S10.1–2014 Steel Bridge Erection Guide Specification

Preface

This document is a standard developed by the AASHTO/NSBA Steel Bridge Collaboration. The primary goal of the Collaboration is to achieve steel bridge design and construction of the highest quality and value through standardization of the design, fabrication, and erection processes. Each standard represents the consensus of a diverse group of professionals.

It is intended that Owners adopt and implement Collaboration standards in their entirety to facilitate the achievement of standardization. It is understood, however, that local statutes or preferences may prevent full adoption of the document. In such cases Owners should adopt these documents with the exceptions they feel are necessary.

Disclaimer

The information presented in this publication has been prepared in accordance with recognized engineering principles and is for general information only. While it is believed to be accurate, this information should not be used or relied upon for any specific application without competent professional examination and verification of its accuracy, suitability, and applicability by a licensed professional engineer, designer, or architect.

The publication of the material contained herein is not intended as a representation or warranty of the part of the American Association of State Highway and Transportation Officials (AASHTO), the National Steel Bridge Alliance (NSBA), or of any other person named herein, that, this information is suitable for any general or particular use and is free from infringement of any patent or patents. Anyone making use of this information assumes all liability arising from such use.

Caution must be exercised when relying upon other specifications and codes developed by other bodies and incorporated by reference herein since such material may be modified or amended from time to time subsequent to the printing of this edition. The authors and publishers bear no responsibility for such material other than to refer to it and incorporate it by reference at the time of the initial publication of this edition.
EXECUTIVE COMMITTEE
2014–2015

Voting Members

Officers:

President: Mike Hancock, Kentucky
Vice President: John Cox, Wyoming
Secretary-Treasurer: Carlos Braceras, Utah

Regional Representatives:

REGION I: Chris Clement, New Hampshire, One-Year Term
Shailen Bhatt, Delaware, Two-Year Term
REGION II: Sheri LeBas, Louisiana, One-Year Term
John Schorer, Tennessee, Two-Year Term
REGION III: Paul Trombino, Iowa, One-Year Term
Vacant, Two-Year Term
REGION IV: John Halikowski, Arizona, One-Year Term
Malcom Dougherty, California, Two-Year Term

Nonvoting Members

Immediate Past President: Michael P. Lewis, Rhode Island
Executive Director: Bud Wright, Washington, DC
S10.1–2014 Steel Bridge Erection Guide Specification

DELAWARE RIVER AND BAY AUTHORITY,
Shoukry Elnahal

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

MDTA, Dan Williams

N.J. TURNPIKE AUTHORITY,
Richard J. Raczyński

N.Y. STATE BRIDGE AUTHORITY,
William J. Moreau

PENN. TURNPIKE COMMISSION,
James L. 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, Tom Gillens

ALBERTA, Lloyd Atkin

KOREA, Eui-Joon Lee, Sang-Soon Lee

SASKATCHEWAN, Howard Yea

TRANSPORTATION RESEARCH
BOARD, Waseem Dekelbab

Copyright © 2014 by the AASHTO/NSBA Steel Bridge Collaboration
All rights reserved.
AASHTO/NSBA Steel Bridge Collaboration
Task Group 10, Steel Bridge Erection

JAMIE F. FARRIS, Texas Department of Transportation, Chair

Shane Beabes, AECOM
Allan Berry, Stantec
Frank Blakemore, Garver
Brandon Chavel, HDR Engineering
Stuart Chen, University of New York at Buffalo
Robert Cisneros, High Steel Structures
Domenic Coletti, HDR Engineering
Ronald Crockett, American Bridge Co
Bradley Dillman, High Steel Structures
Karl Frank, Hirschfeld Industries
Christina Freeman, Florida Department of Transportation
Michael Garlich, Collins Engineers, Inc.
Christopher Garrell, National Steel Bridge Alliance
John Gast Jr., Erection Consultant
Walter Gatti, Tensor Engineering
Heather Gilmer, Florida Structural Steel
Tom Kiener, Ewell W. Finley
Brian Kozy, Federal Highway Administration
Natalie McCombs, HNTB
Bill McElenev, National Steel Bridge Alliance
Ronnie Medlock, High Steel Structures
Stephen Percassi, Erdman Anthony
Kevin Pruski, Texas Department of Transportation
Calvin Schrage, National Steel Bridge Alliance
Ted Sheppard, DuRoss Group
Jason Stith, Michael Baker
Stephen Walsh, Upstate Detailing
Donald White, Georgia Institute of Technology
Brian Witte, Parsons
John Yadlosky, HDR Engineering
# Table of Contents

**Section 1** General ................................................................................................................................. 1  
1.1 Definition ........................................................................................................................................ 1  
1.2 Erector Qualifications ..................................................................................................................... 3  

**Section 2** Erection Engineering ........................................................................................................ 4  
2.1 General ............................................................................................................................................ 4  
2.2 Erection Plans ................................................................................................................................ 5  
2.3 Guidelines for Methods of Structural Analysis ............................................................................... 10  
2.4 Requirements for Calculations for Structural Adequacy and Stability ........................................ 12  
2.5 Coordination Items ........................................................................................................................ 17  

**Section 3** Transportation ................................................................................................................... 19  
3.1 Responsibility ................................................................................................................................. 19  
3.2 Handling .......................................................................................................................................... 19  
3.3 Fasteners ....................................................................................................................................... 19  

**Section 4** Material Storage at Jobsite ................................................................................................. 20  
4.1 Fabricated Material .......................................................................................................................... 20  
4.2 Fasteners and Machine-Finished Parts ............................................................................................ 20  
4.3 Welding Consumables ...................................................................................................................... 20  
4.4 Damage .......................................................................................................................................... 20  

**Section 5** Bearings and Anchorages .................................................................................................... 21  
5.1 Survey ............................................................................................................................................ 21  
5.2 Bridge Seats .................................................................................................................................. 21  
5.3 Temperature Adjustments .............................................................................................................. 21  
5.4 Tolerances ..................................................................................................................................... 21  

**Section 6** Lifting and Assembly .......................................................................................................... 22  
6.1 General ......................................................................................................................................... 22  
6.2 Lifting Devices ............................................................................................................................... 22  
6.3 Erection Stability ............................................................................................................................. 22  
6.4 Trusses .......................................................................................................................................... 22  
6.5 Falsework and Temporary Supports .............................................................................................. 22  
6.6 Pins .............................................................................................................................................. 23  
6.7 Connections ................................................................................................................................. 23  
6.8 Abnormalities ............................................................................................................................... 23  

**Section 7** Field Bolted Connections .................................................................................................... 24  
7.1 Fastener Testing ............................................................................................................................... 24  
7.2 Faying Surfaces ............................................................................................................................... 24  
7.3 Installation Method Verification ...................................................................................................... 24  
7.4 Installation ................................................................................................................................... 25  

**Section 8** Field Welded Connections .................................................................................................. 27  
8.1 General .......................................................................................................................................... 27  
8.2 Weld Procedure Specifications ....................................................................................................... 27  
8.3 Qualification .................................................................................................................................. 27  
8.4 Welding Requirements ................................................................................................................... 28
# S10.1–2014 Steel Bridge Erection Guide Specification

**Section 9** Inspection ................................................................. 29  
  9.1 General ................................................................................. 29  
  9.2 Tolerances for Plate Girder or Rolled Beam Spans ................. 29  
  9.3 Surveys .................................................................................. 31  
  9.4 Bolting .................................................................................. 31  
  9.5 Welding .................................................................................. 31  

**Section 10** Repair ................................................................. 32  
  10.1 Documentation ................................................................. 32  
  10.2 Implementation ............................................................... 32  
  10.3 Repair Procedures ............................................................ 32  
  10.4 Welds .................................................................................. 32  

**Appendix A:** Rotational Capacity Test (ASTM A325 and ASTM A490 Long Bolts in Tension Calibrator) ............................................................. 33  

**Appendix B:** Rotational Capacity Test (ASTM A325 and ASTM A490 Bolts too Short to Fit Tension Calibrator) ................................................ 35  

**Appendix C:** Direct Tension Indicators (DTI) ............................... 37  

**Appendix D:** Field Rotational Capacity Test ......................... 39  

**Appendix E:** Erection Plan and Procedures Checklist .................. 41  

**Appendix F:** Erection Calculations Checklist ............................ 43  

**Appendix G:** Erection Inspection Checklist ............................... 45  

**Appendix H:** Example Erection Plans ...................................... 47
Section 1  
General

1.1 Definitions

1.1.1 Steel Bridge Erection

Steel bridge erection is the process of transporting, handling, and assembling steel bridge components to create a bridge structure that meets all the geometric and structural requirements of the contract documents.

C1.1.1  
Steel erection is complete when all field connections are finished to the final design condition and falsework or temporary bracing is/can be removed. Erection should proceed in a safe, methodical fashion ensuring all performance criteria are satisfied.

1.1.2 Erector

In this document, “Erector” refers to the entity that is responsible for the erection of the structural steel.

1.1.3 Contractor

The Contractor is responsible for proper completion of all tasks required by the Contract. Subcontractors, including fabricators, erectors, and field painters, may be used by the Contractor, but the Contractor retains responsibility for all material, operations, and the final product. The Contractor may permit direct subcontractor interaction with the Owner to expedite the project, but subcontractors must inform the Contractor of any proposed modifications to Contract requirements accepted by the Owner.

1.1.4 Design Engineer

In this document, “Design Engineer” refers to the licensed professional who is responsible for sealing the contract documents, which indicates that he or she has performed or supervised the analysis, design, and document preparation for the structure and has knowledge of the load-carrying structural system.

1.1.5 Erection Engineer

In this document, “Erection Engineer” refers to the individual who is responsible for developing, evaluating, and specifying the Contractor’s specific procedures and plans for erecting the structural steel of the bridge.

1.1.6 Fabricator

In this document, “Fabricator” refers to the facility(ies) performing such shop activities as cutting, welding, drilling, punching, cleaning, and painting of structural steel. “Fabricator” also includes any agents of the Fabricator, such as subcontract fabricators. In some cases, the Fabricator is subcontracted by the Contractor.
1.1.7 Inspection
The examination by the Owner or Fabricator of processes and products to verify conformance with the Contract requirements.

1.1.8 Owner
In this document, “Owner” refers to the entity paying the Contractor to fulfill the terms of the Contract. The Owner also encompasses the following: those preparing the Contract documents, including those responsible for the structure’s adequate design; and those authorized to represent the Owner during construction, commonly called the “Engineer” and the “Inspector.” The Engineer and Inspector may be employees either of the Owner or of professional firms contracted for the work.

1.1.9 Plans
In this document, if not otherwise noted or modified by adjectives, the term “Plans” refers to the engineering drawings prepared by the Design Engineer. The terms “Design Plans” and “Contract Plans” are identical in meaning to the generic term “Plans.”

1.1.10 Erection Plans
In this document, the term “Erection Plans” refers specifically to the engineering drawings prepared by the Erection Engineer describing and specifying the erection (i.e., the field-installation and member-placement) of the structural steel. In this document, the term “Erection Plans” may also refer in a more general context to the combination of engineering drawings and Erection Procedures describing and specifying the erection (i.e., the field-installation and member-placement) of the structural steel.

1.1.11 Erection Procedures
In this document, the term “Erection Procedures” refers to the documents which describe the specific sequence, methods, equipment, and other directives that the Contractor is to follow in erecting the structural steel. The terms “Erection Plans” and “Erection Procedures” are not synonymous, but the Erection Plans and Erection Procedures shall be fully integrated with each other and shall together describe and specify all aspects of how the structural steel is to be erected, including, but not limited to, sequence of erection, methods or techniques to be used, equipment to be used, and materials to be used along with any temporary works or other devices necessary. Items identified as required by these

C1.1.9
The term “Plans” can refer to many documents, but typically refers to the engineering drawings prepared by the Design Engineer unless modified by a descriptive adjective(s) to denote different meaning (e.g., “Erection Plans” refers to the engineering drawings prepared by the Erection Engineer). When not otherwise clear, the term “Plans” should be interpreted (in this document) as referring to the plans prepared by the Design Engineer, which can also be denoted as the “Design Plans” or the “Contract Plans.”

C1.1.10
The intent of these definitions is not to create requirements for separating information shown on the Erection Plans from information presented in the Erection Procedures; the two documents are intended to be complementary. The required information can be shown in either the Erection Plans or the Erection Procedures as is appropriate for clear presentation, efficiency, and simplicity; the key is that all required information is presented in either one or the other.

