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.

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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 result in a bridge structure that meets all the geometric and structural requirements of the contract documents.

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.

C1.1.1

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

The examination by the Owner, General Contractor, Erector, 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 which 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, materials to be used, along with any temporary works or other devices necessary. Items identified as required by these 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) or Advance 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 movable 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. In the Contract Documents language, “An erection plan is required” or similar invokes a requirement for submittal of Erection Plans and Procedures and the associated Erection Engineering Calculations 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. In the Contract Documents language, “Erection engineering calculations are required” or similar invokes a requirement for submittal of Erection Plans and Procedures and the associated Erection Engineering Calculations as described in this Guide Specification.

Unless otherwise specified in the Contract Documents, if the submittal of Erection Plans and Procedures (with or without 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 licensed in the state(s) or jurisdiction(s) in which the subject bridge is being built. 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 Article 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 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 Article 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, and 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 prebid 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, temporary components, or both, 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 fourteen (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.

### 2.2—ERECTION PLANS AND PROCEDURES

#### 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,

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 listing all items discussed below is provided in Appendix B as an aid for engineers preparing or reviewing erection submittals.
• structures and conditions that may limit access (consideration of clearance requirements over roadways or railroads),
• 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 (but not limited to) holding crane positions, temporary supports, and falsework. 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 pick (see [Article 2.2.2]), the crane type, crane pick radius, the crane support methods (crane mats, barges, work trestles, etc.), and the means of attachment to the girders being lifted or supported.

C2.2.2

The erection sequence should indicate specific structural components to be erected at a given stage, such as (but not limited to) the girders, cross-frames, and lateral bracing. The erection sequence should also indicate lifting crane positions, as well as any temporary support conditions necessarily to facilitate a certain erection stage, such as (but not limited to) temporary supports, holding crane positions, tie-down stability provisions, and blocking of the bearings. The erection sequence drawings should provide instructions for construction of the bridge and should be written, and followed, as mandatory directives.

C2.2.3

The maximum crane lift radius is often controlled by the material delivery location, hence the need to indicate the delivery location on the Erection Plans and Procedures. Correct girder segment orientation at the delivery location is important since the ability to rotate long segments under the crane boom may be restricted.

C2.2.4

The erection submittal should include adequate documentation of any items needed to support cranes. For example, if a work trestle is used to support a crane, the erection submittal should include plans for the work trestle. Likewise, if the steel erection takes place on a navigable waterway, the configuration of the barges,
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.). When cranes are required to be placed on existing structures (bridges, culverts, etc.), the structure shall be evaluated to ensure it has adequate capacity to withstand crane loading.

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, but 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 fourteen (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 loading sequence, and stability provisions (tie-downs, supports, etc.) should 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, pick 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 of the originally proposed cranes, mechanical problems, etc. 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.
(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 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 Article 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 details, tie-down details, or both for the bridge bearings, and associated force demands, as necessary.

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, are prone to lateral–torsional buckling and require particular attention during lifting/handling operations. The flange width, $b$, should be taken as the smallest width flange within the field section being lifted. The definition of a slender beam as having an $L/b$ ratio greater than 85 should only be used as an approximate guide; recent research has suggested other means of identifying the potential for instability during lifting and handling. In addition, other types of structural members may also have issues of slenderness, stability, or both, which should be addressed in the Erection Plans and Procedures as appropriate.

2.2.7

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. The final tensioning sequence for field splices and cross frames should be considered by the Erection Engineer when evaluating bolting requirements.

2.2.8

Depending on their details, bridge bearings may allow movement (translation) in any direction and rotation about any axis. During steel erection, in addition to other stability provisions, the bearings may require blocking to prevent or limit the translational movements and rotations. In addition, bearings may need temporary tie-downs to prevent uplift at various stages during construction. The Contractor’s Engineer should determine the blocking and tie-down requirements such that the structure remains stable during all stages of
2.2.9—Load Restrictions

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

C2.2.9

Limits may be placed on wind velocities during lifting of girder field pieces or during various stages of erection when the structure is only partially complete. The limitations on wind velocities are intended to prevent girder over-stress and instabilities that could be caused by certain wind speeds and associated wind pressure loading. Calculations may show that a girder, or girder system may not be stable at a certain wind velocity, and this needs to be communicated to the Contractor and Steel Erector via the Erection Plans and Procedures. If appropriate, the Erection Plans and Procedures should include instructions and details for temporary support or tie-down of partially completed structures during high wind conditions. The Erection Plans and Procedures should also explicitly state restrictions on construction live loads (vehicles, equipment, personnel, etc.) and construction dead loads (formwork/falsework, stored materials, etc.). Inadvertent overloading by construction loads could lead to structural collapse and could also affect geometry control.

For additional recommendations and guidance on the application of wind loads during construction see AASHTO’s Guide Specifications for Wind Loads on Bridges During Construction.

2.2.10—Temporary Supports

The Erection Plans and Procedures shall include the location of any temporary support structures (see Article 2.2.2) 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; 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 used to provide temporary

C2.2.10

In many cases, temporary supports are integral to maintaining profile and alignment in the construction of a steel bridge. As such, they should be included in the Erection Plans and Procedures, whether the support is a falsework tower, hold crane, tie-down, bearing blocking, or other support.

Refer to Article C9.2.3 for discussion of “as-fabricated” camber and how it may influence girder erection elevations.
support to the steel assembly (see Article 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 or layover at supports. Girders should be restrained from twist 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.

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 for the given analysis task(s), and that the methods meet or exceed the recognized or implied standard of care for similar analysis tasks.

C2.2.11

In some cases, jacking devices may be required at temporary support structures, or at the permanent supports, 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.

C2.3

The Owner should specify their minimum expectations regarding the methods of structural analysis in order to identify prior to bidding 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 or 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 recommendations, can be found in Appendix B of the AASHTO/NSBA Steel Bridge Collaboration G13.1, Guidelines for Steel Girder Bridge Analysis, 3rd Edition.

The FHWA manual Engineering for Structural Stability in Bridge Construction, publication FHWA-NHI-15-044, provides guidance for erection engineering analysis of steel girder bridges and preparation of erection submittals. It also serves as the reference manual for the identically named National Highway Institute training course NHI 130102.

Note that a checklist, listing all items discussed below, is provided in Appendix C 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 Article 2.1. This section 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.

This section provides guidance on a variety of topics associated with calculations for structural adequacy and stability. As a general default, the AASHTO specifications referenced in this commentary 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 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.
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, 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 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 load, construction dead load, construction live load, and wind loads, and any other loads which may be applicable.

Wind loads shall be considered in each step 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 Article 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

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 address 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 specifications. Commonly cited design specifications include AISC specifications for steel design and ASCE specifications for wind loads, among others. Applicable design criteria are provided in Appendix D of the FHWA manual Engineering for Structural Stability in Bridge Construction.

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.
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.

### C2.4.3

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 is 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 or bracing, or 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, during deck placement, or both. Narrow, long-span segments during steel erection are the most susceptible to this global buckling phenomenon. Methods to investigate the global stability of girder systems are available in the FHWA manual *Engineering for Structural Stability in Bridge Construction*, publication FHWA-NHI-15-044.

#### 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. AASHTO/NSBA Steel Bridge Collaboration 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, 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 due to self-weight (and any other applied loads) to a level at which the moment is less than the lateral–torsional bucking capacity. Typically, a hold crane should not be
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.

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 cranes, hold cranes, or both 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 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 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.

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.

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. The FHWA manual *Engineering for Structural Stability in Bridge Construction*, publication FHWA-NHI-15-044, 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. Another reference available is Volume 13, *Bracing System Design*, of the *Steel Bridge Handbook*, FHWA-HIF-16-002.

C2.4.9

Temporary works are a critical part of many steel bridge erection projects and their design should be
temporary shoring, temporary 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 or catalog cuts for pre-engineered devices may be used to meet this requirement.

Lifting beams, 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.

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.

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.
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.

