-----------|------------------------|-----------|------------|
| $t$                                                                                                                               | $R_{min}$ | $R_{max}$              |           |            |
| $\leq 1$ in.                                                                                                                      | 0         | $1/8$ in.              |           |            |
| $> 1$ in.                                                                                                                         | 0         | $3/16$ in.             |           |            |
| $\leq 2$ in.                                                                                                                      |           |                        |           |            |
| 2 in.                                                                                                                             | 0         | $1/4$ in. <sup>a</sup> |           |            |
| Schedule B ( $t$ = thickness of thicker plate jointed for CJP; $t$ = throat size for PJP; $C$ = allowable convexity or concavity) |           |                        |           |            |
| $t$                                                                                                                               | $R_{min}$ | $R_{max}$              | $C_{min}$ | $C_{max}$  |
| $< 1$ in.                                                                                                                         | 0         | Unlimited              | 0         | $1/8$ in.  |
| $\geq 1$ in.                                                                                                                      | 0         | Unlimited              | 0         | $3/16$ in. |
| Schedule C ( $W$ = width of weld face or individual surface bead; $C$ = allowable convexity)                                      |           |                        |           |            |
| $W$                                                                                                                               | $C_{min}$ | $C_{max}^b$            |           |            |
| $\leq 5/16$ in.                                                                                                                   | 0         | $1/16$ in.             |           |            |
| $> 5/16$ in.                                                                                                                      | 0         | $1/8$ in.              |           |            |
| $< 1$ in.                                                                                                                         |           |                        |           |            |
| $\geq 1$ in.                                                                                                                      | 0         | $3/16$ in.             |           |            |
| Schedule D ( $t$ = thickness of thinner of the exposed edge dimensions; see Figure 2.1.1.4-1 (b))                                 |           |                        |           |            |
| $t$                                                                                                                               | $C_{min}$ | $C_{max}$              |           |            |
| Any value of $t$                                                                                                                  | 0         | $t/2$                  |           |            |

Notes:

a. For cyclically loaded structures,  $R_{max}$ , for materials  $> 2$  in. thick is  $3/16$  in.b.  $C$  shall not exceed  $R$ .c. *ANSI/AWS D1.1/D1.1M:2010, Structural Welding Code—Steel*, Table 5.10, reproduced with permission of the American Welding Society (AWS), Miami, Florida.

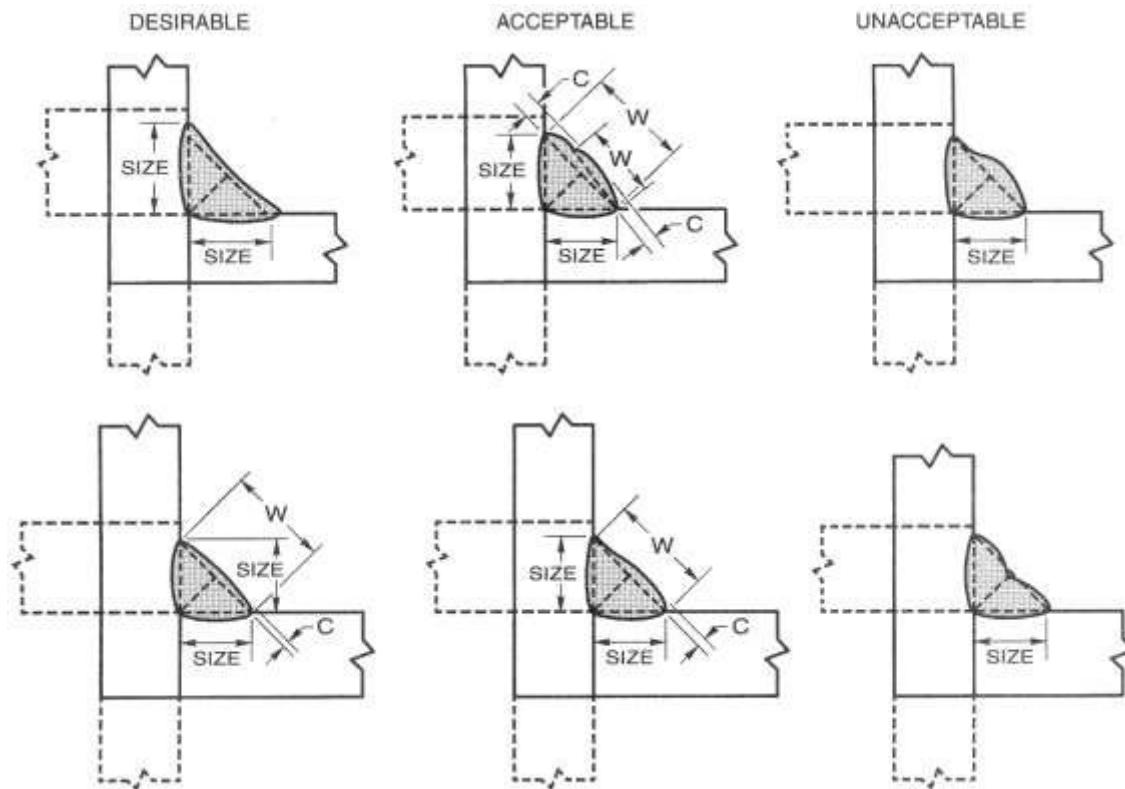
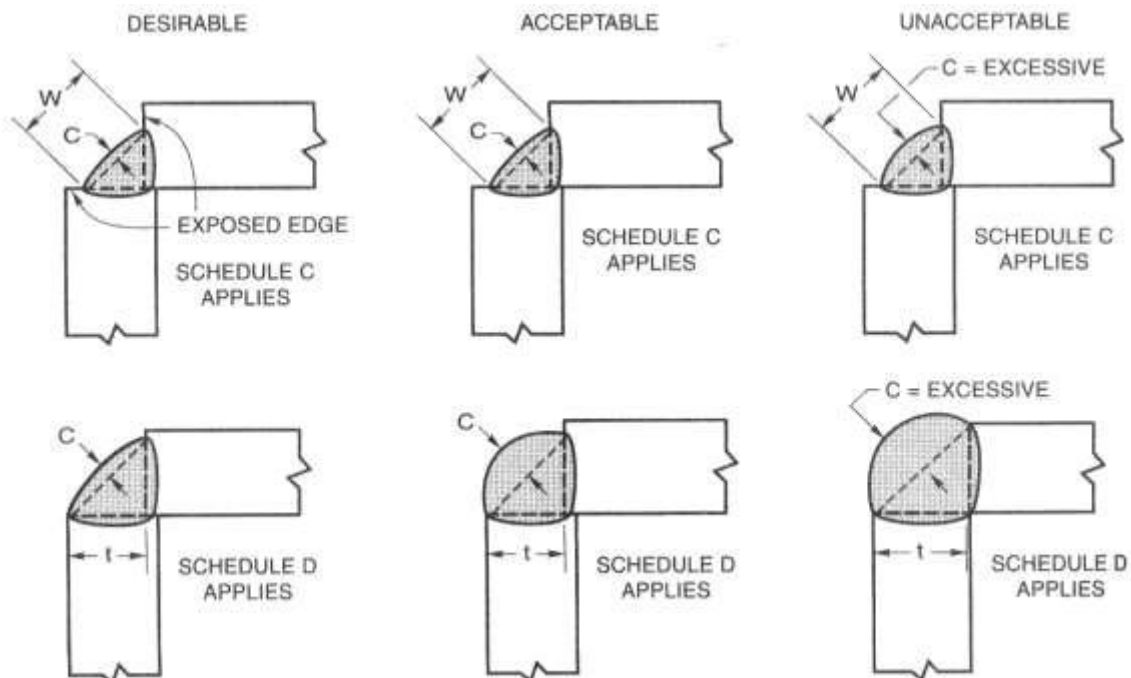
(a) Fillet Weld Profiles for Inside Corner Joints, Lap Joints and T-Joints <sup>(5)</sup>(b) Fillet Weld Profiles for Outside Corner Joints <sup>(5)</sup>

Figure 2.1.1.4-1—Fillet Weld Profiles

Note: *ANSI/AWS D1.1/D1.1M:2010, Structural Welding Code—Steel*, Figure 5.4E and Figure 5.4F, reproduced with permission of the American Welding Society (AWS), Miami, Florida.

