11.30 BRIDGES

For some bridge project work over traffic roadways (ie: new bridges, bridge replacements, bridge widening, bridge rehabilitation, etc.) changes in the vertical clearance above the traffic roadway may occur. All changes in vertical clearance over traffic roadways need to communicated when they occur since this vertical clearance change information needs to be provided to Motor Carrier Services for permitting and routing of vehicles.

Reporting of vertical clearance changes is accomplished by placing information on "CARS 511" (Condition Acquisition & Reporting System). Refer to the CARS Users' Manual for more information (http://dotnet/construct/CARS.doc).

11.31 FALSEWORK

Temporary Fastenings

Contractors often request permission to use anchor supports for face forms, concrete curbs, and raised medians on bridges. Any contractor desiring to use a temporary floor fastening may be allowed to use only some form of weakened section bolt, or tie, cast in the floor. The weakened section must be so positioned that when broken off the break will be recessed below the surface. The resulting void must be patched with mortar.

NOTE:

1. ***No bolt without a weakened section may be used.***
2. ***No hold-down device shot into the floor will be allowed.***

Falsework Plans

Specification 1105.03 requires the contractor to submit 2 copies of falsework plans. These plans shall be prepared by an engineer licensed in the State of Iowa. Falsework plans are required for all bridges where the contractor intends to support plastic concrete on, or from a specially constructed structure. Typically such practices are used for concrete slab bridges, concrete cast-in-place girder bridges, and concrete arch bridges.

Submitting Plans

The contractor should be informed at preconstruction conferences that falsework plans must be submitted and reviewed prior to the erection of any falsework elements. The Office of Bridges & Structures has revised their policy on falsework plan submittal and review to improve the efficiency and timeliness of response. The process for falsework plan submittal is explained in the following:

Falsework plan submittals should include the following information: County, Project Number, Design Number, and Contractor. The contractor should submit the falsework plans directly to the Office of Bridges & Structures to the attention of the Working & Shop Drawing Coordinator with a cover letter requesting review for approval. The contractor will also distribute copies of the cover letter from the plan submittal to the RCE and Office of Construction.

The Office of Bridges & Structures will review the falsework plan submittal and send the final approved copies to the contractor, RCE, and retain a copy in the bridge file. If the project is a consultant design, the Office of Bridges & Structures may have the consultant review the falsework plan in which case the consultant would also retain a final copy of the approved plans for their file. Resubmittal will be required when the original falsework plans are deemed inadequate.

Included with the distribution of the final approved falsework plans will be a cover letter. This cover letter will be copied to the Office of Construction for tracking purposes.

Special instructions for counties and cities are included in *Appendix 11-22*.

NOTE: An approval of falsework plans does not imply that OSHA regulations are satisfied, that the Iowa DOT or the project engineer assumes any liability for the falsework.

Falsework Inspection

Contract requirements governing falsework construction are contained in Specification 2403.03, L under "Design and Construction of Forms and Falsework."

The project engineer is responsible to inspect the falsework as it is erected to ensure that construction:

- Is in accordance with previously approved drawings
- That only sound materials are used
- That quality work is used
- That all specific contract requirements are met

Note: Any inspection and/or acceptance by the project engineer is not intended to relieve a contractor of responsibility under the contract for falsework design and construction.

By specification, a contractor is responsible for proper evaluation of the quality of their falsework materials. However, the project engineer should not permit use of any material, when there is doubt as to the materials ability to safely carry the load. If there is any question, the contractor should be required to perform a load test or furnish other evidence of structural adequacy.

Timely inspection is essential. Falsework deficiencies should be brought to the contractor's attention at once. Deficiencies include:

- Poor quality work
- Use of unsound or poor quality materials
- Construction which does not conform to the approved drawings

If the contractor fails to take corrective action, a non-compliance notice shall be issued. Corrective action will be required prior to placement of any additional dead or live load to the support structure.

Falsework Foundations

Specifications require that falsework piling be driven to adequate bearing unless mudsills or spread footings can be founded on rock, shale, compact gravel, coarse sand, firm clays in natural beds, or well-compacted fill.

A. Falsework Piles

If requested, pile bearing values will be determined by the wave equation. Otherwise, the contractor is responsible for adequate foundation support.

The pile bearing value required to support the design load must be shown on falsework drawings, and the pile driving operation must be inspected sufficiently to ensure that falsework piles attain required bearing.

B. Mudsills and Spread Footings

Specifications limit the use of mudsills or spread footings to rock, shale, deep compact gravel, dense sand, firm undisturbed clays, or well-compacted fills.

Foundation material should be inspected before the footings are placed.

To ensure uniform soil bearing, falsework pads must be set on material that provides a firm even surface, free of humps or depressions within the pad bearing area. If necessary to obtain uniform bearing, a thin layer of sand may be used to fill in surface irregularities.

Continuous pads must be analyzed differently than individual pads, and the two should not be considered equivalent. A change from one to the other requires resubmittal for review by the Office of Bridges and Structures.

Falsework pads should be level. Benches in fill slopes should be cut into firm material, with the pad set well back from the edge of the bench.

Many soils lose their supporting capacity when saturated. Adequate falsework construction must provide for drainage and protect pads from being undermined or ponded in water.

C. Soil Load Test

Project engineers should require the contractor to perform a soil bearing test if there is any doubt as to the ability of foundation material to support the falsework load without appreciable settlement. One method to evaluate in-situ bearing capacity is to perform a plate bearing test as per ASTM D-1194. (The above referenced method is not the only such test procedure, but is included to provide "one" method of determining in-situ capacity.)

Materials

One aspect of a falsework design and review is based on the use of undamaged, high-quality materials. Material strength values must be reduced if lower quality materials are to be used. Obviously, evaluation of the quality of materials actually furnished is an important, and essential, part of the falsework inspection procedure.

A. Timber

Inspecting falsework materials is necessary to prevent the use of materials which obviously do not meet the "undamaged high-quality" design criteria.

Falsework materials delivered to the job site should be equal to or greater than the grade, or type of material, assumed in the design review. Timber having large shakes, checks or knots, or which are warped or split should not be used at critical locations. Abused timber, although stress graded, may no longer be capable of withstanding the original allowable stress.