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

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

b) construction activities which occur concurrently with steel erection, such as setting forms, or concrete deck pours.

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 schedules of obstructing the navigable channel should be shown.
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 to ensure members will not be subjected to stresses in excess of those provided for in the design.

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 more than 25 feet

c) Cantilevered overhang exceeds 20 percent 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 plans 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 coating 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 Article 7.3 to verify bolt installation method.

Fastener manufactured condition is defined as that which exists when the manufacturer’s sealed container is first opened.

Fastener manufacturers apply various coatings and oils that become an essential variable in the bolt installation method. If these coatings are compromised after a tested lot of bolts have been verified for a specific installation method, the test is not valid for those bolts with the compromised coating.

4.3—WELDING CONSUMABLES

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

Refer to Article C8.3.5 for more information regarding consumable storage.

C4.2

C4.3

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.

5.2—BRIDGE SEATS

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

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.

5.4—TOLERANCES

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

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.

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, rotation, or both.

C5.3
See recommendations in AASHTO/NSBA Steel Bridge Collaboration G9.1, Steel Bridge Bearing Design and Detailing Guidelines for thermal movement calculations.
SECTION 6
LIFTING AND ASSEMBLY

6.1—GENERAL

Lift, position, and assemble all members in accordance with the procedures in 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.), 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 thereof until a sufficient number of adjacent girders are erected with diaphragms or cross-frames connected to provide the necessary local and global stability, and make 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

Shoring towers may be used to provide stability and aid in fit-up during erection by providing additional supports, controlling deflections, and reducing the unbraced lengths. Therefore, the shoring should be lowered or removed before the concrete deck is placed, unless it is explicitly designed for by the Engineer of Record (EOR).

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 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

Shored construction is permitted by the AASHTO LRFD Bridge Design Specifications; however, per Article 6.10.1.1.a of those specifications, it is not recommended for composite bridges. Per the Commentary, “Shored composite bridges that are known to have been constructed in Germany did not retain the composite action. Furthermore, there is an increased likelihood of significant tensile stresses.
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 Article 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.

occurring in the concrete deck at permanent support points when shored construction is used.”

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.”

C6.6

Examples of abnormal member distortion would include strain exceeding yield and perceptible web distortion. Abnormal hole distortion may include holes that are non-cylindrical, not perpendicular to the faying surface, or out of round by more than $\frac{1}{16}$ in.

C6.7

Filled holes should be distributed between the web and flange connections for primary members such that approximately 50 percent of the web connections are filled and approximately 50 percent of the flange connections are filled. For diaphragms or cross-frames, the filled holes should be uniformly distributed between all the bolt groups connecting the diaphragm or cross-frame to the primary member.

Achieving the no-load condition on the ground will require blocking. Refer to Article C9.2.3 for discussion on “as-fabricated” camber and how it may influence girder blocking.
SECTION 7
FIELD BOLTED CONNECTIONS

7.1—FASTENER ASSEMBLY TESTING

The manufacturer or distributor shall perform rotational capacity (RC) tests on ASTM F3125/F3125M Grade A325, A490, A325M, and A490M fastener assemblies in accordance with ASTM F3125/F3125M Annex A2. Additionally, perform the RC test at the point of installation if the condition of the fastener assembly, the lubrication, or both are in question.

7.2—FAYING SURFACES

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

7.3—PREINSTALLATION 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 A.

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 ASTM F3125/F3125M Annex A2 for each RC lot whenever the condition of the fastener assemblies is in question. Verify direct tension indicators (DTI) per Appendix A.

7.4—INSTALLATION

Install fastener assemblies using any of the methods allowed per the contract specifications. Pretension assemblies to the tension required by the specifications.

C7.2

The steel erector is generally not responsible for faying surface preparation, unless required by the contract or to correct impediments to proper assembly. The erector is responsible for keeping the faying surfaces free from contamination during erection. If tightened fastener assemblies do not bring adjacent faying surfaces into complete contact due to non-parallel areas, sufficient frictional transfer of load may be provided by the total clamping force acting on the areas.

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 fastener assemblies are installed, rather than testing all fastener assemblies at the beginning of the project. Testing each fastener assembly type as it comes up for installation will help keep the crew familiar with that particular fastener assembly. Too long a time interval 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.

C7.4

Proceeding from the interior to the free edges, all bolts in a connection are typically brought to the snug-tight condition prior to pretensioning, which will follow
Fastener assemblies specified to be pretensioned may remain temporarily snug-tight but untensioned, if necessary to permit subsequent steel erection or adjustment before final tensioning. A similar pattern. For large primary member connections, which have many bolts and/or plies of thick material, bringing all bolts to the snug-tight condition may require repeating the sequence multiple times as deformations in the plates are reduced. To expedite the snugging process, the Owner may permit filling a portion of the connection with pretensioned temporary fit-up bolts prior to installing permanent bolts in the remaining holes to the snug-tight condition. Snug-tight permanent bolts can then replace the temporary bolts, resulting in a connection completely filled with snug-tight bolts.

Thick elements (e.g., over 2 in. (50 mm)) at slip-critical joints may have deformations permitted by ASTM A6/A6M that prevent intimate contact with adjoining material by snug-tight or even fully pretensioned fastener assemblies. So long as, so that these deviations affect a small percentage of the total faying surface, the connection should perform as designed. If the deviations cause a significant loss of contact between faying surfaces, the EOR and fabricator should be contacted to determine appropriate actions. Using higher strength fastener assemblies to increase clamping force or sealing the edges with structural epoxy are two options to prevent corrosion. In extreme cases, machining to remove high spots and refinishing surfaces may be an option if the remaining material will be adequate. This method may also be. This method may be appropriate when using tension control (twist-off type) fasteners or direct tension indicators. When snug-tight fastener assemblies have suitably compressed the plies, pretensioning can proceed in accordance with the specifications.

Fastener assemblies left in the snug-tight condition for an extended period prior to pretensioning may experience a loss in their lubrication. Tension-control bolts and bolts installed using the calibrated wrench may not achieve the required pretension due to increased friction affecting their resistance to rotation. Bolts installed using turn-of-the-nut or direct tension indicators may experience torsional distortion, affecting their tension and integrity. If there is a question regarding the adequacy of the lubrication, remove and test representative assemblies to determine if all fastener assemblies must be relubricated or replaced. Relubricated fastener assemblies should be subsequently retested per Article 7.3 to verify their adequacy. Tension-control bolts may only be relubricated by the manufacturer.

When possible, pretension bolts before exposure to the elements, which affect their rotational characteristics.

7.4.1—Direct Tension Indicators and Tension-Control Bolts

If direct tension indicators (DTIs) or tension-control bolts are used, bring all fastener assemblies to the snug condition, in accordance with the manufacturer’s devices such as direct tension indicators and tension-control bolts help ensure fastener assemblies are properly pretensioned, but they can be used improperly.
recommendations and the *AASHTO LRFD Bridge Construction Specifications.*

If a fastener assembly with an indicating method is pretensioned before connection plates are drawn firmly together to a snug-tight condition, it may become loose once the plies are pulled together. Therefore, care must be taken not to engage the pretensioning indication mechanism until all the fastener assemblies are snug with the plies solidly joined.
SECTION 8
FIELD WELDED CONNECTIONS

8.1—GENERAL

Field welding and nondestructive testing shall be performed in accordance with the AASHTO/AWS D1.5M/D1.5, Bridge Welding Code (referred hereafter in this section as “D1.5M/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.

D1.5M/D1.5 is written mostly for use in 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 are more difficult to control in the field than in the shop. D1.5M/D1.5 does have provisions to address weather and wind. 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.

Low-hydrogen practices are required for field welding and can produce good quality welds when done in accordance with D1.5M/D1.5. When wind speeds exceed 20 mph, the granular flux required for submerged arc welding (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).

8.2—QUALIFICATION

8.2.1—Welder Qualification

Qualify welders in accordance with D1.5M/D1.5, and any additional Owner requirements, for the positions and processes approved for field welding.