### 2.1.2—Wood

**Wood Quality**—The design values for new lumber are obtained from grading rules published by several agencies, including National Lumber Grades Authority (a Canadian agency), Northeastern Lumber Manufacturers Association, Northern Softwood Lumber Bureau, Southern Pine Inspection Bureau, West Coast Lumber Inspection Bureau, and Western Wood Products Association. Design values for most species and grades of visually graded dimension lumber are based on the provisions of ASTM D1990. <sup>(7)</sup> Design values for visually graded wood, decking, and some species and grades of dimension lumber are based on the provisions of ASTM D245. <sup>(8)</sup>

The methods in ASTM D245 involve adjusting the strength properties of small clear specimens of wood, as given in ASTM D2555, <sup>(9)</sup> for the effects of knots, slope of grain, splits, checks, size, duration of load, moisture content, and other influencing factors, to obtain design values applicable to normal conditions of service. ASTM D245 describes the procedures for rating lumber on the basis of strength ratio. Strength ratio of a structural wood is the ratio of its strength to that which it would have if no weakening characteristics were present.

**Used Lumber**—Where the origin and grading of the material is no longer known, it should be regraded by a qualified agency or individual. Wood should be discarded if it has been painted such that it prevents assessment, if there is any sign of rot (fungal or chemical), if there is mechanical damage, or if there is any undue distortion of shape. Wood should never be reused without careful inspection.

**Wood Characteristics**—Because wood is an organic material, it is subject to variations in structure or properties or both. Some important characteristics of wood and their effects on the strength of wood members are as follows:

**Knots**—A knot is a portion of a branch or limb which has been surrounded by subsequent growth of the wood of the trunk. Knots reduce the strength of wood because they interrupt the continuity and direction of wood fibers. They also cause local stress concentrations where grain patterns are abruptly altered. The influence of a knot depends on its size, location, shape, soundness, and the type of stress considered. In general, knots have a greater effect in tension than in compression, whether stresses are applied axially or as a result of bending. Shapes of knots in various structural members and methods of measurement are illustrated in Figure 2.1.2-1.

**Slope of Grain**—Slope of grain or cross grain are terms used to describe the deviation in wood fiber orientation from the line parallel to the edge of the specimen. It is expressed as a ratio such as 1 in 6 or 1 in 14, and is measured over sufficient distance along the piece to be representative of the general slope of the wood fibers. Slope of grain has a significant effect on wood mechanical properties. Strength, for example, decreases as the grain deviation increases. Specimens with severe cross grain are also more susceptible to warp and other dimensional deformations due to changes in moisture content. The technique to measure slope of grain is illustrated in Figure 2.1.2-2.

**Checks and Splits**—Checks and splits are separations of the wood across or through the rings of annual growth, usually as a result of drying shrinkage during seasoning. Checks are partial depth fractures, while splits extend through the full cross section. If members are subject only to tension or compression, checks and splits do not greatly affect strength, unless they occur in zones of severe grain slope.

**Moisture Content**—Design values prescribed by the *National Design Specification for Wood Construction* (NDS) <sup>(10)</sup> are for normal load duration under dry conditions of service. Dry lumber is defined as lumber that has been seasoned to a moisture content of 19 percent or less by weight. Green lumber is defined as lumber having moisture content in excess of 19 percent. Because the strength of wood varies with the conditions under which it is used, these design values should only be applied in conjunction with appropriate design and service recommendations from the National Design Specification.

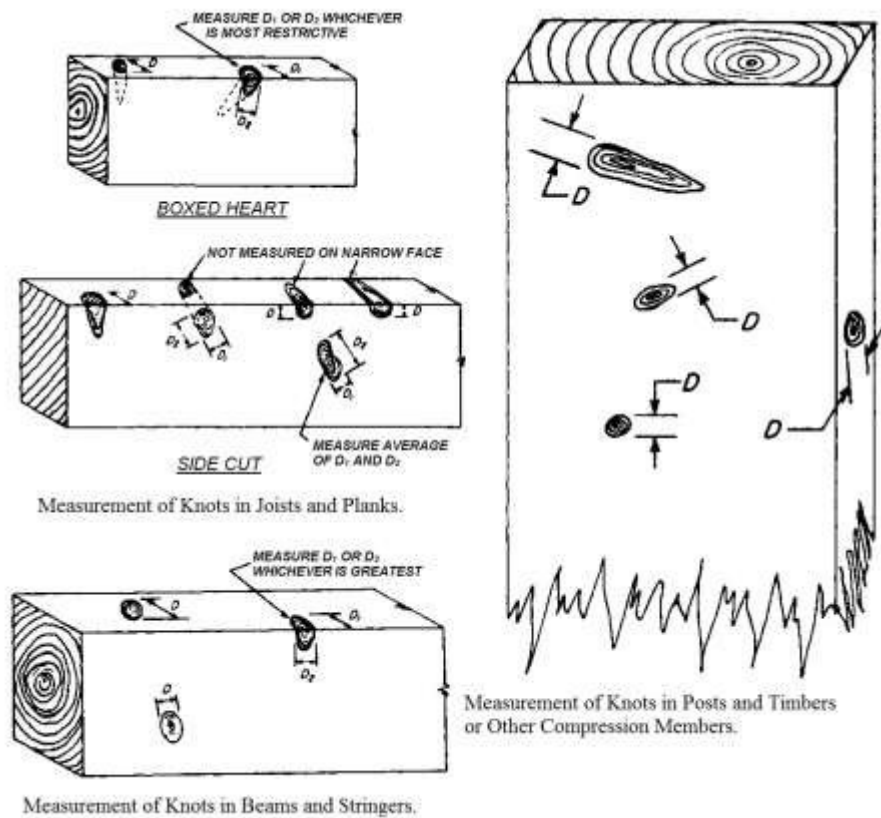


Figure 2.1.2-1—Shapes in Which Knots Appear in Various Structural Members and Methods of Measurement <sup>(11)</sup>

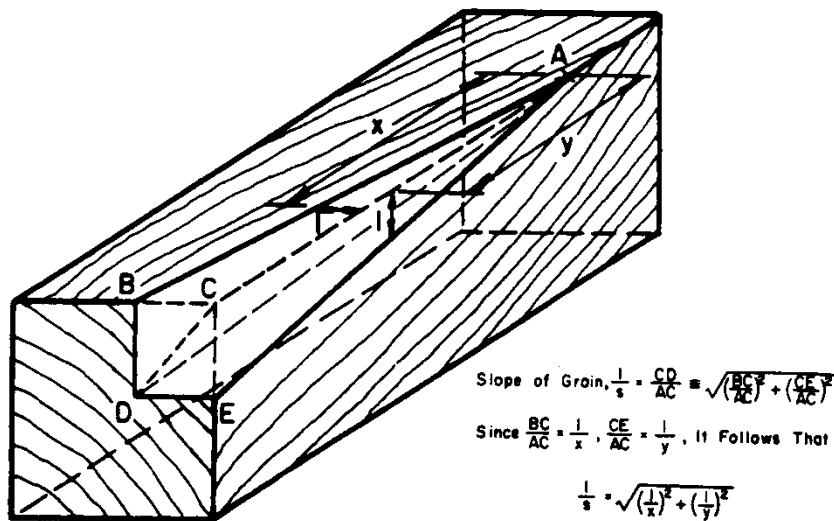


Figure 2.1.2-2—Determination of Combined Slope of Grain <sup>(11)</sup>

Note: Figures 2.1.2-1 and 2.1.2-2 were reproduced from *Wood Engineering*, Second Edition, with permission of the author, German Gurfinkel, PhD.

**Member Size**—Wood members should be generally assumed to be standard dressed (S4S) sawn lumber unless otherwise shown on the falsework drawings. Section properties of S4S lumber are furnished in Appendix A. While these sizes are generally available on a commercial basis, it is good practice to consult the local lumber dealer(s) to determine local availability.

Typically, the dimensions of rough-cut lumber will vary appreciably from nominal, particularly in the larger sizes commonly used in falsework construction. If the use of rough-cut material is required by the falsework design, the actual member size should be verified prior to use.

### 2.1.3—Manufactured Components

As defined in the *Guide Design Specifications for Bridge Temporary Works*, manufactured components include proprietary shoring systems and manufactured assemblies. The proprietary shoring systems consist of vertical and horizontal shoring. Cantilever overhang brackets, hangers, and circular friction collars are examples of manufactured assemblies commonly used in bridge construction.