C1.1.11
The Erection Procedures should be presented in some written format (e.g., verbal directives are not sufficient to constitute Erection Procedures). The Erection Procedures can include references to standard operating procedures of the Contractor (to avoid unnecessary repetition or excessive documentation), but in such a case, the standard operating procedures should be written, and should be available for review by the Owner.
specifications and not addressed in the Erection Plans shall be addressed in the Erection Procedures.

1.1.12 Erection Engineering Calculations

In this document, the term “Erection Engineering Calculations” refers to any engineering calculations associated with the substantiation of the Erection Plans and Erection Procedures.

1.1.13 Contract Documents

In this document, the term “Contract Documents” refers to the documents that define the responsibilities of the parties that are involved in bidding, fabricating, and erecting structural steel (and other elements of the project). These documents normally include the design drawings, the specifications, and the contract.

1.2 Erector Qualifications

Structural steel shall be erected by a qualified, competent erection contractor. The Owner shall specify qualifications for the steel erector based on the complexity of the project.

C1.2

A ‘qualified, competent erection contractor’ has knowledge, training, and experience; and has demonstrated the technical proficiency and ability to complete the work specified. The contractor should be able to resolve common problems associated with the complexity of work proposed. AISC credentials such as Certified Steel Erector (CSE), Advanced Certified Steel Erector (ACSE), or other similar industry based qualification should be considered based on the requirements for such certifications and the complexity of the bridge. Certification alone may not be sufficient evidence of qualification for complex or monumental bridge structure types, such as suspension, cable stayed, tied arch, cantilever truss, or moveable bridges.
Section 2
Erection Engineering

2.1 General

2.1.1 Required Erection Plans and Procedures
and Erection Engineering Calculations

The Contractor shall submit Erection Plans and Erection Procedures to the Owner for each bridge structural unit identified on the contract plans and specifications. The Contract Documents language, “An erection plan is required,” or similar language, invokes a requirement for submittal of Erection Plans and Procedures as described in this Guide Specification.

The Contractor shall submit Erection Engineering Calculations to the Owner for each bridge structural unit identified on the contract plans and specifications. The Contract Documents language, “Erection engineering calculations are required,” or similar language, invokes a requirement for submittal of Erection Engineering Calculations as described in this Guide Specification.

Unless otherwise specified in the Contract Documents, if the submittal of Erection Plans and Procedures, and/or the submittal of Erection Engineering Calculations, is required, the Owner shall be allowed a minimum of fifteen (15) working days to review the submittal, after which the Contractor may assume the submittal has been approved by the Owner, unless the Owner provides written notification that the submittal was not approved.

2.1.2 Erection Plans and Procedures Overview

The Erection Plans and Procedures shall be prepared by a licensed Professional Engineer qualified in steel erection. The Erection Plans and Procedures submittal shall address all requirements for erection of the structural steel into the final designed configuration. Any and all written review comments provided by the Owner shall be addressed to the Owner’s satisfaction prior to the start of erection. As a minimum, the Erection Plans and Procedures shall include consideration of all items described in Section 2.2.

C2.1.1

Formal submittal and review of Erection Plans and Procedures and Erection Engineering Calculations may not be warranted for all bridges; Owners may choose to forego requiring formal submittal and review of Erection Plans and Procedures and/or Erection Engineering Calculations where the additional cost and time is not justified. For simpler structures where the risk associated with problems is minimal, the Owner may choose to rely upon the contractor’s expertise to erect the bridge without requiring a formal submittal. For example, for a shorter, rural, simple-span creek crossing bridge, formal submittal and review of Erection Plans and Procedures and associated Erection Engineering Calculations may not be warranted.

Note that as explained in Section 1.1, the term Erection Plan encompasses both engineering drawings (defined specifically as Erection Plans) and any associated Erection Procedures documents.

C2.1.2

The qualifications of the Engineer preparing the Erection Plans and Procedures and the Erection Engineering Calculations should be evidenced by knowledge, training, experience in steel erection, and having demonstrated the ability to resolve problems related to steel bridge erection. Many states also require that erection procedures and temporary falsework design be prepared by a Professional Engineer (PE) licensed or registered in that state. Some states may specifically require licensure or registration as a Structural Engineer (SE); in such cases, the specification language should be revised as appropriate.

The submission date(s) and review period(s) should be established and agreed to by the Owner and the Contractor as soon as possible after the Contract award, and should be established such that sufficient time is allotted for development of the erection submittal by the Contractor’s Engineer and for review by the Owner. Erectors are encouraged to attend pre-bid and preconstruction meetings to help understand the complexities associated with the steel
erection well in advance. Projects that involve complex erection or multi-agency reviews can be expected to require additional time for review of the submitted Erection Plans and Procedures. In these cases, the established submission dates and review periods should reflect the need for appropriate reviews by all involved parties. In some cases, particularly for bridges with complex erection schemes, it may be appropriate to establish one or more interim submittals, including an early submittal of preliminary Erection Plans and Procedures that illustrate the proposed erection sequence and reflect any fabrication changes required to accommodate the proposed erection sequence.

2.1.3 Erection Engineering Calculations Submittal

Erection Engineering Calculations to substantiate the structural adequacy and stability of the erected structure and any associated temporary works and/or temporary components do not need to be included in the Erection Plans and Procedures submittal, unless otherwise specifically required on the contract plans or in special provisions. However, the Owner reserves the right to request the submittal of Erection Engineering Calculations for review and approval at any time. If requested, such calculations shall be submitted within 14 calendar days of request by the Owner.

In the absence of Erection Engineering Calculation submittal requirements, the Contractor may provide calculations in any format of their own choosing, including without limitation electronic analysis files, spreadsheets, copies of hand calculations, etc. The Contractor shall provide reading software for any electronic analysis files prepared using analysis software not otherwise already owned and used by the Owner or freely available to the Owner.

Complex or signature structures should have specific requirements noted in the Contract documents. Complex erection projects may require input from the structural designer in addition to the original design calculations such that the contractor can confirm constructability of the structure during various erection stages. The Owner should ensure that the structural designer is available to consult with the Contractor in these cases. Further, it is beneficial for the Owner to discuss with the Contractor particular issues or concerns with the Erection Plans and Procedures to secure an explanation.

When calculations are required, it is beneficial for the Owner to specify their preferred format for submittal. Printed (or .pdf) reports of output are common; if the Owner would like actual data files, this should be explicit in the contract documents.

A checklist showing all items discussed below is provided in Appendix E as an aid for engineers preparing or reviewing Erection submittals.

2.2 Erection Plans

2.2.1 Plan of Work Area

The Erection Plans shall include:

- a plan of the work area showing the proposed bridge,
- the permanent support structures (piers and abutments),
- roads,
- railroad tracks,
- waterways (including location and dimensions of any navigational channel(s) and any navigational clearances which must be respected during construction),
- overhead and underground utilities,
- structures and conditions that may limit access (consideration of clearance requirements over roadways or railroads),

The plan of work area drawing should provide a general overview of the area where the bridge is to be erected, preferably drawn to scale. It allows all involved to see site conditions; access routes and staging areas, utilities, roadways, existing structures and other possible site constraints; and better understand why certain procedures or details are being specified.

Example erection plans can be found at the end of this specification in Appendix H.
• staging or material storage areas,
• right-of-way and property lines,
• information, plans, etc. regarding maintenance of traffic requirements, lane or road closures, restrictions, durations, etc. necessary to protect public safety for all erection operations over or adjacent to live traffic,
• and any other information that may be pertinent to the steel erection.

Unless otherwise clearly allowed by the Owner’s standard specifications or unless otherwise clearly allowed in the Contract Documents, erection of structural steel over live traffic shall not be permitted.

2.2.2 Erection Sequence

The Erection Plans and Procedures shall indicate the erection sequence for all primary members (including indication of any attached secondary members), noting the use of temporary support conditions, such as holding crane positions, temporary supports, falsework, etc. The erection sequence shall be shown in an illustrative plan view of the bridge for each erection stage, highlighting the structural components to be erected, their weights and center of gravity locations, lifting crane locations for primary member picks, and any temporary support conditions that are necessary during the particular stage. The illustrative plan view shall be accompanied with a written narrative of the procedure to be followed by the steel erector, which shall state items such as structural components to be erected, use of temporary supports, use of temporary bracing, hold cranes, etc. Member reference marks, when reflected on the Erection Plans and Procedures, should be the same as used on shop detail drawings.

2.2.3 Delivery Location

The Erection Plans and Procedures shall indicate the delivery location and orientation of all primary members.

2.2.4 Crane Information

The Erection Plans and Procedures shall show the location of each crane to be used for each primary member to pick (see Section 2.2.2) the crane type, crane pick radius, crane support methods (crane mats, barges, work trestles, etc.), and the means of attachment to the girders being lifted or supported.

The Erection submittal shall include capacity charts or tables that address and demonstrate the adequacy of each
crane configuration, boom length, counterweight configuration, outrigger configuration, and pick weight required to do the proposed work. The Erection Plans and Procedures shall also indicate any potential above- or below-ground obstructions or restrictions to crane operations (such as existing structures, utilities, etc.).

In the event that the submitted cranes are not available at the time of construction, the Contractor can propose alternate cranes, subject to review and approval by the Owner. The submittal package for alternate cranes shall include capacity charts or tables that address and demonstrate the adequacy of each crane configuration, boom length, counterweight configuration, outrigger configuration, and pick weight required to do the proposed work; however, resubmittal of the full Erection Plans and Procedures and the Erection Engineering Calculations package is not required.

Any plans associated with crane supports (such as crane mats, barges, work trestles, etc.) shall also be included. When applicable, manufacturers’ certification documents or catalog cuts for pre-engineered devices or equipment may be used to meet this requirement; these items shall be included with the Erection Plans and Procedures and shall be subject to review and approval by the Owner. Calculations for crane supports (crane mats, barges, work trestles, etc.) do not need to be included in the Erection Plans and Procedures and Calculations submittal, unless otherwise specifically required on the plans or in special provisions, but the Owner reserves the right to request their submittal for review and approval at any time. If requested, such calculations shall be submitted within 14 calendar days of request by the Owner.

### 2.2.5 Primary Member Crane Pick Information

The Erection Plans and Procedures shall include the lifting weight of the primary member picks, including all rigging and pre-attached elements (such as cross-frames or splice plates). The Erection Plans and Procedures shall also include the approximate center of gravity locations for the primary member picks of non-symmetric girders and assemblies.

### 2.2.6 Lifting Devices and Special Procedures

The Erection Plans and Procedures shall include the details, weight, capacity, and arrangement of all rigging (beam clamps, lifting lugs, etc.) and all lifting devices (such as spreader and lifting beams) required for lifting primary members. The Erection Plans and Procedures shall also specify details for rigging or lifting devices bolted or welded to permanent members, including the method and time (shop or field) of attachment and be provided in the Erection Plans and Procedures.

Communication between the Contractor and the Contractor’s Engineer is vital to ensure the cranes assumed by the Contractor’s Engineer are available to the Contractor. Providing the crane types, pick radii and weight, boom lengths, possible obstructions, etc. in the Erection submittal will help to prevent crane failures, overloads, and interferences during the steel erection process in the field. Owners should recognize that it is not uncommon for a Contractor to need to substitute alternate cranes at the time of construction due to lack of availability, mechanical problems, etc. of the originally proposed cranes. The Owner and the Contractor should agree to procedures and review times for alternate crane submittals as part of their establishment of dates and review periods for Erection submittals. Typically, Crane submittals are relatively simple to review, and so it is generally appropriate to establish relatively short review periods to allow the contractor reasonable flexibility in managing their equipment needs.

### C2.2.5

The lifting weights and the approximate centers of gravity for each pick will provide the steel erector with necessary information to safely lift various components. The centers of gravity provided on the plans should be taken as approximate locations, as these are typically calculated assuming nominal material sizes and approximations of minor items such as bolted connections, etc. The actual center of gravity locations should reasonably match these approximate locations, and will aid the steel erector in determining the proper lifting location in the field.

### C2.2.6

Assumptions regarding the weight of rigging, spreader beams, etc. should be included in the Erection Plans and Procedures. Explicitly indicating all details related to rigging and spreader or lifting beams will help to ensure that the appropriate devices are being properly used in the field.

Slender beams, traditionally defined as those having a length-to-flange-width ratio \((L/b)\) greater than 85,
capacity, as well as methods, time, and responsibility for removal.