Rough sawn timbers should be measured to determine their actual dimensions. Unlike surfaced/finished material, the dimensions of rough-cut timber are not uniform from piece to piece. The variation may be appreciable, particularly in the larger sizes commonly used for falsework posts and stringers. If actual dimensions are smaller than the dimension assumed in design, the member may not be capable of carrying the imposed load without overstress. Therefore, undersized material should not be incorporated into the falsework, unless the design is reevaluated using smaller dimensions.

B. Structural Steel

Used beams, particularly beams salvaged from a previous commercial use, should be examined carefully for loss of section due to welding, rivet or bolt holes, or web openings which may adversely affect the ability of the beam to safely carry the load imposed by the falsework design.

Welded splices should be inspected visually for obvious defects. Radiographic inspection or other methods of nondestructive testing will not be required as a means of determining the quality of the splices unless the project engineer has reason to believe the welds are defective.

If falsework design is based on using steel other than A36, the contractor should be required to furnish evidence that all beams furnished are in fact the grade of steel as noted on the falsework plans.

C. Manufactured Products

Manufacturer's ratings are based on the use of new material or used material in good condition. The determination as to whether a manufactured product is in good condition is highly subjective and requires experience and judgment.

When manufactured assemblies are used in falsework, they shall be shown on the falsework plans along with their identification number. Actual assembly shall be clearly and permanently marked with the identification number.

Identification numbers will allow field inspectors to verify the capacity and proper application of various devices.

Identification by the contractor applies not only to jacks, beam hangers, overhang brackets, and similar devices, but to all vertical steel shoring systems as well.

Manufactured products such as tubular steel shoring and steel overhang brackets are particularly vulnerable to damage by continual reuse. Fabricated units in which individual members are bent, twisted, or broken will have a substantial reduction in load-carrying capacity. Steel shoring materials should be examined carefully prior to use. Shoring components should not be used if they are heavily rusted, bent, dented, or have broken weldments or other defects. Connections, in particular, should be examined for evidence of cracked or broken welds. Miscellaneous components such as screw jack extensions, clamps, and adjusting pins should be inspected as well.

Proprietary scaffolding must be used as intended and not subjected to additional stresses or conditions for which it was not originally designed and tested.

D. Cable Bracing

Cable bracing systems must be carefully inspected to ensure that field installation conforms to details shown on the approved falsework drawings. This is particularly important with respect to the location and method of cable attachment falsework.

Prior to installation, cable should be inspected to verify that the type, size, and condition (new or used) are consistent with design assumptions. Used cable should be inspected for strength-reducing flaws. Use of obviously worn, frayed, kinked, or corroded cable should not be permitted.

Particular attention should be paid to cable clamp fasteners. Improperly installed clamps will reduce the safe working load by as much as 90%. Also, the omission of the thimble in a loop connection will reduce the safe working load by approximately 50 percent. After installation, clamps should be inspected periodically and tightened as necessary to ensure their effectiveness.

This author could never remember which way to install cable clamps. The following little phrase may be beneficial:

"It does no good to saddle a dead horse."

While the phrase may seem nonsensical, it defines how to install clamps since a cable clamp has two parts - the "U-Bolt" and the "Saddle." Also, a cable has two parts, the wrapped non-continuous end (dead end) and the continuous portion which supports the load (live side). Therefore, always put the cable clamp's "saddle" on the live side and the "U-bolt" over the "dead end."

Project Quality

High quality work, particularly in such details as wedges, fasteners, bracing, friction collars, jack extensions, etc., is critical to the proper performance of falsework. Accordingly, construction details should receive close attention from the project inspector.

A. Timber Construction

The following checklist is included as a guide to points which require special consideration:

Size and spacing of falsework members must agree with details shown on the falsework drawings.

Diagonal bracing, including connections, must conform to details shown on the falsework drawings.

Diagonal bracing should be inspected after any falsework has been adjusted to grade. Connections must be securely fastened to ensure their effectiveness in resisting horizontal forces. Bolted connections may need retightening.

Timber posts may be wedged at either the top or bottom for grade adjustments, but not at both locations. Large posts may require two or more sets of wedges (side by side) to reduce compression stresses perpendicular to the grain.

Blocking and wedging should be kept to a minimum. It is poor workmanship to extend a short post by piling up blocks and wedges. This practice should not be permitted.

Particular attention should be given to falsework bents where grade adjustment is provided at the bottom of the posts. Differential grade adjustment of posts within a particular bent may induce undesirable stresses in the diagonal bracing.

Splicing of wood posts will not be allowed unless shown on approved falsework plans.

The ends of spliced posts must be cut square. Proper size splice plates, and proper size, pitch and edge distance of nails need to be used. The need for a post splice should have been anticipated by the contractor and the splice detail shown on falsework drawings. If this is not the case, the contractor must submit a detail for approval.

Posts must be plumb and centered over the falsework pad or corbel.

Abutting edges of soffit plywood should be set parallel to the joists and continuously supported on a common joist.

A sufficient number of telltales must be installed to accurately determine the amount of joint take-up and settlement. Telltales should be attached to the joists as close as possible to the supporting post or bent.

Full bearing must be obtained between all members in contact. Deficiencies in this respect may be improved by feather wedging. If the joint requires more than a single shim or wedge, extra care should be taken to ensure that full bearing is obtained.

- When using wedges, as illustrated in *Appendix 11-23*, it is a good practice to use wedges inserted from both sides rather than deeply setting a single wedge. Using only one wedge increases the twisting effect on the member.
- When using wedges, it is good practice to install them parallel to and with the flat (non-tapered) side against the main member. This improves contact with the main member and decreases the chance of a wedge "backing out" from vibration.
- Nail or clamp the wedge in place after installation.

B. Steel Shoring (Scaffolding)
This checklist may be used as a guide by inspectors when inspecting falsework constructed of steel shoring.

Shoring components should be inspected prior to erection. Any component that is heavily rusted, bent, dented or rewelded, or which is otherwise defective, should be rejected. Fabricated units having individual members that are bent, twisted, broken, or where welded connections are cracked or show evidence of rewelding should be rejected.