Unlike shop welding, workers welding in the field for contractors move from project to project and keeping track of welders that are qualified can be difficult. Some owners have programs that address qualification of field welders.

8.2.2—Welding Procedure Qualification

Field welding shall be performed in accordance with welding procedure specifications (WPSs) approved by the Owner for the specific application and location. Welding procedures that do not satisfy D1.5M/D1.5 requirements for prequalification shall be qualified by test per D1.5M/D1.5.

Welding procedure qualification tests should be performed prior to arrival at the jobsite. Variations in consumables or geometry are governed by D1.5M/D1.5.
8.3—WELDING REQUIREMENTS

8.3.1—Welders

Welders shall have a written copy of the approved WPS.

8.3.2—Contact Surfaces

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

8.3.3—Joined Parts

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

8.3.4—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.

8.3.5—Consumables

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

C8.3.4

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 D1.5M/D1.5 Commentary for a detailed explanation of the effect of environmental conditions on welds.

C8.3.5

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 D1.5M/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 D1.5M/D1.5.

8.3.6—Preheat

Surfaces to be welded shall satisfy preheat requirements of D1.5M/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.
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 D.

9.2—TOLERANCES FOR PLATE GIRDER OR ROLLED BEAM SPANS

C9.2

Geometric tolerances for other structures (arches, trusses, etc.) should be established by the contract or mutually agreed between the Owner and erector.

9.2.1—Deviation from Theoretical Horizontal Alignment

±$\frac{1}{8}$ inch $\times$ (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 use to compute the girder field section camber, which (for I-girders) is typically considered to be the no-load (NLF) profile.

C9.2.1

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 $\frac{1}{8}$ inch $\times$ 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.

C9.2.2

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, beyond the control of the Contractor, or both. 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) The fit condition chosen for establishing the connections between girders and cross-frames (the “drops”)
c) Fabrication tolerances
d) The erection sequence
e) The deck pouring sequence
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)

\[ -0.25 \text{ inch } \times \left( \frac{\text{total length, in feet, from nearest support}}{10} \right) \]
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 and shall not deviate from the theoretical erected vertical alignment by more than the value computed above. Maximum deviation is ¾ inch in cantilever sections or 1½ 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 D1.5M/D1.5. Welds shall be evaluated for acceptance in accordance with D1.5M/D1.5.

Plans or specifications shall indicate “tension or stress reversal areas” so Contractors know where to apply tension/stress reversal acceptance criteria under D1.5M/D1.5.
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 D1.5M/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 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.
The following list of references is for information only and should be considered as reference text to supplement the commentary provided within this document.


A1—Direct Tension Indicators

Direct tension indicators (DTIs) conforming to the requirements of ASTM F959/F959M may be used with the bolts, nuts, and washers that meet the requirements of ASTM F3125/F3125M. DTIs that also incorporate a self-indicating feature or captive DTI/nuts may also be used. The use of the self-indicating feature to replace the use of feeler gauges shall be subject to the approval of the Engineer.

CA1

DTIs are washers with protrusions on one face. They measure load by compressing the protrusions on the DTI with a proportional reduction in the gap in the spaces between the protrusions. Attaining the required tension is verified by the number of “gauge refusals,” which are gaps that are too tight to permit the insertion of a feeler gauge of the prescribed thickness.

A DTI affixed to a hardened heavy hex structural nut by the fastener manufacturer is referred to herein as a captive DTI/nut. A DTI which incorporates a self-indicating feature to indicate bolt tension is referred to herein as a self-indicating DTI. Captive DTI/nuts and self-indicating DTIs must still meet the applicable requirements of ASTM F959/F959M and ASTM F3125/F3125M.

Different Owners have established different policies for the use of self-indicating DTIs to replace measuring gaps with feeler gauges. Some permit their use in accordance with the DTI manufacturer’s recommendations to indicate snug and fully tensioned conditions; some permit their use once the appearance of the indicating feature is verified against a feeler gauge; and some permit them only for the installer’s reference and convenience, but still require the use of feeler gauges.

A2—Rotational-Capacity Tests

Rotational-capacity testing by the Manufacturer shall be required for all fastener assemblies with ASTM F3125/F3125M Grade A325 or A490 bolts. Rotational-capacity testing shall not be required for twist-off bolts (ASTM F3125/F3125M Grade F1852 or F2280). DTIs or captive DTI/nuts shall not be included in rotational-capacity testing assemblies. Assemblies specified as galvanized shall be tested after galvanizing. Washers shall be required as part of the test even though they may not be required as part of the installation procedure. Rotational-capacity testing shall be performed in accordance with ASTM F3125/F3125M Annex A2.

CA2

An assembly lot is defined as a combination of fastener components of different types which are configured as they are to be installed in the steel. An example would be a bolt, nut, and washer. Each component in an assembly lot will have come from a production lot of similar components. Any change in component lots warrants additional testing of the assembly lots into which the component lots are integrated.

Rotational-capacity testing is not appropriate for twist-off bolts (ASTM F3125/F3125M Grade F1852 or F2280), or for DTIs and captive DTI/nuts, because these installation processes do not rely upon the ductility of the fastener. DTIs and captive DTI/nuts do not have to be included in rotational-capacity testing assemblies as this test is designed only to test the capacity of the nut and bolt.

The required starting tension in the ASTM F3125/F3125M rotational-capacity test is 10 percent of the required minimum installation tension, and is assumed to bring the connection to a snug condition.
The required nut rotations from the snug condition in the rotational-capacity test are approximately twice the required rotations adjusted to provide roughly equal ductility demand across different bolt sizes.

CA3

Captive DTIs/nuts are designed for the DTI protrusions to bear against the turned nut.

A3—Direct Tension Indicator Installation Method

When DTIs (see Article A1) are used with high-strength bolts to indicate bolt tension, they shall be installed with the protrusions bearing against the hardened bearing surface of the bolt head or nut, or against a hardened washer if under the turned element. Installation of a DTI under the turned element shall only be permitted if a washer is used to separate the turned element from the DTI, except in the case of captive DTIs/nuts.

CA3a

The purpose of the verification testing is to validate the DTI assembly’s ability to indicate installation tension above the minimum and to minimize risk of bolt failure during installation. The verification tension shown in Table A3b-1 is 5 percent higher than the required installation tension in Table 6.13.2.8-1 from the AASHTO LRFD Bridge Design Specifications. The increase provides confidence that the installation tension can be achieved for the lot. Table A3a-1 is based upon the criterion that a DTI with more than half of its spaces compressed to less than 0.005 in. indicates a bolt tension above the required minimum tension.

CA3a

The thread test is required for DTI verification but for no other bolt installation method because the DTI method is the only force-control method. For torque-control methods, such as calibrated wrench and twist-off bolts, the torque setting of the wrench or the twisting off of the spline limit the load on the bolt. In the turn-of-the-nut method, a strain-control method, the fastener assembly is tested to beyond the installation tolerance during rotational capacity testing. However, a DTI is capable of meeting protrusion compression requirements at loads above the bolt capacity. Therefore, the specific combination of bolt and DTI lot must be tested to verify that a combination of strong DTI and weak bolt will not increase the likelihood of bolt failure during installation.

A3a—Verification

Three verification tests without failure shall be required for each combination of bolt, nut, and washer rotational-capacity lot; DTI lot; DTI position and orientation; and turned element (bolt head or nut) planned in the work. The element intended to be stationary (bolt or nut) shall be restrained from rotation if the DTI protrusions bear directly against it without an intervening washer.

The bolt, nut, washer, and DTI assembly shall be installed in a calibrated bolt tension measuring device so that at least three and preferably not more than five threads are located between the bearing face of the nut and the bolt head. The bolt shall be tensioned to the Verification Tension listed in Table A3b-1. If an impact wrench is used, the tension developed using the impact wrench shall be no more than two-thirds of the required tension, and a nonimpacting method shall be used to attain the required tension. The number of refusals of the 0.005-in. tapered feeler gauge in the spaces between the protrusions shall be recorded.