As necessary, the Erection Plans and Procedures shall provide special lifting/handling procedures for any primary member with potential stability or slenderness issues.

2.2.7 Bolting Requirements

The Erection Plans and Procedures shall indicate the bolting requirements for field splices and cross-frame (or diaphragm) connections for each stage.

Refer to Section 6.7 for minimum bolting requirements during erection.

2.2.8 Bearing Blocking and Tie-Down Details

The Erection Plans and Procedures shall indicate blocking and/or tie-down details for the bridge bearings, and associated force demands as necessary.

Steel I-girders depend on their connections to adjacent girders through bracing members for their stability and stiffness during steel erection. This is especially true for curved steel girders, as the cross-frames serve as primary load carrying members. Therefore, loosely connected cross-frames should not be used during steel girder bridge erection, as this may compromise the girder alignment (geometry control) and stability.

The bolting requirements for girder field splices during steel erection need to be considered as well. In accordance with the AASHTO LRFD Bridge Construction Specifications, Article 11.6.5, “splices and field connections shall have one-half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins) before installing and tightening the balance of the high-strength bolts.” In addition, the Contractor’s Engineer developing the Erection Plans and Procedures must ensure that the number of bolts or erection pins to be used provides enough capacity for transfer of loads for the given stage of steel erection.

Copyright © 2014 by the AASHTO/NSBA Steel Bridge Collaboration
All rights reserved.
2.2.9  Load Restrictions

Restrictions regarding wind loading, construction dead and live loadings, and any other applicable loading restrictions shall be included on the Erection Plans and Procedures, as necessary.

2.2.10  Temporary Supports

The Erection Plans and Procedures shall include the location of any temporary support structures (see Section 2.2.3) and bracing, as well as details of the temporary support structure itself. If the temporary support is to be prefabricated (selected from a supplier’s catalogue), the type and capacity shall be defined in the Erection Plans and Procedures, as necessary.; lateral capacity as well as vertical capacity requirements shall be considered as appropriate. If the temporary support is to be constructed by the Contractor on site, a complete design with full details, including member sizes, connections, and bracing elements shall be provided in the Erection Plans and Procedures. In either case, details regarding the upper grillage and temporary bearing assembly (i.e., details of how the steel girders will bear on the temporary support), including the top of falsework (bottom of structural steel) elevations, shall also be included in the Erection Plans and Procedures. In addition, all foundation requirements for temporary support structures shall be provided in the Erection Plans and Procedures.

The Erection Plans and Procedures shall indicate the location of hold cranes that are used to provide temporary support to the steel assembly (see Section 2.2.2) and the associated crane loads. The hold crane type, capacity, boom lengths, pick radius, and means of attachment to the girders shall also be indicated in the Erection Plans and Procedures.

The Erection Plans and Procedures shall include the
location and details for temporary tie-downs that are required to facilitate the steel erection, as well as the associated tie-down loads. At a minimum, the details shall include the tie-down, girder attachment devices, and anchoring devices.

The Erection Plans and Procedures shall clearly indicate when, and under what conditions, any temporary supports or holding cranes may be released in the erection sequence, and if they may be left in place while subsequent erection proceeds.

The Erection Plans and Procedures shall clearly indicate appropriate restraint of girders from twisting and/or layover at supports. Girders should be restrained from twist and/or layover at supports unless the need for such restraint is demonstrated to be unnecessary by appropriate analysis in the Erection Engineering Calculations.

2.2.11 Jacking Devices
The Erection Plans and Procedures shall indicate jacking devices that will be required to complete the steel erection. Their location, type, size, and capacity shall be indicated on the Erection Plans and Procedures, as well as their intended use, sequence of engagement, load level, jack pressure table, and any other key parameters of their operation.

C2.2.11
In some cases, jacking devices may be required at temporary or permanent support structures to align the structure during the erection process. If the Erection Plans and Procedures do indeed require jacking devices, they should be indicated in the Erection Plans and Procedures to alert the Contractor to their need, and their intended use should be explicitly presented.

2.3 Guidelines for Methods of Structural Analysis
The Owner may specify in the Contract Documents the minimum requirements regarding the methods of structural analysis used in any structural engineering calculations supporting the Erection Procedures submittal. Note that the Owner’s specification of minimum requirements for methods of analysis does not in any way relieve the Contractor or the Erection Engineer of their obligations to perform correct and appropriate structural analyses.

If the Owner does not specify the minimum requirements regarding the methods of structural analysis to be used, the Contractor may elect to use any appropriate methods of analysis, provided that the methods can be demonstrated to be appropriate and conservative for the given analysis task(s), and that the methods meet or exceed the recognized or implied standard of care for similar analysis tasks.

C2.3
The Owner should specify their minimum expectations regarding the methods of structural analysis prior to bidding in order to identify what is required. This helps establish a uniform basis for bidding by communicating these requirements to the Contractor in advance. The required methods of analysis should reflect the complexity of the structure and the complexity of the erection sequence (at least of the erection sequence presented in the contract documents). Since each project is different, requirements regarding the methods of structural analysis will vary from project to project. Some Owners may choose to establish standing rules/categories in this regard and publish those in their standard specifications. In lieu of this, the minimum requirements should be specified in the contract documents.

Recommendations for the selection of the appropriate method of structural analysis can be found in NCHRP Report 725 (NCHRP Project 12-79). NCHRP Report 725 provides recommendations on the appropriate methods of analysis to employ when investigating the adequacy of the erection sequence of curved or skewed steel girder bridges. The methods of analysis considered include 1D (approximate), 2D, and 3D methods. Tables are
provided that aid the engineer in selecting an appropriate analysis method. For bridges with straight girders and non-skewed supports, 1D (approximate) analysis methods are generally adequate. A summary of these recommendations, including some more recent updated suggestions, can be found in Appendix B of the AASHTO/NSBA Steel Bridge Collaboration Guideline document [*G13.1, Guidelines for Steel Girder Bridge Analysis*, 2nd Edition (anticipated publication 2014)].

The FHWA is currently (at the time of writing of this edition of S10.1–2014) preparing an FHWA/NHI course and associated reference manual titled “Engineering for Structural Stability in Bridge Construction.” Publication is anticipated in the near future. This manual is expected to provide comprehensive guidance with regard to erection engineering and should prove to be an additional valuable resource.

Note that a checklist, listing all items discussed below, is provided in Appendix F as an aid for engineers preparing or reviewing erection submittals.
2.4 Requirements for Erection Engineering Calculations for Structural Adequacy and Stability

Appropriate Erection Engineering Calculations to substantiate the structural adequacy and stability of the bridge system for each step of the steel erection shall be performed to substantiate the erection procedures. Requirements addressing the submittal of calculations are presented in Section 2.1 of this specification. This section of these specifications only addresses the content of calculations.

The Erection Engineering Calculations shall be performed in accordance with erection design criteria established or approved by the Owner, or as stated in the contract plans.

2.4.1 Design Criteria

The Erection Engineering Calculations shall be prepared in accordance with the AASHTO LRFD Bridge Design Specifications, the AASHTO LRFD Bridge Construction Specifications, and the AASHTO Guide Design Specifications for Bridge Temporary Works, unless otherwise directed by the Owner or the contract documents. The Contractor can propose alternate criteria for specific items. Alternate criteria shall be limited to specifications published by AISC, ASCE, ACI, or other recognized, national specification-writing organizations. Proposals for alternate design criteria shall be submitted by the Contractor for review and approval by the Owner prior to the Contractor or the Contractor’s Engineer beginning work on the Erection Plans and Procedures and calculations. The Owner shall be allowed a minimum of ten (10) working days to review the submittal, after which the Contractor may assume the submittal has been approved.

C2.4

The following subsections [2.4.1 through 2.4.10] provide guidance on a variety of topics associated with calculations for structural adequacy and stability. As a general default, AASHTO specifications are cited for criteria, but some opportunity is provided for the Contractor’s Engineer to exercise reasonable discretion, subject to the approval of the Owner in advance.

For each project, the Owner (or the Owner’s design engineer) should evaluate the complexity of the bridge and of the proposed erection sequence prior to bidding. If there are any particular areas of concern, the Owner (or the Owner’s design engineer) should specify their expectations explicitly in the contract documents. This may include specification of design criteria, analysis methods, or identification of specific items to be addressed in the Erection Plans and Procedures, procedures, and calculations submittal, including identification of how these items are expected to be addressed.

The specifications in this section of this document provide only the minimum requirements regarding calculations for structural adequacy and stability. This section does not provide a comprehensive “checklist” of items needing evaluation for erection of any steel bridge; each project is unique and may have particular issues requiring the attention of the Contractor’s Engineer. Only basic requirements and suggested evaluation items (in commentary) are presented herein.

C2.4.1

Traditionally, the Contractor’s Engineer has been allowed reasonable discretion in identifying appropriate design criteria for erection engineering calculations, for the design of temporary works, etc. In some cases, the provisions published in AASHTO documents do not adequately address some of the unique situations associated with erection engineering and temporary works. In other cases, construction engineers have established efficient and effective methods based on criteria other than AASHTO. Commonly cited design specifications include AISC specifications for steel design and ASCE specifications for wind loads, among others.
approved by the Owner, unless the Owner provides written notification that the submittal was not approved.

2.4.2 Loads and Load Combinations

The Erection Engineering Calculations shall consider all applicable loads, including permanent dead loads, construction dead loads, construction live loads, wind loads, and any other loads which may be applicable.

Wind loads shall be considered in each step of the steel erection analysis, and are to be computed in accordance with the agreed erection design criteria. Provisions shall be made by the Contractor’s Engineer to ensure that girders are stable in wind events. It is permissible to set limits on maximum wind velocities during steel erection; these limits shall be stated in the Erection Plans and Procedures. If applicable, include provisions in the Erection Plans and Procedures for temporary supports, tie-downs, or both to address high wind conditions.

Load combinations shall be in accordance with the AASHTO LRFD Bridge Design Specifications, unless otherwise noted in the contract documents or unless otherwise approved by the Owner. If the Contractor proposes alternate design criteria (in accordance with the provisions of Section 2.4.1), the Contractor may also propose alternate load combinations for specific items provided the alternate load combinations are consistent with the proposed design criteria. Proposals for alternate load combinations shall be submitted by the Contractor for review and approval by the Owner prior to the Contractor or the Contractor’s Engineer beginning work on the Erection Plans and Procedures and the Erection Engineering Calculations. The Owner shall be allowed a minimum of ten (10) working days to review the submittal, after which the Contractor may assume the submittal has been approved by the Owner, unless the Owner provides written notification that the submittal was not approved.

2.4.3 Girder and System Stability

The Erection Engineering Calculations supporting the erection procedures shall verify the stability both of individual girders and also of the entire erected steel framing for each step of the bridge erection. These calculations are dependent upon the particular features of the bridge being erected and also of the particular sequence of erection of each part of the bridge. The assumptions used in the analysis should directly and fully conform to all steps and all details in the Erection Plans and Procedures.

C2.4.2

Permanent dead loads typically include the self-weight of the structural members and detail attachments. Construction dead and live loads may consist of deck placement machinery, Contractor’s equipment, deck overhang brackets, concrete formwork, or other similar attachments applied in the appropriate sequence.

C2.4.3

The constructability provisions of Article 6.10.3 of the AASHTO LRFD Bridge Design Specifications should be referenced by the Contractor’s Engineer when investigating structural adequacy and stability during steel erection. A partial list of suggested evaluation items and guidelines regarding appropriate investigations are as follows:

Single Girder Stability

Particular attention should be given to the lateral torsional buckling capacity of a singly erected I-girder. One of the most critical stages during I-girder erection is when the first girder has been erected, but not yet connected to adjacent girders in the cross section. Assuming the girder is adequately braced at the supports and there is no additional
bracing within the span, the unbraced length for the girder will be the distance between supports. Long unbraced lengths typically correspond to very low lateral-torsional buckling capacity of the girder. Tub-girders typically have much higher lateral-torsional buckling capacity, but only if provided with a properly-designed top flange lateral bracing system that provides for quasi-closed section behavior of the girder. Global overturning stability is also a concern for single curved girders, whether I- or tub-girders. The offset of the center of gravity of the girder from a chord line drawn between the support points results in an overturning moment. Single girders typically have no torsional restraint at their supports unless tie downs, bracing, temporary shoring, or hold cranes are provided.