A base plate, shore head, or screw jack extension device should be used at the top and bottom of all vertical components.

All base plates, shore heads, and extension devices must be in firm contact with the footing at the bottom and the cap or stringer at the top.

Shoring components should fit together evenly, without any gap between the upper end of one unit and the lower end of the other unit. Any component which cannot be brought into proper contact with the component it is intended to fit, should not be used.

Shore heads, extension devices, and similar components must be axially loaded. Eccentric loads are not permitted on any shoring component.

All locking devices on frames and braces must be in good working order, coupling pins must align the frame or panel legs, and pivoted cross-braces must have the center pivot in place.

Shoring should be plumb in both directions. Maximum deviation from true vertical should not exceed 3 mm per meter (1/8 inch per 3 feet).

Miscellaneous Items

This checklist covers items that may be used in either type of support system:

- New high strength bolts shall be used on any item that requires bolts to be torqued.
- Friction collar bolts and concrete anchors should be torqued initially and checked again just prior to concrete placement.
- Permanently deflected stringers should be placed with the crown turned upward.
- Jacks should be plumb and not overextended.

Falsework Adjacent to Traffic

This will be an unusual situation in Iowa. If it occurs, the Office of Construction should be notified.

Field Changes

If supplemental calculations are necessary to verify compliance with contract requirements, the change will be considered substantial. In this case, the proposed change must be submitted for review and approval in the same manner as the original drawings.

The following are examples of changes considered substantial and must be shown on revised falsework drawings, regardless of other considerations:

- A change in size or spacing of any primary load-carrying member
- A change in method of providing lateral or longitudinal stability
- Any change, however minor, which affects the falsework to be constructed over or adjacent to a traffic opening
- A revised concrete placing sequence, if it significantly affects the stresses in load-carrying members
- When revised drawings are required, they must be submitted for review in the same manner as the original falsework drawings. Work shown on a revised falsework drawing may not begin until that drawing has been approved by the project engineer. Time shall be allowed for review and approval of revised falsework drawings. Typically this is the same as required for the original submittal.
- Any change in an approved falsework design, however minor it may appear to be, has the potential to adversely affect other falsework members or components. Before approving any change, the project engineer should ask, and then answer the question: ***"How does this change affect the integrity of the falsework system as a whole?"***

Inspection During Concrete Placement

As concrete is being placed, the falsework should be inspected at frequent intervals. In particular, look for the following indications of potential failure:

- Excessive compression at the tops and bottoms of posts and under the ends of stringers
- Pulling of nails in lateral bracing
- Movement or deflection of braces
- Excessive deflection of stringers
- Tilting or rotating of joists or stringers
- Excessive settlement of "tell-tales"
- Posts or towers that are moving out of plumb
- Sounds of falling concrete or breaking timbers
- If any member deflects unduly or shows evidence of distress, such as splintering on the bottom of stringers, crushing of joints or wedges, etc., placement work in the affected area should be stopped immediately and the falsework strengthened by addition of members, installation of supplementary supports, or some other means.

- Settlement of the falsework should be limited to a maximum of 10 mm (3/8 inch) deviation from the anticipated settlement. Should actual settlement exceed the anticipated settlement by more than the 10 mm (3/8 inch) allowable, and if it appears that a serious problem is developing, concrete placing should be temporarily discontinued in affected areas until the contractor provides satisfactory corrective measures. Concrete placing should not be resumed until the project engineer is satisfied that further settlement will not occur.
- If it is apparent that satisfactory corrective measures cannot be provided prior to initial setting of the concrete, the project engineer shall stop placing of concrete and contact the Office of Construction.
- One important and often overlooked point is the danger of curing water softening the falsework foundation. Some means should be provided to prevent curing water from reaching and soaking the foundation material beneath the falsework bearing pads.
- The contractor should provide the drainage for any water that accumulates in box-girder cells. Such accumulated water could easily overstress the falsework.

Removal of Falsework

Specifications and applicable special provisions contain specific criteria which must be met before falsework may be removed. Project engineers should review these sections prior to falsework removal operations.

The project engineer should discuss falsework removal methods and procedures at the preconstruction and/or prepour meeting. The need to provide for employee and public safety is of particular concern.

In general, all elements of the falsework bracing system must remain in place for the specified time period or until concrete attains the specific strength. For continuous concrete slab bridges that are stage constructed, the falsework for all stages must remain in place until the last stage concrete as attained the specified strength. The reason is that the concrete slab deflection does not occur until the falsework is removed and this deflection must occur for the full width of the bridge deck at the same time. In the case of cast-in-place, post tensioned construction, falsework elements must not be removed until stressing is completed.

11.32 BRIDGES - STEEL BEAM

In February 1994, the Specification Committee approved using weathering steel (A 588) for steel structures. While the change made little difference to field erection and inspection, it did:

- Change the type of fasteners. They remained "high strength," but changed to A325 Type III bolts, A563 Grade DH3 nuts, and F463 Type III washers.
- Limit shop painting to only areas under expansion joints and all bearings. Shop painting will be a Zinc-rich primer and a colored top coat. Field touch-up will be required for paint that is damaged and to fasteners in these areas.
- Require special care to assure concrete "slobbers" are eliminated (or at least removed) from steel surfaces before the concrete hardens. Washing with water is the preferred method of removing concrete "slobbers."
- Require all drains and drop pipes to be galvanized (inside and out). Plus, the outside will be painted with the colored top coat when specified by the contract documents.

Prebolting Meeting

The objective of a prebolting meeting is to establish a clear understanding of the principles and purpose of rotational capacity testing, bolting procedures, Turn-of-Nut process, inspection process, and the communication needs of the contractor and inspector during installation.

A prebolting meeting shall be held prior to erecting structural steel. In addition to construction residency staff and contractor, notifications of the scheduled dates for prebolting meeting and rotational capacity testing should be provided to:
- Office of Bridges & Structures Engineer
- Structural Steel Materials Engineer
- Office of Construction Structural Engineer
- District Materials Engineer
- Structural Steel Fabrication Inspector

Each of these persons can be a valuable resource during the prebolting meeting and throughout the structural steel erection process in providing technical assistance.