The bolt shall be further tensioned until the feeler gauge is refused at all spaces with a visible gap remaining in at least one space, and the tension at this condition shall be recorded. The bolt shall be removed from the tension-measuring device and the nut run down by hand for the complete thread length of the bolt excluding thread run-out.

Test failure, which indicates that the combination of test parameters is not acceptable but does not necessarily indicate failure of the DTI lot, shall be deemed to occur under either of the following conditions:

(a) the “Maximum Verification Refusals” in Table A3a-1 are exceeded at the verification tension; or

(b) the nut cannot be run down for the full thread length and the final tension exceeds 95 percent...
of the average peak tension measured during rotational capacity testing of the fastener lot.

If self-indicating DTIs (see Article A1) are used to replace the use of feeler gauges, the manufacturer’s instructions shall be used to verify the self-indicating feature.

If bolts are too short to fit in a calibration device, longer “surrogate” bolts shall be substituted in the first part of the verification test to verify that the number of DTI verification refusals satisfies the requirements of Table A3a-1. The combination of bolt, nut, washer, and DTI lots to be used in the work shall be tensioned in a steel plate until the feeler gauge is refused in all spaces with a visible gap remaining in at least one space. The bolt shall then be removed and the nut shall be able to be run down by hand for the complete thread length of the bolt excluding thread run-out.

Table A3a-1—DTI 0.005 in. Feeler Gauge Refusal Requirements

<table>
<thead>
<tr>
<th>DTI Spaces</th>
<th>Maximum Verification Refusals</th>
<th>Minimum Installation Refusals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coated DTIs under turned element</td>
<td>Coated DTIs under turned element</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
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<td>7</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

A3b—Installation

Installation of fastener assemblies using DTIs shall be performed in two stages: snug-tightening and final tensioning. The element against the DTI, if no washer is used to separate the DTI from that element, shall be held stationary for both stages.

All the bolts in the connection shall be snug-tightened to bring all the plies into firm contact. After snug-tightening, the number of DTI spaces in which a 0.005-in. feeler gauge is refused shall not exceed the Maximum Verification Refusals in Table A3a-1. Assemblies that do not meet the requirements of the table shall be replaced.

Tensioning shall continue until the number of feeler gauge refusals meets or exceeds the Minimum Installation Refusals in Table A3a-1 with a visible gap remaining in at least one of the DTI spaces. If no visible gap remains, the assembly shall be replaced.

When self-indicating DTIs (see Article A1) are used instead of a feeler gauge to indicate tension, the visual appearance of the installed DTI shall be in accordance with the Manufacturer’s instructions; otherwise the assembly shall be replaced.

CA3b

Turning a fastener element against the DTI needs to be avoided because it influences the relationship between gap and tension.

Refusals during snug-tightening cannot exceed the maximum verification refusals because of group-influenced relaxation. A DTI does not fully rebound when tension is reduced and if not replaced could give a false indication of bolt tension.

The 0.005 gap is intended to address concerns about corrosion due to water intrusion into larger gaps. A visible gap must remain in at least one space after installation to help ensure that the fasteners are not tensioned beyond their ultimate strength.
Table A3b-1—Verification Tension

<table>
<thead>
<tr>
<th>Bolt Size, in.</th>
<th>Verification Tension, kips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade A325</td>
</tr>
<tr>
<td>1/2</td>
<td>13</td>
</tr>
<tr>
<td>5/8</td>
<td>20</td>
</tr>
<tr>
<td>3/4</td>
<td>29</td>
</tr>
<tr>
<td>7/8</td>
<td>41</td>
</tr>
<tr>
<td>1</td>
<td>54</td>
</tr>
<tr>
<td>1 1/8</td>
<td>67</td>
</tr>
<tr>
<td>1 1/4</td>
<td>85</td>
</tr>
<tr>
<td>1 3/8</td>
<td>102</td>
</tr>
<tr>
<td>1 1/2</td>
<td>124</td>
</tr>
</tbody>
</table>
# APPENDIX B
## ERECTION PLAN AND PROCEDURES CHECKLIST

<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>Permanent and temporary structures shown</td>
</tr>
<tr>
<td></td>
<td>All roads, railroads, waterways, clearances, overhead and underground utilities, potential conflicts shown</td>
</tr>
<tr>
<td></td>
<td>Framing plan with member shipping marks (matching those on shop drawings) and field splice locations as applicable</td>
</tr>
<tr>
<td></td>
<td><strong>Erection Sequence</strong></td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>Delivery location of components shown, as applicable</td>
</tr>
<tr>
<td></td>
<td>Crane locations shown</td>
</tr>
<tr>
<td></td>
<td>Temporary supports, hold cranes, blocking, tie-downs shown</td>
</tr>
<tr>
<td></td>
<td>Load restrictions for certain stages (i.e. wind)</td>
</tr>
<tr>
<td></td>
<td>Bracing of girders at supports</td>
</tr>
<tr>
<td></td>
<td><strong>Crane Information</strong></td>
</tr>
<tr>
<td></td>
<td>Crane capacity charts indicating crane type, lifting capacity at given radius and orientation, counterweight requirements, and boom length</td>
</tr>
<tr>
<td></td>
<td>Approximate crane pick points shown</td>
</tr>
<tr>
<td></td>
<td>Crane pick weights shown. Pick weights should include weight of member, rigging, and any other attachments</td>
</tr>
<tr>
<td></td>
<td>Hold crane loads</td>
</tr>
<tr>
<td></td>
<td>Crane support method: barges, mats, etc.</td>
</tr>
<tr>
<td></td>
<td><strong>Details of Lifting Devices and Special Procedures</strong></td>
</tr>
<tr>
<td></td>
<td>Detail and arrangement of member rigging: showing sizes, capacities, and location of member pick points (or center of gravity)</td>
</tr>
<tr>
<td></td>
<td>Include in the submittal manufacturer cut sheets for rigging devices: beam clamps, wire rope, shackles, turnbuckles, chains, straps, etc., and pre-engineered falsework, as applicable.</td>
</tr>
<tr>
<td>Bolting Requirements</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td>Bearing Blocking and Tie-Down Details</td>
<td></td>
</tr>
<tr>
<td>Temporary Supports</td>
<td></td>
</tr>
<tr>
<td>Details of structure shown</td>
<td></td>
</tr>
<tr>
<td>Temporary support details should include capacities and sizes</td>
<td></td>
</tr>
<tr>
<td>Loads and elevations indicated</td>
<td></td>
</tr>
<tr>
<td>Jacking Devices and Procedures</td>
<td></td>
</tr>
<tr>
<td>Coordination Items</td>
<td></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>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C
ERECTION CALCULATIONS CHECKLIST