**Multi-Girder (Global) Stability**

A girder system may be vulnerable to global buckling during the steel erection sequence and/or during deck placement. Narrow, long span segments during steel erection are the most susceptible to this global buckling phenomenon. Methods for investigating the global stability of girder systems are available (Yura et al., 2008).

**Second-Order Amplification Estimates**

Second-order amplification of the girder lateral-torsional stresses may cause a loading condition that is greater than the theoretical elastic buckling load. In this situation, the lateral-torsional displacement of the girder results in non-linear torsional loading. In addition, the displacement amplifications may complicate the prediction and control the structure’s geometry during erection. The AASHTO/NSBA Steel Bridge Collaboration’s guideline document *G13.1, Guidelines for Steel Girder Bridge Analysis* provides further discussion of second-order amplification considerations.

In addition, a relatively simple method for identifying potentially adverse response amplifications due to second-order effects was developed as part of NCHRP Project 12-79 (NCHRP Report 725). In this method, the linear response prediction obtained from any first-order analysis is multiplied by a simple amplification factor.

**Cantilever Girders**

During the various stages of erection of most steel girder bridges, there are often cases where field sections of girders are supported in a cantilevered position. Typically, these intermediate cantilever conditions were not addressed by the Design Engineer during the original bridge design, so it is incumbent on the Contractor’s Engineer to investigate these conditions. For long cantilevers,
lateral-torsional buckling will typically govern over yielding of the section. To examine cantilevers, the lateral-torsional buckling capacity can be estimated using the procedures provided in Galambos (1998), Ziemian (2010), or a similar appropriate method. For curved girders, additional consideration needs to be given to the torsional forces that develop due to the offset centroid of the cantilever.

2.4.4 Uplift

The potential for uplift at temporary and permanent supports during steel erection shall be considered and accounted for in the development of the Erection Engineering Calculations.

C2.4.4

Typically, uplift is undesirable and should be prevented, either by changing the Erection Plans and Procedures or by providing tie-down restraints. If uplift is indicated in the analysis but no tie-down restraint is provided, then the analysis should recognize the absence of vertical restraint at that particular support by modeling the boundary condition appropriately. Curved or skewed I-girder bridge systems are particularly susceptible to uplift during various stages of steel erection due to the torsional twisting of the system caused by curvature or skew. Incorrect consideration of uplift invalidates the analysis; if not considered correctly, uplift can result in girder misalignment and unintended lateral/longitudinal movement due to floating at bearings (if blocked prior to final bolting/field welding) with potential instability.

2.4.5 Temporary Hold Cranes

Hold crane loads (if used) shall be properly accounted for in the Erection Engineering Calculations.

C2.4.5

Hold cranes are used to apply an upward load at some location within the span of a girder, thereby reducing the load carried by the girder. Often, the hold crane load is used to reduce the girder flexural moment caused by self-weight (and any other applied loads) to a level at which the moment is less than the lateral-torsional buckling capacity. Typically a hold crane should not be considered as a brace point in the evaluation of the lateral-torsional buckling capacity of a girder; in most cases, the crane cable and crane system are flexible and not capable of providing the lateral resistance necessary to be considered as a brace point.

2.4.6 Temporary Support Loads

Temporary support loads (if used) shall be properly accounted for in the Erection Engineering Calculations. Calculations shall include computations for all loads on any and all temporary supports provided at critical stages of the erection sequence.

Temporary bracing shall be verified to have adequate strength and stiffness to provide stability to girders and resist appropriate force effects from assumed lateral loads that may occur during erection.

C2.4.6

These loads may include vertical and lateral reactions from the superstructure, self-weight of the temporary support, wind loads on the temporary support, etc.


2.4.7  **Bearings**

The Erection Engineering Calculations shall consider bearing rotations during construction. Computed bearing rotations during construction shall not exceed the rotational capacity of the bearings.

2.4.8  **Cross-Frames and Bracing**

The number, size, and location of installed cross-frames and/or other bracing members required to ensure adequate strength and stability before girders are released from lifting and/or hold cranes shall be addressed in the Erection Engineering Calculations, including evaluation of associated connection details and evaluation of the strength and stiffness of the provided cross-frames. The required number, size, and location of cross-frames and/or other bracing members shall be indicated in the Erection Plans and Procedures.

2.4.9  **Structural Adequacy of Temporary Components**

Substantiate the structural adequacy and stability of any and all temporary support components (including temporary shoring and crane supports, crane mats, barges, work trestles, girder tie-downs, jacking devices, or any other temporary components) necessary for each step of the steel erection. When applicable, manufacturers’ ratings and/or catalog cuts for pre-engineered devices may be used to meet this requirement.

Lifting devices, rigging components (rigging), and jacking devices shall meet all applicable Occupational Safety and Health Administration (OSHA) requirements for marking with rated loads and proof testing of special custom design grabs, hooks, clamps, or other lifting accessories for prefabricated structures to 125 percent of their rated loads.

C2.4.7

Skewed bridges are particularly vulnerable to twisting about the longitudinal axis of the girder. During steel erection, the girder could be rotated beyond the rotational capacity of the bearing, regardless of the vertical load on the bearing.

C2.4.8

The presence and correct installation of cross-frames in curved or skewed steel I-girder bridge erection is an important issue. The cross-frames and bracing members and their associated connections must be structurally adequate, and they must also provide sufficient stiffness to the bridge system.

During steel erection, the erector may choose to install the minimum required number of cross-frames when initially erecting the girders, so as to decrease erection time, allowing a follow-up crew to install the remaining cross-frames later. Therefore, correct determination of the minimum number of required cross-frames to prevent lateral-torsional buckling of the girders is critical to ensuring the stability of the girders during erection. Yura (1998) provides a general method to check whether cross-frames in a girder system provide sufficient bracing for the girders. Additional calculations may be required to check that individual cross-frame members and connections have adequate capacity.

C2.4.9

Temporary works are a critical part of many steel bridge erection projects and their design should be subject to a standard of care similar to other erection engineering calculations. The Erection Engineering Calculations should be done in accordance with design criteria established by the Owner, or as stated in the contract plans.

Temporary support structures should be designed to carry all applicable vertical and horizontal loads resulting from the proposed erection sequence and possibly occurring during construction. As necessary, calculations for the design of an upper grillage, temporary bearings, and foundations should also be included. The elevation of the bearing support (bearing seat elevation) at the top of the temporary support structure should be computed and provided in the Erection Plans and Procedures. The bearing seat elevations at the temporary supports can aid the steel erector in controlling the geometry of the structure during steel erection.

Special custom design lifting accessories are a critical part of many steel bridge erection projects.
Applicable OSHA regulations and other codes and standards require proof testing such devices to 125 percent of rated loads. OSHA requires marking rated loads on manufactured hooks, shackles, beam clamps, slings, etc.

Tie-downs are a critical part of many steel bridge erection projects and their design should be subject to a standard of care similar to other erection engineering calculations. The Erection Engineering Calculations should be done in accordance with design criteria established by the Owner, or as stated in the contract plans. Tie-downs may be used to resist wind loads, uplift, lateral dead load forces resulting from horizontal curvature, or other loads.

Jacking devices are a critical part of many steel bridge erection projects, and the selection of appropriate jack types and the determination of jacking loads should be subject to a standard of care similar to other erection engineering calculations. Any load calculations should be done in accordance with design criteria established by the Owner, or as stated in the contract plans. Manufacturers’ rated jack capacities should not be exceeded. In addition, written jacking procedures should be prepared and submitted for review and approval and should be included with the Erection Plans and Procedures.

2.4.10 Miscellaneous Calculations

2.4.10.1 Crane Pick Locations

Crane pick locations shall be determined with consideration of the center of gravity of the entire assembly being lifted, including the girder as well as any attached cross-frames, splice plates, stiffening trusses, or other attached items.

2.4.10.2 Support Conditions

The boundary (support) conditions assumed in the erection analysis shall accurately reflect the actual support conditions in the structure at all stages of erection (including accurate consideration of any and all temporary supports). If the character of the support at a location changes at various stages in the erection sequence, this shall be considered in the analysis model.

2.5 Coordination Items

The Erection Procedures submittal shall include documentation of all required coordination items. These include, but are not necessarily limited to, the following:

a) review/approval by other agencies as required, e.g., railroads, Coast Guard, local jurisdictions.

c2.4.10.1

The center of gravity should be determined by reasonably accurate calculations to facilitate correct rigging of lifts to avoid instability problems during lifting.

c2.4.10.2

Improper modeling of boundary conditions leads to erroneous results and invalidates the analysis.

c2.5

The Contractor should coordinate activities with the Owner/Engineer, Fabricator, and Erector. Special coordination requirements may be included in the Contract. Examples would be maintenance and protection of traffic, waterway navigation, school bus routes, and emergency vehicle routes. Safety measures (emergency boat, notification plans), coordination plan for regulatory agencies and other water traffic, and the details and anticipated
b) construction activities that occur concurrently with steel erection, such as setting forms, or concrete deck pours.
Section 3
Transportation

3.1 Responsibility

The Contractor is responsible for coordinating delivery from the fabricator to the jobsite and for providing adequate site access.

3.1.1 Shipping Plan

Unless otherwise specified by the Owner, the Contractor is responsible for preparing an informal shipping plan indicating support, lateral bracing, and tie-down points for primary members during transportation to the job site.

C3.1.1 Generally, the requirements for the transportation vary by Owner. For example, some Owners require a formal transportation drawing with supporting engineering analysis only when:

a) Girders are transported on their sides (supported via flanges)

b) Curved girders overhang the trailer by more than 25 feet

c) Cantilevered overhang exceeds 20% of the piece length

d) There is doubt as to the intensity of stress that the piece will experience under the transportation plan’s support conditions

Most specifications seek to limit factored stress and are reviewed under the authority of the Owner’s structural engineering group. Axle loads are typically governed by separate permitting authorities along the route. Thus, well-developed transportation will typically satisfy the requirements of both Owner/agency types.

3.2 Handling

Ship primary members upright, unless otherwise approved by the Owner. Load, support, and unload primary members in a manner that will not damage, excessively stress, or permanently deform the steel, and not cause repeated stress reversals.

C3.2 Care should be exercised to avoid coatings damage from slings, chokers, clamps, etc. Also, limiting the length of members overhanging the rear wheels of a trailer may reduce the range of stress reversals and potential damage from ground strikes.

3.3 Fasteners

Ship all fastener components in sealed, watertight containers, with contents clearly listed on external tags.

C3.3 High-strength steel fastener thread lubrication requires protection from the elements. This does not apply to anchor rods or end-welded shear studs.
Section 4
Material Storage at Jobsite

4.1 Fabricated Material
Store fabricated material on blocking above the ground. Properly drain the ground and keep material clean. Store primary members upright and shored or braced for stability. Support all members to prevent permanent distortion or damage.

4.2 Fasteners and Machine-Finished Parts
Store fasteners in covered containers to protect them from dirt and moisture. Store fastener containers and machine-finished parts inside covered structures or otherwise protect them from the weather. Install fasteners removed from covered containers by the end of the work shift. Return unused fasteners to covered containers at the end of a work shift or otherwise protect them from the weather. Do not install fasteners that have accumulated dirt or rust, or otherwise deviate from their manufactured condition. Fastener components, other than those incorporated into twist-off type fastener assemblies, may be cleaned and relubricated by the erector. Relubricated fasteners shall be subsequently retested per Section 7.3 to verify bolt installation method.

4.3 Welding Consumables
Store and handle welding consumables in accordance with the AASHTO/AWS D1.5 Bridge Welding Code.

4.4 Damage
Report any damaged structural steel to the Owner, including a description of the damage and proposed Contractor disposition (repair or replace).
Section 5
Bearings and Anchorages

5.1 Survey
Verify all substructure locations (lateral and longitudinal), existing anchor rod locations, bearing seat elevations, and other pertinent information in a Contractor survey, conducted prior to start of associated erection operations. Resolve any discrepancies between the Contractor-conducted survey and contract plans with the Owner prior to performance of erection operations.

C5.1
The Contract survey should be performed by the general contractor, erector, or neutral third party. The third party should be the general contractor or a representative of the general contractor. The erector should verify the survey data before steel erection.

5.2 Bridge Seats
Place bearing devices on properly finished bridge seat bearing areas. Notify the Owner if seats are not level or are at incorrect elevations, and propose corrective actions.

C5.2
Bridge bearings may allow movement or rotation in all planes and axes. During erection of a single girder, in addition to other stability provisions, the bearings may require blocking to limit movement and/or rotation.