Suggested agenda items for discussion at prebolting meeting:

- Identify all persons and their responsibilities

- Discuss communication and coordination needs of those involved in the structural steel erection process

- Review documentation and inspection (refer to *I.M. 453.06B* and *Specification 2408*)

Suppliers to Furnish:	Mill Test Reports Manufacturer's Certified Test Reports Distributor Certified Test Report Lot Numbers RC-Lot Numbers Statement of Compliance
Iowa DOT to Furnish:	Mechanical Test Reports (Bolts, Nuts, & Washers)
Contractor to Perform & DOT to Witness in Field:	RC-Testing Tension Testing Calibration "Snug-Tightening" Turn-of-Nut Procedure Bolt Tension Verification of Installations

- Required equipment for rotational capacity test:
  - Calibrated bolt tension measuring device (every 6 months)
  - Calibrated torque wrench (every 6 months)
  - Shims should be of varying thicknesses to ensure that no more than five shims are needed for any bolt length to be tested. Shims must have a minimum cross sectional area of five times the cross sectional area of the bolt being tested. Shim adjacent to the washer cannot be longer than 1/16" diameter greater than the bolt diameter being tested.
  - Steel section for mounting tension measuring device.

- Identify all sizes of high strength fastener assemblies to be rotational capacity tested.

- Review contractor's plan for structural steel erection and bolting of connections. The contractor shall submit a written plan for their proposed structural steel erection sequence including ensuring steel girder stability during erection and management of traffic if construction is under active traffic conditions. This submitted erection plan is to be reviewed by the Engineer to identify any concerns that may need to be addressed prior to initiating the actual structural steel erection.

- Discuss procedures for:
  - Rotational capacity testing (long bolt and short bolt methods)
  - Field erection of structural steel
  - Fastener assembly installation
  - Turn-of-Nut method
  - Inspection of completed bolted connections

- Review of Installation Checklist

Erecting Steel Beams

When erecting steel beams, the beams shall be supported until at least 25% of the bolt holes are filled with drift pins and another 25% of the holes filled with fitting-up bolts which are "snug" tightened. This will apply to both sides of the splice. (Refer to Specification 2408.03, Q.

Beam support shall consist of adequate falsework or other approved means as directed by the engineer. The process of splicing of beams on the ground prior to lifting and setting should not be permitted until contractor's methods are reviewed and approved by the engineer. The following are some of the criteria to be considered if this method is proposed:

- Each beam section must be supported at beam ends and/or splice connections such that the difference in beam end elevations on the ground will be the same as the supporting substructure on which the beams will be set.
- All temporary drift pins will be required to be driven tight and all fitting-up bolts shall be "snugged" prior to lifting spliced girder units off the ground supports to set on the substructure. **NOTE:** Bolts should not be tensioned until the girder units have been set and adjusted in their final position on the substructure.
- After girder unit has been set on the substructure, adjustments shall be made to establish correct final grade and alignment.

Specification 2408.03, R requires that the structure shall be adjusted to correct grade and alignment before placing permanent bolts in field connections. Grade and alignment should be checked by the contractor and verified by the inspector as each girder unit is set. All adjustments are to be completed before initiating the final phase of bolt tightening.

High Strength Fasteners

Specification 2408.03, S, 5, b. Turn-of-Nut method shall be followed for tightening all high strength fasteners.

High Strength bolts and nuts, which have been torqued as outlined below, shall not be reused. This includes both black and galvanized bolts and nuts.

A. Bolting

Receiving Shipments

Prior to installation, check shipping certifications and compare these to bolting kegs on site. Check for size, length, heat numbers, and general fastener condition i.e., rusted black bolts or non-lubricated galvanized nuts. Rotational-Capacity (RC) lots will need to be checked. When containers of washers, bolts, and nuts have been delivered to the project, the contractor shall group the fastener elements according to like Rotation Capacity Lot numbers. All fastener elements to be installed must be matched by the same Rotational Capacity Lot numbers as indicated on the containers. The inspector on the project should confirm that the fastener elements have been grouped prior to the contractor initiating steel erection and bolting.

Installation Checklist

- Schedule dates for prebolting meeting and Rotational Capacity testing. Provide notification to all appropriate participants
- Rotational Capacity test training for project inspectors is available through Office of Materials. This training consists of “hands-on” testing of fastener assemblies in the Materials Lab and will be most beneficial if scheduled prior to the Prebolting Meeting. To schedule training, contact Office of Construction at least two weeks in advance for coordination of a training date with the Office of Materials.
- Verify current calibrations of skidmore and torque wrench
- Site storage of fasteners is important to ensure: 1) protection of lubrication on fastener assemblies from moisture, dirt, dust, etc. 2) identity of fasteners according to their respective rotational capacity lot number is maintained.
- Stress the importance of rotational capacity lot number tracing from the time fasteners are received through final installation in the structure. All fastener elements, to be assembled for installation, must have the same rotational capacity lot numbers as identified by the manufacturer’s rotational capacity tests.
- All fasteners shall be free of dirt, moisture, rust, and be “well” lubricated.
- Black bolts and nuts shall be “oily” to the touch when delivered and installed.
- Galvanized nuts shall be checked to verify lubrication. A uniform dye color indicates lubricant has not been damaged. If there is no color, or color is not uniform, bolts and nuts shall be field lubricated with beeswax, stick wax, or other approved dry wax prior to installation.
- Rusted or dirty bolts or nuts shall be cleaned and relubricated prior to installation.

- RC tests conducted for each lot must represent the intended installation procedure. The element (bolt or nut) to be turned during installation must also be the turned element during performance of the RC test.

- Washers (when required) are to be placed under the “turned element”.

- If an RC test shows that a specified amount of rotation (i.e. 1/3 turn) does not fully develop the required minimum installation tension, then designate the new rotation required to achieve it.

- Use caution when accepting an installed fastener assembly based on the allowable rotational tolerances given in Specification 2408.03, S, 5, b. Verify that the low value of the rotational tolerance is still achieving the required minimum installation tension.

- Suggest the use of temporary bolts for connections during initial erection of structural steel. This can reduce potential damage to permanent fastener assemblies that are intended for the final connection.