**Vertical Shoring**—The vertical shoring systems can be divided into three general categories. The so-called “pipe-frame” systems consist of ladder or cross-braced welded frames with maximum allowable leg loads from 10,000 to 15,000 lb. When externally unbraced, pipe-frame assemblies are generally limited to 30 ft. heights. Intermediate frames are described as cross-braced welded frames with an allowable load-carrying capacity of up to 30,000 lb per leg. Heavy-duty shoring systems are defined as having allowable leg loads of greater than 30,000 lb. This terminology and the corresponding allowable leg loading can vary from one manufacturer to the next.

In the U.S., there are several manufacturers of proprietary shoring systems. However, no industry standards exist for the various components of these systems, and as a general rule, towers or components produced by different manufacturers should not be intermixed. Some other limitations or general characteristics of modular systems are as follows:

- Allowable leg capacities are generally reduced when the screw jacks, or extension legs, are fully extended.
- Multi-tiered towers stacked in excess of two frames high have lower allowable leg capacities than single- or double-tier towers.
- External bracing is generally recommended when the height to width ratio exceeds 4:1.
- The drift characteristics of proprietary systems can vary considerably, depending upon their bracing configurations. Ladder frames exhibit the least lateral stiffness, and very little benefit is derived from the horizontal braces. The buckling mode of ladder-type and cross-braced frames are illustrated in Figure 2.1.3-1.

**Horizontal Shoring**—The term “horizontal shoring” can describe a variety of adjustable or fixed length beams or trusses used as load-carrying members in falsework systems. Unlike vertical shoring systems, where the prescribed factor of safety is 2.5, horizontal shoring beams are specified to have a safety factor of 2.0. General safety rules for the use of horizontal shoring are prescribed by the Scaffolding, Shoring, and Forming Institute (SSFI) and are commonly found in manufacturer’s literature. <sup>(12)</sup>

An application of horizontal shoring is shown in Figure 2.1.3-2. For this particular bridge structure, temporary wood pile bents were constructed between the permanent bridge piers and abutments. Horizontal shoring beams spanned half the normal bridge spans and supported the formwork.

**Cantilever Overhang Brackets**—Adjustable, proprietary overhang brackets are common in bridge construction due to their adaptability to various bridge dimensions. In general, the longer the vertical leg, the farther apart the brackets can be spaced. In cases where a bridge deck finishing machine is supported at the outer edge of a cantilevered deck overhang, however, particular care must be taken to prevent excessive deflection of the overhang bracket and excessive lateral load on the bridge stringer web. For design purposes, load–deflection curves or tables are generally produced by the manufacturer. An example of this data is shown in Figure 2.1.3-3.

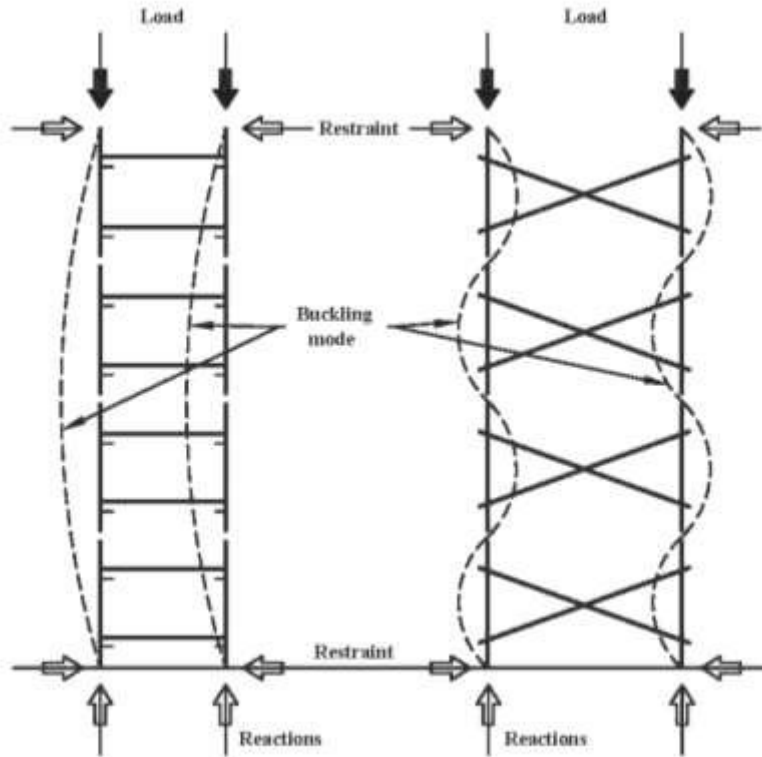


Figure 2.1.3-1—Frame and Braced Tower Buckling Modes

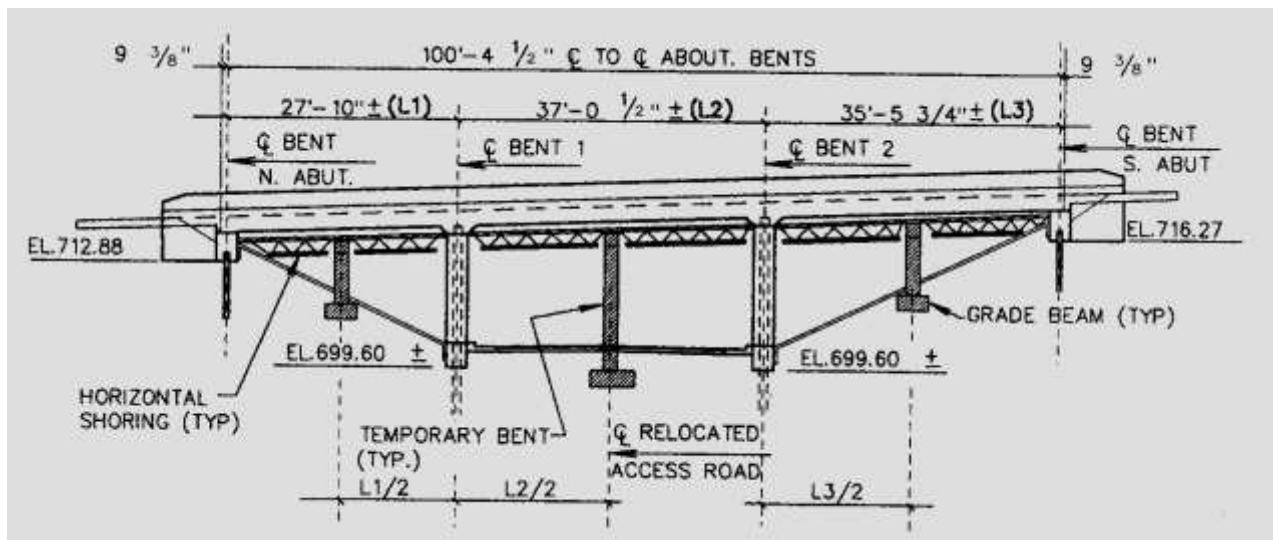


Figure 2.1.3-2—Adjustable Horizontal Shoring Beams Spanning between Bridge Piers and Temporary Wood Bents

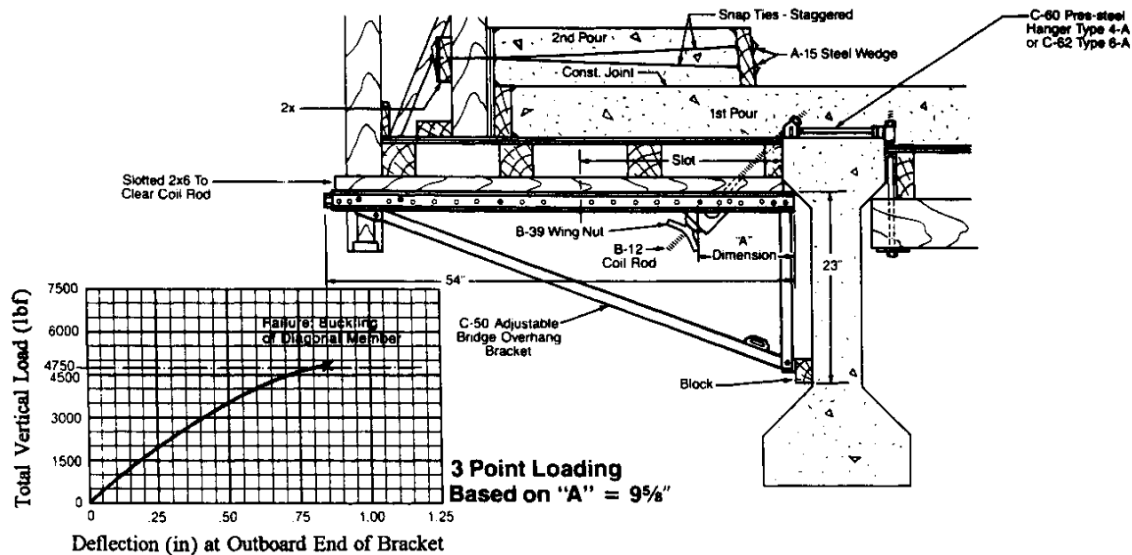


Figure 2.1.3-3—Adjustable Overhang Bracket for Precast Concrete Stringer <sup>(13)</sup>

## 2.2—FOUNDATIONS

Foundations for falsework are generally temporary in nature. Depending upon the site conditions, foundation support is most easily provided by simple spread footings unless deep foundations are required. The objective of this section is to familiarize the field engineer with available methods of onsite testing. Field monitoring should also include all site features likely to influence foundation behavior.