5.3 Temperature Adjustments
When setting bearings, make appropriate corrections for ambient temperature and anticipated rotation due to dead load deflection of the supported member. Position high-load, multi-rotational bearings such that the initial position, including corrections for temperature and dead load rotation, is within manufacturer’s requirements. Notify the Owner if anchor bolt locations do not permit proper positioning, and propose corrective actions.

C5.3
See recommendations in AASHTO/NSBA Steel Bridge Collaboration G9.1, Steel Bridge Bearing Design and Detailing Guidelines for thermal movement calculations.

5.4 Tolerances
In addition to the dimensional tolerances in the AASHTO/AWS D1.5 Bridge Welding Code for steel bearing contact areas, members shall seat on bearing devices with no final gaps exceeding 1/16 inch.
Section 6
Lifting and Assembly

6.1 General
Lift, position, and assemble all members in accordance with the procedures satisfying [Section 2]. The proposed crane location(s) and member delivery location(s) may require modification in the field to suit changing jobsite conditions. However, cranes and material must be located such that the lift is safe and within the crane manufacturer’s rated capacity for all required positions.

6.2 Lifting Devices
Install lifting devices, including welded lugs and bolted assemblies using existing bolt holes (splices, cross-frame connection plates, etc.), that are in accordance with Sections 7 or 8 and use Owner-approved details.

6.3 Erection Stability
Girders shall be stabilized with falsework, temporary bracing, holding cranes, or a combination of these until a sufficient number of adjacent girders are erected with diaphragms or cross-frames that connect to provide the necessary local and global stability, making the structure self-supporting.

6.4 Trusses
Trusses erected by assembling individual components in place (stick built) shall be erected on falsework unless approved by the Owner. When erecting trusses on falsework, the falsework shall remain in place until all connections are completed and the truss is self-supporting. Specific cases that may not require falsework include balanced cantilevered erection, cable stayed truss erection, and trusses spliced in the air while in the falls of two cranes.

6.5 Falsework and Temporary Supports
Falsework and temporary supports shall be detailed to insure that the temporary elevation of supported steel accommodates the deflections expected to occur as the structure is completed.

C6.1
Jobsite conditions vary on a daily basis and are often not as they were anticipated to be when the erection procedure was conceived and submitted to the Owner. Consequently, the need to deviate from the submitted erection procedure may arise during the course of a bridge project. It is the Contractor’s responsibility to erect the steel in a safe and efficient manner. The Owner's review and disposition of erection procedure changes to suit jobsite conditions should be handled in an expeditious fashion and should avoid delaying the work.

C6.3
Removal of falsework, temporary bracing, or holding cranes shall be in accordance with stability calculations provided in the erection procedure.

C6.5
If dead load, beyond the steel dead load, is to be applied to the structure while temporary supports remain in place, they must have provision to be lowered, or “jacked down.”
6.6 Pins

Pins are normally used to align holes for bolted field connections. Field reaming to facilitate fit-up will only be allowed with the Owner's prior approval. Any abnormal distortion of the member or of the holes during the alignment process shall be immediately reported to the Owner.

6.7 Connections

For splice connections of primary members, as well as connections of diaphragms or cross-frames designed to brace curved girders, fill at least 50 percent of the holes prior to crane release. The 50 percent may be either erection bolts in a snug tight condition or full-size erection pins, but at least half (25 percent of all holes) shall be bolts, and sufficient pins shall be used near outside corners of splice plates and at member ends near splice plate edges to ensure alignment. Uniformly distribute the filled holes.

The 50 percent requirement may be waived if a reduced percentage is calculated as sufficient and shown on the approved erection procedure.

Permanent bolts may be used as erection bolts, provided they are installed in accordance with Section 7.4. For complex structures (arches, trusses, etc.), install bolts and pins in accordance with erection procedures.

Primary member splice connections that are made up on the ground (prior to erection) shall be 100 percent complete, in the no-load condition, prior to any lifting operation.

6.8 Abnormalities

Any abnormal member deformation or brace deflection after crane release or temporary support removal shall be immediately reported to the Owner, seeking immediate resolution. Further work affecting the area, except for restoring support or adding bracing, shall be stopped until the deformation or deflection is resolved.
7.1 Fastener Testing

For ASTM A325 or A490 bolts, have the manufacturer or distributor perform rotational capacity (RC) testing on fastener assemblies per Appendix A or B.

7.2 Faying Surfaces

No loose mill scale, dirt, metal shavings, or other foreign material that would preclude solid seating of the parts or frictional transfer of load is allowed on faying surfaces of bolted connections.

7.3 Installation Method Verification

Verify bolt installation method prior to bolt installation, in accordance with the Specification for Structural Joints Using High Strength Bolts by the Research Council on Structural Connections (referred hereafter as “the Bolt Specification” and available at http://www.boltcouncil.org). Verify direct tension indicators (DTIs) per Appendix C.

For turn-of-the-nut installation or DTI installation, have the verification test performed by each bolting crew, for each combination of grade, length, and diameter that the crew will be installing and whenever the condition of the bolts or the understanding of the crew is in question. The Bolt Specification requires daily verification testing for the calibrated wrench method.

Additionally, perform fastener assembly field rotational capacity RC test per Appendix D or the conventional RC test per Appendix A or B] for each RC lot and whenever the condition of the fasteners is in question. Perform the verification test procedure for direct tension indicators per Appendix C. For turn-of-the-nut installation, the field RC test may be performed in combination with a verification test.

C7.2

The steel erector is generally not responsible for faying surface preparation, unless required by the contract. The erector’s only responsibility is to keep the faying surfaces clean from contamination during erection.

C7.3

It is important to have the bolting crew, rather than an inspector, perform the Installation Verification test because part of the function of this test is to verify that the installer’s notion of “snug” leads to the required installation tension. If the same crew is repeatedly installing the same bolts, there should be no need to repeat the verification test for turn-of-the-nut or DTI installation. Daily verification is required for the calibrated wrench method to ensure that the equipment is still accurate.

Where daily testing is not required, it is recommended that tests on particular sizes, lengths, and grades be performed shortly before those particular fasteners are installed, rather than testing all fasteners at the beginning of the project. Testing each fastener type as it comes up for installation will help keep the crew familiar with that particular fastener assembly. Too much time between testing and installation may be considered reason to question the understanding of the crew. Owner and Contractor should agree on an appropriate interval, taking into account the complexity of the project and the experience of the crew.

The field RC test is intended to give confidence in the condition of the bolts without the use of a calibrated torque wrench (unless it is part of the installation method), and to allow the combination of RC and installation verification testing into one test. Steps 1–3 are, in essence, the Bolt Specification preinstallation verification test for the turn-of-the-nut method. Step 4 provides reassurance that the bolt is in good condition and is not about to exhaust its capacity at installation. Step 5 is common to both the RC test and the preinstallation verification test. The primary difference between this test and the conventional FHWA RC test of Appendix A is the maximum torsion requirement given in Appendix A.
Since the FHWA RC test will already have been performed by the fastener manufacturer or distributor, the field RC test should give sufficient confidence that the fasteners and lubricant have been maintained in good condition.

7.4 Installation
Install and pretension bolts using any of the methods allowed per the Bolt Specification. Pretension bolts to the minimum tension shown in the Bolt Specification.
Bolts may remain untensioned until just before completion of steel erection.

C7.4
All bolts in a connection are installed in the snug tight condition prior to pretensioning. However, it may be difficult to achieve the snug tight condition for large primary member connections, which have many bolts and/or plies of thick material. In this case, the Owner may permit a portion of each connection be filled with pretensioned temporary fit-up bolts prior to installing permanent bolts in the remaining holes to the snug tight condition. The temporary bolts are then replaced with the snug-tightened permanent bolts. Joints can then be pretensioned in accordance with the Bolt Specification. The use of temporary fit-up bolts, or some other method to achieve the snug tight condition throughout the connection before pretensioning, should also be considered when using twist-off type fasteners or direct tension indicators.

Bolts installed in the snug tight condition and left in place for an extended period of time prior to pretensioning may experience a change in their lubrication characteristics, and may not achieve required tension when pretensioned per the project verified installation method. Remove and relubricate, or replace such bolts when appropriate. Relubricated fasteners shall be subsequently retested per Section 7.3 to verify bolt installation method.

Pretension bolts before exposure to the elements affects their rotational capacity test characteristics.

7.4.1 Direct Tension Indicators and Tension Control Bolts
If DTIs or tension control bolts are used, bring all plies into firm contact before engaging the indication mechanism.

C7.4.1
Devices like direct tension indicators and tension control bolts work well to help ensure fasteners are completely and properly pretensioned, but they can be misleading if not used properly.

On large connections, such as bridge girder flange-to-flange or web-to-web bolted splice, fasteners close gaps within faying surfaces. It is only when these gaps are closed that proper pretensioning may begin, regardless of the method being used (turn-of-the-nut, DTI, tension control bolt, or other). Typically it takes about 20 percent of the bolts to close the gaps in a connection; often fit-up bolts are used for this step.

If a fastener with an indicating method is pretensioned before connection plates are drawn down, the fastener will be loose once the plies are indeed closed. Therefore, care must be taken not to
engage the pretensioning indication mechanism until the plies are drawn down and the gaps are closed.
Section 8
Field Welded Connections

8.1 General
Field welding and nondestructive testing shall be performed in accordance with the AASHTO/AWS D1.5 Bridge Welding Code (referred hereafter in this section as “D1.5”) or other codes as specified in the contract documents. Field welding on permanent material is not allowed unless shown on the plans or approved by the Owner.

8.2 Weld Procedure Specifications
All structural field welding shall be done using automatic stud welding per D1.1 Clause 7 for stud welding orOwner-approved welding procedure specifications (WPSs).

8.3 Qualification
8.3.1 Welder Qualification
Qualify welders in accordance with D1.5, and any additional Owner requirements, for the positions and processes approved for field welding.

C8.1
D1.5 is written mostly for the use of shop fabricating structural steel members. Field welding structural steel members presents environmental and geometric conditions that exceed those in the shop. Rain, humidity, temperature, and wind are examples of conditions that cannot be controlled in the field but can be controlled in the shop. Difficulty in steel fit-up, access to the joint by the welder, and welding position are geometric constraints that can adversely affect the quality of the weld.

However, despite the environmental and geometric challenges, experience on numerous bridges over the past 50-plus years has shown that field welding can readily be accomplished successfully and provides a useful tool for experienced contractors.

Because bridge field welding is not customary in many states, the contract documents should make it clear whether or not field welding is allowed.

8.2.1 C8.2
D1.1 Clause 7 for stud welding is referenced rather than the equivalent clause in D1.5 because, although the clauses are almost identical in the two documents, the D1.1 clause has had more recent revisions, such as allowing processes other than SMAW for fillet welding studs. D1.1 and D1.5 both require wind shielding.

Low hydrogen practices are required for field welding and can produce good quality welds when done in accordance with D1.5. When wind speeds exceed 20 mph, the granular flux required for SAW may blow away if precautions are not taken to block strong winds. Welding with gas-shielded processes has been prohibited because of potential loss of shielding gases by drafts from nearby moving objects or when wind speeds exceed 5 mph (barely perceptible).

C8.3.1
Keeping track of welders that are qualified can be difficult because, unlike shop welding, a Contractor’s workers welding move from project to project. Some Owners have programs that address qualification of field welders.
8.3.2 Welding Procedure Qualification
Field welding shall be performed in accordance with WPSs approved by the Owner for the specific application and location. Welding procedures that do not satisfy D1.5 requirements for prequalification shall be qualified by test per D1.5.

8.4 Welding Requirements

8.4.1 Welders
Welders shall have a written copy of the approved WPS.

8.4.2 Contact Surfaces
Prior to welding, the contact surfaces and joints are to be field welded, and the surrounding area shall be cleaned of contaminants in accordance with D1.5.

8.4.3 Joined Parts
The parts to be joined shall be aligned in accordance with D1.5, and joint faces shall comply with the geometric tolerances of D1.5.

8.4.4 Environmental Conditions
Field welding shall not be allowed when the ambient air temperature is below 0°F or during periods of precipitation unless the welder is housed in a heated or protected area in a manner approved by the Owner.

8.4.5 Consumables
Electrodes and flux shall be purchased, stored, dried, and used in accordance with D1.5.

8.4.6 Preheat
Surfaces to be welded shall satisfy preheat requirements of D1.5 for 3 inches in all directions from the weld. Higher preheat, post-weld heating, or both may be required for fracture critical welds, for welds in areas with high restraint, or to avoid defects. Preheating methods shall avoid damage to adjacent coated surfaces, neoprene bearings, and other heat-sensitive components. Damage caused by heating shall be corrected at the Contractor’s expense.