- Often contract documents will specify which way a bolt is to be installed. If there is no specific guidance, threaded ends of bolts will be turned inside away from normal exposure to pedestrian and/or vehicular traffic for aesthetic reasons.

- Faying surfaces shall be free of burrs, foreign material, and bolted faying surfaces are to be painted with zinc rich paint.

- During installation, particular care should be exercised so a snug-tight condition is achieved. Bolts shall be considered “snug-tight” when tensioned to approximately 20% of the minimum bolt tension and faying surfaces are in full contact. Retightening to achieve snug-tight is acceptable. If full contact of faying surfaces is not achieved after all bolts have been tensioned to 20% of minimum tension, contractor shall submit a corrective procedure to the engineer for approval.

- Fastener assembly must be properly marked after “snug-tightening” and before proceeding with Turn-of-Nut process. Proper marking consists of match-marking the bolt point, nut, and base steel to provide a straight reference line for determining final relative rotation of parts.

- Check alignment and elevation of the full girder line for adjustment before torquing of connections.

- Reuse of high strength bolts is not allowed by Specification 2408.03, S, 5, d. This applies to bolts that have previously been tightened. If there is a question as to the condition of the bolt and nut and whether it can be reused, the condition can be field checked. If the nut will thread the full length of the bolt with the use of fingers only, the bolt and nut can be reused.

- Final inspection of connections shall include verifying Turn-of-Nut rotation amount of all fasteners and random checking of 10% (minimum of two fasteners) in each connection with inspection torque wrench.

B. Rotational-Capacity

Specification 2408.03, S, 4 and *Specification 4153.06* require a Rotational-Capacity (RC) test for all "high strength" fasteners. This test confirms component compatibility and the presence of adequate lubrication.

There are two separate Rotational-Capacity requirements:

1. Fasteners (bolts, nuts, and washers) received at the project shall have been RC tested by the supplier or manufacturer prior to shipment. Therefore, each combination of production lots must have a unique RC lot number. This number must be readily identifiable on each container of fasteners.
2. Prior to installation, the contractor shall field test all RC lots as supplied. Field tests are not intended to match the values provided by the supplier, but as a separate and added acceptance test.

Field testing procedures are given in *Materials I.M. 453.06B, Appendix A* (long bolts), and *Appendix B* (short bolts). Supplemental step-by-step pictures are provided in *Appendix 11-12* for visual reference, and *Appendix 11-13* has Rotational-Capacity worksheets to document these tests. Since the worksheets are not in the Office Supply system, please photocopy as needed.

Rotational Capacity testing using Metric units has not been developed as of the date of this revision. Product suppliers of high strength fasteners are currently supplying English unit fasteners that have been “soft converted” to Metric units. At present, it is not known if or when producers will develop standard diameters, lengths, and rotational values for Metric fasteners.

In the interim, Rotational Capacity testing for Metric unit projects will continue to be performed in English units representative of the “soft converted” fasteners being supplied by producers. For all Metric unit projects involving structural steel, contact the Office of Construction for additional guidance on Rotational Capacity testing. In *Appendix 11-13* is an example worksheet for long bolts completed in conjunction with the photographs. The example is only in English units and assumes:

- 3/4 inch "high strength" "black" bolts, 3 inches long

- A Skidmore which is calibrated as:
  GAUGE = 30.0 kip
  Calibration Average = 30.6 kip
  Difference is 30.6 - 30.0 = + 0.6 kip

- After installation of fastener in the Skidmore, the nut was tightened to a "Minimum" tension. This was read from the Skidmore as 28.4 kips and corrected to:
  28.4 + 0.6 = 29.0 kips

  It is more than the minimum tension and thus passes the first requirement.

- As the fastener reached 28.4 kips (noted above), torque was read from the torque wrench. Its value was recorded as 350 ft-lbs.

- Maximum permitted torque was computed:
  $0.25 \times \frac{0.75"}{12"} \times 29 \text{ kips} \times 1{,}000 \text{ lbs/kip} = 453 \text{ ft-lbs.}$

Since the "Measured" torque is less than the "Maximum" permitted torque the fastener passes the second requirement.

- The nut is now turned 1 Turn-of-Nut rotation. In this example that is 1/3 of a turn. Bolt tension as indicated on the Skidmore was read and recorded as 40.0 kips.

- The "corrected" Skidmore tension is computed as:
  40.0 + 0.6 = 40.6 kips

  The "Minimum Adjusted" tension is computed by multiplying the "Specified Minimum" tension times 1.15. For a 3/4 inch bolt this is:
  28.4 x 1.15 = 32.7 kips

  Since the "Corrected" Skidmore tension is larger than the "Minimum Adjusted" tension, the fastener passes the third requirement.

- Finally, the fastener is removed from the Skidmore and visually examined for signs of thread stripping, and cracking in the valley of the threads.

Failure of any one of the above criteria is cause to reject that Rotational-Capacity lot.

C. Turn-of-Nut Method
"Turn-of-Nut" method involves the following simple steps. Adherence to this procedure will assure a properly fitted and clamped connection. (Refer to *Appendix 11-14*.)

- Adequate number of bolts and pins shall be installed to bring a joint in tight contact and alignment. These bolts shall be brought to a snug-tight condition to insure that the joint is maintained in good contact during installation of remaining bolts. A washer shall be placed under the element to be turned.

- Remaining bolts in a connection shall be installed and brought to a snug-tight condition.

- Check initially installed bolts to assure they remained in a snug-tight condition.

- Tighten all bolts by the applicable Turn-of-Nut amount specified in *Specification 2408.03, S, 5, b.* Rotation depends on the bolt length to diameter ratio and shape of connected pieces. For MOST installations (both faces normal to bolt axis), the following table can be used to determine additional rotation for Turn-of-Nut:

  NOTE: As previously discussed in the Installation Checklist, adjustments in the specified Turn-of-Nut rotation may be necessary based upon the results of the Rotational Capacity test of fastener assemblies. If an RC test shows that a specified amount of rotation (i.e. 1/3 turn) does not fully develop the required minimum installation tension, then designate the new rotation required to achieve it.