### 2.2.1—Shallow Foundations

Falsework foundations are designed to limit the stress levels in the soil to provide an adequate factor of safety against bearing capacity failure and to limit settlement. The design soil pressures may be selected on the basis of measured or assumed properties of the foundation soils that were determined from a site investigation. The construction engineer should familiarize himself with the site investigation data and assumptions used in the design of the foundations to confirm that the site soil and design assumptions are consistent with the conditions in the field.

In many instances, there will be no doubt as to the adequacy and uniformity of the soil or rock supporting the falsework to receive the applied loads safely. In cases of variable strata, or where any doubt exists concerning the adequacy of the soil or rock or the general stability of the site, additional investigation involving in situ tests, test pits, proof-rolling, and/or load tests should be undertaken to obtain sufficient information to ensure the safety of the foundations of the falsework.

**In Situ Testing**—In situ tests can provide sufficient information for confirmation of foundation design. In homogeneous cohesive soils without fissures or inclusions, a hand penetrometer can be used to estimate the unconfined compressive strength of the deposit. Tests should be made at various locations within the bearing area and compared to the results of the previous site investigation and/or the designer's assumed value of unconfined compressive strength. In granular soils, field verification of soil strength and compressibility is more difficult. Simple tests include a dynamic cone penetration test where the number of blows to advance a rod with a cone at the tip are recorded. The number of blows are a rough indicator of relative density. Field density tests (AASHTO T 191) <sup>(14)</sup> can also be performed to determine the unit weight of the soil from which an estimate of relative density can also be obtained. The measured unit weight can be compared with published information on maximum or minimum unit weights for various soil types. Alternatively, the maximum and minimum unit weights can be determined by performing laboratory tests AASHTO T 180 <sup>(15)</sup> for maximum unit weight and ASTM D4252 <sup>(16)</sup> for minimum unit weight and calculation of relative density.

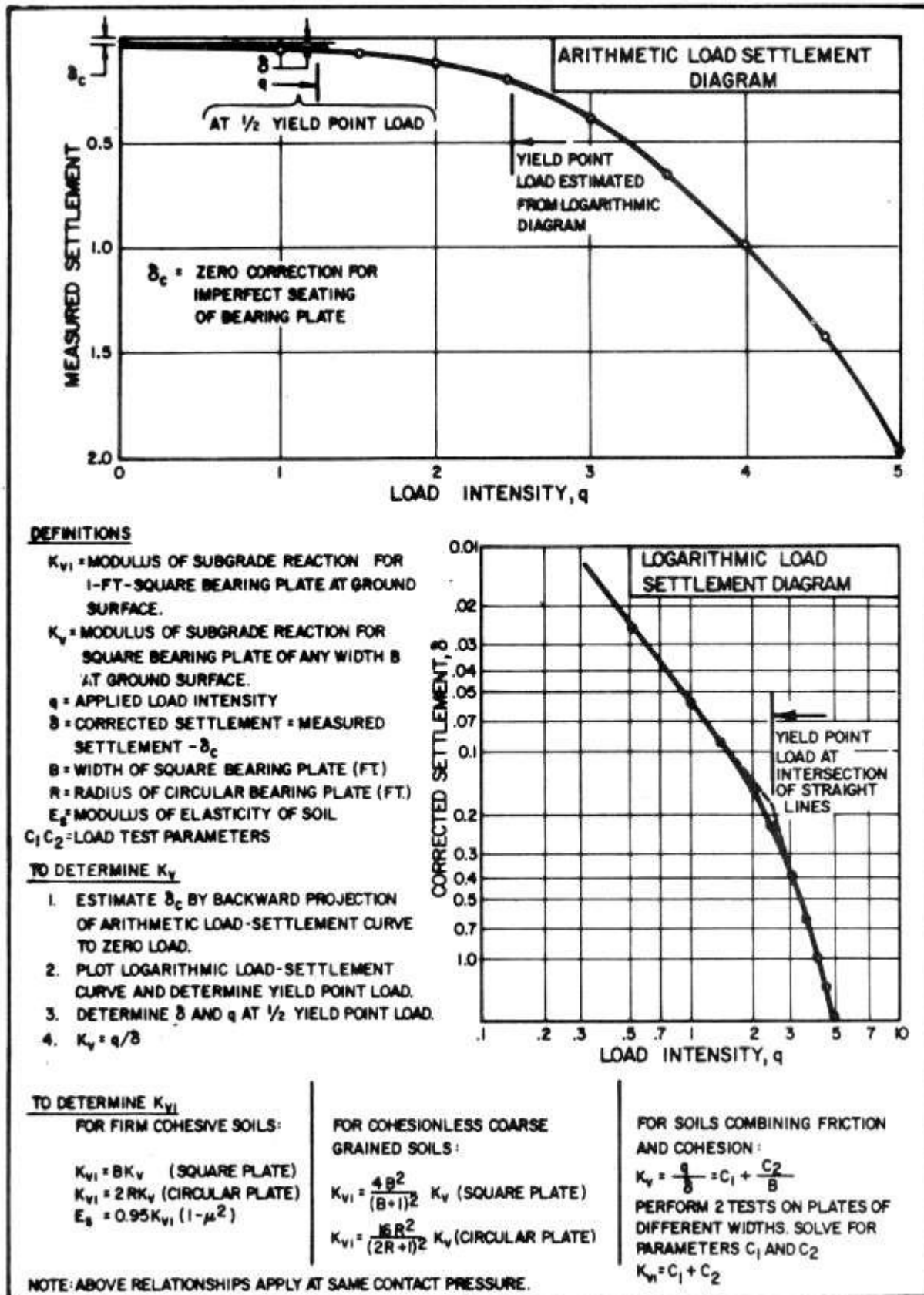
A better procedure for determining the suitability of granular and mixed soil deposits to support the footings is to perform pressuremeter testing (ASTM D4719) <sup>(17)</sup> or dilatometer testing in shallow hand auger holes extended below bearing level.

**Test Pits**—Test pits can be dug throughout the area to investigate the various soil or rock formations. Test pits should be used to supplement other field monitoring wherever erratic or discontinuous subsurface conditions are present.

Determining the thickness and character of these deposits from a large excavation is more accurate than from examination of smaller diameter samples from borings. Block samples can also be obtained for laboratory testing.