<table>
<thead>
<tr>
<th>✓ or N/A</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Complete analysis of erection sequence</td>
</tr>
<tr>
<td></td>
<td>Proper level of analysis used</td>
</tr>
<tr>
<td></td>
<td>Support conditions modeled appropriately at all stages</td>
</tr>
<tr>
<td></td>
<td>Appropriate design criteria employed</td>
</tr>
<tr>
<td></td>
<td>Appropriate loads and load combinations investigated</td>
</tr>
<tr>
<td></td>
<td>Complete checks of structural adequacy of bridge components</td>
</tr>
<tr>
<td></td>
<td>Calculations should substantiate that members do not experience loads greater than their capacities prior to completion of the bridge assembly.</td>
</tr>
<tr>
<td></td>
<td>Complete checks of stability of girder and bridge system</td>
</tr>
<tr>
<td></td>
<td>Calculations should substantiate structural stability of members and sub-assemblies prior to completion of the bridge assembly.</td>
</tr>
<tr>
<td></td>
<td>Girder second-order amplification effects are addressed as needed</td>
</tr>
<tr>
<td></td>
<td>Girder reactions checked for uplift</td>
</tr>
<tr>
<td></td>
<td>Calculations for temporary hold crane loads</td>
</tr>
<tr>
<td></td>
<td>Calculations for temporary support loads</td>
</tr>
<tr>
<td></td>
<td>Calculations for substantiating that bearing capacity and design rotations are not exceeded during steel erection</td>
</tr>
<tr>
<td></td>
<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></td>
<td>Calculations substantiating the stability and structural adequacy of temporary supports and devices</td>
</tr>
<tr>
<td></td>
<td>Falsework towers/temporary support structures</td>
</tr>
<tr>
<td></td>
<td>Girder tie-downs</td>
</tr>
<tr>
<td></td>
<td>Lifting and/or spreader beams</td>
</tr>
<tr>
<td></td>
<td>Jacking devices</td>
</tr>
<tr>
<td></td>
<td>Calculations of loads</td>
</tr>
<tr>
<td></td>
<td>Calculations of support elevations</td>
</tr>
<tr>
<td>✓ or N/A</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td>Calculations indicating capacity of temporary crane supports</td>
</tr>
<tr>
<td></td>
<td>Calculations to substantiate structural integrity of abutment and retaining walls affected by surcharge from cranes</td>
</tr>
<tr>
<td></td>
<td>Calculations for crane pick locations (center of gravity)</td>
</tr>
<tr>
<td></td>
<td>Calculations indicating structural integrity of any partially bolted primary splices after release of external support system</td>
</tr>
<tr>
<td></td>
<td>Checks of displacements at field splices</td>
</tr>
<tr>
<td></td>
<td>Checks of web layover of erected girders at supports, differential deflection potential at traffic staging, etc. (See Article 9.2.2).</td>
</tr>
</tbody>
</table>
APPENDIX D
ERECTION INSPECTION CHECKLIST
(See Article 1.1.7 for definition)

PART 1—PRE-ERECTION

☐ Erection Procedure—approved

☐ Site preparation——access roads, crane pads, bearing pedestals, finish & 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 & instruction complete

☐ Lifting Equipment
  • crane inspection—current, schedule during project
  • lifting devices & rigging—certification, inspection

☐ Bolted Connections
  • check bolt quality, size & lengths, certifications
  • installation procedure, method of tensioning
  • Skidmore machine—calibration, certification
  • impact wrenches—condition, proper size & 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, life-line lanyards, platforms, scaffolds, manlifts, floats, emergency boat

☐ Coordination Items—railroads, local agencies, Coast Guard, emergency services, 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
APPENDIX E
SAMPLE ERECTION PLANS

The sets of sample bridge girder erection plans contained in this Appendix are provided to illustrate typical contents of such plans. They are not intended as definitive examples, nor to convey a standard-of-care for erection plan preparation. The actual contents of any specific set of erection plans will depend upon the erection contractor’s proposed means and methods, owner requirements, and the complexity of the bridge. These drawings should be developed in conjunction with a set of erection engineering calculations.
Erection Procedure

1. Verify Steel Profile.

2. With Crane-A, lift Girder G1A into Erected Position and continue to hold.


4. With Crane-B, lift Girder G1B into Erected Position and continue to hold.

5. Verify Crossframes of G1B at Position 4 are clean and straight. Connect Crossframes marked (*) on Plan between Girder lines 1 and 2.


8. With Crane-B, lift Girder G1B at Position 3 and walk to Position 5. Lift Girder G1B into Erected Position and connect Crossframes marked (*) on Plan between Girder lines 1 and 2.


10. Verify Crossframes of G2B at Position 5 are clean and straight. Connect Crossframes marked (*) on Plan between Girder lines 2 and 3.

11. Erection Procedure continued:

12. Lift Girder G4A into Erected Position and connect Crossframes marked (*) on Plan between Girder lines 4 and 5.

13. Lift Girder G5A into Erected Position and connect Crossframes marked (*) on Plan between Girder lines 5 and 6.


16. Lift Girder G1B into Erected Position and continue to hold.

17. Lift Girder G2B into Erected Position and continue to hold.

18. Lift Girder G3B into Erected Position and continue to hold.

19. Lift Girder G4B into Erected Position and continue to hold.

20. Lift Girder G5B into Erected Position and continue to hold.

21. Lift Girder G6B into Erected Position and continue to hold.

22. Lift Girder G7B into Erected Position and continue to hold.

23. Lift Girder G8B into Erected Position and continue to hold.

24. Lift Girder G9B into Erected Position and continue to hold.

25. Lift Girder G10B into Erected Position and continue to hold.

26. Lift Girder G11B into Erected Position and continue to hold.

27. Lift Girder G12B into Erected Position and continue to hold.

28. Lift Girder G13B into Erected Position and continue to hold.

29. Lift Girder G14B into Erected Position and continue to hold.

30. Lift Girder G15B into Erected Position and continue to hold.

31. Lift Girder G16B into Erected Position and continue to hold.

32. Lift Girder G17B into Erected Position and continue to hold.

33. Lift Girder G18B into Erected Position and continue to hold.

34. Lift Girder G19B into Erected Position and continue to hold.

35. Lift Girder G20B into Erected Position and continue to hold.

36. Lift Girder G21B into Erected Position and continue to hold.

37. Lift Girder G22B into Erected Position and continue to hold.

38. Lift Girder G23B into Erected Position and continue to hold.

39. Lift Girder G24B into Erected Position and continue to hold.

40. Lift Girder G25B into Erected Position and continue to hold.

41. Lift Girder G26B into Erected Position and continue to hold.

42. Lift Girder G27B into Erected Position and continue to hold.

43. Lift Girder G28B into Erected Position and continue to hold.

44. Lift Girder G29B into Erected Position and continue to hold.

45. Lift Girder G30B into Erected Position and continue to hold.

46. Lift Girder G31B into Erected Position and continue to hold.

47. Lift Girder G32B into Erected Position and continue to hold.

48. Lift Girder G33B into Erected Position and continue to hold.

49. Lift Girder G34B into Erected Position and continue to hold.

50. Lift Girder G35B into Erected Position and continue to hold.

51. Lift Girder G36B into Erected Position and continue to hold.

52. Lift Girder G37B into Erected Position and continue to hold.

53. Lift Girder G38B into Erected Position and continue to hold.

54. Lift Girder G39B into Erected Position and continue to hold.

55. Lift Girder G40B into Erected Position and continue to hold.

56. Lift Girder G41B into Erected Position and continue to hold.

57. Lift Girder G42B into Erected Position and continue to hold.

58. Lift Girder G43B into Erected Position and continue to hold.

59. Lift Girder G44B into Erected Position and continue to hold.

60. Lift Girder G45B into Erected Position and continue to hold.

61. Lift Girder G46B into Erected Position and continue to hold.

62. Lift Girder G47B into Erected Position and continue to hold.

63. Lift Girder G48B into Erected Position and continue to hold.

64. Lift Girder G49B into Erected Position and continue to hold.

65. Lift Girder G50B into Erected Position and continue to hold.

66. Lift Girder G51B into Erected Position and continue to hold.

67. Lift Girder G52B into Erected Position and continue to hold.

68. Lift Girder G53B into Erected Position and continue to hold.

69. Lift Girder G54B into Erected Position and continue to hold.

70. Lift Girder G55B into Erected Position and continue to hold.
### Notes:

1. For additional erection details and notes see EP-2.

## Beam Clamps

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Working Load Limit (ton)</th>
<th>Flange Spacing</th>
<th>Column Spacing</th>
<th>Handrail Spacing</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-10</td>
<td>2</td>
<td>20</td>
<td>20</td>
<td>50</td>
<td>12</td>
<td>13</td>
<td>32</td>
<td>32</td>
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</tr>
<tr>
<td>F-20</td>
<td>2</td>
<td>20</td>
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<td>32</td>
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<tr>
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<td>13</td>
<td>32</td>
<td>32</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

## General Bridge Erection Details - 2

### Shoring Tower Yard Frame (Two Towers)

- All dimensions in ft unless otherwise noted.
- All drawings in inches unless otherwise noted.
APPENDIX E: SAMPLE ERECTION PLANS

GENERAL NOTES (CONT'D.)