3/4" Diameter Bolts		7/8" Diameter Bolts	
Bolt Length	Rotation from "Snug Tight"	Bolt Length	Rotation from "Snug Tight"
0 - 3"	1/3 turn	0 - 3.5"	1/3 turn
>3" - 6"	1/2 turn	>3.5" - 7"	1/2 turn
>6" - 9"	2/3 turn	>7" - 10.5"	2/3 turn

NOTE: All additional rotations have a ± tolerance. Refer to *Specification 2408.03, S, 5, b.*

1" Diameter Bolts		1-1/8" Diameter Bolts	
Bolt Length	Rotation from "Snug Tight"	Bolt Length	Rotation from "Snug Tight"
0 - 4"	1/3 turn	0 - 4.5"	1/3 turn
>4" - 8"	1/2 turn	>4.5" - 9"	1/2 turn
>8" - 12"	2/3 turn	>9" - 13.5"	2/3 turn

NOTE: All additional rotations have a ± tolerance. Refer to Specification 2408.03, S, 5, b.

D. "Snug Tight"
"Snug tight" is defined as the tightness that exists when all plies of a joint are in "firm" contact with each other. There shall not be air gaps between metal to metal or metal to bolt surfaces.

- Bolts shall be considered "snug tight" when tensioned to approximately 20% of the minimum bolt tension and faying surfaces are in full contact, refer to Specification 2408.03, S, 5, b.
- Contractor's equipment and methods used to achieve "snug tight" should be reviewed for the first fastener assemblies installed. Fasteners that have been installed to a "snug tight" condition should be checked to verify that they have been tightened to approximately 20% of the minimum bolt tension. This check for "snug tight" should be repeated periodically during installation of structural steel to ensure that a uniform "snug tight" condition is being achieved.

After **ALL** bolts in the connection are "snug tight":

- **ALL** "snug-tight" fasteners shall be match-marked with bolt point, nut, and base steel using paint, crayon, or other means to provide a straight reference line for determining relative rotation of parts during tightening. This marking sequence, prior to applying Turn-of-Nut, ensures that rotation applied can be visually reviewed.

  Note: No other markings on the structural elements should be allowed. The contractor may use marks on the sockets of their tightening equipment, in addition to match-marking (bolt, nut, and base steel), to aid in visually determining the correct amount of rotation to be applied.

- All bolts in a connection shall then be tightened additionally by an applicable amount of nut rotation specified above. Tightening should progress from the most rigid part of the joint to its free edges. On our normal web and flange splices, this would mean beginning at the centerline of a splice and progressing away (in each direction) from the centerline of the splice.

Inspectors should observe this operation at intervals to make certain the match-marking is done correctly, and that the opposite bolt head or nut does not turn during the tightening process. Inspectors also should check to see if proper rotation has been made considering tolerances given at the bottom of the nut rotation chart. Remember that on a 6-sided nut, there is 60^{o} from one point to the next point on the nut.

E. Inspection Wrench Calibration

1. Tension Measuring Calibrated Devices

Tension measuring calibrated devices (typically Skidmore-Wilhelm Calibrator) are calibrated to a high degree of accuracy, but can lose some of this accuracy after an extended period of time. Recalibration of these tension measuring devices is required every six months. Contractors can have the devices calibrated at the Central Materials Laboratory in Ames.

When each device is calibrated, a calibration sheet will be issued indicating the date the test was performed. Contractors must keep the calibration sheet with the tension measuring device.

Attentiveness needs to be exercised when using this Calibration Sheet. The inspector needs to check the sheet and compare the "Indicated Load on Gauge" column to those values listed in the "AVG" column under "Actual Load on Testing Machine." These are usually ***NOT*** the same.

For Example: Refer to sample (English units) Calibration Sheet provided in *Appendix 11-15*. The Indicated Load on Gauge for 30,000 lbs., has an Average Actual Load of 29,000 lbs. (Gauge is reading 1,000 lbs. low at 30,000 lbs.) When one goes to a GAUGE of 40,000 lbs., the actual Average is 38,800 lbs., or a difference of 1,200 lbs. While it may not "seem" like much difference, it amounts to 3%.

NOTE: ***Be sure to take any difference (INDICATED versus ACTUAL) into account when calibrating the Job Torque Wrench!***

2. Torque Wrench Calibration - Long Bolt

At least once a day, three bolts of the same grade, size, and condition as those used in the structure shall be placed individually in a calibration device capable of indicating bolt tension. A washer shall be used under the part to be turned.

NOTE: ***3 - 5 threads must be exposed behind the nut. Check and add washers if required. For longer bolts, steel shim plates should be used.***

a. Tension bolt to 100 percent of "Minimum Bolt Tension" listed for a particular bolt diameter. Tension is read directly from the tension measuring calibrated device as corrected by accounting for differences between INDICATED versus ACTUAL. (Refer to *Specification 2408.03, S, 5, a, 6* for "Minimum Bolt Tension.")

b. Apply inspection torque wrench, rotate nut or bolt, and increase tension by an additional 5%. Remember, a dial type wrench must be set to zero before checking torque. Record the inspection wrench's "TORQUE" when 105% of the tension is achieved.

NOTE: *The turned element must be moving to indicate the* ***correct torque.***

EXAMPLE: (English units)
Assume:
1. 7/8" Diameter bolt
2. Skidmore Calibration (*Appendix 11-15*)

Minimum Bolt Tension
39,250 lbs-force *Specification 2408.03, S, 5, a, 6*

Skidmore Calibration (*from Appendix 11-15*)
Gauge Reading 40,000 lbs-force
Actual Ave. at 40,000 = **38,800 lbs-force**

Calculations
- For 100% tension, corrected Skidmore gauge should read:
  39,250 + (40,000 - 38,800) = **40,450 lbs-force**
- For 105% tension, corrected Skidmore gauge should read:
  40,450 x 1.05 = **42,473 lbs-force**

  The torque reading on Inspection Wrench at 42,470± lbs-force is recorded as xxx.xx foot-lbs.

c. Repeat this process for a total of three fasteners.

d. The inspector notes the torque for three fasteners, averages this torque, and that becomes the Job Inspection Torque Value until the wrench is recalibrated the next day, or another size or length of bolt is to be inspected.