C8.3.2
Qualification tests for non-standard joints or primary member WPSs should be performed prior to arrival at the jobsite. Variations in consumables or geometry are governed by D1.5.

C8.4.4
When the ambient air temperature is below 0°F, when surfaces are wet or exposed to rain or snow, or the welders’ ability to make sound welds is a concern, heating, housing, or both should be used. See D1.5 Commentary for a detailed explanation of the effect of environmental conditions on welds.

C8.4.5
It is required that electrodes and flux be kept dry at all times. Electrodes should be purchased in hermetically sealed containers. If electrodes are not stored according to the requirements of D1.5, they will absorb moisture and produce poor quality welds during production welding. Electrode drying ovens should be at the project site located near the welders work station at all times. Once the electrode container is opened, electrodes should be placed in the ovens and stored at temperatures meeting the requirements of D1.5.
Section 9
Inspection

9.1 General
Inspect and test repaired welds, coatings, and base metal in accordance with this Section. Verify the alignment, profile, and fastening of the erected steel conforms to the contract requirements.

C9.1
Material quality, damage repair and conformance to plan dimensions, and assembly requirements are subject to the verification inspection of the Owner.

An erection inspection checklist can be found in Appendix G.

9.2 Tolerances for Plate Girder or Rolled Beam Spans

9.2.1 Deviation from Theoretical Horizontal Alignment
± 1/8 inch × (total length along girder, in feet, between supports)/10.

Erected horizontal alignment shall be measured under steel dead load at the centerline of the top flange or other location mutually acceptable to the Owner and Contractor, and shall not deviate from the theoretical horizontal alignment by more than the value computed above. The theoretical horizontal alignment shall be provided by the Owner (at final or total dead load position) along with cambers that the detailer can compute the girder field section camber with, which (for I-girders) is typically considered to the no-load (NLF) profile.

The bearing points should be properly surveyed for alignment and elevation prior to erection.

9.2.2 Deviation from Theoretical Erected Web Position (Web Plumbness)

Unless specified otherwise on the plans, the erected web position shall be measured under steel dead load conditions (i.e., all structural steel erected and connected, prior to placement of any deck concrete) and shall be taken as the differential in horizontal displacement between the top and bottom of the web divided by the web depth. The erected web position shall not deviate from the theoretical position by more than 1/8 inch x web depth in feet unless otherwise approved by Owner. In addition, the deviation from the theoretical position shall not compromise the performance of the bearing in the final condition. The theoretical erected web position is to be provided by the Owner and calculated under the steel dead load only condition.

The location and nature of the measurement for deviation from theoretical web position may vary depending on bridge type. Webs of straight girders in non-skewed bridges should be plumb at all locations under steel dead load, and should typically remain plumb after placement of the deck. In straight girder bridges with skewed supports, webs typically deform laterally, both at supports and away from supports, as load is applied; the magnitude and direction of deformation may change along the length of the bridge and from girder to girder. In curved girder bridges with non-skewed (radial) supports, the webs typically remain plumb at the supports under all loading conditions, but the webs will typically deform laterally as load is applied. In curved girder bridges with skewed (non-radial) supports, the webs may deform laterally, both at supports and away from supports, as load is applied; again, the magnitude and direction of deformation may change along the length of the bridge and from girder to girder. For other
bridge types, measurement positions should be provided by the Owner.

Web position can be affected in the field by conditions not considered by the designer and/or beyond the control of the Contractor. Web positions within the tolerance noted here are considered acceptable. Web positions beyond the tolerance noted here may be acceptable; however, they must be evaluated regarding cause and impact on bridge service, and approved by the Owner.

Typical considerations include, but may not be limited to:

a) Bearing design (bearings are typically designed to accommodate 0.005 radians of rotational construction tolerance)
b) Girder stresses
c) Cross-frame fit-up and associated locked-in force effects

The actual plumb condition of each girder is influenced by many factors, including:

a) How well the design deflections predict the actual deflections
b) Fit conditions chosen for establishing the connections between girders and cross-frames (the “drops”)
c) Fabrication tolerances
d) Erection sequences
e) Deck pouring sequences
f) Support conditions
g) Environmental conditions (sun position, temperature, etc.)

When attached to cross-frames, girders on skewed and curved bridges rotate laterally as the girders deflect from the no-load to the steel dead-load and finally the full dead-load condition. The condition of plumb in each of these three states depends heavily (but not entirely) on the fit condition chosen for the drops. For example, if a skewed bridge is detailed for steel dead-load fit, the girders should be nominally plumb at erection but laying over somewhat in the final condition; or if a skewed bridge is detailed for full dead-load fit, the girders will be laying over at erection but should be nominally plumb under full dead load. Therefore, when considering use of a tolerance for girder plumbness in the field, it is important to be mindful of the fit condition used in detailing and fabrication.
9.2.3 Deviation from theoretical vertical alignment (elevation)

- 0, + 1/4 inch × (total length, in feet, from nearest support)/10

Erected vertical alignment shall be measured under steel dead load at the centerline of the top flange or other location mutually acceptable to the Owner and Contractor shall not deviate from the theoretical erected vertical alignment by more than the value computed above. Maximum deviation is 3/4 inch in cantilever sections or 1 1/2 inches between supports. The theoretical vertical alignment is to be provided by the Owner and calculated under the steel dead-load-only condition.

9.3 Surveys

It is the Contractor’s responsibility to survey steel profile and alignment during and after completion of steel erection, with verification by the Owner. Surveys during erection must consider support conditions and anticipate deflections from subsequent steel placement or support release.

9.4 Bolting

Bolting inspection shall conform to the requirements of the Bolt Specification.

9.5 Welding

Unless the Owner requires otherwise, visual inspection and nondestructive testing (NDT) shall be performed on field welds in accordance with D1.5. Welds shall be evaluated for acceptance in accordance with D1.5.

Plans or specifications shall indicate “tension or stress reversal areas” so Contractors know where to apply tension/stress reversal acceptance criteria under D1.5.

C9.2.3

Tolerance in the negative direction, i.e., vertical alignment lower than theoretical, has been prohibited to ensure that the distance between top of flange and top of deck can be maintained, thereby avoiding thickening the haunch (or deck) to suit. Installed locations lower than theoretical may be acceptable upon review by the Owner. For a typical girder bridge, some agencies may choose to control only the elevation of the girder splices and accept vertical alignment between splices (within the tolerance on shop camber). Some of the tolerance on vertical alignment may be “consumed” by the tolerance on shop camber of the fabricated girder.

Splice elevation should be verified prior to crane or temporary support release.
Section 10
Repair

10.1 Documentation
The Contractor is responsible for documenting damage due to handling, removal of erection aids, aligning members and other actions, uncorrected misfits at connections or misalignments exceeding tolerances in erected members, and as-received damage attributable to transport or fabrication.

10.2 Implementation
The Contractor shall propose a method of repair and basis for acceptance for the Owner’s review.

10.3 Repair Procedures
Submit repair procedures for damaged or misaligned steel in the form of sketches, written procedures, or both as applicable. Information must provide sufficient detail for the Owner to adequately review the repair application. After repairs are complete, the contractor shall provide as-built detailed drawings, NDT results and procedures/materials used to the Owner for inclusion in the project file.

10.4 Welds
Field or shop welds that are unacceptable must be repaired in accordance with D1.5. Responsibility for the cost of the repair and subsequent inspection shall be based on the cause.

C10.1
Damage such as minor arc strikes or handling damage done to paint may not need extensive documentation, unless it is a recurring problem. Widespread problems such as paint damage throughout several girders, especially if the cause is not apparent, or multiple misaligned girders may require the services of outside expertise.
Appendix A
Rotational Capacity Test
(ASTM A325 and ASTM A490 Long Bolts in Tension Calibrator)


EQUIPMENT REQUIRED:
1. Calibrated bolt tension measuring device to determine the size required for the bolts to be tested.
2. Calibrated torque wrench and spud wrenches.
3. Spacers with holes 1/16 inch larger than bolt to be tested, or nominal diameter washers.
4. Steel section to mount the tension calibrator.

PROCEDURE:
A rotational capacity test consists of 2 assemblies.
1. Measure the bolt length (the distance from the end of the bolt to the washer face at the bolt head to shank interface).
2. Install the bolt in the tension calibrator with the required spacers or washers so that the bolt stick-out is flush with the nut to a maximum of three threads. This will typically provide three to five threads within the grip (the distance between the bolt head and the inside face of the nut). This same stick-out requirement applies during installation.
3. Tighten the fastener assembly using a spud wrench to the tensions listed below –0 kips / +2 kips.

<table>
<thead>
<tr>
<th>Bolt Diameter (inch)</th>
<th>1/2</th>
<th>5/8</th>
<th>3/4</th>
<th>7/8</th>
<th>1</th>
<th>1 1/8</th>
<th>1 1/4</th>
<th>1 3/8</th>
<th>1 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A325 Initial Tension (kips)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>ASTM A490 Initial Tension (kips)</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>15</td>
</tr>
</tbody>
</table>

4. Match mark the bolt, nut, and face plate of the calibrator.
5. Using the calibrated torque wrench, tighten the fastener assembly to at least the minimum installation tension listed below and record both the tension and torque. Torque shall be read with the nut rotating. The torque value from the test shall not exceed \( T = 0.25 \times PD \). \( P \) = tension in pounds. \( D \) = diameter (in./12 = bolt diameter in feet.

<table>
<thead>
<tr>
<th>Bolt Diameter (inch)</th>
<th>1/2</th>
<th>5/8</th>
<th>3/4</th>
<th>7/8</th>
<th>1</th>
<th>1 1/8</th>
<th>1 1/4</th>
<th>1 3/8</th>
<th>1 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A325 Tension (kips)</td>
<td>12</td>
<td>19</td>
<td>28</td>
<td>39</td>
<td>51</td>
<td>56</td>
<td>71</td>
<td>85</td>
<td>103</td>
</tr>
<tr>
<td>ASTM A490 Tension (kips)</td>
<td>15</td>
<td>24</td>
<td>35</td>
<td>49</td>
<td>64</td>
<td>80</td>
<td>102</td>
<td>121</td>
<td>148</td>
</tr>
</tbody>
</table>

6. Further tighten the bolt to the rotation listed below. The rotation is measured from the initial marking in Step 4.

| Bolt Length (L) | \( L \leq 4 \times \text{Bolt Diameter (BD)} \) | \( 4 \times BD < L \leq 8 \times BD \) | \( 8 \times BD < L \) |
|-----------------|---------------------------------------------|---------------------------------------------|
| Required Rotation | \( \frac{2}{3} \) | 1 | \( \frac{1}{6} \) |

7. Record the tension at the completion of the rotation in Step 6. The tension shall equal or exceed 1.15 times the minimum installation tension. The minimum required values are listed in the table below.

<table>
<thead>
<tr>
<th>Bolt Diameter (inch)</th>
<th>1/2</th>
<th>5/8</th>
<th>3/4</th>
<th>7/8</th>
<th>1</th>
<th>1 1/8</th>
<th>1 1/4</th>
<th>1 3/8</th>
<th>1 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A325 Tension (kips)</td>
<td>14</td>
<td>22</td>
<td>32</td>
<td>45</td>
<td>59</td>
<td>64</td>
<td>82</td>
<td>98</td>
<td>118</td>
</tr>
<tr>
<td>ASTM A490 Tension (kips)</td>
<td>17</td>
<td>28</td>
<td>40</td>
<td>56</td>
<td>74</td>
<td>92</td>
<td>117</td>
<td>139</td>
<td>170</td>
</tr>
</tbody>
</table>
8. Loosen and remove the nut. There shall be no signs of thread shear failure, stripping or torsional failure. The nut shall turn, with your fingers, on the bolt threads to the position it was in during the test. The nut does not need to run the full length of the threads. If you cannot turn the nut with your fingers it is considered thread failure.

**FAILURE:**
The following constitute a failure of the rotational capacity test.
1. Exceeding the maximum allowable torque in the torque/tension comparison.
2. Failure to achieve the required rotation.
3. Failure to achieve the required tension at the required rotation.
4. Thread failure.