1. THESE DRAWINGS SHOWN AS DESIGNER FOR USE AS A REFERENCES TO THE CONTRACT DOCUMENTS REFERENCED ON THE TITLE SHEET AND APPLY ONLY TO THIS APPLICATION.

2. ALL VERTICAL AND HORIZONTAL SHORING INSTALLATIONS SHALL COMPLY WITH SAFE PRACTICE AND WITH THE REQUIREMENTS OF GOVERNMENTAL REGULATIONS, CODES, AND STANDARDS. DRAWINGS PREPARED FOR THE GUIDELINES AND ACCORDING TO THE PRACTICES ANALYZED FOR THE DRAWINGS, SHORING SHOUL NOT BE PERMITTED IN THIS DOCUMENT(S).

3. IMPLIED SHORING PLANS ARE CONSIDERED AS APPLIED CONVENTIONALLY TO THEIR VERTICAL SUPPORT MEMBERS, ALL BEAMS AND COLUMNS SHALL BE CENTERED LATERAL AND NOT BE LATERALLY EXPOSED VERTICALLY.

4. LEVEL, UNLESS OTHERWISE INDICATED ON THESE PLANS.

5. ALL BEAMS OR JOISTS SHALL BE SECURED TO SHORE HEADS WITH 1/4 " BOLTS, UNLESS SHOWN OR IF PICKED PIECE APPEARS UNSTABLE.

6. POUR DECK (SEQUENCE, DETAILS AND STABILITY CHECKS BY OTHERS).

7. COMPLETE FINAL BOLTING.

8. ERECT STAGES 1-5 IN ORDER.

9. CONTROL LINES SHALL BE ATTACHED TO EACH END OF ALL PIECES PICKED AND NO BOLTS EXCEED THOSE PICKED PIECES TO VERIFY THAT THEY FLY LEVEL. CONTACT ENGINEER IF PICKED PIECE APPEARS UNSTABLE.

10. CONTRACTOR SHALL CONFIRM THE ADEQUACY OF ALL BURIED UTILITIES TO RESIST ALL CRANE LOADINGs SHOWN OR ASSOCIATED WITH THESE ERECTION PLANS.

11. CONTRACTOR SHALL HAVE THE CRANE ANNUAL INSPECTION REPORTS ON SITE AND AVAILABLE BY OSHA. CONTRACTOR IS RESPONSIBLE FOR PROVIDING A SAFE SITE IN ACCORDANCE WITH ALL

12. CONTRACTOR SHALL NOT PICK GIRDERS IN WINDS OR ANTICIPATED WINDS THAT EXCEED XX MPH.

13. CONTRACTOR SHALL CONFIRM THE ADEQUACY OF ALL SHORING, BEAMS, HORIZONTAL SUPPORT MEMBERS, ALL BEAMS AND GIRDERS SHALL BE CENTERED LATERALLY AND BUTTED OR LAPPED CENTRALLY OVER VERTICAL SUPPORT MEMBERS.

14. CONTRACTOR SHALL VERIFY ADEQUATE BEARING CAPACITY PRIOR TO PLACING SHORING.

15. CRANE LOADINGS SHOWN OR ASSOCIATED WITH THESE ERECTION PLANS.

16. FIELD WELDERS SHALL BE PREQUALIFIED ACCORDING TO THE STANDARD QUALIFICATION SPECIFIED IN THE CRANE MANUFACTURER MANUFACTURING SPECIFICATIONS OF TRANSPORTATION SYSTEMS SUBARTICLE 501.3.01(B). FIELD WELDERS MUST HAVE CURRENT USE ONLY E70XX (EXCLUDING E7014 AND E7024) LOW HYDROGEN ELECTRODES FOR MANUAL WELDING.

17. CONTRACTOR SHALL HAVE THE CRANE ANNUAL INSPECTION REPORTS ON SITE AND AVAILABLE BY OSHA. CONTRACTOR IS RESPONSIBLE FOR PROVIDING A SAFE SITE IN ACCORDANCE WITH ALL

18. FIELD WELDERS SHALL BE PREQUALIFIED ACCORDING TO THE STANDARD QUALIFICATION SPECIFIED IN THE CRANE MANUFACTURER MANUFACTURING SPECIFICATIONS OF TRANSPORTATION SYSTEMS SUBARTICLE 501.3.01(B). FIELD WELDERS MUST HAVE CURRENT USE ONLY E70XX (EXCLUDING E7014 AND E7024) LOW HYDROGEN ELECTRODES FOR MANUAL WELDING.

19. CRANE LOCATIONS SHOWN ARE APPROXIMATE. CONTRACTOR SHALL ADJUST CRANE LOCATIONS AS NECESSARY TO AVOID OBSTRUCTIONS AND TO SATISFY CRANE OPERATOR REQUIREMENTS.

20. ALL SHORING, BEAMS, HORIZONTAL SUPPORT MEMBERS, ALL BEAMS AND GIRDERS SHALL BE CENTERED LATERALLY AND BUTTED OR LAPPED CENTRALLY OVER VERTICAL SUPPORT MEMBERS.

21. CONTRACTOR SHALL CONFIRM THE ADEQUACY OF ALL SHORING, BEAMS, HORIZONTAL SUPPORT MEMBERS, ALL BEAMS AND GIRDERS SHALL BE CENTERED LATERALLY AND BUTTED OR LAPPED CENTRALLY OVER VERTICAL SUPPORT MEMBERS.

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27. CONTRACTOR SHALL CONFIRM THE ADEQUACY OF ALL SHORING, BEAMS, HORIZONTAL SUPPORT MEMBERS, ALL BEAMS AND GIRDERS SHALL BE CENTERED LATERALLY AND BUTTED OR LAPPED CENTRAL
ERECTION SEQUENCE

1. PLACE CRANES IN POSITIONS 1 AND 2.
2. DELIVER GIRDERS 17D1 AND 24D2 TO UNLOAD POSITION.
3. PAIR GIRDERS BY CONNECTING ALL CROSS FRAMES.
4. DELIVER GIRDER 16CD1 TO UNLOAD POSITION. COMPLETE SPLICE WITH GIRDER 17D1.
5. DELIVER GIRDER 31D3 TO UNLOAD POSITION. ATTACH CROSS FRAMES TO BOTH SIDES OF GIRDER. COMPLETE SPLICE WITH GIRDER 30CD3.
6. TRANSFER LOAD TO PERMANENT BEARINGS AND RELEASE GIRDER FROM CRANES.
7. PICK PAIRED GIRDERS AND SWING GIRDERS INTO PLACE ON TO BENTS 4 AND 5.
8. SECURE GIRDERS AT BENT 4 AS PER DETAIL D AND DETAIL E, AS SHOWN ON SHEET 5.
9. TRANSFER LOAD TO PERMANENT BEARINGS AND RELEASE GIRDERS FROM CRANES.
10. DELIVER GIRDER 31D3 TO UNLOAD POSITION AND ATTACH CROSS FRAMES TO BOTH Sides of GIRDER. COMPLETE SPLICE WITH GIRDER 38D4.
11. DELIVER GIRDER 30CD3 TO UNLOAD POSITION AND ATTACH CROSS FRAMES TO BOTH SIDES OF GIRDER. COMPLETE SPLICE WITH GIRDER 38D4.
12. PICK GIRDERS AND SWING INTO PLACE ON TO BENTS 4 AND 5, AND THEN HOLD.
13. SECURE GIRDERS AT BENT 4 AS PER DETAIL D AND DETAIL E, AS SHOWN ON SHEET 5.
15. TRANSFER LOAD TO PERMANENT BEARINGS AND RELEASE GIRDER FROM CRANES.
16. PICK GIRDERS AND SWING INTO PLACE ON TO BENTS 4 AND 5.
17. DELIVER GIRDER 37CD4 TO UNLOAD POSITION. COMPLETE SPLICE WITH GIRDER 38D4.
18. PICK GIRDERS AND SWING INTO PLACE ON TO BENTS 4 AND 5, AND THEN HOLD.
19. SECURE GIRDERS AT BENT 4 AS PER DETAIL D AND DETAIL E, AS SHOWN ON SHEET 5.
20. ATTACH CROSS FRAMES BETWEEN GIRDERS 30CD3 AND 37CD4 AND BETWEEN GIRDERS AS PER DETAIL E, AS SHOWN ON SHEET 5.
APPENDIX E: SAMPLE ERECTION PLANS