Inspector shall record:
- The job inspection torque
- *The Tension Measuring device's calibration "date reported," serial and model number, and calibration lab number*

3. Torque Wrench Calibration – Short Bolt
NOTE: For short bolts that will not fit the calibration device (ie: Skidmore) the following procedure should be used:

At least once a day, three bolts of the same grade, size, and condition as those used in the structure shall be used to calibrate the job inspection torque wrench.

a. Place fastener into an appropriate size hole in any available splice. Use washer/shims under “turned” element. Need a minimum of 3 to 5 exposed threads behind the nut. (NOTE: May use a maximum of 3 washers &/or shim plates).

b. Initially tension fastener to values in Table 1 of Appendix 11-13.2 to establish “snug tight” condition.

c. Match mark bolt tip, nut corner, washer/shims, and the base steel (mark shall be a straight line).

d. Set inspection torque wrench to zero. Turn nut to total rotation values in Table For Nut Rotation from "Snug Tight" Condition in Specification 2408.03, S, 5, b. and record torque. NOTE: The turned element must be moving to indicate the **correct torque**.

e. Test a total of three fasteners and average the recorded inspection torque wrench values. This average job inspection torque wrench value is to be used for inspection monitor check of completed fasteners in each connection according to Specification 2408.03, S, 5, c.

F. Turn-of-Nut Inspection

After all fasteners in a joint are properly tightened by the Turn-of-Nut method, they shall be inspected as indicated:

1. Installed fasteners shall be inspected:
   - The same day as installed to ensure that inspection check is not affected by changes in fastener condition due to moisture, dust, or loss of lubrication.
   - By the contractor with the inspector present

2. The contractor shall use a "calibrated" torque wrench for the inspection operation. Contractors can have their torque wrenches at the Central Materials Laboratory in Ames.

3. Ten percent of the bolts which have been tightened in the structure shall be tested with the inspection wrench the same day as installed. At least two bolts, selected at random, in each connection shall be tested. If no rotation (nut or bolt head) is noted by job inspecting torque wrench and the faying surfaces are in tight contact, the connection shall be accepted as properly tightened. If any nut or bolt head is turned, inspection shall be applied to all bolts in the connection, and all bolts whose nut or head is turned shall be tightened and reinspected.

   Bolts tightened by the Turn-of-Nut method may reach tensions substantially above minimum torque values specified, but this shall not be cause for rejection.

   Care should be taken, however, to not overstress the bolts. If most of the bolts exceed 20% of minimum bolt tension when snug tightened, the contractor's procedures should be reviewed to determine:
   a. Is the "snug tight" procedure correct?
   b. Are there nicks or burrs on the threads?
   c. Are the nuts or bolts rusty or dirty?
   d. Check for residual lubrication. All threaded fasteners (black and galvanized) are required to be lubricated. Black bolts and nuts need to have a water soluble oil, and galvanized nuts are to be lubricated as per ASTM A563. Pre-lubricated galvanized nuts will be dyed typically to a blue color. If there is no indication of color OR if the color is faded, the bolts shall be field lubricated with bees wax, stick wax, or some other dry lubricant.
   e. Is calibrating device correct?

4. Bolts and nuts must always be inspected prior to installation. Items of major concern are:
   a. Nicks or burrs in the threads
   b. Rust
   c. Presence of dirt or other foreign material
   d. Fastener lubrication

   All dirt, foreign material, and rust must be removed prior to use. Black bolts may require reoiling to remove rust, etc. If reoiling is required, excess oil must be removed prior to installation. When rust cannot be removed by oiling, the bolt or nut must be rejected. Bolts or nuts with nicks or burrs on threads must be rejected. Relubrication will necessitate rechecking fasteners in the lot for Rotational-Capacity.

5. Plan ahead before girder splices have been fully tightened. Make necessary adjustments prior to tightening the bolts in a connection. The best way to assure that beam lines are straight and true is to:
   - Scribe a line at the center of each bearing on all masonry plates or concrete.
   - Set beams and make snug tight connections proceeding to the forward pier. Then go back and straighten the beam line, checking to be sure bearings remain centered on their seats. Once the previous span is aligned and tightened, proceed to the next forward span.
   - Check to be sure beam ends are aligned prior to tightening the splice.

   This will require coordination between survey and inspection crews and the contractor.

G. Galvanized Bolts

Specification 2408.03, S, 5, a requires galvanized bolts for all bolted connections on non-weathering steel structures. This specification also requires galvanized nuts to be lubricated prior to installation.

When using galvanized hardware, a lubricant approved by ASTM A563 shall be applied to the nuts. Galvanized nuts "typically" are delivered to the project pre-lubricated. Usually, pre-lubricated nuts are stained and have a distinguishing color. If a lubricant has been applied at the fabrication shop, a field reapplication is not necessary provided original lubrication has not been removed in some manner. For situations where fabrication shop lubricant is in question, field application of beeswax, stick wax, or some other dry lubrication shall be required. Rotational-Capacity requires the test to be conducted with fasteners in the same condition as they will be during installation.

A WORD OF CAUTION:
Lubrication is required to minimize galling during installation. Since nuts are lubricated (both threads and faces), it is important that nuts be rotated during tightening.

Fasteners (bolts and nuts of any type) shall not be tightened, then removed, reinstalled, and retightened.

Painting

A. New Non-Weathering Structural Steel
Supplemental Specifications for Surface Preparation and Painting Requirements For Non-Weathering Structural Steel Applications changed our shop applied structural steel paint system. With this change:
- Shop applied solvent borne inorganic zinc silicate paint shall be used for non-weathering steel bridges.
- There will no longer be a field applied "top coat," unless specified by the contract documents. A top coat will be required only when it is deemed necessary due to aesthetics.
- All structural bolts for painted structural steel bridges will be galvanized.
- The contractor will be required to touch-up any damaged areas after erection. Touch-up paint shall be the same paint as the shop coat.