Failure of any one of these items on either assembly constitutes a failure of the rotational capacity test. When a failure occurs, the subject lot of fasteners is rejected. The contractor is given the option to clean and re-lubricate as necessary and then retest the fastener assemblies.
Appendix B
Rotational Capacity Test
(ASTM A325 and ASTM A490 Bolts too Short to Fit Tension Calibrator)


Only those bolts too short to fit in the tension measuring device shall be tested using this procedure. Typically, these bolts are less than four times the bolt diameter in length.

EQUIPMENT REQUIRED:
1. Calibrated torque wrench and spud wrenches.
2. Spacers with holes \( \frac{1}{16} \) inch larger than bolt to be tested or nominal diameter washers.
3. Steel section with holes \( \frac{1}{16} \) inch larger than the bolt diameter. Splice holes in the steel on the project can be used.

PROCEDURE:
A rotational capacity test consists of 2 assemblies.
1. Measure the bolt length (the distance from the end of the bolt to the washer face at the bolt head to shank interface).
2. Install the bolt in the steel plate with the required spacers or washers so that the bolt-stick out is flush with the nut to a maximum of three threads. This will typically provide three to five threads within the grip (the distance between the bolt head and the inside face of the nut). This same stick-out requirement applies during installation.
3. Provide an initial tension in the fastener assembly using a spud wrench. The torque should not exceed 20 percent of the maximum torque allowed in Step 5.
4. Match mark the nut, bolt, and plate.
5. Tension the bolt using a torque wrench to rotate the nut as required in the table below. Prevent the bolt head from rotation. Read the torque at the required rotation with the nut in motion.

<table>
<thead>
<tr>
<th>Bolt Length ((L)) (\leq 4 \times \text{Bolt Diameter} (BD))</th>
<th>(4 \times BD &lt; L \leq 8 \times BD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Rotation</td>
<td>(\frac{1}{3})</td>
</tr>
</tbody>
</table>

The measured torque shall not exceed the values listed below. Assemblies that exceed the listed torques have failed the test. These torque values are based on an assumed tension of 1.15 times the minimum installation tension.

<table>
<thead>
<tr>
<th>Bolt Diameter (inch)</th>
<th>(\frac{1}{2})</th>
<th>(\frac{5}{8})</th>
<th>(\frac{3}{4})</th>
<th>(\frac{7}{8})</th>
<th>1</th>
<th>(\frac{1}{8})</th>
<th>(\frac{1}{4})</th>
<th>(\frac{1}{8})</th>
<th>(\frac{1}{2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A325 Torque (ft-lbs)</td>
<td>150</td>
<td>290</td>
<td>500</td>
<td>820</td>
<td>1230</td>
<td>1500</td>
<td>2140</td>
<td>2810</td>
<td>3690</td>
</tr>
<tr>
<td>ASTM A490 Torque (ft-lbs)</td>
<td>180</td>
<td>370</td>
<td>630</td>
<td>1020</td>
<td>1540</td>
<td>2160</td>
<td>3050</td>
<td>3980</td>
<td>5310</td>
</tr>
</tbody>
</table>

Further tighten the bolt to the rotation listed below. The rotation is measured from the initial marking in Step 4. Assemblies that fail prior to this rotation either by stripping or fracture fail the test.

<table>
<thead>
<tr>
<th>Bolt Length ((L)) (\leq 4 \times \text{Bolt Diameter} (BD))</th>
<th>(4 \times BD &lt; L \leq 8 \times BD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Rotation</td>
<td>(\frac{2}{3})</td>
</tr>
</tbody>
</table>

6. Loosen and remove the nut. There shall be no signs of thread shear failure, stripping, or torsional failure. The nut shall turn, with your fingers, on the bolt to the position it was in during the test. The nut does not need to run the full length of the threads. If you cannot turn the nut with your fingers, it is considered thread failure.

FAILURE:
The following constitute a failure of the rotational capacity test.
1. Exceeding the maximum allowable torque.
2. Failure to achieve the required rotation.
3. Thread failure.

Failure of any one of these items on either assembly constitutes a failure of the rotational capacity test. When a failure occurs, the subject lot of fasteners is rejected. The contractor is given the option to clean and re-lubricate as necessary and then retest the fastener assemblies.
Appendix C
Direct Tension Indicators (DTI)
(Verification Test Procedure)


EQUIPMENT REQUIRED:
1. Calibrated bolt tension measuring device with a special flat insert in place of the normal bolt head holding insert. Special insert required to allow access to measure DTI gap.
2. Tapered leaf thickness (feeler) gage 0.005 inch. Same gage as to be used to inspect the bolts after installation.
3. Bolts, nuts, and standard washers to be used in the work with the DTIs.
4. Impact and manual wrench to tighten bolts. Equipment should be the same as to be used in the work.

PROCEDURE:
1. Install bolt, nut, DTI and standard washer (if used) into bolt tension measuring device. Assembly should match that to be used in the work.
2. Use another wrench on the bolt head to prevent rotation of the head against the DTI if the DTI is against the turned element.
3. Tighten bolt to tensions listed below (1.05 times the minimum installation tension). Use another wrench on the bolt head to prevent rotation of the head against the DTI if the DTI is against the turned element. If an impact wrench is used, tighten to a load slightly below the required load and use a manual wrench to attain the required tension. The load indicating needle of the tension measuring device cannot be read accurately when only an impact wrench is used.

<table>
<thead>
<tr>
<th>Bolt Dia. (inch)</th>
<th>1/2</th>
<th>5/8</th>
<th>3/4</th>
<th>7/8</th>
<th>1</th>
<th>1 1/8</th>
<th>1 1/4</th>
<th>1 3/8</th>
<th>1 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A 325 Bolt</td>
<td>13</td>
<td>20</td>
<td>29</td>
<td>41</td>
<td>54</td>
<td>59</td>
<td>75</td>
<td>89</td>
<td>108</td>
</tr>
<tr>
<td>ASTM A 490 Bolt</td>
<td>na</td>
<td>na</td>
<td>37</td>
<td>51</td>
<td>67</td>
<td>84</td>
<td>107</td>
<td>127</td>
<td>na</td>
</tr>
</tbody>
</table>

4. Determine and record the number of spaces between the protrusions on the DTI that a 0.005 in. thickness gage is refused. The total number of spaces in the various sizes and grades of DTIs is shown below.

<p>| Number of Spaces |
|------------------|---------|-------|------|</p>
<table>
<thead>
<tr>
<th>Bolt Dia. (inch)</th>
<th>1/2</th>
<th>5/8</th>
<th>3/4</th>
<th>7/8</th>
<th>1</th>
<th>1 1/8</th>
<th>1 1/4</th>
<th>1 3/8</th>
<th>1 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A 325 Bolt</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>ASTM A 490 Bolt</td>
<td>na</td>
<td>na</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>na</td>
<td></td>
</tr>
</tbody>
</table>
5. The number of spaces which the 0.005 in. gage is refused should not exceed the number given in the table below. If the number of spaces exceeds the number in the table, the DTI fails the verification test.

<table>
<thead>
<tr>
<th>Number of spaces in washer</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Number of spaces gage is refused</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

* If the test is a coated DTI under the turned element, the maximum number of spaces the gage is refused is the number of spaces on the washer minus one.

6. The bolt should be further tightened to the smallest gap allowed in the work. Normally, this smallest gap condition is achieved when the gaps at all the spaces are less than 0.005 in. (or a gap size as approved by the Engineer) and when not all gaps are completely closed. When such a condition is achieved the 0.005 in. gage is refused at all spaces, but a visible gap exists in at least one space. Note the load in the bolt at this smallest gap. The bolts in this verification test and in the actual installation should not be tightened to a no visible gap condition, i.e. a condition when all the gaps are completely closed. The load in the bolt becomes indeterminate when no gap exists. It is possible to cause bolt failure by tightening beyond complete crushing of the washer.

7. Remove the bolt from the calibrator and turn the nut on the threads of the bolt by hand. The nut should be able to be turned on the complete length of the threads, excluding the thread run-out. Alternatively, if the nut is unable to go the full thread length, but the load at the minimum DTI gap (measured in step 6 above) is less than 95% of the maximum load achieved in step 6 of the Rotational Capacity test, the assembly, including the DTI, is deemed to have passed this test. If the nut cannot be run the full thread length, and if the load at the smallest gap condition is greater than the 95% of the maximum strength of the bolts from the Rotational Capacity test, the load required for the smallest gap in step 6, is too large. If approved by the Engineer, the test could be repeated with a larger minimum gap, for example one space that will accept a 0.005 in. feeler gage, or the DTIs could be replaced.

**SHORT BOLTS:**

Bolts from Rotational Capacity lots that are too short to fit in the tension measuring device shall be tested by tightening to the minimum gap in step 6 above and checked in accordance with step 7 above. The 95% alternative cannot be used since short bolts are not tested in the tension measuring device for rotational capacity. The DTI used with the short bolt should be checked in accordance with steps 1 through 5 above using longer bolt in the tension measuring device.
Appendix D
Field Rotational Capacity Test
(and Optional Combined Installation Verification Test)

EQUIPMENT REQUIRED:
1. Calibrated bolt tension measuring device to determine the size required for the bolts to be tested.
2. Wrenches of the type needed to snug and tension the bolts.
3. Spacers with holes 1/16 inch larger than bolt to be tested, or nominal diameter washers.
4. Steel section to mount the tension calibrator.

PROCEDURE:
A rotational capacity test consists of 2 assemblies. A combined rotational capacity and installation verification test consists of 3 assemblies.

1. Install fastener into tension-measuring device. Ensure that 3 to 5 threads are between the face of the nut and the shank of the bolt by stacking the appropriate spacers and flat washers. The end of the bolt will be flush with or extend beyond the outer nut face.

2. Snug-tighten the fastener by the method that will be used in production, to a minimum of 10% of the required fastener installation tension. If this test is being used as an installation verification test, snug-tighten the fastener without relying on the tension-measuring device, since this feedback will not be available during installation, and only use the tension-measuring device to check for minimum required tension after snug-tightening.

3. If this test is combined with an installation verification test, tighten the fastener the required number of turns using the wrench and air or electric supply that will be used in tightening the bolts in the work. The wrench shall be capable of tightening the fastener to the required rotation in 10 seconds or less. The tension in the bolt shall be at least 1.05 × the required installation tension given in the table below.

<table>
<thead>
<tr>
<th>Bolt Diameter (inch)</th>
<th>1/2</th>
<th>5/8</th>
<th>3/4</th>
<th>7/8</th>
<th>1</th>
<th>1 1/8</th>
<th>1 1/4</th>
<th>1 3/8</th>
<th>1 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A325 Initial Tension (kips)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>ASTM A490 Initial Tension (kips)</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>15</td>
</tr>
</tbody>
</table>

4. Tighten the fastener to the rotation listed below. The measured tension must equal or exceed 1.15 × the required installation tension.

<table>
<thead>
<tr>
<th>Bolt Length (L)</th>
<th>L ≤ 4 × Bolt Diameter (BD)</th>
<th>4 × BD &lt; L ≤ 8 × BD</th>
<th>8 × BD &lt; L &lt; 12 × BD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Rotation</td>
<td>2/3</td>
<td>1</td>
<td>1 1/6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bolt Diameter (inch)</th>
<th>1/2</th>
<th>5/8</th>
<th>3/4</th>
<th>7/8</th>
<th>1</th>
<th>1 1/8</th>
<th>1 1/4</th>
<th>1 3/8</th>
<th>1 1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A325 Tension (kips)</td>
<td>14</td>
<td>22</td>
<td>32</td>
<td>45</td>
<td>59</td>
<td>64</td>
<td>82</td>
<td>98</td>
<td>118</td>
</tr>
<tr>
<td>ASTM A490 Tension (kips)</td>
<td>17</td>
<td>28</td>
<td>40</td>
<td>56</td>
<td>74</td>
<td>92</td>
<td>117</td>
<td>139</td>
<td>170</td>
</tr>
</tbody>
</table>

Copyright © 2014 by the AASHTO/NSBA Steel Bridge Collaboration
All rights reserved.
5. Remove the fastener from the tension-measuring device and examine the threads. There shall be no signs of thread shear failure, stripping, or torsional failure. The nut shall turn, using only one’s fingers, on the bolt to the position it was in during the test. The nut does not need to run the full length of the threads. If the nut cannot be turned using only one’s fingers, it is considered thread failure.

**FAILURE:**
The following constitutes a failure of the rotational capacity test.
1. Failure to achieve the required rotation at Step 4.
2. Failure to achieve the minimum required torque at Step 4.
3. Thread failure.