**Erection Sequence**

1. Place Cranes in Positions 1 and 2.
2. Deliver Orders 60C and 205C to Unload Position.
11. Complete Space 5 and Secure Girder at Bent 3 as per Detail D, as shown on Sheet 5.
12. Complete Space 5 and Secure Girder at Bent 3 as per Detail D, as shown on Sheet 5.
14. Transfer Load to Permanent Bearing and Release Girder from Cranes.
15. Transfer Load to Permanent Bearing and Release Girder from Cranes.
16. Transfer Load to Permanent Bearing and Release Girder from Cranes.
17. Transfer Load to Permanent Bearing and Release Girder from Cranes.
18. Transfer Load to Permanent Bearing and Release Girder from Cranes.
19. Transfer Load to Permanent Bearing and Release Girder from Cranes.
20. Transfer Load to Permanent Bearing and Release Girder from Cranes.

**Erection Procedure**

1. Place Cranes in Positions 1 and 2.
2. Deliver Orders 60C and 205C to Unload Position.
11. Complete Space 5 and Secure Girder at Bent 3 as per Detail D, as shown on Sheet 5.
12. Complete Space 5 and Secure Girder at Bent 3 as per Detail D, as shown on Sheet 5.
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15. Transfer Load to Permanent Bearing and Release Girder from Cranes.
16. Transfer Load to Permanent Bearing and Release Girder from Cranes.
17. Transfer Load to Permanent Bearing and Release Girder from Cranes.
18. Transfer Load to Permanent Bearing and Release Girder from Cranes.
19. Transfer Load to Permanent Bearing and Release Girder from Cranes.
20. Transfer Load to Permanent Bearing and Release Girder from Cranes.

**Lift Point Locations**

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 205C</td>
<td>206C</td>
</tr>
<tr>
<td>2. 29C3</td>
<td>36C4</td>
</tr>
<tr>
<td>3. 35BC4</td>
<td>36C4</td>
</tr>
<tr>
<td>4. 21BC2</td>
<td>22C2</td>
</tr>
<tr>
<td>5. 28BC3</td>
<td>36C4</td>
</tr>
</tbody>
</table>

**Lift Points**

- **Stage 1:** 205C, 206C, 29C3, 35BC4, 21BC2, 28BC3
- **Stage 2:** 206C, 29C3, 36C4, 21BC2, 28BC3

**Lift Weights (lbs)**

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 205C</td>
<td>206C</td>
</tr>
<tr>
<td>2. 29C3</td>
<td>36C4</td>
</tr>
<tr>
<td>3. 35BC4</td>
<td>36C4</td>
</tr>
<tr>
<td>4. 21BC2</td>
<td>22C2</td>
</tr>
<tr>
<td>5. 28BC3</td>
<td>36C4</td>
</tr>
</tbody>
</table>

**Company Logo**

- **Project Name:** Bridge X
- **Project Number:** XXXX-9999-99
- **Location:** County, State
- **Scale:** 1:30

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ERECTING PROCEDURE

1. Install shoring, top cribbing and shims as shown on Sheet 4. Adjust tops of shims to elevation "A".

2. Place crane in position 1.

3. Deliver Girders 11A1 and 18A2 to unloading position.

4. Pair Girders by connecting all Cross Frames.

5. Pick Girders and swing into position on to bent 1 and shoring towers, and then hold.

6. Secure Girders at bent as per Detail D and as per Detail E, as shown on Sheet 5.

7. Transfer load to shoring and permanent bearing, and release Girders from cranes.

8. Deliver Girders 25A3 to unloading position and attach Cross Frames to both sides of Girders.

9. Pick Girders and swing into place on to bent 1 and shoring towers, and then hold.

10. Secure Girders at bent as per Detail D and as per Detail E, as shown on Sheet 5.


12. Transfer load to shoring and permanent bearing, and release Girders from cranes.


14. Pick Girders and swing into place on to bent 1 and shoring towers, and then hold.

15. Secure Girders at bent as per Detail D and as per Detail E, as shown on Sheet 5.


17. Transfer load to shoring and permanent bearing, and release Girders from cranes.

ERECTING SEQUENCE

Stage 3: Girders 11A1 - 18A2 - 25A3 - 32A4

1. Install Shoring, Top Cribbing and Shims as shown on Sheet 4. Adjust Tops of Shims to Elevation "A".

2. Place Crane in Position 1.

3. Deliver Girders 11A1 and 18A2 to unloading position.

4. Pair Girders by connecting all Cross Frames.

5. Pick Girders and swing into position on to bent 1 and shoring towers, and then hold.

6. Secure Girders at bent as per Detail D and as per Detail E, as shown on Sheet 5.

7. Transfer load to shoring and permanent bearing, and release Girders from cranes.

8. Deliver Girders 25A3 to unloading position and attach Cross Frames to both sides of Girders.

9. Pick Girders and swing into place on to bent 1 and shoring towers, and then hold.

10. Secure Girders at bent as per Detail D and as per Detail E, as shown on Sheet 5.


12. Transfer load to shoring and permanent bearing, and release Girders from cranes.

Stage 3 Shoring

There are no lane closures during Stage 3 Steel Erection.
**APPENDIX E: SAMPLE ERECTION PLANS**

**ERECTION PROCEDURE**

1. Place cranes in positions 1 and 2.
2. Lower cranes down and back to upload position.
3. Pick paired girder and swing into place onto splice 1 and onto bent 2.
4. Complete splice 1 and secure girder at bent 2 as per detail D, as shown on sheet 1.
5. Transfer load to permanent bearing and release girder from crane.
6. Pick girder and swing into place onto splice 1 and onto bent 2, and then hold.
7. Complete splice 1 and secure girder at bent 2 as per detail D, as shown on sheet 1.
8. Transfer load to permanent bearing and release girder from crane.
9. Complete splice 1 and secure girder at bent 2 as per detail D, as shown on sheet 1.
10. Transfer load to permanent bearing and release girder from crane.
11. Complete splice 1 and secure girder at bent 2 as per detail D, as shown on sheet 1.
12. Deliver girder 33AB4 to unload position.
13. Transfer load to permanent bearing and release girder from crane.
14. Complete splice 1 and secure girder at bent 2 as per detail D, as shown on sheet 1.
15. Attach cross frames between girder 26AB3 and 33AB4.
16. Transfer load to permanent bearing and release girder from crane.
17. Complete splice 1 and secure girder at bent 2 as per detail D, as shown on sheet 1.
18. Transfer load to permanent bearing and release girder from crane.
19. Complete splice 1 and secure girder at bent 2 as per detail D, as shown on sheet 1.
20. Transfer load to permanent bearing and release girder from crane.