B. New Weathering (ASTM A 588) Structural Steel
Supplemental Specifications for Surface Preparation and Painting Requirements For Weathering Structural Steel Applications require shop applied prime paint to selected areas on the structure. They also require:
- Shop applied solvent borne inorganic zinc silicate paint to areas under expansion joints and bridge drains.
- A field applied brown top coat to all areas shop painted.
- All structural bolts installed in the painted areas to be field painted.
- The contractor to touch-up any damage to primed areas after erection prior to top coating. This includes bolts in those areas. Touch-up paint shall be the same paint as the shop coat.

C. Field Painting
For field painting of structural steel, refer to *Chapter 10 of the Construction Manual.*

11.33 BRIDGES - CONCRETE BEAM

Precast - Prestressed Deck Panels

Precast - prestressed concrete deck panels are stay-in-place forms that can be used on prestressed beam bridges. The Office of Bridges and Structures has a policy on when these panels can be used. Under this policy, prestressed deck panels would be permitted to be used only if all of the following conditions are met:

- The bridge is constructed with pretensioned prestressed concrete beams.
- The bridge is not an overhead bridge and the intermediate diaphragms are steel.
- Bridge skew is 45 degrees or less.
- The bridge is on a rural highway with a traffic volume ADT of less than 3000 VPD.
- The bridge is not being built by staged construction.

Standard Design Sheet 1037 will be added to the plans when deck panels are allowed. If deck panels are used, shop drawings will be required. (Refer to *Specification 2425*.)

The following are some guidelines which should be followed when using deck panels:
- Check shop drawings to make certain the right widths of prestressed beams have been used to calculate the width of panels.

- Prestressed beams should be set carefully. Make certain tops of the beams have proper spacing so the panels will fit within tolerances allowed. Also make certain tops of beams over the diaphragms have proper spacing before tightening bolts in the diaphragms.
- Beam elevations to set bridge deck grades should be taken before deck panels are set. These elevations need to be taken at frequent intervals to account for the "stair stepping" effect of deck panels. Deck panels range from 1.3 to 2.4 m (4 to 8 feet) in width, depending on the application. It is recommended to have a beam elevation at each panel joint for panels 1.8 m (6 feet) and over and at every other joint for panels less than 1.8 m (6 feet).
- Fiberboard should be glued or attached to the beams prior to setting panels. The fiberboard should be cut so a relatively flat surface is developed for panels to set on. Make certain the fiberboard is located at the outside edge of the beams. The beams should be finished smooth on this outside edge.

  NOTE: ***Styrofoam and/or "bead-board" will not be an approved substitute for fiberboard.***

- A minimum of 50 mm (2 inches) of space is required between the fiberboard and edge of panels. It is very important this space be thoroughly cleaned before pouring the deck as the area needs to fill with concrete during deck placement.
- Use lifting hooks when placing the deck panels.
- Deck panels should be set as near as possible and parallel to the beams. The deck panel should be evenly placed so overlap on each beam is approximately the same.
- End panels should be tied to the adjacent panel or to the beams.
- Cracks between panels can be covered with tape or they can be caulked. BE CAREFUL: If tape is used, recheck seams and cracks because some types of tape tend to come off when panels are cleaned.
- Sandblasting the deck panels is not considered necessary under normal conditions, but it is required to remove unusual surface laitance or other surface contaminants.
- Prior to placing steel, make certain deck panels are clean and remove all debris from under the edges of the deck panels.
- Variable height chairs will have to be used if the contractor does not choose to vary the thickness of the fabric filler.
- Deck panel surface shall be clean, dry, and dust free when the deck is poured.
- Make certain the concrete is vibrated well over the beams.
- Minimum slab thickness of 125 mm (5 inch) over the panels is required for a 200 mm (8 inch) deck.

Pretensioned Prestressed Concrete Beam (PPC Beam) Erection

The contractor shall submit a written plan for their proposed PPC beam erection sequence including ensuring PPC beam stability during erection and management of traffic if construction is under active traffic conditions. This submitted erection plan is to be reviewed by the Engineer to identify any concerns that may need to be addressed prior to initiating the actual PPC beam erection.

Diaphragms (Steel or Concrete)

Steel diaphragms, if allowed, are shown on the plans for prestress concrete beam structures. Shop drawings are required for steel diaphragms showing details of beam layouts, location of the diaphragms, and location of the mounting holes.

Contractor requests for substitution of steel diaphragms for concrete diaphragms on prestressed concrete beam bridges over traffic will not be approved. The reason they will not be allowed on overhead bridges is that steel diaphragms are not considered structurally adequate to sustain potential impact from an overheight vehicle.

Intermediate concrete diaphragm construction on overhead bridges that involve staged construction have long presented a constructability problem. The problem relates to the difficulty in placing the concrete for the intermediate diaphragms that are located along the longitudinal construction joint.

This problem was previously resolved by allowing the use of steel intermediate diaphragms between the beams immediately adjacent to each side of the longitudinal construction joint. The remaining intermediate diaphragms between beams were still required to be concrete:

Upon further review by the Office of Bridges & Structures, a determination has been made that intermediate diaphragms in the location of the longitudinal construction joint may not be necessary. On future plans for staged bridges, the plan notes will state whether the intermediate diaphragms are omitted between beams immediately adjacent to the longitudinal construction joint.

High strength bolts for steel diaphragms shall be tightened by Turn-of-Nut method. (Refer to Specification 2408.03, S, 5, b. for information on proper bolt inspection and installation.) Inspection and field installation acceptance will be based on observing proper Turn-of-Nut procedures. (A tensioning device and inspection torque wrench is recommended, but will not be required.)

Concrete diaphragms are intended to be placed monolithically with the deck slab. However, there are instances where allowance has been given for specific diaphragms to be placed prior to slab placement. These are typically intermediate diaphragms which tie adjacent beams together near the midpoint of the beam. If the diaphragm is placed before the slab, it shall be struck off at an elevation above the bottom of the deck, but below the bottom mat of steel.

Concrete diaphragms located at the piers and abutments must be placed monolithically with the deck. This is to ensure that the beam ends remain free to move during deadload deflection of the beams to prevent cracking over the piers and abutments. Consult with the Office of Construction in situations where the contractor requests to place concrete diaphragms before a deck placement.