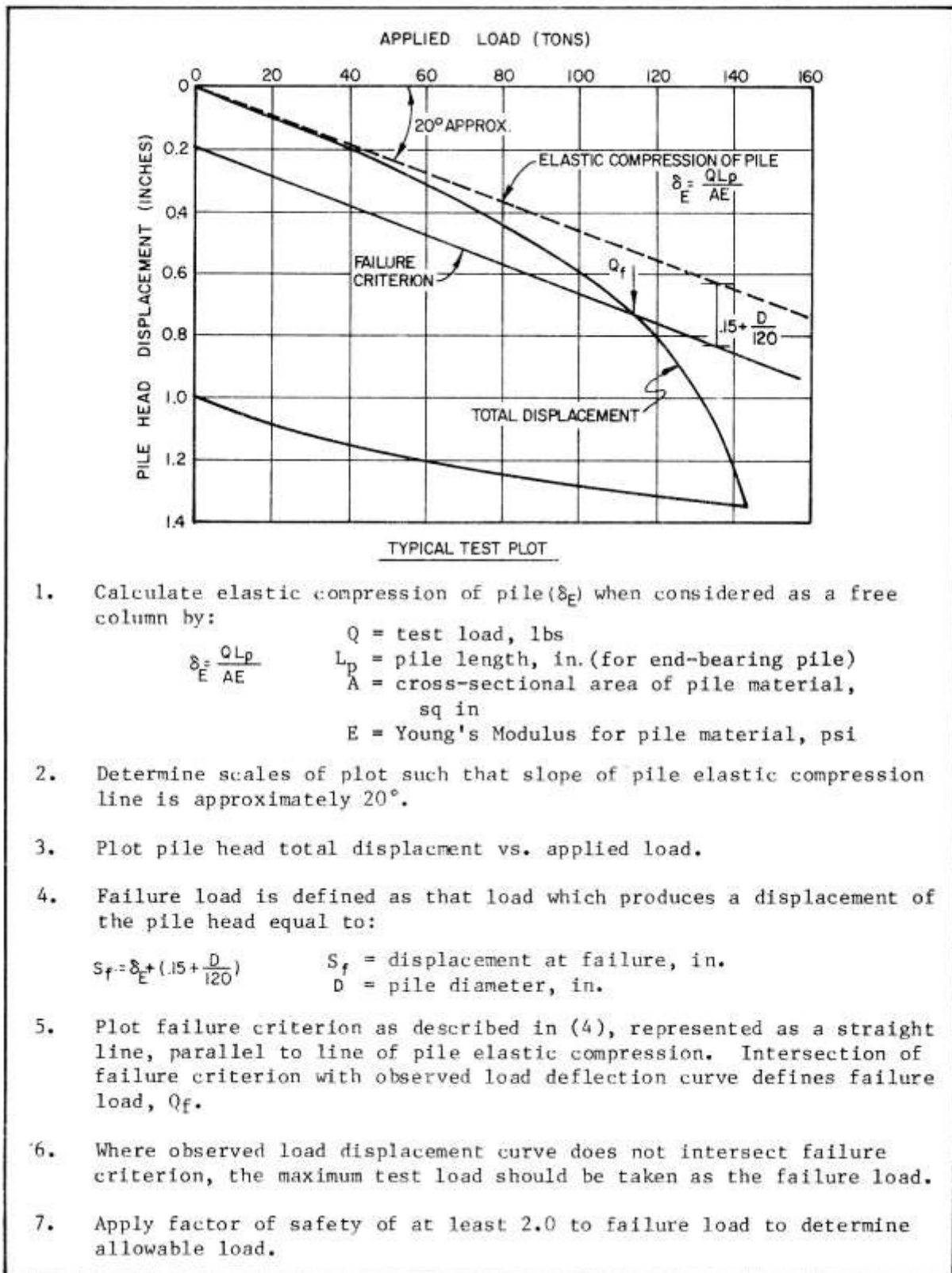
**Proof-Rolling**—Proof-rolling is a field observation test that can be used to indicate if and where problem soils are located at shallow distances below grade. The procedure consists of making multiple passes over the area with a fully loaded dump truck having a minimum weight of 20 tons. As the dump truck traverses the area, the amount of ground deflection under loading shall be observed. Deflections of 2 in. or less are indications of reasonably good support conditions. Large deflections and severe rutting are indicative of very poor support conditions. The depth of influence of proof-rolling is likely to be on the order of 2 to 5 ft. Any weak soil below this depth will remain undetected.

**Load Testing**—The procedures for performing plate bearing tests are described in ASTM D1194.<sup>(18)</sup> The plate load test consists of a loading plate with a minimum 12-in. diameter with a jack to provide a force, with a truck or other heavy object used as a reaction. Deflections are measured with either survey instruments or dial gauges. As the jack loads are applied, deflection readings should be taken to the design load and at twice the design load. The test results are analyzed in accordance with Figure 2.2.1-1. The depth of influence of a plate load test is only about 1.5 times the diameter of the plate. Thus, larger foundations that stress the soil to greater depths may perform differently than the plate load test would indicate.

Figure 2.2.1-1—Analysis of Plate Bearing Tests<sup>(20)</sup>

### 2.2.2 – Deep Foundations

If piles are driven to support the falsework, the driving resistance of each pile should be recorded and compared to the required driving resistance that has been developed for the project, using either a wave equation analysis or acceptable driving formula. Plumbness, length of pile installed, type of hammer and cushion, surface alignment of the driven pile, and any other observations that could affect pile performance should also be recorded. This data should be given to the designer for review. If a load test is required, it should be performed in accordance with ASTM D1143/D1143M.<sup>(19)</sup> The procedure to calculate the failure load test is identified in Figures 2.2.2-1 and 2.2.2-2.

Figure 2.2.2-1—Interpretation of Pile Load Test<sup>(21)</sup>

- $$Q_{P'} = \frac{3AE\delta_E}{2l} - \frac{Q_A}{2}$$

Full document details: AASHTO CHTBW-2-2017

### 2.2.3—Protection of the Foundation

Falsework foundations, in general, are set at a very shallow depth compared with those of permanent structures. This places them within the zone affected by seasonal moisture content changes, frost action, scour, and so forth. The area covered by the foundations under the falsework should be considered in relation to the general topography of the surrounding ground and the likelihood of outside influences affecting it. Steps should be taken to safeguard it and avoid undermining conditions such as shown in Figure 2.2.3-1. The stability of the ground under and around the falsework foundations will depend on the ground remaining unaffected by local influences of water from extreme rainfall, melting snow, or burst water mains; severe frosts or excessively dry and hot weather; movements of surrounding ground subjected to excavation, filling, or other changes; and all pressures applied by adjacent construction operations.



Figure 2.2.3-1—Washout under Sill Support

**Falsework in Streams**—Where supports (usually consisting of piles or pier) are installed in rivers or streams, they should be designed to withstand the horizontal loads arising from flood conditions applied to an area of resistance substantially greater than that offered by the supports alone. This increase should account for the accumulation of river debris. To minimize this accumulation and avoid the impact of larger pieces, measures should be specified and installed upstream to divert such debris from the supports or to retain it independently. The measures adopted will depend on the circumstances. The use of fenders, floating booms, and cutwaters should be considered for this purpose.

Scour is likely to occur in areas of increased stream velocity. It is likely to affect the bed of the waterway around and under the falsework and any banks, channels, or other existing features of the waterway. Protection should be provided where such scouring forces are likely to occur.

**Foundations on Sloping Ground**—The stability of foundations on sloping ground should be examined by a qualified engineer specializing in soil mechanics. For rock slopes, special attention should be given to the geometry of bedding, cleavage planes, or joint planes that might provide a sliding surface for block failure. In many sandstone, siltstone, and mudstone formations, it is not possible to predict the shear strength at bedding planes. Here, it is necessary to ensure that the bedding does not intersect the slope in a manner that would permit blocks to move out of face.

Where the requirements are such that the foundation members need to be set other than level, appropriately shaped packs should be used at the base of the vertical member. The foundation member should be effectively prevented from moving down the slope as shown in Figure 2.2.3-2.



Figure 2.2.3-2—Sole plate and Bracing Details for Falsework Supported on a Sloped Surface

*Note: Figure is courtesy of Scaffolding, Shoring, and Forming Institute*

**Fill Material**—Where falsework is to be supported on fill of unknown origin or quality, the fill should be investigated. Fill may have abrupt variations in composition, compaction, and strength. Where falsework is supported on a compacted fill whose properties have been determined, it is important to ensure that both the fill and the underlying ground are protected, so that no disturbance or loss of material results from the movement of water or environmental changes. In cases where the fill material is variable in consistency, and unable to receive and transmit loads uniformly, a minimum depth of 18 in. of the fill should be removed and replaced by well-compacted and stabilized granular material of known bearing capacity.

**Heavy Vibrations**—Deposits or layers of granular materials, if not fully compacted, are susceptible to consolidation and settlement if subjected to vibrations either from the falsework above, from adjacent operations (for example, piling), or the passage of heavy traffic. This condition is not accounted for by modification factors applied to the presumed bearing pressures. Either the granular materials should be compacted, or the sources of vibration stopped during critical stages of construction. Some uniformly graded sands and silts may also be adversely affected by vibration from the compaction of concrete above the falsework.

## 2.3—CONSTRUCTION

### 2.3.1—General

In falsework construction, overall stability is a function of both internal (local) and external (global) conditions. Internally, falsework can be subject to a wide variety of local horizontal forces produced by out-of-plumb members, superelevation, differential settlement, and so forth. Therefore, it is necessary for the falsework assembly to be adequately connected to resist these forces. Although friction often provides means of load transfer, so-called “positive connections” eliminate, or at least reduce, the probability of underestimating the necessary restraint. The need for positive load transfer is particularly apparent when superelevation exists or the soffit is inclined.