**ERECTION SEQUENCE**

1. 040-0402 PAN
2. 26AB3
3. 33AB4

**GIRDERS PICK LEGEND**

- X: Lift point on girder
- 0: Crane lift point
- δ: Attached cross frame
- A: Crane center pin

**LIFT POINT LOCATIONS**

<table>
<thead>
<tr>
<th>Piece Number</th>
<th>Piece Detail</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Pick Weight (Lb)</th>
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<tbody>
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<td>010-100-000</td>
<td>90</td>
<td>57</td>
<td>67</td>
<td>85</td>
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<td>57</td>
<td>67</td>
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<td>01700</td>
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<td>90</td>
<td>57</td>
<td>67</td>
<td>85</td>
<td>41,700</td>
</tr>
</tbody>
</table>

**PICK WEIGHTS (Lb)**

- 040-0402 PAN: 84,100 Lb
- 26AB3: 56,500 Lb
- 33AB4: 56,500 Lb

**CAPACITIES**

- RADIUS = 75' OF 360° CHART CAPACITY

- CAPACITY

- 040-0402 PAN
- 26AB3
- 33AB4

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Erection Procedure

1. Place girders in Position 1 and 2.
2. Deliver girder 13B1 to unloading position.
3. Pick girder and swing girder into place into splice 2 and 3, and then hold.
4. Complete splice 2 and release from girder 1.
5. Complete splice 3 and release from girder 2.
6. Complete splice 3 and release from girder 2.
7. Delivered girder 13B1 to unloading position.
8. Pick girder and swing girder into place into splice 2 and 3, and then hold.
9. Complete splice 2 and release from girder 1.
10. Complete splice 3 and release from girder 2.
11. Delivered girder 13B1 to unloading position.
12. Pick girder and swing girder into place into splice 2 and 3, and then hold.
13. Complete splice 2 and release from girder 1.
15. Pick girder and swing girder into place into splice 2 and 3, and then hold.
16. Complete splice 2 and release from girder 1.
17. Pick girder and swing girder into place into splice 2 and 3, and then hold.
18. Complete splice 2 and release from girder 1.
19. Complete splice 2 and release from girder 2.
20. Complete splice 3 and release from girder 2.

Note:
- Girders shall be placed at 24 hours of placing.
- Girders shall be placed if winds are expected to exceed 10 mph in the following 48 hours.

Stage 5 Traffic:
- One lane closure required for I-99 SB.
- One lane closure required for I-599 EB.
- Rolling closure for I-99 SB required while cranes are in place.
- 1 lane closure required for I-599 WB.
- One lane closure required for I-99 SB.

Lifting Plan

- All capacities shown with 123,500 lb. counterweight.
- Girders shall be placed at 24 hours of placing.

Erection Sequence

1. 13B1
2. 20B2
3. 27B3
4. 34B4

Order Pick Legend

- X = Lift point on girder
- O = Crane lift point
- A = Attached splice
- C = Attached cross frame
- L = Crane center pin

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Bridge 0172 North Bound (Abutment 1 to Pier 3N)

<table>
<thead>
<tr>
<th>Crane position 1A</th>
<th>G6</th>
<th>47.0</th>
<th>16.470</th>
<th>36.32</th>
<th>1.436</th>
<th>2.94</th>
<th>10.70</th>
<th>49.96</th>
<th>80</th>
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<td>35.78</td>
<td>0.00</td>
<td>10.70</td>
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<td>90</td>
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<td>1.69</td>
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<tr>
<td>G8A</td>
<td>16.202</td>
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<td>70</td>
<td>111.80</td>
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<tr>
<td>G10A with diaphrags</td>
<td>16.101</td>
<td>35.50</td>
<td>1.436</td>
<td>2.94</td>
<td>10.70</td>
<td>49.15</td>
<td>60</td>
<td>138.90</td>
<td>2.83</td>
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<tr>
<td>G11A</td>
<td>15.967</td>
<td>35.25</td>
<td>0.00</td>
<td>10.70</td>
<td>45.95</td>
<td>50</td>
<td>179.90</td>
<td>3.92</td>
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<tr>
<td>G12A</td>
<td>15.538</td>
<td>34.26</td>
<td>0.00</td>
<td>10.70</td>
<td>44.96</td>
<td>50</td>
<td>179.90</td>
<td>4.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Manitowoc M-250 Series 2 Crawler, 20% crane CWT + 60% carbody CW, No 44 boom with heavy-lift top

| Crane position 5A | G6E with diaphragms | 115.0 | 54.668 | 120.54 | 4.668 | 9.57 | 14.00 | 144.11 | 170 | 55 | 157.10 | 1.09 |
|-------------------|-------------------|------|---------|--------|-------|------|-------|-------|----|-------|------|
| G7E               | 53.971 | 119.01 | 0.00 | 14.00 | 133.01 | 60 | 138.90 | 1.04 |
| G9E               | 47.249 | 104.18 | 0.00 | 14.00 | 118.18 | 50 | 179.90 | 1.52 |
| G10E with diaphragms | 46.899 | 103.41 | 4.668 | 9.57 | 14.00 | 126.98 | 60 | 138.90 | 1.09 |
| G11E              | 46.555 | 102.65 | 0.00 | 14.00 | 116.65 | 50 | 179.90 | 1.35 |
| G12E              | 45.195 | 99.66 | 0.00 | 14.00 | 113.65 | 50 | 179.90 | 1.58 |

Bridge 0172 North Bound (Abutment 1 to Pier 3N)

| Crane position 6A | G6F with diaphragms | 115.0 | 39.433 | 86.95 | 5.744 | 11.79 | 14.00 | 112.72 | 170 | 60 | 138.90 | 1.23 |
|-------------------|-------------------|------|---------|--------|-------|------|-------|-------|----|-------|------|
| G7F               | 38.306 | 84.46 | 0.00 | 14.00 | 98.46 | 70 | 111.80 | 1.14 |
| G9F               | 34.433 | 75.92 | 0.00 | 14.00 | 89.92 | 50 | 179.90 | 2.00 |
| G10F with diaphragms | 34.187 | 75.38 | 5.744 | 11.79 | 14.00 | 101.16 | 60 | 138.90 | 1.37 |
| G11F              | 33.939 | 74.84 | 0.00 | 14.00 | 88.84 | 50 | 179.90 | 2.03 |
| G12F              | 32.280 | 71.18 | 0.00 | 14.00 | 85.18 | 50 | 179.90 | 2.11 |

Manitowoc M-250 Series 2 Crawler, 20% crane CWT + 60% carbody CW, No 44 boom with heavy-lift top

| Crane position 7 | G6G with diaphragms | 73.0 | 25.617 | 56.49 | 3.232 | 6.63 | 10.70 | 73.81 | 170 | 75 | 101.50 | 1.38 |
|------------------|-------------------|------|---------|--------|-------|------|-------|-------|----|-------|------|
| G7G               | 25.143 | 55.44 | 0.00 | 10.70 | 66.14 | 85 | 85.00 | 1.29 |
| G9G               | 23.239 | 51.24 | 0.00 | 10.70 | 61.94 | 65 | 124.10 | 2.00 |
| G10G with diaphragms | 23.081 | 50.89 | 3.232 | 6.63 | 10.70 | 68.22 | 55 | 157.10 | 2.30 |
| G11G              | 22.899 | 50.49 | 0.00 | 10.70 | 61.19 | 55 | 157.10 | 2.57 |
| G12G              | 22.044 | 48.61 | 0.00 | 10.70 | 59.31 | 55 | 157.10 | 2.65 |

PICK SCHEDULE

SCALE: 1:100
APPENDIX E: SAMPLE ERECTION PLANS

FW-1 ELEVATION

SCALE: 1:50

FW-4 ELEVATION

SCALE: 1:50
NOTES:

1) ALL TOWERS SHALL BE SET PLUMB. STEEL SHIMS MAY BE USED FOR ADJUSTMENT.

2) ALL FULLER TOWER SEGMENTS, HEADER, GRIFFIN BEAMS SHALL BE CONNECTED BY (6) 1/2" HIGH STRENGTH BOLTS AT ALL LOCATIONS.

3) ABOVE BOLT CONNECTION CAN BE SUBSTITUTED WITH WELDING METHOD SHOWN BELOW:

- 3/8" HOLE FOR EACH BOLT SUBSTITUTED
- 3/8" TURN BOLTS
- W1 HIGH TENSILE STEEL BOLT TYP

**JACKING & CONNECTION FOR SINGLE TOWER**

**SCALE: 1:25**

**TYP. JACKING & CONNECTION**

**SCALE: 1:25**

**CABLE BRACING DETAIL**

**SCALE: 1:20**

**CABLE BRACING DETAIL**

**SCALE: 1:20**