**Commentary:**
“Oversnugging” (e.g., to be over 30% of required installation tension) in Step 2 may lead to a failure at Step 4. This does not necessarily mean that there is a problem with the bolts or the installation method, but that the combination of “oversnugging” and the additional rotation of Step 4 is too much for the bolt; this combination would not be present in production. The FHWA RC test, which requires double the installation rotation, starts at 10% of required installation tension with a tolerance of only +2 kips. However, the FHWA test does not require that installation tension be reached at the prescribed installation rotation; using the FHWA starting tension for this test may result in a failure at Step 3. If the test passes at Step 3 but fails at Step 4, a replacement assembly should be tested with less snugging effort.
# Appendix E

## Erection Plan and Procedures Checklist

| Project: |  |
| Bridge: |  |
| Location: |  |
| General Contractor: |  |
| Erection Sub-contractor: |  |
| Erection Engineer: |  |
| Reviewer: |  |
| Date of Review: |  |
| Comments: |  |

<table>
<thead>
<tr>
<th>✓ or N/A</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Plan of Work</strong></td>
</tr>
<tr>
<td></td>
<td><em>Permanent and temporary structures shown</em></td>
</tr>
<tr>
<td></td>
<td><em>All roads, railroads, waterways, clearances, overhead and underground utilities, potential conflicts shown</em></td>
</tr>
<tr>
<td></td>
<td><em>Framing plan with member shipping marks (matching those on shop drawings) and field splice locations as applicable</em></td>
</tr>
<tr>
<td></td>
<td><strong>Erection Sequence</strong></td>
</tr>
<tr>
<td></td>
<td><em>Step-by-step procedure – figures and narrative dictating work. Written procedure should indicate erection sequence for primary and secondary members (typically cross frames, diaphragms, etc.), as well as the following: methods of tie down of individual pieces, time and method of connection of diaphragm, lateral bracing, and field splices.</em></td>
</tr>
<tr>
<td></td>
<td><em>Delivery location of components shown as applicable</em></td>
</tr>
<tr>
<td></td>
<td><em>Crane locations shown</em></td>
</tr>
<tr>
<td></td>
<td><em>Temporary supports, hold cranes, blocking, tie-downs shown</em></td>
</tr>
<tr>
<td></td>
<td><em>Load restrictions for certain stages (i.e. wind)</em></td>
</tr>
<tr>
<td></td>
<td><em>Bracing of girders at supports</em></td>
</tr>
<tr>
<td></td>
<td><strong>Crane Information</strong></td>
</tr>
<tr>
<td></td>
<td><em>Crane capacity charts indicating crane type, lifting capacity at given radius and orientation, counterweight requirements, and boom length</em></td>
</tr>
<tr>
<td></td>
<td><em>Approximate crane pick points shown</em></td>
</tr>
<tr>
<td></td>
<td><em>Crane pick weights shown; pick weights should include weight of member, rigging, and any other attachments</em></td>
</tr>
<tr>
<td></td>
<td><em>Hold crane loads</em></td>
</tr>
<tr>
<td></td>
<td><em>Crane support method: barges, mats, etc.</em></td>
</tr>
<tr>
<td></td>
<td><strong>Details of Lifting Devices and Special Procedures</strong></td>
</tr>
<tr>
<td></td>
<td><em>Detail and arrangement of member rigging: showing sizes, capacities, and location of member pick points (or center of gravity)</em></td>
</tr>
</tbody>
</table>
Include in the submittal manufacturer cut sheets for rigging devices: beam clamps, wire rope, shackles, turnbuckles, chains, straps, etc., as well as pre-engineered falsework as applicable.

<table>
<thead>
<tr>
<th>Bolting Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing Blocking and Tie-Down Details</td>
</tr>
<tr>
<td>Temporary Supports</td>
</tr>
<tr>
<td>Details of structure shown</td>
</tr>
<tr>
<td>Temporary Support Details should include capacities and sizes</td>
</tr>
<tr>
<td>Loads and elevations indicated</td>
</tr>
<tr>
<td>Jacking Devices and Procedures</td>
</tr>
<tr>
<td>Coordination Items</td>
</tr>
<tr>
<td>Include in the submittal statements as to the status of coordination with parallel entities requiring review: railroads, Coast Guard, Corps of Engineers, etc.</td>
</tr>
</tbody>
</table>
### Appendix F

**Erection Calculations Checklist**

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete analysis of erection sequence</td>
</tr>
<tr>
<td>Proper level of analysis used</td>
</tr>
<tr>
<td>Support conditions modeled appropriately at all stages</td>
</tr>
<tr>
<td>Appropriate design criteria employed</td>
</tr>
<tr>
<td>Appropriate loads and load combinations investigated</td>
</tr>
<tr>
<td>Complete checks of structural adequacy of bridge components</td>
</tr>
<tr>
<td>Calculations should substantiate members to not experience loads greater than their capacities prior to completion of the bridge assembly.</td>
</tr>
<tr>
<td>Complete checks of stability of girder and bridge system</td>
</tr>
<tr>
<td>Calculations should substantiate structural stability of members and sub-assemblies prior to completion of the bridge assembly.</td>
</tr>
<tr>
<td>Girder second-order amplification effects are addressed as needed</td>
</tr>
<tr>
<td>Girder reactions checked for uplift</td>
</tr>
<tr>
<td>Calculations for temporary hold crane loads</td>
</tr>
<tr>
<td>Calculations for temporary support loads</td>
</tr>
<tr>
<td>Calculations for substantiating that bearing capacity and design rotations are not exceeded during steel erection</td>
</tr>
<tr>
<td>Calculations indicating structural integrity of the sub-assembly for cross-frame and bracing placement (adequate bracing strength and stiffness verified)</td>
</tr>
<tr>
<td>Calculations substantiating the stability and structural adequacy of temporary supports and devices</td>
</tr>
<tr>
<td>Falsework towers / temporary support structures</td>
</tr>
<tr>
<td>Girder tie-downs</td>
</tr>
<tr>
<td>Lifting and/or spreader beams</td>
</tr>
<tr>
<td>Jacking devices</td>
</tr>
<tr>
<td>Calculations of loads</td>
</tr>
</tbody>
</table>
### Calculations of support elevations

<table>
<thead>
<tr>
<th>Calculations indicating capacity of temporary crane supports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculations to substantiate structural integrity of abutment and retaining walls affected by surcharge from cranes</td>
</tr>
<tr>
<td>Calculations for crane pick locations (center of gravity)</td>
</tr>
<tr>
<td>Calculations indicating structural integrity of any partially bolted primary splices after release of external support system</td>
</tr>
<tr>
<td>Checks of displacements at field splices</td>
</tr>
<tr>
<td>Checks of web layover of erected girders at supports, differential deflection potential at traffic staging, etc. (See <a href="#">Section 9.2.2</a>).</td>
</tr>
</tbody>
</table>
PART 1–Pre-Erection

☐ Erection procedure—approved

☐ Site preparation—access roads, crane pads, bearing pedestals, finish and elevation, anchor bolts survey, falsework foundation pads, all obstacles noted

☐ Personnel
  – Foreman—competent person
  – Crane operators—qualified, licensed, training, medical
  – Welders—certification current, qualified for positions
  – Any required training and instruction complete

☐ Lifting equipment
  – Crane inspection—current, schedule during project
  – Lifting devices and rigging—certification, inspection

☐ Bolted connections
  – Check bolt quality, size, and lengths; certifications
  – Installation procedure, method of tensioning
  – Skidmore machine—calibration, certification
  – Impact wrenches—condition, proper size and capacity
  – Torque wrenches—calibration

☐ Welded connections
  – Weld procedure specifications (WPS)—approved
  – Welding equipment—sufficient capacity, grounding
  – Welding consumables—proper storage, drying ovens

☐ Safety/fall protection—nets, lifeline lanyards, platforms, scaffolds, manlifts, floats, emergency boat

☐ Coordination items—railroads, local agencies, Coast Guard, emergency services, overhead and underground utilities, etc.

PART 2—Erector Responsibility

☐ Provide for inspector—prior to erection
  - Framing plan, erection procedure
  - Crane operator qualifications
  - Welder certifications
  - Crane inspection certifications
  - Skidmore and torque wrench calibration certifications
  - Bolt manufacturer certifications
  - Weld procedure specifications

☐ Provide for inspector—during erection
  – Access to work—ladders, manlift, scaffold, or platform
  – Torque wrench
  – Skidmore
  – Temperature indication crayons
PART 3—Inspector Responsibility

☐ Check all personnel certifications—crane operator, welders, etc.
☐ Check all equipment certifications—cranes, etc.
☐ Check fall protection—requirements, installation
☐ Check crane radii
☐ Check temporary supports—installed per erection procedure
☐ Check assembly marks—proper location and orientation
☐ Check minimum number of bolts and pins installed before release of crane/temporary supports
☐ Monitor bolt installation procedure
☐ Check field weld size/geometry, consumables, and variables per WPS and NDT results
☐ Check bearing alignment/adjustment
☐ Verify all Erection Plans and Procedures submittals as well as Erection Engineering Calculation submittals are approved
Section 1 Appendix H
Example Erection Plans
### PROCEDURE

1. **PLACE 300 TON CRANE IN POSITION 1** and 300 TON CRANE IN POSITION 4.

2. **PLACE 300 TON CRANE IN POSITION 5** and 300 TON CRANE IN POSITION 6.

3. **PLACE 300 TON CRANE IN POSITION 2** and 300 TON CRANE IN POSITION 3.

   **STEP 1: PLACE 300 TON CRANE IN POSITION 1**
   - Swing crane in position 1 and hold.
   - Use the crane to inspect the bottom flange of the girders.

   **STEP 2: PLACE 300 TON CRANE IN POSITION 2**
   - Use the crane to inspect the bottom flange of the girders.

   **STEP 3: PLACE 300 TON CRANE IN POSITION 3**
   - Use the crane to inspect the bottom flange of the girders.

   **STEP 4: PLACE 300 TON CRANE IN POSITION 4**
   - Use the crane to inspect the bottom flange of the girders.

   **STEP 5: PLACE 300 TON CRANE IN POSITION 5**
   - Use the crane to inspect the bottom flange of the girders.

   **STEP 6: PLACE 300 TON CRANE IN POSITION 6**
   - Use the crane to inspect the bottom flange of the girders.

---

### DRAWINGS

**CHARGE - POSITION 1**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TON-LOAD</th>
<th>WLT</th>
<th>WLS</th>
<th>MAX. WLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5t</td>
<td>37,500</td>
<td>25,000</td>
<td>25,000</td>
<td>25,000</td>
</tr>
<tr>
<td>0.4t</td>
<td>30,000</td>
<td>19,000</td>
<td>19,000</td>
<td>19,000</td>
</tr>
<tr>
<td>0.3t</td>
<td>40,000</td>
<td>25,000</td>
<td>25,000</td>
<td>25,000</td>
</tr>
</tbody>
</table>

**CHARGE - POSITION 2**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TON-LOAD</th>
<th>WLT</th>
<th>WLS</th>
<th>MAX. WLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5t</td>
<td>37,500</td>
<td>25,000</td>
<td>25,000</td>
<td>25,000</td>
</tr>
<tr>
<td>0.4t</td>
<td>30,000</td>
<td>19,000</td>
<td>19,000</td>
<td>19,000</td>
</tr>
<tr>
<td>0.3t</td>
<td>40,000</td>
<td>25,000</td>
<td>25,000</td>
<td>25,000</td>
</tr>
</tbody>
</table>

---

### GENERAL NOTES

- The construction is to be performed by the contractor in accordance with the specifications and in accordance with the order of the owner.
- All equipment used shall be properly locked in place.
- All equipment used shall be properly locked in place.
- All equipment used shall be properly locked in place.
- All equipment used shall be properly locked in place.
- All equipment used shall be properly locked in place.
- All equipment used shall be properly locked in place.

### EQUIPMENT

- **Two 300 Ton Hydraulic Crane**
- **Two 300 Ton Hydraulic Crane**
- **Two 300 Ton Hydraulic Crane**
- **Two 300 Ton Hydraulic Crane**
- **Two 300 Ton Hydraulic Crane**
- **Two 300 Ton Hydraulic Crane**

---

**NOTE ON DRAWINGS**

- The direction of each arrow is shown.
- All measurements are shown in feet and inches.
- All dimensions are shown in feet and inches.
- All dimensions are shown in feet and inches.
- All dimensions are shown in feet and inches.