Wood cross-bracing between adjacent steel beams, shown in Figure 2.3.1-1, is commonly used for flange support in falsework construction. In this method, wood struts are set diagonally in pairs between the top flange of one beam and the bottom flange of the adjacent beam, and securely wedged into place. However, wood cross-bracing alone will

not prevent flange buckling because the wood struts resist only compression forces. A more effective flange support method uses steel tension ties welded, clamped, or otherwise secured across the top and bottom of adjacent beams in combination with wood cross-bracing between the beams.



Figure 2.3.1-1—Wood Cross-Bracing Between Longitudinal Stringers

Uplift can occur when falsework beams are continuous over a long span, coupled with a relatively short adjacent span. Two common examples of this condition are longitudinal beams with short end spans and a transverse beam with a relatively long overhang. In the longitudinal example, uplift can occur at the end support. For the latter case, shown in Figure 2.3.1-2, uplift can occur at the first interior post (support). Both of these conditions can contribute to instability and, therefore, should be avoided. If uplift cannot be prevented by loading the short span first, the end of the beam must be tied down or the span lengths changed.

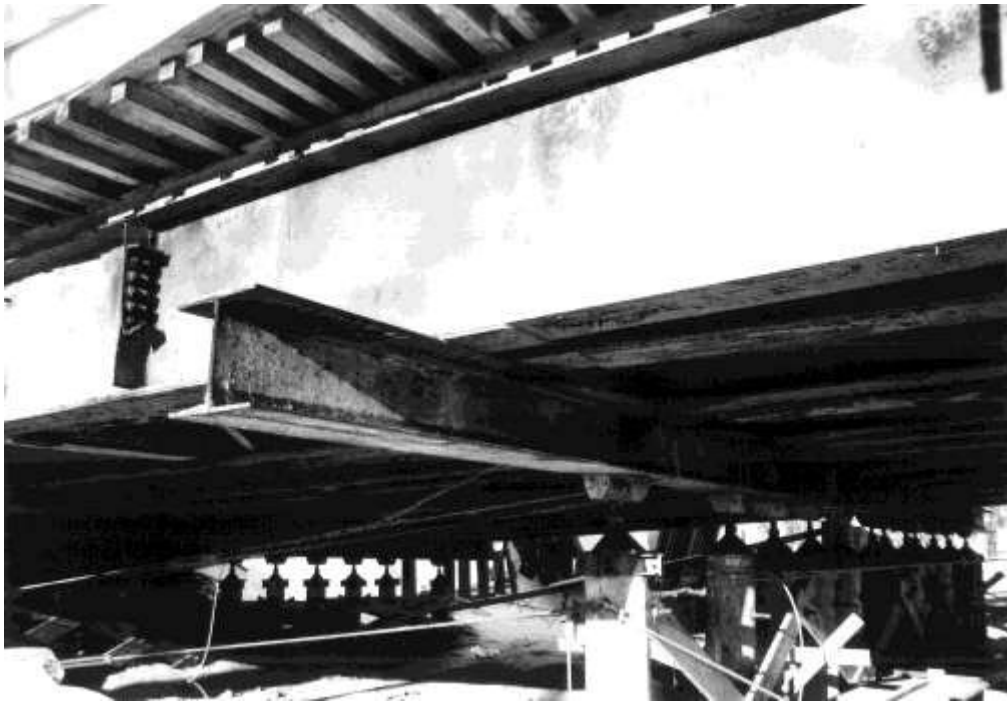


Figure 2.3.1-2—Cantilevered Ledger Beam at Temporary Pile Bent

In order to ensure longitudinal stability, it is necessary to provide a system of restraint to prevent the falsework bents from overturning when the horizontal design load is applied in the longitudinal direction. This type of restraint can be furnished by diagonal bracing between pairs of adjacent bents, or by direct transfer of horizontal load into the permanent piers.

### 2.3.2—Wood Construction

**Lateral Support of Wood Beams**—Deep, narrow beams may fail by buckling before the allowable bending stress is reached if they are not laterally restrained. The amount of restraint needed to ensure beam stability is a function of the depth-to-width ratio.

Section 4.4.1 of the NDS <sup>(10)</sup> provides approximate guidelines regarding the lateral restraint of rectangular sawn lumber beams. These guidelines, modified to reflect the temporary nature of falsework construction, are as follows:

- If the nominal depth-to-width ratio of a wood beam is 2:1 or less, no lateral support is required
- If the nominal depth-to-width ratio exceeds 2:1, but is not more than 4:1, the ends of the member shall be held in position as by full depth solid blocking, bridging, hangers, nailing, or bolting to other framing members, or other acceptable means.
- If the ratio exceeds 4:1, but is not more than 5:1, the compression edge shall be held in line for its entire length to prevent lateral displacement as by adequate sheathing or subflooring in addition to the requirement stated above.
- If the ratio exceeds 5:1, but is not more than 6:1, full depth solid blocking or diagonal cross bracing shall be installed at intervals not exceeding 8 feet in addition to the requirements stated above.
- If the ratio exceeds 6:1, but is not more than 7:1, both edges of the member shall be held in line for their entire length and ends at points of bearing shall be held in position to prevent rotation and/or lateral displacement.
- If a bending member is subjected to both flexure and axial compression, the depth-to-breadth ratio shall not exceed 5:1 if one edge is firmly held in line.

**Nail Spacing**—The NDS guidelines for spacing between nails or spikes in a wood connection are very subjective. The requirement is that the spacing be sufficient “to avoid unusual splitting of the wood.” In recent years, there has been a trend toward the use of a greater number of nails in wood construction than would appear warranted by prudent design considerations. In view of this, the California Department of Transportation (Caltrans) has established the following guidelines to govern the spacing of nails and spikes in wood connections. <sup>(22)</sup>

- The average center-to-center distance between adjacent nails, measured in any direction, shall not be less than the required penetration into the main member for the size of nail being used.
- The minimum end distance in the side member and the minimum edge distance in both the side member and the main member shall not be less than one half of the required penetration.

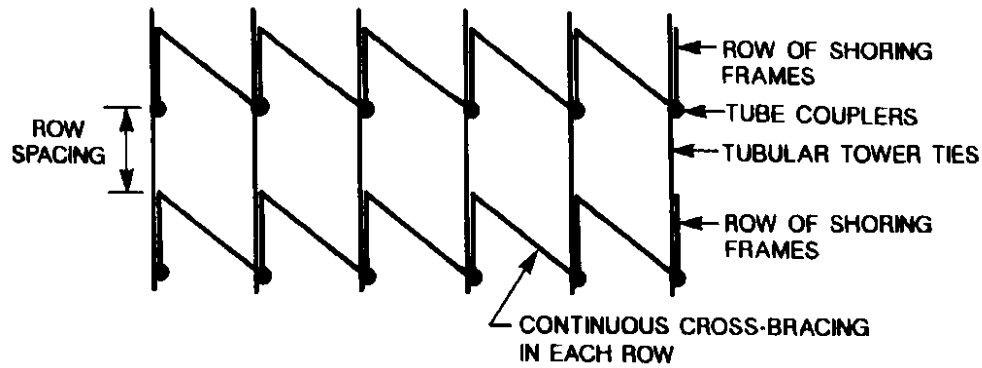
Toe-nailing has little or no reliable structural connection value and should not be relied on for any construction load capacity. By splintering areas needed for bearing, toe-nailing often does more harm than good.

### 2.3.3—Vertical Shoring Systems

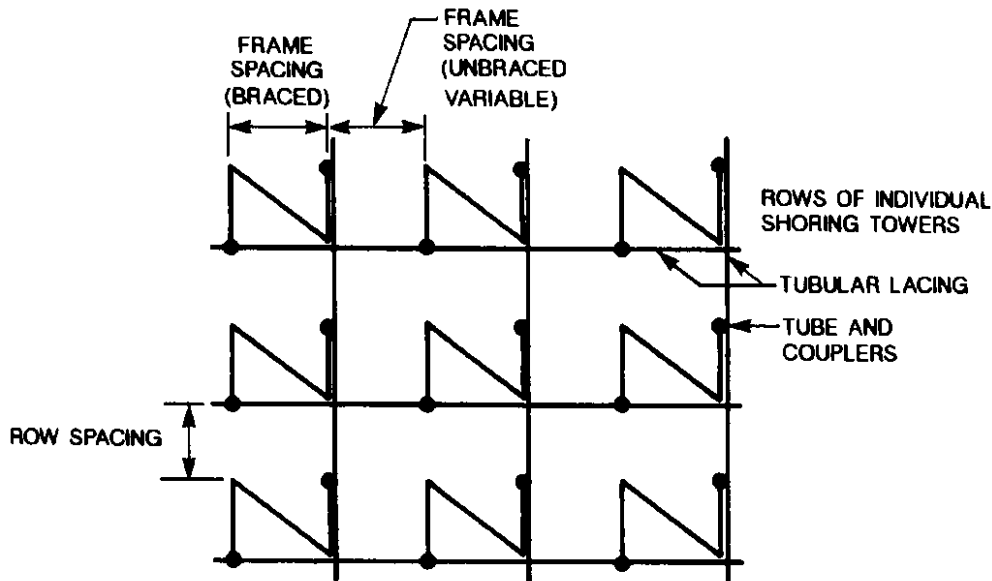
The following is a general discussion of vertical shoring systems that addresses their general characteristics and utilization. Discussion of specific products has been avoided. It is recommended that the reader refer to the manufacturer's literature as it relates to specific applications. As noted earlier, there are several manufacturers of proprietary shoring systems in the United States, but no uniform industry standards exist for these products.

**Erection Tolerances**—Most available guidelines, such as those produced by SSFI, simply recommend that vertical shoring be erected “plumb.” A maximum allowable deviation from vertical equal to  $\frac{1}{8}$  in. in 3 ft, but not greater than the radius or least dimension of the vertical member, is a recurring tolerance found in some literature. However, the source of this quantity is not well-documented. For reference, the AISC Code for Standard Practice prescribes that the deviation of the working line from a plumb line does not exceed 1:500 for individual columns. <sup>(23)</sup> Similarly, the Precast/Prestressed Concrete Institute recommends an out-of-plumb tolerance of 1:480. <sup>(24)</sup>

**Bracing**—As a general rule, manufacturers of modular frames recommend external bracing when the height exceeds four times the least base dimension. Therefore, it is common practice to connect rows of towers to each other with tube and coupler horizontal lacing members or, where practical, with additional cross bracing, so that rows of frames are continuously cross-braced in one plane. Braces should be connected as near as possible to nodes and, where continuous diagonal bracing tubes are used, connections at the node points of intermittent node points are recommended. Examples of plan bracing are shown in Figure 2.3.3-1.



(a) Lacing of Shoring Tower Rows in One Direction, Continuous Cross Bracing in Other Direction



(b) Shoring Tower Laced in Both Directions

Figure 2.3.3-1—Examples of Plan Bracing of Modular Frames <sup>(25)</sup>

In general, plan bracing should be provided at the top lifts (tiers) and at least every third intermediate lift. The plan bracing at the top tier may be omitted when the grillage used to support the permanent structure is capable of acting as a diaphragm. When shoring a sloped surface, the tube bracing illustrated in Figure 2.3.3-2 is recommended.



Figure 2.3.3-2—Bracing Detail for Screw Leg Supporting a Sloped Soffit

**Screw-leg Extensions**—Leg load capacity for modular frames generally decreases as the screw-leg extensions increase. Eccentric loads on screw (extension) heads should also be avoided. Variations between various proprietary systems preclude generalizations regarding the extent of load reduction for screw-leg extension. However, extensions at the top and bottom of a frame totaling 12 in. generally do not significantly affect the allowable leg capacity.

#### 2.3.4—Cable Bracing

Bracing systems consisting of securely anchored cable guys are widely used to resist overturning of falsework. In particular, cable systems provide an effective means of ensuring the stability of heavy-duty shoring and are relatively inexpensive when compared to other bracing methods. Cable is also used extensively as temporary bracing to stabilize falsework bents being erected or removed adjacent to traffic. However, the effect of preloading the tower legs should be carefully analyzed before implementing this bracing technique. The cable bracing should also be applied symmetrically to a shoring assembly to avoid unbalanced loading or overturning.

Cables, with their fastening devices and anchorages, are “manufactured assemblies” as defined in the *Guide Design Specifications for Bridge Temporary Works*. Accordingly, and in addition to information that may be shown on the falsework drawings, the contractor should be requested to furnish a manufacturer’s catalog or brochure showing technical data pertaining to the type of cable to be used. Technical data should include the cable diameter, the number of strands and the number of wires per strand, the ultimate breaking strength or recommended safe working strength, and such other information as may be needed to identify the cable in the field. Prior to installation, cable should be inspected to verify that the type and size of the cable and its condition (new or used) is consistent with design assumptions. Used cable should be inspected for strength-reducing flaws, such as obviously worn, frayed, kinked, or corroded cable, which should not be permitted in construction.

U-bolt clips must be placed on the rope with the U-bolts bearing on the short or dead end of the rope, and the saddle bearing on the long or live end of the rope. Improperly installed clips will reduce the safe working load by as much as 90 percent. Also, the omission of the thimble in a loop connection will reduce the safe working load by approximately 50 percent. After installation, clips should be inspected periodically and tightened as necessary to ensure their effectiveness. General guidelines regarding the number of wire rope clips and their spacing are shown in Figure 2.3.4-1. However, efficiency factors and prescribed clip spacings can vary, and the manufacturer's literature should be consulted for a given application.

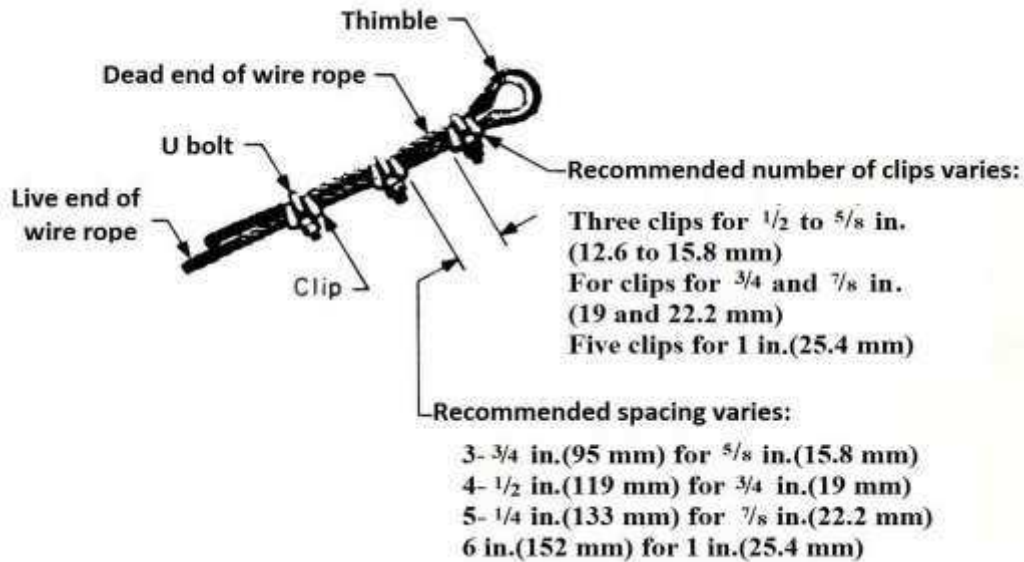


Figure 2.3.4-1—Typical Installation of Wire Rope Slip <sup>(25)</sup>

### 2.3.5—Bridge Deck Falsework

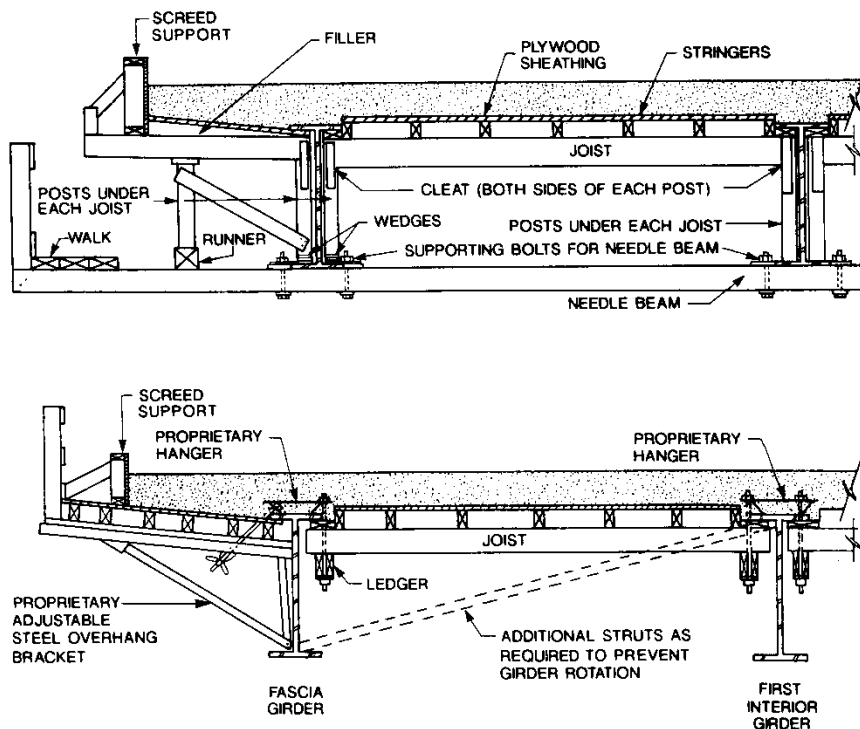
Multiple girder bridges rarely have ground-supported deck formwork. Deck casting is usually performed using hanger beams attached to the interior girders, and cantilever brackets affixed to the exterior or fascia girders. Figure 2.3.5-1 illustrates this forming method, with examples for both steel and concrete girders. Design examples of bridge deck falsework are provided in Appendix B.

The deck forms between interior stringers are generally set on joists hung from the top flange or supported from the bottom flange. Proprietary hangers include removable brackets or coil-bolt assemblies that remain permanently embedded in the deck slab. The embedded hangers are generally hung over the top of the stringer, or welded to stirrups or shear studs projecting from the top surface. Welding the hangers creates a positive connection that will prevent movement during casting. However, several states prohibit welding these devices to the permanent structure.

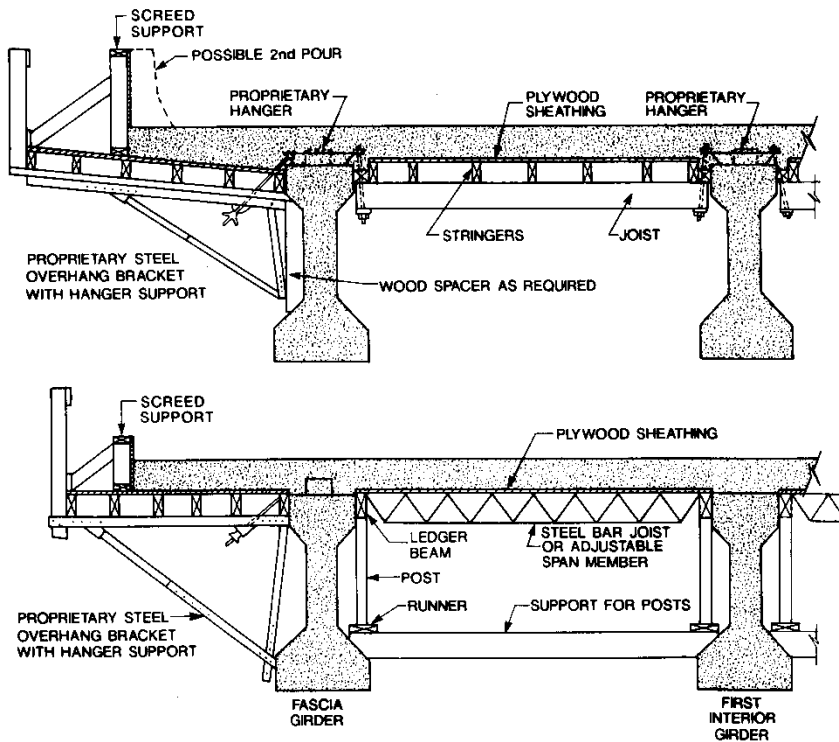
In order to form the cantilevered portion of the deck slab, a needle beam arrangement or overhang bracket can be used. As shown in the top illustration of Figure 2.3.5-1 (a), a needle beam arrangement works well for shallow steel girders where bottom flange tension hangers can be easily attached. This support arrangement is temporarily attached to the steel members, with no embedment anchors required in the slab.

A more common method of forming the overhang consists of an overhang bracket tied to the fascia girder with a hanger support. Gravity loads from the formwork, concrete deck, and screed machine act downward on the bracket. These loads create a force couple on the bracket, where tension is resisted by a hanger support rod and compression is applied horizontally to the girder web. This compressive force is resisted by bending in the beam web. For steel stringers, the web could buckle inward due to this out-of-plane force if the magnitude of compressive force is large enough. Therefore, bracket reactions should be investigated with respect to compressive force resistance, and interior diagonal struts may be required to prevent bottom flange rotation. Some general guidelines regarding the use of overhang brackets are as follows:

- The diagonal leg brace should bear on the web within 6 in. of the bottom flange.
- The exterior stringer should have its top flange tied at regular interval to prevent outward rotation. Recommended maximum spacing intervals are 2 ft, when finishing machine rails are located on the bracket-supported formwork, and 4 ft when finishing machine rails are on the top flange of the stringer.
- Precast, prestressed concrete I-girders should have ties at 8 ft maximum spacing.
- Steel girder diaphragm cross frames are not to be considered as ties if they do not have a top horizontal strut.
- Hardwood blocking [4 in. by 4 in. minimum] or the equivalent should be wedged between webs of the exterior and interior stringer within 6 in. of the bottom flange, located below the top ties.



(a) Bridge Deck Forming Methods with Steel Stringers

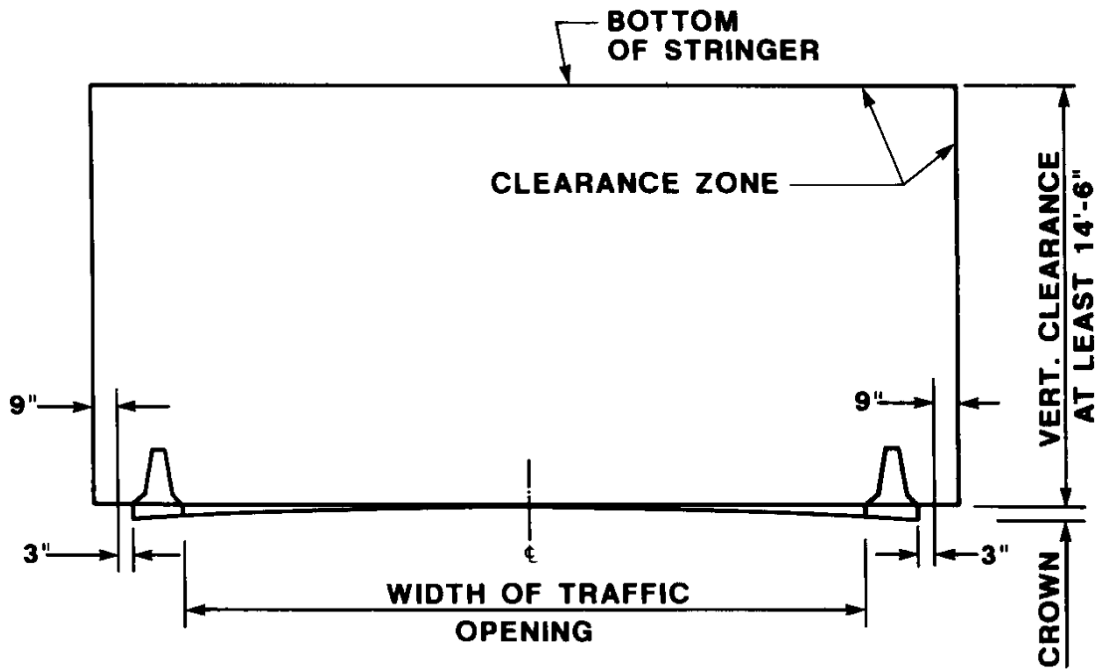


(b) Bridge Deck Forming Methods with Precast AASHTO Girders

Figure 2.3.5-1—Bridge Deck Falsework

### 2.3.6—Traffic Openings

The width of a traffic opening is generally defined as the distance between the temporary railings and, as illustrated in Figure 2.3.6-1, the clear distance between falsework posts will be considerably greater than the prescribed width. For a vehicular opening, no portion of the falsework should encroach into the clearance zone established by: a vertical plane located 3 in. behind the back edge of the temporary barrier at its base and extending upward to a horizontal plane at the top of the rail; and a second vertical plane located 9 in. behind the first plane and extending from the horizontal plane, at the top of the rail upward to the falsework stringer.



(a) Minimum Clearance Diagram



(b) "Set-Back" Distance between Traffic Barrier and Vertical Shoring

Figure 2.3.6-1—Traffic Openings